COMMONWEALTH DEPARTMENT OF
TRANSPORT AND REGIONAL DEVELOPMENT

8

Flora and Fauna

Proposal for a Second Sydney Airport
at Badgerys Creek or Holsworthy Military Area

Technical Paper

PPK
Environment & Infrastructure

Prepared for:

COMMONWEALTH DEPARTMENT OF
TRANSPORT AND REGIONAL DEVELOPMENT

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Explanatory Statement

This technical paper is not part of the Draft Environmental Impact Statement (EIS) referred to in paragraph 6 of the Administrative Procedures made under the Environment Protection (Impact of Proposals) Act 1974.

The Commonwealth Government is proposing to construct and operate a second major airport for Sydney at Badgerys Creek. This technical paper contains information relating to the Badgerys Creek airport options which was used to assist the preparation of the Draft EIS.

The technical paper also assesses the impacts of developing a major airport at the Holsworthy Military Area. On 3 September 1997, the Government eliminated the Holsworthy Military Area as a potential site for Sydney's second major airport. As a consequence, information in this technical paper relating to the Holsworthy Military Area is presented for information purposes only.

Limitations Statement

This technical paper has been prepared in accordance with the scope of work set out in the contract between Rust PPK Pty Ltd and the Commonwealth Department of Transport and Regional Development (DoTRD) and completed by PPK Environment and Infrastructure Pty Ltd (PPK). In preparing this technical paper, PPK has relied upon data, surveys, analyses, designs, plans and other information provided by DoTRD and other individuals and organisations, most of which are referenced in this technical paper. Except as otherwise stated in this technical paper, PPK has not verified the accuracy or completeness of such data, surveys, analyses, designs, plans and other information.

This technical paper has been prepared for the exclusive use of DoTRD. PPK will not be liable to any party other than DoTRD and assumes no responsibility for any loss or damage suffered by any other party arising from matters dealt with in this technical paper, including, without limitation, matters arising from any negligent act or omission of PPK or for any loss or damage suffered by any other party in reliance upon the matters dealt with and opinions and conclusions expressed in this technical paper.

Acknowledgments

Data used to develop the figures contained in this document have been obtained and reproduced by permission of the Australian Bureau of Statistics, NSW Department of Land and Water Conservation, NSW National Parks and Wildlife Service (issued 14 January 1997), NSW Department of Urban Affairs and Planning and Sydney Water. The document is predominantly based on 1996 and 1997 data.

To ensure clarity on some of the figures, names of some suburbs have been deleted from inner western, eastern, south-eastern and north-eastern areas of Sydney. On other figures, only 'Primary' and 'Secondary' centres identified by the Department of Urban Affairs and Planning's Metropolitan Strategy, in addition to Camden, Fairfield and Sutherland, have been shown.

Copyright

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Introduction

CHAPTER 1 OVERVIEW OF THE PROPOSAL

1.1 INTRODUCTION

This technical paper addresses the potential flora and fauna impacts identified as part of the previously proposed development of the Second Sydney Airport at either Badgerys Creek or the Holsworthy Military Area. It contains information used to prepare the Draft Environmental Impact Statement (EIS) which addresses the overall environmental impacts of the Badgerys Creek airport options.

1.2 A BRIEF HISTORY

The question of where, when and how a second major airport may be developed for Sydney has been the subject of investigation for more than 50 years. The investigations and the associated decisions are closely related to the history of the development of Sydney's existing major airport, located at Mascot.

The site of Sydney Airport was first used for aviation in 1919. It was acquired by the Commonwealth Government in 1921, and was declared an International Aerodrome in 1935. In 1940 the first terminal building and control tower were opened.

In 1945 the airport had three relatively short runways. A major expansion began in 1947, and by 1954 the current east-west runway was opened. The north-south runway was first opened in 1954 and was extended to its current length in 1972. The present international terminal was opened in 1970.

Planning and investigations for a site for a second Sydney airport first started in 1946. A large number of possible sites both within and outside the Sydney Basin have been investigated.

The *Second Sydney Airport Site Selection Program Draft Environmental Impact Statement* (Kinhill Stearns, 1985) re-examined all possible locations for the second airport and chose 10 for preliminary evaluation. Two sites, Badgerys Creek and Wilton, were examined in detail and an EIS was prepared. In February 1986 the then Commonwealth Government announced that Badgerys Creek had been selected as the site for Sydney's second major airport.

The Badgerys Creek site, which is about 46 kilometres west of Sydney's Central Business District and is 1,700 hectares in area, was acquired by the

Commonwealth between 1986 and 1991. A total of $155 million has been spent on property acquisition and preparatory works.

Since 1986, planning for Sydney's second airport has been closely linked to the development of the third runway at Sydney Airport. In 1989 the Government announced its intention to construct a third runway. An EIS was undertaken and the decision to construct the runway was made in December 1991.

At the same time as investigations were being carried out on the third runway, detailed planning proceeded for the staged development of the second airport at Badgerys Creek. In 1991 it was announced that initial development at Badgerys Creek would be as a general aviation airport with an 1,800 metre runway.

The third runway at Sydney Airport was opened in November 1994. In March 1995, in response to public concern over the high levels of aircraft noise, the Commonwealth Senate established a committee in March 1995 to examine the problems of noise generated by aircraft using Sydney Airport and explore possible solutions. The committee's report, *Falling on Deaf Ears?*, containing several recommendations, was tabled in parliament in November 1995 (Senate Select Committee on Aircraft Noise, 1995).

During 1994 and 1995 the Government announced details of its proposed development of Badgerys Creek, and of funding commitments designed to ensure the new airport would be operational in time for the 2000 Olympics. This development included a 2,900 metre runway for use by major aircraft.

The decision to accelerate the development of the new airport triggered the environmental assessment procedures in the *Environment Protection (Impact of Proposals) Act 1974*. In January 1996 it was announced that an EIS would be prepared for the construction and operation of the new airport.

In May 1996, the present Commonwealth Government decided to broaden the environmental assessment process. It put forward a new proposal involving the consideration of 'the construction and operation of a second major international/domestic airport for Sydney at either Badgerys Creek or Holsworthy on a site large enough for future expansion of the airport if required' (Department of Transport and Regional Development, 1996). A major airport was defined as one 'capable of handling up to about 360,000 aircraft movements and 30 million passengers per year' (Department of Transport and Regional Development, 1996).

The Government also indicated that 'Badgerys Creek at this time remains the preferred site for Sydney's second major airport, subject to the favourable outcome of the EIS, while Holsworthy is an option to be considered as an alternative' (Minister for Transport and Regional Development, 1996). The two sites considered in this technical paper are shown in *Figure 1.1*.

Following the substantial completion of a Draft EIS on the Badgerys Creek and Holsworthy airport options, the Government eliminated the Holsworthy Military Area as a potential site for Sydney's second major airport. The environmental assessment showed that the Badgerys Creek site was significantly superior to the Holsworthy Military Area. As a result a Draft EIS was prepared which examines only the Badgerys Creek site. While this technical paper examines both the Badgerys Creek and Holsworthy airport options, only the parts of the assessment relating to the Badgerys Creek airport options were used to assist the preparation of the Draft EIS.

1.3 THE PROPOSAL

The Commonwealth Government proposes the development of a second major airport for Sydney capable of handling up to 30 million domestic and international passengers a year. By comparison, Sydney Airport will handle about 20 million passengers in 1997. The *Second Sydney Airport Site Selection Program Draft Environmental Impact Statement* anticipated the airport would accommodate about 13 million passengers each year (Kinhill Stearns, 1985).

A stated objective of the Government is the building of a second major airport in the Sydney region to a full international standard, subject to the results of an EIS. In the Government's view, Sydney needs a second major airport to handle the growing demand for air travel and to control the level of noise experienced by Sydney residents (Coalition of Liberal and National Parties, 1996).

Government policy (Coalition of Liberal and National Parties, 1996) indicates:

- that Sydney's second airport will be more than just an overflow airport and will, in time, play a major role in serving Sydney's air transport needs; and

- a goal of reducing the noise and pollution generated by Sydney Airport as much as possible and that the Government would take steps to ensure that the noise burden around Sydney Airport is shared in a safe and equitable way.

The assumptions made on how the Second Sydney Airport would operate and the master plans which set out the broad framework for future physical development of the airport are based on an operational limit of 30 million passengers a year. The main features include parallel runways, a cross wind runway and the provision of the majority of facilities between the parallel runways.

Consideration has also been given to how the airport may be expanded in the future and the subsequent environmental implications. Such an expansion could not proceed, however, unless a further detailed environmental assessment and decision making process were undertaken by the Government.

Five airport options are considered, as well as the implications of not proceeding with the proposal. Three of the airport options are located at Badgerys Creek and two are located within the Holsworthy Military Area. Generally, the airport options are:

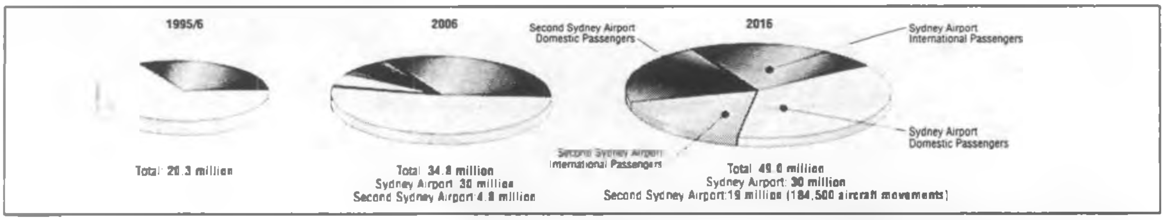
- Badgerys Creek Option A which has been developed to be generally consistent with the planning for this site undertaken since 1986. The airport would be developed within land presently owned by the Commonwealth with two parallel runways constructed on an approximate north-east to south-west alignment;
- Badgerys Creek Option B would adopt an identical runway alignment to Option A, but provides an expanded land area and also a cross wind runway;
- Badgerys Creek Option C would provide two main parallel runways on an approximate north to south alignment in addition to a cross wind runway. Again the land area required would be significantly expanded from that which is presently owned by the Commonwealth;
- Holsworthy Option A would be located centrally within the Holsworthy Military Area and would have two main parallel runways on an approximate north to south alignment and a cross wind runway; and
- Holsworthy Option B would be located in the south of the Holsworthy Military Area and would have two main parallel runways on an approximate south-east to north-west alignment and a cross wind runway.

To ensure that the likely range of possible impacts of the airport options are identified a number of different assumptions about how the airport options would be developed and operate have been adopted. These different assumptions relate to the number and types of aircraft that may operate from the airport, the flight paths used and the direction of take offs and landings.

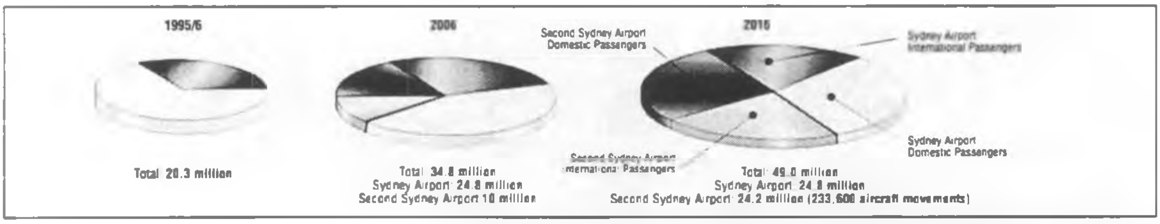
The number of flights into and out of the proposed Second Sydney Airport would depend on a number of factors including the types of aircraft that would use the airport and the associated numbers of passengers in each aircraft. The

Figure 1.1

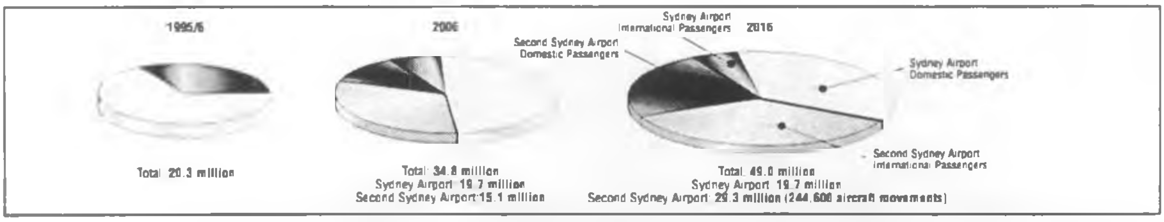
Potential Airport Sites Considered in the Draft EIS



Assumptions about Passenger Movements for Air Traffic Forecast 1



Assumptions about Passenger Movements for Air Traffic Forecast 2



Assumptions about Passenger Movements for Air Traffic Forecast 3

Figure 1.2

Summary of Passenger Movement Forecasts Used for Environmental Assessment

proposal put forward by the Government anticipates a major airport handling 30 million passengers and up to 360,000 aircraft movements per year.

Air traffic forecasts have been developed based on an examination of the number and type of aircrafts that would use the airport as it approaches an operating level of 30 million passengers per year. This examination has shown that if the airport accommodated about 245,000 aircraft movements each year, the number of air passengers would approach 30 million. This assumes a relatively high percentage of international flights being directed to the Second Sydney Airport. Therefore it is appropriate for this Draft EIS to assess the airport operating at a level of 245,000 aircraft movements per year, rather than the 360,000 originally anticipated by the Government. It has been assumed that this level of operation could be reached by about 2016.

1.4 AIR TRAFFIC FORECASTS

Cities around the world which have developed second major airports have responded to their particular needs in different ways. For example, the original airport in Dallas, United States, is now used for short range traffic that does not connect with other flights. Second airports in New York and Washington serve as hubs for particular airlines. In Taipei, Taiwan, smaller domestic aircraft use the downtown airport and larger international flights use a newer airport 40 kilometres from the city.

It is clear that each metropolitan area around the world has unique characteristics and the development of multi-airport systems respond to particular local circumstances. The precise role and consequential staging of development of the Second Sydney Airport would be the subject of future Government decisions. To assist in developing a realistic assessment of the potential impacts of the Second Sydney Airport, three sets of air traffic forecasts for the airport were developed. Each forecast assumes a major airport would be developed, however, this may be achieved at different rates of growth.

The three potential air traffic scenarios considered for the Second Sydney Airport are shown in *Figure 1.2*. They are:

- *Air Traffic Forecast 1* where the Second Sydney Airport would provide only for demand which cannot be met by Sydney Airport. This is an overflow forecast, but would nevertheless result in a significant amount of air traffic at the Second Sydney Airport. The proportion of international and domestic air traffic is assumed to be similar at both airports;

- *Air Traffic Forecast 2* where the Second Sydney Airport would be developed to cater for 10 million passengers a year by 2006, with all further growth after this being directed to the second airport rather than Sydney Airport. The proportion of international and domestic traffic is also assumed to be similar at both airports; and

- *Air Traffic Forecast 3* which is similar to Forecast 2 but with more international flights being directed to the Second Sydney Airport. This would result in the larger and comparatively noisier aircraft being directed to the second airport. It would accommodate about 29.3 million passengers by 2016.

1.5 OPERATION OF THE AIRPORT OPTIONS

At any airport, aircraft operations are allocated to runways (which implies both the physical runway and the direction in which it is used) according to a combination of wind conditions and airport operating policy. The allocation is normally performed by Air Traffic Control personnel.

Standard airport operating procedures indicate that a runway may not be selected for either approach or departure if the wind has a downwind component greater than five knots, or a cross wind component greater than 25 knots. If the runway is wet, it would not normally be selected if there is any downwind component. This applies to all aircraft types, although larger aircraft would be capable of tolerating relatively higher wind speeds. Wind conditions at the airport site therefore limit the times when particular runways may be selected. However, there would be a substantial proportion of the time, under low wind conditions, when the choice of runways would be determined by airport operating policy.

For the environmental assessment, the maximum and minimum likely usage for each runway and runway direction was estimated and the noise impact of each case calculated. The actual impact would then lie between these values and would depend on the operating policy which is applicable at the time.

The three airport operation scenarios were adopted for the environmental assessment, namely:

- *Airport Operation 1* shown in *Figure 1.3*. Aircraft movements would occur on the parallel runways in one specified direction (arbitrarily chosen to be the direction closest to north), unless this is not possible due to meteorological conditions. That is, take offs would occur to the north from the parallel runways and aircraft landing would approach from the south, travelling in a northerly direction. Second priority is given to operations in the other direction on the parallel runways, with operations on the cross wind runway occurring only when required because of meteorological conditions;

- *Airport Operation 2* shown in *Figure 1.4*. As for Operation 1, but with the preferred direction of movements on the parallel runways reversed, that is to the south; and

- *Airport Operation 3*. Deliberate implementation of a *noise sharing* policy under which seven percent of movements are directed to occur on the cross wind runway (equal numbers in each direction) with the remainder distributed equally between the two parallel runway directions.

Since a cross wind runway is not proposed at Badgerys Creek Option A, only Operations 1 and 2 were considered for that option.

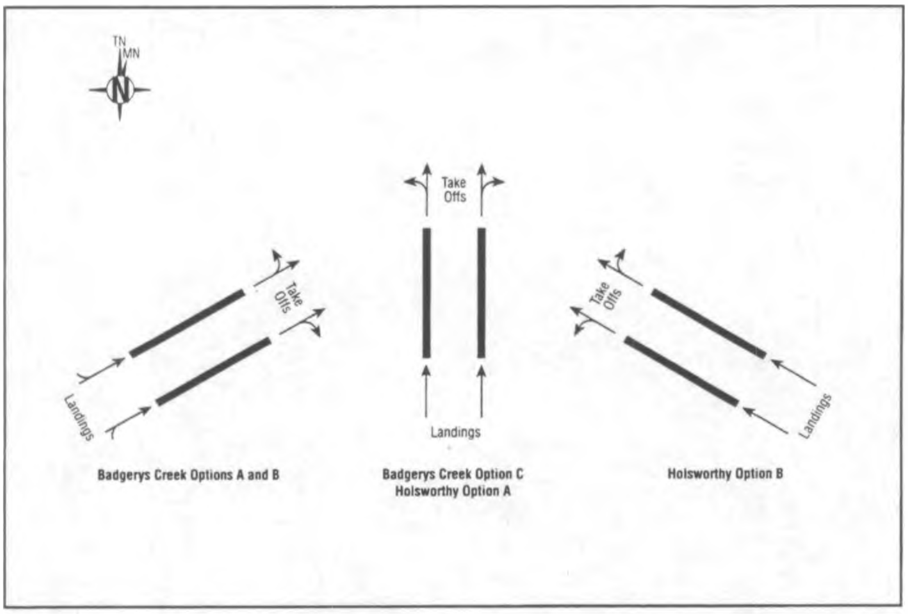


Figure 1.3

Predominant Directions of Movement of Aircraft for Airport Operation 1

Note: Cross wind runway used only when required because of meteorological conditions

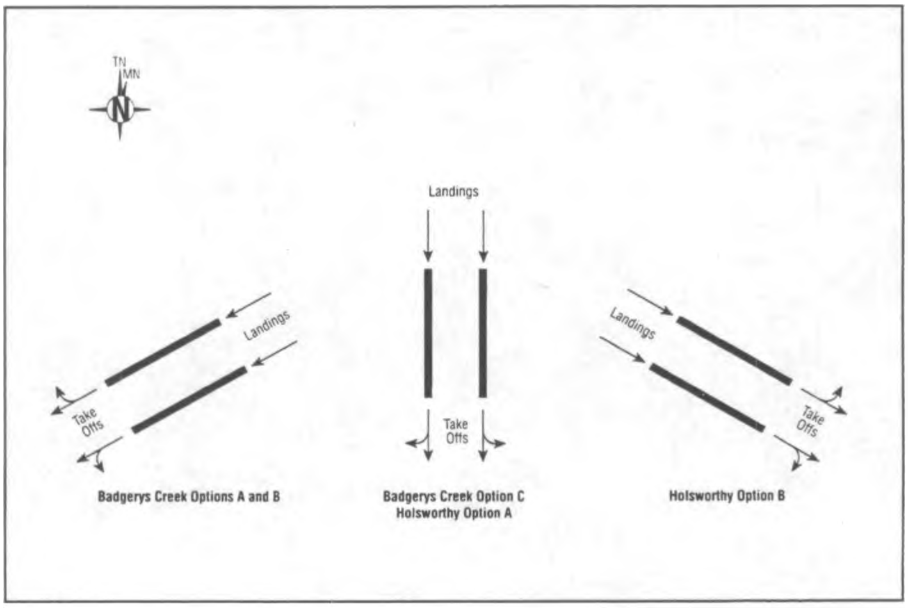


Figure 1.4

Predominant Directions of Movement of Aircraft for Airport Operation 2

Note: Cross wind runway used only when required because of meteorological conditions

CHAPTER 2 CONSULTATIONS

Preparation of this Draft EIS involved consultation with the community, other stakeholders, Commonwealth, State and local Governments and Government agencies.

2.1 COMMUNITY CONSULTATION

The primary role of the consultation process during the preparation of the Draft EIS was to provide accurate, up to date information on the proposals being considered and the assessment process being undertaken. From October 1996 to May 1997, ten separate information documents were released and over 400,000 copies distributed to the community. Four types of display posters were produced and 700 copies distributed. Over 140 advertisements were placed in metropolitan and local newspapers. Non English language documents were produced in 14 languages and over 20,000 copies distributed. Advertisements in seven languages were placed on ethnic radio.

Opportunities for direct contact and two way exchange of information with the community occurred through meetings, information days, displays at shopping centres, telephone conversations and by responding to written submissions. Through these activities over 20,000 members of the community directly participated in the consultation activities.

Written and telephone submissions received were incorporated into a database which grouped the issues in the same way as the chapters of the Draft EIS. The issues raised were progressively provided to the EIS study team to ensure that community input was an integral part of the assessment process.

Further details of consultation with the community and other stakeholders and its outcomes are contained in *Technical Paper No. 1 Consultation.*

2.2 OTHER CONSULTATION

A variety of experts were consulted as part of this assessment. Experts on particular species, and/or fauna groups were consulted at various stages of the study, to confirm habitat preferences at the Holsworthy Military Area and sites of the Badgerys Creek airport options and to assist in the assessment of regional significance.

The experts consulted include: Alan Leishman (Royal Botanic Gardens) (birds); Debbie Andrew (National Parks and Wildlife Service) (regional fauna distribution); Frank Lemckert (State Forests of NSW) (amphibians and reptiles); John Harris (NSW Fisheries) (fish); Tom Grant (Platypus); Rob Close (University of Western Sydney) (Koala, Brush-tailed Rock Wallaby); Peter Gerkhe (NSW Fisheries) (fish); Jonathan Webb (University of the Northern Territory) (Broad-headed Snake), Chris Tidemann (Australian National University) (bats); Alan Morris (NSW Field Ornithologists Club) (birds); Natasha Shedvin (Regent Honeyeater Recovery Team) (Regent Honeyeater); Mark Eldridge (Macquarie University) (Brush-tailed Rock Wallaby); Arthur White (Biosphere Consultants) (amphibians); Gerry Swan (Australian Museum) (reptiles); Julie Spence (Cabramatta Creek Flying Fox Committee) (fruit bats); Karen Thumm (University of Newcastle) (Red-crowned Toadlet); Jacki Recsei (Macquarie University) (Giant Burrowing Frog); Brad Law (State Forests New South Wales) (bats), Peter Horwitz (Edith Cowan University) (crayfish), Andrew Sanger (Tasmanian Inland Fisheries Commission) (galaxiids), Tony Saunders (Cumberland Bird Observers Club) (birds), Peter Harlow (University of Sydney) (Broad-headed Snake).

CHAPTER 3 METHODOLOGY

This section provides an overview of the methods used in the inventory of biological resources and assessment of impacts of the proposal. Full details of scientific methods employed during data collection and analysis are contained in Appendices A, B and C (Flora, Fauna, and Freshwater Fish and Crayfish respectively).

3.1 AIMS AND SCOPE OF WORK

The aim of the study was to investigate the conservation significance of the biological resources of each of the proposed airport sites and to determine the impacts of airport construction and operation, including associated infrastructure, on the terrestrial flora and fauna and freshwater fish and crayfish.

The scope of the study is in accordance with the Draft EIS Guidelines developed by Environment Australia. The investigation comprised a detailed inventory of the biological resources for which there is current scientific knowledge, at each of the proposed sites.

From this data the conservation significance of the sites of the Badgerys Creek airport options and the Holsworthy Military Area were assessed at National, State, Regional and Local levels. For each of the airport options, the impacts of airport construction and operation on biological resources were identified and assessed. The study provides detailed recommendations for amelioration of the identified impacts in *Part D*.

Both the Badgerys Creek and Holsworthy Military Area study sites have been the subject of previous environmental survey work. Existing data has been used as a starting point and supplemented with field survey work as required. The Badgerys Creek area was surveyed for flora and fauna as part of the *Sydney Second Airport Selection Study* undertaken in 1985 by Kinhill Stearns (1985).

As Badgerys Creek Option A airport site was considered to have been adequately sampled by the authors of that report, survey efforts were concentrated on additional land required for Badgerys Creek Options B and C.

In the case of Holsworthy Military Area, a recent environmental audit (AXIS/Australian Museum Business Services, 1995) and a detailed survey of the Wedderburn/Holsworthy Military Area (Phillips *et al.*, 1996) provided baseline data. During the survey, areas which had not previously been sampled (that is, areas difficult to access such as gullies) were targeted. Species which were difficult to detect in previous studies due to the time of year or to weather conditions during data collection were also targeted.

Although the AXIS/Australian Museum Business Services (1995) audit provided a substantial baseline study in the area, it does not constitute an environmental impact study. Several information gaps were identified in the study:

- fauna habitat sampling sites were distributed mainly adjacent to roads along ridgetops and therefore did not adequately sample less accessible habitats;
- bat surveys were undertaken during autumn when bats are less active and therefore less detectable;
- no aquatic survey was undertaken; and
- frog surveys were undertaken during an extended dry period.

Overall, for this study the survey effort at Holsworthy Military Area was higher than that at the sites of the Badgerys Creek airport options. This was considered to be appropriate given the differences in native vegetation cover, area, accessibility and degree of disturbances between the two sites. Every attempt was made to use similar survey techniques for both sites although this was not always possible due to physical and social constraints.

For instance, the risk of vandalism was perceived to be high at the sites of the Badgerys Creek airport options. This precluded the use of unsupervised equipment (for example, bat detectors, harp traps). Limited field survey work at all proposal sites, was supplemented by extensive literature surveys and expert consultation to produce predictive species lists.

It should be noted that survey and assessment of non-vascular plants (mosses, lichens, liverworts, fungi, algae), terrestrial invertebrates and micro-organisms are beyond the scope of this study, as current knowledge of their taxonomy and distribution in New South Wales is not sufficient to enable meaningful analysis. Given the depletion of habitats elsewhere in the region, significant species from these groups may be present at either of the study sites.

It should also be noted that the abundance of particular flora or fauna species was not estimated at any of the proposal sites. Long term studies would be required in order to accurately describe abundance and/or distribution of species, especially considering the large size and inaccessibility of the Holsworthy Military site.

The distribution of significant plant species was mapped wherever observed. Sampling of terrestrial and aquatic fauna was carried out on a presence/absence basis although general observations were made regarding the relative abundance of some species in particular habitat types.

3.2 INFORMATION SOURCES

Data on terrestrial flora and fauna, and freshwater fish and crayfish occurring within the study sites were obtained through map and aerial photo interpretation, literature review, discussions with researchers and naturalists and from several databases and field surveys.

Fauna records from the two sites and surrounds were mainly obtained from the NSW National Parks and Wildlife Service (*Atlas of NSW Wildlife*), the Australian Museum (Australian Museum Fauna Database), Sydney Water, NSW Fisheries, the Royal Australasian Ornithological Union, Illawarra Bird Observers Club, Cumberland Bird Observers Club and the NSW Bird Atlassers (Ulladulla).

An extensive number of existing reports were reviewed as part of this study. In general, there was a much greater level of existing information for the sites of the Badgerys Creek airport options, while Holsworthy Military Area required extensive baseline data collection and expert consultation to fill information gaps.

3.3 REVIEW OF PREVIOUS WORK

Location records were obtained from a review of existing literature with emphasis on recent and/or extensive studies such as: *Second Sydney Airport Site Selection Programme* (Kinhill Stearns 1985); *Fauna Assessments of Five Locations within the Liverpool Local Government Area* (Engel 1996c); *Flora and Fauna Report: Liverpool Rural Lands Study* (Ecotone Ecological Consultants); *Holsworthy Training Area Environmental Audit* (AXIS/Australian Museum Business Services 1995); *Wedderburn Fauna Planning Study* (Phillips et *al*. 1996); *Reptile and Frog Survey of O'Hares Creek Catchment* (Harlow and Taylor 1995); *Mammals of Metropolitan Water, Sewerage and Drainage Board Catchments* (Robinson 1985); *The Birds of Humewood/Beulah Forest, Campbelltown, NSW* (Leishman 1994, 1996); *Holsworthy Military Training Area: Vegetation Survey* (French et *al*. 1995); *The Natural Vegetation of Penrith* (Benson 1992) and *Floristics, structure and diversity of natural vegetation in the O'Hares Creek Catchment, south of Sydney* (Keith 1994).

Information from numerous Environmental Impact Statements, Fauna Impacts Statements and other biological studies undertaken in the vicinity of both the Badgerys Creek and Holsworthy sites were incorporated into this study. The *Western Sydney Urban Bushland Biodiversity Study* (National Parks and Wildlife Service unpublished) provided general information on distribution and regional status of all terrestrial fauna groups in western Sydney. A draft plan of management for Woronora, O'Hares Creek and metropolitan special areas (Sydney Water and NSW NPWS 1997) was also reviewed.

3.4 FIELD SURVEYS

Field survey work was carried out by three teams specialising in flora, fauna and aquatic environments. All field work was undertaken between 28 October 1996 to 31 January 1997. The date, type and location of field surveys are listed in *Table 3.1*. Specialist sub-consultants were commissioned to carry out targeted surveys for significant fauna species and their habitats on the Holsworthy Military site.

TABLE 3.1 DATE, TYPE AND LOCATION OF FIELD SURVEYS (28 OCTOBER 1996 - 30 JANUARY 1997)

Survey Type	Badgerys Creek	Holsworthy
General Flora	17-19 December	28 October - 29 November
General Fauna	17-23 December	28 October -22 November
Eastern Bristlebird Survey	-	26-27 November
Broad-headed Snake Survey	-	29 November, 3-4 December
Additional Owl Playbacks	-	23, 25, 26, 27 November
Additional Bat Detecting	-	17-18 December
Aquatic Fauna and Habitats	27-30 January	16 December - 9 January

3.4.1 BADGERYS CREEK

Flora

Existing vegetation maps and current aerial photos were used to determine the distribution of vegetation communities. Field survey work aimed to ground-truth vegetation community boundaries, compile an inventory of plant species, search for significant plant species and to record the composition, structure and condition of the vegetation.

An inventory of species was compiled from the field survey results, a literature review and from previous studies. Vegetation of the sites of the Badgerys Creek airport options, was mapped. Details of the survey and assessment methodology are given in *Appendix A*.

Fauna

Current aerial photographs and existing vegetation maps were used to determine habitat distribution at the sites of the Badgerys Creek airport options. An inventory of species was compiled from field survey results, existing literature and previous studies.

The field surveys targeted those areas which had not been previously sampled and aimed to detect significant species where appropriate habitats occurred. Observations were made on habitat characteristics such as degree of disturbance, connectivity and condition. Survey techniques are described in detail in *Appendix B*.

Fauna was surveyed using a range of techniques:

- active daytime searching;
- hair tubing transects;
- spotlighting for nocturnal frogs, birds and mammals;
- frog call census;
- bird survey (observations and call identification); and
- bat detecting.

Fauna sampling sites for the sites of the Badgerys Creek airport options are given in *Figure 3.1*.

Apart from some scattered showers on one day (17 December 1996), the weather was ideal for fauna survey work. During the remainder of the survey period, the weather varied from mild and overcast to fine and warm.

Limitations

The sites of the Badgerys Creek airport options were surveyed during early summer. To overcome the possibility of missing seasonally inactive or non-resident animals, the report incorporates results from previous field surveys conducted in the general area, the consultant's own records from the region and those held in biological databases. Furthermore, surveys were conducted to target rare or significant species, including those listed on the Schedules 1 and 2 of the *NSW Threatened Species Act 1995.*

Landowners restricted access to some parts of the Badgerys Creek site. In particular, no access was permitted on land owned by Inghams Enterprises Pty Ltd and the Luddenham Pastoral Company. Aerial photo interpretation revealed that these areas contained riparian vegetation, woodland and a wetland. The habitat values of these sites remain unknown.

Accessibility to the sites of the Badgerys Creek airport options increased the risk of vandalism to equipment. Survey equipment had to be closely monitored, thus restricting survey techniques which could be used. For instance, bat detectors were not left out overnight but were activated for short periods at selected locations where they could be monitored. Harp traps were not used because obvious flyways were not identified at the study site; these act to 'funnel' flying bats into the trap.

Freshwater Fish and Crayfish

Current aerial photos and topographic maps were used to broadly characterise the diversity of stream habitats present. Data on fish and crayfish were derived from the literature, consultation with experts and data bases. Field survey was aimed at ground-truthing habitat attributes with emphasis on locating fish migration obstacles and assessing quality of habitat and susceptibility of degradation. Survey techniques are described in detail in *Appendix C.*

Similar methodology used for both the Badgerys Creek and Holsworthy site, is described below. Aquatic sampling sites used for the sites of the Badgerys Creek options are shown in *Figure 3.1.*

The freshwater fauna survey targeted only fish and crayfish species and their habitats. Other fauna associated with streams and wetlands, such as platypus, turtles and frogs were considered as part of the terrestrial fauna survey. In addition, the Water Quality Subconsultant undertook macroinvertebrate sampling. The results of macroinvertebrate sampling are contained in *Technical Paper No. 7 - Geology, Soils and Water.*

Characterising Freshwater Habitat

The desktop component of the study was undertaken prior to field work. To broadly characterise the diversity of stream habitats present, the following attributes were described in selected stream and river sections using 1:25,000 topographic maps and aerial photos.

Stream elevation - longitudinal profiles of stream elevation form the basis of derivation of stream gradients.

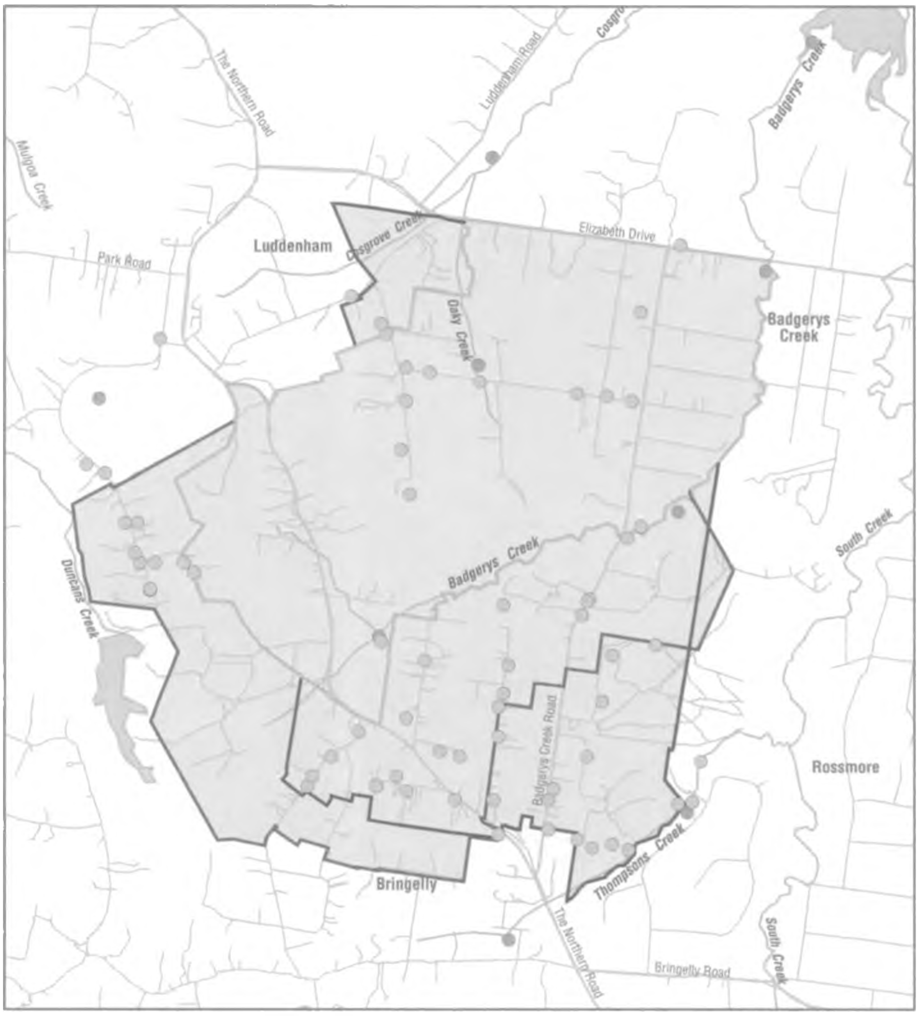


Figure 3.1

Badgerys Creek Terrestrial and Aquatic Fauna Survey Sites

Stream gradient - gradient strongly influences the abundance, size and depth and velocity characteristics of the pool habitats and the occurrence of riffles and migration obstacles.

Stream width - width provides an indication of volume of habitat, a key habitat feature of streams.

Riparian vegetation canopy width - canopy width gives an indication of the integrity of river bank vegetation.

Habitat diversity index - apart from characterising fundamental features of the stream and river environments, analysis of the physiographic and riparian features provides the basis for the development of a measure of habitat diversity for each of the various stream and river sections.

Field studies placed particular emphasis on the following tasks:

- locating fish migration obstacles;
- assessing habitat quality and its susceptibility to degradation; and
- determining the suitability of habitat for 'Macquarie Perch', a species of conservation significance likely to occur in the area.

Characterising Fish and Crayfish Communities

The following sampling methods were used for fish and crayfish:

- six-hour sets of monofilament surveying gillnets;
- six-hour sets of four 'Operahouse' fish/crayfish traps (as per gill nets);
- collecting in shallow areas (less than one metre) with a 10 metre long seine net;
- collecting in shallow areas (less than one metre) with a two millimetre mesh Japanese push seine;
- observing and dipnetting fish at night with the aid of a 50 Watt underwater spotlight;
- recording the occurrence of fish and crayfish during the day by visual observation, using polarising glasses;

- collections during the day by attracting fish and crayfish with bait and capturing individuals with a dipnet; and

- opportunistic collections during the day with a dipnet.

For the Badgerys Creek proposals, field survey work was not undertaken in the lower Nepean River or the upper Hawkesbury River estuary because of intensive sampling recently undertaken by NSW Fisheries (Gerhrke and Harris 1996; Pollard et al. 1994).

Contact with Recreational Anglers

Representatives from a number of recreational fishing clubs (*Table A3.1* in *Appendix C*) were contacted and asked to indicate their use of various stream or river sections relevant to investigations in the sites of the Badgerys Creek options. They were also asked to give an indication of the extent to which they valued the fisheries in these sections (*Table A3.2* and *A3.3* in *Appendix C*).

Limitations

One-off sampling at 10 sites in the Badgerys Creek area provides an initial indication of the fish and crayfish species present in this respective area. In no sense can developed lists be considered complete as seasonal changes in composition (due to migration or other dynamic processes) are expected and these have not been examined in the present study.

Given the number of sampling sites, and the large areas involved (including areas of potential downstream impacts), a high probability exists that species with very patchy distributions could remain unrecorded. This limitation has been to some extent been offset by using information from other studies in the area, relevant databases and consultation with researchers, landholders, anglers and fishing clubs.

Other limitations include:

- denial of access by land managers to the upper reaches of Duncans Creek (Luddenham Pastoral Company in the Badgerys Creek area);

- reduction of sampling efficiency due to high stream flows in Thompsons Creek and some sites in Badgerys Creek, due to prolonged rain during the sampling period;

- late arrival of information from fishing clubs, thus making it impossible to take advantage of location leads regarding high conservation value or recreation-value fish species;

- a requirement set by the NSW Fisheries scientific permit that no set nets to be left unattended - accordingly only one site could be sampled per night with set nets (both areas); and

- conditions imposed by Sydney Water restricting access to the Woronora Reservoir and the river upstream.

3.4.2 HOLSWORTHY MILITARY AREA

Flora

Existing vegetation maps and current aerial photos were used to determine the distribution of vegetation communities. Field survey work aimed to ground-truth vegetation community boundaries, compile an inventory of plant species, search for significant plant species and to record the composition, structure and condition of the vegetation. Survey techniques are described in detail in *Appendix A*.

An inventory of species was compiled from the field survey results, literature review and from previous studies. Vegetation of the Holsworthy Military Area was mapped. Locations of quadrat sampling sites are shown in *Figure 3.2*.

The field survey of French *et al.* (1995) was conducted between October and April. Biosis Research conducted its field survey work between late October and mid-December. Although spring is the optimal time for survey, certain species, mainly orchids, are only detectable at other times of the year. For instance, in summer, orchids take the form of dormant below ground 'tuberoids' which are undetectable above ground.

Given the large size and rugged topography of the Holsworthy Military Area, further survey is likely to result in the recording of more species. While only 12 species of orchids were detected during the present survey, the Australian Native Orchid Society has records of over 70 species which occur in the vicinity of the Holsworthy site (letter from A. Dash to the Minister of Transport and Regional Development, August 1996). In general, the number of unrecorded plant species is considered to be low.

Fauna

Current aerial photographs and existing vegetation maps were used to determine habitat distribution at the Holsworthy Military Area. An inventory of species was compiled from field survey results, existing literature and previous studies.

The field surveys targeted those areas which had not been previously sampled and aimed to detect significant species where appropriate habitats occurred.

Observations were made on habitat characteristics such as degree of disturbance, connectivity and condition. Survey techniques are described in detail in *Appendix B*.

The fauna within the options at Holsworthy Military Area was surveyed using a range of techniques:

- active daytime searching;
- hair tubing transects;
- scat analysis;
- spotlighting for nocturnal frogs, birds and mammals;
- call playback for territorial nocturnal birds and mammals;
- frog call census;
- bird survey (observations and call identification); and
- bat trapping and detection of ultrasonic calls.

Survey techniques are described in *Appendix B*. Fauna sampling sites are shown in *Figure 3.3*.

In general, the weather conditions during the survey period were fine and warm, although at least one week was characterised by cold, wet weather conditions which were atypical of spring. To compensate for this, additional survey work was undertaken to detect bats during warmer weather conditions when bats are most likely to be active.

Limitations

The Holsworthy Military Area was surveyed during one month in late spring. Although spring and summer provide an ideal opportunity to survey fauna species, the site and inaccessibility of the Holsworthy Military Area precluded a thorough survey. As for the Badgerys Creek study areas, the possibility of missing seasonally inactive or absent animals was overcome by incorporating results from previous field surveys conducted in the general area, the consultant's records from the region and those held in biological databases.

The fauna survey was completed during the time of year when the Broad-headed Snake (the only species of National significance known to occur at Holsworthy) is unlikely to be detected (J. Webb, University of the Northern Territory, *pers. comm.*; M. Thompson, University of Sydney, *pers. comm.*).

Figure 3.2

Flora Survey Sites for Holsworthy Military Area

22/9/97

Figure 3.3

Terrestrial and Aquatic Fauna Survey Sites for Holsworthy Military Area

However, because the AXIS/Australian Museum Business Services audit confirmed that this species and its habitat occur on the Military Area, a specialist sub-consultant was engaged to map potential Broad-headed Snake habitat. Extensive heathlands identified at the Holsworthy Military Area provided potential habitat for two bird species of State significance, the Ground Parrot and the Eastern Bristlebird. An expert ornithologist was therefore engaged to undertake surveys for these species and to assess their habitat in the Holsworthy Military Area. There was a high level of public concern over the possible occurrence of these species on the site.

Finally, certain areas within the Holsworthy Military Area were difficult to access. To compensate for this, rare and endangered species were targeted in likely habitats such as gullies and heathland. Access was further restricted by military training activities; in particular the Small Arms Danger Area and Demolition Range 1. By maintaining a highly flexible field schedule, adequate access was gained to both of these areas.

Freshwater Fish and Crayfish

Current aerial photos and topographic maps were used to broadly characterise the diversity of stream habitats present. Data on fish and crayfish were derived from the literature, consultation with experts and databases. Field survey was aimed at ground-truthing habitat attributes with emphasis on locating fish migration obstacles and assessing quality of habitat and susceptibility to degradation. Within the Holsworthy Military Area, sampling targeted primarily Macquarie Perch and crayfish. Survey techniques are described in detail in *Appendix C*.

Similar methodology used for both the Badgerys Creek and Holsworthy site, is described below. Streams considered for the Holsworthy Military Area are shown in *Figure 3.3*.

The freshwater fauna survey targeted only fish and crayfish species and their habitats. Other fauna associated with streams and wetlands, such as Platypus, turtles and frogs were considered as part of the terrestrial fauna survey. In addition, the Water Quality Subconsultants undertook macroinvertebrate sampling. The results of macroinvertebrate sampling are reported in *Technical Paper No. 7 - Geology, Soils and Water*.

Characterising Freshwater Habitat

The desktop component of the study was undertaken prior to field work. To broadly characterise the diversity of stream habitats present, the following attributes were described in selected stream and river sections using 1:25,000 topographic maps and aerial photos.

Stream elevation - longitudinal profiles of stream elevation form the basis of derivation of stream gradients.

Stream gradient - gradient strongly influences the abundance, size and depth and velocity characteristics of the pool habitats and the occurrence of riffles and migration obstacles.

Stream width - width provides an indication of volume of habitat, a key habitat feature of streams.

Riparian vegetation canopy width - canopy width gives an indication of the integrity of river bank vegetation.

Habitat diversity index - apart from characterising fundamental features of the stream and river environments, analysis of the physiographic and riparian features provides the basis for each of the development of a measure of habitat diversity for each of the various stream and river sections.

Field survey timing is shown in *Table 3.1*. Field studies placed particular emphasis on the following tasks:

- locating fish migration obstacles;
- assessing habitat quality and its susceptibility to degradation; and
- determining the suitability of habitat for 'Macquarie Perch', a species of conservation significance likely to occur in the area.

Characterising Fish and Crayfish Communities

The following sampling methods were used for fish and crayfish:

- six-hour sets of monofilament surveying gillnets;
- six-hour sets of four 'Operahouse' fish/crayfish traps (as per gillnets);
- collecting in shallow areas (less than one metre) with a 10 metre long seine net;
- collecting in shallow areas (less than one metre) with a two millimetre mesh Japanese push seine;
- observing and dipnetting fish at night with the aid of a 50 Watt underwater spotlight;

- recording the occurrence of fish and crayfish during the day by visual observation, using polarising glasses;
- collections during the day by attracting fish and crayfish with bait and capturing individuals with a dipnet; and
- opportunistic collections during the day with a dipnet.

At the Holsworthy Military Area, field survey work was not undertaken in the Woronora River downstream of Woronora Dam because of recent intensive sampling undertaken by the Ecology Lab for Sydney Water (in progress).

Contact with Recreational Anglers

Representatives from a number of recreational fishing clubs (*Table A3.1* in *Appendix C*) were contacted and asked to indicate their use of various stream and river sections relevant to investigations in the Holsworthy Military Area. They were also asked to give an indication of the extent to which they valued the fisheries in these sections (see *Table A3.2* and *A3.3* in *Appendix C*).

Limitations

One-off sampling at 16 sites in the Holsworthy Military Area provides an initial indication of the fish and crayfish species present in this respective area. In no sense can developed lists be considered complete as seasonal changes in composition (due to migration or other dynamic processes) are expected and these have not been examined in the present study.

Given the number of sampling sites, and the large areas involved (including areas of potential downstream impacts), a high probability exists that species with very patchy distributions could remain unrecorded. This limitation has been offset to some extent by using information from other studies in the area, relevant databases and consultation with researchers, landholders, anglers and fishing clubs.

Other limitations include:

- limitations on the quantity of sampling equipment which could be carried into inaccessible ravines;
- late arrival of information from fishing clubs, thus making it impossible to take advantage of location leads regarding high conservation value or recreation-value fish species (example 'Macquarie Perch' in the Holsworthy Military Area);

- a requirement set by the NSW Fisheries scientific permit that no set nets to be left unattended - accordingly only one site could be sampled per night with set nets (both areas); and
- conditions imposed by Sydney Water restricting access to the Woronora Reservoir and the river upstream.

Part B

Existing Environment

CHAPTER 4 EXISTING ENVIRONMENT

This section provides a detailed description of the existing biological resources at locations proposed for the Second Sydney Airport at the sites of the Badgerys Creek airport options and at Holsworthy Military Area. An assessment of the conservation significance of the sites of the Badgerys Creek and Holsworthy airport options is also presented. Scientific data that supports the study findings is available in Appendices A, B and C (Flora, Fauna and Freshwater Fish and Crayfish, respectively). The statutory context, including an overview of the relevant legislation, and the bioregional context are presented as a basis for the assessment.

4.1 STATUTORY CONTEXT

Environment Australia issued Draft Guidelines for an EIS for Sydney's Second Major Airport in November 1996. These Guidelines provided specific matters to be considered as part of the biological assessment, including relevant Commonwealth and State legislation. The NSW Department of Urban Affairs and Planning provided a detailed submission on the Draft Guidelines which coordinated comments from the relevant NSW Government agencies. The submission identified issues associated with biodiversity and ecological integrity.

This assessment of impacts on Flora and Fauna has been prepared following a review of the Environment Australia Final EIS Guidelines and has considered the following legislation:

- *Environment Protection (Impact of Proposals) Act* 1974;
- *Endangered Species Protection Act* 1992;
- *NSW Threatened Species Conservation Act* 1995;
- *NSW Environmental Planning and Assessment Act* 1979;
- *NSW National Parks and Wildlife Act* 1974;
- *NSW State Environmental Planning Policy No. 46 (Protection and Management of Native Vegetation);*
- *NSW State Environmental Planning Policy No. 19 (Urban Bushland);*
- *Wilderness Act* 1987;

- *Australian Heritage Commission Act* 1975; and
- *NSW State Environmental Planning Policy No. 44 (Koala Habitat Protection).*

State requirements set out in the *Threatened Species Conservation Act 1995* and the NSW State Environmental Planning Policies are detailed in the species profiles contained in *Appendices B* and C.

A variety of regional and local plans have also been reviewed. Detailed information on planning instruments is provided in *Technical Paper No. 2 Planning*. Of particular relevance is the *Liverpool Draft Local Environmental Plan* which proposes to rezone the Holsworthy Military Area, within Liverpool local government area, to Environment Protection, Bushland. This zone aims to protect and conserve important bushland areas.

4.2 BIOREGIONAL CONTEXT

Both the sites of the Badgerys Creek airport options and Holsworthy Military Area lie within the Sydney Basin, a geological unit which extends roughly from the Pacific Ocean in the east to the Blue Mountains Plateau in the west, and from the Hornsby Plateau in the north to the Woronora Plateau in the south (Benson and Howell, 1990).

The NSW National Parks and Wildlife Service recognises distinct bioregions within NSW. These regions are currently being refined to take into account the *Interim Biogeographic Regionalisation for Australia* report, prepared by Australian Nature Conservation Agency, 1995. There are two bioregions in the Sydney Basin: Coastal Sandstone Plateau and the Cumberland Plain (Environment Protection Authority, 1993).

The plateaus comprise Hawkesbury Sandstone and form the rim of the Sydney Basin. The sandstone landscapes are characterised by steep hills, long narrow ridges and deep rocky valleys and support sandy, shallow infertile soils (Benson and Howell, 1990). Subsidence in the centre of the basin formed the Cumberland Plain. Shales and sandstones of the Wianamatta group overlie the Hawkesbury sandstone on the Cumberland Plain. This geology and gentle topography provides fertile clay soils which retains moisture better than surrounding sandy soils (Benson and Howell, 1990; Robinson, 1991).

The Holsworthy Military Area lies in the south-west of the Sydney Basin. The site comprises approximately 15,000 hectares and contains a large variety of flora and fauna habitats which exhibit a low level of disturbance. It is currently being used as an army training facility and part of it has been developed as firing and demolition ranges. An area of Cumberland Plain

Woodland (2,230 hectares) is located in the north-west of the site. The remainder of the site supports predominantly woodland heath complex and gully forest developed on the Hawkesbury Sandstone of the Woronora Plateau.

The Badgerys Creek area lies roughly in the centre of the Cumberland Plain and forms the central dish of the Sydney Basin. The area comprises approximately 2,800 hectares, most of which has been cleared for grazing and other agricultural purposes. Remnant fauna habitat comprises predominantly scattered Grey Box woodland remnants and riparian creekline vegetation, but also includes small areas of *Melaleuca* woodland and numerous water bodies including dams and wetlands.

Large areas of the Sydney Basin have been cleared for commercial development, housing and agriculture. Habitat loss has been most significant on the Cumberland Plain where relatively fertile shale soils and undulating topography are most suitable for agricultural and urban development. The rugged and infertile sandstone areas have remained largely intact, although they are becoming fragmented due to ridgetop development for roads, rural residential and urban housing. Because of its large size and central location, the metropolitan area forms a significant barrier to wildlife dispersal essentially preventing interaction between flora and fauna populations to the north and south.

Relatively large areas of natural habitat within the Sydney Basin have been extensively modified and remaining natural areas may be subject to direct and indirect impacts of urban development. Therefore, a relatively high proportion of indigenous flora and fauna species that occur in the Sydney Basin are considered to be of regional conservation significance.

For the purposes of this study, regional conservation significance has been assessed with respect to the two recognised bioregions, Coastal Sandstone Plateau and Cumberland Plain Woodland. Since the Holsworthy Military Area includes part of both bioregions, all species which are considered to be of regional significance in either bioregion are listed. Those species considered to be of regional significance on the Cumberland Plain are listed for the sites of the Badgerys Creek airport proposals.

CHAPTER 5 RESULTS OF SURVEYS

5.1 SURVEY RESULTS

5.1.1 BADGERYS CREEK

Flora

This section provides a summary of the study findings for flora. Scientific data is presented in detail in *Appendix A*.

At the national level, significant plant species are listed under Schedules 1 and 2 of the *Endangered Species Protection Act*, 1992. Briggs and Leigh (1995) also list Rare or Threatened Australian Plants (ROTAPs); the list has been maintained by the CSIRO since 1979 and includes taxa which are Presumed Extinct, Endangered, Vulnerable, Rare of Poorly Known at the national level. Plant species considered to be rare in New South Wales are listed in Schedules 1 and 2 of the *NSW Threatened Species Conservation Act, 1995*. Benson and McDougall (1991), Benson (1992), Keith (1994) and Bofeldt (1996) are used as authorities on species and vegetation of regional significance.

Plant Species

A total of 176 indigenous and 84 introduced vascular plant species (ferns, conifers, flowering plants) have been recorded at the sites of the Badgerys Creek airport options (*Appendix A*). These sites have substantial indigenous flora, although more species are likely to have been present prior to extensive clearance, grazing by livestock and weed invasion of habitat remnants.

Significant Plant Species

A total of one species of national significance, nil species of State significance, and 48 species of Regional significance have been recorded at Badgerys Creek (*Table 5.1* and *Table 5.2*). The species of national significance, *Pultanaea parviflora* is discussed in detail in a profile contained in *Appendix A*.

TABLE 5.1 PLANT SPECIES OF NATIONAL CONSERVATION SIGNIFICANCE WITHIN BADGERYS CREEK AIRPORT SITES

Plant name	ROTAP	Status in Study Area	Location
Pultenaea parviflora	2E	Rare	Both sides of Longleys road; east of Ferndale Road; west of Taylor Road

Note:
2 Geographic range in Australia is less than 100 kilometres.
E Endangered.

TABLE 5.2 PLANT SPECIES OF REGIONAL CONSERVATION SIGNIFICANCE WITHIN BADGERYS CREEK AIRPORT SITES

Plant name	Status in Study Area	Location
Acacia implexa	uncommon	Tributary of Badgerys Creek, south of junction of Badgerys Creek and Badgerys Creek Road
Amyema gaudichaudii	uncommon	River flat forest; Badgerys and Cosgrove Creeks
Amyema miquelii	occasional	Grey Box Woodland
Angophora subvelutina	occasional	River flat forest; Badgerys Creek, especially south of Longleys Road
Arthropodium milleflorum	uncommon	Grey Box Woodland; east of Willowdene Avenue
Bothriochloa macra	uncommon	Road reserve Elizabeth Drive
Carex breviculmis	uncommon	Drainage line in Grey Box Woodland; east of Willowdene Avenue
Chrysocephalum apiculatum	rare	Grey Box Woodland; east of Willowdene Avenue
Clematis glycinoides	uncommon	River Flat forest; Badgerys Creek
Convolvulus erubescens	uncommon	River Flat forest, near Badgerys Creek Road
Cymbonotus lawsonianus	rare	Grey Box Woodland; east of Willowdene Avenue
Cymbopogon refractu	rare	River Flat forest; Thompsons Creek
Cyperus difformis	uncommon	Tributary of Badgerys Creek, south of junction of Badgerys Creek and Badgerys Creek Road
Cyperus polystachyos	occasional	Margins of treatment pond, north of Longleys Road
Daviesia genistifolia	occasional	Grey Box Woodland; east of Willowdene Avenue and Longleys Road
Desmodium brachypodum	occasional	Grey Box Woodland; east of Willowdene Avenue; Roadside, Badgerys Creek Road
Dillwynia parvifolia	uncommon	Road reserve; Elizabeth Drive
Einadia nutans	uncommon	Grey Box Woodland; east of Willowdene Avenue and Longleys Road
Eleocharis acuta	uncommon	Drainage line in Grey Box Woodland; east of Willowdene Avenue
Epilobium billardieranum subsp cinereum	uncommon	Tributary of Badgerys Creek, south of junction of Badgerys Creek and Badgerys Creek Road

TABLE 5.2 CONTINUED

Plant name	Status in Study Area	Location
Eremophila debilis	occasional	Grey Box Woodland; east of Willowdene Avenue and Longleys Road
Eucalyptus amplifolia	occasional	River Flat forest; Badgerys and Cosgroves Creek
Eucalyptus bosistoana	rare	Grey Box Woodland, east of Badgerys Creek
Euchiton sphaericus	rare	Grey Box Woodland; east of Willowdene Avenue
Exocarpos strictus	rare	Grey Box Woodland; east of Willowdene Avenue
Geranium solanderi	uncommon	Grey Box Woodland; east of Willowdene Avenue
Leucopogon juniperinus	occasional	Grey Box Woodland; east of Willowdene Avenue and Longleys Road; also in sections of road reserve
Linum marginale	uncommon	Roadside; Badgerys Creek Road
Lythrum hyssopifolia	rare	Tributary of Badgerys Creek, south of junction of Badgerys Creek and Badgerys Creek Road
Marsilea hirsuta	rare	Tributary of Badgerys Creek, south of junction of Badgerys Creek and Badgerys Creek Road
Opercularia aspera	uncommon	Roadside; Willowdene Avenue
Oplismenus aemulus	occasional	Tributary of Badgerys Creek, south of junction of Badgerys Creek and Badgerys Creek Road
Ottelia ovalifolia	uncommon	Tributary of Badgerys Creek, south of junction of Badgerys Creek and Badgerys Creek Road
Oxalis perennans	uncommon	Roadside; Longleys Road
Pandorea pandorana	occasional	On introduced vegetation at foot of small cliff; southern end of Willowdene Avenue
Paspalum distichum	uncommon	Tributary of Badgerys Creek, south of junction of Badgerys Creek and Badgerys Creek Road
Phyllanthus similis	uncommon	Grey Box Woodland; east of Willowdene Avenue
Plantago debilis	uncommon	River Flat forest; Badgerys Creek
Poa labillardieri	occasional	Grey Box Woodland
Potamogeton tricarinatus	uncommon	Tributary of Badgerys Creek, south of junction of Badgerys Creek and Badgerys Creek Road
Ranunculus lappaceus	occasional	Creeklines and drainage lines
Rumex brownii	occasional	Creeklines and drainage lines
Senecio hispidulus	occasional	Grey Box Woodland; east of Willowdene Avenue and OTC site

TABLE 5.2 CONTINUED

Plant name	Status in Study Area	Location
Sida corrugata	uncommon	Grey Box Woodland
Solanum pungetium	occasional	Grey Box Woodland; east of Willowdene Avenue
Tricoryne simplex	occasional	Grey Box Woodland; east of Willowdene Avenue
Vittadinia cuneata	rare	Grey Box Woodland; east of Willowdene Avenue
Vittadinia pustulata	rare	Grey Box Woodland; east of Willowdene Avenue

Source: Benson and McDougall, 1991.

Vegetation Communities

Field investigation identified three vegetation communities (*Table 5.3* and *Appendix A*) in accordance with the regional vegetation classification of the National Herbarium of New South Wales (Benson 1992).

The distribution of native vegetation communities at Badgerys Creek is shown on *Figure 5.1*.

TABLE 5.3 VEGETATION COMMUNITIES WITHIN BADGERYS CREEK AIRPORT SITES

Vegetation Community/Code	Comments
Pasture/Disturbed Woodland/BADG 1	Widespread and extensive
Grey Box Woodland (Altered)/BADG 2	Scattered
River-flat Forest (Altered)/BADG 3	Restricted to creeks

There are two vegetation communities of local significance within the Badgerys Creek airport sites.

A component community of Cumberland Plain Woodland is Grey Box Woodland, altered examples of which occur at Badgerys Creek. Benson and McDougall (1991), Benson and Howell (1990), Travers Morgan (1990), Benson (1992) and QEM (1993) stress the conservation significance of remnant stands of Grey Box Woodland in Western Sydney. Benson and McDougall (1991) observed that 'Clearing for grazing and urban development has often reduced the [Cumberland Plain] woodlands to small remnant stands of trees'. Benson and Howell (1990) stated that 'Liverpool still has a considerable number of bushland areas but very few are protected; with increasing development, each area will be carved up as expendable unless action is taken soon to protect significant areas'. Intact examples of Grey Box Woodland would have state significance but the examples at Badgerys Creek are too small and altered to be assigned this level of significance.

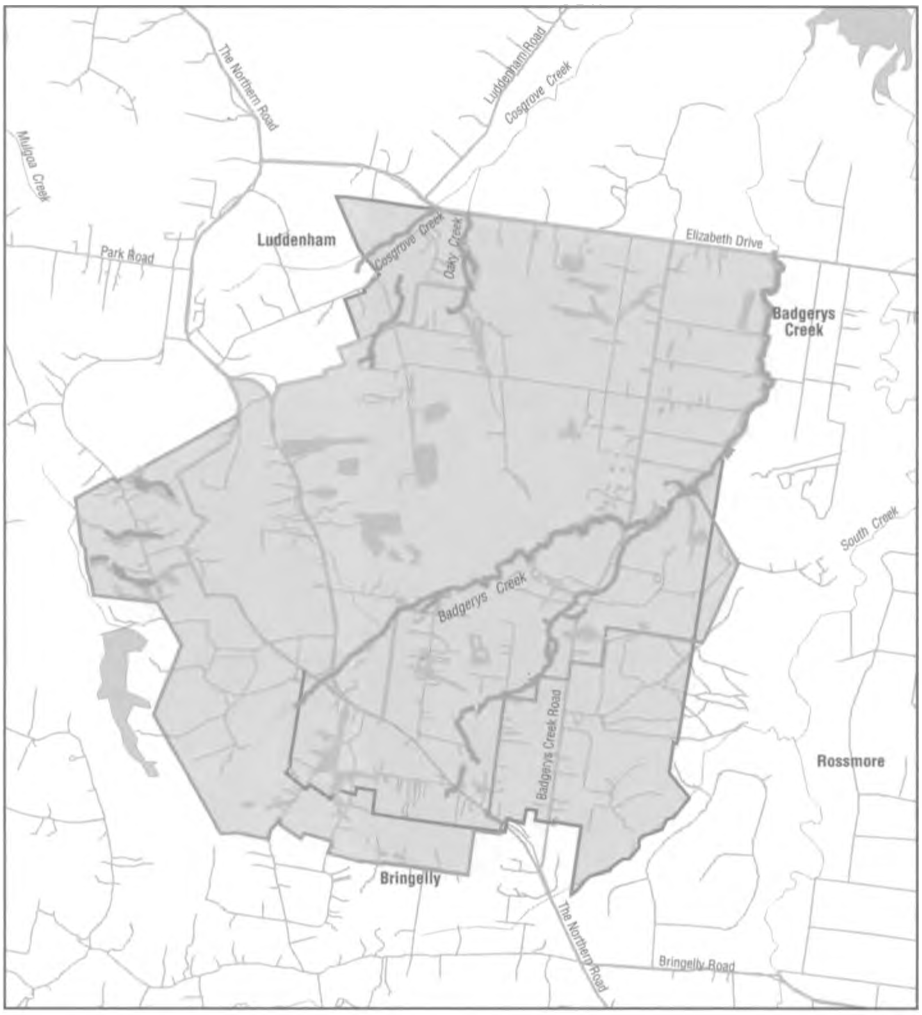


Figure 5.1
Native Vegetation on Sites of Badgerys Creek Airport Options

The NSW Scientific Committee, established under the Threatened Species Conservation Act, 1995, has listed the Cumberland Plains Woodland as an Endangered Ecological Community under Part 3 of Schedule 1 of the *Threatened Species Conservation Act.* It is therefore considered to be a vegetation community of state significance. It is assumed that once the Cumberland Plains Woodland is formally listed a set of criteria will be prepared, outlining minimum size of a stand, minimum number of individuals or species in a stand, connectivity to adjacent stands, condition of canopy and understorey and other factors. As no criteria has so far been published it is difficult to grade the stands occurring in the study area in the regional context.

Vegetation Condition

The condition of vegetation is the degree to which it resembles relatively natural, undisturbed vegetation. This is assessed according to the following criteria:

- species composition: species richness, degree of weed invasion; and
- vegetation structure: representation of each of the original layers in the vegetation.

Vegetation is assessed as being in excellent, good, moderate or poor condition.

The indigenous vegetation of the Badgerys Creek site has been subject to extensive clearance, grazing by livestock and weed invasion of remnant habitats. Little, if any undisturbed vegetation remains and remnant habitats are generally in poor condition.

Fauna

This section provides a summary of the study findings for fauna. Scientific data is presented in detail in *Appendix B*.

National significance for fauna is assessed using the following listings: ANZECC (1991) and species listed under Schedules 1 and 2 of the (Commonwealth) *Endangered Species Protection Act 1992*. Species of State significance are listed on Schedules 1 and 2 of the *Threatened Species Conservation Act, 1995*.

Regional significance for fauna is assessed by referring to relevant government reports, consulting experts familiar with the area, referring to the literature and by drawing upon previous field experience of the consultants. Species listed under International Treaties are those listed under the Japan-Australia Migratory Birds Agreement and the China-Australia Migratory Birds Agreement.

Overall Species

A total of nine amphibian species, six reptile species, 75 bird species (65 native, 10 introduced) and 20 mammal species (10 native, 10 introduced) was recorded during the current study. Taking into account all fauna records collated from the extensive literature review, sites of the Badgerys Creek airport options provide or is likely to provide habitat for at least 16 amphibian species, 27 reptile species, 153 bird species (141 native, 12 introduced) and 39 mammal species (27 native, 12 introduced). A full list of species is given in *Table A2.2* in *Appendix B*.

Table 5.4 lists the species which have been recorded or which may occur on the site.

Significant Species

A total of 17 significant fauna species have been recorded at the Badgerys Creek site, including two species of State significance and 16 species of Regional significance (*Table 5.4*). An additional two species of National significance, 10 species of State significance and 23 species of Regional significance were recorded in the vicinity of the Badgerys Creek site and may occur within the study area or adjacent to the study area. Five species listed in international agreements were also recorded.

Species of National and State significance are discussed in detail in species profiles contained in *Appendix B* of this report. The distribution of significant species in relation to the sites of the Badgerys Creek airport options is listed in *Table A2.6* of *Appendix B*. Species of Regional significance are considered in *Table A2.13*.

It should be noted that a further 11 significant species could possibly occur at the sites of the Badgerys Creek airport options but are considered to be unlikely (T. Saunders, Cumberland Bird Observers Club pers. comm.). These include four species of State significance: Square-tailed Kite, Painted Snipe, Masked Owl and Bush Stone-curlew. The latter two species are known from unconfirmed records adjacent to the study area. The following species of regional significance are also unlikely to occur at the Badgerys Creek site: Black-chinned Honeyeater, Brown Cuckoo-Dove, Brown Treecreeper, Chestnut Breasted Mannikin, Glossy Ibis, Musk Duck and King Quail. Although these species may utilise the sites of the Badgerys Creek airport options, the are unlikely to contain critical habitat for any of them.

TABLE 5.4 SIGNIFICANT FAUNA SPECIES RECORDED OR WHICH MAY OCCUR AT THE SITES OF THE BADGERYS CREEK AIRPORT OPTIONS

Common Name	Scientific Name	Status	This Study	Other Studies
Amphibians				
Brown Toadlet	*Pseudophryne bibronii*	R		
Green and Golden Bell Frog	*Litoria aurea*	S(e)		
Green Tree Frog	*Litoria caerulea*	R		
Tusked Frog	*Adelotus brevis*	R		
Reptiles				
Bearded Dragon	*Pogona barbata*	R		
Diamond Python	*Morelia spilota spilota*	R		
Lace Monitor	*Varanus varius*	R		✓
Birds				
Australasian Bittern	*Botaurus poiciloptilus*	S(v)		
Black Bittern	*Ixobrychus flavicollis*	S(v)		
Brown Songlark	*Cinclorhamphus cruralis*	R	✓	✓
Buff-rumped Thornbill	*Acanthiza reguloides*	R		✓
Cattle Egret	*Ardea ibis*	J/C		✓
Diamond Firetail Finch	*Stagonopleura guttata*	R		✓
Double-barred Finch	*Taeniopygia bichenovii*	R	✓	✓
Flame Robin	*Petroica phoenicea*	R		
Fork-tailed Swift	*Apus pacificus*	J/C		
Fuscous Honeyeater	*Lichenostomus flavescens*	R		
Glossy Black-Cockatoo	*Calyptorhynchus lathami*	S(v)		
Great Crested Grebe	*Podiceps cristatus*	R		
Great Egret	*Ardea alba*	R, J/C		✓
Hooded Robin	*Melanodryas cucullata*	R		
Jacky Winter	*Microeca fascinans*	R		✓
Nankeen Night Heron	*Nycticorax caledonicus*	R	✓	✓
Lathams Snipe	*Gallinago hardwickii*	R, J/C		
Little Eagle	*Hieraaetus morphnoides*	R		
Peaceful Dove	*Geopelia placida*	R	✓	
Peregrine Falcon	*Falco peregrinus*	R		
Powerful Owl	*Ninox strenua*	S(v)		

TABLE 5.4 CONTINUED

Common Name	Scientific Name	Status	This Study	Other Studies
Red-capped Robin	*Petroica goodenovii*	R		
Regent Honeyeater	*Xanthomyza phrygia*	N(e),S(e)		
Restless Flycatcher	*Myiagra inquieta*	R	✓	✓
Rufous Songlark	*Cincloramphus mathewsi*	R		
Shrike-tit	*Falcunculus frontatus*	R		
Speckled Warbler	*Chthonicola sagittata*	R		
Swift Parrot	*Lathamus discolor*	N(v), S(v)		
Wedge-tailed Eagle	*Aquila audax*	R		
Weebill	*Smicrornis brevirostris*	R		✓
Whistling Kite	*Haliastur sphenurus*	R		✓
White-bellied Cuckoo-shrike	*Coracina papuensis*	R		
White-fronted Chat	*Epthianura albifrons*	R		
White-throated Needletail	*Hirundapus caudacutus*	J/C		
White-winged Chough	*Corcorax melanorhamphos*	R	✓	✓
White-winged Triller	*Lalage sueurii*	R		
Yellow-rumped Thornbill	*Acanthiza chrysorrhoa*	R	✓	✓
Zebra Finch	*Taeniopygia guttata*	R		
Mammals				
Common Bentwing Bat	*Miniopterus schreibersii*	S(v)	✓	✓
Eastern False Pipistrelle	*Falsistrellus tasmaniensis*	S(v)	✓	
Eastern Little Mastiff Bat	*Mormopterus norfolkensis*	S(v)		
Greater Broadnosed Bat	*Scoteanax rueppellii*	S(v)		
Grey-headed Flying-fox	*Pteropus poliocephalus*	R	✓	
Large-footed Myotis	*Myotis adversus*	S(v)		
Large Pied Bat	*Chalinolobus dwyeri*	S(v)		
Little Red Flying Fox	*Pteropus scapulatus*	R		
White-striped Mastiff-bat	*Nyctinomus australis*	R		✓
Yellow-bellied Sheathtail Bat	*Saccolaimus flaviventris*	S(v)		

Note: Status: N(e) – Listed on Schedule 1 of the Endangered Species Protection Act (1992); N(v) – Listed on Schedule 2 of the Endangered Species Protection Act 1992; S(e) – Listed on Schedule 1 of the NSW Threatened Species Conservation Act 1995; S(v) – Listed on Schedule 2 of the NSW Threatened Species Conservation Act 1995; R – Regional significance; J/C – JAMBA/CAMBA International Treaties; C – CAMBA; ✓ – Recorded at site. (Blank) – may occur at site.

The species list shown in *Table 5.4* should not be considered as exhaustive.

Fauna Habitats

A habitat type is formed by particular structural and floristic vegetation features which provide a specific set of resources that support a particular range of fauna species. Habitat types generally correspond to the vegetation communities described for the study areas (*Figure 5.1*). It should be noted that boundaries drawn around these habitats are artificial, as many fauna species move between habitats or use more than one habitat according to changing conditions or season.

In general, habitats of high value contain a high diversity and abundance of breeding, nesting, feeding and roosting resources and support high richness and diversity of native fauna species. Habitats of poor value have a low diversity and abundance of breeding, nesting, feeding and roosting resources and support low richness and diversity of native fauna species. Medium value habitats are intermediate in their value to fauna.

Woodland Remnants

This habitat is characterised by small open woodland remnants which have been created by clearing native vegetation for agriculture or other human development. Most remnants in the study area contain mixed-aged regrowth trees which range from about 10 to 20 metres in height. The low proportion of mature trees restricts the availability of suitable nesting and roosting hollows for native species. The understorey varies from sparse to dense depending on grazing pressure. The ground cover contains a mixture of native and exotic grasses and in many areas exotic weeds and wind-blown rubbish was observed. While the native fauna present is usually less diverse than that in the original woodland, these remnants are important for maintaining populations of native species within the rural and semi-urban landscapes and can support significant species. It is an important habitat for native fauna in the local area.

Corresponding Vegetation Community: Grey Box Woodland
Condition: Moderate to Poor

Riparian Woodland

This habitat occurs as a narrow band along wetter drainage lines. It is diverse and structurally rich with a mix of both specialist species and species which occur at the boundary of two different vegetation communities. Riparian Woodland is usually characterised by an over-storey of mature hollow-bearing trees. The understorey varies according to the extent of grazing, with the majority of areas being heavily grazed down to the water's edge. In some areas large amounts of leaf litter and other ground debris, including dumped rubbish were observed. Fauna diversity is high because riparian specialist species and fauna from adjacent habitats use the local resources for food, shelter or movement along this corridor to other habitats. Riparian Woodland is an important habitat and refuge for both these fauna groups.

Corresponding Vegetation Community: River-flat Forest
Condition: Moderate to Poor

Melaleuca Woodland

This is a small area of woodland which consists of medium density trees up to four metres in height. The understorey consists of saplings and exotic shrubs while the ground cover consists of grasses and exotic weeds.

Corresponding Vegetation Community: River-flat Forest
Condition: Poor

Grassland

This is a natural habitat which has usually been modified by human management and generally occurs on private land. It is dominated by native and introduced grasses and herbs, often with mature isolated remnant trees. It supports a small number of common native fauna species and a range of introduced species. Grassland areas provide habitat primarily for introduced and open-country bird species including starlings, skylarks, goldfinches, mynahs, magpie-larks, magpies and finches. Raptors may also hunt over open areas.

Corresponding Vegetation Community: Pasture/Disturbed Woodland
Condition: Moderate to poor

Open Water/Wetlands

The rural landscape contains numerous farm dams of varying sizes. The majority of these contain emergent and floating aquatic vegetation. Many of these dams have been highly disturbed by livestock and are heavily grazed and trampled. There is however, a number of less disturbed artificial wetlands which are likely to be occupied by moorhens, swamphens, herons, coots and possibly by rails and crakes.

Corresponding Vegetation Community: None.
Condition: Moderate to poor

Overall Condition of Fauna Habitats

Generally the condition of the fauna habitats within the Badgerys Creek study area has been highly altered and invasion by introduced plants and animals is evident. The conservation value of substantial portions of the study area has been significantly influenced by factors such as vegetation clearance, soil disturbance (ploughing, road and building construction, etc.), frequent burning, invasion by weeds and introduced predators, and grazing by domestic stock and rabbits.

Freshwater Fish and Cray Fish

This section provides a summary of the study findings for fish and crayfish species and their habitat. Scientific data is presented in *Appendix* C.

Fish species are listed nationally as Endangered, Vulnerable, Potentially Threatened, Indeterminate and Uncertain, by Jackson (1995). At the State level, significant species are listed under the *Fisheries Management Act, 1994*. All crayfish species are considered to have high conservation value. Conservation index derivation followed the procedure used by Bishop (in Meredith *et al*, 1995) for a sample of 1,032 streams in south-eastern Australia.

Habitat

Summary statistics of stream variables used to calculate habitat diversity index values for selected streams in the area are given in *Figure A3.6 in Appendix C*. Streams considered from the Badgerys Creek site are shown in *Figure 3.1*.

Except for South Creek, the streams (excluding artificial water bodies) are all very narrow. All have, at best, only narrow corridors of riparian vegetation. Mean elevations range from only 37 to 79 metres and stream gradients are generally low. Excluding Thompsons Creek, the gradients show minimal variation.

Variation in elevation, stream gradient, stream width and riparian vegetation width strongly and positively influence habitat diversity. The calculated habitat-diversity index values for each stream sampled are shown in *Figure A3.3* in *Appendix C*. These indicate low to moderate habitat diversity.

Fish and Crayfish Species

A list of the fish species recorded in streams in and around the study areas of the Badgerys Creek options are given in *Table A3.4, Appendix* C. A total of 21 species were recorded during the present study. The results are summarised in *Table 5.5*.

TABLE 5.5 SUMMARY OF FISH AND CRAYFISH SPECIES RECORDED WITHIN AND AROUND THE SITES OF THE BADGERYS CREEK AIRPORT OPTIONS

Location	Native Fish Species	High Conservation Value Fish	High Recreation Value Fish	Introduced Fish Species	High Conservation Value Crayfish
South Creek and upper tributaries	10	-	Australian Bass	3	possibly yabby
Duncans Creek to the lower Nepean River	16	'Macquarie Perch'	Australian Bass, Eel-tailed Catfish, 'Macquarie Perch'	3	-

Recreational Fisheries

Most of the fishing clubs contacted indicated that their members rarely fished the streams draining to the Badgerys Creek site. It appeared that members had generally discounted the streams as fishing sites given that they were apparently polluted and only contained European Carp and eels. However, the representative of one fishing club indicated that the quality of fishery was very good (at least in summer) in the lower reaches of South Creek grading down to reasonable in Badgerys Creek. This shift in quality corresponded to catches being dominated by native species (for example, Australian Bass, herring and mullet) in the lower reaches and European Carp and eels in the upper reaches.

A recreational fishing survey conducted in 1996 in the Nepean River downstream of Duncans Creek confluence, indicated that the quality of the fishery was viewed as ranging from "very good" to "excellent". Duncans Creek drains the western edge of the Badgerys Creek site.

5.1.2 HOLSWORTHY

Flora

This section provides a summary of the results collected for flora. Full details are presented in *Appendix A.*

Plant Species

The indigenous flora of the Holsworthy Military Area is particularly rich. This is largely due to its location on the boundary of two biogeographic regions (Cumberland Plain in the north and Coastal Sandstone Plateau in the south).

This is also partly due to its considerable size and relatively undisturbed condition. A total of 546 indigenous and 37 introduced vascular plant species have been recorded within the Holsworthy Military Area (*Appendix A*).

Significant Plant Species

A total of 14 species of National significance, 10 species of State significance, and 65 species of Regional significance have been recorded within the Holsworthy Military Area (*Tables 5.6, 5.7* and *5.8*). Species of National significance are discussed in detail in the species profiles in *Appendix A*.

TABLE 5.6 PLANT SPECIES OF NATIONAL CONSERVATION SIGNIFICANCE AT HOLSWORTHY MILITARY AREA

Plant Name	ROTAP	Status in Study Area	Location[1]
Darwinia diminuta	3RCi	uncommon	Heathland to open woodland on HSS; D; Wild Cat and Wallaby Ridges
Darwinia grandiflora	2RCi	uncommon	Open woodland on rocky sections; D and Complete Creek, Small Arms Firing Range
Eucalyptus luehmanniana	2RCa	rare	Heathland/woodland on HSS upper escarpments; Wild Cat and Wallaby Ridges, Dahlia Creek
Grevillea longifolia	2RC-	occasional	Creeklines and lower slopes; Harris, Williams, Deadmans, Punchbowl and O'Hares Creeks
Hibbertia nitida	2RC-	occasional	Mostly escarpment slopes, occasionally on rocky plateaus; D E G H
Leucopogon exolasius	2VC-	uncommon	Heathland on HSS; D E F H
Lomandra fluviatilis	3RCa	occasional	Creek-beds; Punchbowl, Deadmans, O'Hares and Williams Creeks
Melaleuca deanei	3RC-	uncommon	Heathland to open woodland on HSS plateau; B C D E H and Small Arms Firing Range
Tetratheca neglecta	3RC-	occasional	Heathland to open woodland on HSS;B C D E G
Pultenaea aristata	2VC-	uncommon	Sedgeland/heathland; E
Persoonia nutans	3RC-	rare	Woodland understorey; Small Arms Firing Range and Heathcote Road
Allocasuarina glareicola	2E	rare	Shale/sandstone Forest, tributary of Punchbowl Creek

TABLE 5.6 CONTINUED

Plant Name	ROTAP	Status in Study Area	Location[1]
Pterostylis sp. E	TBA	rare	Rock outcrop; tributary of Harris Creek, Small Arms Firing Range
Monotoca ledifolia	3RC-	rare	Open heath

Note: 1. HSS Hawkesbury Sandstone.
2 – Geographic range in Australia less than 100 kilometres; 3 – Geographic range in Australia greater than 100 kilometres; E – Endangered; V – Vulnerable; R – Rare; C – Reserved; i – less than 1,000 plants known to occur within a conservation reserve; a – 1,000 plants or more known to occur within a conservation reserve; - – reserved population is not accurately known. Letters A to H denote Army ranges within the Holsworthy Military Area.

TABLE 5.7 PLANT SPECIES OF STATE CONSERVATION SIGNIFICANCE AT HOLSWORTHY MILITARY AREA

Plant Name	Reference	Status in Study Area	Location in Study Area[1]
Eucalyptus baueriana	Leonard pers. obs.	rare	Banks of Georges River and Williams Creek; near Moorebank Avenue
Eucalyptus ligustrina	Leonard pers. obs.	rare	HSS woodland and heath; E
Eucalyptus multicaulis	Leonard pers. obs.	rare	Escarpment tops and rocky plateaus; D E
Eucalyptus squamosa	Leonard pers. obs.	occasional	Mainly in Shale/sandstone forest; B D G H
Grevillea diffusa var. *diffusa*	Leonard pers. obs.	occasional	HSS woodland understorey; B C D E F G H
Hakea salicifolia narrow-leaf form	Leonard pers. obs.	occasional	Creeklines; Punchbowl, O'Hares, Deadmans Creeks
Leucopogon amplexicaulis	Leonard pers. obs.	uncommon	Base of rock outcrops upper escarpment slopes: D E
Persoonia mollis subsp *nectens*	Leonard pers. obs.	uncommon	Escarpment slopes; G H
Tetratheca shiressii	Leonard pers. obs.	uncommon	HSS woodland and heath; B
Westringia longifolia	Leonard pers. obs.	uncommon	Creeklines; Punchbowl and O'Hares Creeks

Note: 1. HSS Hawkesbury Sandstone.
Letters A to H denote Army Ranges within the Holsworthy Military Area.

TABLE 5.8 PLANT SPECIES OF REGIONAL CONSERVATION SIGNIFICANCE AT HOLSWORTHY MILITARY AREA

Plant Name	Reference	Status in Study Area	Location in Study Area[4]
Acacia binervia	1	occasional	Banks of Georges River and Williams Creek; near Moorebank Avenue
Acacia implexa	1	occasional	Escarpment slopes and some creeklines; Small Arms Firing Range; F G H
Allocasuarina nana	3	uncommon	HSS heath; B C E
Allocasuarina paludosa	3	occasional	heath on poorly drained HSS ; B C D
Alphitonia excelsa	1	uncommon	Creeklines, lower escarpment slopes; Small Arms Firing Range; G H
Amyema gaudichaudii	1	uncommon	Melaleuca thicket; F
Amyema miquelii	1	occasional	Open forest and woodland; B F
Angophora hispida	3	occasional	HSS woodland and heath; CD B E F G H
Aotus ericoides	1	uncommon	Creeklines, Punchbowl and Deadmans Creeks
Avicennia marina	1	rare	Deadmans Creek, near Heathcote Road
Blechnum ambiguum	3	uncommon	Rocky creeklines; tributary of O'Hares Creek
Bossiaea neo-anglica	2	uncommon	Shale/sandstone forest; B
Bothriochloa decipiens	1	uncommon	Ironbark woodland; Small Arms Firing Range
Caleana major	1	occasional	HSS Woodland; B D H
Calotis lappulacea	1	occasional	Ironbark woodland; Small Arms Firing Range
Cassinia aureonitens	1	uncommon	Upper escarpment slopes; G
Chorizema parviflorum	1	uncommon	Shale/sandstone forest B
Clerodendrum tomentosum	1	uncommon	Creeklines; Punchbowl Creek
Cymbopogon refractus	1	uncommon	Shale/sandstone forest; B

TABLE 5.8 CONTINUED

Plant Name	Reference	Status in Study Area	Location in Study Area[4]
Cyperus polystachyos	1	uncommon	Creekline; Deadmans Creek
Danthonia linkii	1	uncommon	Ironbark woodland; Small Arms Firing Range
Danthonia longifolia	1	uncommon	Shale/sandstone forest; B
Daviesia corymbosa	1	occasional	Creekline; Williams, Punchbowl, Deadmans Creeks
Daviesia genistifolia	1	uncommon	Shale/sandstone forest; B
Dillwynia parvifolia	1	uncommon	Ironbark woodland; Small Arms Firing Range
Doryanthes excelsa	3	occasional	Escarpment slopes; Punchbowl, O'Hares and Deadmans Creeks
Duboisia myoporoides	1	uncommon	Creekline; Punchbowl Creek
Eucalyptus amplifolia	1	rare	Creekline, near Moorebank Avenue
Eucalyptus beyeriana	2	rare	Ironbark woodland; Small Arms Firing Range
Eucalyptus paniculata	1	uncommon	Ironbark woodland; Small Arms Firing Range
Eucalyptus sclerophylla	1	common	Woodland; C F
Exocarpos strictus	1	occasional	Heath; B D
Galium liratum	1	uncommon	Ironbark woodland; Small Arms Firing Range
Glycine microphylla	1	uncommon	Ironbark woodland; Small Arms Firing Range
Gnaphalium gymnocephalum	1	occasional	Creeklines; Williams and Deadmans Creeks
Hibbertia riparia	1	uncommon	Heath; B G H
Lasiopetalum parviflorum	1	uncommon	Open forest understorey on shale/sandstone; B D
Leucopogon juniperinus	1	occasional	Ironbark woodland; Small Arms Firing Range

TABLE 5.8 CONTINUED

Plant Name	Reference	Status in Study Area	Location in Study Area[4]
Linum marginale	1	uncommon	Ironbark woodland; Small Arms Firing Range
Lomandra micrantha	1	occasional	Heath; C G D
Melaleuca squamea	3	occasional	Heath, near creeklines; D G H
Muellerina eucalyptoides	1	rare	Shale/sandstone forest; B
Opercularia aspera	1	occasional	Ironbark woodland; Small Arms Firing Range
Oplismenus aemulus	1	occasional	Riparian scrub; Complete, Punchbowl, Deadmans Creek
Oxalis radicosa	1	uncommon	Ironbark woodland; Small Arms Firing Range
Pandorea pandorana	1	occasional	Creeklines and escarpment slopes
Paspalum distichum	1	uncommon	Ironbark woodland; drainage line; Small Arms Firing Range
Pellaea falcata	1	uncommon	Rocky creekline; tributary of O'Hares Creek
Persicaria praetermissa	1	uncommon	Ironbark woodland; drainage line; Small Arms Firing Range
Phyllanthus gasstroemii	1	occasional	Ironbark woodland; Small Arms Firing Range
Poa labillardieri	1	occasional	Grey box ironbark woodland; Small Arms Firing Range
Podocarpus spinulosus	2	rare	Rock outcrops; F
Pomaderris ferruginea	1	occasional	Escarpment slopes; G H
Pultenaea hispidula	3	uncommon	HSS woodland understorey; B D G
Schizaea bifida	1	uncommon	Heath; B C D
Schoenus moorei	1	uncommon	Heath; B C D E
Senecio hispidulus var dissectus	1	uncommon	Roadsides; B F

TABLE 5.8 CONTINUED

Plant Name	Reference	Status in Study Area	Location in Study Area[4]
Solanum pungetium	1	uncommon	Ironbark woodland; Small Arms Firing Range
Stipa ramosissima	1	occasional	Shale/sandstone forest B
Tricoryne simplex	1	occasional	Ironbark woodland; Small Arms Firing Range; Shale/sandstone forest; B C
Tristaniopsis laurina	1	occasional	Creeklines; Punchbowl, O'Hares, Deadmans and Williams Creeks
Wahlenbergia stricta	1	occasional	Ironbark woodland; Small Arms Firing Range; Shale/sandstone forest; B C
Xanthorrhoea concava	1	occasional	Ironbark woodland; Small Arms Firing Range
Zornia dyctiocarpa	1	occasional	Ironbark woodland; Small Arms Firing Range; C

Notes:
1. Benson and McDougall (1991); relates to the north end of the study area, Liverpool and Campbelltown LGAs.
2. Bofeldt (1996); relates to the Woronora Plateau, south end of the study area.
3. Keith (1994) relates to the Woronora Plateau, south end of the study area.
4. HSS Hawkesbury Sandstone.
Letters A to H denote Army Ranges within the Holsworthy Military Area.

Vegetation Communities

The distribution of native vegetation communities at Holsworthy Military Area is presented on *Figure 5.2*.

The vegetation of the Holsworthy Military Area is complex and was therefore accordingly classified using quadrat data. A quadrat is a 20 metre by 20 metre area where all species are counted and their coverages calculated. Interpretation of the computer analysis of quadrat data indicated the presence of seven vegetation communities (*Table 5.9* and *Appendix A*). This classification is compatible with the regional vegetation classification of the National Herbarium of New South Wales (Benson 1992, Benson and Howell 1994). Further survey work could result in the recognition of other communities.

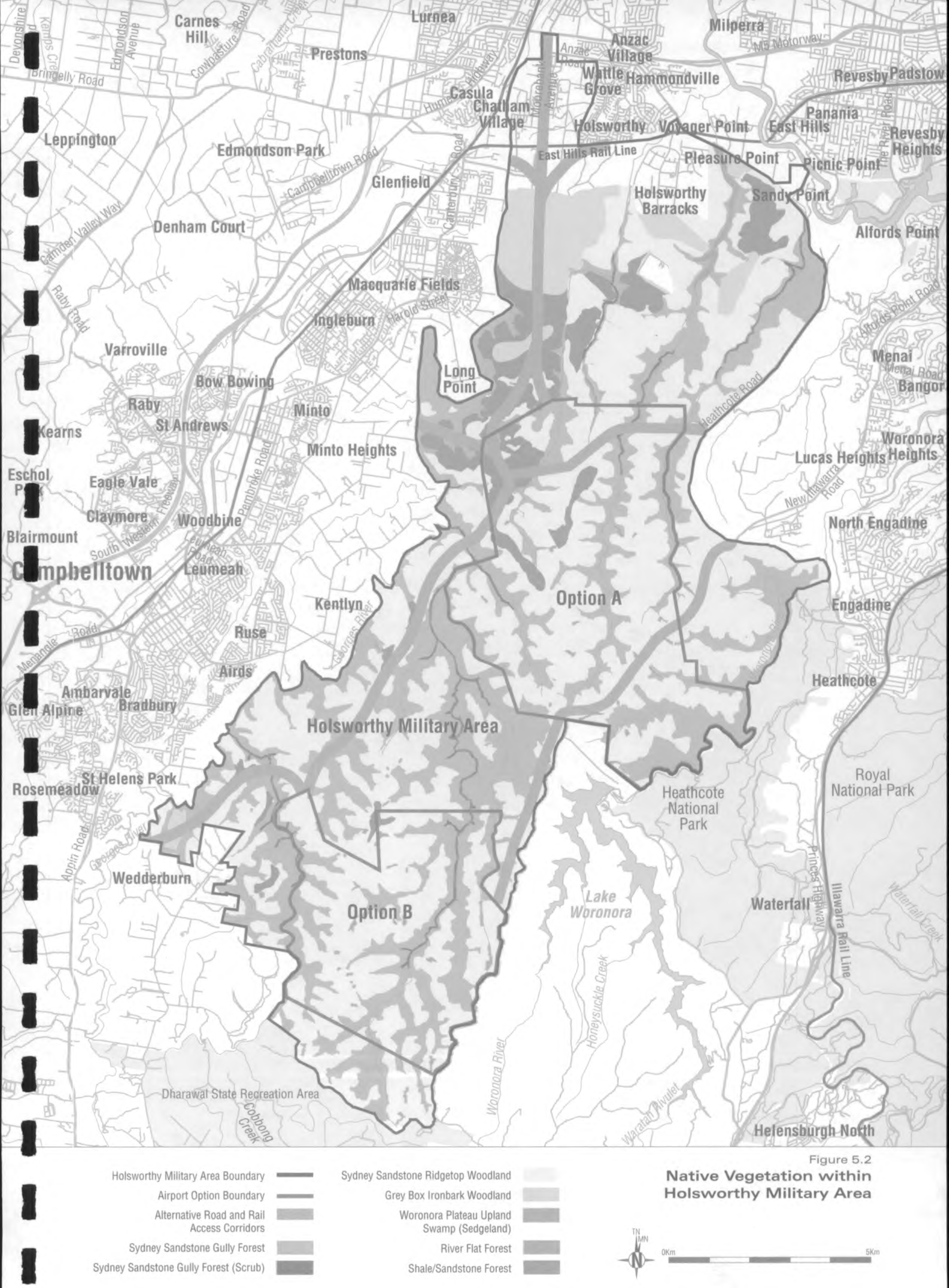


Figure 5.2
Native Vegetation within Holsworthy Military Area

TABLE 5.9 VEGETATION COMMUNITIES AT HOLSWORTHY

Vegetation community/Code	Comments
Grey Box Ironbark Woodland/HOLS 1	Restricted but extensive; north-west section
Shale/sandstone Forest/HOLS 2	Restricted and localised; north-west section
Sydney Sandstone Ridgetop Woodland/ HOLS 3	Widespread and extensive, plateaus, ridges; does not occur in north-west section
Woronora Plateau Upland Swamp/ HOLS 4	Restricted and localised, southern section; perched swamps
Sydney Sandstone Gully Forest/HOLS 5	Widespread but localised; gully slopes
Riparian Scrub/HOLS 6	Widespread but localised; gullies
River-flat Forest/HOLS 7	Restricted and localised, north-east section; streamlines

Relevant data from the quadrats are presented in a floristic table (*Table A1.1, Appendix D*).

The floristic table clusters species according to their occurrence in quadrat samples. For instance, species which tend to occur together and quadrats which have similar species composition are clustered in the top section. Species which are widely distributed across quadrats are found in the central section while those occurring infrequently are clustered at the bottom. Specifically, the following information can be derived from the floristic table:

- the numbers of the quadrats that were sampled in each community read vertically (for example, 012, 097, 098 from left of table);
- species composition of each community; all eucalypt species and all species occurring in more than five percent of quadrats are listed (read vertically);
- cover-abundance provided by each species (a number from 1 to 3 or a + symbol);
- species composition relationships between communities (that is, little overlap, broad overlaps); and
- species composition variation within communities.

Detailed description of these vegetation communities, including their extent and quality are given in *Appendix A*.

Significant Vegetation Communities

One vegetation community within the Holsworthy Military Area is considered to have state significance for nature conservation while six have regional significance.

Prior to European settlement, the Cumberland Plain of Western Sydney supported extensive grassy woodlands restricted to the relatively fertile soils of the plain (Wianamatta Shale). Extensive urban and agricultural development has reduced the original vegetation to scattered remnants, many of which are in altered condition. One of the largest remnants occurs within the Holsworthy Military Area. These grassy woodlands comprised five vegetation communities (Benson 1992). Grey Box Ironbark Woodland was originally extensive on relatively hilly Wianamatta Shale land around the edge of the Cumberland Plain but is now severely depleted (refer map in Benson 1992). The example at Holsworthy is good to excellent condition.

The NSW Scientific Committee, established under the Threatened Species Conservation Act 1995, has listed the Cumberland Plains Woodland as an Endangered Ecological Community under Part 3 of Schedule 1 of the *Threatened Species Conservation Act*. It is therefore considered to be a vegetation community of state significance.

The following communities found in the Holsworthy Military Area are considered to be of regional significance: Shale-sandstone Forest, Sydney Sandstone Ridgetop Woodland, Woronora Plateau Upland Swamp, Sydney Sandstone Gully Forest, Riparian Scrub and River-flat Forest.

Vegetation Condition

Except for the northern area, the Holsworthy Military Area is relatively undisturbed and is in generally good to excellent condition. The great majority of the area is in pristine, weed-free condition, with extensive areas of diverse, species-rich vegetation. Several cleared areas supporting predominantly introduced vegetation occur in the north, and altered (weed-invaded) stands of vegetation occur in some adjacent areas. The lack of weeds along most rivers and creeks is unusual in the Sydney area given the high susceptibility of riparian (creek) vegetation to weed invasion.

Cinnamon Fungus, a widespread soil-borne fungal disease of forest vegetation, may be present at Holsworthy. The sole specimen of *Persoonia nutans* shows symptoms of disease. Cinnamon Fungus has been evident on the Woronora plateau, mainly on Proteaceae, since about January 1994.

Fauna

This section provides a summary of the study findings for fauna. Scientific data is presented in *Appendix B*.

National significance for fauna is assessed using the following listings: ANZECC (1991) and species listed under Schedules 1 and 2 of the (Commonwealth) *Endangered Species Protection Act 1992*. Species of State significance area listed on Schedules 1 and 2 of the *Threatened Species Conservation Act, 1995*.

Regional significance for fauna is assessed by referring to relevant government reports, by consulting experts familiar with the area, referring to the literature and by drawing upon previous field experience of the consultants. Species listed under International Treaties are those listed under the Japan-Australia Migratory Birds Agreement (JAMBA) and the China-Australia Migratory Birds Agreement (CAMBA).

Overall Species

A total of 15 amphibian species, 25 reptile species, 93 bird species (91 native, two introduced) and 31 mammal species (26 native, five introduced) were recorded during the present study. A further three species are probable records. Taking into account all fauna records collated from our extensive literature review, the Holsworthy site provides or is likely to provide habitat for at least 28 amphibian species, 48 reptile species, 148 bird species (143 native, five introduced) and 54 mammal species (47 native, seven introduced). A full list of species is given in *Table A2.7* in *Appendix B*.

Table 5.10 lists the species which have been recorded or which may occur on the site, based on literature research and consultation.

Significant Species

A total of 65 significant fauna species have been recorded within the Holsworthy Military Area, including one species of National significance, 18 species of State significance and 46 species of Regional significance. An additional four species of National significance, nine species of State significance and 12 species of Regional significance were recorded in the vicinity of the Holsworthy Military Area and may occur within the study area. Two species listed under Australian international agreements have been recorded in or adjacent to the study area. Species of National and State significance are discussed in detail in species profiles contained in *Appendix B*. The distribution of significant species in relation to the Holsworthy Military Area is listed in *Table A2.10* of *Appendix B*. Species of Regional significance are considered in *Table A2.14* of *Appendix B*.

TABLE 5.10 SIGNIFICANT FAUNA SPECIES RECORDED OR WHICH MAY OCCUR AT HOLSWORTHY MILITARY AREA

Common Name	Scientific Name	Status	This Study	Other Studies
Amphibians				
Blue Mountains Tree Frog	*Litoris citropa*	R		✓
Brown Toadlet	*Pseudophryne bibronii*	R		✓
Giant Burrowing Frog	*Heleioporus australiacus*	S(v)	✓	✓
Green and Golden Bell Frog	*Litoria aurea*	S(e)		✓
Green Tree Frog	*Litoria caerulea*	R		✓
Heath Frog	*Litoria littlejohni*	R		
Jervis Bay Tree Frog	*Litoria jervisiensis*	R		✓
Red-crowned Toadlet	*Pseudophryne australis*	S(v)	✓	✓
Tusked Frog		R		
Reptiles				
Bearded Dragon	*Pogona barbata*	R		✓
Black Rock Skink	*Egernia saxatilis*	R	✓	
Broad-headed Snake	*Hoplocephalus bungaroides*	N(e)		✓
Diamond Python	*Morelia spilota ssp spilota*	R	✓	✓
Heath Monitor	*Varanus rosenbergi*	S(v)	✓	✓
Lace Monitor	*Varanus varius*	R	✓	
Mountain Dragon	*Tympanocryptis diemensis*	R	✓	✓
Birds				
Australasian Bittern	*Botaurus poiciloptilus*	S(v)		
Bar-shouldered Dove	*Geopelia humeralis*	R		✓
Beautiful Firetail	*Stagonopleura bella*	R	✓	✓
Black Bittern	*Dupetor flavicollis*	S(v)		
Brown Treecreeper	*Climacteris picumnus*	R	✓	
Brush Cuckoo	*Cuculus variolosus*	R		✓
Buff-rumped Thornbill	*Acanthiza reguloides*	R	✓	✓
Bush Stone-curlew	*Burhinus magnirostris*	S(e)		✓
Chestnut-rumped Heathwren	Hylacola pyrrhopygia	R	✓	✓

TABLE 5.10 CONTINUED

Common Name	Scientific Name	Status	This Study	Other Studies
Diamond Firetail Finch	*Stagonopleura guttata*	R	✓	
Double-barred Finch	*Taeniopygia bichenovii*	R	✓	✓
Eastern Bristle Bird	*Dasyornis brachypterus*	N(v), S(v)		✓
Flame Robin	*Petroica phoenica*	R	✓	
Fuscous Honeyeater	*Lichenostomus flavescens*	R		✓
Glossy Black-Cockatoo	*Calyptorhynchus lathami*	S(v)		✓
Grey Goshawk	*Accipiter novaehollandiae*	R		
Ground Parrot	*Pezoporus wallicus*	S(v)		✓
Hooded Robin	*Melanodryas cucullata*	R		✓
Jacky Winter	*Microeca fascinans*	R		✓
Little Eagle	*Hieraaetus morphnoides*	R	✓	
Little Raven	*Corvus mellori*	R	✓	
Masked Owl	*Tyto novaehollandiae*	S(v)		✓
Nankeen Night Heron	*Nycticorax caledonicus*	R		✓
Painted Honeyeater	*Grantiella picta*	S(v)		
Peaceful Dove	*Geopelia placida*	R		✓
Peregrine Falcon	*Falco peregrinus*	R		✓
Powerful Owl	*Ninox strenua*	S(v)		✓
Red-capped Robin	*Petroica goodenovii*	R		✓
Red-rumped Parrot	*Psephotus haematonotus*	R		
Regent Honeyeater	*Xanthomyza phrygia*	N(e),S(e)		✓
Restless Flycatcher	*Myiagra inquieta*	R		✓
Rockwarbler	*Origma solitaria*	R	✓	✓
Shrike-tit	*Falcunculus frontatus*	R		✓
Sooty Owl	*Tyto tenebricosa*	S(v)		✓
Southern Emu-wren	*Stipiturus malachurus*	R	✓	
Speckled Warbler	*Chthonicola sagittata*	R		✓
Swift Parrot	*Lathamus discolor*	N(v),S(v)		✓
Tawny-crowned Honeyeater	*Phylidonyris melanops*	R	✓	✓
Turquoise Parrot	*Neophema pulchella*	S(v)		✓

Common Name	Scientific Name	Status	This Study	Other Studies
Wedge-tailed Eagle	*Aquila audax*	R	✓	
Weebill	*Smicrornis brevirostris*	R	✓	✓
White-bellied Sea-Eagle	*Haliaeetus leucogaster*	C,R		✓
White-fronted Chat	*Epthianura albifrons*	R	✓	
White-throated Needletail	*Hirundapus caudacutus*	J/C	✓	
White-winged Chough	*Corcorax melanorhamphos*	R	✓	✓
Yellow-rumped Thornbill	*Acanthiza chrysorrhoa*	R	✓	✓
Mammals				
Brown Antechinus	*Antechinus stuartii*	R	✓	
Brush-tailed Rock Wallaby	*Petrogale penicillata*	N(v), S(v)	✓[1]	
Common Bentwing Bat	*Miniopterus schreibersii*	S(v)		✓
Common Dunnart	*Sminthopsis murina*	R		
Common Wombat	*Vombatus ursinus*	R	✓	
Eastern Grey Kangaroo	*Macropus giganteus*	R	✓	✓
Greater Glider	*Petauroides volans*	R		
Koala	*Phascolarctos cinereus*	S(v)	✓	✓
Long-nosed Bandicoot	*Perameles nasuta*	R	✓	
Long-nosed Potoroo	*Potorous tridactylus*	S(v)		
New Holland Mouse	*Pseudomys navaehollandiae*	R		✓
Platypus	*Ornithorhynchus anatinus*	R		✓
Red-necked Pademelon	*Thylogale thetis*	R		✓
Red-necked Wallaby	*Macropus rufogriseus*	R	✓	
Squirrel Glider	*Petaurus norfolcensis*	S(v)		✓
Tiger Quoll	*Dasyurus maculatus*	S(v)	✓	✓
Wallaroo	*Macropus robustus*	R		✓
Water Rat	*Hydromys chrysogaster*	R		✓
Yellow-bellied Glider	*Petaurus australis*	S(v)	✓[1]	

TABLE 5.10 CONTINUED

Common Name	Scientific Name	Status	This Study	Other Studies
Eastern False Pipistrelle	*Falsistrellus tasmaniensis*	S(v)	✓	
Eastern Little Mastiff Bat	*Mormopterus norfolkensis*	S(v)		✓
Greater Broadnosed Bat	*Scoteanax rueppellii*	S(v)		✓
Grey-headed Flying-fox	*Pteropus poliocephalus*	R	✓	✓
Large-footed Myotis	*Myotis adversus*	S(v)		✓
Large Pied Bat	*Chalinolobus dwyeri*	S(v)		✓
Little Red Flying Fox	*Pteropus scapulatus*	R		
Eastern Cave Bat	*Vespadelus troughtoni*	S(v)		
White-striped Mastiff-bat	*Nyctinomus australis*	R	✓	✓
Yellow-bellied Sheathtail Bat	*Saccolaimus flaviventris*	S(v)	✓	

Note:
Status: N(e) = Listed on Schedule 1 of the Endangered Species Protection Act (1992);
N(v) = Listed on Schedule 2 of the Endangered Species Protection Act 1992;
S(e) = Listed on Schedule 1 of the NSW Threatened Species Conservation Act 1995;
S(v) = Listed on Schedule 2 of the NSW Threatened Species Conservation Act 1995;
R = Regional Significance; J/C = JAMBA/CAMBA International Treaties; C= CAMBA.
✓ = Recorded at site; (blank) = may occur at site.
1 = Unconfirmed.

The species list shown in *Table 5.10* should not be considered exhaustive. As the Holsworthy Military Area study areas contain two bioregions, all species considered to be of Regional significance in Cumberland Plains Woodland and in Coastal Sandstone Plateau are included.

Fauna Habitats

Habitat types generally correspond to the vegetation communities described for the study areas (*Figure 5.2*).

Grassy Forest

This habitat is characteristically found on the tops of the plateaus and is most common in the north-western part of the Holsworthy Military Area. Grassy Forest (referred to as Plateau Forest by AXIS/Australian Museum Business Services 1995) consists of either an overstorey of ironbark or of other mixed eucalypts and *Angophora*. There is no mid-storey layer; an understorey of herbs and grasses shades the logs and litter covering the thin alluvial or shale soils. At Holsworthy Military Area, the quality of this habitat varies mostly in response to past fire regimes with less structural diversity in more frequently burnt areas such as in the Small Arms Danger Area in the north-west of the study area.

Corresponding Vegetation Communities: Shale/Sandstone Forest, Grey Box Ironbark Forest
Condition: High to moderate

Gully Forest

As its name suggests, this habitat is found in the gullies and their associated slopes. Gully Forest habitat is dominated by an overstorey of *Angophora* and eucalypts, under which a shrubby mid-layer may or may not be present. Logs, litter and sandstone rock are interspersed among lilies, ferns, herbs and grasses. The soil is sandy. This habitat occurred in most of the gullies in the Holsworthy study area, particularly in the south, and was one of the dominant habitats. It provides a variety of habitat resources and is the most important fauna habitat of the Holsworthy study area.

Corresponding Vegetation Community: Sydney Sandstone Gully Forest
Condition: High

Woodland/Heath Complex

The Woodland/heath complex habitat is probably the most common fauna habitat as it is found on most of the ridges and plateaus of the Holsworthy study area. Its floristics vary considerably from north to south, but in all areas it is important for fauna and often supports a diverse assemblage of fauna species. The habitat consists of a shrub layer shading lower level herb and heath species. An overstorey of mixed eucalypts may or may not be present. Logs, litter and sandstone rocks cover the sandy ground and exposed sandstone. At the edges of the ridges where this habitat often borders Gully Forest, there is usually an exposed area of sandstone boulders or escarpment.

Rock outcrops and cliffs form part of this habitat type. These are found mostly in the southern part of the study area where the topography is more varied with elevated ridges and plateaus and deeply dissected gullies and drainage lines. This habitat is commonly found as a narrow band along the edges of the ridges and plateaus and often forms a boundary between the Woodland/heath Complex on the ridges and Gully Forest below on the lower slopes. The vegetation usually consists of Woodland/heath complex as described above, however, the dominant feature of the landscape is the rock formations. This may consist of cliffs, boulders, rock overhangs and rocky crevices. The amount of vegetation present varies with amount and steepness of the rock formations.

Corresponding Vegetation Community: Sydney Sandstone Ridgetop Woodland
Condition: High to moderate

Heath/Swamp Complex

Areas of heath and swamp habitat were found mostly in shallow depressions at the head of drainage lines. Trees are usually absent and herbs mostly form the ground cover. There is little or no rock and the soil is sandy or sandy loam.

Corresponding Vegetation Community: Sydney Sandstone Ridgetop Woodland
Condition: High

Paperbark Woodland

This habitat generally consists of a thin corridor along some drainage lines with the largest such area in Holsworthy being found along the northern reaches of Williams Creek. A thicket of Paperbark trees in waterlogged creeks dominates this habitat. The alluvial soil is usually seasonally waterlogged. Shrubs and herbs and grasses form the mid- and lower vegetation layers.

Corresponding Vegetation Community: River-flat Forest
Condition: High

Sedgelands

Sedgelands usually occur above the upper drainage lines on seepage slopes. This habitat was restricted to the southern half of the study area and consists mainly of a dense ground layer of sedges, grasses and herbs on an organic sandy loam soil. Trees and shrubs, fallen logs and rocks are usually absent.

Corresponding Vegetation Community: Woronora Plateau Upland Swamp
Condition: High

Overall Condition of Vegetation and Habitats

The condition of fauna habitats within the study area varies from relatively intact to moderately disturbed. The conservation value of some portions of the study area has been slightly compromised by the frequent fire regime. There is a very low incidence of introduced plants and animals. Overall, the habitat condition of Holsworthy is high, particularly when its proximity to the Sydney Metropolitan area is taken into account.

Freshwater Fish and Crayfish

This section provides a summary of the study findings for fish and crayfish species and their habitat. Scientific data is presented in *Appendix C*.

Fish species are listed nationally as Endangered, Vulnerable, Potentially Threatened, Indeterminate and Uncertain, by Jackson (1995). At the State level, significant species are listed under the *Fisheries Management Act, 1994*. All crayfish species are considered to have high conservation value. Conservation index derivation followed the procedure used by Bishop (in Meredith *et al*, 1995) for a sample of 1,032 streams in south-eastern Australia.

Habitat

Summary statistics of stream variables used to calculate habitat diversity index values for the selected streams (excluding artificial water structures) in the area are given in *Figure A3.6 (Appendix C)*. Streams considered for the Holsworthy Military Area are shown in *Figure 3.3*.

The streams varied greatly in their mean widths from 0.3 to 0.7 metres for the small tributary streams to 10.5 to 13.0 metres for the major trunk streams. A wide corridor of riparian vegetation borders most of the streams. Mean elevations range considerably between streams, from 37 to 67 metres for the northern streams up to 193 to 257 metres for some of the Georges and Woronora River catchment streams. Stream gradients are generally moderate to high and vary considerably within streams.

The calculated habitat-diversity index values are shown in *Figure A3.3 (Appendix C)*. High to very high habitat diversity is indicated by the resultant values.

High quality fish habitat was abundant in most of the streams. Prime habitat for 'Macquarie' Perch occurs in the Georges River, Punchbowl Creek, Gunya Creek, O'Hares Creek, the lower Woronora River, Deadmans Creek and Williams Creek. However, natural migration barriers such as cascades and waterfalls are common in the streams. Man-made barriers include Woronora Dam on the Woronora River and Liverpool Weir on the Georges River.

Fish and Crayfish Species

A list of the fish and crayfish species recorded in streams in and around the Holsworthy Military Area is given in *Table A3.9 (Appendix C)*. A total of 17 fish species and three (possibly four) crayfish species were recorded during the present study. The results are summarised in *Table 5.11* below.

TABLE 5.11 FISH AND CRAYFISH SPECIES RECORDED WITHIN AND AROUND THE HOLSWORTHY MILITARY AREA

Location	Native Fish Species	High Conservation Value Fish	High Recreation Value Fish	Introduced Fish Species	High Conservation Value Crayfish
Georges River and tributaries	11	Eel-tailed Catfish 'Macquarie' Perch	Australian Bass Estuary Perch 'Macquarie' Perch Eel-tailed Catfish	2	Sydney Crayfish
Woronora River and tributaries	11	'Macquarie' Perch Silver Perch	Australian Bass	1	Sydney Crayfish, Australian Crayfish, Common Yabby
Northern streams	8		Australian Bass	1	Sydney Crayfish, Australian Crayfish, unidentified crayfish

Recreational Fisheries

Representatives of the fishing clubs contacted indicated that they had no experience of almost half the nominated streams which drain the Holsworthy site as a result of very restricted access.

The quality of the fishery in the Georges River was considered to range from 'poor' to 'fair'. This was primarily attributed to the lack of a fish ladder on Liverpool Weir resulting in a major fish migration block between estuarine and freshwater reaches. The Bass Sydney Fishing Club has recently received major funding to remedy this problem. Fishery quality in the major tributary streams, Punchbowl and O'Hares Creek, was also considered to be 'poor' to 'fair'. Restricted access exacerbated this condition in these streams. The fishery in the Woronora River downstream of Woronora Dam was also viewed as 'poor' to 'fair' as a result primarily of poor access.

5.2 CONSERVATION SIGNIFICANCE

5.2.1 ASSESSMENT CRITERIA

Flora and Fauna

The assessment of conservation significance includes all relevant site criteria, using qualitative and quantitative data where available. A summary of the criteria for significance assessment are listed below. A detailed description of a number of these criteria is provided in *Appendix B*.

Ecological Integrity - considers the degree of intactness of vegetation, using indicators such as the proportion of weeds and condition of the understorey.

Habitat Quality - is assessed using descriptive criteria such as the number of indigenous plant species, vegetation community structure, level of disturbance of ground log and/or litter layer, abundance of breeding, nesting, feeding and roosting resources available, richness and diversity of native fauna species.

Rare or Significant Flora and Fauna Species - these are assessed as being of National, State, or Regional significance. The first two levels are assessed using the relevant published lists (*Endangered Species Protection Act, 1992, NSW Threatened Species Conservation Act, 1995*). Regional assessment is based on literature review and expert opinion. Migratory species listed under international treaties are also noted.

Rare or Significant Habitat/Vegetation Community - these areas are listed as endangered under the *Threatened Species Conservation Act 1995*. Areas with particular attributes such as colonial breeding sites are also included.

Size - relates to the overall size of the area considered.

Connectivity - relates to linkages to adjacent areas of native vegetation and fauna habitat.

Viability - factors include area, edge/area ratio, presence of disturbed low quality vegetation within a high value site, presence of threats or disturbances.

Representativeness - is defined as the degree to which the site is a representative example of an ecosystem, vegetation or habitat type, or represents an environmental variation of an ecosystem.

Richness and Diversity - includes species, communities and habitats.

Social Values - (relate to natural heritage) include heritage, wilderness, national estate, scientific and educational values.

Freshwater Fish and Crayfish

The criteria used for the assessment of stream conservation significance are:

- recognised valuable areas in which diminished integrity of stream ecosystems would diminish intrinsic values;

- the naturalness of fish communities;
- high conservation value fish species;
- high recreational value fish species;
- high conservation value freshwater crayfish species; and
- valuable areas for scientific research.

A detailed description of a number of these criteria is provided in *Appendix C*.

In order to facilitate comparisons between streams, a standardised procedure was used to calculate a conservation index based on these criteria. Index derivation followed the procedure used by Bishop (in Meredith *et al*, 1995) for a sample of 1,032 streams in south-eastern Australia.

Two indices were calculated in order to describe stream habitats. They are based on the following estimates:

- riparian vegetation canopy which gives an indication of the integrity of river bank vegetation; and
- habitat diversity which is dependent on factors such as stream elevation, gradient, and width and riparian vegetation characteristics.

5.2.2 BADGERYS CREEK

Assessment of Significance

The relative contribution made by the study areas to nature conservation in New South Wales and Australia has been assessed on the basis of the available information, and is summarised in *Table 5.12*.

Significance is assessed on a hierarchy of national, state, regional and local levels, according to the geographic context in which a species or site makes a substantial contribution to nature conservation. Under this rating system, a site of Regional significance is considered to make a substantial contribution to conservation at the Regional level (rather than at the State level).

Conservation significance for each of the assessment criteria for terrestrial flora and fauna at Badgerys Creek is summarised in *Table 5.12*.

TABLE 5.12 OVERALL CONSERVATION SIGNIFICANCE FOR TERRESTRIAL FLORA AND FAUNA AT THE SITES OF THE BADGERYS CREEK OPTIONS

Criteria	Badgerys Creek		
Terrestrial Flora and Fauna			
Ecological integrity	fragmented; high proportion of weed species (84 in 260 species); condition of understorey generally poor		
Habitat quality	low to moderate		
Introduced flora species	84 species		
Rare/significant flora (spp)	one National	0 State	48 Regional
Rare/significant fauna	two National	12 State	38 Regional
Rare/significant habitat, vegetation community	fragmented, altered Grey Box Woodland of regional significance		
Number of fauna species listed under International Agreements	five		
Size	2,795 hectares		
Connectivity	poor connectivity; limited to narrow riparian corridors (for example, Badgerys Creek, South Creek)		
Viability	small bushland remnants with high edge to area ratio; weedy; altered vegetation structure, especially in understorey; subject to disturbance from agricultural use and development		
Representativeness	regional example of Grey Box Woodland		
Richness and diversity	176 native plant species; three vegetation communities; 211 native fauna species		
Social values	none		

A summary of the derived conservation index values and key components for the Badgerys Creek site is presented in *Table 5.13* below. A summary of stream habitat indices for Badgerys Creek is presented in *Table 5.14*.

TABLE 5.13 SUMMARY OF THE CONSERVATION INDEX AND KEY COMPONENTS AT THE SITES OF THE BADGERYS CREEK OPTIONS

Components and Index	Badgerys Creek and Downstream
Recognised natural areas	2
Naturalness of fish communities	18 native fish species; three introduced fish species
High conservation value fish	one species
High recreation value fish	three species
High conservation value crayfish	possibly one species
Areas for scientific research	0 sites
Conservation Index	0.52 to 0.77

TABLE 5.14 SUMMARY OF TWO STREAM HABITAT VARIABLES FOR BADGERYS CREEK OPTIONS

Stream Habitat Variables	Badgerys Creek and Downstream
Habitat diversity index	1.20 to 1.67 (Duncans Creek); 1.19 to 2.71 (South Creek)
Gross disturbance in riparian zone	99.6 to 100 percent (Duncans Creek); 100 percent (South Creek)

Conclusions

Badgerys Creek is considered to have **Regional** significance for nature conservation for the following reasons:

- the presence of one plant species of National significance and 48 species of Regional significance;
- the possible occurrence of two fauna species of National significance, 12 species of state significance and 39 species of Regional significance; and
- conservation indices for Duncans Creek (0.77) and for South Creek (0.52 to 0.71) indicate that these streams are of Local significance.

5.2.3 HOLSWORTHY

Assessment of Significance

The relative contribution made by the study areas to nature conservation in New South Wales and Australia has been assessed on the basis of the available information.

Significance is assessed on a hierarchy of national, state, regional and local levels, according to the geographic context in which a species or site makes a substantial contribution to nature conservation. Under this rating system, a site of Regional significance is considered to make a substantial contribution to conservation at the Regional level (rather than at the State level).

Conservation significance for each of the assessment criteria for terrestrial flora and fauna for Holsworthy is summarised in *Table 5.15* below.

TABLE 5.15 OVERALL CONSERVATION SIGNIFICANCE FOR TERRESTRIAL FLORA AND FAUNA AT HOLSWORTHY MILITARY AREA

Criteria	Holsworthy Military Area		
Terrestrial Flora and Fauna			
Ecological integrity	intact; low proportion of weeds (37 in 583 species); condition of understorey generally good		
Habitat quality	moderate to high		
Introduced flora species	37 species		
Rare/significant flora (spp)	14 National	10 State	65 Regional
Rare/significant fauna	five National	27 State	58 Regional
Number of fauna species listed under International Agreements	two		
Rare/significant habitat, vegetation community	Grey Box Ironbark Woodland (Cumberland Plain Woodland) in good condition; presently a Preliminary Determination for listing on Part 3 of Schedule 1 of the TSC Act (1995)		
Size	15,000 hectares		
Connectivity	good connectivity to the south-east; forms extensive corridor from Holsworthy through Woronora Catchment, O'Hares Creek Catchment, Heathcote and Royal National Park		
Viability	extensive area which is relatively intact; vegetation structure relatively intact; localised impacts from present land use		

TABLE 5.15 CONTINUED

Criteria	Holsworthy Military Area
Representativeness	statewide example of Grey Box Ironbark Woodland (Cumberland Plain Woodland); good example of Coastal Sandstone Plateau communities
Richness and diversity	546 native plant species; seven vegetation communities; 266 native fauna species
Social values	Listed on the Interim Register of the National Estate

A summary of the derived conservation index values and key components for the Holsworthy Military Area is presented in *Table 5.16* below. A summary of stream habitats for Holsworthy is presented in *Table 5.17*.

TABLE 5.16 SUMMARY OF THE CONSERVATION INDEX AND KEY COMPONENTS FOR HOLSWORTHY MILITARY AREA

Components and Index	Holsworthy and downstream
Recognised natural areas	12
Natural fish communities	15 native fish species; two introduced fish species
High conservation value fish	three species
High recreation value fish	four species
High conservation value crayfish	three species (possibly four)
Areas for scientific research	15 sites
Conservation Index	moderate value set 1.69 to 1.93 high value set 3.46 to 5.07

TABLE 5.17 SUMMARY OF TWO STREAM HABITAT VARIABLES FOR HOLSWORTHY MILITARY AREA

Stream Habitat Variables	Holsworthy and downstream
Habitat diversity index	4.43 to 7.14 (Georges River and tributaries); 5.00 to 5.68 (Woronora River and tributaries); (4.12 to 4.41 (northern streams))
Gross disturbance in riparian zone	0 to 28 percent (Georges River and tributaries); 0 to 23 percent (Woronora River and tributaries); 16 to 27 percent (northern streams)

Conclusions

Holsworthy Military Area is considered to have National significance for nature conservation for the following reasons:

- the presence of 14 plant species of national significance, two of which have their core populations within the Holsworthy Military Area;
- the presence of extensive, undisturbed, diverse, species-rich vegetation;
- the possible occurrence of up to five fauna species of National significance, 27 species of State significance and 58 species of Regional significance;
- it forms the northernmost part of an extensive wildlife corridor extending from Holsworthy through Woronora Catchment, O'Hares Creek Catchment, Heathcote and Royal National Parks; and
- conservation indices for the moderate value set of streams within Holsworthy Military Area (1.69 to 1.93), and for the high to very high value set (3.46 to 5.07), indicate that the former are of State significance and the latter are of National significance.

Part C

Assessment of Impacts

CHAPTER 6 GENERAL CONSTRUCTION AND OPERATION IMPACTS

This section comprises a general description of impacts associated with airport development and provides the contextual basis for the assessment in Chapters 7 and 8. Impact assessment concentrates on the five airport options but also briefly considers issues associated with preliminary access corridor options. The access routes are indicative only and would be subject to separate EIS assessments.

6.1 CONSTRUCTION IMPACTS

Construction impacts are those which are associated with developing the airport site. They include clearing, excavation, noise, lighting, truck traffic, drilling, blasting, etc. Construction impacts are expected to occur over the entire construction period.

6.1.1 DIRECT IMPACTS

Direct impacts are those that occur as a direct consequence of construction activities. For instance, vegetation clearance and loss of habitat which has a direct impact on flora and fauna species inhabiting the area.

Vegetation Clearance

A considerable area of native vegetation would be removed under any option due to the size of the proposed development. Vegetation clearance would eliminate the existing vegetation and may adversely affect the viability of adjoining retained vegetation due to an increased risk of loss for reduced plant populations, decreased opportunities for recolonisation and vegetation edge pressures (discussed further under weed invasion).

Estimates of the area of clearance of each vegetation community are given in this study. These figures are useful for comparison of options but cannot be related to the existing total area of the communities concerned due to a lack of available quantitative data on vegetation in the Coastal Sandstone Plateau and Cumberland Plain regions and within New South Wales generally.

Significant Flora Species

Significant flora species would be depleted under any option. Depletion of populations may adversely affect the viability of adjoining (sub)populations due to an increased risk of extinction for reduced plant populations and decreased opportunities for recolonisation.

The number of significant species directly affected by each option has been determined. These figures are useful for comparison but in many cases there is insufficient available data on the status of these species within the Coastal Sandstone Plateau and Cumberland Plain regions and within New South Wales generally to further quantify impacts.

Habitat Loss

Where airport construction requires clearing of native vegetation, there would be a direct loss of habitat for native fauna. The magnitude of the effect is inversely proportional to the size of the fragment. In a modified landscape some areas of vegetation function as links between larger, less disturbed areas. Fragmentation of these corridors increases the isolation of remnant native vegetation and affects the movement of birds, small terrestrial vertebrates and the population dynamics of vertebrate fauna across all habitat types.

Relatively undisturbed native vegetation supports plants in various growth stages, from new seedlings to mature individuals. In many instances the old-growth components of a vegetation community provide important habitat and resource features for fauna species (for example, hollows, nectar, nest sites). The loss of such resources during the construction phase would be detrimental to local fauna such as tree foraging and nesting birds and arboreal mammals. Resource-rich trees, such as Grey Gum and Narrow-leaved Ironbark, also act as an important focus for local fauna, particularly nectar-feeding birds and mammals. Such trees are often a limited resource. The impact of losing old-growth components is greater where such trees are rarer, as in roadside corridors, clear felled and re-growth forest.

Significant Fauna Species

Although a large number of significant fauna species have been recorded within Badgerys Creek and the Holsworthy Military Area, it is not expected that all of them would be equally affected by the proposed airport construction. This section divides the significant species into "guilds" (groups of species with similar ecological requirements) and discusses potential impacts on these guilds. Detailed descriptions of potential impacts relating to each significant species are contained in *Appendix B*.

Critical Weight Range Mammals

The critical weight range mammals are a group of small to medium-sized mammals that are highly prone to extinction (for example, bandicoot, potoroo). Such species are at risk because of their limited mobility and relatively high energy requirements. It is believed that the key factor with critical weight range species is predation by introduced predators, especially the fox. Introduced predators may preferentially move along cleared corridors when hunting and therefore native fauna would be more prone to predation when moving away from dense cover. Thus, where the airport and associated infrastructure would create new clearings and corridors within currently unroaded forest, critical weight range species may be affected. Where the airport includes existing cleared areas, no significant effect is expected.

Arboreal Mammals

Arboreal mammals include gliders and possums. This fauna group is dependent on mature trees to provide nesting hollows and food resources (for example, nectar, pollen, leaves). Where the airport construction would create a new clearing within unroaded forest, arboreal mammals would be affected by loss of important resources and creation of movement barriers. For critical weight range species, newly cleared areas may expose them to increased predation. Within cleared areas, airport construction may remove isolated habitat remnants or create barriers across existing linear corridors (that is, creek or river riparian strips).

Bats

Insectivorous bats may be dependent on tree hollows or caves for nesting and roosting, insect abundance and distribution, water and/or ecotone habitats. On the other hand, fruit-eating bats require camp sites and nectar and fruits of flowering trees and shrubs. Airport construction would be likely to result in changes to bat foraging patterns in and around newly cleared areas through habitat destruction, alterations to the diversity and abundance of insect prey, loss of flowering trees, loss of roost sites and removal of mature trees. It may also include the removal of artificial roost sites such as those found in culverts, abandoned buildings and under bridges. If, for example, the airport is constructed between a fruit bat camp site and suitable feeding areas, then there is the risk of bat strike (refer *Technical Paper No. 10 - Hazards and Risks*).

Small Terrestrial Mammals

Small terrestrial mammals include antechinus, dunnarts, other native mice and rats. These species are dependent on a wide range of resources including dense ground and/or shrub cover, logs, rocks, insect prey and grass seeds. Airport construction is likely to result in the removal of habitat and to create a movement barrier for these species, thereby potentially increasing the loss of species from the local area. Because of their restricted mobility, this may result in the isolation of some populations. Cleared easements associated with the airport may increase the risk of predation of this fauna group by introduced predators.

Large Mammals and Herbivores

Large mammals and herbivores include the Common Wombat, Eastern Grey Kangaroo, Red-necked Wallaby, Swamp Wallaby and Red-necked Pademelon. These species forage on the ground or amongst lower vegetation layers, shelter in bushland and have relatively large home ranges. Although airport construction is likely to remove shelter and to create a movement barrier for these species, it may increase the amount of grass cover along the periphery of the site and along any access roads. Clearing associated with the airport would provide access for introduced predators which can significantly reduce populations of large mammals and herbivores. Elsewhere in western Sydney the combination of habitat disturbance, small bushland shelter areas and hunting by introduced predators has led to the decline of large mammals and herbivores.

Aquatic Mammals

Aquatic mammals include Platypus and Water Rats. These species are dependent on stream and wetland habitats which provide banks suitable for burrow construction and a diversity and abundance of aquatic prey. Where airport construction would involve the filling in or diversion of streams or causes sedimentation and/or erosion of existing streams, it is likely to result in the removal of habitat and the creation of movement barriers for this fauna group.

Waterbirds

Waterbirds include grebe, swans, ducks, waders, crakes, sandpipers and all those species which are dependent on water and wetlands for their nesting and/or feeding requirements. Where airport construction results in the removal or alteration of existing wetland habitats, it is likely that waterbirds would be adversely affected. On the other hand, newly created detention ponds may attract some waterbird species. There do not presently appear to be any significant breeding colonies on either of the proposed airport sites.

Some migratory waterbird species are protected under international agreements (for example, JAMBA, CAMBA). Although the study areas may provide habitat for small numbers of these species during part of the year, it is marginal to their conservation in New South Wales.

Raptors

Raptors include hawks, harriers, eagles and falcons. This group comprises species which are predominantly aerial but which require tall trees or inaccessible ledges for nesting, small- to medium-sized mammal or bird prey and carrion. Airport construction that results in the removal of habitat or the alteration of prey abundance and distribution is likely to affect this group. Clearing is not likely to pose a barrier for large species of raptors. In previously uncleared areas, some species would be likely to benefit from an increase in the amount of cleared land and edge habitat which support high densities of abundant prey species (for example, rabbits).

Hollow-dependent Birds

Hollow-dependent birds are those which require tree hollows for nesting and/or roosting and include cockatoos, parrots, lorikeets, owls and kingfishers. Airport construction that results in the removal of mature hollow-bearing trees is likely to affect the life cycle of this fauna group.

Passerines

The passerines or small "bush" birds comprise the warblers, flycatchers, wrens, robins, honeyeaters, etc. Passerines utilise forest, woodland, shrub, heath land and grassland habitats where they obtain nesting and feeding resources. Airport construction that would result in the loss and fragmentation of habitat and is likely to create movement barriers for these relatively sedentary species, making them susceptible to population isolation.

This group includes a number of significant species such as Rockwarbler, Eastern Bristlebird, Chestnut Heathwren, White-fronted Chat, Diamond Firetail and a number of finches and robins. Most of these species are dependent on habitats which are restricted in their distribution in the Sydney Region (for example, heath land, sedgeland) or which have undergone noticeable decline in the recent past. Further loss of remnant habitat may affect the regional distribution of these species.

Reptiles

Reptiles utilise a wide variety of habitats which provide logs and other shelter, leaf litter, hollows and/or rocky outcrops. For small terrestrial reptile species, airport construction is likely to create a significant barrier to movement and may result in the isolation of some populations. Although more mobile, larger reptile species (that is, monitor lizards) are likely to be similarly affected by habitat removal.

Frogs

Frogs utilise wetland habitats which provide temporary or permanent water, rocks, leaf litter, low and/or riparian vegetation. Where airport construction results in the removal or alteration of existing wetland habitats or gully forest, it is likely that frogs would be adversely affected. Removal of riparian habitat would be likely to pose a significant movement barrier and may result in the isolation of frog populations. Clearing may also have the secondary effect of drying out ground level habitats by exposing them to the wind and sun.

Habitat Fragmentation/Barriers

The proposed airport development area has the potential to form an impermeable movement barrier for some animal species and to fragment their habitats. Highly mobile species (birds and bats) could potentially traverse cleared areas. Barriers would be most likely to affect large herbivorous mammals, large reptiles, smaller ground-dwelling and arboreal mammals, shade-tolerant reptiles and amphibians.

The greatest potential for the cleared development area to act as a barrier is where it intersects wildlife corridors. A wildlife corridor is an area of habitat that links two or more habitat areas. A wildlife corridor can be natural (for example, a ribbon of riparian forest along a stream) or can result from vegetation clearance (for example, a stand of roadside vegetation connecting two uncleared stands of remnant bushland in an otherwise cleared farming area). Wildlife corridors provide connections between sub-populations, allowing the connected sub-populations to function as a larger 'meta-population'. This encourages stability, particularly in terms of enhancing a species' chances of surviving events such as bushfire, drought or disease. These larger meta-populations can also maintain higher levels of genetic diversity through the avoidance of inbreeding.

Roads, utility easements and cleared farmland have been shown by research, both in Australia and overseas, to pose barriers to some species of small mammals and birds (Adams and Geis 1983, Barnett *et al*. 1978, Leedy and Adams 1982, Mader 1984, Mansergh and Scotts 1989, Schreiber and Graves 1977, Swihart and Slade 1984, Wegner and Merriam 1979). The effects of a barrier on migratory species or species that make long distance movements are minimal. For species which do not move long distances, the barrier formed by the development area is most likely to inhibit local or home range movements. Small bird and mammal species will often use utility corridors as one edge of their home range (Barnett *et al*. 1978, Kroodsma 1982).

Biological barriers may have both genetic and demographic effects on populations (demographic effects are those which alter the birth and death rates and other factors such as lifespan), some of which may ultimately lead to extinctions of sub-populations or even species (Lande 1988).

Demographic processes are affected by such factors as:

- variations in birth and death rates;
- variations in the environment;
- variations in mating success, particularly where they are density-dependant;
- edge effects; and
- local extinctions and re-colonisations for patchily distributed species.

The latter two factors are those that the proposed development areas have the most potential to influence. Edge effects include a decline in habitat quality near a habitat boundary and any loss of individuals that disperse into unsuitable habitat. Any decline in habitat quality adjacent to the development area is likely to be a short distance effect in most instances, related to changes in the vegetation. The effect of most concern would be the possible isolation of sub-populations, increasing the chances of local extinction and decreasing the chances of re-colonisation.

The genetic effects potentially associated with any biological barrier occur where sub-populations become isolated or fragmented. The effects are very different for small populations as compared to large populations. Small populations that are isolated can suffer from significant deleterious effects associated with inbreeding and with the loss of genetic variation through genetic drift. A large population that is split into two populations that are still large may not be affected by either of these processes, although the two populations may slowly diverge genetically.

Inbreeding can cause inbreeding depression (Berger 1990, Ralls *et al.* 1988). Inbreeding depression is often a problem in small population sizes (perhaps 500-1000 individuals), such as might arise where small sub-populations are isolated from the main population. Inbreeding, if it occurs, would only be a problem at the sub-population level in habitat isolates, and is therefore most unlikely to have a species-wide effect or to affect populations in large natural areas.

Genetic drift occurs when an isolated or small population loses genetic variation due to the chance loss of alleles (forms of a particular gene). Because the population is isolated, the lost genetic variation cannot be replaced by gene flow from another population; it can only be replaced by the very slow and random process of mutation, a process that may be too slow to ensure the long term viability of the population. However, the rates of dispersal between populations required to prevent genetic drift occurring are surprisingly low - one or two individuals per generation (Lande and Barrowclough 1987, Sherwin and Murray 1990) - and these figures seem to be of general applicability throughout a wide range of organisms. Thus, a barrier has to cause very low levels of gene flow before genetic drift comes into play.

Aquatic Impacts

Development of the airport would require extensive earth moving and excavation which may have significant impacts on the aquatic environment. Impacts are associated with increased erosion and/or sedimentation and stormwater discharge. The former processes have been considered in detail in *Technical Paper No. 7 - Geology, Soils and Water*. Briefly, potential impacts associated with sedimentation include:

- changes in stream flow characteristics;
- direct smothering of fauna;
- interference with gill function in fish, filter feeding mechanisms;
- reduction in the euphotic (photozynthetic) zone and retardation of aquatic plant function;
- increased turbidity interfering with visual feeding;
- siltation and reduction in stream habitat, removal of water sources for riparian fauna;
- changes in riparian vegetation community composition and structure; and
- changes in microclimate conditions for amphibian fauna.

There would be two major consequences for stormwater discharge. Firstly, a change in existing runoff pattern would occur in the form of diversion of existing streams during construction. Secondly, due to an increase in the amount of impervious surfaces and efficient surface drainage systems, there would be a dramatic increase in the rate and volume of stormwater runoff from the airport site.

Along with the increase in the volume and rate of stormwater runoff an increase in a wide range of water borne pollutants could occur. These would range from wastes associated with hard surfaces such as rubbish, grease and heavy metals, to those associated with vegetated areas such as silt, nutrients, organic matter and herbicides. This overall increase in polluted runoff would have implications for the downstream aquatic environment. The water quality management strategy for the proposed airport development includes detailed proposals for stormwater quality control during construction, which aims to capture and treat such pollutants.

Noise and Lighting

Noise impacts on wildlife are discussed in *Technical Paper No. 3 - Noise*. It is impossible to differentiate the effects of auditory, visual, olfactory and vibrational disturbance stimuli on fauna. Non-auditory stimuli may act to reinforce the effects of noise, thus delaying the habituation process.

Noises can be clearly differentiated between the construction and operational phases. Whereas construction noises would be variable in type and in intensity, sound produced during operation and maintenance phases would in the majority be consistent with those from mobile and continuous sources such as found on transmission line corridors, highways and fast trains.

During construction, the initial wildlife response to noise would be a startle reaction. This could result in increased stress levels and greater distances travelled during the course of normal activities. North American studies have found that this was the case for elk calves in response to simulated disturbance (Kuck 1986) and for elk adults near logging operations (Lyon 1980) or seismic activity (Knight 1981). The authors hypothesised that this could have negative effects on individuals if they were forced into marginal habitat. For species with limited distributions, this would act to decrease the total amount of habitat available or to fragment it. For rare species, the airport noise may effectively isolate groups of individuals or fragment their habitat.

Little is known about the long term impacts of operational noise on wildlife. A recent review of studies investigating the effects of aircraft overflights on wildlife (United States Department of Agriculture and Forest Service 1992) concluded that there was no evidence to suggest that these resulted in significant changes to the reproductive success of fauna groups considered. Most studies showed that individuals coped with sudden loud noises with a startle response but under normal circumstances habituated to them both behaviourally and physiologically. The authors caution however that the impacts of overflight noise should be determined on a species-specific basis with those species under severe ecological stress being given particular consideration.

The effects of overflight noise on broad animal groups is summarised from United States Department of Agriculture and Forest Service (1992) below:

- Amphibians - unknown. Frogs are sensitive to vibration which is difficult to differentiate from acoustic and visual cues;

- Reptiles - unknown. Reptiles do not exhibit well-developed acoustic startle response but may be affected by vibration;
- Birds - variable, behavioural. No clear association between breeding success and aircraft disturbances. Startle response associated with very close approaches (50 to 100 metres). Passerines, waterbirds and raptors appear to adapt behaviourally to overflights over time; and
- Mammals - variable, behavioural. No clear association between breeding success and aircraft disturbances. Startle response and gradual habituation seem to be typical for small mammals, carnivores and large herbivores. Most important predictors of response for large herbivores include prior experience with overflights, aircraft approach distance, stage in breeding cycle, activity or context and group age and sex composition.

In the long term, the ambient noise levels may be high enough to mask communication signals amongst vociferous or social species such as birds, fruit bats, arboreal mammals and frogs. By affecting their ability to maintain contact, warn of predators, defend territories and/or attract mates, noise may directly affect their rate of survival. There is little or no baseline data regarding the effects of noise on communication in Australian animals. A study on Japanese Quail showed that this species calls more frequently when there is a high level of background noise (Potash 1972); this may increase its vulnerability to predation. Mackey and Barclay (1989) found that physical clutter and increased background noise associated with running water may be responsible for reducing activity of some bat species over running water; this implies that noise may interfere with echolocation of some bat species.

Very little is known about the effects of artificial lighting on wildlife. However, it appears that some prey species may alter their activity patterns during moonlit nights in order to escape detection by predators. In desert habitats, strong light at night is known to elicit a predator avoidance response and curtail the movement of nocturnal mammals. In Australia, Goldingay an Kavanagh (1986) found that Feathertail Gliders were more active when the moon was not visible and hypothesized that the distinct shadows cast on a moonlit night may aid predators such as owls to locate potential prey. Law (*in prep.*) Found that Common Blossom Bats delayed their roost departure by up to four hours on moonlit nights presumably to avoid detection by predators such as owls.

Much of what is known about the effects of light on fauna has been derived from actively trying to deter animals using bright lights or reflectors. It appears that reflectors are ineffective in reducing deer-vehicle collisions in the US (Reeve and Anderson 1993) and may be ineffective in deterring Eastern Barred Bandicoots and Koalas from oncoming traffic (Prevett et *al.* 1992). Waterbird pests in fish farms adapted quickly to flashing or amber lights (Salmon *et al.* 1986). Whereas there is little statistical evidence to show that fauna are deterred by light, there is some anecdotal evidence to suggest that some species may be attracted to light, including insectivorous bats and frogs.

Road Kills

Roads form physical barriers to many types of fauna. Those species most at risk of becoming road kills are medium to large-sized mammals, arboreal mammals, some bird species (for example, cockatoos, ravens, magpies) reptiles and frogs. Apart from an increase in overall mortality rates, populations may be further affected by the selective mortality of certain age and/or sex classes that are more prone to move across a roadway. For instance, Coulson (1989) found that more male and juvenile Eastern Grey Kangaroos and Swamp Wallabies were killed on roads during drought years. In the long term, this may affect the distribution and demographic characteristics of the population. Where roads are lined with grassy verges, they are likely to attract grazers such as wombats, wallabies and kangaroos.

6.1.2 INDIRECT IMPACTS

Indirect impacts are those which occur as an indirect consequence of construction activities. For example, clearing for construction and roads may increase the abundance of feral predators gaining access to an area and a consequent increase in the risk of predation to native fauna species.

Feral Animals

It is generally accepted that the construction of roads and the creation of new edges increases predator access into forested areas which may previously have been inaccessible (Andrews 1990; May 1994; Bennett 1990). This is true for both introduced predators (dogs, cats, foxes) and for native species such as quolls and dingos. It appears also that habitat fragmentation resulting in high edge to area ratios may result in high predation rates (Recher et al. 1987; Wilcove 1985; Andren 1992; Yahner and Scott 1988). Species most sensitive to edge-related predation are the critical weight range mammals. Arboreal mammals, small terrestrial mammals, large herbivorous mammals, ground foraging birds and even aquatic mammals are also at risk.

Native frog and reptile species are also at risk from predation by feral predators. In particular, the Mosquitofish (*Gambusia holbrooki)* is presumed to have a detrimental effect on frog populations (NPWS unpublished). The European Carp may also be indirectly linked to frog decline due to its feeding behaviour, which degrades habitat and reduces food for frogs (NPWS unpublished).

Fourteen exotic or feral bird species are established in Western Sydney (NPWS unpublished). Of these the Common Myna is the most successful. Exotic species dominate disturbed habitats and are rare in undisturbed bushland areas. Disturbed habitats also tend to attract native generalist species such as the Noisy Miner and other honeyeater species. These species are highly aggressive and compete heavily with more timid or solitary native species.

Weeds

An important potential effect of the airport proposals on native vegetation outside the development zone is weed invasion. Weed invasion may be promoted by introduction of weed seed/propagules, physical disturbance, increased nutrients or altered drainage. It is an ongoing issue throughout the construction and operation phases.

Boundaries or edges of native vegetation generally experience higher levels of environmental stress and more frequent disturbance than interior zones. Physically disturbed environments provide conditions suitable for plant species with colonising tendencies, particularly introduced plants. Native vegetation is usually bounded by broad edge zones of semi-native (invaded) vegetation. Fragmentation and reduction in area may result in entire remnants becoming effective edge zones. In these situations, weed invasion and loss of sensitive interior species are probable. Zones of susceptible edge vegetation would be created beside most infrastructural developments.

The risk of weed invasion is likely to vary from site to site, depending largely on local topography. Due to limited soil nutrient and water availability, the potential for weed invasion on sites that are upslope from directly disturbed areas is likely to be relatively minor. However, there is considerable potential for weed invasion on sites downslope from directly disturbed areas due to increased nutrient levels and altered drainage. Particularly susceptible sites include rivers, creeks, drainage lines and any other area receiving runoff. Due to the high dispersibility of seed down streamlines, weed invasion may extend many kilometres from the initial point of introduction.

Due to logistic constraints (rugged terrain and dense vegetation in particular), high costs, and the sometimes tenacious nature of the species involved, it is unlikely that weed outbreaks would be controlled. Control of certain woody species may be feasible but large-scale herbaceous weed invasions are generally unmanageable. It is assumed here that invasive exotic species would spread and establish permanently altered vegetation communities where site conditions permit.

The species used in landscape plantings is relevant, as invasive species may inadvertently be used and 'escape' into adjacent areas. Many Australian natives are known to readily escape beyond their natural range as a result of horticulture, and in some cases severe disruptions of ecosystems occur.

Cinnamon Fungus

Cinnamon Fungus *Phytophthora cinnamomi* is a primary cause of dieback in the coastal forests of eastern Australia. It a widespread soil-borne fungal pathogen that has probably been introduced to Australia since European settlement, and is readily spread by infested soil adhering to vehicles. Many native plant species are susceptible to the fungus, including a large number of trees.

The disease may already be present within the Holsworthy Military Area. The sole specimen of *Persoonia nutans* shows symptoms of disease. Cinnamon Fungus has been evident elsewhere on the Woronora plateau since about January 1994. Soil hygiene measures, such as cleaning of vehicles at constructed washdown points, are theoretically possible but are likely to be expensive and impractical and would be breached during fire emergencies. However, no active controls are used in New South Wales apparently because there is no evidence to suggest that there is any unusual cause of disease due to the fungus (D. Binns, SFNSW pers. comm.).

Cumulative Impacts

Cumulative impacts are expected to result from direct and indirect impacts associated with the construction and operation of the airport, and interactions between them.

Cumulative impacts are not well understood because we do not know the sum total of impacts a species has been exposed to over time nor what weighting to give each one. However, Koala populations in NSW appear to have been reduced through the combined effects of harvesting, burning and drought (Reed and Lunney 1990). The effects of predation and fire may also have cumulative effects on critical weight range species, in particular the Long-nosed Potoroo (Newsome et al. 1983). In the case of airport construction, the accumulated impacts of clearing, habitat fragmentation and an increase in feral predators are likely to have a significant impact on a variety of different fauna guilds (for example, arboreal mammals, critical weight range species, small terrestrial mammals). The recognised long term result of cumulative impacts is a gradual reduction of biodiversity and the replacement of highly specialised species with generalist and highly adaptive species (for example, weeds, introduced and feral animals).

6.2 OPERATION IMPACTS

Operation impacts are those associated with long term operation of an airport. Although some impacts are common to both the construction and operation phases, these tend to differ in their nature (for example, noise, aquatic impacts).

Noise and Lighting

Noise impacts on wildlife are discussed in *Technical Paper No. 3 - Noise*. Noise would tend to be loud and unpredictable during the construction phase, however, it would generally have a slower onset time and be more continuous during operation of an airport. Thus noise from engines would be less disruptive to wildlife than the noise from construction blasting. Many species of animals therefore tend to habituate rapidly to operational noise sources. There are numerous records of birds nesting and rearing their young on airfields. Furthermore, we can expect that given the relatively long construction periods for all options, any species remaining on the periphery of the airport or within it would be habituated to noise.

Light associated with the operational phase of an airport is expected to be of higher intensity and more widespread than that associated with construction activities. However, those native species still found on the site after operation begins are likely to be highly adaptable and tolerant of noise and associated human activity.

Fire

Fire has been a significant factor in the evolution of the flora and fauna of Australia. In geologically recent times there have been three successive periods in relation to fire regimes: pre-Aboriginal (lightning and other ignition sources), Aboriginal (deliberate burning and escapes plus natural ignition sources) and European (deliberate burning and escapes plus natural ignition sources). Many native plants and animals have adapted to, or are dependent on a specific fire regime. Any change to the existing fire regime can alter the species composition and structure of vegetation communities and the fauna species they support.

Fire regime is defined by fire frequency, intensity and area affected. Fire regime is influenced by fire hazard, which is in turn affected by slope, vegetation type and density, quantity of fuel and altitude. Two types of fire are broadly recognised in the Australian environment, hazard reduction fires and wildfires. Hazard reduction fires are low intensity burns carried out by landholders to reduce fuel loads and consequently reduce the likelihood of wildfires. Wildfires are typically high intensity fires, burning without control in adverse weather conditions.

The analysis of fire effects is complex and the current state of knowledge allows little more than the delineation of broadly consistent trends. Consistent results of studies relating to fire and fauna and flora are identified below and interpreted in terms of known ecological processes or associations. At the broadest level, the key consistent results of relevant studies are that:

- frequent burning suppresses the shrub component and reduces floristic diversity in the ground and mid-storey layers (Moore and Floyd 1994; Catling 1991; Austeco 1992, 1994, 1995);
- species that require shrubs or structural complexity are negatively associated with frequent fire (Catling 1991; Austeco 1992, 1994, 1995);
- species that forage on grasses and herbs or that require structurally simple or open environments are positively associated with frequent fire (Catling 1991; Austeco 1992, 1994, 1995); and
- in all fauna groups, some species are advantaged, some disadvantaged but, overall, more species are disadvantages and those species advantaged are generally common species (Cheal *et al.* 1979; Christensen and Kimber 1975; Austeco 1992, 1994, 1995).

Airport development and operation have the potential to alter fire regime in the surrounding environment through:

- construction activities leading to accidental fire ignition;
- increased human presence leading to accidental and deliberate fire ignition; and
- fire management activities such as clearing and hazard reduction burning.

Any change in the existing fire regime would impact upon flora and fauna species present in natural areas adjacent to the airport development site. Changes in species composition and vegetation community structure in surrounding natural areas will also be considered as part of the cumulative impacts resulting from the airport development.

Bird and Bat Strike

The issue of bird and bat strike has been discussed in *Technical Paper No. 10 - Hazards and Risks*. A variety of factors contribute to the likelihood of bird and bat strike associated with an airport, these include bird or bat species likely to be present at the airport, the size, behaviour and population sizes of these species and their local and regional movement patterns. Physical and behavioural characteristics of bird species can predispose them to collisions with aircraft. Large birds (for example, raptors, waterbirds) that move in flocks, soar on thermals and are attracted to water bodies currently have an increased risk of collision. Eighteen bird species are considered to be at risk from bird strike. Of these, the Wedge-tailed Eagle and the Whistling Kite are of regional significance in the Cumberland Plain.

Fruit bats have an increased risk of collision with aircraft due to their comparatively large size. Fruit bats known to occur in western Sydney include the Grey-headed Flying Fox and the Little Red Flying Fox. Both of these species are considered to be of Regional significance due to the restricted number of breeding sites. A large breeding colony of the Grey-headed Flying Fox is located at Cabramatta Creek near Warwick Farm Racecourse, around 20 kilometres east of Badgerys Creek and about 26 kilometres north of Holsworthy. Although a maximum of 28,000 bats were estimated to occur at this colony in 1995 (Cullis 1996); between 5,000 and 10,000 occupy the site between September and March each year. Fruit bats are known to disperse long distances from breeding colonies for feeding and occur in large numbers at the Holsworthy options, increasing the risk of collision with aircraft.

The location of the airport in an area which currently supports a variety of bird and bat species would increase the risk of bird and bat strike. The presence of habitat attributes on the site that attract bird species such as large grassed areas and drainage retention basins would increase the likelihood of bird and bat strike. Without appropriate control this could lead to reductions in local or regional populations of some species.

Aquatic Impacts

Aquatic impacts are covered in *Technical Paper No. 7 - Geology, Soils and Water*. Aquatic impacts associated with airport operation could occur due to discharge of treated effluent from an on site sewage treatment plant and from discharge of treated stormwater. Effluent discharge may alter the existing flow regimes of creeks and increase their levels of nitrogen and phosphorous. The eutrophication of streams would potentially lead to changes in aquatic fauna to more tolerant forms, particularly if dissolved oxygen becomes limiting.

The increase in polluted runoff would have implications for the downstream aquatic environment. The concentration of pollutants contained in runoff from the airport is expected to be similar to those typically experienced in urban areas. On-site stormwater quality control measures aim to reduce those levels. However the effectiveness of these measures is uncertain at Holsworthy in particular and as a result the impacts on the downstream aquatic environments and the species they support could be severe.

Fuel Discharges

Fuel-dumping which may occur as a consequence of an emergency situation is discussed in *Technical Paper No. 5 - Air quality*. Under normal procedures, fuel dumping in emergency circumstances is undertaken over the sea at a height of 30,000 feet. It is therefore likely to have a negligible impact on terrestrial and freshwater habitats near the airport options. A plane crash would result in impacts to conservation reserves in the vicinity of the airport. In normal situations, the effects of accidental fuel discharges (such as from fuel venting) on natural areas are expected to be nil to low.

Aerial pollutants generated by aircraft emissions may also have impacts on water quality. In particular, benzene and benzo(a)pyrine represent the more toxic of constituents generated. These are considered in detail in *Technical Paper No. 7 - Geology, Soils and Water.*

Surrounding Wilderness and Conservation Areas

There are several accepted definitions for wilderness. The National Parks and Wildlife Service (1995) describes it as "a large natural area of land that, together with its native plant and animal communities, is essentially unchanged by human activity". At the national level, the Australian Heritage Commission has designed a database of wilderness quality known as the National Wilderness Inventory. Wilderness quality is indicated by remoteness from settlement, remoteness from access, apparent naturalness and biophysical naturalness. Although no formal wilderness assessment has been undertaken within the Holsworthy Military Area, it does contain areas of moderate (10,350 hectares) to high (625 hectares) wilderness quality (A. Cox, Wilderness Conservation Unit National Parks and Wildlife Service *pers comm.*). A more detailed assessment would be required before the areas could be considered as wilderness areas.

At the state level, the *Wilderness Act* 1987 defines a process of assessment, identification and declaration of wilderness areas. There are two declared wilderness areas and one proposed wilderness area within 50 kilometres of the Badgerys Creek and Holsworthy sites (A. Cox, Wilderness Conservation Unit *pers. comm.*):

- Nattai Wilderness is a declared wilderness area of approximately 30,000 hectares located 35 kilometres SSW of Badgerys Creek and 30 kilometres WSW of the Holsworthy Military Area;

- Kanangra-Boyd Wilderness is a declared wilderness area of 111,000 hectares located 30 kilometres WSW of Badgerys Creek and 45 kilometres of the Holsworthy Military Area; and

- Grose Wilderness Assessment Area is an area of proposed wilderness of 60,000 hectares located 20 kilometres NW of Badgerys Creek.

Several other proposed or declared wilderness areas are located between 50 to 100 kilometres of the Badgerys Creek and/or Holsworthy sites. However, the potential impacts of noise and related disturbance are likely to be relatively low for these areas.

This impact assessment is concerned primarily with the effects of the airport on the natural values, including flora and fauna and streams within wilderness areas. Issues relating to visual impacts are the subject of *Technical Paper No. 14 - Visual and Landscape*. Potential impacts associated with airports such as bird and bat strike, excessive noise, pollution associated with fuel-dumping and exhaust and the risk of plane crashes may affect the ecological values of wilderness areas. These impact may reduce the ability of a wilderness area to evolve in the absence of significant human interference (A. Cox, Wilderness Conservation Unit *pers comm.*).

There are no known listed World Heritage areas located in the vicinity of the airport options. However, there has been a proposal to list the Blue Mountains and surrounding plateaux (James 1994). The proposal recommends that the area be nominated as a World Heritage area because of its outstanding geological, geomorphological, biological and cultural values of universal scientific importance. The proposed area includes the Woronora Plateau which is directly adjacent to the two Holsworthy options. It also includes the Blue Mountains which are located to the west of the sites of the Badgerys Creek airport options.

Two areas in the vicinity of the Holsworthy site are listed on the Register of the National Estate: O'Hares Creek Catchment and Voyager Point. The upper reaches of O'Hares Creek are included on the Directory of Important Wetlands (Australian Nature Conservation Agency). A number of National Parks, State Recreation Areas and Nature Reserves occur in the vicinity of both airport sites.

The entire Holsworthy Military Area was placed on the Interim Register of the National Estate by the Australian Heritage Commission in July 1997. The Statement of Significance is contained in *Appendix E* for reference.

6.3 IMPACT ASSESSMENT PROCESS

6.3.1 TERRESTRIAL FLORA AND FAUNA

Impact assessment is based on the Construction Plan and Master Plans for five airport options incorporating mitigation measures (Second Sydney Airport

Planners, 1997a), noise impact assessment work presented in *Technical Paper No. 3 - Noise*, water quality assessment presented in *Technical Paper No. 7 - Geology, Soils and Water* and on bushfire and bird and bat strike assessment included as Appendices to *Technical Paper No. 10 - Hazards and Risks*. It is assumed that all habitat would be removed from within the option boundaries and that there would be some habitat removal and disturbance associated with obstacle limitation areas off-site. Impact assessments for all flora and fauna species listed in the *Threatened Species Conservation Act, 1995* are included in *Appendices A* and *B*.

It is also based on the findings of the present report, namely: significance assessments for vegetation communities, habitats, flora species, fauna species; a review of literature pertaining to other similar developments; and the opinion of the consultants based on their experience in assessing impacts in south-eastern Australia. For each option, a range of construction and operation impacts has been assessed on-site and where applicable, off-site. However, the transport and services corridors have not been assessed specifically as part of these investigations. In addition, no sampling or detailed assessment of Obstacle Limitation Surface clearing areas, which are located outside of the sites of the Badgerys Creek and Holsworthy options, has been undertaken.

Time Frame and Scale of Impacts

Three time frames were considered for impact assessment:

- short term (about one month);
- medium term (between one and two years); and
- long term (beyond three to four years).

Scale of potential impacts for airport construction and operation on flora and fauna is described as low, high or unknown. In general, activities having low impacts are those which:

- result in alterations to behaviour or activities of individuals in the local area; or
- may be associated with a low probability event (that is, a plane crash or malfunction) under normal circumstances.

In general, activities having high impacts are those which:

- result in the elimination of local or regional populations of flora and fauna;

- result in the elimination of restricted habitat resources or types in the local or regional area; or

- result in a long term decrease in reproductive success of populations or species.

Unknown impacts are those which cannot be defined on the basis of existing knowledge. This may be the case where there is a paucity of information (for example, research into the effects of noise and lighting or fauna) or where impacts of the proposed development are difficult to predict due to the difficult nature of the terrain as is the case within the Holsworthy Military Area.

Limitations

Impact assessment of the sites of the Badgerys Creek airport options is more comparable to other major developments in the Sydney region largely because of its location (close to the metropolitan area), history of land use, gentle topography and accessibility. It is more difficult to assess the impacts of a development the scale of the Second Sydney Airport within the largely inaccessible and steeply dissected terrain of the Holsworthy Military Area, there are no comparable developments in the Sydney Region or Australia. Therefore, a precautionary approach has been taken throughout the impact assessment. The following possibilities have been taken into account: high rainfall events could occur during the construction period; some sedimentation and erosion mitigation measures may be inadequate or inappropriate; estimates of treated sewage plant effluent and stormwater discharges may be inaccurate and weeds and feral animals may not be able to be controlled.

6.3.2 FISH AND CRAYFISH

Impact assessment is based on the Construction Plan and Master Plans for five airport options incorporating mitigation measures detailed (Second Sydney Airport Planners, 1997a) and on Water Quality assessment presented in *Technical Paper No. 7 - Geology, Soils and Water*. Taking a conservative approach, impact assessment takes into account the occurrence of a number of major rainfall events, human error and inappropriate or inadequate impact mitigation measures. The latter could only be determined once construction is underway.

Construction Impact Assessment Methodology

Further details on impact assessment methodology are included in *Appendix C*. A list of airport construction activities which may lead to impacts on freshwater fish and crayfish was derived by K. Bishop and included a minimum of 31 activities (see *Table A3.12, Appendix C*). These can be broadly classified as: six causing habitat destruction/removal; four initiating habitat degrading processes; nine causing sediment inputs to streams; five causing nutrient inputs to streams; and seven causing miscellaneous contaminant inputs to streams.

The following was considered for each stream potentially directly affected:

Three time frames:

- short term (about one month);
- medium term (up to one to two years); and
- long term (beyond three to four years).

Estimates of likely spatial extent of stream impacts:

- no impact likely;
- localised impact likely (up to one kilometre downstream);
- moderately extensive (1-10 kilometres downstream);
- very extensive (beyond 10 kilometres downstream); and
- unknown, unsupplied or unable to predict in coarse estimates.

Estimates of likely intensity of stream impacts:

- no impact likely;
- low intensity;
- moderate intensity;
- high intensity;
- very high intensity (for example, habitat removal); and
- unknown, unsupplied or unable to predict in coarse estimates.

For each activity, stream and time frame category, scores were awarded on the basis of impact extent multiplied by impact intensity, providing a measure of the scale of impact. These scores were then summed across activities to provide a measure of the scale of impact for each stream and time frame. The scale of impact for each stream is described as minor, major, very major, severe or very severe.

These also represent a sliding scale of impacts for fish and crayfish inhabiting these streams. A minor scale of impacts indicates subtle reductions in the abundance of sensitive native fish and crayfish taxa; associated subtle community composition changes favouring pollution tolerant taxa; and slight reductions in reproductive success. A very severe scale of impacts indicates virtual elimination of the majority of native fish taxa down affected tributaries and well into trunk streams, elimination of all crayfish taxa and the cessation of reproduction altogether.

Operation Impact Assessment Methodology

Further details on impact assessment methodology are included in *Appendix C*. A list of airport operational activities which may lead to impacts on freshwater fish and crayfish was derived by K. Bishop and included a minimum of 28 activities (see *Table A3.13, Appendix C*). These can be broadly classified as: three causing habitat destruction/removal; four initiating habitat degrading processes; one causing sediment inputs to streams; six causing nutrient inputs to streams; one causing biological contaminants input to streams; and 13 causing miscellaneous contaminant inputs to streams.

The primary differences between construction and operation activities are a reduction in activities involving sediment inputs, an increase in activities causing miscellaneous contaminant inputs and the introduction of activities causing biological contaminant inputs. The effects of activities causing habitat destruction and/or removal and habitat degrading processes essentially continue from the construction phase to the operational phase.

Assessment for operational impacts was similar to that for construction impacts, with the exception that the release of treated sewerage effluent into the Georges River (Holsworthy options) was considered in relation to operational impacts and that surrounding streams not hydrologically connected to those draining the airport sites had to be considered for operational impacts due to potential gaseous pollutants from aircraft and increased vehicular traffic.

Limitations

Impact assessment for stream biota impacts is difficult given the number of activities potentially undertaken and a general lack of quantitative information regarding the likely input of construction derived materials to the streams. It is recognised that most of these inputs would be influenced by unpredictable factors such as the occurrence of intense rainfall events, human error, inappropriate mitigation and other factors.

Considering the link between the physical and chemical impacts and stream biota impacts, a very high level of complexity is apparent when the range of possible impact mechanisms is examined for each group of activities. For example, for each activity involving sediment inputs, there are at least 11 stream-biota impact mechanisms and there is a high probability of interactions between some of these mechanisms (see *Attachment 1, Appendix C*). Similarly, for each activity involving nutrient inputs, there are at least nine impact mechanisms; interactions between mechanisms are likely (see *Attachment 1, Appendix C*).

Because of the complexity, the key initial task of impact assessment procedure was to simplify the number of potential impacts and their interactions. The overall objective was to derive a measure of the scale of impacts likely to occur for each airport option for comparative purposes.

CHAPTER 7 IMPACTS OF BADGERYS CREEK OPTIONS

This section comprises an impact assessment of the proposals at the Badgerys Creek site. Impact assessment concentrates on the three airport options but also briefly considers issues associated with preliminary transport corridor options. The routes are indicative only and are subject to separate EIS assessments.

7.1 OVERALL IMPACTS OF BADGERYS CREEK OPTIONS

Impact assessment is based on preliminary Master Plans prepared by Second Sydney Airport Planners (1997a).

7.1.1 VEGETATION CLEARANCE

Airport construction at the sites of the Badgerys Creek options would result in the removal of between 1,700 and 2,900 hectares of vegetation (depending on the option selected) (Second Sydney Airport Planners, 1997a). Although most of this area consists of cleared farmland, some remnant native vegetation is present. Vegetation clearance would be associated with the following activities: construction of the airport and its associated infrastructure; realignment of roads and utility corridors; temporary or permanent road construction, upgrading and widening; construction of detention ponds, and stream diversion. The Northern Road and Badgerys Creek Road would require detours or temporary construction; Bringelly Road may require widening. Most vegetation would be cleared, although bushland at the perimeter of the site and localised bushland within the development could be retained where possible.

7.1.2 HABITAT LOSS

The four habitat types described for the sites of the Badgerys Creek options provide critical resources for at least 17 significant fauna species; additional significant species were recorded in the vicinity of Badgerys Creek and may occur within the study area. The area of the Badgerys Creek options also contains habitat for 49 significant plant species. The impact of airport construction on habitat types is assessed below for each option; impacts relating to particular species are described in *Appendix A* and *B*.

Woodland Remnants

These comprise Grey Box Woodland which are a component of Cumberland Plain Woodland. This community has been largely cleared in western Sydney and remnants are generally highly degraded (altered). This habitat type is found in small patches or along riparian corridors on the site. It is considered to be a habitat of high local significance and covers approximately 200 hectares.

Woodland remnants provide habitat for at least nine species of National and State significance as shown in *Table 7.1*. Many of the fauna species typical of the Cumberland Plain, in particular passerine bird species, have declined markedly in the past probably due to clearing and fragmentation of this habitat type. Further loss and/or fragmentation of this habitat is likely to affect the regional distribution of some of the species.

TABLE 7.1 SIGNIFICANT (NATIONAL AND STATE) FLORA AND FAUNA SPECIES RECORDED FROM OR LIKELY TO OCCUR WITHIN VEGETATION COMMUNITIES/HABITAT TYPES AT BADGERYS CREEK

Fauna Habitat	Vegetation Community	Rare Fauna Species	Rare Plant Species
Woodland Remnants	Grey Box Woodland (Altered)/BADG 2	Regent Honeyeater Powerful Owl Swift Parrot Common Bentwing Bat Eastern False Pipistrelle Eastern Little Mastiff Bat Greater Broadnosed Bat Yellow-bellied Sheathtail Bat Eastern Cave Bat	
Riparian Woodland	River-Flat Forest (Altered)/BADG 3	Regent Honeyeater Australasian Bittern Black Bittern Glossy Black-Cockatoo Powerful Owl Swift Parrot Common Bentwing Bat Eastern False Pipistrelle Eastern Little Mastiff Bat Greater Broadnosed Bat Large-footed Myotis Large Pied Bat Yellow-bellied Sheathtail Bat Eastern Cave Bat	
Grassland	Pasture/Disturbed Woodland/BADG 1	Common Bentwing Bat Eastern False Pipistrelle Eastern Little Mastiff Bat Greater Broadnosed Bat Yellow-bellied Sheathtail Bat	*Pultanaea parviflora*
Open Water/ Wetlands		Green and Golden Bell Frog Black Bittern Australasian Bittern Large-footed Myotis Lathams Snipe	

Riparian Woodland

Riparian Woodland covers approximately 20 hectares of the site. This habitat has also been largely cleared and fragmented and is generally in poor to moderate condition. It is considered to be a habitat of high local significance because it forms an integral part of riparian wildlife corridors along Badgerys Creek and other creeks.

This type of vegetation provides habitat for at least 14 species of National and State significance (*Table 7.1*). These are mainly highly mobile species such as birds and bats but also includes frogs.

Grassland

Grassland covers most of the sites of the Badgerys Creek options and may contain isolated trees. It largely comprises introduced grasses which have been used for agricultural purposes. It is generally in poor to moderate condition due to grazing and other disturbances. It has limited habitat values and is considered to be of local significance. It provides habitat for five bat species of state significance and one plant species of National significance (*Table 7.1*).

Open Water/Wetlands

Wetlands within the site are generally artificially created although open water is also found along Badgerys Creek. These cover a relatively small proportion of the site and tend to be in poor condition due to trampling and other disturbances associated with agricultural practices. Wetlands are considered to be of local significance and provide habitat for five species of State significance (*Table 7.1*) including bats, birds and frogs.

Wildlife Corridor Values

Riparian vegetation within the sites of the Badgerys Creek options form wildlife corridors of high local significance. Although it is relatively narrow and fragmented with a degraded understorey, it still provides a canopy layer which is utilised by a range of bird and bat species. Open water provides habitat for amphibians. Riparian vegetation provides the only remaining extensive wildlife movement corridors within this part of Sydney.

7.1.3 HABITAT FRAGMENTATION/BARRIERS

Although much of the Badgerys Creek area has already been cleared for agricultural purposes, remnant vegetation communities occur there. Existing habitat is likely to be further fragmented by clearing for construction of an airport and associated infrastructure. Habitat fragmentation is also likely to be associated with roads, railways, pipelines, powerlines, communication lines, temporary storage dams and stream diversions. Movement barriers are associated with clearing and fencing of the preferred site and with newly-constructed and/or altered road and utility easements located off-site. The airport site would be surrounded by security perimeter fencing 2.4 metres high with outward facing barbed wire at the top (Second Sydney Airport Planners, 1997a). Both sides of the fence would be cleared with a roadway present on the inside of the fence. This would pose a considerable barrier for most terrestrial and arboreal fauna groups. The need to upgrade some of the roads and to relocate utility corridors is dependent on the final option selected.

7.1.4 AQUATIC IMPACTS

Aquatic impacts both on and off-site are likely to be associated with erosion and sedimentation, stream diversion or culverting, stormwater drainage, pollution and sewerage release. There is also the risk of fuel spills although there is a high level of confidence in the effectiveness of fuel containment. Creek diversions involve the construction of temporary creek excavations before final release of waters into permanent stormwater drainage facilities. Badgerys Creek, OakyCreek and Cosgroves Creek would be partly infilled during airport construction.

7.1.5 NOISE AND LIGHTING

The effects of noise and lighting are associated with airport construction and operation. During construction, noise is associated with heavy machinery (dozers, scrapers, excavators, compactors, graders), vehicular traffic, batching plants, generators and other human activity. Lighting is required for security and during times when overnight construction activities are anticipated. Although most construction activities are likely to take place between 0700 and 1700, six days per week, those associated with concrete production, excavation, trench dewatering and concrete placements could occur over 24 hour periods. Approximately 20 percent of construction work is expected to occur at night (Second Sydney Airport Planners, 1997a).

7.1.6 TRAFFIC

Traffic would increase considerably during the construction phase of the project and is expected to reach one million vehicle movements per year (Second Sydney Airport Planners, 1997a). Traffic is expected to arrive mainly from the south with some traffic coming from the north-west. Truck movements are expected to occur at all times of the day and night, including dawn and dusk. Deliveries of pavement materials are expected to be made at night; deliveries of construction materials would be likely to occur in the afternoons and early evenings. During construction, Bringelly Road, Badgerys Creek Road, Northern Road and Elizabeth Drive would be utilised. Dust is likely to be a problem, especially in summer. Increased traffic would be associated with the following:

- workers' vehicles entering and leaving the site each day;
- transfer of solid and putrescible wastes from the site to a waste transfer stationer, landfill such as Eastern Creek;
- sewage transfer from site to St Marys treatment plant;
- delivery of asphalt by tipper trucks from western Sydney plants;
- fuel tanker loads over the construction period;
- transfer of salvage material from demolished buildings from site to landfills;
- delivery of pavement materials from Glenfield, Camden, Port Kembla, Kiama, Shellharbour, Penrith Lakes, Kurnell, Kandos, Portland and Prospect;
- delivery of fly-ash from power stations;
- delivery of pipes from Rooty Hill, Emu Plains, Port Kembla; and
- delivery of building materials.

7.1.7 AIRPORT OPERATION

Noise and Lighting

Noise levels would be consistent with Air Traffic Forecast 1, 2 or 3 levels, as described in *Chapter 1*. It has not been decided if a curfew would apply to the new airport (that is, whether aircraft noise would continue throughout the night).

Fire and Fire Management

The fire regime at Badgerys Creek is not expected to change significantly from the current situation. The risk of bush or grass fires would be expected to increase slightly over the construction phase. The risk of fires during the operational phase is expected to be minimal due to regular mowing of grass aprons. The potential impacts of fire on native flora and fauna are not expected to change significantly with development of the airport options.

Fire management at Badgerys Creek has been discussed in detail in *Technical Paper No. 10 - Hazards and Risks.* In summary, Badgerys Creek does not present a significant bushfire threat. Fuel management planning and grass maintenance works would provide fire protection.

Bird and Bat Strike

This issue has been discussed in detail in *Technical Paper No. 10 - Hazards and Risks.* In summary, birds at the Badgerys Creek site are most likely to occur in normal numbers for airport grassland habitat and are not expected to undertake significant movements or to occur in large flocks. Bird and bat groups most at risk of colliding with aircraft include cockatoos, fruit bats, raptors, waterbirds and grassland birds. The occurrence of waterbirds most at risk of colliding with aircraft would be related to stormwater management on-site.

Each airport layout has been developed with several major discharge subcatchments. The proposed arrangement is a wet extended detention pond that would provide a large temporary water body which would potentially attract water birds. A potential impact of creating such ponds is the increased likelihood of bird strike associated with increased numbers of birds in the airport environs.

Aquatic Impacts

This issue is discussed in *Technical Paper No. 7 - Geology, Soils and Water.* Once the airport is operational, the streams within the site would form part of the drainage system and would no longer be part of the aquatic ecosystem.

The two major operational impacts would include stormwater and effluent discharge. Stormwater discharge into Badgerys, Oaky and Cosgroves Creeks (depending on the option) is not expected to affect their nitrogen and phosphorous loadings significantly. Effluent discharge however, would alter the flow characteristics of Badgerys Creek downstream of the airport from a highly variable regime with predominantly low flow to a perennial, medium flow situation. This is likely to double existing nitrogen levels and increase phosphorous by five times from current levels. The eutrophication of streams would potentially lead to changes in aquatic fauna to more tolerant forms, particularly if dissolved oxygen becomes limiting.

Aerial pollutants generated by aircraft emissions may also have impacts on water quality. Predicted levels of benzene for all Badgerys Creek airport options are 10 million times lower than ecosystem protection guidelines (ANZECC, 1992). Ecosystem guidelines are based on chronic and acute toxicity data for aquatic test organisms. Gases such as benzene do not accumulate over time. Polycyclic aromatic hydrocarbons were not able to be quantified but are not considered to be a major risk to natural waterways. However, the potential effects of accumulation are unknown.

Surrounding Wilderness and Conservation Areas

The declared Kanangra-Boyd and Nattai Wilderness Areas and the proposed Grose Valley Wilderness Area are located in the vicinity of Option A. A number of National Parks and reserves are found to the north, west and south-west of the Badgerys Creek options. The nearest ones include Blue Mountains National Park and Mulgoa Nature Reserve to the north-west and Bents Basin State Recreation Area, Gulguer State Recreation Area and Burragorong State Recreation Area to the west.

7.2 BADGERYS CREEK OPTION A

Impact assessment is based on the preliminary Master Plan for Badgerys Creek Option A (Second Sydney Airport Planners, 1997a).

7.2.1 CONSTRUCTION IMPACTS

Clearing of land proposed for airport development would begin soon after acquisition and fencing. Although some of the original vegetation may be retained, it is likely to be patchy in its distribution and highly disturbed from adjacent clearing activities. The result would be a complete loss of terrestrial and aquatic habitats from the airport option sites.

Vegetation Clearance

On the basis of the available information, Badgerys Creek Option A would require removal of 121 hectares of native vegetation (*Table 7.2*).

TABLE 7.2 MAXIMUM AREA OF EACH VEGETATION COMMUNITY/HABITAT TYPE DIRECTLY AFFECTED BY OPTION A

Vegetation community	Habitat Type	Area in Option A (hectares)
Grey Box Woodland (Altered)	Woodland Remnants	117
River-Flat Forest (Altered)	Melaleuca Woodland	4
Other	Grassland/dams/building	-
Total		**121**

Significant Flora Species

Development of Option A would result in the removal of at least one species of national significance and 33 species of regional significance. The impacts of the airport development on significant species are assessed in *Appendix A*.

Significant Vegetation Communities

On the basis of the available information, construction of Badgerys Creek Option A would not result in the removal of any significant vegetation communities.

Significant Fauna Species

One significant species, the Common Bent-wing Bat was recorded in Option A. However, the four habitat types represented within Option A provide habitat for a number of other significant species (*Table 7.1*). Three species of regional significance were recorded within or adjacent to the site of Option A. It is expected that additional significant species would be found there. The impacts of the airport development on significant species are assessed in *Appendix B*.

Loss of Habitat

Development of Option A would involve the complete removal of 121 hectares of habitat of high local significance. It is likely that most fauna would be lost from the site as a direct result of habitat clearing. Individuals occupying remnant habitat adjacent to the site may extend or relocate their home ranges; the probability of these individuals surviving is minimal based on the assumption that all suitable habitat in the area is already occupied. The final airport site is unlikely to support any native fauna species except for bird species which prefer highly landscaped garden-like settings. The creation of habitat areas is generally avoided in airport situations in order to reduce the risk of bird or bat strike (see *Technical Paper No. 10 - Hazards and Risks*).

Habitat Fragmentation/Barriers

The removal of approximately 121 hectares of native vegetation together with the erection of a 2.4 metre fence over most of the site is likely to form a movement barrier for fauna. It would also form a substantial barrier across the Badgerys Creek wildlife corridor of high local significance.

The Badgerys Creek site is already highly fragmented and existing riparian corridors probably act as movement corridors for a number of species, especially birds, bats and frogs. Mammals and reptiles are less likely to utilise the corridor because it lacks a well-developed understorey. Existing roads would be diverted or widened in order to accommodate increased construction traffic; no new corridors are planned. It is not known whether planned upgrading of roads would remove remnant roadside vegetation but the impact of fragmentation off-site is likely to be low.

Aquatic Impacts

Streams which would be affected by direct or indirect impacts associated with airport construction include Badgerys Creek, Oaky Creek, Cosgroves Creek, Duncans Creek and South Creek. As part of construction of Option A, Oaky Creek would be infilled or taken up with stormwater detention structures for over three kilometres and Cosgroves Creek would be similarly impacted over 1.8 kilometres (Second Sydney Airport Planners, 1997a). Duncans Creek is expected to have minimal impacts from construction of Option A. Stormwater would discharge to Badgerys, Cosgroves and Oaky Creeks.

Airport construction would involve substantial filling of gullies and complete removal of habitat and aquatic biota. Over the construction period, there is also a risk of finer sediments escaping detention during storm events and being transported into receiving streams and ultimately South Creek.

Aquatic Mammals and Amphibians

Aquatic impacts are likely to be high for amphibians on-site. Downstream impacts would be associated with habitat loss or degradation due to changes in microhabitats, prey distribution, and/or riparian and submerged vegetation communities.

Fish and Crayfish

In the short and medium term, it is likely that fish and crayfish within Cosgroves, Oaky and Badgerys Creeks (and their downstream trunk streams such as South Creek) will be subject to major impacts. These impacts are likely to persist in the long term. These would include changes in abundance and community composition of populations, elimination of some species, proliferation of pollution tolerant species and reduction in reproduction success. Duncans Creek is likely to suffer major impacts in the short and long term (see *Table 13, Appendix C*).

Noise and Lighting

Noise associated with the use of conventional earthmoving equipment is expected to occur over the construction period. The immediate effects of construction noises and associated stimuli would be to startle wildlife. The sporadic occurrence of sudden loud burst of noise and the general unpredictability and intensity of human activity would act to delay habituation. This could lead to an increase in stress levels and in greater distances travelled during the course of normal activities. As habitat in the area is likely to be patchy in its distribution, few native fauna are expected to occur adjacent to the airport site. It is therefore expected that the potential impact of construction noise on fauna would be low.

Lighting associated with security or nighttime construction activities is not likely to have a significant impact on fauna off-site. In fact bats and frogs may be attracted to insects drawn to lights. The impacts of lighting on fauna are expected to be low as there are few areas of fauna habitat off site.

Road Kills

Vehicular traffic associated with construction activities would increase substantially from that related to current land use. The impact of road kills on fauna is not expected to be high in the vicinity of Option A since few remnant habitat patches remain in the area and existing roads were constructed some time ago. However, there is the potential for an increase in road kills within the region; this would be related to the amount of forest located along roadways utilised by trucks travelling to and from the site and to the proportion of truck travel undertaken at night, dawn and dusk.

Weeds

Weeds are already predominant within the understoreys of forest vegetation at Badgerys Creek. This high level of weed cover is largely related to the small size of many vegetation remnants and their management history (primarily in terms of grazing). Weed invasion is therefore not a major management issue in relation to Badgerys Creek, although care should be taken not to further exacerbate existing weed problems.

Indirect effects of airport construction and maintenance on flora outside the development zone are difficult to predict, as future management of the remaining areas of native vegetation is not clear, particularly as much of the land at Badgerys Creek is in private ownership. In many cases on private land, there is a gradual, ongoing loss of vegetation extent and condition due to vegetation clearance, grazing, lack of regeneration, weed invasion and other disturbances associated with increasingly intensive land use. These ongoing impacts on vegetation are already major and, at any given site, may be more significant than the indirect effects of an adjacent airport.

Cumulative Impacts

Cumulative impacts are relevant to the assessment of Option A. Further clearing and fragmentation of native vegetation associated with the construction phase is likely to place native flora and fauna under increasing pressure to locate suitable habitat. However, indirect impacts would not be expected to have a significant impact because weeds and feral animals are already abundant within and around the site.

7.2.2 OPERATION IMPACTS

Operation impacts would be likely to be similar for all three options at Badgerys Creek.

Noise and Lighting

Noise impacts would be likely to be highest during the initial part of the construction phase and to decrease thereafter. Because noise associated with operation is likely to be more continuous and to have slower onset times, impacts on fauna would be likely to be low (refer *Technical Paper No. 3 - Noise*). Impacts of lighting on fauna are expected to be low (refer construction impacts).

Fire and Fire Management

The risk of fires at Badgerys Creek during the operational phase would be expected to be minimal due to regular mowing of grass aprons. The potential impacts of fire on native flora and fauna are not expected to change significantly with development of the airport options.

No differences in fire management hazard are expected for the three Badgerys Creek airport options. Fire management at Badgerys Creek would involve fuel management and grass maintenance. Loss of significant species due to fire management would be closely linked to changes in the existing fire regime in habitats surrounding the airport sites (refer *Technical Paper No. 10 - Hazards and Risks*).

Bird and Bat Strike

There are not expected to be any differences in the bird and bat strike hazards for the three Badgerys Creek airport options. As significant bird and bat species inhabiting the Badgerys Creek area generally do not occur in large flocks and are unlikely to undertake significant movements, it is assumed that individuals may be most at risk of bird strike. The effect of bird strike on local and regional populations is unknown. The diversity and abundance of species at risk of colliding with aircraft would be partly dependent on the management of stormwater and other potential habitat on-site (that is, landscaping) and off-site (for example, landfills) (refer *Technical Paper No. 10 - Hazards and Risks*).

Aquatic Impacts

Once the airport is operational, the streams within the site would form part of the drainage system and would no longer be part of the aquatic ecosystem. Changes in flow characteristics in Badgerys, Oaky and Cosgroves Creeks and eutrophication of Badgerys Creek and potentially South Creek, are likely to lead to changes in aquatic fauna. This is likely to have a high impact on amphibian species utilising these habitats.

Increased nutrient levels may alter downstream habitats through alterations to microhabitats, prey availability and plant communities.

Fish and crayfish

For all time frames, it is likely that fish and crayfish within Cosgroves, Oakey, Badgerys and Duncan Creeks (and their downstream trunk streams such as South Creek) would be subject to major impacts (see Construction Impacts). No impacts are predicted in Thompsons Creek and its tributaries and surrounding streams as they are not hydrologically connected to the airport site (see *Table A3.15, Appendix C*).

Fuel Discharges

The potential effects of aerial pollutants such as benzene and polycyclic aromatic hydrocarbons are considered to be nil. However, the potential effects of polycyclic aromatic hydrocarbon accumulation are unknown.

Surrounding Wilderness and Conservation Areas

Option A has a north-east to south-west runway alignment. Preliminary flight paths radiating to the north-west and to the south-west would therefore be likely to approach and/or take off over declared and proposed Wilderness Areas, Blue Mountains National Park, nature reserves and several State Recreation Areas. Previous research has shown that the behaviour and reproductive success of fauna inhabiting these natural areas are unlikely to be affected by overflights (see above).

7.3 BADGERYS CREEK OPTION B

Impact assessment is based on the preliminary Master Plan for Badgerys Creek Option B (Second Sydney Airport Planners, 1997a).

7.3.1 CONSTRUCTION IMPACTS

Vegetation Clearance

On the basis of the available information, Badgerys Creek Option B would require removal of 212 hectares of native vegetation (*Table 7.3*).

TABLE 7.3 MAXIMUM AREA OF EACH VEGETATION COMMUNITY/HABITAT TYPE DIRECTLY AFFECTED BY OPTION B.

Vegetation community	Habitat Type	Area in Option B (hectares)
Grey Box Woodland (Altered)	Woodland Remnants	198
River-Forest (Altered)	Melaleuca Woodland	14
Other	Grassland/dams/building	-
Total		**212**

Significant Flora Species

Development of Badgerys Creek Option B would result in the removal of one species of national significance and 34 species of regional significance. The impacts of the airport development on significant species are assessed in *Appendix A*.

Significant Vegetation Communities

On the basis of the available information, Badgerys Creek Option B would not result in the loss of any significant vegetation communities.

Significant Fauna Species

Two species of state significance, the Common Bent-wing Bat and the Eastern False Pipistrelle, were recorded in Option B. However, the four habitat types represented within Badgerys Creek Option B provide habitat for a number of other significant species (*Table 7.1*). Seven regionally significant species were recorded within or adjacent to Option B; it is expected that additional significant species are likely to occur there. The impacts of the airport development on significant species are assessed in *Appendix B*.

Loss of Habitat

Development of Option B would involve the complete removal of 212 hectares of habitat of high local significance. It is likely that most fauna would be lost from the site as a direct result of habitat clearing (see Badgerys Creek Option A).

Habitat Fragmentation/Barriers

Overall, the removal of approximately 212 hectares of native vegetation together with the erection of a 2.4 metre fence around most of the site is likely to form a movement barrier for fauna. It would also form a substantial barrier across the Badgerys Creek wildlife corridor of high local significance (see Badgerys Creek Option A).

Aquatic Impacts

Streams which would be affected by direct or indirect impacts associated with airport construction include Badgerys Creek, Oaky Creek, Cosgroves Creek, Duncans Creek and South Creek. As part of Option B, Badgerys Creek would be infilled or taken up with stormwater detention structures for over 5.4 kilometres, Oaky Creek would be similarly impacted over three kilometres and Cosgroves Creek would be impacted over 1.5 kilometres (*Second Sydney Airport Planners,* 1997a). Airport construction would involve substantial filling of gullies and complete removal of habitat and aquatic biota.

Over the construction period, there is also a risk of finer sediments escaping detention during storm events and being transported into receiving streams and ultimately South Creek. Because Option A is also likely to impact upon Duncans Creek, there is a high probability that sediment would be transferred to the Nepean River near Wallacia, increasing river turbidity and transferring attached pollutants. Dams, including the large storages on the headwaters of Duncans Creek and those at the junction of Badgerys Creek and South Creek could potentially receive sediment from construction of Badgerys Creek Option B.

Aquatic Mammals and Amphibians

The impact of construction on amphibian species would be likely to be as high as for Option A.

Fish and crayfish

In the short and medium term, it is likely that fish and crayfish in Cosgroves, Oakey, Badgerys and Duncans Creeks (and their downstream trunk streams such as South Creek) would be subject to very major impacts. Major impacts are likely to persist in the long term (as for Option A). Fish and crayfish within Thompsons Creek would be likely to be subject to minor impacts in the short and medium term (see *Table 15, Appendix C*).

Noise and Lighting

Because relatively small amounts of native vegetation and fauna habitats occur within the site of Badgerys Creek Option B, the impact of noise on fauna would be expected to be low. The potential impact of light would also be expected to be low.

Road Kills

The impact of increased traffic on existing fauna would be expected to be low adjacent to Badgerys Creek Option B but may increase in the region depending on the location of most frequently used travel routes for trucks and on the timing of travel (that is, overnight, dawn, dusk).

Weeds

Weeds are already predominant within the understoreys of forest vegetation at Badgerys Creek. This high level of weed cover is largely related to the small size of many vegetation remnants and their management history (primarily in terms of grazing). Weed invasion is therefore not a major management issue in relation to Option B, although care should be taken not to further exacerbate weed problems (as for Badgerys Creek Option A).

Cumulative Impacts

The impact of cumulative impacts is relevant to the assessment of Option B. Further clearing and fragmentation of native vegetation associated with the construction phase would be likely to place native flora and fauna under increasing pressure to locate suitable habitat. However, indirect impacts would not be expected to have a significant impact because weeds and feral animals are already abundant within and around the site (as for Option A).

7.3.2 OPERATION IMPACTS

Noise and Lighting

Noise impacts would be likely to be highest during the initial part of the construction phase and to decrease thereafter. Because noise associated with operation are likely to be more continuous and to have slower onset times, the potential impact on fauna is likely to be low. Potential impacts of lighting on fauna are similarly expected to be low (as for Option A).

Fire and Fire Management

The risk of fires at Badgerys Creek during the operational phase would be expected to be minimal due to regular mowing of grass aprons. The potential impacts of fire on native flora and fauna are not expected to change significantly with development of the airport options.

No differences in fire management hazard would be expected for the three Badgerys Creek airport options. Fire management at Badgerys Creek would involve fuel management and grass maintenance. Loss of significant species due to fire management would be closely linked to changes in the existing fire regime in habitats surrounding the airport sites (as for Option A).

Bird and Bat Strike

There are not expected to be any differences in the potential bird and bat strike hazards for the three airport Badgerys Creek options. As significant bird and bat species inhabiting the Badgerys Creek area generally do not occur in large flocks and are unlikely to undertake significant movements, it is assumed that individuals may be most at risk of bird strike. The effect of bird strike on local and regional populations is unknown. The diversity and abundance of species at risk of bird strike would be partly dependent on the management of stormwater and other potential habitat on site (as for Option A).

Aquatic Impacts

Once the airport is operational, the streams within the site would form part of the drainage system and would no longer be part of the aquatic ecosystem. Changes in flow characteristics in Badgerys, Oaky and Cosgroves Creeks and eutrophication of Badgerys Creek and potentially South Creek, would be likely to lead to changes in aquatic fauna. This would be likely to have a high impact on amphibian species utilising these habitats (as for Option A).

Fish and crayfish

For all time frames considered, it would be likely that fish and crayfish in Cosgroves, Oakey, Badgerys and Duncans Creeks would be subject to major impacts (see Option A). Potential minor impacts are likely in Thompsons Creek and its tributaries and no impacts are likely in surrounding streams as their hydrological connection to the airport option is limited (see *Table 16, Appendix C*).

Fuel Discharges

The potential effects of aerial pollutants such as benzene and polycyclic aromatic hydrocarbons are considered to be nil. However, the potential effects of polycyclic aromatic hydrocarbon accumulation are unknown.

Surrounding Wilderness and Conservation Areas

Badgerys Creek Option B has a north-east to south-west runway alignment. Air traffic would therefore be likely to approach and/or descend over the Nattai Wilderness Area and State Recreation Areas located to the south-west. However, noise impacts are likely to be minimal for flora and fauna.

7.4 BADGERYS CREEK OPTION C

Impact assessment is based on the preliminary Badgerys Creek Master Plan for Option C (Second Sydney Airport Planners, 1997a).

7.4.1 CONSTRUCTION IMPACTS

Vegetation Clearance

On the basis of the available information, Badgerys Creek Option C would require removal of 183 hectares of native vegetation (*Table 7.4*).

TABLE 7.4 MAXIMUM AREA OF EACH VEGETATION COMMUNITY/HABITAT TYPE DIRECTLY AFFECTED BY BADGERYS CREEK OPTION C

Vegetation community	Habitat Type	Area in Option C (hectares)
Grey Box Woodland (Altered)	Woodland Remnants	168
River-Forest (Altered)	Melaleuca Woodland	15
Other	Grassland/dams/building	-
Total		**183**

Significant Flora Species

Development of Badgerys Creek Option C would result in the removal of one species of national significance and 37 species of regional significance. The impacts of the airport development on significant species are assessed in *Appendix A*.

Significant Vegetation Communities

On the basis of the available information, Badgerys Creek Option C would not result in the loss of any significant vegetation communities.

Significant Fauna Species

Two species of state significance, the Common Bent-wing Bat and the Eastern False Pipistrelle, were recorded in Option C. However, the four habitat types represented within Option C provide habitat for a number of other significant species (*Table 7.1*). Five species of regional significance were recorded within or adjacent to Option C; it is expected that additional significant species occur there. The impacts of the airport development on significant species are assessed in *Appendix B*.

Loss of Habitat

Development of Option C would involve the complete removal of 183 hectares of habitat of high local significance. It would be likely that most fauna would be lost from the site as a direct result of habitat clearing (as for Option A).

Habitat Fragmentation/Barriers

Overall, the removal of approximately 183 hectares of native vegetation together with the erection of a 2.4 metre fence over most of the site would be likely to form a movement barrier for fauna. It would likely that most fauna would be lost from the site as a direct result of habitat clearing (as for Option A).

Aquatic Impacts

Streams which would be affected by direct or indirect impacts associated with airport construction include Badgerys Creek, Oaky Creek, Cosgroves Creek, Duncans Creek and South Creek. For construction of Option C, Badgerys Creek would be infilled or taken up with stormwater detention structures for over 5.7 kilometres and Oaky Creek would be similarly impacted over 3.9 kilometres (Second Sydney Airport Planners 1997a). Duncans Creek is likely to have minimal impact from Badgerys Creek Option C. Stormwater would be discharged to Badgerys Creek.

Airport construction would involve substantial filling of gullies and complete removal of habitat and aquatic biota. Over the construction period, there is also a risk of finer sediments escaping detention during storm events and being transported into receiving streams and ultimately South Creek.

Aquatic Mammals and Amphibians

The impact of construction on amphibian species would be likely to be high (as for Option A).

Fish and Crayfish

In the short and medium term, it is likely that fish and crayfish in Cosgroves, Oaky, Badgerys, Duncans and Thompsons Creeks (and their downstream trunk streams such as South Creek) would be subject to very major impacts (as for Option A). Major impacts are likely to persist in the long term in Oaky, Badgerys and Thompsons Creeks. Fish and crayfish in Cosgroves and Duncans Creeks would be likely to be subject to minor impacts in the long term (see *Table 17, Appendix C*).

Aerial Pollutants

The potential effects of aerial pollutants such as benzene and polycyclic aromatic hydrocarbons are considered to be nil. However, the potential effects of polycyclic aromatic hydrocarbon accumulation are unknown (as for Option A).

Noise and Lighting

As habitat in the area is likely to be patchy in its distribution, few native fauna are expected to occur adjacent to the airport site, the impacts of noise and light are expected to be low (as for Option A).

Road Kills

The impact of increased traffic would be expected to be low adjacent to Badgerys Creek Option C but may increase in the region depending on the location of most frequently used travel routes for trucks and on the timing of travel (that is, overnight, dawn, dusk).

Weeds

Weeds are already predominant within the understoreys of forest vegetation at Badgerys Creek. This high level of weed cover is largely related to the small size of many vegetation remnants and their management history (primarily in terms of grazing). Weed invasion is therefore not a major management issue in relation to Badgerys Creek Option C, although care should be taken not to further exacerbate weed problems.

Cumulative Impacts

The impact of cumulative impacts is relevant to the assessment of Badgerys Creek Option C. Further clearing and fragmentation of native vegetation associated with the construction phase would be likely to place native flora and fauna under increasing pressure to locate suitable habitat. However, indirect impacts would not be expected to have a significant impact because weeds and feral animals are already abundant within and around the site.

7.4.2 OPERATION IMPACTS

Noise and Lighting

Noise impacts are likely to be highest during the initial part of the construction phase and to decrease thereafter. Noise associated with operation would be likely to be more continuous and to have slower onset times, and subsequent impact on fauna would be likely to be low. Impacts of lighting on fauna would be similarly expected to be low (as for Option A).

Fire and Fire Management

The risk of fires at Badgerys Creek during the operational phase would be expected to be minimal due to regular mowing of grass aprons. The potential impacts of fire on native flora and fauna are not expected to change significantly with development of the airport options.

No differences in fire management hazard would be expected for the three Badgerys Creek airport options. Fire management at Badgerys Creek would involve fuel management and grass maintenance. Loss of significant species due to fire management would be closely linked to changes in the existing fire regime in habitats surrounding the airport sites (as for Option A).

Bird and Bat Strike

There are not expected to be any differences in the potential bird and bat strike hazards for the three Badgerys Creek airport options. As significant bird and bat species inhabiting the Badgerys Creek area generally do not occur in large flocks and are unlikely to undertake significant movements, it is assumed that individuals may be most at risk of bird strike. The effect of bird strike on local and regional populations is unknown. The diversity and abundance of species at risk of bird strike would be partly dependent on the management of stormwater and other potential habitat on site (as for Option A).

Aquatic Impacts

Once the airport is operational, the streams within the site would form part of the drainage system and would no longer be part of the aquatic ecosystem. Changes in flow characteristics in Badgerys Creek and eutrophication of Badgerys Creek and potentially South Creek, would be likely to lead to changes in aquatic fauna. This would be likely to have a high impact on amphibian species utilising these downstream habitats (as for Option A).

Fish and Crayfish

For all time frames, it would be likely that Oakey, Badgerys and Thompsons Creeks (and their downstream trunk streams such as South Creek) would be subject to major impacts (as for Option A). Potential minor impacts are likely in Cosgroves Creek and Thompsons Creeks and their tributaries. No impacts are likely for surrounding streams as they have no hydrological connection to the airport site (see *Table 18, Appendix C*).

Aerial Pollutants

The potential effects of aerial pollutants such as benzene and polycyclic aromatic hydrocarbons are considered to be nil. However, the potential effects of polycyclic aromatic hydrocarbons accumulation are unknown (as for Option A).

Surrounding Wilderness and Conservation Areas

Badgerys Creek Option C has east-west and north-south runway alignments. Preliminary flight paths radiating to the north-west, south-west and to the west would therefore be likely to approach and/or take off over declared and proposed Wilderness Areas, Blue Mountains National Park, nature reserves and several State Recreation Areas. The behaviour and reproductive success of fauna within these natural areas are unlikely to be affected by noise.

Under normal (non-emergency) situations, the impacts of fuel dumping are likely to be nil to low over conservation reserves.

CHAPTER 8 IMPACTS OF HOLSWORTHY OPTIONS

This section comprises an impact assessment of the proposal, within the Holsworthy Military Area. Impact assessment concentrates on the five airport options but also briefly considers issues associated with preliminary transport corridor options. The routes are indicative only and are subject to separate EIS assessments.

8.1 OVERALL IMPACTS OF HOLSWORTHY OPTIONS

Impact assessment is based on preliminary master plans prepared by Second Sydney Airport Planners, (1997a).

8.1.1 VEGETATION CLEARANCE

Construction of the Holsworthy airport options would result in the removal of between 2,800 and 4,200 hectares of vegetation (depending on the option selected). As the sites of both Holsworthy options are covered by predominantly native forest vegetation, site clearance would involve extensive tree felling and removal. Vegetation clearance would be associated with the following activities: construction of the airport and its associated infrastructure; realignment of roads; construction of temporary and permanent roads, utility corridors and detention ponds; construction of temporary and permanent detention basins; filling in of gullies; and stream diversion. Most existing roads would require some rerouting; additional temporary roads would be required to separate military traffic from construction traffic. Most vegetation within the preferred option would be cleared, although areas not included in earthworks could be retained where possible.

Additional off-site clearing associated with obstacle clearance works is estimated to impact on between 90 and 150 hectares. These areas were not surveyed and have not been assessed.

8.1.2 HABITAT LOSS

The six habitat types described for the Holsworthy options provide resources for at least 52 significant fauna species; additional significant species were recorded in the vicinity of Holsworthy Military Area and may occur within the Holsworthy options. The Holsworthy Military Area also contains habitat for 89 significant plant species. The potential impact of airport construction on habitat types is assessed below for each option; impacts on particular species are described in *Appendix A* and *B*.

TABLE 8.1 SIGNIFICANT (NATIONAL AND STATE) FLORA AND FAUNA SPECIES RECORDED FROM OR LIKELY TO OCCUR WITHIN HABITATS/COMMUNITIES IDENTIFIED AT HOLSWORTHY MILITARY AREA

Fauna Habitat	Vegetation Community	Rare Fauna Species	Rare Plant Species
Grassy Forest	Grey Box Ironbark Woodland/HOLS 1 Shale/sandstone Forest/HOLS 2	Regent Honeyeater Swift Parrot Giant Burrowing Frog Red-crowned Toadlet Bush Stone-curlew Black Bittern Glossy Black-Cockatoo Turquoise Parrot Painted Honeyeater Squirrel Glider Koala Eastern Little Mastiff Bat Greater Broad-nosed Bat Yellow-bellied Sheathtail Bat Eastern Cave Bat	*Pultanea parviflora* *Grevillea longifolia* *Tetratheca neglecta* *Persoonia nutans* *Allocasuarina glareicola* *Pterostylis* (sp.E) *Eucalyptus multicaulis* *Eucalyptus squamosa*
Woodland/ heath complex	Sydney Sandstone Ridgetop Woodland/HOLS 3	Broad-headed Snake Brush-tailed Rock Wallaby Regent Honeyeater Red-crowned Toadlet Glossy Black-Cockatoo Turquoise Parrot Giant Burrowing Frog Heath Monitor Powerful Owl Masked Owl Painted Honeyeater Tiger Quoll Yellow-bellied Glider Squirrel Glider Koala Yellow-bellied Sheathtail Bat Large-footed Myotis Common Bentwing Bat Eastern Little Mastiff Bat Eastern False Pipistrelle Large Pied Bat Eastern Cave Bat	*Eucalyptus luehmanniana* *Leucopogon exolasius* *Melaleuca deanei* *Tetratheca neglecta* *Monotoca ledifolia* *Eucalyptus ligustrina* *Eucalyptus multicaulis* *Grevillea diffusa* (var.) *diffusa* *Tetratheca shiressii*
Heath/swamp complex	Sydney Sandstone Ridgetop Woodland/HOLS 3	Red-crowned Toadlet Heath Monitor Giant Burrowing Frog	*Eucalyptus luehmanniana* *Leucopogon exolasius* *Melaleuca deanei* *Tetratheca neglecta* *Monotoca ledifolia* *Eucalyptus ligustrina* *Eucalyptus multicaulis* *Grevillea diffusa* (var.) *diffusa* *Tetratheca shiressii*

TABLE 8.1 CONTINUED

Fauna Habitat	Vegetation Community	Rare Fauna Species	Rare Plant Species
Sedgelands	Woronora Plateau Upland Swamp/ HOLS 4	Australasian Bittern Black Bittern Green and Golden Bell Frog	*Pultenaea aristata* *Darwinia diminuta* *Darwinia grandiflora* *Eucalyptus luehmanniana*
Gully Forest	Sydney Sandstone Gully Forest/HOLS 5	Broad-headed Snake Heath Monitor Brush-tailed Rock Wallaby Regent Honeyeater Giant Burrowing Frog Glossy Black-Cockatoo Powerful Owl Sooty Owl Masked Owl Painted Honeyeater Tiger Quoll Yellow-bellied Glider Squirrel Glider Koala Long-nosed Potoroo Yellow-bellied Sheathtail Bat Eastern Little Mastiff Bat Greater Broadnosed Bat Eastern False Pipistrelle Large-footed Myotis Common Bentwing Bat Large Pied Bat Eastern Cave Bat	*Grevillea longifolia* *Hibbertia nitida* *Pterostylis* (sp.E) *Hakea salicifolia* (narrow-leaf form) *Leucopogon amplexicaulis* *Persoonia mollis* (subsp nectens) *Westringia longifolia* *Leucopogon exolasius*
Paperbark Woodland	River-Flat Forest/ HOLS 7 Riparian Scrub/ HOLS 6	Green and Golden Bell Frog Australasian Bittern Black Bittern Glossy Black-Cockatoo Greater Broadnosed Bat Large-footed Myotis Common Bentwing Bat Large Pied Bat Eastern Cave Bat	*Lomandra fluviatilis* *Eucalyptus baueriana* *Hakea salicifolia* (narrow-leaf form) *Westringia longifolia*

Grassy Forest

Grassy Forest (Cumberland Plain Woodland) has been largely cleared to produce a rural landscape with patches of remnant forest habitat; the Holsworthy Military Area may contain one of the largest remaining patches in western Sydney (M. Peterson, Department of Defence *pers. comm.*). It is listed as an Endangered Ecological Community on Part 3, Schedule 1 of the *Threatened Species Conservation Act, 1995*. It is therefore a vegetation community of state significance. Because of its simplified structure and lack of fallen timber, it is considered to be a habitat of high regional significance. It comprises 2,230 hectares of the site.

Grassy Forest provides habitat for at least 15 fauna species of National and State significance and eight flora species of National and State significance (see *Table 8.1*). Many of the fauna species typical of the Cumberland Plain, in particular passerine bird species, have declined markedly in the recent past probably due to clearing and fragmentation of this habitat type. Further loss and/or fragmentation of this habitat is likely to affect the regional distribution of some of the species.

Woodland/Heath Complex

Woodland/heath complex covers approximately 8,742 hectares of the Holsworthy Military Area. This habitat is largely intact throughout the area; it is less degraded than other habitats due to its shallow infertile soils and rugged topography. Although the distribution of Woodland/heath Complex in the bioregion is likely to be extensive, its proximity to the Sydney metropolitan area is also taken into account in assessing its significance. It is considered to be a habitat of regional significance as:

- its vegetation communities are of moderate to high condition;
- it has relatively few weeds and feral animals;
- it may provide strongholds for the Broad-headed Snake, Red-crowned Toadlet, Giant Burrowing Frog and possibly other species in the Sydney region; and
- it is relatively unfragmented and therefore contributes to an extensive wildlife corridor.

The woodland/heath complex provides habitat for at least 22 fauna species of National and State significance and nine flora species of National and State significance (see *Table 8.1*). This habitat provides critical resources for a wide diversity of fauna species at the Holsworthy Military Area. Furthermore, it forms a significant part of an extensive corridor linking Holsworthy to O'Hares Creek Catchment, Woronora Catchment and Heathcote and Royal National Parks. Rocky outcrops would be used by a number of significant bat species which roost in rock fissures, cavities or sandstone overhangs (for example, Large Pied Bat, Eastern Cave Bat, Common Bent-wing Bat, Large-footed Myotis).

Heath/Swamp Complex

Heath/swamp Complex covers a small proportion of the Holsworthy Military Area. This habitat type is confined to shallow depressions at the head of drainage lines and is treeless. This habitat type is in good condition and is restricted in the bioregion and within Holsworthy Military Area; it is therefore considered to be of regional significance.

Heath/swamp Complex provides habitat for at least three fauna species of State significance and nine flora species of National and State significance (see *Table 8.1*). Heathy habitats are restricted in their distribution in the Sydney region. These habitats are of particular importance to significant species which are dependent on heathland and sedgeland habitats such as the Eastern Bristlebird, Ground Parrot and New Holland Mouse.

Sedgeland

Sedgelands also cover a small proportion of the Holsworthy Military Area (approximately 50 hectares). This habitat type is generally found on seepage slopes above drainage lines in the southern half of the study site. It is dominated by low sparse ground cover and is treeless. This habitat type is in generally good condition and is restricted in its distribution within the bioregion and within Holsworthy Military Area; it is therefore considered to be of regional significance.

Sedgeland provides habitat for at least three fauna species of State significance and four flora species of National significance (see *Table 8.1*). Sedgeland has a restricted distribution in the Sydney region. It is of particular importance to species which are dependent on heathland and sedgeland habitats such as the Eastern Bristlebird and the Ground Parrot.

Gully Forest

Gully forest covers a large proportion of the Holsworthy Military Area (6,739 hectares). It provides habitat for the greatest diversity of mammal and reptile fauna on the site. This habitat type provides a diversity of habitats for fauna including tall mature trees, a well-developed canopy and mid-storey layer of vegetation and a complex ground layer including fallen logs and leaf litter. Although the distribution of Gully Forest in the bioregion is likely to be extensive, its proximity to the Sydney metropolitan area is also taken into account in assessing its significance. It is considered to be a habitat of regional significance as:

- its vegetation communities are of high condition;
- it has relatively few weeds and feral animals;
- it may provide a stronghold for Critical Weight Range species, arboreal mammals, Tiger Quolls, Platypus and Rockwarblers in the Sydney region;

- it contains most of the old-growth and therefore provides the highest density of nesting, roosting and feeding resources within Holsworthy Military Area; and

- it provides important movement corridors for a high diversity of species.

Gully Forest provides habitat for at least 23 fauna species of National and State significance and eight flora species of National and State significance (see *Table 8.1*). Gully Forest together with adjacent sandstone outcrops is of particular importance to species such as the Broad-headed Snake and Brush-tailed Rock-wallaby and to species which are restricted to the Sydney region (that is, Lesueur's Gecko) and species which are found in greatest numbers there (that is, Diamond Python).

Paperbark Woodland

Paperbark Woodland is only found in the north-eastern part of the Holsworthy Military Area and together with River-Flat Forest occupies approximately 85 hectares. This habitat is found along drainage lines which are seasonally waterlogged. This habitat is in good condition and is restricted within the bioregion and within Holsworthy Military Area; it is therefore considered to be of regional significance. Paperbark Woodland provides habitat for four flora species of National significance and at least nine fauna species of State significance (see *Table 8.1*).

Wildlife Corridor Values

The Holsworthy Military Area is considered to be the northernmost part of an extensive wildlife corridor extending south-eastwards through to the Woronora Catchment, Heathcote National Park and Royal National Park and southwards to O'Hares Creek Catchment, Wedderburn and the Metropolitan Catchments. The relatively good condition of vegetation communities and habitats together with high connectivity make it a corridor of high regional significance.

8.1.3 HABITAT FRAGMENTATION/BARRIERS

The Holsworthy Military Area is an extensive, largely intact tract of forest and other sandstone vegetation communities. Existing habitat would be substantially fragmented by clearing for construction of an airport and associated infrastructure. Habitat fragmentation would also be associated with roads, railways, pipelines, powerlines, communication lines, temporary storage dams and stream diversions. Movement barriers would be associated with clearing and fencing of the preferred site and with newly-constructed roads and utility easements off-site. The airport site would be surrounded by security perimeter fencing 2.4 metres high with outward facing barbed wire at the top (Second Sydney Airport Planners, 1997). Both sides of the fence would be cleared with a perimeter roadway located on the inside. This would pose a considerable barrier for most terrestrial and arboreal fauna groups.

8.1.4 AQUATIC IMPACTS

Aquatic impacts both on and off-site would be associated with clearing, excavation, filling in gullies, stockpiling topsoil, stream diversions, stormwater events, pollution and sewerage release. There is also the slight risk of fuel spills although there is a high level of confidence in the effectiveness of fuel containment. Creek diversions would involve the construction of temporary creek excavations before final release of waters into permanent stormwater drainage facilities. Williams Creek, Harris Creek, Deadmans Creek, Wappa Creek and tributaries of O'Hares Creek would be partly infilled by airport construction.

8.1.5 NOISE AND LIGHTING

The effects of noise and lighting are associated with airport construction and operation. During construction, noise is associated with blasting, drilling, heavy machinery (dozers, scrapers, excavators, compactors, graders), vehicular traffic, batching plants, generators and other human activity.

Blasting already occurs at the Holsworthy Military Areas as part of military activities but is primarily restricted to Demolition Areas 1 and 2. Information on blasting conducted during 1996 was supplied by M. Peterson (Environmental Officer, Department of Defence *pers. comm.*). Demolitions were carried out by the Navy at Demolition Area 1 over 40 days; each demolition was restricted to 4.5 kilograms and the number conducted each day varied. Demolition Area 2 was used to conduct 30 demolitions; each demolition was restricted to 25 kilograms and the number conducted each day varied between one and four. Noise is presently associated with military activities conducted at the Small Arms Firing Range and at Demolition Areas 1 and 2. However, noise associated with airport construction would be generated over a much larger area and would be more consistent over time.

For comparative purposes, the removal of 50,000 cubic metres of rock at Holsworthy would require 10,000 to 15,000 kilograms of explosives comprising 20 to 30 blasts using 500 kilograms each (Second Sydney Airport Planners, 1997a). Blasting and drilling are likely to cause significant noise and vibration in the local area. It is likely that drilling would be undertaken 24 hours/day and that blasting would occur at dawn and dusk at a minimum of two blasts per day at each of four locations.

Lighting is required for security and during times when night construction activities are anticipated. Although most construction activities would be likely to take place between 0700 and 1700 hours, six days per week, those associated with concrete production, excavation, trench dewatering and concrete placements could occur over 24-hour periods. Approximately 35 percent of construction work would be expected to occur at night (Second Sydney Airport Planners, 1997a).

8.1.6 TRAFFIC

Traffic would increase considerably during the construction phase of the project. Traffic would be expected to arrive mainly from the north (Second Sydney Airport Planners, 1997a). Truck movements would be expected to occur at all times of the day and night, including dawn and dusk. Deliveries of pavement materials are expected to be made at night; deliveries of construction materials would be likely to occur in the afternoons and early evenings. Dust is likely to be a problem, especially in summer. Increased traffic would be associated with:

- workers' vehicles entering and leaving the site each day;
- transfer of solid and putrescible wastes from the site to the existing landfill at Lucas Heights or another Environment Protection Authority approved site;
- sewage transfer from site to the Glenfield or Liverpool sewage treatment plant;
- delivery of asphalt by tipper trucks from western Sydney plants;
- fuel tanker loads over the construction period;
- delivery of pavement materials from Glenfield, Camden, Port Kembla, Kiama, Shellharbour, Penrith Lakes, Kurnell, Kandos, Portland and Prospect;
- delivery of fly-ash from power stations;
- delivery of pipes from Rooty Hill, Emu Plains, Port Kembla;
- delivery of building materials; and
- delivery of explosive materials, primers and boosters or detonator cords.

8.1.7 AIRPORT OPERATION

Noise and Lighting

Noise levels would be consistent with Air Traffic Forecasts 1, 2 or 3 levels as described in *Chapter 1*. It has not been decided if a curfew would apply to the new airport (that is, whether aircraft noise would continue throughout the night).

Fire and Fire Management

The Holsworthy Military Area has a history of regular fires, due mainly to accidental causes and to military activities. AXIS/Australian Museum Business Services (1995) reported that the fire frequency is higher than considered optimal for native flora and fauna based on the following indicators:

- a high abundance of fire-adapted species;
- absence of shrubby under-storey and its replacement by grasses in Plateau Forest (Cumberland Plain Woodland);
- low abundance of hollow-bearing trees;
- low abundance of branches and logs on the ground; and
- recent declines in a number of bird species.

The authors concluded that high fire frequency was due to the following: high rates of fire initiation by the military, high rates of arson and accidental fires, limited knowledge of optimal fire regimes for flora and fauna and logistical details involved in fighting fires. Current policy on fire management involves immediate suppression followed by monitoring; fires generally run down into gullies and eventually burn out (M. Peterson, Environmental Officer, Department of Defence *pers. comm.)*.

Fire management at Holsworthy has been discussed in detail in *Technical Paper No. 10 - Hazards and Risks*. In summary, Holsworthy would require significant fire management in the short and long term. The report indicates that a total extinguishment policy on most fires would be required to manage fire and smoke during the operation of the airport.

Total extinguishment would primarily involve helicopters for aerial fire control. Ground troops would be supplementary as access would be limited by terrain and unexploded ordnance. The extinguishment of fires by ground troops would also require the establishment of a superior fire trail network in areas surrounding the airport sites. This would involve clearing and maintenance works and contribute to habitat loss, barrier effects and fragmentation. The report recognises that fuel management at Holsworthy would require preparation of detailed fire management plans.

It is expected that fire frequency within Holsworthy would decrease as a result of the cessation of military activities, in particular firing, shelling and demolition. However, the frequency of fire associated with arson and accidental causes would be expected to increase from present levels due to human activity in and around the airport site. Logistical problems associated with fire fighting may be partly overcome by the use of aerial fire suppression techniques but will persist on the ground unless the existing fire trail system is extended and improved. Effective suppression of the majority of fires around the airport site would be likely to result in the regeneration of vegetation communities within the Holsworthy area; increased fuel levels (shrubby vegetation, fallen logs) may also increase the risk of major wildfires.

Bird and Bat Strike

This issue has been covered in detail in *Technical Paper No. 10 - Hazards and Risks*. In summary, birds occurring at Holsworthy are most likely to be forest-dwelling species; no defined regular significant movements are known for birds or bats. Bird and bat groups most at risk of colliding with aircraft include cockatoos, fruit bats, raptors and forest-dwelling species. The occurrence of waterbirds most at risk of colliding with aircraft would be related to stormwater management on-site.

Aquatic Impacts

Water quality issues are covered in *Technical Paper No. 7 - Geology, Soils and Water*. During airport operation, treated stormwater would be discharged into Williams, Harris and Punchbowl Creeks (depending on the option selected). The discharge of treated stormwater would be expected to result in a sevenfold increase in the phosphorous loads and a doubling of the nitrogen exports. The proposed discharge point for effluent is immediately downstream of Punchbowl Creek.

The impact of effluent on aquatic ecosystems would be to increase phosphorous loadings by 200 percent and to increase algal or plant productivity. This would be likely to alter or remove stream microhabitats, aquatic invertebrate diversity and abundance and riparian vegetation which would impact directly on populations of fish, amphibians and aquatic mammals in these streams.

Each airport option layout has been developed with several major subcatchments, each discharging to a stormwater detention pond. The proposed arrangement is a wet extended detention pond that would provide a large temporary water body which would potentially attract water birds. A potential impact of creating such ponds is the increased likelihood of bird strike associated with increased numbers of birds in the airport environs.

Aerial Pollutants

Aerial pollutants generated by aircraft emissions may also have impacts on water quality. This is discussed in *Technical Paper No. 7 - Water.* Predicted levels of benzene for Holsworthy airport options are more than one million times lower than ecosystem protection guidelines (Australia and New Zealand Environment Conservation Council 1992). Ecosystem guidelines are based on chronic and acute toxicity data for aquatic test organisms. Gases such as benzene do not accumulate over time. Polycyclic aromatic hydrocarbons were not able to be quantified but are not considered to be a major risk to natural waterways. However, the potential effects of accumulation are unknown.

Surrounding Wilderness and Conservation Areas

Although no formal wilderness assessment has been undertaken within the Holsworthy Military Area, it does contain areas of moderate (10,350 hectares) to high (625 hectares) wilderness quality (A Cox, Wilderness Conservation Unit, National Parks and Wildlife Service *pers. comm.).* A more detailed assessment would be required before these areas could be considered as wilderness areas.

The Holsworthy Military Area is surrounded by a number of National Parks and Reserves. The Woronora Plateau has been proposed as part of a World Heritage site (James 1994). O'Hares Creek Catchment is listed on the Register of the National Estate and is located adjacent to the southern boundary of the Holsworthy Military Area. Voyager Point has been nominated for listing on the Register of the National Estate and is located to the north-east of the Holsworthy Military Area. Georges River National Park is also located to the north-east while Heathcote and Royal National Parks are located to the south-east. Dharawal State Recreation Area covers part of O'Hares Creek Catchment. The upper reaches of the O'Hares Creek are listed in the Directory of Important Wetlands (Australian Nature Conservation Agency 1996). There is also a proposal to make the Wedderburn area into a Nature Reserve.

8.2 HOLSWORTHY OPTION A

Impact assessment is based on the preliminary Master Plan for Holsworthy Option A (Second Sydney Airport Planners, 1997a).

8.2.1 CONSTRUCTION IMPACTS

It should be noted that in general, clearing of land proposed for airport development would begin soon after acquisition and fencing. For the Holsworthy options, unexploded ordnance removal and vegetation removal would be undertaken simultaneously. Although some of the original vegetation may be retained, it is likely to be patchy in its distribution and highly disturbed from adjacent clearing activities. The result would be a complete loss of terrestrial and aquatic habitats from the airport option site.

Vegetation Clearance

On the basis of the available information, Holsworthy Option A would require removal of approximately 4,200 hectares of native vegetation (*Table 8.2*). In addition, 90 hectares would be cleared off-site (Woronora catchment) as part of the obstacle limitation works.

TABLE 8.2 MAXIMUM AREA OF EACH VEGETATION COMMUNITY/HABITAT TYPE DIRECTLY AFFECTED BY HOLSWORTHY OPTION A

Vegetation community	Habitat type	Area in Option A (hectares)
Grey Box Ironbark Woodland	Grassy Forest	304
Shale Sandstone Forest	Grassy Forest	4
Sydney Sandstone Ridgetop Woodland	Woodland/heath Complex	2,340
Woronora Plateau Upland Swamp	Sedgeland	15
Sydney Sandstone Gully Forest	Gully Forest	1,454
Paperbark Woodland	Riparian Scrub	4
Total		**4,121**

Significant Flora Species

Development of Holsworthy Option A would result in the loss of at least 10 species of National significance, one species of State significance and 12 species of regional significance. The potential impacts of the airport development on significant species are assessed in *Appendix A*.

Loss of and disturbance to the northern portion of the Woronora catchment may result in the removal (directly or indirectly) of additional rare flora species.

Significant Vegetation Communities

On the basis of the available information, Holsworthy Option A would result in the loss of 308 hectares of Cumberland Plain Woodland (comprising Grey Box Iron Bark Woodland and Shale/Sandstone Forests), a vegetation community of State significance. It would also result in the removal of five other vegetation communities of regional significance (*Table 8.2*). A significant stand of Grey Box Ironbark Woodland, one of the largest remnants in the state to the north of the site of Holsworthy Option A, would be mostly retained but could be transected by an access corridor.

There would also be a loss of approximately 89 hectares of native vegetation off-site (Woronora Catchment). This area was not surveyed or assessed as part of the present study. This land is contained within a Sydney Water Special Area; activities on this land are strictly controlled with the aim of maintaining the water quality within the catchment.

Significant Fauna Species

Four species of State significance have been recorded within Holsworthy Option A: the Giant Burrowing Frog, Red-crowned Toadlet, Eastern False Pipistrelle and Yellow-bellied Sheathtail Bat. A koala was also recorded within 250 metres of the site of Holsworthy Option A. However, the five habitat types represented within the site of Option A provide habitat for a number of other significant species (*Table 8.1*). Fourteen species of regional significance were recorded within or adjacent to Holsworthy Option A; more are likely to be found there. The impacts of the airport development on significant species is assessed in *Appendix B*.

Loss of Habitat

The site of Holsworthy Option A contains approximately 308 hectares of habitat of high regional significance and approximately 3,812 hectares of habitat of regional significance. No River-Flat Forest would be removed as part of the development. There would also be a loss of approximately 89 hectares of habitat off-site (Woronora Catchment) as part of obstacle limitation works; this area was not surveyed or assessed as part of the present study.

During construction, it is likely that most fauna would be lost from the site as a direct result of habitat clearing and unexploded ordnance removal. Those individuals near the perimeter of the site may extend or relocate their home ranges outside the site; the probability of these individuals surviving is minimal based on the assumption that all suitable habitat within the area is already occupied. The final airport site would be unlikely to support any native fauna species except for bird species which prefer highly landscaped garden-like settings. The creation of habitat areas is generally avoided in airport layouts in order to reduce the risk of bird or bat strike (see *Technical Paper No. 10 - Hazards and Risks*).

Habitat Fragmentation/Barriers

The removal of over 4,000 hectares of native vegetation together with the erection of a 2.4 metre high fence over most of the site would pose a significant barrier to fauna movement within the Holsworthy Military Area.

Holsworthy Option A essentially isolates the northern and southern parts of the Holsworthy Military Area, leaving only narrow connecting corridors to the east and west. The corridor to the east would be less than 500 metres wide at its narrowest point and would be bordered on its eastern side by Heathcote Road. It would potentially be transected by the eastern access corridor option (see *Section 8.2.3*). To the west, the retained corridor would be confined to the area bounded by the airport perimeter and the Georges River; it would potentially be transected by the proposed western access corridor option (see *Section 8.2.3*). The Holsworthy site to the north of the airport development would be further fragmented if the proposed northern access corridor was selected (see *Section 8.2.3*). Narrow corridors and relatively small habitat fragments (including the northern section of Holsworthy) would become highly susceptible to weed invasion and other indirect impacts, thereby reducing their value to native fauna.

Construction of Holsworthy Option A would also create a significant barrier between the northern part of the Holsworthy Military Area and the Woronora catchment, Heathcote National Park and Royal National Park, an extensive vegetated corridor which is considered to be of high regional significance. Species most likely to be affected are those dependent on Gully Forest, Critical Weight Range species, aquatic species, species with limited mobility and species occurring at low densities or in patchy distributions. Apart from restricting normal fauna movement patterns and flora dispersal, a major barrier would restrict the availability of escape routes for fauna in case of either bushfires or other natural or artificial disasters. It would also restrict or even prevent recolonisation of regenerating habitats (that is, post-fire).

Aquatic Impacts

Streams which would be actually affected by direct or indirect impacts associated with airport construction include: Harris Creek, Punchbowl Creek, Dingo Creek, Williams Creek, Deadmans Creek, Lyretail Creek, Wappa Creek, Lake Woronora catchment and Gunyah Creek. Of these, the following would be infilled or affected by stormwater detention structures for part of their length: Harris Creek, Punchbowl Creek, Dingo Creek, Williams Creek, Deadmans Creek and Wappa Creek. At the time of writing, particular creeks to be dammed have not been specified. Airport construction would involve substantial filling of gullies and complete removal of habitat and aquatic biota. Over the construction period, there would also be a risk of finer sediments escaping detention during storm events and being transported into streams, rivers and reservoirs. Any increase in the sediment load and associated pollutants would be expected to have a large impact on stream water quality and ecology over the entire length of the streams, to their confluence with the Georges River and for a high proportion of the Woronora River.

Aquatic Mammals and Amphibians

Significant species have been recorded in streams potentially impacted by development. Platypus are known to occur in Punchbowl, Williams and Deadmans Creeks. The Water Rat possibly occurs in Punchbowl Creek. The Giant Burrowing Frog is found in Gunyah, Punchbowl and Harris Creeks and in the Woronora River. The Red-crowned Toadlet was recorded from Punchbowl and Lyrebird Creeks.

Construction of Holsworthy Option A would result in the removal of habitat for these species within the airport site and would be likely to alter downstream habitats, thus affecting the distribution and abundance of aquatic invertebrate and vertebrate prey. The diversity of habitats available would be likely to decline and lead to changes in stream and riparian zone flora and fauna. Aquatic impacts associated with construction would therefore be likely to be high within the site and downstream of it. Removal of aquatic habitat would be likely to affect the regional distributions of aquatic mammals, the Giant Burrowing Frog and the Red-crowned Toadlet.

Fish and Crayfish

In the short and medium term, it is likely that fish and crayfish in Harris and Williams Creeks (and their downstream trunk streams) would be subject to severe impacts. These would include elimination of a high proportion of native fish and crayfish taxa and cessation of reproduction. Major to very major impacts would be likely to persist in the long term. It is likely that fish and crayfish in Deadmans, Lyretail, Wappa, Kalibucca and Punchbowl Creeks (and their downstream trunk streams such as the Georges River and the Woronora River) would be likely to be subject to very major impacts in the short and medium term. Major impacts would be likely to persist in these streams in the long term. No assessment was undertaken for four other sets of streams: Complete Creek, Wallaby Creek, miscellaneous lower Woronora River tributaries and miscellaneous Woronora Reservoir feeder streams. It is predicted that minor impacts would occur in these streams (see *Table 19, Appendix C*).

Road Kills

Vehicular traffic associated with construction activities would increase substantially from that related to current land use. The probability of road kills would therefore be expected to increase significantly within Holsworthy Option A for nocturnal species; in particular, arboreal mammals, large herbivorous mammals, small terrestrial mammals and frogs are likely to be negatively affected. Similarly, the impact of road kills associated with the proposed access corridors for Option A are likely to be high because they would create substantial barriers within the Holsworthy Military Area. Issues associated with proposed access corridors for Option A are discussed in more detail below.

Noise and Lighting

Noise impacts on wildlife are discussed in *Technical Paper No. 3 - Noise*. The potential impacts of noise are likely to be relatively high over the construction period. Of primary concerns are the noise, vibration and dust generation associated with blasting. Blasting on an irregular basis has the potential to disturb sensitive wildlife species. Blasting noise would be audible over long distances and may cause native fauna near the perimeter of the construction site to avoid the area, thus altering their utilisation of home range or possibly leaving it altogether. Little is known about the behavioural impacts of noise on fauna but there is some evidence that fauna stress levels may increase. At least initially, it is expected that the impacts of blasting on fauna behaviour would be high, however, the long term impacts of noise are unknown.

Noise and vibrational impacts are closely associated making it impossible to analyse their effects separately. The impact of vibration associated with blasting and drilling on fauna which use caves, overhangs or rocky shelters for roosting or sheltering (for example, bats, Broad-headed Snake, owls) are unknown but are potentially moderate to high since the distribution of suitable roost sites is expected to be restricted in the region. The impacts of vibration on reptiles and amphibians are unknown.

Noise associated with the use of conventional equipment would be likely to have less impact on native fauna because it is likely to be more continuous and more predictable than blasting and drilling. At the start of the construction period, impacts associated with noise and associated human activity would be expected to affect behaviour of individuals in the short term. Long term effects on fauna populations are unknown. The impacts of lighting associated with security or night-time construction activities are unknown. The presence of artificial lighting may alter activity patterns of some fauna species in order to avoid predation or take advantage of swarms of insects drawn to the lights.

Feral Animals

Clearing associated with the airport, obstacle limitation surface areas and associated transport and services easements would be likely to attract feral predators. Presently, Holsworthy Military Area has a low diversity and abundance of feral predators. Construction activities would increase accessibility to the site and would provide food and shelter for dogs, cats and foxes. Feral predators would be likely to prey upon small terrestrial mammals, arboreal mammals, Critical Weight Range species, ground foraging birds, reptiles and frogs. It is likely that they would opportunistically prey upon those individuals which have been displaced from the site. It is probable that the two main factors allowing the persistence of the Tiger Quoll at Holsworthy have been the inaccessibility of gully habitats and the general lack of foxes. Airport construction may result in the local extinction of quoll populations (see *Appendix B*). An increase in the number of predators is likely to have a high impact on native fauna species.

Open landscaped areas are also likely to attract introduced bird species such as Starlings and Common Mynas as well as more generalist open-country native species (for example, magpies, ravens, Noisy Miners). These species are aggressive and compete with native species for food and nesting hollows.

Weeds

Within the Holsworthy Military Area there are relatively extensive areas of native vegetation with intact understoreys. Many of these areas are likely to experience weed invasion due to introduction of exotic seed/propagules, physical disturbance, increased nutrients and altered drainage. Weed invasion would also be associated with off-site clearing (OLS sites) within the Woronora catchment. The impact of weed invasion both on and off site is likely to be high in the long term.

Cumulative Impacts

In the case of airport construction, clearing, habitat fragmentation, edge effects and an increase in feral predators and weeds are likely to have cumulative impacts on adjacent areas. The long term result of cumulative impacts would be a gradual reduction of biodiversity and the replacement of highly specialised species with generalist and highly adaptive species (for example, weeds, introduced and feral animals).

8.2.2 OPERATION IMPACTS

Noise and Lighting

Noise impacts on wildlife are discussed in *Technical Paper No. 3 - Noise*. The noise associated with airport operation would have a slower onset time and is more continuous than that associated with construction activities. However, fauna inhabiting areas adjacent to airport boundaries or runways may respond to noise by altering their behaviour. Individuals are expected to habituate in the short term by altering their behaviour or activity patterns. Ambient noise levels close to the airport may be high enough to mask communication signals amongst vociferous or social species such as birds, fruit bats, arboreal mammals and frogs. By affecting their ability to maintain contact, warn of predators, defend territories and/or attract mates, noise may indirectly affect their survival. Long term impacts on populations and reproductive success are unknown.

As for the construction phase, impacts of lighting associated with airport operation on fauna off-site is unknown. The presence of artificial lighting may alter activity patterns of some fauna species in order to avoid predation or take advantage of swarms of insects drawn to the lights.

Fire and Fire Management

There is the potential for an increased risk of fire during the construction phase due to the following: vegetation clearing, large amounts of combustible material on-site, human related causes and clearing of unexploded ordnance. Bush fire risks are discussed in *Technical Paper No. 10 - Hazards and Risks*. Direct impacts of fire on native flora and fauna include mortality of individuals and loss of habitat. Fires originating on the development site and spreading into surrounding forested areas have the potential to eliminate populations of significant flora and fauna species.

A variety of significant flora species may be negatively affected by altered fire regimes in surrounding natural areas, including: *Memaleuca deani, Persoonia nutans, Pterostylis sp.E, Pultanaea aristata, Darwinia diminuta, Darwinia grandiflora, hibbertia nitida, Tetratheca neglecta*. Detailed information on fire and significant flora species is presented in *Appendix A*.

Detailed information on the sensitivity of fauna species to fire is provided in *Appendix B*. A variety of significant fauna species may be affected by altered fire regimes, including: the Giant Burrowing Frog, Red-crowned Roadlet and the Lace Monitor. A number of bird species may be adversely impacted by altered fire regimes, including the Eastern Bristlebird, Bush Stone-curlew, Glossy Black Cockatoo and Turquoise Parrot. Arboreal mammals such as the Squirrel Glider, Brush-tailed Rock-wallaby and Tiger Quoll may also be disadvantaged by frequent burning. A variety of bat species which require a shrub layer or habitat complexity would also be disadvantaged by frequent burning.

The risk of bush or grass fires during the operational phase would be minimal due to the nature of the airport landscape. However, the potential for bushfires to occur in lands external to the airport zone is significant. Fire management would involve aerial fire control, fuel management and construction and maintenance of fire trails in surrounding natural areas. These measures would be likely to impact on flora and fauna in a variety of ways. The use of phosphorous-based fire retardants as part of aerial fire control methods may lead to the direct loss of native vegetation and/or alteration of species composition on the nutrient-poor soils of Holsworthy. The use of seawater would not be appropriate for similar reasons. Fuel management may include hazard reduction burning which may also alter fire regimes and lead to changes in species composition and vegetation community structure. Fire trail construction and maintenance would contribute to habitat loss, fragmentation and barrier effects.

Effective suppression of the majority of fires around the airport site would be likely to result in the recovery of vegetation communities within the Holsworthy area. However, increased fuel levels (that is, shrubby vegetation, fallen logs) may also increase the risk of major wildfires occurring at greater intervals. The cumulative impacts of wildfire, habitat fragmentation and the creation of a significant barrier across and important wildlife corridor are unknown.

Bird and Bat Strike

Bird and bat strike is discussed in *Technical Paper No. 10 - Hazards and Risks*. There are not expected to be any significant differences in the bird and bat strike hazards for the two Holsworthy airport options. Although bird and bat species inhabiting the Holsworthy Military Area do not undertake significant defined movements, the Yellow-tailed Black Cockatoo and Grey-headed Fruit Bat may occur in large flocks. Because of their large numbers and dispersed feeding movements, fruit bats may be most at risk from collisions with aircraft. The impact of removing up to 4,000 hectares of feeding habitat for airport construction may also have a significant effect on bat movements. Long term effects on local and regional populations of this species are unknown. There are no known techniques of preventing bats from flying over airports. The diversity and abundance of species at risk of bird strike would be partly dependent on the management of stormwater and other potential habitat on site (that is, landscaping) and off-site (for example, landfills).

Surrounding Wilderness and Conservation Reserves

Holsworthy Option A contains areas with moderate to high wilderness values which have not been assessed by the National Wilderness Inventory. Construction of an airport and associated infrastructure on the site would effectively eliminate any wilderness values of the area.

Option A has east-west and north-south runway alignments. Preliminary flight paths radiating to the south and south-west would therefore be likely to approach and/or take off over declared Wilderness Areas, Blue Mountains National park, Heathcote National park, Royal National Park, State Recreation Areas, Woronora and O'Hares Creek Catchments and the proposed Wedderburn Nature Reserve. It is unlikely that the behaviour and reproductive success of fauna inhabiting distant natural areas would be affected by noise. However, the behaviour and stress levels of individuals located directly adjacent to the proposed airport (Holsworthy Military Area, O'Hares Woronora catchment) may be affected in the short term. Long term effects of noise on population are unknown.

Under normal (non-emergency, no malfunction) situations, the impacts of fuel dumping are likely to be nil to low for conservation reserves in the vicinity.

Aquatic Impacts

During airport operation, treated stormwater would be discharged into Williams, Harris and Punchbowl Creek. Impacts of stormwater discharges are discussed in *Technical Paper No. 7 - Geology, Soils and Water*. The discharge of treated stormwater would be expected to result in a sevenfold increase in the phosphorous loads and a doubling of the nitrogen exports. The proposed discharge point for effluent is immediately downstream of Punchbowl Creek.

Aquatic Mammals and Amphibians

The potential impact of effluent on aquatic ecosystems would be to increase phosphorous loadings by 200 percent and to increase algal or plant productivity. Because of the pristine conditions of the Holsworthy Military Area streams, operational impacts would be high for aquatic mammals and frogs in downstream habitats. Higher nutrient levels would be expected to alter micro habitats, prey distributions and aquatic and riparian vegetation communities.

Fish and Crayfish

For all time frames, it is likely that fish and crayfish in Harris, Williams, Deadmans, Lyretail, Wappa, Kalibucca and Punchbowl Creeks would be subject to major impacts. These would include changes in abundance and community composition of populations, elimination of some species, proliferation of pollution tolerant species and reduction in reproduction success. Minor long term impacts would be expected for the four unassessed streams. No impacts would be likely for the surrounding streams as they have no hydrological connection to the airport site (see *Table 20, Appendix C*).

Aerial Pollutants

The potential effects of aerial pollutants such as benzene and polycyclic aromatic hydrocarbons are considered to be nil. However, the potential effects of polycyclic aromatic hydrocarbons accumulation are unknown. This is discussed in *Technical Paper No. 7 - Geology, Soils and Water.*

8.2.3 EXTERNAL INFRASTRUCTURE

Although this assessment is primarily concerned with the direct impacts on terrestrial flora and fauna, fish and crayfish, it is recognised that there may be additional impacts from access and utility corridors as well as potential long term impacts from commercial/industrial or residential development which may be associated with airport development. These issues would need to be subject to additional environmental assessment.

The access corridors associated with Holsworthy Option A are indicative only. They would be 150 metres wide and are likely to comprise road, rail and some utility easements. The potential exceptions to this are sewerage and water. Some flora and fauna issues associated with the transport options are summarised here:

Northern Access Corridor Option (Road Alternative 1)

This corridor would link the north-western corner of the airport site to the M5 Expressway and the South Western Freeway. Potential issues associated with this option are:

- creation of an east-west fauna movement barrier in the northern part of Holsworthy Military Area;
- fragmentation of preferred koala habitat (known existing population) at Wedderburn;
- aquatic impacts associated with crossing Harris Creek;
- fragmentation of Grey Box Ironbark Woodland, a vegetation community of state significance; and

- the following significant species were recorded within 500 metres of the proposed corridor: Eastern Grey Kangaroo, Lace Monitor, Giant Burrowing Frog, *Persoonia nutans* and *Pterostylis* sp. E.

Eastern Access Corridor Option (Road Alternative 3)

This corridor would link the north-eastern corner of the airport site to Menai. Potential issues associated with this option are:

- creation of a north-south fauna movement barrier during and post-construction (will cross Heathcote Road);
- a species of regional significance, the Lace Monitor was recorded within 125 metres of the access corridor; and
- aquatic impacts associated with crossing the Woronora River, Mill Creek, Deadmans Creek and Williams Creek.

Western Access Corridor Option (Road Alternative 4)

This corridor would link the north-western corner of the airport site to Minto Heights, crossing the Georges River. Potential issues associated with this option are:

- creation of a fauna movement barrier between the northern and southern parts of the Holsworthy Military Area during and post-construction;
- aquatic impacts associated with crossing the Georges River (aquatic impacts);
- creation of a fauna movement barrier for a significant population of koalas in the Wedderburn area (Georges River corridor); and
- fragmentation of Grey Box Ironbark Woodland, a vegetation community of state significance.

Estimates of the areas of native vegetated affected by access corridors (provided by PPK Environment & Infrastructure) are summarised in *Table 8.3*.

TABLE 8.3 ESTIMATED AREAS OF VEGETATION AFFECTED BY ACCESS CORRIDORS

Access Corridor Option	Area of Vegetation Likely to be Affected (Hectares)		
	State Significance	Regional Significance	Total
Road Alternatives 1 and 2	70	10	80
Road Alternative 3	0	10	10
Road Alternative 4	10	20	30

Effluent and Water Supply Pipelines

The effluent transfer pipeline proposes to follow the ridgeline to the Georges River. Water supply pipelines could come from MacArthur Water Purification Plant, crossing the Georges River, O'Hares Creek and Punchbowl Creek.

8.3 HOLSWORTHY OPTION B

Impact assessment is based on the preliminary Master Plan for Holsworthy Option B (Second Sydney Airport Planners, 1997a).

8.3.1 CONSTRUCTION IMPACTS

Many of the construction impacts are likely to be the same as for Holsworthy Option A (see *Section 8.2.1*).

Vegetation Clearance

On the basis of available information, Holsworthy Option B would require removal of approximately 2,783 hectares of native vegetation (*Table 8.4*). An additional 150 hectares would be expected to be cleared as part of the obstacle limitation works off-site (O'Hares Creek Catchment). This has not been assessed during this study.

TABLE 8.4 MAXIMUM AREA OF EACH VEGETATION COMMUNITY/HABITAT TYPE DIRECTLY AFFECTED BY HOLSWORTHY OPTION B

Vegetation community	Habitat	Area in Option B (hectares)
Shale/sandstone Forest	Grassy Forest	10
Sydney Sandstone Ridgetop Woodland	Woodland/heath Complex	1,656
Woronora Plateau Upland Swamp	Sedgeland	19
Sydney Sandstone Gully Forest	Gully Forest	1,088
Sydney Sandstone Gully (Scrub)	Riparian Scrub	10
Total		**2,783**

Significant Flora Species

Development of Holsworthy Option B is likely to result in the loss of at least seven species of National significance, one species of State significance, and 14 species of regional significance. The impacts of airport development on significant species are assessed in *Appendix A*.

Loss of and disturbance to the northern portion of O'Hares Creek Catchment as part of obstacle limitation works is likely to result in the removal (directly or indirectly) of additional rare flora species.

Significant Vegetation Communities

On the basis of the available information, Holsworthy Option B would result in the loss of 10 hectares of Grey Box Ironbark Woodland, a vegetation community of state significance. It would also result in the loss of five vegetation communities of regional significance (see *Table 8.3*). The significant stand of Grey Box Ironbark Woodland, one of the largest remnants in the state, would be mostly retained but could be transected by an access corridor.

Significant Fauna Species

State significant species recorded within Holsworthy Option B are: Giant Burrowing Frog, Red-crowned Toadlet, Tiger Quoll and Koala. Unconfirmed records also occur for Heath Monitor and Yellow-bellied Glider. However, the five habitat types represented within Option B provide habitat for a number of other significant species (*Table 8.1*). Twelve species of regional significance were recorded from Option B; it is expected that additional significant species occur there. The impacts of airport development on significant species are assessed in *Appendix B*.

Habitat Loss

Development of Option B would result in the removal of 10 hectares of habitat of high regional significance and approximately 2,773 hectares of habitat of regional significance. No River-Flat Forest would be removed as part of the development.

There would also be a loss of approximately 150 hectares of habitat off-site (O'Hares Creek Catchment) as part of obstacle limitation works; this area was not surveyed or assessed as part of the present study. This area is listed under the Register of the National Estate and is therefore protected by the *Australian Heritage Commission Act* 1975, against any activities which threaten its high natural values (that is, changes to hydrology, topography).

Habitat Fragmentation/Barriers

The removal of almost 3,000 hectares of native vegetation together with the erection of a 2.4 metre high fence over most of the site would be likely to pose a significant barrier to fauna movement.

Option B creates a substantial barrier between Wedderburn and O'Hares Creek catchment and between Wedderburn and the Woronora catchment. Terrestrial fauna movement on the western side would be confined to a narrow corridor (less that 500 metres wide) between the airport perimeter and the Georges River. This corridor would potentially be transected by the proposed western access corridor (see *Section 8.3.3*). To the east, terrestrial fauna movement would be restricted to a corridor between the airport boundary and the Woronora Dam.

The proposed northern access corridor would essentially create a significant barrier across the entire north-south axis of the Holsworthy Military Area, thereby creating the potential to isolate populations on either side (see *Section 8.3.3*). Retained narrow corridors and relatively small habitat fragments would become highly susceptible to weed invasion, thereby reducing their value to native fauna. It would also act as a barrier between the Holsworthy site and O'Hares Creek Catchment and the Metropolitan Catchments; the whole area forms a wildlife corridor of high regional significance. Species most likely to be affected are those dependent on Gully Forest, Critical Weight Range species, aquatic species, species with limited mobility and species occurring at low densities or in patchy distributions. Apart from restricting normal fauna movement patterns and flora dispersal, a major barrier would restrict the availability of escape routes for fauna in case of bushfires and/or other natural or artificial disasters. It would also restrict or even prevent recolonisation of regenerating habitats (that is, post-fire).

Aquatic Impacts

Streams which would be affected by direct or indirect impacts associated with airport construction include: Punchbowl Creek and major tributaries, Gunyah Creek, O'Hares Creek, Dahlia Creek and Woronora River tributaries. Of these, Punchbowl Creek would be infilled or be impacted by stormwater detention infrastructure along approximately 16 kilometres of its length and the tributaries of O'Hares Creek would be impacted along 4.8 kilometres of their length (Second Sydney Airport Planners, 1997a). At this stage, particular creeks to be dammed have not been specified. Airport construction would involve substantial filling of gullies and complete removal of habitat and aquatic biota. Over the construction period, there is also a risk of finer sediments escaping detention during storm events and being transported into streams, rivers and reservoirs. This is discussed in *Technical Paper No. 7 - Geology, Soils and Water*. Any increase in the sediment load and associated pollutants would be expected to have a large impact on stream water quality and ecology over the entire length of the streams to their confluence with the Georges River and for a high proportion of the Woronora River.

Aquatic impacts are also likely to affect the O'Hares Creek Catchment area which is protected under the *Australian Heritage Commission Act, 1975* against any changes in hydrology which threaten to degrade the area's high natural values.

Aquatic Mammals and Amphibians

A number of significant species have been recorded in potentially impacted streams. Within the Holsworthy Military Area, Platypus are known to occur in Punchbowl Creek. The Water Rat also possibly occurs in Punchbowl Creek. The Giant Burrowing Frog and Red-crowned Toadlet occur in Punchbowl Creek; the former also occurs in O'Hares Creek.

Holsworthy Option B would result in the removal of habitat for these two species within the site and may alter downstream habitats, thus affecting the distribution and abundance of aquatic invertebrate and vertebrate prey. The diversity of available habitats could decline and lead to changes in stream and riparian zone flora and fauna. Given the fairly pristine condition of the Holsworthy Military Area streams, aquatic impacts associated with construction are likely to be high within the site and downstream. Removal of aquatic habitat is likely to affect the regional distributions of aquatic mammals, the Giant Burrowing Frog and the Red-crowned Toadlet.

Fish and Crayfish

In the short and medium term, it is likely that fish and crayfish in Punchbowl and O'Hares Creek (and their downstream trunk stream the Georges River) would be subject to severe to very severe impacts (see Option A). Major to very major impacts are likely to persist in these two streams in the long term. Fish and crayfish in Gunya, Upper Woronora River tributaries and Dahlia Creek tributaries (and their downstream trunk stream the Georges River) would be subject to major to very major impacts in the short and medium term. Minor to major impacts are likely to persist in these three streams in the long term (see *Table 21, Appendix C*).

Road Kills

Vehicular traffic associated with construction activities would increase substantially from that related to current land use. The probability of road kills is therefore expected to increase significantly within the Holsworthy Military Area for nocturnal species; in particular, arboreal mammals, large herbivorous mammals, small terrestrial mammals and frogs are likely to be negatively affected. Similarly, the impact of road kills associated with the proposed access corridors for Option B, especially the northern access corridor, are likely to be high because they would create substantial barriers within the Holsworthy Military Area. Road kills may also increase off-site depending on the truck travel routes to and from the site and on the times at which they travel (for example, overnight, dawn, dusk). Issues associated with proposed access corridor options for Option B are discussed in *Section 8.3.3*.

Noise and Lighting

The impacts of noise are likely to be high over the anticipated nine year construction period. At least initially, it is expected that the impacts of blasting on fauna would be high (as for Option A); long term impacts on populations are unknown. The impact of vibration associated with blasting and drilling on fauna which use caves, overhangs or rocky shelters for roosting or sheltering (for example, bats, Broad-headed Snake, owls) are unknown but are potentially moderate to high since the distribution of suitable roost sites is expected to be restricted in the region. At the start of the construction period, impacts associated with noise and associated human activity would be expected to be moderate to high for fauna. Long term effects on fauna populations are unknown.

The impacts of lighting associated with security or night-time construction activities are unknown. The presence of artificial lighting may alter activity patterns of some fauna species in order to avoid predation or take advantage of swarms of insects drawn to the lights.

Feral Animals

Given that there is a relatively low abundance and diversity of feral animals in the Holsworthy Military Area, an increase in the number of feral predators would be likely to have a high impact on native fauna species (as for Option A).

Weeds

Weed invasion would also be associated with off-site clearing for obstacle limitation surfaces within O'Hares Creek Catchment. The impact of weed invasion both on and off site would be likely to be high in the short and long term.

Cumulative Impacts

In the case of airport construction, the accumulated impacts of clearing, habitat fragmentation, edge effects and an increase in feral predators and weeds would be likely to have cumulative impacts on adjacent areas. The long term result of cumulative impacts would be a gradual reduction of biodiversity and the replacement of highly specialised species with generalist and highly adaptive species (for example, weeds, introduced and feral animals).

8.3.2 OPERATION IMPACTS

Noise and Lighting

Fauna inhabiting areas directly adjacent to airport boundaries or runways may respond to noise by altering their behaviour or activity patterns. Individuals are expected to habituate or move away in the short term. Long term impacts on populations and reproductive success are unknown.

The impacts of lighting associated with security or night construction activities are unknown. The presence of artificial lighting may alter activity patterns of some fauna species in order to avoid predation or take advantage of swarms of insects drawn to the lights.

Fire and Fire Management

There is the potential for an increased risk of fire during the construction phase due to the following: vegetation clearing, large amounts of combustible material on site, human related causes and clearing of unexploded ordnance. This is discussed in *Technical Paper No. 10 - Hazards and Risks*. Direct impacts of fire on native flora and fauna include mortality of individuals and loss of habitat. Fires originating on the development site and spreading into surrounding forested areas have the potential to eliminate populations of significant flora and fauna species.

A variety of significant flora and fauna species may be negatively affected by altered fire regimes in surrounding natural areas (as for Option A). Detailed information on the sensitivity of species to fire is provided in *Appendices A* and *B*.

The risk of bush or grass fires during the operational phase would be minimal due to the nature of the airport landscape. However, the potential for bushfires to occur in lands external to the airport zone is significant. Fire management would involve aerial fire control, fuel management and construction and maintenance of fire trails in surrounding natural areas. These measures may impact on flora and fauna in a variety of ways. The use of seawater or phosphorus based fire retardants as part of aerial fire control methods may lead to direct loss of native vegetation and/or alteration of species composition. Fuel management may include hazard reduction burning which may also alter fire regimes and lead to changes in species composition and vegetation community structure. Fire trail construction and maintenance would contribute to habitat loss, fragmentation and barrier effects.

Effective suppression of the majority of fires around the airport site would be likely to result in the recovery of vegetation communities within the Holsworthy area. However, increased fuel levels (that is, shrubby vegetation, fallen logs) may also increase the risk of major wildfires occurring at greater intervals. The cumulative impacts of wildfire, habitat fragmentation and the creation of a significant barrier across an important wildlife corridor are unknown.

Bird and Bat Strike

Bird and bat strike is discussed in *Technical Paper No. 10 - Hazards and Risks.* There are not expected to be any significant differences in the bird and bat strike hazards for the two airport options. Because of their large numbers and dispersed feeding movements, fruit bats may be most at risk from collisions with aircraft. Removal of up to 3,000 hectares of feeding habitat for airport construction may also have a significant effect on bat movement. Long term effects on local and regional populations of this species are unknown. There are no known techniques of preventing bats from flying over airports. The diversity and abundance of waterbirds at risk of bird strike will be partly dependent on the management of stormwater and other potential habitat on site (that is, landscaping) and off-site (for example, landfills).

Aquatic Impacts

Treated stormwater would be discharged into Punchbowl Creek. The impacts of stormwater discharges are discussed in *Technical Paper No. 7 - Geology, Soils and Water.* The discharge of treated stormwater would be expected to result in a sevenfold increase in the phosphorous loads and a doubling of the nitrogen exports. A proposed discharge point for sewage treatment plant effluent is upstream of O'Hares Creek and west of Mt Giliad.

Aquatic Mammals and Amphibians

The impact of the discharge of sewage treatment plant effluent on aquatic ecosystems would be to increase phosphorous loadings by 200 percent and to increase algal or plant productivity. This would be likely to alter or remove stream microhabitats, aquatic invertebrate diversity and abundance and riparian vegetation which would impact directly on populations of fish, amphibians and aquatic mammals in these streams. Operational impacts are likely to be high for aquatic mammals and frogs in downstream habitats (as for Option A).

Fish and Crayfish

For all time frames, fish and crayfish in Punchbowl Creek and its tributaries (and its downstream trunk stream the Georges River) would be subject to very major impacts, as for Option A. It is likely that Gunya Creek and its tributaries, O'Hares Creek and its tributaries and the Georges River and its tributaries would also be subject to major impacts for all time frames. Minor impacts are expected for the upper Woronora River and its tributaries, Dahlia Creek and its tributaries. No impacts are expected for the surrounding streams as they have no hydrological connection to the airport option (see *Table 22, Appendix C*).

Aerial Pollutants

The potential effects of aerial pollutants such as benzene and polycyclic aromatic hydrocarbons are considered to be nil. However, the potential effects of polycyclic aromatic hydrocarbons accumulation are unknown. This is discussed in *Technical Paper No. 7 - Geology, Soils and Water.*

Surrounding Wilderness and Conservation Areas

Holsworthy Option B contains areas with moderate to high wilderness values which have not been assessed by the National Wilderness Inventory. Construction of an airport and associated infrastructure on the site would effectively eliminate any wilderness values of the area.

Holsworthy Option B has north-west to south-east and north-south runway alignments. Preliminary flight paths radiate in an arc from the west to the south-east and would therefore be likely to approach and/or take off over declared Wilderness Areas, Blue Mountains National Park, Heathcote National Park, Royal National Park, State Recreation Areas, Woronora and O'Hares Creek Catchments and the proposed Wedderburn Nature Reserve. It is unlikely that the behaviour and reproductive success of fauna inhabiting distant natural areas would be affected by noise. However, the behaviour and stress levels of individuals located close to the proposed runways (Holsworthy Military Area, O'Hares Creek Catchment, Woronora catchment, Wedderburn) may be affected. Long term effects of noise on population are unknown.

Under normal (non-emergency, no malfunction) situations, the impact of fuel dumping on natural areas is likely to be nil to low.

8.3.3 EXTERNAL INFRASTRUCTURE

Although this assessment is primarily concerned with the direct impacts of airport construction and operation on terrestrial flora and fauna, fish and crayfish, it is recognised that there may be additional impacts from access and utility corridors as well as potential long term impacts from commercial, industrial or residential development which may be associated with airport development. These issues would need to be subject to additional environmental assessment.

The access corridors associated with Holsworthy Option B are indicative only. They would be 150 metres wide and are likely to comprise road, rail and utility easements. The potential exceptions to this are sewerage and water. Some flora and fauna issues associated with some of the access corridor options are summarised here.

Northern Access Corridor Option (Road Alternatives 1 and 2)

This corridor would link the north-western corner of the airport site to the M5 Expressway and the South Western Freeway. Potential issues associated with this option are:

- creation of an east-west fauna movement barrier along almost the entire length of Holsworthy (increased road kills, edge effects);
- substantial edge effects associated with weed invasion, vehicle emissions, dust, increased human activity, increased accessibility to feral predators along entire length of Holsworthy;
- fragmentation of preferred koala habitat for a known population at Wedderburn;
- aquatic impacts associated with crossing Harris Creek;
- fragmentation of Grey Box Ironbark Woodland, a vegetation community of state significance; and
- the following significant species were recorded within 500 metres of the proposed corridor: Common Wombat, Eastern Grey Kangaroo, Yellow-rumped Thornbill, Giant Burrowing Frog, *Persoonia nutans, Pterostylis* sp. E.

Western Access Corridor Option (Road Alternative 6)

This corridor would link the north-western corner of the airport site to Campbelltown, crossing the Georges River at the site boundary. Potential issues associated with this option are:

- creation of a fauna movement barrier between the northern and southern parts of the Holsworthy site during and post-construction;

- aquatic impacts associated with crossing the Georges River (aquatic impacts); and

- creation of a fauna movement barrier for known population of koalas at Wedderburn (Georges River corridor).

Two other access corridor options exist, however they have not been described here.

Estimates of areas of native vegetation affected by all potential access corridors (provided by PPK Environment & Infrastructure) are summarised in *Table 8.5*.

TABLE 8.5 ESTIMATED AREAS OF VEGETATION AFFECTED BY ACCESS CORRIDORS

Access Corridor Option	Area of Vegetation Likely to be Affected (Hectares)		
	State Significance	**Regional Significance**	**Total**
Road Alternatives 1 and 2	140	140	280
Road Alternative 3	60	200	260
Road Alternative 4	50	140	190
Road Alternative 6	10	60	70
Road Alternative 7	0	180	180

Note: Road Alternatives 1, 2, 3 and 4 incorporate Road Alternative 5.

Effluent and Water Supply Pipelines

The effluent transfer pipeline would cross O-Hares Creek and Pheasants Creek. Water supply pipelines could come from MacArthur Water Purification Plant, crossing the Georges River and O'Hares Creek and Punchbowl Creek.

Part D

Environmental Management

CHAPTER 9 ENVIRONMENTAL MANAGEMENT

9.1 MITIGATION MEASURES

Airport development of any of the five options would result in the complete removal of vegetation and consequently in the loss of all native species of flora and fauna within the specified airport boundaries. Mitigation measures for sedimentation and erosion form part of the construction plan. Mitigation measures described here apply mainly to the protection of fauna and fauna habitat at the periphery of the site, within adjacent high quality areas and along transport and services easements associated with the airport development. However, they would also include guidelines for emergency rescue procedures for injured and displaced fauna, pre-construction surveys for rare flora and fauna and long term monitoring.

9.1.1 ENVIRONMENTAL MANAGEMENT PLAN

It is difficult to nominate specific mitigation measures and environmental safeguards for a large-scale development such as an airport. To ensure that environmental impacts are minimised during design and construction, an Environmental Management Plan should be prepared. The plan would contain detailed guidelines and procedures for impact mitigation for use by land either managers or construction personnel.

The following principles would provide a sound basis for the Environmental Management Plan:

- a commitment to sound environmental practice;
- clear environmental objectives;
- specific responsibilities for environmental matters;
- clear guidelines and procedures;
- supervision, inspection, monitoring and auditing;
- documenting and reporting of key issues; and
- a review system.

A variety of measures that would be included in the Environmental Management Plan have been briefly considered in this document. It is envisaged the preparation of the Environmental Management Plan would provide an opportunity to fully research and assess relevant mitigation measures and to ensure that all recent scientific research is taken into account. Two components of the Environmental Management Plan require further discussion at this stage. The targeted pre-construction surveys for rare flora and fauna are discussed in *Section 9.4* and the emergency rescue plan for injured and displaced fauna is discussed below.

Impact assessment has revealed that the majority of fauna present on the preferred site would be displaced or perish during construction. As a result, on-site mitigation measures for fauna are difficult to recommend. It is possible that individuals may become isolated, trapped or injured during the construction phase. An emergency rescue plan is recommended as a measure to deal with such occurrences so survival opportunities for such fauna can be maximised.

The plan would benefit Holsworthy options most effectively, however elements of the plan would be applicable to the Badgerys Creek options. The nature and scale of the development may preclude a variety of small or highly mobile fauna species from rescue. Individual fauna species and fauna guilds that may benefit from a rescue plan include: Koalas, amphibians, reptiles, medium-sized mammals, raptors, and hollow-dependent fauna, including arboreal mammals, bats, owls and bird species.

The other key flora and fauna mitigation measures to be included would be based on the findings of the Draft EIS:

- fauna habitat management guidelines;
- on-site education program for construction workers in the identification of rare and vulnerable fauna species;
- fire management;
- weed control measures; and
- monitoring.

9.2 BADGERYS CREEK OPTIONS

A variety of mitigation measures would be available to reduce the overall impacts of construction and operation of the Badgerys Creek airport proposal. A brief description of mitigation measures is provided below. Detailed guidelines for mitigation measures should be contained in the Environmental Management Plan.

9.2.1 CONSTRUCTION

- construct river and stream crossings so as to maintain downstream water quality;
- create wetland habitat (that is, reed beds) as part of stormwater management on the sites of the Badgerys Creek proposals;
- utilise only non-invasive species in plantings for soil stabilisation and landscaping;
- check all sheds, buildings, culverts prior to demolition for the presence of bats and to recommend a suitable time to demolish them (that is, when bats are absent) (a known bat maternity colony is located in a building at Badgerys Creek);
- adopt strategies to prevent and control bushfires during construction; and
- implement weed and dieback control strategies.

9.2.2 OPERATION

- adopt strategies to reduce bird strike through habitat management and birdscaring techniques (see *Technical Paper No. 10 - Hazards and Risks*);
- monitor stormwater and erosion control measures on a regular basis to ensure minimum water quality levels are maintained. Results of monitoring should be included in the Environmental Management Plan and recommendations arising from results addressed (see *Technical Paper No. 7 - Geology, Soils and Water*); and
- adopt alternative measures for disposal of treated sewage, such as land disposal.

9.3 HOLSWORTHY OPTIONS

The construction and operation of the Holsworthy airport proposals can be reduced through a variety of innovative mitigation measures. A brief description of these measures is provided below. Detailed guidelines for the implementation and operation of mitigation measures should be provided in the Environmental Management Plan.

9.3.1 CONSTRUCTION

- construct river and stream crossings so as to maintain downstream water quality;

- install permanent detention ponds on the lower end of all catchments to be disturbed by construction activities (presently, only some catchments to be disturbed will have permanent detention ponds);

- install detention ponds designed to capture the volume of at least one in 10 year average return interval two hour storm event, rather than a one in one year event, to further reduce the potential input of sediments into streams;

- use extreme care when using polyelectrolyte flocculating agents to reduce water turbidity. Overdosing with these agents may cause significant downstream impacts on stream biota;

- support collection and propagation of rare plants, in accordance with the necessary permits and conditions, and as authorised by the appropriate authorities;

- utilise only non-invasive species in plantings for soil stabilisation and landscaping;

- assess opportunities for effective weed control, taking into account new technology and relevant research into the latest weed control techniques;

- minimise any impacts outside the airport boundary including edge effects, spread of weeds, littering, etc;

- develop an on-site education program for construction workers in the identification of rare and vulnerable fauna species;

- check all sheds, buildings, culverts prior to demolition for the presence of bats and recommend a suitable time to demolish them (that is, when bats are absent);

- adopt strategies to prevent and control bushfires during construction;

- do not use phosphorous based fire retardants or sea water for aerial fire control;

- develop, in consultation with the Natural Parks and Wildlife Service, protocols for the reporting of Schedule 1 and 2 fauna (*Threatened Species Conservation Act, 1995*) and other significant species encountered during construction;

- ensure that construction vehicles are driven responsibly and safely to avoid road kills; and

- implement weed and dieback control strategies.

9.3.2 OPERATION

- treated sewage arising from either of the Holsworthy airport options should not be released at the sites nominated in the Georges River. Downstream of the Bunbury Curren Creek confluence, the Georges River is notably degraded and is therefore a more suitable location for the release of sewage effluents. Ideally, the effluent should be disposed of through a system controlled by the Sydney Water Corporation (that is, marine disposal or land based disposal);

- adopt strategies to reduce bird strike through habitat management and birdscaring techniques (see *Technical Paper No. 10 - Hazards and Risks*);

- retain a ground layer or understorey of native vegetation in the perimeter cleared area;

- adopt fire control plans that identify the requirements for various fire regimes for significant flora and fauna species;

- do not use phosphorous based fire retardants or sea water for aerial fire control;

- ensure that vehicles are driven responsibly and safely to avoid road kills (for example, signage, speed bumps, etcetera); and

- monitor stormwater and erosion control measures on a regular basis to ensure minimum water quality levels are maintained. Results of monitoring should be included in the Environmental Management Plan and recommendations arising from results addressed (see *Technical Paper No. 7 - Geology, Soils and Water*).

9.3.3 EXTERNAL INFRASTRUCTURE

It was beyond the scope of the present study to assess the impacts and outline mitigation measures for proposed transport corridors. The options considered are indicative only and are subject to separate investigations and approvals. However, given that any corridors under consideration are likely to traverse extensive forested areas at the Holsworthy Military Area, a number of mitigation measures would appear to be appropriate:

- provide aerial walkways for arboreal mammals if necessary;
- provide overpasses and underpasses (tunnels and bridges) for proposed transport corridors;
- ensure that stream crossings do not result in bed changes that inhibit movement of aquatic species;
- minimise and localise trenching work (services corridors);
- careful siting of proposed transport and services corridors to minimise habitat fragmentation;
- record and remove native fauna that become trapped in the trench in key areas. Species should be suitably relocated by experienced personnel as detailed in the emergency rescue plan; and
- place trench plugs to allow movement of wildlife, where the trench is to be left open for more than 48 hours.

9.4 MONITORING

A detailed monitoring strategy for the preferred airport location would be prepared as part of the Environmental Management Plan. The strategy would facilitate and prioritise monitoring and research. Presented below are recommendations for consideration in preparation of the monitoring strategy.

9.4.1 BADGERYS CREEK OPTIONS

The scope for effective and useful monitoring to be carried out at the Badgerys Creek site is limited due to the degraded nature of the site. However two mitigation measures would provide important information on the effectiveness of mitigation measures:

- water quality monitoring; and
- monitoring of the effectiveness of bird scaring techniques.

Technical Paper No. 7 - Geology, Soils and Water provides detailed information on water quality monitoring. Monitoring of birdscaring techniques is discussed in the following section.

9.4.2 HOLSWORTHY OPTIONS

The Holsworthy Military Area provides many opportunities to measure the effectiveness of mitigation measures. This is due to the undisturbed nature of the site and the likelihood that many native flora and fauna species would be either disturbed or displaced by the proposal. A monitoring strategy with clear priorities and flexible response measures would be provided as part of the Environmental Management Plan. A variety of recommendations for that strategy are listed below.

Targeted Pre-construction Surveys

As monitoring programs can be highly time-consuming and expensive, their efficiency can be considerably improved by targeting species which are widespread and sometimes abundant. Those species which have been researched extensively and whose habitat requirements are well understood should be targeted. The basis of monitoring programs is a collection of accurate baseline data. This data should be collected at the site during targeted pre-construction surveys. These surveys would aim to locate populations of species and provide site specific data on their habitat requirements. The surveys would also enable long term monitoring of fauna populations to be established. A number of significant fauna species have been identified as suitable targets for pre-construction surveys, they include:

- Broad-headed Snake;
- Brush-tailed Rock-wallaby;
- Red-crowned Toadlet;
- Tiger Quoll;
- Koala;
- Large-footed Myotis;
- Common Bent-wing Bat;
- Glossy Black-Cockatoo; and
- Large forest owls.

Monitoring Indicator Species

Monitoring programs should target species known or suspected to be sensitive to habitat loss and fragmentation. These can be referred to as indicator or target species and their presence is likely to indicate habitat quality for a range of other species or whole communities (Milledge *et al*. 1991). Monitoring a limited number of species is a practical approach and allows sensitive species to be targeted. Relevant indicator species for the Holsworthy sites are those listed above for pre-construction surveys. A number of other relevant points that should be taken into account in the development of the monitoring strategy are:

- target survey methods should be standardised so that the results are subject to statistical analysis; and

- monitoring should continue over the long term (at least 15 years). It is important to collect data on long term impacts (that is, cumulative impacts, increases in predation pressure, edge and barrier effects).

Monitoring Birdscaring Techniques

A monitoring strategy for bird and bat scaring techniques should be developed following a review of national and international research. This strategy should include a flexible response approach to ensure monitoring results are considered.

Monitoring Feral Pests

Regular monitoring of introduced feral predators (that is, fox, dog, cat) should be carried out as part of the feral animal control program. Some appropriate monitoring techniques include:

- systematically searching swept tracks or roads for prints; and

- collection and analysis of predator scats.

Monitoring Fire and Fire Control

The extent and characteristics of all fires adjacent to the airport should be recorded annually and the effects on the surrounding vegetation communities and understorey structure and its dependent faunal communities should be subject to further monitoring.

Compliance

Adequacy of mitigation measures depends not only on design and scope of the measures but also on the degree of compliance by construction workers and land managers. Compliance needs to be strictly enforced and the following measures are recommended:

- development and implementation of an ongoing program to monitor compliance with impact mitigation measures;
- penalties set in place to be a real disincentive to non-compliance; and
- complementary incentive-based approach should be taken, with construction managers and land managers offered bonuses for high rates of compliance upon completion of key construction phases.

Monitoring the Aquatic Environment

Support is given to the incorporation of all surface-water monitoring procedures described in *Technical Paper No. 7 - Geology, Soils and Water.*

Additional monitoring activities to be considered should include:

- monitoring the effectiveness of specific impact mitigation measures (focussing on rain events and including a rigorous review process); and
- close monitoring of the supervision of activities to maintain mitigation measures.

Monitoring Weeds

Programs to monitor weed outbreaks and control measures should be developed with a view to improving and refining strategies used to control weed species. As discussed previously, while the potential for weed invasion is high, the scope for weed control is limited given considerable logistic constraints, high costs the tenacious species often involved, and the low priority usually assigned to weed control. Weed invasion of the Holsworthy Military Area is appropriately considered a likely environmental cost associated with the development. Weed monitoring is less worthwhile at the sites of the Badgerys Creek airport options where heavy weed infestations are already present and the land is primarily managed for agriculture.

Monitoring Environmental Change

A monitoring program would be designed and implemented to assess changes in environmental conditions in response to construction and operation of the airport.

Part E

Summary of Impacts

CHAPTER 10 SUMMARY OF IMPACTS

A summary of the construction and operation impacts predicted for the Badgerys Creek and Holsworthy airport options are collated below in *Table 10.1*.

TABLE 10.1 SUMMARY OF FLORA AND FAUNA IMPACTS FOR THE FIVE AIRPORT OPTIONS.

Impacts	Badgerys Creek			Holsworthy	
	A	B	C	A	B
Size (ha)	1,700	2,900	2,850	4,200	2,800
			Construction (Direct)		
Loss of terrestrial habitat	121 hectares of habitat of high local significance	212 hectares of habitat of high local significance	183 hectares of habitat of high local significance	308 hectares of habitat of high regional significance; 3,812 hectares of habitat of regional significance	10 hectares of habitat of high regional significance; 2,772 hectares of habitat of regional significance
Loss of stream habitat	Oaky Creek (3 kms): Cosgroves Creek (1.8 kms)	Badgerys Creek (5.4 kms); Oaky Creek (3 kms); Cosgroves (1.5 kms)	Badgerys Creek (5.7 kms); Oaky Creek (3.9 kms)	Harris Creek (4.5 kms); Williams Creek (8.1 kms); Deadmans Creek (0.6 km); Wappa Creek 4 kms);	Punchbowl Creek (16 kms); O'Hares Creek (4.8 kms)
Fragmentation and barriers	Creates a barrier across a wildlife corridor of high local significance	Creates a barrier across a wildlife corridor of high local significance	Creates a barrier across a wildlife corridor of high local significance	Creates a barrier across a wildlife corridor of high regional significance	Creates a barrier across a wildlife corridor of high regional significance
Aquatic impacts	frogs - high fish and crayfish - 3 streams very major impact; 1 stream major impact aerial pollutants - nil (accumulation - unknown)	frogs - high fish and crayfish - 4 streams very major impact; 1 stream major aerial pollutants - nil (accumulation - unknown)	frogs - high fish and crayfish - 5 streams major to very major impact; 2 streams minor impacts aerial pollutants - nil (accumulation - unknown)	aquatic mammals and frogs - high fish and crayfish - 2 streams severe impacts; 5 streams very major impacts aerial pollutants - nil (accumulation - unknown)	aquatic mammals and frogs - high fish and crayfish - 2 streams severe to very severe; 3 streams major to very major impacts aerial pollutants - nil (accumulation - unknown)
Noise, vibration and lighting	noise - low lighting - low	noise - low lighting - low	noise - low lighting - low	noise and vibration - potentially high short term behavioural impact; long term population impact lighting - unknown	noise and vibration - potentially high short term behavioural impact; long term population impact lighting- unknown
Road Kills	Low	Low	Low	Potentially high	Potentially high

TABLE 10.1 CONTINUED

Impacts	Badgerys Creek			Holsworthy	
	A	B	C	A	B
Loss of significant vegetation communities	None	None	None	308 hectares of vegetation community of state significance; 3,812 hectares of 5 vegetation communities of regional significance	10 hectares of vegetation community of state significance; 2,773 hectares of 5 vegetation communities of regional significance
Loss of and/or disturbance to adjacent conservation areas	None	None	None	Woronora Catchment - 90 ha	O'Hares Creek Catchment - 150 ha
Loss of significant flora species	National - 1 sp. Regional - 33 spp.	National - 1 sp. Regional - 34 spp.	National - 1 sp. Regional - 37 spp.	National - 10 spp. State - 1 sp. Regional - 12.	National - 7 State - 1 Regional - 14
Loss of significant fauna species	Potentially 2 spp. of National and 12 spp. of State 38 spp. of regional significance, 5 species listed under International Agreements	Potentially 2 spp. of National; 12 spp. of State and 38 spp. of regional significance, 5 species listed under International Agreements	Potentially 2 spp. of National; 12 spp. of State and 38 spp. of regional significance, 5 species listed under International Agreements	Potentially 5 spp. of National, 27 spp. of State and 58 spp. of regional significance, 2 species listed under International Agreements	Potentially 5 spp. of National, 27 spp. of State and 58 spp. of regional significance, 2 species listed under International Agreements
Construction (Indirect)					
Feral animals	Low	Low	Low	Potentially high	Potentially high
Weeds	Low	Low	Low	Potentially high	Potentially high
Cumulative Impacts	Low	Low	Low	Potentially high	Potentially high
Operation					
Noise and lighting	Low	Low	Low	Noise - potential short term behavioural impacts; unknown long term population impacts	Noise - potential short term behavioural impacts; unknown long term population impacts
Fire	Low	Low	Low	Potentially high	Potentially high
Bird and Bat Strike	Low	Low	Low	Potentially high	Potentially high
Wilderness and Conservation Areas	Noise impact low; fuel dumping nil to low	Noise impact low; fuel dumping nil to low	Noise impact low; fuel dumping nil to low	Noise impact low for Wilderness Areas, unknown for adjacent natural areas; fuel dumping nil to low	Noise impact low for Wilderness Areas, unknown for adjacent natural areas; fuel dumping nil to low

TABLE 10.1 CONTINUED

Impacts	Badgerys Creek			Holsworthy	
	A	B	C	A	B
Aquatic impacts	frogs - high fish and crayfish - 4 streams major	frogs - high fish and crayfish - 4 streams major ; 1 stream minor	frogs - high fish and crayfish - 3 streams major impacts; 2 streams minor impacts	aquatic mammals and frogs - high fish and crayfish - 7 streams major; 1 stream very major; 4 streams minor	aquatic mammals and frogs - high fish and crayfish- 1 stream very major; 2 streams major; 2 streams minor

10.1 BADGERYS CREEK

10.1.1 TERRESTRIAL FLORA AND FAUNA

The habitat values within the sites of the Badgerys Creek options are generally degraded; however, remnant native vegetation communities provide the only habitat for significant flora and fauna species. Furthermore, the Badgerys Creek riparian corridor acts as a wildlife corridor of high local significance. The development of any of the three Badgerys Creek airport options would result in the loss of terrestrial and stream habitats and in the creation of a barrier across a wildlife corridor of high local significance. Indirect impacts are not expected to be significant for any of the options. However, Badgerys Creek Option A minimises the area to be developed and consequently the loss of remnant terrestrial and stream habitats.

10.1.2 FISH AND CRAYFISH

Given the existing degraded stream conditions and the associated low conservation values of the streams, the predicted major stream impacts from the Badgerys Creek airport options are unlikely, in an absolute sense, to result in profound deleterious changes to the stream biota. It is highly likely that the fish fauna would become even more dominated by pollution tolerant pest species.

The scale of impacts expected from each airport option is quite similar. This is well-illustrated in *Figures A3.7* to *A3.9* in *Appendix C* where the conservation value of selected streams is plotted against the scale of short term and medium term construction impacts, long term construction impacts and long term operational impacts, respectively. However, in terms of minimising the number of streams to be affected, Badgerys Creek Option A is desirable; only four stream systems are to be directly affected compared with five in Options B and C.

10.2 HOLSWORTHY

10.2.1 TERRESTRIAL FLORA AND FAUNA

The habitat values within the Holsworthy Military Area are generally high to very high. Holsworthy Military Area forms part of an extensive corridor of native vegetation in good condition with little evidence of weed invasion or feral animals. It forms part of a wildlife corridor of high regional significance. The development of either of the Holsworthy airport options would result in the loss of large amounts of terrestrial and stream habitats and in the creation of a barrier across a wildlife corridor of high regional significance.

Holsworthy Option A involves the development of the largest area and consequently requires the removal of large amounts of native vegetation, including vegetation communities of State significance and habitats of high regional significance. It would also form a substantial barrier across a wildlife corridor extending from Holsworthy Military Area through to the Woronora catchment, Heathcote and Royal National Parks.

Option B also requires the removal of a large amount of native vegetation, including steep inaccessible gully habitats which support the highest diversity of fauna within Holsworthy Military Area. It would create a substantial barrier in a wildlife corridor extending from Holsworthy Military Area in the north through to O'Hares Creek Catchment, Wedderburn and the Metropolitan catchments to the south. Indirect impacts are expected to be significant for both options; these are likely to reduce biodiversity in the long term.

Either option would result in the fragmentation of bushland of Regional significance.

10.2.2 FISH AND CRAYFISH

Given the existing high-quality stream conditions, and the associated high conservation value of the streams (National to State significance), the predicted major to very severe stream impacts from the Holsworthy airport options are likely, in an absolute sense, to result in profound deleterious changes to the stream biota, including fish and crayfish fauna. It is likely that many of the streams will become highly degraded with their conservation values being severely compromised.

Compared with the Badgerys Creek airport options, major stream-environment losses are expected with the Holsworthy options - generally the scale of impacts is predicted to be larger and, because of the stream's high conservation value, more can be lost. This is well illustrated in *Figures A3.7* to *A3.9* in *Appendix* C (plots of conservation value versus scale of impacts).

The scale of impacts expected from each Holsworthy airport option is generally similar (*Figures A3.7* to *A3.9* in *Appendix C*). However, the most severe impacts on a particular stream would be expected from Option B (southern). The stream system affected (Punchbowl Creek) is large, has a very high conservation value and is an important stream for Australian bass (a recreationally valuable fish species) within the Georges River system.

In terms of minimising of the number of streams to be affected, Holsworthy Option B is the most desirable - only six stream systems are to be directly affected compared with 12 in Option A.

References

REFERENCES

Airservices Australia (1996), *Australian Manual of Air Traffic Services*, Canberra, 5 December 1996.

Airservices Australia (1996), *The Long Term Operating Plan for Sydney (Kingsford Smith) Airport and Associated Airspace - Report Summary*, Commonwealth of Australia, Canberra.

Alabaster J.S. and Lloyd R. (1982). *Water Quality Criteria for Fish.* Butterworths, London.

ANZECC (1992). *Australian Water Quality Guidelines for Fresh and Marine Waters*, Australian and New Zealand Environment and Conservation Council, Canberra.

Austeco Pty Ltd (1992). *Fauna Impact Statement for the Proposed Forestry Operations in the Glen Innes Forest Management Area - Supplement to the Environmental Impact Statement.* Austeco Pty Ltd and State Forests of New South Wales.

Austeco Pty Ltd (1994). *Terrestrial Fauna of the Grafton and Casino State Forest Management Areas: Description and Assessment of Forestry Impacts.* Draft Report prepared for SFNSW, Grafton. Austeco Pty Ltd, Armadale.

Austeco Pty Ltd (1995). *Description and Assessment of Forestry Impacts on the Fauna of the Urunga-Coffs Harbour Management Areas.* Draft Report prepared for SFNSW, Grafton. Austeco Pty Ltd, Armidale.

Australian and New Zealand Environment and Conservation Council (1992). Australian Water Quality Guidelines for Fresh and Marine Waters.

Australian Museum Business Services (1992). *Fauna Survey of South Creek, Sydney.* Report prepared by the Australian Museum Business Services for Environmental Management Unit - Sydney Water Board.

Australian Museum Business Services (1994). *Assessment of Wildlife Health at Castlereagh Waste Depot.* Environmental Protection's Authority.

Australian Nature Conservation Agency (1991). *Threatened Australian Vertebrate Fauna.*

Australian Nature Conservation Agency (1995). *An Interim Biogeographic Regionalisation for Australia.*

Australian Nature Conservation Agency (1996). *Directory of Important Wetlands, Second Edition,* ANCA, Canberra.

Australian Water Technologies (Ensight) (1995). *Stream Water Quality and Biota in the Picton Region, 1992-94.* Report No. 94/177.

AXIS Environmental/Australian Museum Business Services (1995). *Holsworthy Training Area Environmental Audit.* Report to Department of Defence.

Baker J. (1992). *Occurrence and Habitat Preference of the Eastern Bristlebird* (Dasyornis brachypterus) *in the Illawarra Region, NSW.* University of Wollongong, unpublished.

Baker J. (1996). *Strategy for Conservation and Management of the Ground Parrot and Eastern Bristlebird Populations at Nadgee Nature Reserve, NSW Jervis Bay National Park and Beecroft Peninsula.* Report to NSW National Parks and Wildlife Services and Australian Nature Conservation Agency.

Baker J. and Whelan R.J. (1994). Ground Parrots and fire at Barren Grounds, New South Wales: a long term study and an assessment of management implications. *Emu* 94(4): 300-4.

Bannerman S. and Hazelton P. (1990). *Soil Landscapes of the Penrith 1:100,000 map sheet.* Soil Conservation Service of NSW, Sydney.

Barnett J.L., How R.A. and Humphreys W.F. (1978). *The use of habitat components by small mammals in eastern Australia. Aust. J. Ecol.* 3: 277-85.

Bell J.D., Berra T.M., Jackson P.D., Last P.R. and Sloane R.D. (1980). Recent records of the Australian Grayling *Prototroctes maraena* Gunther (Pisces: Prototroctidae) with notes on its distribution. *Aust. Zool.* 20: 419-431.

Bennett A.F. (1987). *Conservation of Mammals within a Fragmented Forest Environment: The Contributions of Insular Biogeography and Autecology.* In: Sanders, A. Arnold, W. A., Burbridge, A. A., and Hopkins, A. J. M. (eds). *Nature Conservation: The Role of Remnants of Native Vegetation.* Surrey Beatty and Sons, Chipping Norton, Sydney, pp 41-52.

Bennett A.F. (1993). Microhabitat use by the Long-nosed Potoroo, *Potorous tridactylus,* and other small mammals in remnant forest vegetation of South-Western Victoria. *Wildlife Research* 20: 267-85.

Benson D. (1992). The natural vegetation of the Penrith 1:100,000 sheet. *Cunninghamia* 2(4): 541-596.

Benson D. and Howell J. (1990). *Taken for Granted: The Bushland of Sydney and its Suburbs*. Kangaroo Press, Sydney

Benson D. and Howell J. (1994). *Hawkesbury-Nepean Catchment Studies: Explanatory Notes for the Wollongong 1:100,000 Vegetation Map Sheet*. Royal Botanic Gardens, Sydney.

Benson D., Howell J. and McDougall L. (1996). *Mountain Devil to Mangrove: A guide to natural vegetation in the Hawkesbury-Nepean Catchment*. Royal Botanic Gardens, Sydney.

Benson D. and McDougall L. (1991). *Rare Bushland Plants of Western Sydney*. Royal Botanic Gardens, Sydney.

Berger J. (1990). *Persistence of different-sized populations: an empirical assessment of rapid extinctions in Bighorn Sheep. Conserv. Biol.* **4**: 91-8.

Bishop K.A. (1989). *A Preliminary Summer Survey of the Fish Communities of the Wingecarribee River, Hawkesbury River system, New South Wales*. Report to the Metropolitan Waster Sewage and Drainage Board, Sydney.

Bishop K.A. (1993). *Woronora Reservoir Proposed Water Quality Treatment Plant, Freshwater Fish Study: Woronora River downstream*. Study undertaken for Mitchell McCotter Associates on behalf of the Metropolitan Water Sewage and Drainage Board, Sydney.

Bishop K.A. (1995a). *Review of Existing Water Quality and Land/Water Use Data from the Karuah River Catchment: Prerequisite for the Development of Strategic Water Quality Monitoring*. Study undertaken for the River Management Subcommittee of the Karuah/Great Lakes Total Catchment Management Committee.

Bishop K.A. (1995b). *Hastings District Water Supply Augmentation EIS: Aquatic Ecology Study for the Intake Pump Station Upgrading at Kore Island*. Study undertaken for Connell Wagner Pty Ltd on behalf of the Department of Public Works and Hastings Municipal Council.

Blakers M., Davies S.J.J.F. and Reilly P.N. (1984). *The Atlas of Australian Birds*. RAOU and Melbourne University Press, Carlton.

Blomberry A. and Maloney B. (1992). *The Proteaceae of the Sydney Region*. Kangaroo Press, Kenthurst.

Blyth J.D. and Jackson P.D. (1985). The aquatic habitat and fauna of East Gippsland, Victoria. *Aust. Soc. Limnol. Bull.*, 10: 89-109.

Boudreau G.W. (1968). Alarm sounds and responses of birds and their application in controlling problem species. *The Living Bird* 7: 27-46.

Braithwaite L.W., Dudzinski M.L. and Turner J. (1983). Studies on the arboreal marsupial fauna of eucalypt forests being harvested for woodpulp at Eden, NSW III: Relationship between the fauna density, richness and diversity, and measured variables of the habitat. *Aust.Wildl.Res.* 10: 231-47.

Briggs J. and Leigh J. (1995). *Rare or Threatened Australian Plants.* CSIRO, Canberra.

Brough T. (1968). Recent Developments in Bird Scaring on Airfields. In: R.K. Murton & E.N. Wright (eds), *The Problems of Birds as Pests.* Academic Press, London.

Bryant S. (1991). *The Ground Parrot,* Pezoporus wallicus, *in Tasmania: Distribution, Density and Conservation Status.* Scientific Report 91/1, Parks, Wildlife and Heritage.

Burchmore J.J. (1988). *Preliminary survey of the fisheries resources of the upper Wingecarribee River.* Fisheries Research Institute, Cronulla.

Burchmore J.J. (ed) (1993). *Freshwater habitat management guidelines.* NSW Fisheries, 1993 Edition.

Calaby J.H. (1966). *Mammals of the Upper Richmond and Clarence Rivers, New South Wales.* Technical Paper No. 10, CSIRO Division of Wildlife Research: Canberra.

Campbell I.C. and Doeg T.J. (1989). Impact of timber harvesting and production on streams: a review. *Aust. J. Mar. Freshwater Res.* 40: 519-39.

Catling P.C. (1991). Ecological effects of prescribed burning practices on the mammals of south-eastern Australia. In: Lunney D (Ed.). *Conservation of Australia's Forest Fauna* pp. 353-363. Royal Zoological Society of NSW, Sydney.

Cheal P.D., Day J. and Meredith C. (1979). *Fire in the National Parks of North-west Victoria.* National Parks Service, Melbourne.

Chessman B.C. (1995). Rapid assessment of rivers using macroinvertebrates: A procedure based on habitat specific sampling, family level identification and a biotic index. *Aust. J. Ecol.*, 20: 122-129.

Chessman B.C. and Growns J. (1994). *Williams River macroinvertebrate study*. Report prepared for the Hunter Water Corporation and the Hunter Management Trust, Australian Water Technologies Ensight, Report No. 94/84, December 1994.

Christensen P.E.S. and Kimber, P. (1975). Effects of prescribed burning on the flora and fauna of northwest Australian forests. *Proc. Ecol. Soc. Aust. 9:85-107.*

Claridge A.W., Tanton M. and Cunningham R.B. (1993). Hypogeal fungi in the diet of the Long-nosed Potoroo (*Potorous tridactylus*) in mixed-species and regrowth eucalypt forest stands in South-eastern Australia. *Wildlife Research* 20: 321-37.

Close R. (1992). Report to Campbelltown Council on fauna on Lots 11 and 12 DP207 295 Wedderburn Road and Lot 190.191 DP713609 and Lot 7DPP 258769 O'Hares Road Wedderburn.

CMPS&F Environmental (1995). *Gloucester and Chichester Management Areas Environmental Impact Statement, supporting document No.2, Hydrology and Water Quality*. Report prepared for the Forestry Commission of NSW, November 1995.

Coalition of Liberal and National Parties (1996), *Putting People First, Coalition Policy on Sydney Airport and Sydney West Airport,* Commonwealth of Australia, Canberra.

Cogger H.G. (1996). *Reptiles and Amphibians of Australia*. Reed, Chatswood, New South Wales.

Cogger H.G., Cameron E.E., Sadlier R.A. and Eggler P. (1993). *The Action Plan for Australian Reptiles.* Australian Nature Conservancy Agency Endangered Species Program. Project No. 124.

Coulson, G (1989). The effect of drought on road mortality of macropods. *Aust. Wild. Res.* **16:** 79-83.

Crome F. and Shields J. (1992). *Parrots and Pigeons of Australia*. The National Photographic Index of Australian Wildlife. Angus and Robertson, Sydney.

Dames and Moore (1983). *East Hills - Campbelltown Railway*. Environmental Impact Statement. Report prepared for the State Rail Authority of New South Wales.

Dames and Moore (1990). *Assessment of the Importance of Vertebrate Fauna for the Planning of the Urbanisation of South Creek.* Report prepared for Travis Partners Pty. Ltd., February 1990.

Dames and Moore (1991). *Land Capability appraisal, Holsworthy Military Area.* Report to Australian Property Group, October 1991.

Dames and Moore (1993). *Environmental Management Plan: Holsworthy Land Purchase adjacent to Wattle Grove Development.* Report prepared for Delfin Management Services Pty. Ltd., June 1993.

Davey S.M. (1993). Notes on the habitat of four Australian owl species. In: Olsen P.D. (Ed) *Australian Raptor Studies.* Australasian Raptor Association, RAOU, Melbourne.

Debus S.J.S. and Rose A.B. (1994). The Masked Owl *Tyto novaehollandiae* in New South Wales. *Australian Birds Supplement* 28: 540.

Debus S.J.S., Ford H.A. and Recher H.F. (in prep.). Conservation status and management of large forest owls in northern New South Wales, Australia. *Pacific Conservation Biology.*

Department of Transport and Regional Development (1996), *Location and Development of the Second Sydney Airport, The Proposal,* 5 August 1996, Sydney West Airport Taskforce, Canberra.

Don Fox Planning Pty. Ltd. (1994). *Liverpool Rural Lands Study.* Report prepared for Liverpool City Council, May 1994.

Dufty S. (1986). *Genetic and morphological divergence between populations of Macquarie perch* (Macquaria australasica) *east and west of the Great Dividing Range.* BSc (Hons) thesis, University of New South Wales, Sydney.

DWR (1987). *Wild and scenic rivers in New South Wales, Report No.1, identification, classification and inventory.* Report prepared by Cameron McNamara Consultants for NSW Department of Water Resources, November 1987.

Dwyer P.D. (1965). The breeding biology of *Miniopterus schreibersi blepotis* (Temminck) (Chiroptera) in north-eastern New South Wales. *Aust. J. Zool.* 11: 219-40.

E.S. and S. Consultants Pty. Ltd. (1976). *Georges River Regional Open Space Study, Campbelltown.* Report to Campbelltown City Council.

Ecotone Ecological Consultants (1994). *Flora and Fauna Report.* In: Don Fox Planning Pty Ltd. *Liverpool Rural Lands Study.* Liverpool City Council.

Ecotone Ecological Consultants (1994). *Natural Areas Assessment for Liverpool Rural Lands Survey.* Report prepared for Liverpool City Council.

Ecotone Ecological Consultants (1995). *Fauna survey of Gloucester and Chichester Management Areas.* Ecotone Ecological Consultants, Waratah, NSW.

EDAW/Biosis Research (1996). *Voyager Point: Koala Habitat Assessment.* Report to Delfin Management Services Pty. Ltd., July 1996.

Ehmann H., Swan G. and Smith B. (1991). Nesting, egg incubation and hatching by the Heath Monitor *Varanus rosenbergi* in a termite mound. *Herpetofauna* 21(1): 17-24.

Environmental Management and Planning Services Pty Ltd (1995). *Aquatic environmental surveys, Karuah River catchment New South Wales, August 1995 Survey.* Report to CIM Resources, December 1995.

Emison W.B., Beardsell S.M., Norman, F.I., Loyn R.H. and Bennett S.C. (1987). *Atlas of Victorian Birds.* Department of Conservation, Forests and Lands, Victoria and Royal Ornithologists Union, Melbourne.

Engel D. (1994a). *Fauna survey of Voyager Point, Liverpool, New South Wales.* A joint report to Liverpool City Council and NSW Department of Education by Lesryk Contractors and Georges River Education Centre, February 1994.

Engel D. (1994b). *Fauna Survey of both Anzac Creek, Holsworthy, and the Headwaters of Mill Creek, Lucas Heights.* Joint report by Lesryk Environmental Consultants and Georges River Education Centre, December 1994.

Engel D. (1995). *Amphibian and Microchiropteran Survey, Henry Lawson Drive between the River Road and west of the Sydney South Electricity Substation.* Report prepared by Lesryk Environmental Consultants, November 1995.

Engel D. (1996a). *Fauna Assessment of Proposed Road Works along Three Sections of Heathcote Road, between Lucas Heights and the Holsworthy Military Establishment.* Report prepared for the Roads and Traffic Authority, January 1996.

Engel D. (1996b). *Supplementary Report relating to the Amphibian and Microchiropteran Survey, Henry Lawson Drive between the River Road and west of the Sydney South Electricity Substation.* Report prepared by Lesryk Environmental Consultants, February 1996.

Engel D. (1996c). *Fauna Assessments of Five Locations within the Liverpool Local government Area.* Report to Campbelltown City Council, June 1996.

Engel D. and Chafer C.J. (1994). *Vertebrate Fauna Assessment of Mill Creek Catchment, West Menai.* Report prepared for The Georges River Catchment Management Committee, June 1994.

Environment Protection Authority (1993). *New South Wales State of the Environment.* Environment Protection Authority, Chatswood.

Environment Protection Authority NSW (1994). *Water quality, Hawkesbury-Nepean River system, June 1990 to June 1993.*

ERM Mitchell McCotter (1996a). *Voyager Point Threatened Species Assessment.* Report for Delfin Management Services, October 1996.

ERM Mitchell McCotter (1996b). *Threatened Species Assessment: Wattle Grove Stage 16C.* Report for Delfin Management Services, October 1996.

ERM Mitchell McCotter (1996c). *Picton Regional Sewerage Scheme, Environmental Impact Statement.* Volumes 1 and 2. Statement produced for Sydney Water Corporation, January 1996.

Essory C. (1995). Discussion Session IV: Water Quality Issues. In: Brierley G. and Nagel F. (eds). *Geomorphology and river health in New South Wales.* Working Paper 9501, Graduate School of the Environment, Macquarie University.

Fairley A. and Moore P. (1989). *Native Plants of the Sydney District: An Identification Guide.* Kangaroo Press, Kenthurst.

Fanning D. (1995). *Fauna survey and Impact Statement of Residential Development, Warabin Street, Waterfall.*

Fanning F.D. and Dodson J.R. (1989). *Nepean Dam Flood Protection Measures, Assessment of Impacts on Fauna and Flora, Supplementary Environmental Surveys.* A report to the Water Board, Sydney.

Fanning F.D. and Leonard G. (1996). *Holsworthy Sewerage Scheme Fauna and Flora Assessment.* Report submitted to Sinclair Knight Merz and Sydney

Water Corporation for Proposed Holsworthy Sewerage Scheme Transfer Environmental Impact Statement. June 1996.

Felton S. (1993). *The Distribution, Abundance and Seed Ecology of the Rare Plant* Melaleuca deanei. *BEnvSc (Hons)* thesis, University of Wollongong.

Ferraro T.J. and Burgin S. (1993a). A review of environmental factors influencing the decline of Australian frogs. In: D. Lunney D. & Ayers D. (eds). *Herpetology in Australia: a Diverse Discipline.* Royal Zoological Society of New South Wales: Mosman.

Ferraro T.J. and Burgin S. (1993b). Amphibian decline: a case study in western Sydney. In: Lunney D. and Ayers D. (eds) *Herpetology in Australia: a Diverse Discipline.* Royal Zoological Society of New South Wales: Mosman.

Ferrier S., Shields J., Lemckert F., Wilson P., Mackowski M. and Saxon M. (1993). *Fauna Impact Statements - A Standard Methodology for Surveying Endangered Species.* A joint report for the National Parks and Wildlife Service and NSW Forestry Commission.

Forestry Commission of New South Wales (1993). *Fauna Impact Statement June-July 1993 - Proposed Forestry Operations in Hardwood Forests of the Walcha Area.*

French K., Henderson M. and Pellow B. (1995). *Holsworthy Military Training Area. Vegetation Survey.* Janet Cosh Herbarium, Dept of Biological Sciences, University of Wollongong.

Garnett S. (1992). *Threatened and Extinct Birds of Australia.* R.A.O.U. Report No. 82. York Press, Richmond.

Gehrke P.C. and Harris J.H. (1996). *Fish and fisheries of the Hawkesbury-Nepean River system.* Final report to the Sydney Water Corporation. Co-operative Research Centre for Freshwater Ecology and NSW Fisheries Research Institute, May 1996.

Gibbons P. (1994). Sustaining key old-growth characteristics in native forests used for wood production: retention of trees with hollows. In: Norton T.W. and Dovers S.R (eds) *Ecology and Sustainability of Southern Temperate Ecosystems* Chapter 5.

Gillespie G.R. (1990). Distribution, habitat and conservation status of the Giant Burrowing Frog, *Heleioporus australasicus* (Myobatrachidae), in Victoria. *Vic. Nat.* 107: 144-51.

Goldingay R.L. and Kavanagh R.P. (1986). Detectability of the Feathertail Glider, *Acrobates pygmaeus* (Marsupialia: Burramyidae), in relation to measured weather variables. Aust. Mammal. 11:67-70.

Goldingay R.L. (1987). Sap feeding by the marsupial, *Petaurus australis*: an enigmatic behaviour? *Oecologia (Berlin)* 73: 154-158.

Goldingay R.L. (1990). The foraging behaviour of a nectar feeding marsupial, *Petaurus australis*. *Oecologia (Berl.)* 85: 191-99.

Goldingay R.L. and Kavanagh R.P. (1991). *The yellow-bellied glider: a review of its ecology, and management considerations.* In Lunney D. (Ed.) *Conservation of Australia's Forest Fauna*. pp365-75. Royal Zoological Society of New South Wales, Mosman.

Gordon N.D., McMahon T.A. and Finlayson B.L. (1992). *Stream hydrology, an introduction for ecologists.* John Wiley and Sons, New York.

Green B. and King D. (1993). *Goanna. Biology of varanid lizards.* New South Wales University Press, Sydney.

Gullan P.K. (1978). Vegetation of the Royal Botanic Gardens Annexe at Cranbourne, Victoria. *Proc. R. Soc. Vic.* 70: 225-240.

Gullan P.K., Walsh N.G. and Forbes S.J. (1981). Vegetation of the Gippsland Lakes catchment. *Muelleria* 4: 333-383.

Gunninah Consultants (1995). Upgrading of Elizabeth Drive; fauna and flora assessment. Report prepared for Western Sydney Orbital study.

Hall L.S and Richards G.C. (1979). *Bats of Eastern Australia.* Queensland Museum booklet No. 12, Brisbane.

Hall L.S., Young R.A. and Spate A.P. (1975). *Roost selection of the eastern horseshoe bat* Rhinolophus megaphyllus. Australian Speleological Federation. Proceedings 10th Biennial Conference pp47-56.

Harden G. (ed) (1990). *Flora of New South Wales Vol 1.* NSW University Press, Kensington.

Harden G. (ed) (1991). *Flora of New South Wales Vol 2.* NSW University Press, Kensington.

Harden G. (ed) (1992). *Flora of New South Wales Vol 3.* NSW University Press, Kensington.

Harden G. (ed) (1993). *Flora of New South Wales Vol 4.* NSW University Press, Kensington.

Hardwick R., Chessman B. and Growns J. (1995). *Gloucester and Chichester Management Areas Environmental Impact Statement, supporting document No.3, Aquatic Environment Report.* Report prepared for the Forestry Commission of NSW, October 1995.

Harlow P. and Taylor J. (1995). *Reptile and frog survey of O'Hares Creek Catchment, Wedderburn, N.S.W.* Report to National Parks Association of NSW Inc., Macarthur Branch.

Harris J.H. (1985). Diet of the Australian bass, *Macquaria novemaculeata* (Perciformes: Percichthyidae), in the Sydney basin. *Aust. J. Mar. Freshwat. Res.* 36: 219-34.

Hazelton P. and Tille P. (1990). *Soil Landscapes of the Wollongong-Port Hacking 1:100 000 Sheet.* Soil Conservation Service of NSW, Sydney.

Heatwole H., de Baray J., Webber P. and Webb G. (1995). Faunal survey of New England. IV. The Frogs. *Memoirs of The Queensland Museum* 38(1): 229-249.

Heemstra S. (1994). *Classification and Assessment of Vegetated Land of Western Sutherland Shire.* BSc(Hons) Thesis, School of Geography, University of New South Wales.

Hellawell J.M. (1986). *Biological indicators of freshwater pollution and environmental management.* Elseveir App. Sci. Pub., London.

Hill F.A.R. (1991). *A research recovery plan for the Brush-tailed Rock-wallaby Petrogale penicillata penicillata (Gray 1825), in south-eastern Australia.* Unpublished report to the Australian National Parks and Wildlife Service, Department of Conservation and Environment, Victoria.

Hill K. and Johnson L. (1995). Systematic studies in the eucalypts. 7. A revision of the bloodwoods, genus *Corymbia* (Myrtaceae). *Telopea* 6(2-3): 185-504.

Hogg I.D. and Norris R.H. (1991). Effects of runoff from landclearing and urban areas on the distribution and abundance of macroinvertebrates in pool areas of a river. *Aust. J. Mar. Freshwater Res.* 42: 507-18.

Hoy G. (1993). *Report on a preliminary survey for bats of a site at Wedderburn, New South Wales.* Report prepared for Antcliff Ecological Surveys, March 1993.

Hume I.D. (1990). Biological basis for the vulnerability of Koalas to habitat fragmentation. In: Lunney D., Urquharts C.A. and Reed P. (eds). *Koala Summit Managing Koalas in NSW.* National Parks and Wildlife Service Sydney. pp: 32-35.

Hutchinson M.N., Donnellan S.C., Bavistock P.R., Krieg M, Simms S and Burgin S. (1990). Immunological relationships and generic revision of the Australian lizards assigned to the genus *Leiolopisma* (Scincidae: Lygosominae). *Aust. J. Zool.* 38: 535-554.

Hynes H.B.N. (1970). *The ecology of running waters.* Liverpool University Press, Liverpool, 555 pp.

International Union for the Conservation of Nature and Natural Resources (1994). *1994 IUCN Red List of Threatened Animals.* Geneva.

Jackson P.D. (1994). *Australian threatened fishes - 1994 supplement.* ASFB Neslet. 24: 18-26.

Jackson P.D. (1995). *Australian threatened fishes - 1995 supplement.* ASFB Newslet. December 1995: 30-34.

Joblin K.P.W. (1983). *Behaviour and ecology of the Brushtailed Rock Wallaby,* Petrogale penicillata, *in the New England region.* Unpublished M.Nat.Res. thesis, University of New England, Armidale.

Johnson G. and Baker-Gabb D. (1994). The Bush Thick-knee in Northern Victoria (part 1): conservation and management. *ARIER Tech. Rep. Ser.* 129: 1-52.

Jones P.R.F. (1991). A *preliminary study of post-logging recovery by aquatic macroinvertebrates and stream sediments in the Karuah hydrology research catchments.* University of Technology (Dept. of Applied Biology), Sydney.

Kavanagh R.P. (1984). Seasonal changes in habitat use by gliders and possums in South-eastern NSW. In: Smith A.P. and Hume I.D. (Eds) *Possums and Gliders.* Australian Mammal Society, Sydney.

Kavanagh R.P. (1987). Forest phenology and its effect on foraging behaviour and selection of habitat by the Yellow-bellied Glider, *Petaurus australis* Shaw. *Aust. Wildl. Res.* 14: 371-84.

Kavanagh R.P. (1988). The impact of predation by the Powerful Owl, *Ninox strenua*, on a population of the Greater Glider, *Petauroides volans. Aust J. Ecol.* 13: 445-450.

Kavanagh R.P. (1990). *Survey of Powerful and Sooty Owls in south-eastern New South Wales.* Final Report to the World Wildlife Fund. Project 120.

Kavanagh R.P. (1991). *The target species approach to wildlife management: gliders and owls in the forests of south eastern New South Wales.* In Lunney D. (ed) *Conservation of Australia's Forest Fauna.* The Royal Zoological Society of New South Wales, Sydney. pp 377-384.

Kavanagh R.P. and Peake P. (1993). Distribution and habitats of nocturnal forest birds in south-eastern New South Wales. In: Olsen P.D. (ed) *Australian Raptor Studies.* Australasian Raptor Association, RAOU, Melbourne.

Keast A. (1995). Habitat loss and species loss: the birds of Sydney 50 years ago and now. *Australian Zoologist* Vol 30 (1): 3-25.

Keith D. (1994). Floristics, structure and diversity of natural vegetation in the O'Hares Creek Catchment, south of Sydney. *Cunninghamia* 3(3): 543-94.

Kennedy M. (1992). *Australasian Marsupials and Monotremes. An Action Plan for their Conservation.* IUCN/SCC Australian Marsupial and Monotreme Specialist Group, Gland. Switzerland.

Kent M. and Coker P. (1995). *Vegetation Description and Analysis: A Practical Approach.* John Wiley and Sons, Chichester.

Kevin Mills and Associates (1986). *Flora and Fauna Survey Wedderburn Coal Project Area, Wedderburn, New South Wales.* A report prepared for Kembla Coal and Coke Pty. Ltd., October 1986.

Kevin Mills and Associates (1988). *Vegetation Survey and Fauna Assessment of Proposed No. 4 Shaft Area, West Cliff Mine Area Three Development.* A report prepared for Kembla Coal and Coke Pty. Ltd., January 1988.

Kevin Mills and Associates (1989). *Fauna Survey and Assessment, Kembla Coal and Coke Pty. Ltd., Western Reserves Development Option.* A report prepared for Kembla Coal and Coke Pty. Ltd., August 1989.

Kevin Mills and Associates (1990a). Investigation of the Significant Plant Species *Bossiaea buxifolia, Chorizema parviflorum, Dillwynia parvifolia* and *Persoonia nutans* at Pleasure Point, East Hills. Report prepared for Sinclair Knight.

Kevin Mills and Associates (1990b). *Flora and Fauna Survey and Assessment, Amended Coal Conveyor Route, Western Reserves Development Option, O'Hares Creek Catchment.* A report prepared for Kembla Coal and Coke Pty. Ltd., August 1990.

Kinhill Engineers (1994). *Review of Environmental factors: proposed flood mitigation works for South Creek.* Report prepared for Liverpool City Council.

Kinhill Stearns (1985), *Second Sydney Airport, Site Selection Programme, Draft Environmental Impact Statement*, Kinhill Stearns and the Department of Aviation.

Kinnear J.E., Onus M.L. and Bromilow R.N. (1988). Fox control and rock-wallaby population dynamics. *Aust. Wildl. Res.* 15: 435-50.

Koehn J.D. and O'Conner W.G. (1990). *Biological information for management of native freshwater fish in Victoria.* Victorian Government Printing Office on behalf of the Freshwater Fish Management Branch, Department of Conservation and Environment, Melbourne.

Koehn J.D., O'Conner W.G. and O'Mahony D. (1991). *The effects of sediments on fish.* Australian Society for Limnology, Abstracts for the 1991 conference held at Lorne, July 12-15th.

Kroodsma R.L. (1982). Edge effect on breeding forest birds along a powerline corridor. *J. Appl. Ecol.* 19: 361-70.

Lande R. (1988). Genetics and demography in biological conservation. *Science* **241**: 1455-9.

Lande R. and Barrowclough G.F. (1987). *Effective population size, genetic variation and their use in population management.* In: Soule M.E. (ed), *Viable Populations For Conservation* pp. 87-123. Cambridge University Press, Cambridge.

Lamb D., Turnbull M.H. and Meyers N. (1993). *Eastern Bristlebird Habitat Assessment.* University of Queensland, Brisbane.

Landscope (1995). *Vegetation Survey of Three Sites along Heathcote Road.* Unpublished report prepared for Roads and Traffic Authority.

Law B.S. (In prep.). The Lunar Influences Time of Roost Departure in The Common Blossom Bat *Syconycteris australis.* Unpublished manuscript.

Lee A.K. and Martin R. (1988). *The Koala - A Natural History.* NSW University Press, Sydney.

Leigh J. and Briggs J. (1992). *Threatened Australian Plants. Overview and Case Studies.* ANPWS, Canberra.

Leishman A.J. (1994). The birds of Humewood/Beulah Forest, Campbelltown, NSW. *Australian Birds.* 28(1): 14-26.

Leishman A.J. (1996). *The Birds of Mount Annan Botanic Garden.* Royal Botanic Garden, Sydney.

Lindenmeyer D.B. (1994). Timber harvesting in the montane ash forests of the Central Highlands of Victoria: Impacts at different spatial scales on arboreal marsupials and the implications for ecologically sustainable forest use. In: Norton T.W. and Dovers S.R. (eds). *Ecology and Sustainability of Southern Temperate Ecosystems.* Chapter 3: pp31-.

Llewellyn L.C. (1983). *The distribution of fish in New South Wales.* Australian Society for Limnology, Special Publication No. 7.

Loyn R.H. (1985). *Ecology, distribution and density of birds in Victorian forests.* In: Keast A., Recher H. F., Ford H. and Saunders D (eds) *Birds of the Eucalypt Forests and Woodlands: Ecology, Conservation and Management.* Surrey Beatty and Sons, Chipping Norton, Sydney, pp33-46.

Lumsden L.F. and Menkhorst P.W. (1995). *Large-footed Myotis.* In: Menkhorst P.W. (ed). *Mammals of Victoria.* Oxford University Press, Australia.

Lunney D. and Leary T. (1988). The impact on native mammals of land-use changes and exotic species in the Bega district, NSW since settlement. *Australian Journal of Ecology* 13: 67-92.

Lunney D., Law B. and Rummery C. (in press). An ecological interpretation of the historical decline of the Brush-tailed Rock-wallaby *Petrogale penicillata* in New South Wales. *Aust. Mamm.* 00: 000-000.

Lunney D., Urquhart C.A. and Reed P. (1990). *Koala Summit: Managing Koalas in New South Wales.* Proc. of the Koala Summit, University of Sydney, 7-8 November 1988. NSW National Parks and Wildlife Service, Sydney.

Mackey R.L. and Barclay R.M.R. (1989). The influence of physical clutter and noise on the activity of bats over water. *Can. J. Zool.* 67:1167-1170.

Mackowski C.M. (1984). The ontogeny of hollows in Blackbutt (*Eucalyptus pitularis*) and its relevance to the management of forests for possums, gliders and timber. In: Smith A.P. and Hume I.D. (eds). *Possums and Gliders.* Australian Mammal Society, Sydney.

Mackowski C.M. (1988). Characteristics of eucalypts incised for sap by the Yellow-bellied Glider, *Petaurus australis* Shaw (Marsupialia:Petauridae) in Northeastern NSW. *Aust. Mammal.* 11: 5-13.

Mahony M.J. (1993). The status of frogs in the Watagan Mountains area the central coast of New South Wales. In: D. Lunney and D. Ayers. (eds). *Herpetology in Australia: a Diverse Discipline*. Royal Zoological Society of New South Wales: Mosman.

Mansergh I.M. (1984). The status, distribution and abundance of Tiger Quoll (*Dasyurus maculatus*) in Victoria. *Australian Zoology* 21: 109-122.

Maxwell, S., Burbidge, A.A. and Morris, K. (1996), *The 1996 Action Plan for Australian Marsupials and Monotremes*, Wildlife Australia, Canberra.

McDowall, R.M. (1996). *Freshwater fishes of south-eastern Australia*. Reed books, Sydney.

McFarland D.C. (1989). *The Ground Parrot* Pezoporus wallicus wallicus *(Kerr) in Queensland: Habitat, Biology and Conservation*. Division of Conservation, Parks and Wildlife, Department of Environment and Conservation.

Menkhorst P.W. and Collier M. (1987). Diet of the Squirrel Gliders, *Petaurus norfolcensis* (Marsupialia: Petauridae), in Victoria. *Aust. Mammal.* 11: 109-116.

Menkhorst P.W. (in press). Regent Honeyeater Recovery Plan 1994 - 1998. Department of Natural Resources and Environment, Melbourne.

Menkhorst P.W., Weavers B.W. and Alexander J.A.S. (1988). Distribution, Habitat and Conservation Status of the Squirrel Glider *Petaurus norfolcensis* (Petauridae: Marsupialia) in Victoria. *Aust. Wildl. Res.* 15: 59-71.

Meredith C., Mueck S., Delaney R., Smith L., Petch D., Williams L., Daly G., Leonard G. and Bishop K. (1995). *Eastern Gas Pipeline Project: Flora, Fauna and Ecology*. Draft Environmental Impact (Commonwealth), Environmental Impact Statement (New South Wales) and Environmental Effects Statement (Victoria). Report prepared for BHP and Westcoast Energy.

Meredith C.W., Gilmore A.M. and Isles A.C. (1984). The Ground Parrot (*Pezoporus wallicus* Kerr) in south-eastern Australia: a fire-adapted species? *Aust. J. Ecol.* 9: 367-380.

Merrick J.R. (1993). *Freshwater crayfishes of New South Wales*. Linnean Society of NSW, Sydney. 127pp.

Merrick J.R. (1993). *Freshwater fishes of south-eastern Australia*. Reed Books, Sydney.

Merrick J.R. and Rimmer M.A. (1984). *Reservoir fishes and water quality monitoring systems, baseline studies 1981-83*. Report to the Metropolitan Water Sewerage and Drainage Board, Sydney.

Milledge D., Palmer C. and Nelson J. (1991). Barometers of Change: the distribution of large owls and gliders in mountain ash forests of the Victorian Central Highlands and their potential as management indicators. In: Lunney D. (ed). *Conservation of Australia's Forest Fauna*. The Royal Zoological Society of NSW.

Mills K., Muston R., Sefton C. and Young A. (1985). *Environmental values of the Metropolitan Catchment Areas*. A submission to a study by MWSDB.

Minister for Transport and Regional Development (1996), *Media Release*, "Environmental Impact Statement for Holsworthy", 21 May, 1996.

Mitchell McCotter and Kevin Mills and Associates (1991). *Llandillo Flora Study*. Report prepared for CAA.

Mitchell P. (1990). The home ranges and social activity of Koalas - a quantitative analysis. In: A.K. Lee, K.A. Handasyde and G.D. Sanson (eds). *Biology of the Koala*. Surrey Beatty and Sons, Sydney. pp171-87.

Mitchell P. and Martin R. (1990). The structure and dynamics of koala populations - French Island in perspective. In: A.K. Lee, K.A. Handasyde and G.D Sanson. (eds). *Biology of the Koala*. Surrey Beatty and Sons, Sydney.

Moon C. (1990). Koala corridors: a case study from Lismore. In: Lunney D., Urquharts C.A. and Reed P. (eds). *Koala Summit: Managing Koalas in NSW*. NSW National Parks and Wildlife Service Sydney. pp87-.

Moore D.M. and Floyd A.G. (1994). *A Description of the Flora and an Assessment of Impacts of the Proposed Forestry Operations in the Grafton Forest Management Area*. SFNSW, Grafton.

Morris A.K., McGill A.R. and Holmes G. (1981). *Handlist of Birds in New South Wales*. New South Wales Field Ornithologists Club, Sydney.

Mount King Ecological Surveys (1990). *Hoxton Park Stage 2 Release Areas Vegetation Survey* (unpub.). Report prepared for Liverpool City Council.

Mount King Ecological Surveys (1996). *Habitat assessment of Stonequarry Creek and Nepean River for the proposed sewerage scheme for the Picton* *region: detailed assessment and fauna impact statement.* 15 February 1994 (Revision dated 28 November 1995).

Nash S. and Matthes M. (1995). *A Review of the Status of Five Rare Plants in the Cumberland Plain.* Australian Nature Conservation Agency Endangered Species Program.

National Parks and Wildlife Service (1995). *National Parks and Wildlife Service submission to SFNSW regarding the environmental impact statement on the proposed forestry operations in the Grafton Management Area.* Forest Conservation Unit, NSW. (unpublished report).

National Parks and Wildlife Service (1995). Wilderness - how wilderness is identified. NSW National Parks and Wildlife Service, Hurstville.

National Parks and Wildlife Service (unpublished). *Urban Bushland Biodiversity Study; Stage I.* Draft Flora Report.

National Parks and Wildlife Service (unpublished). *Urban Bushland Biodiversity Survey Western Sydney Stage 1.* Draft Fauna Report.

Newsome A.E., Catling P.C. & Corbett L.K. (1983). The feeding ecology of the dingo. II. Dietry and numerical relationships with fluctuating prey populations in south-eastern Australia. Australian J. Ecology. ***8: 345-366***

NSW Environment Protection Authority (1993). *Draft report on the analysis of data collected in the Williams River in July and August 1992.* Progress report to the Hunter Water Corporation, March 1993.

Odum E.P. (1971). *Fundamentals of ecology.* W.B. Saunders Co., London, 574 pp.

Osborne W.S. (1982). *Vertebrate faunal studies in the Washpool - Gibraltar region.* Unpublished report to the Australian Conservation Foundation and Total Environment Centre, Sydney.

Osborne W.S. (1990). *Frog population declines and extinctions in the A.C.T.* (Unpublished) M.S.

Owen G. (1991). *Catchment management issues in the Karuah basin - survey of community perceptions.* NSW State Management Coordinating Committee.

Parnaby H. (1992). *An Interim Guide to Identification of Insectivorous Bats of South-eastern Australia.* Technical Report No. 8, Australian Museum, Sydney.

Parnaby H. and Cherry K. (1992). *A Trapping Study of the Bat Fauna of Mountain Ash Plantations and Old Growth Forest of the Strzelecki Ranges,* Victoria. VSP Internal Report No.5 Department of Conservation and Natural Resources, Victoria.

Payne R. (1990). *Vegetation Survey of the main Wedderburn Plateau and minor creek systems.* Report prepared for Andrews Neil.

Peake P., Conole L.E., Debus S.J.S, McIntyre A. and Bramwell M. (1993). The Masked Owl *Tyto novaehollandiae* in Victoria. *Aust. Bird Watcher* 15: 124-36.

Perkins I. (1992). *Eastern Creek/Prospect/Horsley Park Corridor: Land and Management Plan for the Horsley Park Corridor.* Prepared for the NSW Department of Planning, and Greening Australia.

Phillips S. and Callaghan J. (1996). *Koala Habitat Atlas, Project No. 5: Campbelltown Local Government Area.* Draft report prepared for the Campbelltown City Council by The Australian Koala Foundation, August 1996.

Phillips S., Callaghan J., Parnaby H. and Fitzgerald M. (1996). *Wedderburn Fauna Planning Study.* Report prepared for the Campbelltown City Council by The Australian Koala Foundation, February 1996.

Pollard D.A. (1990). Threatened fishes in Australia - an overview. *J. Fish Biol.* 37: 67-78.

Pollard D.A. and Growns I.D. (1993). *The fish and fisheries of the Hawkesbury-Nepean River system, with particular reference to the environmental effects of the Water Board's activities on the system.* NSW Fisheries Research Institute Interim Report to the Water Board, April 1993.

Pollard D.A., Growns I.O., Pethebridge R.L. and Marsden T.J. (1994). *Hawkesbury-Nepean fish ecology study.* NSW Fisheries Research Institute, Six-monthly Report to the Water Board, May 1994.

Poore M. (1955). The use of phytosociological methods in ecological investigations. I. The Braun-Blanquet system. *Journal of Ecology* 43:226-44.

Prevett P.T., Hives N.W. and Cerini G.E. (1992). *Koala Protection and Fenced Freeways.* Report to VicRoads, Ballarat Bypass Project, Victoria.

Pryor L. (1981). *Australian Endangered Species: Eucalypts. Special Publication No 5.* Australian National Parks and Wildlife Service, Canberra.

QEM (1993). *Flora and Fauna Working Paper; Liverpool-Hornsby Highway Strategy Study* (unpub.). Report prepared for NSW Roads and Traffic Authority Department of Transport and Communications.

Quin B.R. and Baker-Gabb D.J. (1993). *Conservation and Management of the Turquoise Parrot Neophema pulchella in North-east Victoria*. Technical Report Series No. 125. Wildlife Branch DCNR, Victoria.

Ralls K., Ballou J.D. and Templeton, A. (1988). Estimates of Lethal Equivalents and the Cost of Inbreeding in Mammals. *Conserv. Biol.* 2: 185-193.

Reed P.C. and Lunney D. (1988). Habitat loss: the key problem for the long term survival of koalas in NSW. In: Lunney D., Urquharts C.A. and Reed P. (eds). *Koala Summit: Managing Koalas in NSW.* NSW National Parks and Wildlife Service Sydney.

Reed P.C., Lunney D. and Walker P. (1990). A 1986-1987 survey of the Koala *Phascolarctos cinereus* (Goldfuss) in NSW and an ecological interpretation of its distribution. In: A.K. Lee, K.A. Handasyde and G.D. Sanson. (eds). *Biology of the Koala*. Surrey Beatty and Sons, Sydney.P:55-57.

Richards G. (1992). *Fauna Survey, Wingham Management Area, Port Macquarie Region Part 4. Bats.* Forest Resources Series No. 22, Forestry Commission of NSW.

Richardson B.A. (1985). The impact of forest road construction on the benthic invertebrate and fish fauna of a coastal stream in southern New South Wales. *Aust. Soc. Limnol. Bull.*, 10: 65-88.

Robinson D. (1994). *Research Plan for Threatened Woodland Birds of Southeastern Australia*. Technical Report No. 133, Arthur Rylah Institute for Environmental Research, Melbourne.

Robinson L (1991). *Field Guide to the Native Plants of Sydney*. Kangaroo Press, Sydney.

Robinson N.H. (1985) *Mammals of the Metropolitan Water, Sewerage and Drainage Board Catchments.* General Technical Reports No. 3, Department of Biology, University of Wollongong, Wollongong.

Robinson N.H. (1987). *Mammals of the National Parks and Nature Reserves between Port Hacking and the Shoalhaven River.* Illawarra Heritage Committee, Wollongong.

Rowland S.J. (1988). *Murray cod.* N.S.W. Agriculture and Fisheries, AGFACT F3.2.4.

Rust PPK (1993). *Elizabeth Drive Landfill Proposal to Accept General Solid Waste. Environmental Impact Statement. Volume 2: Working Papers.* Report prepared for Department of Transport, September 1993.

Rust PPK (1995). *Elizabeth Drive Environmental Impact Statement: Upgrade of Elizabeth Drive form East of Mamre Road to Luddenham Road.* Report prepared for Pacific Waste Management, October 1995.

Rust PPK (1996). *Western Sydney Orbital: Prestons to Cecil Park, Sydney.* Environmental Impact Statement Main Report.

Ryder R.A. (1978). Fish yield assessment of large lakes and reservoirs - a prelude to management. In: S.D. Gerking (ed.). *Ecology of freshwater fish production.* Blackwell Scientific Publications, Oxford, 520 pp.

Sammut J. and Erskine W.D. (1995). Hydrological impacts of flow regulation associated with the upper Nepean Water Supply Scheme. *Australian Geographer* 26: 71-86.

Schedvin N. (1996) Where do the Regents Roam?. *Wingspan December 1996.*

Schodde R. and Mason I.J. (1980). *Nocturnal Birds of Australia*. Lansdowne, Melbourne.

Schodde R. and Tidemann C. (eds) (1986). *Readers Digest Complete Book of Australian Birds*. Second Edition. Readers Digest Services, Sydney.

Scotts D. (1991). Old-growth forests: their ecological characteristics and value to fores-dependent vertebrate fauna of south-east Australia. In: Lunney D. (ed). *The Conservation of Australia's Forest Fauna*. The Royal Zoological Society of NSW.

Scotts D. (1994). Sustaining sensitive wildlife within temperate forest landscapes regional systems of retained habitat as a planning framework. In: Norton T.W. and Dovers S.R. (eds) *Ecology and Sustainability of Southern Temperate Ecosystems*. CSIRO, Australia.

Second Sydney Airport Planners (1997a). *Draft Second Sydney Airport - Planning and Design Report.* Sydney.

Second Sydney Airport Planners (1997b). *Preliminary Flight Paths, Second Sydney Airport Proposal.*

Seebeck J.H., Bennett A.F. and Scotts D.J. (1989). Ecology of the Potoroidae - a review. In: Grigg G., Harmon P. & Hume I. (eds). *Kangaroos, Wallabies and Rat-kangaroos.* Surrey Beatty and Sons, NSW.

Senate Select Committee on Aircraft Noise in Sydney (1995), *Falling on Deaf Ears? Report of the Senate Select Committee on Aircraft Noise in Sydney*, Commonwealth of Australia.

SFNSW (1995). *Morisset Forestry District Environmental Impact statement Volume C Fauna Impact Statement.* State Forest of New South Wales.

Shea G.M. (1994). Three species of goanna in the Sydney basin. *Herpetofauna.* 24 (2): 14-18.

Sherwin W.B. and Murray N.D. (1990). Population and conservation genetics of marsupials. *Aust. J. Zool.*, **37**:161-80.

Shine R. (1983). Aboreality in snakes: ecology of the Australian elapid genus *Hoplocephalus. Copeia* 1983: 198-205.

Shine R., Webb J.K., Fitzgerald M. and Sumner J. (1995). *An ecological survey of the Broad-headed Snake,* Hoplocephalus bungaroides *(Serpentes: Elapidae).* Final Report to Endangered Species Unit, Australian Nature Conservancy and to Threatened Species Unit, NSW National Parks and Wildlife Service.

Short J. (1982). Habitat requirements of the brush-tailed rock-wallaby, *Petrogale penicillata*, in New South Wales. *Aust Wildl. Res.* 9: 239-46.

Sinclair Knight Merz (1994). *Environmental Impact Statement for the proposed Woronora Water Filtration Plant.* A report for the Water Board and the New South Wales Government.

Smith P. (1991). *The Biology and Management of Waders (Suborder Charadrii) in NSW.* NSW National Parks and Wildlife Service Species Management Report No. 9.

Smith P. and Smith J. (1994). *Significant wetlands of the Hawkesbury-Nepean River Valley.* Report to the NSW Department of Planning.

Speight J., Engel D. and Leonard G. (1996). *Proposed Widening of Henry Lawson Drive, Picnic Point. Flora and Fauna Assessment. Supplementary Report.* Report prepared for the Roads and Traffic Authority by Landscope Environmental Consultants, March 1996.

Speight J., Engel D., Leonard G and Thumm K. (1995). *Flora and Fauna Impact Assessment for Widening of Henry Lawson Drive between Sydney*

South Electricity Sub-station and River Road, Picnic Point. A report prepared for Roads and Traffic Authority, Sydney Region by Landscope Environmental Consultants, Bundeena.

Spencer P.B.S. (1991). Evidence of predation by a feral cat *Felix catus* (Carnivora: Felidae) on an isolated Rock-wallaby colony in tropical Queensland. *Aust. Mammal.* 14: 143-44.

State Forest of NSW (1995). *Morisset Forestry District Environmental Impact statement Volume C Fauna Impact Statement.*

State Pollution Control Commission (1980). *An atlas of classified waters in New South Wales.*

Strahan R. (ed) (1995). *The Mammals of Australia.* Australian Museum/Reed Books, Sydney.

Swan G. (1990). *A Field Guide to the Snakes and Lizards of New South Wales.* Three Sisters, Sydney.

Sydney Pre-history Group (1983). *In search of the Cobrakall: A survey of aboriginal sites in the Campbelltown area south of Sydney, Part 1.* NSW National Parks and Wildlife Service, Sydney.

Sydney Water and NSW National Parks and Wildlife Service (1997), *Woronora, O'Hares Creek and Metropolitan Special Areas, Draft Plan of Management*, Sydney Water Corporation Limited.

Traill B.J. (1991). Box-Ironbark forests: tree hollows, wildlife and management. In Lunney D. (ed.). *Conservation of Australia's Forest Fauna*, pp. 119-125. Royal Zoological Society of NSW, Sydney.

Traill B.J. (1994). *Resource partitioning and competition in a community of forest vertebrates. PhD* thesis, Department of Ecology and Evolutionary Ecology, Monash University.

Travers Morgan (1990). *The regional distribution of* Melaleuca deanei *and five plants occurring in West Menai and the Southern Sydney Region.* Report to the Department of Housing, Sydney.

Travers Morgan P/L and Andrews Neil (1990). *Western Sydney Recreation Area.* Report prepared for Department of Planning.

Triggs B (1996). *Tracks, Scats and Other Traces A Field Guide to Australian Mammals.* Oxford University Press, Melbourne.

Truyard Pty Ltd (1992). *Wingham Management Area Environmental Impact Statement - Proposed Forest Management.* Forestry Commission of New South Wales.

Tyler M.J. (1993). Frogwatch: to shun a silent spring. *Australian Natural History* 24(5): 22-29.

Tyler M.J. (1994). Frogs of western New South Wales. In: D. Lunney, S. Hand, P. Reed and D. Butcher (eds) *Future of the Fauna of western New South Wales.* Royal Zoological Society of New South Wales: Mosman.

United States Department of Agriculture and Forest Service (1992). *Effects of Overflying on Wildlife.* Report to Congress. US Department of Agriculture and Forest Service.

van Tets, G.F., Trounson A.D., Clampett M.C. (1979). *Readers Digest Complete Book of Australian Birds.* Readers Digest, Surry Hills.

Wagner R and Jackson. P.D. (1993). *The action plan for Australian freshwater fishes.* ANCA, Canberra.

Webb J.K. and Shine R. (1994). *Habitat use by the Broad-headed Snake,* Hoplocephalus bungaroides. Unpublished research report, University of Sydney.

Webster R. and Menkhorst P. (1992). The Regent Honeyeater (*Xanthomyza phrygia*):population status and ecology in Victoria and New South Wales. *Arthur Rylah Institute for Environmental Research Technical report Series* No. 126, Department of Conservation and Environment, Victoria.

White A. (1994). *Frog survey: Gloucester-Chichester Forestry Management Areas.* Unpublished report to State Forests, Biosphere Environmental Consultants.

White A. W. and Pyke, G. H. (1996). Distribution and conservation status of the Green and Golden Bell Frog *Litoria aurea* in NSW . *Australian Zoologist* 30(2): 177-189.

Whitehouse J.F. (1990). The role of NSW National Parks and Wildlife Service in koala conservation. In: Lunney D. Urquhart C.A. and Reed P. (eds) *Koala Summit: Managing Koalas in New South Wales.* Proc. of the Koala Summit, University of Sydney, 7-8 November 1988. NPWS, Sydney.

York A., Binns D. and Shields J. (1991). *Flora and Fauna Assessment in NSW State Forests. Procedures for sampling flora and fauna for environmental impact statements.* Version 1.1a. Forestry Commission of NSW. Sydney.

ADDENDUM

Significant Flora Species

Allocasuarina diminuta, a species of regional significance, is found within the Holsworthy Military Area and would potentially be adversely affected by airport development. It should be added to species listed in *Table 5.8* in this technical paper. Inclusion of this species increases the total number of regionally significant species within the Holsworthy Military Area from 65 (as stated in the technical paper) to 66. This species should also be referred to where relevant throughout *Appendix A*.

***Allocasuarina diminuta* LAS Johnson subsp *mimica* LAS Johnson**

Erect shrub to 1.5 metres, usually with several stems from the base. Branchlets are erect and glaucous and preferred habitats include heath, woodland and margins of sedge-swamps. Robinson (1990) describes the distribution of this species in the Sydney region as '..uncommon or rare..; restricted to a few small populations, one along Heathcote Road at Lucas Heights, one in woodland on the Appin-Bulli Road, and another in the Eastern suburbs..'. Harden (1990) also records occurrences at Bundanoon and Blackheath to Taralga.

This species was mainly recorded at Holsworthy in open heath stands, particularly in B and C Ranges. Option A would require removal of nearly all of these stands. No large populations would be affected in Option B.

This species has regional significance, in that no individuals were recorded by Keith (1994) in O'Hares Creek catchment, to the immediate south of the Holsworthy site, so the Holsworthy stands probably represent the western limit of the Heathcote/Lucas Heights population.

Significant Vegetation Community

The NSW Scientific Committee, established under the *Threatened Species Conservation Act, 1995* has made a final determination to list Cumberland Plains Woodland as and Endangered Community under Part 3 of Schedule 1 of the *Threatened Species Conservation Act*. Although remnant woodland surveyed at Badgerys Creek during the present study was not considered to be significant due to its small size and altered condition, this may need to be reviewed once significant criteria are clearly defined.

Significant Fauna Species

Schedules 1, 2 and 3 of the *Endangered Species Act, 1992* were revised as of 20 August 1997. The Tiger Quoll (*Dasyurus maculatus*) is now considered to be vulnerable (Schedule 2) at the National level. This has not been taken into account as it was not known during preparation of this technical paper.

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STUDY TEAM

The Biosis Research core study team comprised: Renata Bali, Mark Chidel, Robyn Delaney, Lance Williams, Jeff Yugovic, Carolyn Hall, Gary Leonard, Keith Bishop and Greg Gill. Botanical assistants included Alison Cook, Vanessa Allen, Suzanne Fyfe and Simon Heemstra Deryk Engel (Lesryk Environmental Consultants) and Jack Baker (Wollongong University) conducted specialist surveys targeting Broad-headed Snakes, Eastern Bristlebirds and Ground Parrots. Field assistance for fauna trapping was provided by Jeremy Pepper and Michelle Cousineau (Rust PPK). Debbie Saunders assisted with the editing.

Jason Anderson analysed bat tapes; Barbara Triggs undertook scat and hair analyses.

The project management team from Rust PPK included: Mark Keogh (Project Manager), David Gamble (Team Leader, Biological and Physical Environment), Michelle Cousineau (Biological and Physical Environment) and Karen Markwort (Team Leader, Planning, Land Use and Economics). Susan Crick, Rowena Lennings and Ann Shaw Rungie from the Community Consultation Team provided assistance with community consultation issues. Christine Gunn facilitated liaison with relevant government departments.

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Appendices

Appendix A

Flora

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1. APPENDIX A - FLORA

The flora and vegetation were surveyed, an inventory of plant species was compiled, searches were made for rare species, and observations were made on the composition, structure and condition of the vegetation. Vegetation of the Badgerys Creek and Holsworthy Military Area was mapped. Existing information was reviewed and incorporated into this study where relevant.

1.1 DATA COLLECTION

Fieldwork took place between 17 and 19 December 1996 (Badgerys Creek) and between 28 October and 12 December 1996 (Holsworthy).

A general survey (see York *et al.* 1991) was conducted in order to compile an inventory of the flora, delineate vegetation communities, map the vegetation and review previous studies.

Specific searches were made for rare or endangered flora species in locations identified by French *et al.* (1995) and other studies, as well as in similar habitats in other parts of the study area.

Thirty 20 x 20 m quadrats were taken at Holsworthy to supplement 73 quadrats taken by French *et al.* (1995). For each quadrat:

- Each species was assigned a cover-abundance measure on a modified Braun-Blanquet scale.

+	cover <5%, uncommon/rare
1	cover <5%, common
2	cover 5-20%; <5%, abundant
3	cover 20-50%
4	cover 50-75%
5	cover 75-100%

Quadrats 92-103 use 25% as 2-3 boundary (The widespread use in NSW of 20% as the 2-3 boundary is not in accord with the correct Braun-Blanquet value of 25% used elsewhere. The classification procedure uses presence/absence and is therefore not sensitive to such differences in the data which are not significant in any case).

- Location, altitude, aspect, topography and vegetation structure and condition were recorded.

Locations of quadrat sampling sites (Holsworthy) are shown in Figures A1 and A2.

Relevant data from the previous survey by French *et al.* (1995) has been incorporated in this study.

1.2 TAXONOMY

Plant taxonomy (naming) follows Harden (1990, 1991, 1992, 1993) with modifications in accordance with *Telopea*, the taxonomic journal of the National Herbarium of New South Wales. For example, bloodwoods are *Corymbia* rather than *Eucalyptus* (Hill and Johnson 1995). *Eucalyptus saligna* and *E. botryoides* hybridise extensively at Holsworthy; records of *E. saligna* refer to this hybrid swarm.

1.3 VEGETATION CLASSIFICATION

The vegetation of Badgerys Creek was classified according to the regional vegetation classification of the National Herbarium of New South Wales (Benson 1992), based on examination of vegetation in the field. Application of this classification was relatively straightforward.

The vegetation of the Holsworthy Training Area was considerably more complex and was accordingly classified using quadrat data. Classification took the form of an agglomerative, polythetic, numerical classification coupled with a hand sorting procedure (Gullan 1978, 1981). This produced a floristic (two-way) table, containing the raw data in sorted form displaying the composition and relationships of the identified vegetation communities(Table A1.1 contained in Appendix D).

1.3.1 Terminology

Terms used in the vegetation quadrat classification are briefly defined as follows:

Community

A community is a group of vegetation quadrats of similar floristic (species) composition. As in other vegetation classifications, including numerical classification procedures, the number of final groups (communities) is based on floristic and ecological grounds (Kent and Coker 1995).

Character species

A character species occurs frequently in the quadrats of a community (more than 50% of quadrats). It is a useful indicator of that community although it may not be restricted to that community.

Community name

A community name is a descriptive term applied to a community to convey an impression of its dominant species, structure and environment. Names of communities in this study are based on the National Herbarium's regional vegetation map units (Benson 1992, Benson and Howell 1994).

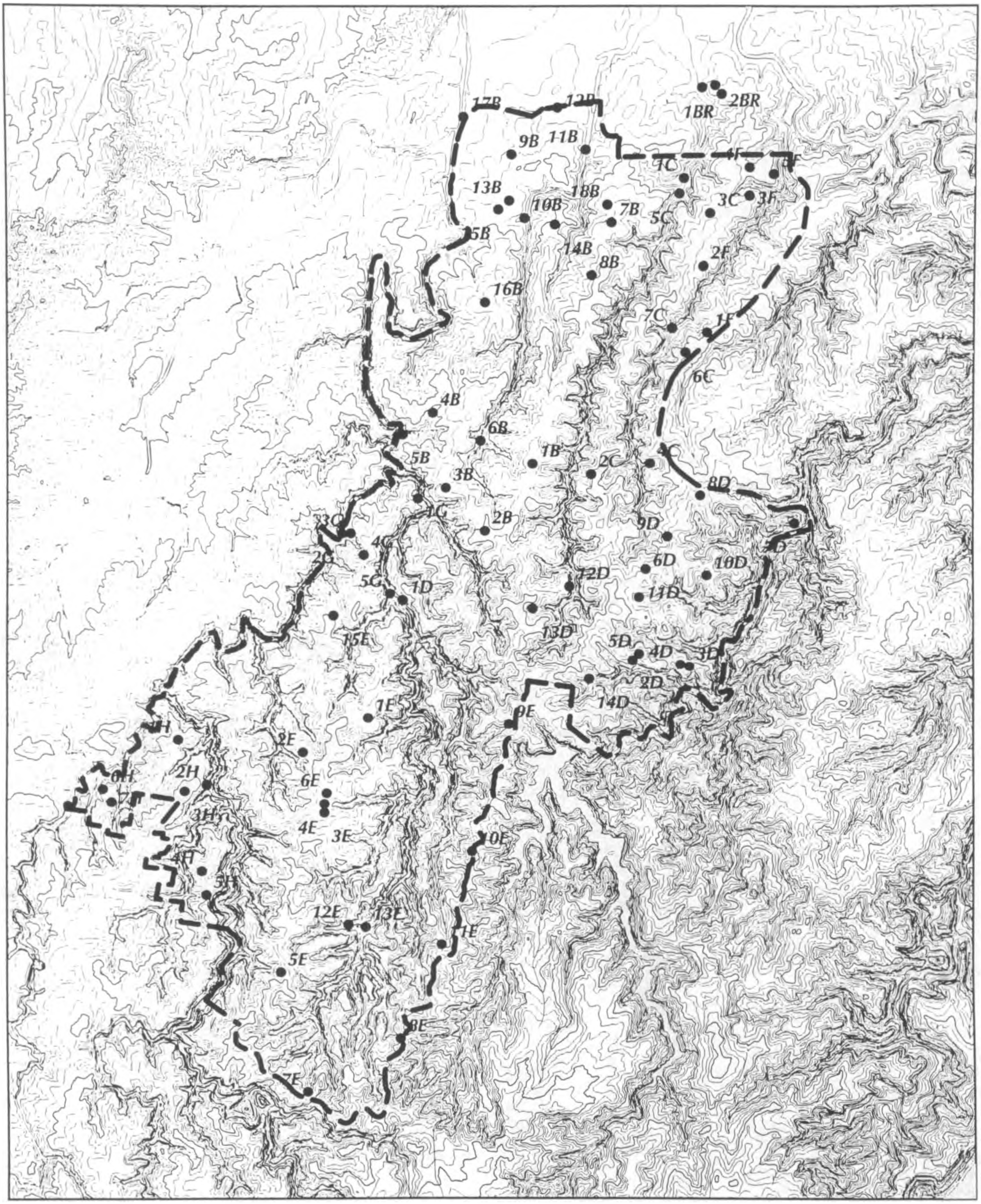
1.4 DEFINING SIGNIFICANT SPECIES AND COMMUNITIES

Assessment of conservation status, and hence significance, can be made at the individual species level and at the vegetation community level. A vegetation community may be significant due to depletion or other factors, even though it may contain no significant plant species.

A species is considered significant at one of these levels (for example at the regional level) if it is rare within that geographic context. A rare species is not necessarily threatened; it may be represented by a relatively large population in a restricted area or by smaller populations spread over a wider range.

A vegetation community (or group of related communities) is considered significant if it is rare or threatened within a particular geographic context. As for species, a hierarchy of national, state, regional and local levels of significance is used in assessing vegetation community significance.

The Endangered Species Protection Act (1992), Briggs and Leigh (1995) and Schedules 1 and 2 of the Threatened Species Conservation Act 1995 are used as authorities on plant species of national significance. There is no available listing of plant species that are rare in New South Wales; the personal knowledge and experience of G. Leonard is used to determine species of state significance. Benson and McDougall (1991), Benson (1992), Keith (1994) and Bofeldt (1996) are used as authorities on species and vegetation of regional significance. Two biogeographic regions are represented at Holsworthy: Coastal Sandstone Plateau, Cumberland Plain; Badgerys Creek lies entirely within the Cumberland Plain.



Legend

● Holsworthy Vegetation Survey Sites

Military Boundary

Rivers

Water

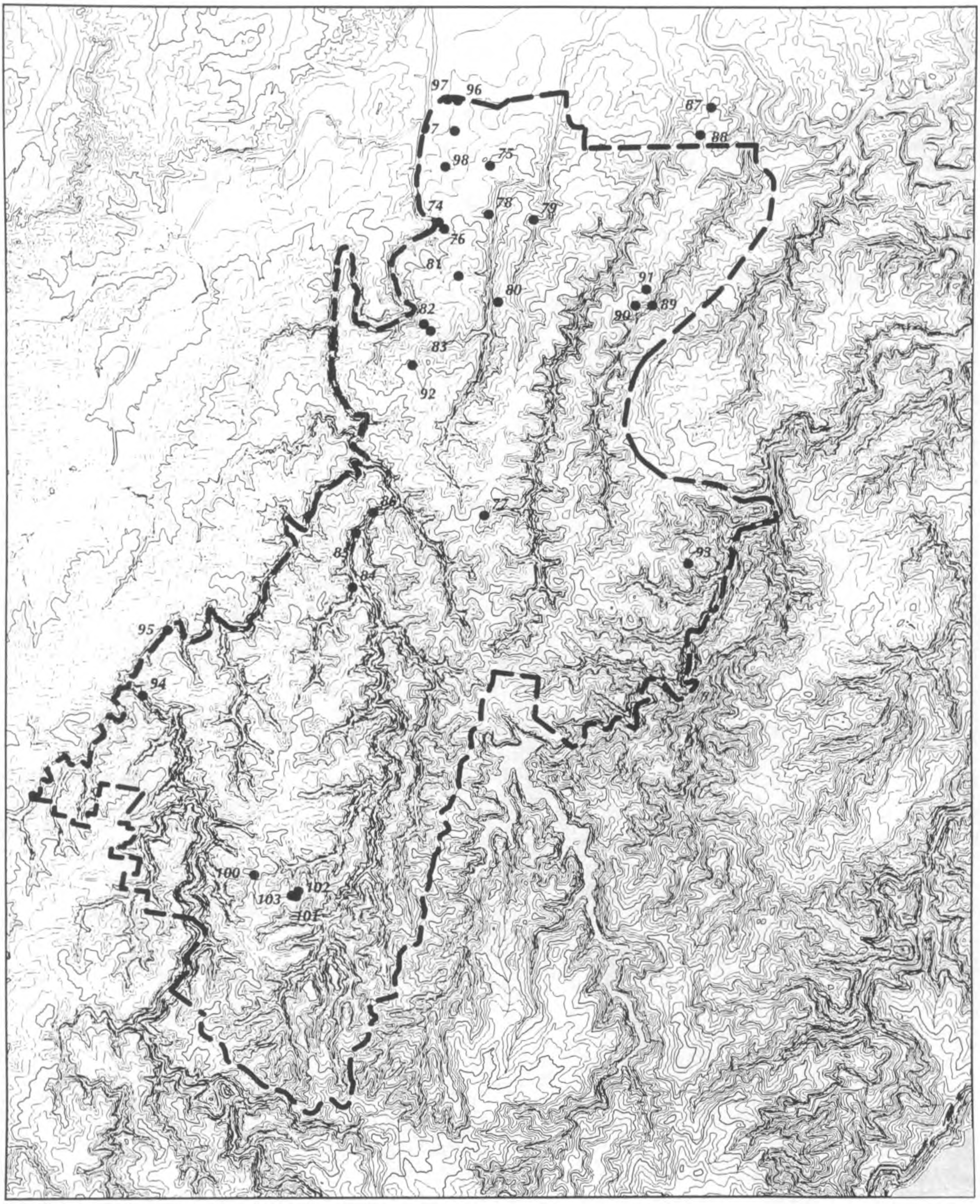
50m contour

10m contour

Figure A1
Quadrat Sampling Sites Used by French (1995)

1:120,000

28/7/97



Legend

Figure A2
Quadrat Sampling Sites Used by Biosis

1:120,000

28/7/97

Determination of vegetation significance is based on evaluations made by Benson & Howell (1990), Benson & McDougall (1991), Benson (1992), Keith (1994) and NPWS (unpublished). Individual stands of vegetation types which are highly altered, for example by grazing or weed infestation, are assigned a rating of local significance even if such vegetation types are rare in the region.

1.5 VEGETATION CONDITION

The condition of vegetation is the degree to which it resembles relatively natural, undisturbed vegetation. This is assessed according to the following criteria:

- species composition: species richness, degree of weed invasion
- vegetation structure: representation of each of the original layers in the vegetation

Vegetation is assessed as being in excellent, good, moderate or poor condition.

1.6 LIMITATIONS

Field survey of French *et al.* (1995) was conducted between October and April. Field survey of Biosis Research was conducted between late October and mid-December. Although spring is the optimal time for survey, certain species, mainly orchids, are only detectable at other times of the year; for instance in summer, orchids take the form of dormant below ground 'tuberoids' which are undetectable above ground. Given the large size and rugged topography of the Holsworthy site, further survey is likely to result in the recording of more species. Whereas only 12 species of orchids were detected during the present survey, the Australasian Native Orchid Society has records of over 70 species which occur in the vicinity of the Holsworthy site (letter from A. Dash to the Ministry of Transport and Regional Development, August 1996). In general, the number of unrecorded plant species is considered to be low.

1.7 SUMMARY OF FLORA RESULTS

A total of 176 indigenous and 84 introduced vascular plant species (ferns, conifers, flowering plants) was recorded from Badgerys Creek. A total of 546 indigenous and 37 introduced vascular plant species was recorded from Holsworthy (Table A1.2).

Table A1.2. Summary of vascular flora

Site	Indigenous species	Introduced species	Total species
Badgerys Creek	176	84	260
Holsworthy	546	37	583
Total (combined areas)	626	98	724

Badgerys Creek has a substantial indigenous flora, although more species are likely to have been present prior to extensive clearance, grazing by livestock and weed invasion of remnants.

The indigenous flora of the Holsworthy Training Area is particularly rich. This is largely due to its location on the boundary of two biogeographic regions, Cumberland Plain in the north and Coastal Sandstone Plateau in the south. It is also partly due to its considerable size and relatively undisturbed condition. Indicative of species richness at Holsworthy are 30 recorded eucalypts and 20 recorded acacias. The recorded orchid flora is somewhat small (21 species); this may be due to the timing of surveys (see *Limitations*). The family Orchidaceae forms a large component of the Sydney flora, and it is likely that more species would be recorded with further survey.

1.8 VEGETATION COMMUNITIES

1.8.1 Badgerys Creek

The vegetation of Badgerys Creek was classified in accordance with the regional vegetation classification of the National Herbarium of New South Wales (Benson 1992). Examination of the vegetation in the field indicated the presence of three communities (Table 5.4).

Table 5.4 (repeated). Vegetation communities at Badgerys Creek.

Vegetation community	Comments
Pasture/Disturbed Woodland BADG 1	Widespread and extensive
Grey Box Woodland (Altered) BADG 2	Scattered
River-flat Forest (Altered) BADG 3	Restricted to creeks

Each community is discussed in more detail below.

1.8.1.1 Pasture/Disturbed Woodland

1.8.1.1.1 Floristics

The most common tree species are grey box and forest redgum. Trees and shrubs are rare in heavily grazed stands, the vegetative cover mainly consisting of introduced grasses, with some native grass and herb species. Persistent, prickly species such as *Bursaria spinosa, Daviesia ulicifolia, D. genistifolia* and *Dillwynia sieberi* occur in scattered stands. Shrubs mostly occur near drainage or fence lines or in areas not regularly grazed. Common introduced shrubs include lantana and privets. Common introduced herbaceous species include kikuyu, paspsalum and clover.

1.8.1.1.2 Structure

Grassland/open woodland/open scrub. Open paddocks of grazed grasses, sometimes with scattered trees or, small stands of trees to 20 m, usually well spaced. Within fenced paddocks, there is generally a grass understorey, although some apparently unpalatable native herbs are also present. Along fencelines and road reserves, there may be an understorey of scattered shrubs, or occasionally dense stands, to 2 m. Along some fence lines introduced trees or shrubs also occur.

1.8.1.1.3 Distribution

This vegetation type occurs over most of Badgerys Creek, where the level to undulating land has been utilized for horticultural or agricultural purposes.

1.8.1.1.4 Condition

Poor. Vegetation is highly altered from original condition. In many areas of grassland, native herb species are sparse to absent. Remnant native trees are generally widely spaced, while planted lines of introduced trees or shrubs are occasional along fencelines. Most areas of this vegetation type are regularly or infrequently grazed or mown such that native shrub species are uncommon.

1.8.1.2 Grey Box Woodland (Altered)

1.8.1.2.1 Floristics

Dominant tree species are grey box and forest redgum, while thin-leaved stringybark, rough-barked apple and narrow-leaved ironbark are occasional. Common native shrub species include everlasting, Parramatta green wattle and blackthorn. Ground cover species include kangaroo grass, three-awned spear grass, kidney weed, blue trumpet and false sarsparilla. Introduced species are common in this community.

1.8.1.2.2 Structure

Woodland. Trees to 20 m, occurring with an understorey consisting of grassland and scattered dense to sparse stands of shrubs.

1.8.1.2.3 Distribution

This vegetation type occurs along sections of Badgerys Creek, with isolated stands occurring east of Badgerys Road and north of Gardiner Road; east of Oaky Creek and north of Longley Road; east of Willowdene Road and at several sites within the OTC site. Smaller, more sparse stands occur to the east of the Northern Road. The larger stands are shown on the Natural Vegetation of the Penrith area 1:100 000 map sheet (Benson 1992).

1.8.1.2.4 Condition

Poor to moderate: Very few stands of this vegetation type contain a complete suite of native understorey species, but more frequently consisting of grazed grasses with scattered stands of less palatable native or introduced shrubs. Recruitment of native tree species is generally poor, with very few seedlings and occasional lignotuber regrowth which is either grazed or trampled.

1.8.1.3 River-flat Forest

1.8.1.3.1 Floristics

Commonly occurring tree species are forest redgum and grey box. Swamp oak, snow-in-summer and broad-leaved apple are occasional. Aquatic species include native reed, cumbungi, sedges, water peppers and rush. Mat rush occurs occasionally on creek banks. Common weeds include privets, African Olive and Wandering Jew.

1.8.1.3.2 Structure

Woodland. Trees to 15m, either occurring as single remnants or as scattered regenerating individuals.. Shrub understorey varies from dense to sparse or absent, depending on grazing intensity and density of understorey. Dense stands of reed swamp occur around the margins of some farm dams, as well as in drainage lines and creek tributaries.

1.8.1.3.3 Distribution

This vegetation type occurs along sections of Badgerys, Oaky, Cosgrove and Thompsons Creeks, as well as along the margins of dams and large water bodies, such as the sewerage treatment ponds.

1.8.1.3.4 Condition

Poor (generally). High incidence of introduced shrub, climber and herb species. These often form dense mats, probably inhibiting growth and regeneration of native understorey species as well as the regeneration of native canopy species.

1.8.2 Holsworthy

The vegetation of the Holsworthy Training Area was classified using quadrat data. Interpretation of the computer classification indicated the presence of seven vegetation communities (Table 5.8). This classification is compatible with the regional vegetation classification of the National Herbarium of New South Wales (Benson 1992, Benson and Howell 1994). Further survey could result in the recognition of two more communities (see *Relationships with Other Classifications*).

Table 5.8 (repeated). Vegetation communities, Holsworthy

Vegetation community/code	**Comments**
Grey Box Ironbark Woodland/HOLS 1	Restricted but extensive, north-west section
Shale/sandstone Forest/HOLS 2	Restricted and localised; north-west section
Sydney Sandstone Ridgetop Woodland/HOLS 3	Widespread and extensive, not north-west section; plateaus and ridges
Woronora Plateau Upland Swamp/HOLS 4	Restricted and localised, southern section; perched swamps
Sydney Sandstone Gully Forest/HOLS 5	Widespread but localised, gully slopes
Riparian Scrub/HOLS 6	Widespread but localised, gullies
River-flat Forest/HOLS 7	Restricted and localised, north-east section; streamlines

Relevant data from the quadrats are presented in a floristic table (Appendix D) which displays the:

- quadrats that comprise each community
- species composition of each community; all eucalypt species and all species occurring in more than 5% of quadrats are shown
- cover-abundance provided by each species
- species composition relationships between communities (i.e. little overlap, broad overlap)
- species composition variation within communities

It can be seen from Table A1.1 that the vegetation at Holsworthy is a complex multi-dimensional continuum. Primary factors controlling the continuum appear to be water and nutrient availability. Floristic boundaries between certain communities are somewhat arbitrary whereas other communities have sharp definition. Furthermore, some communities display internal floristic variation consistent with the overall continuum. It is noted that the vegetation has low weed levels.

The distribution of vegetation communities is shown in Figure 3.2.

Each community is described below.

1.8.2.1 Grey Box Ironbark Woodland/HOLS 1

1.8.2.1.1 Floristics

Common tree species are ironbarks, stringybarks, grey box and forest redgum. Common shrub species include bitter pea, blackthorn and cranberry. Ground layer species include grasses and other herbs.

1.8.2.1.2 Structure

Woodland. Trees to 20 m with tall straight trunks and spreading canopies; trunks usually spaced more than 5 m apart and projective canopy to 30%. Understorey generally consists of grasses, although sparse to dense stands of shrubs to 2 m occasionally occur.

1.8.2.1.3 Distribution (study area)

Largely restricted to Small Arms Firing Range, with disjunct stands in B, C and F Ranges.

1.8.2.1.4 Condition

Good to excellent. Condition appears to vary with disturbance history. Weed species are more common along road and track sides, firing ranges and drainage channels. Tree trunks and branches generally display more gunfire and shrapnel damage in these areas. Some extensive stands south and east of the firing range areas are relatively weed-free and display the foristics and structure described by Benson (1992) as being characteristic of this vegetation type. In areas which appear to be rarely disturbed the understorey consists of a dense sward of native grasses, with scattered native shrubs. In the areas which appear to be more frequently disturbed, the understorey often consists of stands of native shrub and herb species, interspersed with introduced shrub and herb species. In most cases a small number of species comprise these understorey stands, in comparison with less frequently disturbed sites, *Bursaria spinosa* often forming dense stands. At the time of the survey one area had been recently burnt, and large sections appeared to be recovering from fire events of between five and two years. French *et al.* (1995) observed that '...The lack of shrub stratum species ... would suggest that fires are occurring more frequently and are leading to a loss in both species diversity and structural diversity...' Benson (1992), however, observed that '...The understorey is generally grassy with patches of shrubs ... *Bursaria spinosa* is the most common shrub species, often forming dense thickets'.

HOLS 1

CHARACTER SPECIES	%FRQ	C-A	CHARACTER SPECIES	%FRQ	C-A	CHARACTER SPECIES	%FRQ	C-A
Aristida vagans	100	1	Lomandra multiflora	72	1	Lissanthe strigosa	54	+
Themeda australis	100	2	Entolasia stricta	72	1	Daviesia ulicifolia	54	+
Eucalyptus fibrosa	90	2	Hardenbergia violacea	63	1	Glycine tabacina	54	1
Brunoniella australis	81	1	Eucalyptus crebra	63	2	Microlaena stipoides	54	1
Dianella revoluta	81	1	Bursaria spinosa	63	1	Panicum simile	54	+
Glycine clandestina	72	1	Cheilanthes sieberi	63	1			

NUMBER OF SITES: 11 STRUCTURE: Woodland

DISTRIBUTION: Northern Holsworthy

ENVIRONMENT: Wiannamatta shae soils

MEAN FLORISTIC RICHNESS: 33 species per site MEAN WEED COMPOSITION: 2% of species, 1% of cover

1.8.2.2 Shale/Sandstone Forest/HOLS 2

1.8.2.2.1 Floristics

Common tree species are grey gum, stringybarks. Scalybark is occasional, as is red bloodwood and apples. Common shrub species include geebungs, hair-pin banksia, paper-bark tea-tree and prickly moses. Ground layer species include *Themeda australis*, *Lomandra obliqua*, *Dianella revoluta* and *Pimelea linifolia*.

1.8.2.2.2 Structure

Woodland. Trees to 28 m, usually with tall, straight trunks and sparse canopies with up to 25% projective canopy cover. Shrub understorey is rarely dense, more commonly scattered, to 1.5 m. Grasses and herbs form up to 50% cover, especially where shrub cover is sparse.

1.8.2.2.3 Distribution (study area)

Common at the north end of Holsworthy, extending from the more hilly parts of Small Arms Firing Range, southwards into B and C Range. As the name implies, this vegetation type occurs on transitional areas between Wianamatta Shales and Hawkesbury Sandstone or on areas of sandstone with overlying shale lenses.

1.8.2.2.4 Condition

Very good to excellent. In most areas this vegetation type is in excellent condition, although in areas recently affected by fire, there are only scattered understorey shrubs and patches of bare earth. These areas mainly occur along the western boundary of the Small Arms Firing Range.

1.8.2.2.5 Comments

This vegetation type was not described by French *et al.* (1995), but was referred to by Benson (1992) as Unit 10ar (iii), and will be identified as a full community in the forthcoming vegetation map of the Wollongong Natmap sheet. It is a distinct unit although somewhat transitional in nature, with a floristic composition and structure similar to that described elsewhere in the region by Benson & Howell (1994) and NPWS (unpublished). Douglas (1995) described a community of 'Ridgetop Interface Woodland' in the Cattai Region which has similar characteristics.

HOLS 2

CHARACTER SPECIES	%FRQ	C-A	CHARACTER SPECIES	%FRQ	C-A	CHARACTER SPECIES	%FRQ	C-A
Lomandra obliqua	85	1	Entolasia stricta	66	2	Lomandra multiflora	57	+
Themeda australis	85	2	Isopogon anemonifolius	66	+	Acacia ulicifolia	57	+
Banksia spinulosa	80	1	Lomandra filiformis	61	1	Persoonia levis	57	+
Eucalyptus punctata	76	2	Persoonia linearis	61	+	Acacia terminalis	52	+
Leptospermum trinervium	76	+	Pomax umbellata	61	+	Corymbia gummifera	52	1
Dianella revoluta	76	1	Pimelea linifolia	61	+	Pterostylis species	52	1
Cyathochaeta diandra	71	1	Lissanthe strigosa	57	+	Aristida vagans	52	1
Phyllanthus hirtellus	66	+	Goodenia hederacea	57	+	Hakea sericea	52	+

NUMBER OF SITES: 21 STRUCTURE: Woodland

DISTRIBUTION: Northern Holsworthy

ENVIRONMENT: Transition between Wianamatta Shales and Hawkesbury Sandstone

MEAN FLORISTIC RICHNESS: 47 species per site MEAN WEED COMPOSITION: 0% of species, 0% of cover

1.8.2.3 Sydney Sandstone Ridgetop Woodland/HOLS 3

1.8.2.3.1 Floristics

Scribbly gum and red bloodwood are often dominant canopy species while stringybark, Silver-top ash and scalybark are occasional. Yertchuck is common at the southern end of Holsworthy, especially in E Range. Common understorey shrubs are paper-bark tea-tree, Mountain Devil, hairpin banksia, dagger bushes, cone stick and grey spider flower. Common ground layer species include *Cyathochaeta diandra*, *Dampiera stricta*, *Actinotus minor*, *Lepyrodia scariosa*, mat rushes and flag lilies.

1.8.2.3.2 Structure

Woodland/heathland. Some sites are treeless. Trees to 20 m, generally spaced up to 8 m apart, with twisted trunks, low spreading canopies and a projective canopy cover of up to 30%, but more typically <20%. Shrub understorey varies from sparse to dense, but is more typically dense, consisting of shrubs to 2.5 m and mallees to 3 m. Groundcover is generally sparse, to 0.5 m.

1.8.2.3.3 Distribution (study area)

Sandstone ridges of the Woronora Plateau.

1.8.2.3.4 Condition

Excellent. Introduced species are uncommon and generally restricted to roadsides.

HOLS 3

CHARACTER SPECIES	%FRQ	C-A	CHARACTER SPECIES	%FRQ	C-A	CHARACTER SPECIES	%FRQ	C-A
Leptospermum trinervium	96	2	Patersonia sericea	74	+	Bossiaea heterophylla	59	+
Isopogon anemonifolius	96	1	Cassytha pubescens	74	+	Lindsaea linearis	59	+
Cyathochaeta diandra	92	2	Platysace ericoides	70	1	Pterostylis species	59	2
Lambertia formosa	92	1	Leucopogon microphyllus	70	1	Caustis flexuosa	55	1
Dampiera stricta	88	+	Corymbia gummifera	70	1	Banksia marginata	55	1
Hakea dactyloides	88	1	Persoonia levis	70	+	Platysace linearifolia	51	1
Actinotus minor	85	2	Lomandra obliqua	66	1	Schoenus ericetorum	51	+
Petrophile sessilis	85	1	Banksia spinulosa	66	1	Hibbertia riparia	51	+
Lomandra glauca	81	1	Pimelea linifolia	66	+	Angophora hispida	51	1
Lepyrodia scariosa	81	1	Hakea sericea	62	+	Grevillea diffusa	51	+
Eriostemon australasius	77	1	Xanthorrhoea media	62	1			
Pultenaea elliptica	74	1	Grevillea sphacelata	62	1			

NUMBER OF SITES: 27 STRUCTURE: Woodland/heathland

DISTRIBUTION: Widespread and extensive over most of Holsworthy except north

ENVIRONMENT: Rocky ridges and plateaus

MEAN FLORISTIC RICHNESS: 51 species per site MEAN WEED COMPOSITION: 0% of species, 0% of cover

1.8.2.4 Woronora Upland Swamp/HOLS 4

1.8.2.4.1 Floristics

Eucalypts are absent. Where shrubs occur, common species are banksias, broad-leaved apple, *Epacris microphylla*, *Hakea teretifolia*, *Pimelea linifolia*, *Leucopogon microphyllus* and *Leptospermum* spp. Sedges occurring either as understorey in shrub stands or as canopy species include *Schoenus brevifolius*, *Lepyrodia scariosa* and *Cyathochaeta diandra*. Herbaceous species include *Dampiera stricta* and *Actinotis minor*.

1.8.2.4.2 Structure

Sedgeland/shrubland. Sedges to 1.2 m may form dense swards, although in some areas a shrub canopy to 2.5 m occurs. Trees are rare to absent.

1.8.2.4.3 Distribution (study area)

This vegetation type occurs on poorly-drained sandstone ridges, especially in D and E ranges. Stands are usually not extensive in comparison with surrounding woodland stands. Benson & Howell (1994) observed that upland swamps were a '...conspicuous feature of the poorly-drained headwater valleys of the eastern side of the Woronora Plateau'.

1.8.2.4.4 Condition

Good to excellent. Only small areas of this vegetation type occur in the study area, and in some cases these areas appear to be used as targets for mortar bombing. Some weed species were recorded in these disturbed areas, mainly around bomb craters or near dugouts, although they generally occurred as scattered individuals rather than in extensive stands. Changes in indigenous species frequencies were noted within bomb craters, probably related to water availability.

HOLS 4

CHARACTER SPECIES	%FRQ	C-A	CHARACTER SPECIES	%FRQ	C-A	CHARACTER SPECIES	%FRQ	C-A
Banksia ericifolia	100	2	Haemodorum corymbosum	72	+	Cyathochaeta diandra	54	2
Epacris microphylla	90	1	Leptospermum arachnoides	72	1	Cassytha pubescens	54	+
Dampiera stricta	90	1	Leptospermum trinervium	72	+	Baeckea imbricata	54	2
Hakea teretifolia	90	1	Pterostylis species	72	2	Banksia oblongifolia	54	2
Pimelea linifolia	81	+	Platysace linearifolia	63	+	Hakea dactyloides	54	+
Actinotus minor	72	1	Angophora hispida	63	1	Petrophile sessilis	54	1
Schoenus brevifolius	72	2	Lepyrodia scariosa	63	2			
Leucopogon microphyllus	72	1	Xanthorrhoea resinifera	63	1			

NUMBER OF SITES: 11 STRUCTURE: Sedgeland/shrubland

DISTRIBUTION: Southern Holsworthy

ENVIRONMENT: Poorly drained sandstone benches

MEAN FLORISTIC RICHNESS: 43 species per site MEAN WEED COMPOSITION: 0% of species, 0% of cover

1.8.2.5 Sydney Sandstone Gully Forest/HOLS 5

1.8.2.5.1 Floristics

Common tree species on upper slopes include Sydney peppermint, blackbutt and smooth-barked apple. Blue stringybark mainly occurs on lower slopes. Red bloodwood and grey gum are occasional on upper slopes. Common understorey shrub species include *Grevillea mucronulata*, *Banksia spinulaosa*, *Lomatia silaefolia* and *Persoonia levis*. Rich ground layer includes *Xanthosia pilosa*, *Pteridium exculentum*, *Lomandra* spp, *Entolasia stricta* and *Lepidosperma laterale*.

1.8.2.5.2 Structure

Woodland/open forest. Trees to 25 m or more, depending on location. Canopies are usually sparse, with up to 25% projective cover. Understorey shrubs are usually sparse, becoming dense on lower slopes. Shrub heights vary from 1.5 m to 4 m. Ground cover is usually sparse on upper slopes, becoming more dense on lower slopes.

1.8.2.5.3 Distribution (study area)

Gully slopes of all major creeklines at Holsworthy.

1.8.2.5.4 Condition

Excellent. Generally undisturbed, apart from occasional fires and road construction. Extensive, continuous stands occur along most major creeklines.

HOLS 5

CHARACTER SPECIES	%FRQ	C-A	CHARACTER SPECIES	%FRQ	C-A	CHARACTER SPECIES	%FRQ	C-A
Grevillea mucronulata	89	1	Ceratopetalum gummiferum	68	2	Hardenbergia violacea	57	+
Xanthosia pilosa	84	1	Lepidosperma laterale	68	1	Dampiera purpurea	57	+
Banksia spinulosa	84	1	Bossiaea heterophylla	68	+	Acacia linifolia	57	+
Lomatia silaifolia	84	+	Acacia terminalis	68	+	Acacia ulicifolia	57	+
Persoonia levis	84	+	Eucalyptus piperita	68	1	Caustis flexuosa	52	+
Pteridium esculentum	78	1	Xanthosia tridentata	63	+	Lomandra filiformis	52	+
Lomandra obliqua	78	1	Corymbia gummifera	63	1	Dianella caerulea	52	+
Entolasia stricta	78	2	Leptospermum trinervium	63	+	Persoonia linearis	52	+
Lomandra gracilis	73	1	Platysace linearifolia	57	1	Smilax glyciphylla	52	+
Angophora costata	73	2	Phyllanthus hirtellus	57	+			
Banksia serrata	73	1	Dillwynia retorta	57	+			

NUMBER OF SITES: 19 STRUCTURE: Woodland/open forest

DISTRIBUTION: Widespread

ENVIRONMENT: Gully slopes

MEAN FLORISTIC RICHNESS: 52 species per site MEAN WEED COMPOSITION: 1% of species, 0% of cover

1.8.2.6 *Riparian Scrub/HOLS 6*

1.8.2.6.1 Floristics

Common shrub species include water gum, sheoke, river lomatia, tea-tree, Coach-wood and *Acacia obtusifolia*. Ground layer is usually sparse.

1.8.2.6.2 Structure

Open scrub/closed scrub. Scrub to 5 m high, in a narrow band along creekbanks. Understorey is usually sparse, dense clumps of mat-rush are occasional.

1.8.2.6.3 Distribution (study area)

Sandy soil along margins of deeper, protected sections of Punchbowl, O'Hares, Williams and Deadmans Creeks.

1.8.2.6.4 Condition

Excellent. Generally undisturbed, apart from occasional fires and road construction. Continuous stands occur along most major creeklines.

HOLS 6

CHARACTER SPECIES	%FRQ	C-A	CHARACTER SPECIES	%FRQ	C-A	CHARACTER SPECIES	%FRQ	C-A
Tristaniopsis laurina	100	2	Grevillea oleoides	77	1	Schoenus melanostachys	55	1
Xanthosia tridentata	88	+	Stenocarpus salignus	77	1	Drosera spatulata	55	+
Allocasuarina littoralis	88	1	Phebalium dentatum	77	+	Pseudanthus pimeleoides	55	+
Ceratopetalum apetalum	88	1	Lomandra fluviatilis	66	+	Daviesia corymbosa	55	1
Acacia obtusifolia	88	1	Acacia terminalis	66	+	Gleichenia microphylla	55	+
Leptospermum morrisonii	88	1	Grevillea mucronulata	66	+	Austromyrtus tenuifolia	55	+
Lomatia myricoides	88	2	Hakea salicifolia	66	2	Entolasia stricta	55	+
Lepidosperma laterale	77	+	Persoonia pinifolia	66	+	Dodonaea triquetra	55	+
Pultenaea flexilis	77	+	Bauera rubioides	55	+	Smilax glyciphylla	55	+
Sticherus flabellatus	77	1	Ceratopetalum gummiferum	55	+			

NUMBER OF SITES: 9 STRUCTURE: Scrub

DISTRIBUTION: Widespread

ENVIRONMENT: Sheltered sections of major creeks

MEAN FLORISTIC RICHNESS: 44 species per site MEAN WEED COMPOSITION: 2% of species, 1% of cover

1.8.2.7 *River-flat Forest/HOLS 7*

1.8.2.7.1 Floristics

Snow-in summer forms dense stands in some sections of these creeklines. Bluegum hybrid occurs along more open sections of Williams Creek. Lower shrub strata are formed by Snow-in summer or bottlebrush, ironwood and introduced species such as privet. Ground layer species include *Pteridium esculentum*, *Gahnia sieberiana*, *Lomandra longifolia*, *Imperata cylindrica* and *Viola hederacea*.

1.8.2.7.2 Structure

Forest. Trees to 30 m with tall, straight trunks and narrow canopies, with a second, more dense canopy to 8 m. Low shrubs and groundcover are generally scattered.

1.8.2.7.3 Distribution (study area)

Restricted to northern Holsworthy, occurring in the northern sections of Harris and Williams Creek, and in sections of Georges River.

1.8.2.7.4 Condition

Moderate to good. Weed species are common in most stands, especially where Harris Creek crosses Artillery Road and where Williams Creek passes near a quarry. A continuous stand of *Melaleuca linariifolia*, with only sparse occurrences of weed species, follows the banks of Williams Creek from Heathcote Road for a distance of approximately 40 m.

HOLS 7

CHARACTER SPECIES	%FRQ	C-A	CHARACTER SPECIES	%FRQ	C-A	CHARACTER SPECIES	%FRQ	C-A
Pteridium esculentum	100	1	Viola hederacea	80	1	Pratia purpurascens	60	+
Gahnia sieberiana	80	1	Hydrocotyle laxiflora	60	2	Eucalyptus saligna	60	2
Lomandra longifolia	80	1	*Conyza albida	60	+	Leptospermum juniperinum	60	2
Melaleuca linariifolia	80	3	Isolepis cernua	60	2	Entolasia stricta	60	2
Imperata cylindrica	80	+	Calochlaena dubia	60	+	Microlaena stipoides	60	+

NUMBER OF SITES: 5 STRUCTURE: Forest

DISTRIBUTION: Northern Holsworthy

ENVIRONMENT: Creeklines

MEAN FLORISTIC RICHNESS: 30 species per site MEAN WEED COMPOSITION: 10% of species, 9% of cover

1.9 RELATIONSHIPS WITH OTHER CLASSIFICATIONS

1.9.1.1 Badgerys Creek

Kinhill Stearns (1985) grouped two of the communities in this study, Grey Box Woodland and River-flat Forest and called it red gum - grey box remnant woodland.

Benson (1992) describes a plant community 28a Freshwater Reed Swamp for the Penrith mapsheet area but does not map any at Badgerys Creek (only Grey Box Woodland is mapped). Stands of reed *Phragmites australis* are present at Badgerys Creek, but they are generally small, discontinuous and weed-infested and are not assigned community status in this study.

Relationships between available classifications (Badgerys Creek) are summarised below (Table A1.3).

Table A1.3. Relationships between vegetation classifications (Badgerys Creek).

This study	**National Herbarium**	**Kinhill Stearns (1985)**	**NPWS (unpublished)**
Pasture/Disturbed Woodland BADG 1	Cleared C	Cleared areas 2	N/A
Grey Box Woodland (Altered) BADG 2	Grey Box Woodland 10c	red gum - grey box remnant woodland	Grey Box River-flat Forest Woodland
River-flat Forest BADG 3	River-flat Forest 9f		River-flat Forest

1.9.1.2 Holsworthy

The classification in this study is congruent with the vegetation units of the regional mapping project of the National Herbarium of New South Wales published in *Cunninghamia* (Benson 1992, Benson and Howell 1994), and with the classification of French *et al.* (1995). However the National Herbarium of New South Wales and French *et al.* (1995) are not consistent in their delineation of communities. Although French *et al.* (1995) provide a reasonable interpretation of the vegetation, the analysis here supports the classification of the National Herbarium.

Benson (1992) shows an area of Castlereagh Scribbly Gum Woodland 14a within Holsworthy, part of a larger occurrence extending north. In this study, the area in Holsworthy is tentatively classified with Grey Box Ironbark Woodland 10d pending further study, although it has floristic affinities with 14a. Scribbly Gum *Eucalyptus sclerophylla* has very limited occurrences at Holsworthy, and no floristic unit associated with this species was identified by French *et al.* (1995). Anomolous plant species associations in the Small Arms Firing Range resembling 14a may be artefacts of long-term disturbance including the establishment of a large vineyard in the nineteenth century, and logging associated with a large internment camp constructed during the 1940s.

Benson (1992) shows an area of Grey Box Woodland 10c in northern Holsworthy, but this area is (more appropriately) classified as Grey Box Ironbark Woodland 10d in this study.

There may be some justification for including Shale/Gravel Transition Forest 9d, described by Benson (1992) as occurring on the transition zone between Wianamatta Shale and tertiary alluvium (the only mapped stands are outside Holsworthy). Two narrow stands resembling this vegetation occur in the south-west section of the Small Arms Firing Range.

Relationships between available classifications (Holsworthy) are summarised below (Table A1.4).

Table A1.4. Relationships between classifications (Holsworthy).

This study	**National Herbarium**	**NPWS (unpublished)**	**French *et al.* (1995)**
Grey Box Ironbark Woodland HOLS 1	Grey Box Ironbark Woodland 10d	Shale Lens Ironbark Forest	Plateau Forest
Shale/sandstone Forest HOLS 2	Shale/Sandstone Forest 9r		
Sydney Sandstone Ridgetop Woodland HOLS 3	Sydney Sandstone Ridgetop Woodland 10ar	Sydney Sandstone Ridgetop Woodland	Woodland/Heath Complex - Dry Open Woodland
			Woodland/Heath Complex - Northeast and Central Woodland/Heath
Woronora Plateau Upland Swamp HOLS 4	Woronora Plateau Upland Swamp (Sedgeland) 21s		Sedgeland
		Wet Heath	Heath/Swamp Complex
Sydney Sandstone Gully Forest HOLS 5	Sydney Sandstone Gully Forest 10ag.1	Sydney Sandstone Gully Forest	Gully Forest
Riparian Scrub HOLS 6	Sydney Sandstone Gully Forest (Scrub) 10ag.2		Riparian Forest
River-flat Forest HOLS 7	River-flat Forest 9f	Melaleuca Open-forest	Melaleuca Thicket

1.10 SIGNIFICANT FLORA

Several species were identified within, or in the vicinity of, the proposed airport sites as having national, state or regional significance. Species of national and state significance for Badgerys Creek and Holsworthy are discussed in detail in species profiles in the following sections.

Species of national (ESP 1992; Briggs and Leigh 1995) and state significance (TSC Act 1995) in the Holsworthy and Badgerys Creek study areas are listed in Table A1.5. Because the TSC Act (1995) does not list those species that are rare in NSW (i.e. they are all nationally significant), the personal knowledge and experience of G. Leonard was used to derive a list of species of state significance. These are listed below but have not been considered in separate profiles as this is only required for those species listed under the TSC Act (1995). Only those species recorded during the present study, the French *et al.* (1995) study, the Kinhill Stearns (1985) study and from NPWS Database can be considered under Options. Locations for significant flora species are shown in Figure A3.

Table A1.5. List of flora species of national significance (Briggs and Leigh 1995; ESP Act 1992) and state significance (TSC Act 1995; G. Leonard *pers. obs.*) which were recorded from (✓) or which may occur (blank) on the options at the Badgerys Creek and Holsworthy sites. This species list should not be considered exhaustive.

			Holsworthy Options			**Badgerys Creek Options**		
SCIENTIFIC NAME	**L¹**	**Status²**	**A**	**B**	**Other**	**A**	**B**	**C**
National Significance								
Pultanaea parviflora	Y	N(v), 2E S(e)				✓	✓	✓
Allocasuarina glareicola	Y	N(v), 2E S(e)	✓					
Persoonia nutans	Y	N(e), 3RC- S(e)			✓			
Pterostylis sp E	Y	TBA			✓			
Pultanaea aristata	Y	N(v), 2VC- S(v)	✓	✓				
Leucopogon exolasius	Y	2VC-, S(v)	✓					
Melaleuca deanei	Y	3RC-	✓	✓				
Darwinia diminuta	Y	3RCi	✓					
Darwinia grandiflora	Y	2RCi	✓					
Eucalyptus luehmanniana	Y	2RCa		✓				
Grevillea longifolia	Y	2RC-	✓	✓				
Hibbertia nitida	Y	2RC-	✓	✓				
Lomandra fluviatilis	Y	3RCa	✓	✓				
Tetratheca neglecta	Y	3RC-	✓	✓				
Monotoca ledifolia	Y	3RC-		✓				
State Significance								
Eucalyptus baueriana		G. Leonard			✓			
E. ligustrina		G. Leonard		✓				
E. multicaulis		G. Leonard	✓	✓				
E. squamosa		G. Leonard	✓	✓				
Grevillea diffusa var. *diffusa*		G. Leonard	✓	✓				
Hakea salicifolia narrow-leaved form		G. Leonard		✓				
Leucopogon amplexicaulis		G. Leonard	✓	✓				
Persoonia mollis subsp. *nectens*		G. Leonard			✓			
Tetratheca shiressii		G. Leonard			✓			
Westringia longifolia		G. Leonard		✓				

NOTE:
1. Abbreviation L is Licence required to harm, pick or damage habitat: Y = Yes, N = No.
2. Status: N = national, S = state significance, (e) endangered, (v) vulnerable 2 = Geographical range in Australia less than 100 kms; 3 = Geographical range in Australia greater than 100 kms; E = Endangered; V = Vulnerable; R = Rare; C = Reserved; i = less than 1000 plants known to occur within a

conservation reserve; a = 1000 plants or more known to occur within a conservation reserve; - = reserved population is not accurately known.

1.10.1 Note on Impact Assessment

Impacts on significant species are considered in terms of their distributions, the presence of core populations and population losses. Guidelines used to define impacts are presented below.

National impact occurs when a species is restricted to the Cumberland Plain, the species is at its limit of distribution, a core population will be lost or 20 % or more of a national population will be lost.

State impact occurs when a species is restricted to the Cumberland Plain and population losses will be incurred as a result of the proposal.

High regional impact occurs when a species is limited to the Woronora Plateau and Cumberland Plain and is at its limit of distribution and population losses will be incurred as a result of the proposal.

Regional impact occurs when a species is restricted to the Sydney basin, is limited or disjunct in its known distribution and population losses will be incurred as a result of the proposal.

High local impact occurs when a species is restricted to the Sydney basin, is widely distributed within that distribution and population losses will be incurred as a result of the proposal.

1.11 BADGERYS CREEK

1.11.1 National Significance

1.11.1.1 Pultanaea parviflora

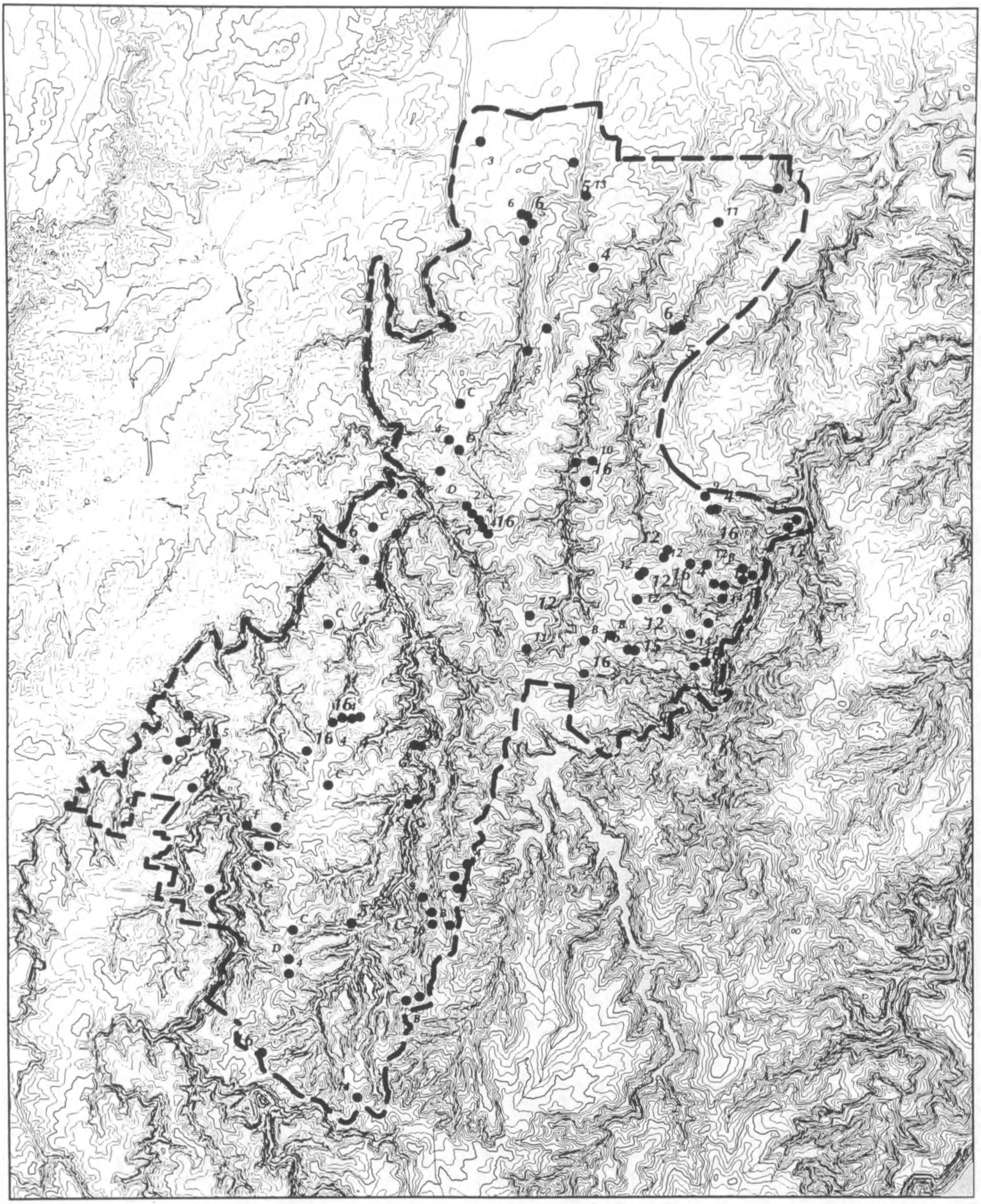
Pultenaea parviflora has a conservation rating of 2E. This species is listed on Schedule 2 (Vulnerable) of the Endangered Species Protection Act (1992). It is also listed on Schedule 1 (Endangered) of the Threatened Species Conservation Act (1995).

1.11.1.1.1 Distribution

Statewide distribution: This species is mainly restricted to the northern part of the Cumberland Plain, extending as far south as Liverpool.

Regional distribution: Records occur for Blacktown, Hawkesbury, Liverpool and Penrith LGAs. In the Liverpool LGA, Mount King Ecological Surveys (1990) recorded a population of less than 100 plants at Hoxton Park. NSW Herbarium records include populations at Kemps Creek (Cnr Elizabeth Drive and Devonshire Street); Austral, west of Liverpool; Prestons (listed as "probably gone"); and Longleys Road, Badgerys Creek. All the Liverpool populations are small (M. Matthes *pers. comm.*).

Local distribution and abundance: Kinhill Stearns (1985) reported that the Badgerys Creek population consisted of approximately 30 individuals, occurring on both sides of Longleys Road between Ferndale and Taylors Road. The authors concluded that clearing of this vegetation stand would "destroy the only population of *P. parviflora* in the area". Ecotone Ecological Consultants (1994) considered that conservation of this population should be "of moderate priority, at least until a stock of plants propagated from their genetic material can be established for replanting on the site after airport construction".



Legend

● Rotaps_fr_2.shp

● Rotaps.shp

Military Boundary

Rivers

Water

50m contour

10m contour

Figure A3
Locations of Significant Flora Species at Holsworthy

1:120,000

28/7/97

1.11.1.1.2 Environmental pressures

Environmental pressures on this species and its habitat include: loss of habitat through clearing for development and fire mitigation purposes, sand and gravel extraction, habitat fragmentation, competition from introduced species (Nash and Matthes 1995). Fairley & Moore (1989) considered that suburban subdivision places this species at risk.

1.11.1.1.3 Critical Habitat

This species is a small, much-branched shrub to one metre high with yellow and red flowers and occurs in open forest on heavy shale soils and in the Castlereagh Woodlands (Robinson 1991). This species is considered to be very restricted in distribution, with most records occurring on roadsides, vacant crown land or private property (Nash & Matthes 1995).

No large populations of *P. parviflora* occur in Liverpool LGA. Populations exceeding 1000 have been recorded at CAA, Llandillo, Castlereagh State Forest and at the Australian Defence Industries (ADI) site, St Marys, suggesting that the core population of this species occurs to the north of Liverpool LGA. The population in the study area occurs at the southern limit of the species' distribution.

1.11.1.1.4 Sensitivity to habitat modification

This species has a patchy distribution at the ADI site, St Marys, generally occurring in larger numbers along ecotones, or within vegetation stands where the canopy cover is sparse. Only small numbers of scattered individuals generally occur in areas where these conditions are not met (G. Leonard *pers. obs.*).

1.11.1.1.5 Effects of proposed activities

Direct impacts of airport construction on this species are likely to be habitat loss and fragmentation. Option A will result in the loss of 117 ha of Grey Box Woodland. Option B will result in the loss of 197.3 ha of Grey Box Woodland. Option C will result in the loss of 168.2 ha of Grey Box Woodland. One small population occurring along Longleys Road would be completely removed by all three airport options. Indirect impacts of airport construction include competition from introduced species and changes in fire regime.

This species is at its southern limit of distribution at Badgerys Creek. It occurs in Grey Box Woodland which has a very limited distribution in Western Sydney. Construction of all airport options will lead to local depletion of this species.

The impact of the airport development on this species is considered high regional.

1.11.1.1.6 Ability of species/habitat to recover

Wrigley and Fagg (1992) observed that seeds of most *Pultenaea* species required scarification for germination to take place. The large population at the ADI site, St Marys contains mainly mature individuals with very few seedlings, so it is possible that a specific fire regime is required in order to ensure survival of the population (G. Leonard *pers. obs.*)

1.11.1.1.7 Amelioration measures

Preconstruction surveys should be carried out to locate populations of this species. A stock of *P. parviflora* plants should be propagated from the existing population at Badgerys Creek to ensure conservation of their genetic material. Minimise habitat fragmentation by careful siting of proposed transport and services corridors.

1.11.1.1.8 Known to occur in nearby conservation reserves

The only conserved area in which the species has been recorded is Windsor Downs Nature Reserve, in Hawkesbury LGA. It is not listed as occurring in any conservation areas in Briggs & Leigh (1995).

1.12 HOLSWORTHY

1.12.1.1 Allocasuarina glareicola

Allocasuarina glareicola is a ROTAP species with a conservation rating of 2E. It is listed under Schedule 2 (Vulnerable) of the Endangered Species Protection Act (1992). It is also listed under Schedule 1 (Endangered) of the Threatened Species Conservation Act (1995).

1.12.1.1.1 Distribution

Statewide distribution: This species is restricted to the Castlereagh Woodlands, from Holsworthy in the south to Castlereagh State Forest in the north.

Regional distribution: NSW Herbarium records include occurrences at Llandillo Road to Berkshire Park, Llandillo Road opposite Castlereagh State Forest and Castlereagh State Forest.

Local distribution and abundance: G. Robertson (NPWS) has recorded the occurrence of two individuals, growing on tertiary alluvium, in the headwaters of a tributary of Punchbowl Creek at Holsworthy. These individuals occur at the known southern limit of the species' distribution.

1.12.1.1.2 Environmental pressures

Environmental pressures on this species and its habitat include: habitat loss.

1.12.1.1.3 Critical Habitat

Allocasuarina glareicola is an open erect shrub to two metres high, "restricted to a few small populations in the Castlereagh Woodlands " (Robinson 1991). Harden (1990) list the preferred habitat as open forest on lateritic soil and notes that the species is "restricted to a few small populations in or near Castlereagh State Forest, NE of Penrith". This vegetation type has been extensively cleared from Western Sydney. Remnant stands are generally small, and may contain a high proportion of weed species.

1.12.1.1.4 Sensitivity to habitat modification

Unknown but assumed to be very sensitive (G. Robertson *pers. comm.*).

1.12.1.1.5 Effects of proposed activities

Direct impacts of airport construction on this species are habitat loss. Option A will result in the loss of 4 ha of Grey Box Ironbark Woodland. Option B will result in the loss of .0221 ha of Grey Box Iron Bark Woodland. Both individuals recorded during the present survey would be removed by Option A. The population represents 20% of the known national population.

The individuals of *Allocasuarina glareicola* recorded at Holsworthy occur at the known southern limit of the species' very limited distribution. Construction of Option A will lead to national depletion of this species.

The impact of the airport development on this species is considered national.

1.12.1.1.6 Ability of species/habitat to recover

Unknown.

1.12.1.1.7 Amelioration measures

Preconstruction surveys should be carried out to locate populations of this species. A stock of *Allocasuarina glareicola* plants should be propagated from the existing population at Holsworthy to ensure conservation of their genetic material. Minimise habitat fragmentation by careful siting of proposed transport and services corridors.

1.12.1.1.8 Known to occur in nearby conservation reserves

There are no records of the species occurring in conservation reserves listed by Briggs & Leigh (1995).

1.12.1.2 Melaleuca deanei

Melaleuca deanei is a ROTAP species with a conservation rating of 3RC-.

1.12.1.2.1 Distribution

Statewide distribution: This species is restricted to the Sydney Basin. Two main populations occur in NSW. One is located to the north of Sydney with small disjunct stands occurring between Pymble and Gosford, and another larger population is located to the south of Sydney extending from Holsworthy to Wedderburn and as far west as Menai and Heathcote.

Regional distribution: Felton (1993) observed that, although this species has an extensive distribution, large populations occurred only at two sites: Holsworthy and Ku-ring gai National Park. The largest southern population occurs in Holsworthy, with smaller populations occurring in O'Hares Creek Catchment (Keith 1994), West Menai and Wedderburn (Travers Morgan 1990) and Lucas Heights (Fairley & Moore 1989).

Local distribution and abundance: Small populations were recorded in Sydney Sandstone Ridgetop Woodland/Heathland from near Complete Creek in the Small Arms Danger Area to Gilday. The largest apparent population was recorded near Mackel Airstrip, where up to 50 ramets were counted over an area of 1000 square metres; it is possible that these ramets originate from a small number of parent rootstocks as the area is regularly disturbed by tanks

1.12.1.2.2 Environmental pressures

Environmental pressures on this species and its habitat include: road widening; development, and altered fire regimes (Felton 1993).

1.12.1.2.3 Critical Habitat

Melaleuca deanei is a shrub to three metres high with blue-green leaves and creamy yellow inflorescences. Harden (1991) describes the preferred habitat as wet heath on sandstone. Payne (1990) suggested that this species may occur "either on shale or sandstone in damp areas". Felton (1993) observed that the species "is restricted to open heath and low open woodland situated on ridge tops or the upper slopes...on shallow, low-nutrient soils derived from Hawkesbury Sandstone".

Although this species would have originally occurred throughout the Sydney Basin, it is now divided into separate southern and northern populations. Based on our current knowledge about the distribution of *M. deanei*, the Holsworthy site appears to contain the core population for this species. At other sites, most populations generally only consist of 2-3 plants and so the long-term survival of the species probably depends on the two large populations. For this reason, Felton (1993) recommended the conservation of the Holsworthy populations including research into its low seed viability and improved management strategies with particular reference to the fire regime.

1.12.1.2.4 Sensitivity to habitat modification

Felton (1993) observed that the species was probably distributed more extensively but has been reduced to scattered stands as a result of clearing for development. Small populations apparently rarely flower, so survival of the species probably depends on conservation of the larger populations where flowering generally takes place.

1.12.1.2.5 Effects of proposed activities

Direct impacts of airport construction on this species are habitat loss and fragmentation and altered fire regimes. Option A will result in the loss of 2339.7 ha of Sydney Sandstone Ridgetop Woodland. Option B will result in the loss of 1655.5 ha of Sydney Sandstone Ridgetop Woodland. No large populations are known to occur within either of the airport options. However small populations would be removed through development of Options A or B. Up to 40% of the known Holsworthy population would be removed by Option A.

The core population of *Melaleuca deanei* occurs at Holsworthy. Construction of Option A will lead to local depletion of this species.

The impact of the airport development on this species is considered national.

1.12.1.2.6 Ability of species/habitat to recover

The main limitation to recruitment of seedlings appears to be the low viability rate and short life of seeds, as well as the possibility that the seeds are also subject to attack by pathogens. Felton (1993) also found that the population at Holsworthy did not produce viable seed. Vegetative growth is apparent on some individuals, particularly at Mackel Airstrip where regular disturbance by tanks appears to be stimulating lignotuberous regrowth.

1.12.1.2.7 Amelioration measures

Preconstruction surveys should be carried out to locate populations of this species. A stock of *Melaleuca deanei* plants should be propagated from the existing population at Holsworthy to ensure conservation of their genetic material. Weed control measures should be strictly adhered to during and after construction. Minimise habitat fragmentation by careful siting of proposed transport and services corridors.

1.12.1.2.8 Known to occur in nearby conservation reserves

This species occurs in the following conservation reserves: Brisbane Waters, Garigal, Heathcote, Royal, Ku-ring-Gai Chase and Morton National Parks (Briggs & Leigh 1995).

1.12.1.3 Persoonia nutans

This species has a conservation rating of 3RC- (Briggs & Leigh 1995). Nationally, this species is listed under Schedule 1 (Endangered) of the *Endangered Species Protection Act 1992*). Listed in Schedule 1 (Endangered) of the *Threatened Species Conservation Act 1995*.

1.12.1.3.1 Distribution

Statewide distribution: This species only occurs on the western side of the Cumberland Plain.

Regional distribution: Benson & Howell (1990) observed that populations have been recorded on low-nutrient Tertiary Sediments in Liverpool, Castlereagh State Forest, Penrith and Londonderry. NSW Herbarium records for Liverpool LGA include occurrences at Kemps Creek, Glenfield, Hargrave Park and Voyager Point. The species tends to occur in small scattered populations, with some extensive stands regenerating on disturbed sandy soils at Agnes Banks (Mitchell McCotter and Kevin Mills & Associates 1991).

Local distribution and abundance: One individual of this species was recorded in the study area; it was located on the edge of a cleared rifle range within the Small Arms Danger Area. Disjunct occurrences of this species in areas near Holsworthy include: Pleasure Point (Kevin Mills & Associates 1990a); Voyager Point (Landscope 1995); an area to the north of Range Control, approximately 150 metres east of Moorebank Avenue (M. Peterson pers. comm; G. Robertson *pers. comm*), and the Heathcote Road road reserve approximately 500 metres north of the Pleasure Point intersection (G. Leonard *pers. obs.*). The individuals recorded by Landscope (1995) have since been removed during road-widening operations.

1.12.1.3.2 Environmental pressures

Environmental pressures on this species and its habitat include: clearing and fragmentation of vegetation, inappropriate fire regimes, grazing.

1.12.1.3.3 Critical Habitat

Persoonia nutans is an erect, bushy shrub growing to two metres, generally occurring on alluvial sands, gravels and laterites on the western edge of the Cumberland Plain and the Lower Blue Mountains. Preferred habitat is shrub-woodland and dry sclerophyll forest (Blomberry & Maloney 1992). The leaves are soft and narrow and the bright yellow flowers are borne on long pendulous peduncles. The main flowering period is summer although the fruits remain on the plant for an extended period.

Harden (1991) observed that this species was “confined to the Cumberland Plain”. As much of the original Cumberland Plain vegetation has been cleared or modified (see Benson and Howell 1990), it is reasonable to assume that a large proportion of suitable habitat has been removed from Western Sydney. Only one individual of this species was recorded at Holsworthy during the survey. It occurs near the Small Arms Danger Area. Suitable habitat for this species extends across large sections of F Range and smaller sections of the Small Arms Firing Range.

1.12.1.3.4 Sensitivity to habitat modification

Unknown. The individual recorded at Holsworthy occurs on the edge of an access track, so may be damaged by vehicular traffic. At least one quarter of the plant appears to be affected by symptoms associated with *Phytophthora cinnamoni* infestation. The individuals recorded on the edge of Heathcote Road have been badly scorched by a recent fire.

1.12.1.3.5 Effects of proposed activities

Direct impacts of airport construction on this species are habitat loss and fragmentation. Option A will result in the loss of 2339.7 ha of Sydney Sandstone Ridgetop Woodland and 4 ha of Grey Box Ironbark Woodland. Option B will result in the loss of 1655.5 ha of Sydney Sandstone Ridgetop Woodland and 0.0221 ha of Grey Box Iron Bark Woodland. indirect impacts of airport construction would include altered fire regimes. The single plant recorded from the Holsworthy site would not be directly affected by airport development. However, the Northern Transport Corridor (Option A) would pass within 400 metres of this individual.

The regional distribution of *Persoonia nutans* is scattered in vegetation communities confined to the Cumberland Plain.

The impact of the airport development on this species is considered of state significance.

1.12.1.3.6 Ability of species/habitat to recover

Recruitment by seedlings appears to be poor. Fruits were found at the base of the individual at Holsworthy and at Heathcote Road No sprouted seeds were observed. Blombery and Maloney (1992) observed that this species is generally propagated commercially by cuttings.

1.12.1.3.7 Amelioration measures

Weed control measures should be strictly adhered to during and after construction. Minimise habitat fragmentation by careful siting of proposed transport and services corridors.

1.12.1.3.8 Known to occur in nearby conservation reserves

This species is considered to be conserved at Agnes Banks and Windsor Downs Nature Reserves (Briggs & Leigh 1995).

1.12.1.4 Pterostylis sp E

This species is not currently listed as a ROTAP; however Mr D. Jones (Australasian Native Orchid Society) will describe it in the March 1997 *Orchadian*, proposing the name *Pterostylis saxicola* and a conservation rating of 2E.

1.12.1.4.1 Distribution

Statewide distribution: This species has not been recorded beyond the Campbelltown-Ingleburn area.

Regional distribution: Robinson (1991) observed that the species was thought to be extinct, but was recently rediscovered in the Campbelltown-Ingleburn area growing in gullies along the Georges River.

Local distribution and abundance: A single population of this species has been recorded on a rocky site near Harris Creek, in the Small Arms Danger Area. This population appears to be the core population as all known recordings outside the Holsworthy range mainly consist of a few scattered individuals (A. Dash *pers. comm.*).

1.12.1.4.2 Environmental pressures

Environmental pressures on this species and its habitat include: altered fire regimes, fragmentation and clearing of vegetation. Proposed developments along the Georges River are a threat to the survival of several populations.

1.12.1.4.3 Critical Habitat

Pterostylis sp E is a terrestrial herb with up to eight rosette leaves. This species is also known as 'Sydney Plains Rufa' or *Pterostylis* sp. aff. *gibbosa*. The flowers, which are borne between September and November, are transparent with dark red-brown markings and suffusions. This species is rare, occurring between Picnic Point and Picton, the preferred habitat being "shallow soil over sandstone sheets, often near streams" (Harden 1993).

A population of at least ten individuals has been recorded at one site in the Small Arms Danger Area. No other individuals or populations have been recorded in Holsworthy, although suitable habitat occurs in a few other sections of the Small Arms Danger Area and possibly in B and F Ranges.

1.12.1.4.4 Sensitivity to habitat modification

This species has only recently been described. It is likely that populations occurred over a larger area but have since become extinct. *Pterostylis gibbosa*, a related species, appears to have similar habitat requirements, including: sparse litter and grass cover; a discontinuous shrub layer; particular soil type, moisture regime and plant association; and a delicate fire/grazing relationship (see Roslyn Muston & Associates 1991).

1.12.1.4.5 Effects of proposed activities

Direct impacts of airport construction on this species are habitat loss and fragmentation and altered fire regimes. Option A will result in the loss of 2339.7 ha of Sydney Sandstone Ridgetop Woodland. Option B will result in the loss of 1655.5 ha of Sydney Sandstone Ridgetop Woodland. The single population recorded from the Holsworthy site would not be directly affected by either of the airport options. However, the Northern Transport Corridor (Option A) is located 400 metres to the west of the population. This population represents 20% of the known national population.

Indirect effects of airport construction may be associated with edge effects or altered hydrology

The core population of *Pterostylis* sp E occurs at Holsworthy. Construction of airport transport corridors could lead to national depletion of this species.

The impact of the airport development on this species is considered national

1.12.1.4.6 Ability of species/habitat to recover

As this species has only recently been described, little data is currently available. *Pterostylis gibbosa*, a related species, reproduces by out-crossing rather than cloning; Jones (1988) comments that vegetative reproduction in the Rufa group of the genus *Pterostylis* is not common. If this is the case with *Pterostylis* sp E, it would appear that only larger populations, rather than scattered individuals, have long-term survival potential.

1.12.1.4.7 Amelioration measures

Any proposed transport corridor should be located to avoid the core population of *Pterostylis* sp E located at Holsworthy. A stock of *Pterostylis* sp E plants should be propagated from the existing population at Holsworthy to ensure conservation of their genetic material. Weed control measures should be strictly adhered to during and after construction.

1.12.1.4.8 Known to occur in nearby conservation reserves

Not known from any conservation reserves.

1.12.1.5 Pultenaea aristata

Pultenaea aristata has a conservation rating of 2VC-. Nationally, it is listed under Schedule 2 (Vulnerable) in the Endangered Species Protection Act (1992). It is also listed under Schedule 2 (Vulnerable) of the Threatened Species Conservation Act (1995).

1.12.1.5.1 Distribution

Statewide distribution: Woronora Plateau, with a disjunct occurrence in the Budawang Ranges.

Regional distribution: Mills *et al.* (1985) described this species as being endemic to the Woronora Catchment area, extending along the eastern edge of the plateau south to Macquarie Pass. Keith (1994) recorded the occurrence of this species between Helensburgh and Mt Keira, as well as in the Budawang Ranges.

Local distribution and abundance: This species is not common at Holsworthy, although it was recorded at sites on the eastern, as well as the eastern side of the study area. It is possible that the populations of *Pultenaea aristata* at Holsworthy occur at the western limit of the species' distribution, as the species was not recorded by Payne (1990) at Wedderburn.

1.12.1.5.2 Environmental pressures

Environmental pressures on this species and its habitat include: altered fire regimes, clearing, altered moisture regimes.

1.12.1.5.3 Critical Habitat

Robinson (1991) describes this species as an erect shrub to one metre tall, with yellow and red flowers and leaves with a "long bristle at the tip". Preferred habitat of this species ranges from "moist sites, in dry sclerophyll woodland to heath on sandstone" (Harden 1991). Keith (1994) observed that three of the most restricted taxa in O'Hares Creek Catchment area, *Pultanaea aristata*, *Leucopogon exolasius* and *Grevillea longifolia* occur as "major populations, whose maintenance is important for overall conservation". Within Holsworthy, individuals of this species were only recorded on sandstone areas with high moisture retention, such as occurred on the margins of hanging swamps. Tree canopy cover was sparse to absent. The total area over which this habitat type occurs in Holsworthy is less than 1%.

1.12.1.5.4 Sensitivity to habitat modification

Unknown. This species is likely to be sensitive alterations to the existing moisture regime.

1.12.1.5.5 Effects of proposed activities

Direct impacts of airport construction on this species are habitat loss and fragmentation and altered fire regimes. Option A will result in the loss of 14.6 ha of Woronora Plateau Upland Swamp. Option B will result in the loss of 18.7 ha of Woronora Plateau Upland Swamp. Indirect effects of airport construction may be associated with altered hydrology

Pultanaea aristata is considered endemic to the Woronora Plateau, it is not common at Holsworthy, which is considered the western limit of its distribution. Individuals of this species occur within both airport options and throughout the airport site. No large populations occur on the site.

The impact of the airport development on this species is considered high regional.

1.12.1.5.6 Ability of species/habitat to recover

Wrigley and Fagg (1992) observed that the seeds of *Pultanaea* species require scarification for successful germination, which suggests that either the species is fire-facultative or the seeds may not germinate for some time. Alterations to the existing fire regime or disturbance to topsoil may therefore hinder recovery of the species.

1.12.1.5.7 Amelioration measures

Weed control measures should be strictly adhered to during and after construction. Minimise habitat fragmentation by careful siting of proposed transport and services corridors.

1.12.1.5.8 Known to occur in nearby conservation reserves

This species is not considered to be adequately conserved within its range (Briggs & Leigh 1995).

1.12.1.6 Leucopogon exolasius

Leucopogon exolasius has a conservation rating of 2VC-. It is also listed under Schedule 2 (Vulnerable) in the Threatened Species Conservation Act (1995).

1.12.1.6.1 Distribution

Statewide distribution: Occurs between the Woronora River in the south and the Grose River in the north. The occurrence in the Grose River area also represents the western limit of its range. The species has not been recorded in coastal areas.

Regional distribution: Robinson (1991) describes the distribution of this species as Upper Georges River, Woronora Plateau and the Grose River. The populations recorded by Keith (1994) and Mills *et al.* (1985) in the O'Hares Creek/Woronora River area occur at the southern limit of the species' distribution. The species has also been recorded along Stokes Creek in Royal NP (Harden 1992) and at Wedderburn (Payne 1990).

Local distribution and abundance: Scattered stands of this species were recorded from the north-east to the south-west corners of the study area.

1.12.1.6.2 Environmental pressures

Environmental pressures on this species and its habitat include: habitat loss

1.12.1.6.3 Critical Habitat

This species is an erect shrub to one metre high, with pubescent branchlets and white pendulous flowers. Preferred habitat is woodland on sandstone (Harden 1992). Individuals of this species were recorded at several locations on steep slopes which are occasionally burned, probably as a result of explosions or hazard reduction. Keith (1994) observed that three of the most restricted taxa in O'Hares Creek Catchment area, *Pultenaea aristata*, *Leucopogon exolasius* and *Grevillea longifolia* occur as "major populations, whose maintenance is important for overall conservation".

1.12.1.6.4 Sensitivity to habitat modification

Unknown

1.12.1.6.5 Effects of proposed activities

Direct impacts of airport construction on this species are habitat loss and fragmentation. Option A will result in the loss of 2339.7 ha of Sydney Sandstone Ridgetop Woodland and 1454.3 ha of Sydney Sandstone Gully Forest. Option B will result in the loss of 1655.5 ha of Sydney Sandstone Ridgetop Woodland and 1087.5 ha of Sydney Sandstone Gully Forest. Indirect impacts of airport construction include altered fire regimes. A small population of this species would be removed through development of Option A. Small populations occur to the west of Option B and are not likely to be directly affected by airport development.

Leucopogon exolasius occurs in widespread habitat in the Upper Georges River, Woronora Plateau and Grose River, scattered stands occur within Holsworthy.

The impact of the airport development on this species is considered high regional.

1.12.1.6.6 Ability of species/habitat to recover

Unknown. Wrigley and Fagg (1992) observed that "very few (species of *Leucopogon*) have been successfully brought into cultivation" and that "seed is difficult to germinate".

1.12.1.6.7 Amelioration measures

Weed control measures should be strictly adhered to during and after construction. Minimise habitat fragmentation by careful siting of proposed transport and services corridors.

1.12.1.6.8 Known to occur in nearby conservation reserves

Heathcote National Park is the only conservation area listed in which this species occurs (Briggs & Leigh 1995).

1.12.1.7 Darwinia diminuta

Darwinia diminuta has a conservation rating of 3RCi.

1.12.1.7.1 Distribution

Statewide distribution: This species is restricted to two populations in the Sydney Basin, one to the north of Sydney and one to the south.

Regional distribution: The distribution of this species is restricted to two populations: one on the plateau between Terrey Hills and Manly and the Woronora Plateau between Sutherland and Helensburgh.

Local distribution and abundance: Keith (1994) recorded occurrences of this species in mallee heath near Northcliff mine. This species is an occasional to common occurrence in D Range, especially on Wild Cat and Wallaby Ridges.

1.12.1.7.2 Environmental pressures

Environmental pressures on this species and its habitat include: altered fire regimes, altered moisture regimes, vegetation clearance.

1.12.1.7.3 Critical Habitat

This species is a spreading shrub to 1.5 metres high, bearing pink-white flowers between September and January. Preferred habitat is heath, scrub and woodland on poorly drained sandy soils or laterites (Robinson 1991).

1.12.1.7.4 Sensitivity to habitat modification

Unknown.

1.12.1.7.5 Effects of proposed activities

Direct impacts of airport construction on this species are habitat loss and fragmentation. Option A will result in the loss of 14.6 ha of Woronora Plateau Upland Swamp. Option B will result in the loss of 18.7 ha of Woronora Plateau Upland Swamp. Small populations occur within Option A and to the north of it.

Indirect effects of airport construction may be associated with altered hydrology and altered fire regimes.

The regional distribution of *Darwinia diminuta* is very restricted. Construction of the airport will result in local depletion of this species.

The impact of the airport development on this species is considered high regional.

1.12.1.7.6 Ability of species/habitat to recover

Blomberry (1980) observed that, in the genus *Darwinia* "seed is frequently infertile and often difficult to germinate". Where this species was recorded at Holsworthy, stands generally occurred in narrow bands along vegetation, so it is possible that the species has specialised habitat requirements and may not respond well to habitat disturbance.

1.12.1.7.7 Amelioration measures

Weed control measures should be strictly adhered to during and after construction. Minimise habitat fragmentation by careful siting of proposed transport and services corridors.

1.12.1.7.8 Known to occur in nearby conservation reserves

It is listed by Briggs & Leigh (1995) as being conserved in the Royal National Park.

1.12.1.8 Darwinia grandiflora

Darwinia grandiflora has a conservation rating of 2RCi.

1.12.1.8.1 Distribution

Statewide distribution: This species only occurs on the Hawkesbury Sandstone Plateau from just south of Wollongong to Waterfall.

Regional distribution: Distribution is restricted to the Nepean Ramp between Waterfall and Dapto, with recorded occurrences at Helensburgh, Darkes Forest, Heathcote, Maddens Plains, Mt Ousley and West Dapto (Fairley & Moore 1989), Bulli Lookout (G. Leonard *pers. obs.*) and the eastern part of O'Hares Creek Catchment (Keith 1994).

Local distribution and abundance: This species was recorded on rocky sites near Harris Creek in the Small Arms Danger Area as well as at several areas of exposed sandstone in D Range.

1.12.1.8.2 Environmental pressures

Environmental pressures on this species and its habitat include: altered fire regimes, vegetation clearance, altered moisture regimes.

1.12.1.8.3 Critical Habitat

This species is a prostrate shrub which forms adventitious roots along the branches. Preferred habitat is dry sclerophyll forest and woodland on poorly drained sandy soil.

1.12.1.8.4 Sensitivity to habitat modification

This species occurs along fire trails along Bulli Lookout, where it appears to respond poorly to fire and to mowing (G. Leonard pers. *obs.*). At Holsworthy, the species generally occurs in areas that are not regularly disturbed.

1.12.1.8.5 Effects of proposed activities

Direct impacts of airport construction on this species are habitat loss and fragmentation. Option A will result in the loss of 14.6 ha of Woronora Plateau Upland Swamp. Option B will result in the loss of 18.7 ha of Woronora Plateau Upland Swamp.

Indirect effects of airport construction may be associated with altered hydrology and altered fire regimes.

The regional distribution of *Darwinia grandiflora* is restricted. Construction of the airport will result in local depletion of this species

The impact of the airport development on this species is considered regional

1.12.1.8.6 Ability of species/habitat to recover

Blomberry (1980) observed that, in the genus *Darwinia* "seed is frequently infertile and often difficult to germinate". This species however develops roots along protrate stems so is able to reproduce vegetatively.

1.12.1.8.7 Amelioration measures

Weed control measures should be strictly adhered to during and after construction. Minimise habitat fragmentation by careful siting of proposed transport and services corridors.

1.12.1.8.8 Known to occur in nearby conservation reserves

It is listed by Briggs & Leigh (1995) as being conserved in Royal National Park.

1.12.1.9 Eucalyptus luehmanniana

Eucalyptus luehmanniana has a conservation rating of 2RCa.

1.12.1.9.1 Distribution

Statewide distribution: This species is restricted to parts of the Sydney Basin.

Regional distribution: Keith (1994) recorded scattered occurrences in mallee heath in the eastern part of the O'Hares Creek Catchment. Other small stands occur at Waterfall and Garrawarra (G. Leonard *pers. obs.*).

Local distribution and abundance: Harden (1991) observed that the species is "...locally abundant but restricted". It was recorded in D and E range, the largest stand occurring along cliff edges at the eastern end of Wildcat Ridge.

1.12.1.9.2 Environmental pressures

Environmental pressures on this species and its habitat include: habitat loss.

1.12.1.9.3 Critical Habitat

Yellow Top Mallee Ash is a small or moderate-sized mallee with closely spaced stems to eight metres. Robinson (1991) describes the species as "impressive and beautiful...remarkable for its large stiff leaves and stately somewhat drooping habit". This species appears to be restricted to sites of low fertility, from near sea level to 300 metres altitude (Pryor 1981).

1.12.1.9.4 Sensitivity to habitat modification

Unknown. Stands of this species are usually small and site-specific so it is possible that sensitivity to habitat modification is high.

1.12.1.9.5 Effects of proposed activities

Direct impacts of airport construction on this species are habitat loss. Option A will result in the loss of 2339.7 ha of Sydney Sandstone Ridgetop Woodland and 14.6 ha of Woronora Plateau Upland Swamp. Option B will result in the loss of 1655.5 ha of Sydney Sandstone Ridgetop Woodland and 1087.5 ha and 18.7 ha of Woronora Plateau Upland Swamp. Two small populations occur at the southern limit of Option B and may be directly affected by airport development. Two larger populations occur to the east of Option A.

The regional distribution of *Eucalyptus luehmanniana* is restricted and airport construction will result in local depletion of this species

The impact of the airport development on this species is considered regional.

1.12.1.9.6 Ability of species/habitat to recover

Several stands which previously occurred near Waterfall were burned in the January 1994 fires and have not recovered with no lignotuberous or epicormic regrowth or emergence of seedlings being evident (G. Leonard *pers. obs.*).

1.12.1.9.7 Amelioration measures

Weed control measures should be strictly adhered to during and after construction. Minimise habitat fragmentation by careful siting of proposed transport and services corridors.

1.12.1.9.8 Known to occur in nearby conservation reserves

This species occurs in the following conservation areas: Garawarra SRA; Brisbane Waters, Garigal, Royal and Ku-ring-Gai Chase National Parks (Briggs & Leigh 1995).

1.12.1.10 Grevillea longifolia

Grevillea longifolia R. Br. has a conservation rating of 2RC-.

1.12.1.10.1 Distribution

Statewide distribution: This species is restricted to parts of the Lower Blue Mountains and the south-western margins of the Cumberland Plain.

Regional distribution: Robinson (1991) observed that this species is common along the Woronora and Georges Rivers as well as in scattered occurrences along the southern rim of the Cumberland Plain. The distribution is described by Fairley & Moore (1989) as Springwood-Lawson area in the Blue Mountains, and the Heathcote Creek and Georges, Woronora and Nepean Rivers, as far south as Appin and the Lower Cataract River. Keith (1994) recorded occurrences of this species along O'Hares and Stokes Creeks.

Local distribution and abundance: This species was recorded in several creek systems in Holsworthy, including Harris, O'Hares, Williams and Punchbowl Creeks. Distribution is generally restricted to creek banks and lower gully slopes, although scattered occurrences were also recorded on the slopes of a low plateau to the east of Harris Creek, in the Small Arms Danger Area.

1.12.1.10.2 Environmental pressures

Environmental pressures on this species and its habitat include: disturbance, weeds.

1.12.1.10.3 Critical Habitat

This species is a spreading shrub, from two to four metres high with attractive red inflorescences and long thin saw-toothed leaves (Fairley & Moore 1989). It occurs mainly on sheltered gully slopes, generally close to creeks. Keith (1994) observed that three of the most restricted taxa in O'Hares Creek Catchment area, *Pultenaea aristata*, *Leucopogon exolasius* and *Grevillea longifolia* occur as "major populations, whose maintenance is important for overall conservation".

1.12.1.10.4 Sensitivity to habitat modification

Blomberry and Maloney (1992) observed that it " is an adaptable species and will grow under a range of conditions" although flowering only takes place in sunny conditions.

1.12.1.10.5 Effects of proposed activities

Direct impacts of airport construction on this species include habitat loss and fragmentation. Option A will result in the loss of 1454.3 ha of Sydney Sandstone Gully Forest and 14.6 ha of Woronora Plateau Upland Swamp. Option B will result in the loss of 1087.5 ha of Sydney Sandstone Gully Forest and 18.7 ha of Woronora Plateau Upland Swamp. Indirect impacts of airport construction include disturbance and competition from introduced species.

Small populations of *Grevillea longifolia* occur along Punchbowl, Harris and Deadmans Creeks in Option A. These make up a significant proportion of the known Holsworthy population. Small populations also occur along Punchbowl Creek and along tributaries of O'Hares Creek in Option B. Construction of the airport will lead to local depletion of this species.

The impact of the airport development on this species is considered regional.

1.12.1.10.6 Ability of species/habitat to recover

Unknown. Blomberry and Maloney (1992) observed that this species is "readily raised from seed".

1.12.1.10.7 Amelioration measures

Minimise habitat fragmentation by careful siting of proposed transport and services corridors. Weed control measures should be strictly adhered to during and after construction.

1.12.1.10.8 Known to occur in nearby conservation reserves

It is listed by Briggs & Leigh (1995) as occurring in the Blue Mountains and Heathcote National Parks.

1.12.1.11 Hibbertia nitida

Hibbertia nitida has a conservation rating of 2RC-.

1.12.1.11.1 Distribution

Statewide distribution: This species is restricted to parts of the Sydney Basin.

Regional distribution: This species is found in heath and woodland growing on sandstone in the following areas: the Georges River, Middle Harbour, West Head and Upper Lane Cove River (Robinson 1991). Keith (1994) records occurrences along O'Hares and Stokes Creeks and describes its distribution as Thornleigh-Manly and Oatley- Nepean Dam. Fairley & Moore (1989) list Picnic Point as a recorded occurrence, while scattered occurrences have also been recorded in the Cataract and Cordeaux Catchments (G. Leonard *pers. obs.*; Meredith *et al.* 1995).

Local distribution and abundance: This species occurs on gully slopes along Williams, Punchbowl and O'Hares Creeks and also occurs in scattered groups below cliff lines above Deadmans and Gunyah Creeks.

1.12.1.11.2 Environmental pressures

Environmental pressures on this species and its habitat include: altered fire regimes, vegetation clearance, weed infestation.

1.12.1.11.3 Critical Habitat

Shiny Guinea Flower is a spreading shrub to one metre high, with distinctive glossy green leaves found in heath and woodland growing on sandstone. It is possible that this species occurs more frequently along ecotones (G. Leonard *pers. obs.*).

1.12.1.11.4 Sensitivity to habitat modification

Wrigley and Fagg (1992) observed that many species of *Hibbertia* are "very susceptible to *Phytophthera cinnamoni*".

1.12.1.11.5 Effects of proposed activities

Direct impacts of airport construction on this species include habitat loss. Option A will result in the loss of 1454.3 ha of Sydney Sandstone Gully Forest. Option B will result in the loss of 1087.5 ha of Sydney Sandstone Gully Forest. Indirect impacts of airport construction include disturbance, altered fire regimes and competition from introduced species.

Large numbers of individuals or small groups of individuals occur throughout slopes in both Options A and B. No large populations occur on the site. Construction of the airport will lead to local depletion of *Hibbertia nitida*.

The impact of the airport development on this species is considered regional.

1.12.1.11.6 Ability of species/habitat to recover

Blomberry (1980) observed that the seeds of many *Hibbertia* species were uncommon and slow to germinate.

1.12.1.11.7 Amelioration measures

Minimise habitat fragmentation by careful siting of proposed transport and services corridors. Weed control measures should be strictly adhered to during and after construction.

1.12.1.11.8 Known to occur in nearby conservation reserves

It occurs within the following conservation areas: Garigal, Heathcote and Royal National Parks (Briggs & Leigh 1995).

1.12.1.12 Lomandra fluviatilis

Lomandra fluviatilis has a conservation rating of 3RCa.

1.12.1.12.1 Distribution

Statewide distribution: This species is restricted to the Sydney Basin.

Regional distribution: Distribution extends mainly along the coastal zone around Sydney, with recorded occurrences in: Heathcote and Flat Rock Creeks (Royal NP); Colo, Woronora and Nepean Rivers (Bents Basin SRA) (Fairley & Moore 1989); O'Hares and Stokes Creeks (Keith 1994); Pheasants Creek (Payne 1990); Georges River, Cataract and Cordeaux Catchments (G. Leonard *pers. obs.*).

Local distribution and abundance: This species was recorded in Williams, Harris, Punchbowl and O'Hares Creeks. This species was found to occur in extensive stands along sections of O'Hares Creek, particularly on broad rock shelves.

1.12.1.12.2 Environmental pressures

Environmental pressures on this species and its habitat include: disturbance, weed invasion.

1.12.1.12.3 Critical Habitat

Although Robinson (1991) described this species as common, Fairley & Moore (1989) observed that it is at risk because of its small populations and restricted habitat preference.

1.12.1.12.4 Sensitivity to habitat modification

Harden observed that this species is known to hybridise with *L. longifolia*. It is likely that this species would not respond well to altered moisture regimes.

1.12.1.12.5 Effects of proposed activities

Direct impacts of airport construction on this species include habitat loss. Option A will result in the loss of 3.6 ha of Paperbark Woodland. Option B will result in the loss of 10.3 ha of Paperbark Woodland. Indirect impacts of airport construction include disturbance and competition from introduced species.

A large population of *Lomandra fluviatil* occurs along O'Hares Creek adjacent to Option B and may be directly affected by it. A small population on Punchbowl Creek would also be removed by Option B. Small populations recorded from Williams, Harris and Punchbowl Creeks would be removed. Construction of the airport will lead to local depletion of this species.

The impact of the airport development on this species is considered regional.

1.12.1.12.6 Ability of species/habitat to recover

Populations are generally small and disjunct, although some extensive dense stands were recorded in O'Hares Creek Catchment.

1.12.1.12.7 Amelioration measures

Minimise habitat fragmentation by careful siting of proposed transport and services corridors. Weed control measures should be strictly adhered to during and after construction.

1.12.1.12.8 Known to occur in nearby conservation reserves

This species occurs in the following conservation areas: Bents Basin SRA, Blue Mountains, Garigal, Royal, Marramarra and Morton National Parks (Briggs & Leigh 1995).

1.12.1.13 Tetratheca neglecta

Tetratheca neglecta has a conservation rating of 3RC-.

1.12.1.13.1 Distribution

Statewide distribution: This species extends from the Sydney region southwards to Robertson (Harden 1992).

Regional distribution: Distribution includes small populations in the southern Blue Mountains (Robinson 1991), the plateau between Cordeaux and Cataract dams and several reserves in Sutherland Shire (G. Leonard *pers. obs.*). Disjunct populations occur at Carrington Falls and Yerranderie (Fairley & Moore 1989). Keith (1994) recorded occurrences of this species throughout the O'Hares Creek Catchment.

Local distribution and abundance: *Tetratheca neglecta* has a wide distribution at Holsworthy, extending from the Small Arms Danger Area along all main plateaus to the southern limits of the study area.

1.12.1.13.2 Environmental pressures

Environmental pressures on this species and its habitat include: altered fire regimes, vegetation clearing.

1.12.1.13.3 Critical Habitat

This species is an erect shrub to 0.5 metres high, occurring in heath and woodland on sandstone. Payne (1990) suggested that it was "likely to be present in similar habitats to *Pultenaea aristata*" in the Wedderburn area.

1.12.1.13.4 Sensitivity to habitat modification

Unknown.

1.12.1.13.5 Effects of proposed activities

Direct impacts of airport construction on this species are habitat loss and altered fire regime. Option A will result in the loss of 2339.7 ha of Sydney Sandstone Ridgetop Woodland and 304.1 ha of Shale Sandstone Forest. Option B will result in the loss of 1655.5 ha of Sydney Sandstone Ridgetop Woodland and 10.4 ha of Shale Sandstone Forest.

Large numbers of individuals growing singly or in groups mainly on sandstone plateaus would be removed from both Options A and B. No large populations of *Tetratheca neglecta* were recorded in either option, however airport construction would lead to the local depletion of this species.

The impact of the airport development on this species is considered high local.

1.12.1.13.6 Ability of species/habitat to recover

Blomberry (1980) observed that the seeds of most species of *Tetratheca* germinated readily.

1.12.1.13.7 Amelioration measures

Minimise habitat fragmentation by careful siting of proposed transport and services corridors. Weed control measures should be strictly adhered to during and after construction.

1.12.1.13.8 Known to occur in nearby conservation reserves

This species occurs in the following conservation areas: Blue Mountains, Budderoo, Heathcote and Royal National Parks (Briggs & Leigh 1995).

1.12.1.14 Monotoca ledifolia

Monotoca ledifolia has a conservation rating of 3RC-.

1.12.1.14.1 Distribution

Statewide distribution: This species is restricted to the Woronora Plateau and parts of the Blue Mountains.

Regional distribution: Robinson (1991) observed that the only occurrence of this species in Royal National Park is in the Heathcote-Waterfall area. Keith (1994) recorded occurrences in Rock Pavement Heath in the south-eastern part of O'Hares Creek Catchment.

Local distribution and abundance: This species was only recorded at two sites in Holsworthy where it appears to be restricted to dry open heath on shallow sandstone soils.

1.12.1.14.2 Environmental pressures

Environmental pressures on this species and its habitat include: altered fire regimes, vegetation clearing.

1.12.1.14.3 Critical Habitat

This species is a compact shrub to 0.5 metre high, with stems that are occasionally finely hairy. White flowers are produced in January. Harden (1992) observed that this species grows in "exposed sites in dry sclerophyll forest and shrubland on sandstone in the Woronora Plateau and Blue Mountains area '.

1.12.1.14.4 Sensitivity to habitat modification

Unknown.

1.12.1.14.5 Effects of proposed activities

Direct impacts of airport construction on this species are habitat loss and altered fire regime. Option A will result in the loss of 2339.7 ha of Sydney Sandstone Ridgetop Woodland. Option B will result in the loss of 1655.5 ha of Sydney Sandstone Ridgetop Woodland.

Monotoca ledifolia has a restricted regional distribution in limited habitat.

The impact of the airport development on this species is considered regional.

1.12.1.14.6 Ability of species/habitat to recover

Unknown. Blomberry (1980) observed that the seeds are "difficult to germinate".

1.12.1.14.7 Amelioration measures

Minimise habitat fragmentation by careful siting of proposed transport and services corridors. Weed control measures should be strictly adhered to during and after construction.

1.12.1.14.8 Known to occur in nearby conservation reserves

This species occurs in the following conservation areas: Blue Mountains, Budderoo, Heathcote and Royal National Parks (Briggs & Leigh 1995).

1.13 SUMMARY OF IMPACTS

This section provides a summary of impacts on significant flora species of national (ESP 1992; Briggs and Leigh 1995) and state significance (TSC Act 1995). Detailed impacts assessment for each species has been presented in species profiles in the preceding section.

National impact occurs when a species is restricted to the Cumberland Plain, the species is at its limit of distribution, a core population will be lost or 20 % or more of a national population will be lost.

State impact occurs when a species is restricted to the Cumberland Plain and population losses will be incurred as a result of the proposal.

High regional impact occurs when a species is limited to the Woronora Plateau and Cumberland Plain and is at its limit of distribution and population losses will be incurred as a result of the proposal.

Regional impact occurs when a species is restricted to the Sydney basin, is limited or disjunct in its known distribution and population losses will be incurred as a result of the proposal.

High local impact occurs when a species is restricted to the Sydney basin, is widely distributed within that distribution and population losses will be incurred as a result of the population.

Table A1.6 Summary of impacts on flora species of national and state significance.

Species	Impacts				
	National	State	High Regional	Regional	High Local
Badgerys Creek					
Pultenaea parviflora			✓		
Holsworthy					
Allocasuarina glareicola	✓				
Melaleuca deanei	✓				
Persoonia nutans		✓			
Pterostylis sp E	✓				
Pultanaea aristata			✓		
Leucopogon exolasius			✓		
Darwinia diminuta			✓		
Darwinia grandiflora				✓	
Eucalyptus luehmanniana				✓	
Grevillea longifolia				✓	
Hibbertia nitida				✓	
Lomandra fluviatilis				✓	
Tetratheca neglecta					✓
Monotoca ledifolia				✓	
Total	3	1	3	6	1

1.14 SIGNIFICANT VEGETATION COMMUNITIES

Two vegetation communities are considered to have state significance for nature conservation, while five have regional significance and two have local significance, as follows (Table A1.7).

Table A1.7 Significant vegetation communities.

Vegetation community	Significance
Pasture/Disturbed Woodland BADG 1	nil
Grey Box Woodland (Altered) BADG 2	local (intact Grey Box Woodland has state significance)
River-flat Forest (Altered) BADG 3	local (intact River-flat Forest has regional significance)
Grey Box Ironbark Woodland HOLS 1	state, see below
Shale/sandstone Forest HOLS 2	regional; stands of this vegetation type are small and disturbed in most parts of Western Sydney (NPWS 1996)
Sydney Sandstone Ridgetop Woodland HOLS 3	regional
Woronora Plateau Upland Swamp HOLS 4	regional
Sydney Sandstone Gully Forest HOLS 5	regional
Riparian Scrub HOLS 6	regional
River-flat Forest HOLS 7	regional

Large, intact examples of vegetation communities would have the significance levels assigned earlier in the Conservation Values section of the report, however not every example of a community has this level of significance. The rating of a particular example may be less than this maximum according to its size and condition. Small or degraded examples are less significant than large, intact examples.

Vegetation communities of state or potential state significance are discussed below.

1.14.1 Grey Box Ironbark Woodland

Prior to European settlement, the Cumberland Plain of western Sydney supported extensive grassy woodlands restricted to the relatively fertile soils of the plain (Wianamatta Shale). Extensive urban and agricultural development has reduced the original vegetation to scattered remnants, many of which are in altered condition. One of the largest remnants occurs within the Holsworthy Training Area. These grassy woodlands comprised five vegetation communities (Benson 1992). Grey Box Ironbark Woodland was originally extensive on relatively hilly Wianamatta Shale land around the edge of the Cumberland Plain but is now severely depleted (refer map in Benson 1992). The example at Holsworthy is in good to excellent condition (see *Results - Flora*).

1.14.2 Grey Box Woodland

Another component community of Cumberland Plain Woodland is Grey Box Woodland, altered examples of which occur at Badgerys Creek. Benson and McDougall (1991), Benson and Howell (1990), Travers Morgan (1990), Benson (1992) and QEM (1993) stress the conservation significance of remnant stands of Grey Box Woodland in Western Sydney. Benson & McDougall (1991) observed that 'Clearing for grazing and urban development has often reduced the [Cumberland Plain] woodlands to small remnant stands of trees'. Benson & Howell (1990) stated that 'Liverpool still has a considerable number of bushland areas but very few are protected; with increasing development, each area will be carved up as expendable unless action is taken soon to protect significant areas'. Intact examples of Grey Box Woodland would have state significance but the examples at Badgerys Creek are too small and altered to be assigned this level of significance.

The NSW Scientific Committee, established under the Threatened Species Conservation Act 1995 has listed the Cumberland Plains Woodland as an Endangered Ecological Community under Part 3 of Schedule 1 of the TSC Act (Chris Dickman, NSW Scientific Committee *pers. comm.*). It is assumed that once the Cumberland Plains Woodland is formally listed a set of criteria will be prepared, outlining minimum size of a stand, minimum number of individuals or species in a stand, connectivity to adjacent stands, condition of canopy and understorey and other factors. As no criteria have so far been published it is difficult to grade the stands occurring in the study area in the regional context.

1.15 PLANT SPECIES RECORDED AT THE STUDY SITES

N	national significance
S	state significance
R	regional significance
*	introduced species

		Badgerys Creek	*Holsworthy*
GYMNOSPERMS			
CUPRESSACEAE			
	Callitris muelleri		+
PINACEAE			
*	*Pinus radiata*	+	
PODOCARPACEAE			
R	*Podocarpus spinulosus*		+
FERNS			
ADIANTACEAE			
	Adiantum aethiopicum	+	+
ASPLENIACEAE			
	Asplenium flabellifolium	+	+
BLECHNACEAE			
R	*Blechnum ambiguum*		+
	B. cartilagineum		+
	Doodia aspera	+	
DENNSTAEDTIACEAE			
	Hypolepis muelleri		+
	Pteridium esculentum	+	+
DICKSONIACEAE			
	Calochlaena dubia		+
GLEICHENIACEAE			
	Gleichenia dicarpa		+
	G. microphylla		+
	G. rupestris		+
	Sticherus flabellatus		+
LINDSAEACEAE			
	Lindsaea linearis		+
	L. microphylla		+
LYCOPODIACEAE			
	Lycopodium laterale		+
MARSILEACEAE			
R	*Marsilea hirsuta*	+	
OSMUNDACEAE			
	Todea barbara		+
SCHIZAEACEAE			
R	*Schizaea bifida*		+
SELAGINELLACEAE			
	Selaginella uliginosa		+

SINOPTERIDACEAE			
	Cheilanthes distans	+	+
	C. sieberi	+	+
R	*Pellaea falcata*		+
ZAMIACEAE			
	Macrozamia communis		+
	M. spiralis		+
ANGIOSPERMS			
MONOCOTYLEDONS			
AGAVACEAE			
	* *Yucca aloifolia*	+	
ALISMATACEAE			
	Damasonium minus	+	
AMARYLLIDACEAE			
	* *Clivea miniata*	+	
ANTHERICACEAE			
R	*Arthropodium milleflorum*	+	
	Caesia calliantha		+
	C. parviflora		+
	Laxmannia gracilis	+	+
	Sowerbaea juncea		+
	Thysanotus juncifolius		+
	Tricoryne elatior		+
R	*T. simplex*	+	+
ASPARAGACEAE			
	* *Myrsiphyllum asparagoides*	+	+
	* *Protasparagus densiflorus*	+	
CANNACEAE			
	* *Canna* x *generalis*	+	
COLCHICACEAE			
	Burchardia umbellata		+
COMMELINACEAE			
	Commelina cyanea	+	+
	* *Tradescantia albiflora*	+	
CYPERACEAE			
	Baumea juncea		+
	B. rubiginosa		+
	Carex appressa	+	
R	*C. breviculmis*	+	
	Caustis flexuosa		+
	C. pentandra		+
	C. recurvata		+
	Chorizandra cymbaria		+
	C. sphaerocephala		+
	Cyathochaeta diandra		+
R	*Cyperus difformis*	+	
	* *C. eragrostis*	+	+
	C. gracilis	+	
R	*C. polystachyos*	+	+
R	*Eleocharis acuta*	+	
	E. gracilis	+	
	E. sphacelata		+
	Fimbristylis dichotoma	+	
	Gahnia clarkei		+
	G. sieberiana		+
	Gymnoschoenus sphaerocephalus		+
	Isolepis cernua		+
	Lepidosperma concavum		+
	L. filiforme		+
	L. forsythii		+
	L. laterale		+
	L. limicola		+
	L. neesii		+

	L. urophorum		+
	Schoenus apogon		+
	S. brevifolius		+
	S. ericetorum		+
	S. lepidosperma subsp. pachylepis		+
	S. melanostachys		+
R	*S. moorei*		+
	S. paludosus		+
	S. turbinatus		+
	S. villosus		+
	Tetraria capillaris		+
	Tricostularia pauciflora		+
DORYANTHACEAE			
R	*Doryanthes excelsa*		+
HAEMODORACEAE			
	Haemodorum corymbosum		+
HYDROCHARITACEAE			
R	*Ottelia ovalifolia*	+	
	Vallisneria gigantea		+
IRIDACEAE			
	Patersonia glabrata		+
	P. sericea		+
	* *Romulea rosea*		+
JUNCACEAE			
	* *Juncus acutus*	+	
	* *J. bufonius*	+	
	J. continuus		+
	J. planifolius	+	+
	J. subsecundus	+	
	J. usitatus	+	+
JUNCAGINACEAE			
	Triglochin procerum	+	+
LOMANDRACEAE			
	Lomandra brevis		+
	L. cylindrica		+
	L. filiformis		+
N	*L. fluviatilis*		+
	L. glauca		+
	L. gracilis		+
	L. longifolia	+	+
R	*L. micrantha*		+
	L. multiflora	+	+
	L. obliqua		+
LUZURIAGACEAE			
	Geitonoplesium cymosum	+	
ORCHIDACEAE			
	Acianthus fornicatus		+
	Caladenia ?carnea		+
R	*Caleana major*		+
	Calochilus sp.		+
	Cryptostylis erecta		+
	Cymbidium suave		+
	Dendrobium linguiforme		+
	D. speciosum		+
	Dipodium punctatum		+
	Diuris aurea		+
	D. maculata		+
	Liparis reflexa		+
	Microtis ?oblonga		+
	M. unifolia		+
	Prasophyllum flavum		+
	Prasophyllum sp.		+
	Pterostylis sp.		+

N	*Pterostylis* species E		+
	Spiranthes sinensis		+
	Thelymitra circumsepta		+
	Thelymitra sp.		+
PHILYDRACEAE			
	Philydrum lanuginosum	+	+
PHORMIACEAE			
	Dianella caerulea		+
	D. longifolia	+	+
	D. revoluta	+	+
	Thelionema caespitosum		+
POACEAE			
	Amphipogon strictus		+
	* *Andropogon virginicus*	+	+
	Anisopogon avenaceus		+
	Aristida ramosa	+	+
	A. vagans	+	+
	A. warburgii		+
	* *Axonopus affinis*	+	
R	*Bothriochloa decipiens*		+
R	*B. macra*	+	
	* *Briza minor*	+	+
	* *Bromus catharticus*		+
	Chionochloa pallida		+
	* *Chloris gayana*	+	
	C. truncata	+	
	C. ventricosa	+	
	* *Cortaderia selloana*	+	
R	*Cymbopogon refractus*	+	+
	Cynodon dactylon	+	+
R	*Danthonia linkii*		+
R	*D. longifolia*		+
	D. tenuior	+	+
	Deyeuxia contracta		+
	D. quadriseta		+
	Dichelachne micrantha	+	+
	Digitaria parviflora		+
	* *Echinochloa esculenta*	+	
	Echinopogon caespitosus	+	+
	E. ovatus	+	+
	* *Eleusine indica*	+	+
	Entolasia marginata	+	+
	E. stricta		+
	Eragrostis brownii	+	+
	E. leptostachya	+	
	E. parviflora		+
	Hemarthria uncinata		+
	* *Hordeum leporinum*		+
	Imperata cylindrica	+	+
	Microlaena stipoides	+	+
R	*Oplismenus aemulus*	+	+
	Panicum effusum		+
	P. simile	+	+
	Paspalidium distans		+
	P. gracile		+
	* *Paspalum dilatatum*	+	+
R	*P. distichum*	+	+
	* *P. urvillei*	+	
	* *Pennisetum clandestinum*	+	
	* *Phalaris aquatica*	+	
	Phragmites australis	+	
	Plinthanthesis paradoxa		+
	Poa affinis		+

	* *P. annua*	+	
R	*P. labillardieri*	+	+
	P. sieberiana		+
	* *Setaria gracilis*	+	+
	* *Sporobolus indicus* var. *capensis*		+
	Stipa pubescens		+
R	*S. ramosissima*		+
	Tetrarrhena juncea		+
	T. turfosa		+
	Themeda australis	+	+
PONTEDERIACEAE			
	* *Eichhornia crassipes*	+	
POTAMOGETONACEAE			
R	*Potamogeton tricarinatus*	+	
RESTIONACEAE			
	Empodisma minus		+
	Leptocarpus tenax		+
	Lepyrodia gracilis		+
	L. scariosa		+
	Restio australis		+
	R. dimorphus		+
	R. fastigiatus		+
	R. gracilis		+
	R. tetraphyllus		+
SMILACACEAE			
	Smilax glyciphylla		+
TYPHACEAE			
	Typha orientalis	+	
XANTHORRHOEACEAE			
	Xanthorrhoea arborea		+
R	*X. concava*		+
	X. media		+
	X. resinifera		+
XYRIDACEAE			
	Xyris gracilis		+
	X. juncea		+
	X. operculata		+
DICOTYLEDONS			
ACANTHACEAE			
	Brunoniella australis	+	+
	B. pumilio		+
	Pseuderanthemum variabile	+	
AMARANTHACEAE			
	Alternanthera denticulata	+	
	* *Amaranthus retroflexus*	+	
AMYGDALACEAE			
	* *Prunus cerasifera*	+	
	* *P. persica*	+	
APIACEAE			
	Actinotus helianthi		+
	A. minor		+
	Centella asiatica	+	
	* *Foeniculum vulgare*	+	+
	* *Hydrocotyle bonariensis*	+	
	H. laxiflora		+
	H. peduncularis		+
	Platysace ericoides		+
	P. lanceolata		+
	P. linearifolia		+
	Trachymene incisa		+
	Xanthosia pilosa		+
	X. tridentata		+

APOCYNACEAE			
	Parsonsia straminea	+	
ARALIACEAE			
	Astrotricha latifolia		+
	* *Hedera helix*	+	
	Polyscias sambucifolia	+	+
ASCLEPIADACEAE			
	Araujia sericiflora	+	
	* *Gomphocarpus fruticosus*		+
	Marsdenia suaveolens		+
ASTERACEAE			
	* *Aster subulatus*	+	+
R	*Calotis lappulacea*		+
	Cassinia arcuata	+	
R	*C. aureonitens*		+
	C. denticulata		+
	C. uncata		+
R	*Chrysocephalum apiculatum*	+	
	* *Cichorium intybus*	+	
	* *Cirsium vulgare*	+	+
	* *Conyza albida*		+
	* *C. bonariensis*	+	
	* *C. canadensis*		+
	* *Coreopsis lanceolata*	+	
	* *Cotula coronopifolia*	+	
R	*Cymbonotus lawsonianus*	+	
	* *Delairea odorata*	+	
R	*Euchiton sphaericus*	+	
R	*Gnaphalium gymnocephalum*		+
	G. sphaericum		+
	* *G. spicatum*		+
	Helichrysum collinum		+
	H. elatum		+
	H. scorpioides	+	+
	* *Hypochaeris radicata*	+	+
	Lagenifera stipitata		+
	Olearia microphylla	+	+
	O. viscidula		+
	Ozothamnus diosmifolius	+	
	Pseudognaphalium luteo-album	+	+
R	*Senecio hispidulus* var. *dissectus*		+
R	*S. hispidulus* var. *hispidulus*	+	
	S. lautus		+
	S. linearifolius	+	
	* *S. madagascariensis*	+	+
	S. quadridentatus	+	
	* *S. tamoides*		+
	Sigesbeckia orientalis	+	+
	* *Sonchus oleraceus*	+	+
	* *Tagetes minuta*	+	
	* *Taraxacum officinale*		+
	Vernonia cinerea		+
R	*Vittadinia cuneata* var. *cuneata*	+	
R	*V. pustulata*	+	
BASELLACEAE			
	* *Anredera cordifolia*	+	
BAUERACEAE			
	Bauera microphylla		+
	B. rubioides		+
BIGNONIACEAE			
R	*Pandorea pandorana*	+	+
	* *Tecoma capensis*	+	

BLANDFORDIACEAE			
	Blandfordia nobilis		+
BORAGINACEAE			
	Austrocynoglossum latifolium	+	
BRASSICACEAE			
	* *Rorippa palustris*	+	
	* *Sisymbrium irio*		+
CACTACEAE			
	* *Opuntia stricta*	+	
CAMPANULACEAE			
	Wahlenbergia gracilis	+	+
R	*W. stricta*		+
CAPRIFOLIACEAE			
	* *Lonicera japonica*	+	+
CASUARINACEAE			
	Allocasuarina diminuta		+
	A. distyla		+
N	*A. glareicola*		+
	A. littoralis	+	+
R	*A. nana*		+
R	*A. paludosa*		+
	A. torulosa		+
	Casuarina glauca	+	
CELASTRACEAE			
	Maytenus silvestris		+
CHENOPODIACEAE			
	* *Chenopodium album*	+	
	Einadia hastata	+	+
R	*E. nutans*	+	
	E. trigonos		+
CLUSIACEAE			
	Hypericum gramineum	+	+
	* *H. perforatum*	+	
CONVOLVULACEAE			
R	*Convolvulus erubescens*	+	
	Dichondra repens	+	+
	Polymeria calycina	+	
CRASSULACEAE			
	* *Bryophyllum delagoense*	+	
	* *Kalanchoe longiflora*	+	
CUNONIACEAE			
	Ceratopetalum apetalum		+
	C. gummiferum		+
DILLENIACEAE			
	Hibbertia acicularis		+
	H. aspera	+	+
	H. circumdans		+
	H. diffusa	+	+
	H. empetrifolia		+
	H. fasciculata		+
	H. linearis		+
	H. monogyna		+
N	*H. nitida*		+
	H. obtusifolia		+
R	*H. riparia*		+
	H. sericea		+
	H. serpyllifolia		+
DROSERACEAE			
	Drosera peltata		+
	D. spatulata		+
ELAEOCARPACEAE			
	Elaeocarpus reticulatus		+

EPACRIDACEAE			
	Astroloma humifusum	+	
	Brachyloma daphnoides		+
	Epacris longiflora		+
	E. microphylla		+
	E. obtusifolia		+
	E. pulchella		+
S	*Leucopogon amplexicaulis*		+
	L. appressus		+
	L. ericoides		+
	L. esquamatus		+
N	*L. exolasius*		+
R	*L. juniperinus*		+
R	*L. juniperinus*	+	
	L. lanceolatus		+
	L. microphyllus		+
	L. virgatus		+
	Lissanthe strigosa	+	+
	Melichrus procumbens		+
	M. urceolatus		+
	Monotoca elliptica		+
N	*M. ledifolia*		+
	M. scoparia		+
	Sprengelia incarnata		+
	Styphelia laeta var. *laeta*		+
	Woollsia pungens		+
EUPHORBIACEAE			
	Amperea xiphoclada		+
	Bertya pomaderroides		+
	Beyeria lasiocarpa		+
	Breynia oblongifolia	+	
	Chamaesyce drummondii	+	
	Micrantheum ericoides		+
	M. hexandrum		+
R	*Phyllanthus gasstroemii*		+
	P. hirtellus		+
R	*P. similis*	+	
	Poranthera ericifolia		+
	P. microphylla	+	+
	Pseudanthus pimeleoides		+
	Ricinocarpos pinifolius		+
*	*Ricinus communis*	+	
FABACEAE			
	Almaleea paludosa		+
R	*Aotus ericoides*		+
	Bossiaea buxifolia		+
	B. ensata		+
	B. heterophylla	+	+
R	*B. neo-anglica*		+
	B. obcordata		+
	B. prostrata		+
	B. stephensonii		+
R	*Chorizema parviflorum*		+
	Daviesia acicularis		+
R	*D. corymbosa*		+
R	*D. genistifolia*	+	+
	D. ulicifolia	+	+
R	*Desmodium brachypodum*	+	
	D. varians	+	
	Dillwynia floribunda		+
	D. juniperina		+
R	*D. parvifolia*	+	+
	D. retorta		+

	D. sericea		+
	D. sieberi	+	
	D. tenuifolia		+
	* *Genista monspessulana*	+	
	Glycine clandestina		+
R	*G. microphylla*		+
	G. tabacina		+
	Gompholobium glabratum		+
	G. grandiflorum		+
	G. huegelii		+
	G. latifolium		+
	G. minus		+
	G. species B		+
	Hardenbergia violacea	+	+
	Hovea linearis		+
	H. longifolia		+
	Indigofera australis	+	+
	Jacksonia scoparia	+	+
	Kennedia rubicunda		+
	Melilotus officinalis	+	
	Mirbelia rubiifolia		+
	M. speciosa		+
	Phyllota phylicoides		+
N	*Pultenaea aristata*		+
	P. blakelyi		+
	P. daphnoides		+
	P. elliptica		+
	P. flexilis		+
R	*P. hispidula*		+
	P. linophylla		+
N	*P. parviflora*	+	
	P. scabra		+
	P. stipularis		+
	P. villosa	+	+
	* *Senna pendula*	+	
	* *Trifolium arvense*		+
	* *T. dubium*	+	
	* *T. repens*	+	
	Vicia sativa	+	
	Viminaria juncea		+
R	*Zornia dyctiocarpa*		+
GENTIANACEAE			
	* *Centaurium erythraea*	+	+
GERANIACEAE			
R	*Geranium solanderi*	+	
	G. sp.		+
GOODENIACEAE			
	Dampiera purpurea		+
	D. stricta		+
	Goodenia bellidifolia	+	+
	G. dimorpha		+
	G. hederacea	+	+
	G. heterophylla		+
	G. paniculata	+	+
	Scaevola ramosissima		+
HALORAGACEAE			
	Gonocarpus micranthus		+
	G. tetragynus		+
	G. teucrioides		+
	Myriophyllum variifolium	+	
LAMIACEAE			
	Ajuga australis	+	
	Hemigenia purpurea		+

	Plectranthus graveolens		+
	P. parviflorus	+	
	Scutellaria humilis	+	
S	*Westringia longifolia*		+
LAURACEAE			
	Cassytha glabella	+	+
	C. pubescens		+
	* *Cinnamomum camphora*	+	+
LENTIBULARIACEAE			
	Utricularia dichotoma		+
LINACEAE			
R	*Linum marginale*	+	+
LOBELIACEAE			
	Lobelia alata		+
	L. dentata		+
	Pratia purpurascens		+
LOGANIACEAE			
	Logania albiflora		+
	Mitrasacme polymorpha		+
LORANTHACEAE			
R	*Amyema gaudichaudii*	+	+
R	*A. miquelii*	+	+
R	*Muellerina eucalyptoides*		+
LYTHRACEAE			
	* *Lagerstroemia indica*	+	
R	*Lythrum hyssopifolia*	+	
MALACEAE			
	* *Malus domestica*	+	
MALVACEAE			
	* *Modiola caroliniana*	+	+
R	*Sida corrugata*	+	
	* *S. rhombifolia*	+	
MELIACEAE			
	Melia azedarach	+	
MENYANTHACEAE			
	Nymphoides geminata	+	
MIMOSACEAE			
	* *Acacia baileyana*	+	
R	*A. binervata*		+
	A. brownii		+
	A. decurrens	+	+
	A. falcata	+	+
	A. floribunda		+
	A. hispidula		+
R	*A. implexa*	+	+
	A. irrorata		+
	A. linifolia		+
	A. longifolia		+
	A. longissima		+
	A. mearnsii		+
	A. myrtifolia		+
	A. obtusifolia		+
	A. parramattensis	+	+
	A. penninervis		+
	* *A. podalyiifolia*	+	
	A. stricta		+
	A. suaveolens		+
	A. terminalis		+
	A. ulicifolia	+	+
MORACEAE			
	Morus alba	+	
MYOPORACEAE			
R	*Eremophila debilis*	+	

MYRSINACEAE			
	Rapanea variabilis		+
MYRTACEAE			
	Angophora bakeri		+
	A. costata		+
	A. floribunda	+	+
R	*A. hispida*		+
R	*A. subvelutina*	+	
	Austromyrtus tenuifolia		+
	Backhousia myrtifolia		+
	Baeckea brevifolia		+
	B. diosmifolia		+
	B. imbricata		+
	B. linifolia		+
	B. ramosissima		+
	Callistemon citrinus		+
	C. linearis		+
	C. salignus		+
	Calytrix tetragona		+
	Corymbia gummifera		+
N	*Darwinia diminuta*		+
	D. fascicularis		+
N	*D. grandiflora*		+
	Eucalyptus agglomerata		+
R	*E. amplifolia*	+	+
R	*E. baueriana*		+
S	*E. beyeriana*		+
R	*E. bosistoana*	+	
	E. consideniana		+
	E. crebra	+	+
	E. eugenioides	+	+
	E. fibrosa	+	+
	E. globoidea		+
S	*E. ligustrina*		+
	E. longifolia		+
N	*E. luehmanniana*		+
	E. moluccana	+	+
S	*E. multicaulis*		+
	E. oblonga		+
R	*E. paniculata*		+
	E. parramattensis		+
	E. pilularis		+
	E. piperita		+
	E. punctata		+
	E. racemosa		+
	E. resinifera		+
	E. saligna/botryoides		+
R	*E. sclerophylla*		+
	E. siderophloia		+
	E. sideroxylon		+
	E. sieberi		+
	E. sparsifolia		+
S	*E. squamosa*		+
	E. tereticornis	+	+
	Kunzea ambigua	+	+
	K. capitata		+
	Leptospermum arachnoides		+
	L. continentale		+
	L. juniperinum		+
	L. lanigerum		+
	L. morrisonii		+
	L. parvifolium		+
	L. polygalifolium		+

	L. squarrosum		+
	L. trinervium		+
N	*Melaleuca deanei*		+
	M. decora	+	+
	M. linariifolia	+	+
	M. nodosa		+
R	*M. squamea*		+
	M. styphelioides	+	
	M. thymifolia		+
	Syncarpia glomulifera		+
	Tristania neriifolia		+
R	*Tristaniopsis laurina*		+
OLACACEAE			
	Olax stricta		+
OLEACEAE			
	* *Jasminum mesneyi*	+	
	* *Ligustrum lucidum*	+	
	* *L. sinense*	+	+
	Notelaea longifolia		+
	Olea europaea	+	
ONAGRACEAE			
R	*Epilobium billardierianum* ssp. *cinereum*	+	
OXALIDACEAE			
	* *Oxalis corniculata*	+	
R	*O. perennans*	+	+
R	*O. radicosa*		+
PHYTOLACCACEAE			
	* *Phytolacca octandra*	+	
PITTOSPORACEAE			
	Billardiera scandens	+	+
	Bursaria lasiophylla		+
	B. spinosa	+	+
	Hymenosporum flavum		+
	Pittosporum undulatum	+	
	Rhytidosporum procumbens		+
PLANTAGINACEAE			
R	*Plantago debilis*	+	
	* *P. lanceolata*	+	+
POLYGALACEAE			
	Comesperma defoliatum		+
	C. sphaerocarpum		+
	C. volubile		+
POLYGONACEAE			
	* *Acetosa sagittata*	+	
	* *Acetosella vulgaris*		+
	Persicaria decipiens	+	
	P. hydropiper	+	
R	*P. praetermissa*		+
	P. strigosa		+
R	*Rumex brownii*	+	
	* *R. crispus*	+	
PRIMULACEAE			
	* *Anagallis arvensis*	+	+
PROTEACEAE			
	Banksia ericifolia		+
	B. integrifolia		+
	B. marginata		+
	B. oblongifolia		+
	B. serrata		+
	B. spinulosa		+
	Conospermum ellipticum		+
	C. longifolium ssp. *angustifolium*		+
	C. taxifolium		+

	C. tenuifolium		+
	Grevillea buxifolia		+
S	*G. diffusa* ssp. *diffusa*		+
	G. linearifolia		+
N	*G. longifolia*		+
	G. mucronulata		+
	G. oleoides		+
	G. sericea		+
	G. sphacelata		+
	Hakea dactyloides		+
	H. gibbosa		+
	H. propinqua		+
S	*H. salicifolia* narrow leaf form		+
	H. sericea	+	+
	H. teretifolia		+
	Isopogon anemonifolius		+
	I. anethifolius		+
	Lambertia formosa		+
	Lomatia myricoides		+
	L. silaifolia		+
	Persoonia lanceolata		+
	P. laurina		+
	P. levis		+
	P. linearis		+
S	*P. mollis* ssp. *nectens*		+
N	*P. nutans*		+
	P. pinifolia		+
	Petrophile pedunculata		+
	P. pulchella		+
	P. sessilis		+
	Stenocarpus salignus		+
	Symphionema paludosum		+
	Telopea speciosissima		+
	Xylomelum pyriforme		+
RANUNCULACEAE			
	Clematis aristata	+	+
R	*C. glycinoides*	+	
R	*Ranunculus lappaceus*	+	
RHAMNACEAE			
R	*Alphitonia exelsa*		+
	Cryptandra amara		+
	C. ericoides		+
	Pomaderris discolor		+
	P. elliptica		+
R	*P. ferruginea*		+
	P. intermedia		+
	P. lanigera		+
ROSACEAE			
	* *Rubus fruticosus* spp. agg.	+	
ROSACEAE S. STR.			
	* *Rosa rubiginosa*	+	
	Rubus parvifolius	+	
RUBIACEAE			
	Asperula conferta	+	+
R	*Galium liratum*		+
	G. propinquum	+	
R	*Opercularia aspera*	+	+
	O. diphylla	+	+
	O. varia		+
	Pomax umbellata		+
	* *Richardia stellaris*	+	+

RUTACEAE			
	Boronia ledifolia		+
	B. parviflora		+
	B. ruppii		+
	Eriostemon australasius		+
	E. scaber		+
	Phebalium dentatum		+
	P. diosmeum		+
	P. squameum		+
	P. squamulosum		+
	Zieria fraseri ssp. *B*		+
	Z. pilosa		+
	Z. smithii		+
SALICACEAE			
	* *Populus nigra*	+	
	* *Salix alba*	+	
	* *S. babylonica*	+	
SANTALACEAE			
	Exocarpos cupressiformis	+	+
R	*E. strictus*	+	+
	Omphacomeria acerba		+
	Santalum obtusifolium		+
SAPINDACEAE			
	Alectryon subcinereus		+
	* *Cardiospermum grandiflorum*	+	
	Dodonaea triquetra	+	+
	D. viscosa ssp. *cuneata*	+	
SCROPHULARIACEAE			
	* *Verbascum virgatum*		+
	Veronica plebeia	+	
SOLANACEAE			
R	*Dubiosia myoporoides*		+
	* *Physalis peruviana*	+	
	* *Solanum mauritianum*	+	
	* *S. nigrum*	+	+
	S. prinophyllum	+	+
R	*S. pungetium*	+	+
STACKHOUSIACEAE			
	Stackhousia nuda		+
	S. viminea	+	+
STERCULIACEAE			
	Brachychiton populneus	+	
	Lasiopetalum ferrugineum var. *cordatum*		+
	L. ferrugineum var. *ferrugineum*		+
	L. macrophyllum		+
R	*L. parviflorum*		+
STYLIDIACEAE			
	Stylidium graminifolium		+
	S. laricifolium		+
	S. lineare		+
	S. productum		+
TEMANDRACEAE			
S	*Tetratheca shiressii*		+
THYMELAEACEAE			
	Pimelea linifolia	+	+
TREMANDRACEAE			
	Tetratheca ericifolia		+
N	*T. neglecta*		+
VERBENACEAE			
R	*Avicennia marina*		+
R	*Clerodendrum tomentosum*		+
	* *Lantana camara*	+	
	* *Verbena bonariensis*	+	+

VIOLACEAE		
Hybanthus monopetalus		+
Viola hederacea		+
VITACEAE		
Cayratia clematidea	+	

1.15.1 Quadrat Data

Quadrat data (Holsworthy) used in this study comprise 73 quadrats collected by French *et al.* (1995) and 30 additional quadrats collected by Biosis Research. For brevity, only Biosis Research quadrats are given here. Refer to French *et al.* (1995) for quadrats 01 to 73.

Quadrat: 074

Number of species: 46 Date: 13 November 1996 Altitude: 60 m

Latitude: 34°00'05" Longitude: 150°54'45" Quadrat Area: 400 m^2 Collector: GL

Vegetation Community: HOLS 2

2244	+	Acacia linifolia
2286	+	Acacia terminalis
2290	+	Acacia ulicifolia
2332	1	Angophora bakeri
0950	+	Ceratopetalum gummiferum
1012	+	Cyathochaeta diandra
2982	+	Dianella revoluta
3260	+	Eragrostis brownii
2434	2	Eucalyptus eugenioides
2504	2	Eucalyptus punctata
2506	1	Eucalyptus racemosa
1481	+	Gompholobium grandiflorum
1482	+	Gompholobium huegelii
1718	+	Goodenia hederacea
3642	+	Grevillea linearifolia
3671	1	Hakea dactyloides
0436	+	Helichrysum scorpioides
1191	+	Hibbertia obtusifolia
3307	1	Imperata cylindrica
3685	+	Isopogon anemonifolius
1505	1	Jacksonia scoparia
2548	+	Kunzea ambigua
2550	+	Kunzea capitata
2594	1	Leptospermum trinervium
1274	+	Leucopogon juniperinus
2039	+	Lindsaea microphylla
2078	+	Lomandra filiformis
2081	+	Lomandra gracilis
2086	+	Lomandra obliqua
3694	+	Lomatia silaifolia
2604	1	Melaleuca nodosa
2065	+	Mitrasacme polymorpha
3717	+	Persoonia levis
3718	+	Persoonia linearis
1369	+	Phyllanthus hirtellus
4303	1	Pimelea linifolia
3945	+	Pomax umbellata
1374	+	Poranthera microphylla
2903	+	Pterostylis species
1582	+	Pultenaea hispidula
4267	+	Stylidium lineare
3483	1	Themeda australis
0106	+	Tricoryne elatior
1154	+	Tricostularia pauciflora
0170	+	Xanthosia pilosa
0171	+	Xanthosia tridentata

Quadrat: 075

Number of species: 34 Date: 13 November 1996 Altitude: 40 m

Latitude: 33°59'24" Longitude: 150°55'32" Quadrat Area: 400 m^2 Collector: GL

Vegetation Community: HOLS 1

2250	+	Acacia mearnsii
2290	+	Acacia ulicifolia
2090	+	Amyema miquelii
3081	+	Aristida vagans
0001	+	Brunoniella australis
3005	2	Bursaria spinosa
1012	+	Cyathochaeta diandra
1447	+	Daviesia ulicifolia
2982	+	Dianella revoluta
4094	+	Dodonaea triquetra
3238	+	Echinopogon caespitosus
3257	+	Entolasia stricta
2419	2	Eucalyptus crebra
2434	2	Eucalyptus eugenioides
2440	1	Eucalyptus fibrosa
1479	+	Glycine tabacina
0436	+	Helichrysum scorpioides
1187	+	Hibbertia linearis
3307	1	Imperata cylindrica
1113	+	Lepidosperma laterale
2594	1	Leptospermum trinervium
1290	+	Lissanthe strigosa
2080	+	Lomandra glauca
2085	+	Lomandra multiflora
3325	1	Microlaena stipoides
644	+	Notelaea longifolia
3942	+	Opercularia diphylla
3357	+	Panicum simile
4303	+	Pimelea linifolia
0152	+	Platysace ericoides
1603	+	Pultenaea villosa
3483	2	Themeda australis
1154	+	Tricostularia pauciflora
4371	1	Viola hederacea

Quadrat: 076

Number of species: 57 Date: 13 November 1996 Altitude: 60 m

Latitude: 34°00'10" Longitude: 150°54'50" Quadrat Area: 400 m^2 Collector: GL

Vegetation Community: HOLS 2

2286	+	Acacia terminalis
2290	+	Acacia ulicifolia
2684	+	Acianthus fornicatus
0112	+	Actinotus helianthi
0007	+	Adiantum aethiopicum
0828	1	Allocasuarina littoralis
2332	1	Angophora bakeri
2333	2	Angophora costata
3607	+	Banksia spinulosa
0002	+	Brunoniella pumilio
0950	+	Ceratopetalum gummiferum
4179	+	Cheilanthes distans
3176	+	Danthonia tenuior
2979	+	Dianella longifolia
3256	+	Entolasia marginata
3991	+	Eriostemon australasius
2446	2	Corymbia gummifera
2504	3	Eucalyptus punctata
2506	1	Eucalyptus racemosa
1476	+	Glycine clandestina
1482	+	Gompholobium huegelii
1718	+	Goodenia hederacea
3671	1	Hakea dactyloides
1191	+	Hibbertia obtusifolia
3307	1	Imperata cylindrica
3685	+	Isopogon anemonifolius
1505	1	Jacksonia scoparia
3690	1	Lambertia formosa
1113	+	Lepidosperma laterale
2584	1	Leptospermum polygalifolium
2594	+	Leptospermum trinervium
2081	+	Lomandra gracilis
2082	1	Lomandra longifolia
3694	+	Lomatia silaifolia
2603	+	Melaleuca linariifolia
1362	+	Micrantheum ericoides
1296	+	Monotoca scoparia
0622	+	Pandorea pandorana
3717	+	Persoonia levis
3718	+	Persoonia linearis
3737	+	Persoonia pinifolia
1369	+	Phyllanthus hirtellus
4303	+	Pimelea linifolia
3419	+	Poa sieberiana
3849	+	Pomaderris elliptica
3945	+	Pomax umbellata
1171	1	Pteridium esculentum
1379	+	Ricinocarpos pinifolius
4186	+	Smilax glyciphylla
4267	+	Stylidium lineare
2619	2	Syncarpia glomulifera
3483	1	Themeda australis
0162	+	Trachymene incisa
0106	+	Tricoryne elatior
0761	+	Wahlenbergia stricta
4401	+	Xanthorrhoea media
3752	+	Xylomelum pyriforme

Quadrat: 077

Number of species: 52 Date: 14 November 1996 Altitude: 120 m

Latitude: 34°03'44" Longitude: 150°55'21" Quadrat Area: 400 m^2 Collector: GL

Vegetation Community: HOLS 5

2185	+	Acacia brownii
2227	+	Acacia hispidula
2244	1	Acacia linifolia
2255	+	Acacia myrtifolia
2282	+	Acacia suaveolens
0113	+	Actinotus minor
0828	1	Allocasuarina littoralis
2342	1	Baeckea brevifolia
3604	1	Banksia serrata
3607	1	Banksia spinulosa
1412	+	Bossiaea heterophylla
2366	1	Calytrix tetragona
1004	+	Caustis flexuosa
0950	1	Ceratopetalum gummiferum
1252	+	Epacris microphylla
1254	+	Epacris obtusifolia
3991	+	Eriostemon australasius
2446	2	Corymbia gummifera
2493	1	Eucalyptus pilularis
1481	+	Gompholobium grandiflorum
1482	+	Gompholobium huegelii
3632	+	Grevillea diffusa ssp. diffusa
3651	+	Grevillea mucronulata
3671	1	Hakea dactyloides
3674	1	Hakea gibbosa
1189	+	Hibbertia nitida
1199	+	Hibbertia serpyllifolia
0889	+	Hypericum gramineum
2550	+	Kunzea capitata
3690	2	Lambertia formosa
4249	+	Lasiopetalum ferrugineum var. ferrugineum
4253	+	Lasiopetalum parviflorum
2558	+	Leptospermum arachnoides
2568	1	Leptospermum juniperinum
2584	2	Leptospermum polygalifolium
2594	1	Leptospermum trinervium
1268	+	Leucopogon esquamatus
1281	+	Leucopogon microphyllus
2086	+	Lomandra obliqua
3694	+	Lomatia silaifolia
1843	+	Patersonia sericea
3711	+	Persoonia lanceolata
3717	+	Persoonia levis
3737	+	Persoonia pinifolia
0152	+	Platysace ericoides
3408	+	Poa labillardieri
1171	2	Pteridium esculentum
1574	+	Pultenaea elliptica
1599	+	Pultenaea stipularis
3818	+	Restio tetraphyllus
3468	+	Stipa ramosissima
0171	+	Xanthosia tridentata

Quadrat: 078

Number of species: 52 Date: 13 November 1996 Altitude: 38 m

Latitude: 34°00'00" Longitude: 150°55'30" Quadrat Area: 400 m^2 Collector: GL

Vegetation Community: HOLS 5

2185	+	Acacia brownii
2218	1	Acacia floribunda
2258	1	Acacia obtusifolia
2286	+	Acacia terminalis
0112	+	Actinotus helianthi
0113	+	Actinotus minor
2332	1	Angophora bakeri
1403	1	Aotus ericoides
2349	1	Baeckea linifolia
2352	+	Baeckea ramosissima
3607	1	Banksia spinulosa
0616	1	Bauera rubioides
2994	+	Billardiera scandens
2355	+	Callistemon citrinus
1704	+	Dampiera purpurea
4094	+	Dodonaea triquetra
3257	+	Entolasia stricta
4001	+	Eriostemon scaber
2493	2	Eucalyptus pilularis
2494	1	Eucalyptus piperita
2504	2	Eucalyptus punctata
2506	2	Eucalyptus racemosa
1084	1	Gahnia sieberiana
1695	1	Gleichenia microphylla
1481	1	Gompholobium grandiflorum
1482	+	Gompholobium huegelii
1756	+	Gonocarpus tetragynus
1718	+	Goodenia hederacea
3649	1	Grevillea longifolia
3651	1	Grevillea mucronulata
3679	1	Hakea salicifolia
1179	+	Hibbertia circumdans
1497	+	Hovea longifolia
0889	+	Hypericum gramineum
1896	+	Juncus planifolius
1908	+	Juncus usitatus
1114	+	Lepidosperma limicola
2584	1	Leptospermum polygalifolium
2086	+	Lomandra obliqua
3693	+	Lomatia myricoides
2608	1	Melaleuca squamea
1362	+	Micrantheum ericoides
1296	+	Monotoca scoparia
3717	+	Persoonia levis
4303	+	Pimelea linifolia
3849	1	Pomaderris elliptica
1580	+	Pultenaea flexilis
1138	+	Schoenus ericetorum
3483	+	Themeda australis
0106	+	Tricoryne elatior
1649	+	Viminaria juncea
0170	+	Xanthosia pilosa

Quadrat: 079

Number of species: 49 Date: 13 November 1996 Altitude: 40 m

Latitude: 34°00'05" Longitude: 150°56'10" Quadrat Area: 400 m^2 Collector: GL

Vegetation Community: HOLS 5

0112	+	Actinotus helianthi
2332	1	Angophora bakeri
2342	+	Baeckea brevifolia
2349	+	Baeckea linifolia
3601	1	Banksia oblongifolia
3604	+	Banksia serrata
3966	+	Boronia ledifolia
1408	+	Bossiaea buxifolia
2355	+	Callistemon citrinus
2366	1	Calytrix tetragona
0950	1	Ceratopetalum gummiferum
1010	+	Chorizandra sphaerocephala
1704	+	Dampiera purpurea
1706	+	Dampiera stricta
3163	+	Danthonia longifolia
2375	+	Darwinia grandiflora
1465	+	Dillwynia retorta
2494	2	Eucalyptus piperita
2504	1	Eucalyptus punctata
2506	2	Eucalyptus racemosa
1756	+	Gonocarpus tetragynus
3632	+	Grevillea diffusa ssp. diffusa
3651	1	Grevillea mucronulata
1492	+	Hardenbergia violacea
2550	+	Kunzea capitata
1113	+	Lepidosperma laterale
3805	+	Leptocarpus tenax
2584	2	Leptospermum polygalifolium
2591	1	Leptospermum squarrosum
2078	+	Lomandra filiformis
2081	+	Lomandra gracilis
2086	+	Lomandra obliqua
3694	+	Lomatia silaifolia
2603	1	Melaleuca linariifolia
1362	+	Micrantheum ericoides
1843	+	Patersonia sericea
3717	+	Persoonia levis
3737	+	Persoonia pinifolia
1171	1	Pteridium esculentum
1585	+	Pultenaea linophylla
3813	+	Restio fastigiatus
1379	+	Ricinocarpos pinifolius
1735	+	Scaevola ramosissima
4267	+	Stylidium lineare
0106	+	Tricoryne elatior
1649	+	Viminaria juncea
1315	+	Woollsia pungens
4392	+	Xanthorrhoea concava
0171	+	Xanthosia tridentata

Quadrat: 080

Number of species: 57 Date: 13 November 1996 Altitude: 90 m

Latitude: 34°01'05" Longitude: 150°55'37" Quadrat Area: 400 m^2 Collector: GL

Vegetation Community: HOLS 3

2244	+	Acacia linifolia
2255	+	Acacia myrtifolia
0113	+	Actinotus minor
0824	1	Allocasuarina diminuta
2333	2	Angophora costata
3082	+	Aristida warburgii
2342	+	Baeckea brevifolia
2352	+	Baeckea ramosissima
3600	1	Banksia marginata
3607	1	Banksia spinulosa
2006	+	Cassytha pubescens
1004	+	Caustis flexuosa
1012	+	Cyathochaeta diandra
1704	+	Dampiera purpurea
1706	+	Dampiera stricta
3257	+	Entolasia stricta
1254	+	Epacris obtusifolia
3991	+	Eriostemon australasius
2446	2	Corymbia gummifera
2506	1	Eucalyptus racemosa
2533	1	Eucalyptus squamosa
1718	+	Goodenia hederacea
3632	+	Grevillea diffusa ssp. diffusa
3651	+	Grevillea mucronulata
1086	+	Gymnoschoenus sphaerocephalus
3671	1	Hakea dactyloides
3680	+	Hakea sericea
1926	+	Hemigenia purpurea
1199	+	Hibbertia serpyllifolia
3685	+	Isopogon anemonifolius
2550	1	Kunzea capitata
3690	1	Lambertia formosa
0097	+	Laxmannia gracilis
2594	1	Leptospermum trinervium
3809	+	Lepyrodia scariosa
1264	+	Leucopogon appressus
1268	+	Leucopogon esquamatus
1281	+	Leucopogon microphyllus
2038	+	Lindsaea linearis
2078	+	Lomandra filiformis
2080	+	Lomandra glauca
2086	+	Lomandra obliqua
2598	+	Melaleuca deanei
1362	+	Micrantheum ericoides
1843	+	Patersonia sericea
3711	1	Persoonia lanceolata
3745	+	Petrophile sessilis
1553	+	Phyllota phylicoides
0152	+	Platysace ericoides
1373	+	Poranthera ericifolia
1374	+	Poranthera microphylla
1574	+	Pultenaea elliptica
1585	+	Pultenaea linophylla
1594	+	Pultenaea scabra
4267	+	Stylidium lineare
4401	+	Xanthorrhoea media
0171	+	Xanthosia tridentata

Quadrat: 081

Number of species: 40 Date: 13 November 1996 Altitude: 60 m

Latitude: 34°00'45" Longitude: 150°55'02" Quadrat Area: 400 m^2 Collector: GL

Vegetation Community: HOLS 1

2228	+	Acacia implexa
2290	+	Acacia ulicifolia
2332	1	Angophora bakeri
3081	1	Aristida vagans
0002	+	Brunoniella pumilio
1426	+	Chorizema parviflorum
1012	+	Cyathochaeta diandra
3163	+	Danthonia longifolia
2982	+	Dianella revoluta
3211	1	Dichelachne micrantha
3257	1	Entolasia stricta
2419	3	Eucalyptus crebra
2440	2	Eucalyptus fibrosa
2443	2	Eucalyptus globoidea
2504	1	Eucalyptus punctata
4071	+	Exocarpos cupressiformis
1476	+	Glycine clandestina
1484	+	Gompholobium minus
1753	+	Gonocarpus micranthus
1756	+	Gonocarpus tetragynus
1718	+	Goodenia hederacea
0889	+	Hypericum gramineum
0097	+	Laxmannia gracilis
1116	+	Lepidosperma neesii
2594	+	Leptospermum trinervium
1290	+	Lissanthe strigosa
2078	+	Lomandra filiformis
2082	+	Lomandra longifolia
2085	+	Lomandra multiflora
2086	+	Lomandra obliqua
4415	+	Macrozamia spiralis
3325	1	Microlaena stipoides
3942	+	Opercularia diphylla
3357	+	Panicum simile
1843	+	Patersonia sericea
3718	+	Persoonia linearis
1369	+	Phyllanthus hirtellus
2903	+	Pterostylis species
3483	2	Themeda australis
4403	+	Xanthorrhoea resinifera

Quadrat: 082

Number of species: 51 Date: 16 November 1996 Altitude: 100 m

Latitude: 34°01'20" Longitude: 150°54'30" Quadrat Area: 400 m^2 Collector: GL

Vegetation Community: HOLS 2

2185	+	Acacia brownii
2286	+	Acacia terminalis
3082	+	Aristida warburgii
3600	1	Banksia marginata
3607	1	Banksia spinulosa
1410	+	Bossiaea ensata
3142	+	Cymbopogon refractus
1460	+	Dillwynia juniperina
3256	+	Entolasia marginata
3260	1	Eragrostis brownii
3991	+	Eriostemon australasius
2434	2	Eucalyptus eugenioides
2504	2	Eucalyptus punctata
1481	+	Gompholobium grandiflorum
1482	+	Gompholobium huegelii
1753	+	Gonocarpus micranthus
1709	+	Goodenia bellidifolia
1718	+	Goodenia hederacea
3651	+	Grevillea mucronulata
3680	+	Hakea sericea
1184	+	Hibbertia empetrifolia
1191	+	Hibbertia obtusifolia
1194	+	Hibbertia riparia
1497	+	Hovea longifolia
3685	+	Isopogon anemonifolius
3690	1	Lambertia formosa
1120	+	Lepidosperma urophorum
2594	+	Leptospermum trinervium
1274	+	Leucopogon juniperinus
2086	+	Lomandra obliqua
3694	+	Lomatia silaifolia
1362	+	Micrantheum ericoides
4076	+	Omphacomeria acerba
1843	+	Patersonia sericea
3713	1	Persoonia laurina
3717	+	Persoonia levis
3718	+	Persoonia linearis
4303	+	Pimelea linifolia
3408	+	Poa labillardieri
3945	+	Pomax umbellata
1374	+	Poranthera microphylla
1574	+	Pultenaea elliptica
3013	+	Rhytidosporum procumbens
1735	+	Scaevola ramosissima
4265	+	Stylidium graminifolium
3481	+	Tetrarrhena juncea
3483	1	Themeda australis
0106	+	Tricoryne elatior
1154	+	Tricostularia pauciflora
4403	+	Xanthorrhoea resinifera
3752	+	Xylomelum pyriforme

Quadrat: 083

Number of species: 54 Date: 16 November 1996 Altitude: 95 m

Latitude: 34°01'25" Longitude: 150°54'36" Quadrat Area: 400 m^2 Collector: GL

Vegetation Community: HOLS 2

2185	+	Acacia brownii
2286	+	Acacia terminalis
2090	+	Amyema miquelii
3081	+	Aristida vagans
3600	1	Banksia marginata
3607	1	Banksia spinulosa
1410	+	Bossiaea ensata
0002	+	Brunoniella pumilio
3142	+	Cymbopogon refractus
2982	+	Dianella revoluta
0915	+	Dichondra repens
1460	+	Dillwynia juniperina
2783	+	Diuris aurea
3256	1	Entolasia marginata
2434	1	Eucalyptus eugenioides
2504	2	Eucalyptus punctata
2506	2	Eucalyptus racemosa
1481	+	Gompholobium grandiflorum
1484	+	Gompholobium minus
1756	+	Gonocarpus tetragynus
1718	+	Goodenia hederacea
3632	+	Grevillea diffusa ssp. diffusa
3651	1	Grevillea mucronulata
3671	+	Hakea dactyloides
3680	1	Hakea sericea
1184	+	Hibbertia empetrifolia
1191	+	Hibbertia obtusifolia
1199	+	Hibbertia serpyllifolia
0889	+	Hypericum gramineum
3685	1	Isopogon anemonifolius
3690	+	Lambertia formosa
1113	+	Lepidosperma laterale
2578	1	Leptospermum parvifolium
1281	+	Leucopogon microphyllus
2078	+	Lomandra filiformis
2085	+	Lomandra multiflora
2086	+	Lomandra obliqua
3694	+	Lomatia silaifolia
1362	+	Micrantheum ericoides
1841	+	Patersonia glabrata
3717	+	Persoonia levis
3718	+	Persoonia linearis
4303	+	Pimelea linifolia
3408	+	Poa labillardieri
3945	+	Pomax umbellata
1374	+	Poranthera microphylla
1171	1	Pteridium esculentum
1735	+	Scaevola ramosissima
0099	+	Sowerbaea juncea
4265	+	Stylidium graminifolium
3483	1	Themeda australis
0106	+	Tricoryne elatior
1154	+	Tricostularia pauciflora
0171	+	Xanthosia tridentata

Quadrat: 084

Number of species: 57 Date: 16 November 1996 Altitude: 60 m

Latitude: 34°04'36" Longitude: 150°53'21" Quadrat Area: 400 m^2 Collector: GL

Vegetation Community: HOLS 6

2246	+	Acacia longissima
2258	1	Acacia obtusifolia
2286	+	Acacia terminalis
0828	+	Allocasuarina littoralis
0833	+	Allocasuarina torulosa
1403	+	Aotus ericoides
0235	+	Asplenium flabellifolium
2340	+	Austromyrtus tenuifolia
2349	+	Baeckea linifolia
2352	+	Baeckea ramosissima
0616	1	Bauera rubioides
1336	+	Bertya pomaderroides
2994	+	Billardiera scandens
1004	+	Caustis flexuosa
0949	2	Ceratopetalum apetalum
0950	1	Ceratopetalum gummiferum
1704	+	Dampiera purpurea
1437	+	Daviesia corymbosa
4094	+	Dodonaea triquetra
1204	1	Doryanthes excelsa
1212	+	Drosera spatulata
1257	+	Epacris pulchella
1076	1	Gahnia clarkei
1695	1	Gleichenia microphylla
1481	+	Gompholobium grandiflorum
3651	+	Grevillea mucronulata
3657	+	Grevillea oleoides
3679	2	Hakea salicifolia
1189	+	Hibbertia nitida
1113	+	Lepidosperma laterale
1116	+	Lepidosperma neesii
2573	1	Leptospermum morrisonii
2057	+	Logania albiflora
2079	1	Lomandra fluviatilis
3693	2	Lomatia myricoides
1296	+	Monotoca scoparia
0498	+	Olearia viscidula
3717	+	Persoonia levis
3737	+	Persoonia pinifolia
3744	+	Petrophile pulchella
4009	+	Phebalium dentatum
3849	+	Pomaderris elliptica
3855	+	Pomaderris intermedia
1377	+	Pseudanthus pimeleoides
1580	+	Pultenaea flexilis
1599	+	Pultenaea stipularis
4077	+	Santalum obtusifolium
4186	+	Smilax glyciphylla
3746	1	Stenocarpus salignus
1697	1	Sticherus flabellatus
4266	+	Stylidium laricifolium
1923	+	Triglochin procerum
2624	1	Tristania neriifolia
2626	2	Tristaniopsis laurina
0170	+	Xanthosia pilosa
0171	+	Xanthosia tridentata
4047	+	Zieria smithii

Quadrat: A085

Number of species: 38 Date: 21 November 1996 Altitude: 60 m

Latitude: 34°03'55" Longitude: 150°53'25" Quadrat Area: 400 m^2 Collector: GL

Vegetation Community: HOLS 6

2258	1	Acacia obtusifolia
0828	1	Allocasuarina littoralis
1403	+	Aotus ericoides
2340	+	Austromyrtus tenuifolia
2341	1	Backhousia myrtifolia
2349	+	Baeckea linifolia
0615	1	Bauera microphylla
0616	1	Bauera rubioides
2994	+	Billardiera scandens
2355	+	Callistemon citrinus
0954	1	Callitris muelleri
0949	1	Ceratopetalum apetalum
0950	+	Ceratopetalum gummiferum
1704	+	Dampiera purpurea
1437	+	Daviesia corymbosa
4094	+	Dodonaea triquetra
1212	+	Drosera spatulata
1076	1	Gahnia clarkei
1696	1	Gleichenia rupestris
1481	+	Gompholobium grandiflorum
3651	1	Grevillea mucronulata
3657	1	Grevillea oleoides
3679	2	Hakea salicifolia
1114	+	Lepidosperma limicola
2573	1	Leptospermum morrisonii
2079	+	Lomandra fluviatilis
3693	2	Lomatia myricoides
3737	1	Persoonia pinifolia
4009	+	Phebalium dentatum
3849	+	Pomaderris elliptica
1377	+	Pseudanthus pimeleoides
1580	+	Pultenaea flexilis
3746	1	Stenocarpus salignus
1697	1	Sticherus flabellatus
2624	1	Tristania neriifolia
2626	2	Tristaniopsis laurina
0171	+	Xanthosia tridentata
4047	+	Zieria smithii

Quadrat: 086

Number of species: 43 Date: 21 November 1996 Altitude: 60 m

Latitude: 34°03'40" Longitude: 150°53'41" Quadrat Area: 400 m^2 Collector: GL

Vegetation Community: HOLS 6

2218	1	Acacia floribunda
2258	1	Acacia obtusifolia
2286	+	Acacia terminalis
0828	1	Allocasuarina littoralis
2340	+	Austromyrtus tenuifolia
2342	+	Baeckea brevifolia
2349	+	Baeckea linifolia
2352	+	Baeckea ramosissima
0616	1	Bauera rubioides
2994	+	Billardiera scandens
2355	+	Callistemon citrinus
0949	+	Ceratopetalum apetalum
0950	+	Ceratopetalum gummiferum
1210	+	Drosera peltata
1212	+	Drosera spatulata
2384	+	Eucalyptus agglomerata
2493	1	Eucalyptus pilularis
1695	1	Gleichenia microphylla
1481	+	Gompholobium grandiflorum
3642	+	Grevillea linearifolia
3651	+	Grevillea mucronulata
3657	+	Grevillea oleoides
3663	+	Grevillea sericea
3679	2	Hakea salicifolia
2548	1	Kunzea ambigua
4252	+	Lasiopetalum macrophyllum
1113	+	Lepidosperma laterale
1116	+	Lepidosperma neesii
3805	+	Leptocarpus tenax
2573	1	Leptospermum morrisonii
2584	1	Leptospermum polygalifolium
2079	+	Lomandra fluviatilis
3693	1	Lomatia myricoides
3737	+	Persoonia pinifolia
4009	+	Phebalium dentatum
3855	+	Pomaderris intermedia
3856	+	Pomaderris lanigera
1580	+	Pultenaea flexilis
3746	+	Stenocarpus salignus
1697	1	Sticherus flabellatus
1923	+	Triglochin procerum
2626	2	Tristaniopsis laurina
1794	+	Vallisneria gigantea

Quadrat: 087

Number of species: 55 Date: 07 November 1996 Altitude: 38 m

Latitude: 33°58'45" Longitude: 150°58'50" Quadrat Area: 400 m^2 Collector: GL

Vegetation Community: HOLS 3

2244	1	Acacia linifolia
2286	+	Acacia terminalis
0112	+	Actinotus helianthi
0113	+	Actinotus minor
2089	+	Amyema gaudichaudii
2332	2	Angophora bakeri
3600	1	Banksia marginata
3601	+	Banksia oblongifolia
3607	1	Banksia spinulosa
2994	+	Billardiera scandens
1412	+	Bossiaea heterophylla
2357	1	Callistemon linearis
1012	1	Cyathochaeta diandra
3256	+	Entolasia marginata
3991	+	Eriostemon australasius
2526	1	Eucalyptus sclerophylla
2531	1	Eucalyptus sparsifolia
1482	+	Gompholobium huegelii
1725	+	Goodenia paniculata
3651	+	Grevillea mucronulata
1086	+	Gymnoschoenus sphaerocephalus
3680	1	Hakea sericea
0433	+	Helichrysum elatum
1184	+	Hibbertia empetrifolia
1194	+	Hibbertia riparia
1497	+	Hovea longifolia
3685	+	Isopogon anemonifolius
2548	1	Kunzea ambigua
3690	+	Lambertia formosa
2578	+	Leptospermum parvifolium
2594	1	Leptospermum trinervium
3809	+	Lepyrodia scariosa
1274	+	Leucopogon juniperinus
2038	+	Lindsaea linearis
2080	+	Lomandra glauca
2086	+	Lomandra obliqua
2604	+	Melaleuca nodosa
2611	+	Melaleuca thymifolia
1362	+	Micrantheum ericoides
2065	+	Mitrasacme polymorpha
2637	+	Olax stricta
3357	+	Panicum simile
1843	+	Patersonia sericea
3711	+	Persoonia lanceolata
3717	+	Persoonia levis
3745	+	Petrophile sessilis
4303	+	Pimelea linifolia
2903	+	Pterostylis species
1574	+	Pultenaea elliptica
3466	+	Stipa pubescens
1308	+	Styphelia laeta var. laeta
3483	+	Themeda australis
0162	+	Trachymene incisa
0106	+	Tricoryne elatior
4401	+	Xanthorrhoea media

Quadrat: 088

Number of species: 52 Date: 07 November 1996 Altitude: 39 m

Latitude: 33°59'05" Longitude: 150°58'40" Quadrat Area: 400 m^2 Collector: GL

Vegetation Community: HOLS 2

2202	3	Acacia decurrens
2286	1	Acacia terminalis
0112	+	Actinotus helianthi
2090	+	Amyema miquelii
2332	1	Angophora bakeri
0235	+	Asplenium flabellifolium
3604	+	Banksia serrata
3607	1	Banksia spinulosa
2994	+	Billardiera scandens
2355	+	Callistemon citrinus
2357	+	Callistemon linearis
0950	+	Ceratopetalum gummiferum
4180	+	Cheilanthes sieberi
1012	+	Cyathochaeta diandra
2982	+	Dianella revoluta
3256	+	Entolasia marginata
3260	+	Eragrostis brownii
2419	+	Eucalyptus crebra
2494	1	Eucalyptus piperita
2504	1	Eucalyptus punctata
2522	3	Eucalyptus saligna
1479	+	Glycine tabacina
0422	+	Gnaphalium sphaericum
1086	+	Gymnoschoenus sphaerocephalus
3671	+	Hakea dactyloides
3680	+	Hakea sericea
1492	+	Hardenbergia violacea
3307	1	Imperata cylindrica
2548	2	Kunzea ambigua
1113	+	Lepidosperma laterale
2568	+	Leptospermum juniperinum
2584	2	Leptospermum polygalifolium
1290	1	Lissanthe strigosa
2082	+	Lomandra longifolia
2603	+	Melaleuca linariifolia
2604	1	Melaleuca nodosa
2611	+	Melaleuca thymifolia
2644	+	Notelaea longifolia
0483	+	Olearia microphylla
2941	+	Oxalis perennans
4183	+	Pellaea falcata
3711	+	Persoonia lanceolata
3737	1	Persoonia pinifolia
0202	+	Polyscias sambucifolia
3945	+	Pomax umbellata
2054	+	Pratia purpurascens
1171	+	Pteridium esculentum
0543	+	Senecio lautus
3483	1	Themeda australis
0162	+	Trachymene incisa
0761	+	Wahlenbergia stricta
0170	+	Xanthosia pilosa

Quadrat: 089

Number of species: 57 Date: 07 November 1996 Altitude: 50 m

Latitude: 34°01'10" Longitude: 150°57'55" Quadrat Area: 400 m^2 Collector: GL

Vegetation Community: HOLS 6

2202	+	Acacia decurrens
2218	1	Acacia floribunda
2258	1	Acacia obtusifolia
2282	+	Acacia suaveolens
2286	+	Acacia terminalis
2290	1	Acacia ulicifolia
0828	1	Allocasuarina littoralis
2333	1	Angophora costata
2352	1	Baeckea ramosissima
0616	1	Bauera rubioides
3102	+	Bothriochloa decipiens
2362	+	Callistemon salignus
1010	+	Chorizandra sphaerocephala
3143	+	Cynodon dactylon
1704	+	Dampiera purpurea
1469	+	Dillwynia tenuifolia
4094	1	Dodonaea triquetra
1204	1	Doryanthes excelsa
1212	+	Drosera spatulata
3256	+	Entolasia marginata
4001	+	Eriostemon scaber
2494	1	Eucalyptus piperita
2504	1	Eucalyptus punctata
1076	1	Gahnia clarkei
1695	1	Gleichenia microphylla
1756	+	Gonocarpus tetragynus
3649	+	Grevillea longifolia
3651	+	Grevillea mucronulata
3657	1	Grevillea oleoides
3680	1	Hakea sericea
3307	1	Imperata cylindrica
1875	+	Juncus continuus
1896	1	Juncus planifolius
1113	+	Lepidosperma laterale
1116	+	Lepidosperma neesii
2570	1	Leptospermum lanigerum
2573	2	Leptospermum morrisonii
2082	2	Lomandra longifolia
3693	1	Lomatia myricoides
3717	1	Persoonia levis
3737	1	Persoonia pinifolia
4009	+	Phebalium dentatum
2967	+	Philydrum lanuginosum
3849	1	Pomaderris elliptica
3856	+	Pomaderris lanigera
1373	+	Poranthera ericifolia
1171	1	Pteridium esculentum
1580	1	Pultenaea flexilis
3815	+	Restio gracilis
4077	+	Santalum obtusifolium
3746	1	Stenocarpus salignus
1697	1	Sticherus flabellatus
1923	+	Triglochin procerum
2626	1	Tristaniopsis laurina
1315	+	Woollsia pungens
0171	+	Xanthosia tridentata
3752	+	Xylomelum pyriforme

Quadrat: 090

Number of species: 41 Date: 07 November 1996 Altitude: 80 m

Latitude: 34°01'10" Longitude: 150°57'40" Quadrat Area: 400 m^2 Collector: GL

Vegetation Community: HOLS 6

2282	1	Acacia suaveolens
0833	1	Allocasuarina torulosa
2333	2	Angophora costata
2342	+	Baeckea brevifolia
3604	+	Banksia serrata
3607	1	Banksia spinulosa
0616	+	Bauera rubioides
2730	+	Caleana major
2004	+	Cassytha glabella
1008	+	Caustis recurvata
0950	1	Ceratopetalum gummiferum
1469	+	Dillwynia tenuifolia
1249	+	Epacris longiflora
3991	+	Eriostemon australasius
2446	1	Corymbia gummifera
2494	1	Eucalyptus piperita
1756	+	Gonocarpus tetragynus
3651	1	Grevillea mucronulata
1086	+	Gymnoschoenus sphaerocephalus
1176	+	Hibbertia aspera
1184	+	Hibbertia empetrifolia
1189	1	Hibbertia nitida
3685	+	Isopogon anemonifolius
3690	1	Lambertia formosa
1113	+	Lepidosperma laterale
2594	1	Leptospermum trinervium
1268	+	Leucopogon esquamatus
2078	+	Lomandra filiformis
2081	+	Lomandra gracilis
1292	+	Melichrus urceolatus
1362	+	Micrantheum ericoides
3357	+	Panicum simile
3711	1	Persoonia lanceolata
3744	+	Petrophile pulchella
1570	1	Pultenaea daphnoides
1379	+	Ricinocarpos pinifolius
3481	+	Tetrarrhena juncea
0106	+	Tricoryne elatior
1315	+	Woollsia pungens
0170	+	Xanthosia pilosa
0171	+	Xanthosia tridentata

Quadrat: 091

Number of species: 52 Date: 07 November 1996 Altitude: 100 m

Latitude: 34°00'58" Longitude: 150°57'50" Quadrat Area: 400 m^2 Collector: GL

Vegetation Community: HOLS 3

2244	1	Acacia linifolia
2281	+	Acacia stricta
0113	+	Actinotus minor
0824	+	Allocasuarina diminuta
2337	2	Angophora hispida
2342	+	Baeckea brevifolia
2348	+	Baeckea imbricata
3600	1	Banksia marginata
3601	1	Banksia oblongifolia
3607	+	Banksia spinulosa
2355	+	Callistemon citrinus
2366	1	Calytrix tetragona
2006	+	Cassytha pubescens
3615	+	Conospermum tenuifolium
1012	+	Cyathochaeta diandra
1706	+	Dampiera stricta
1458	+	Dillwynia floribunda
2533	1	Eucalyptus squamosa
3630	+	Grevillea buxifolia
3632	1	Grevillea diffusa ssp. diffusa
3671	1	Hakea dactyloides
3674	+	Hakea gibbosa
3680	1	Hakea sericea
1194	+	Hibbertia riparia
1199	+	Hibbertia serpyllifolia
3685	1	Isopogon anemonifolius
2548	1	Kunzea ambigua
3690	1	Lambertia formosa
1116	+	Lepidosperma neesii
2558	1	Leptospermum arachnoides
2594	+	Leptospermum trinervium
3809	+	Lepyrodia scariosa
1264	+	Leucopogon appressus
2038	+	Lindsaea linearis
2081	1	Lomandra gracilis
2086	+	Lomandra obliqua
2598	+	Melaleuca deanei
3346	+	Panicum effusum
1843	+	Patersonia sericea
3711	1	Persoonia lanceolata
3717	+	Persoonia levis
3745	1	Petrophile sessilis
1553	+	Phyllota phylicoides
0154	+	Platysace linearifolia
3408	+	Poa labillardieri
2903	1	Pterostylis species
1574	+	Pultenaea elliptica
1138	+	Schoenus ericetorum
4265	+	Stylidium graminifolium
0106	+	Tricoryne elatior
4392	1	Xanthorrhoea concava
0171	+	Xanthosia tridentata

Quadrat: 092

Number of species: 61 Date: 21 November 1996 Altitude: 90 m

Latitude: 34°01'50" Longitude: 150°54'19" Quadrat Area: 400 m^2 Collector: GL,JY

Vegetation Community: HOLS 2

2212	1	Acacia falcata
2255	+	Acacia myrtifolia
2263	+	Acacia parramattensis
2286	1	Acacia terminalis
0828	1	Allocasuarina littoralis
2332	1	Angophora bakeri
3066	+	Anisopogon avenaceus
3914	+	Asperula conferta
3600	+	Banksia marginata
2994	+	Billardiera scandens
2357	+	Callistemon linearis
3132	1	Chionochloa pallida
1012	+	Cyathochaeta diandra
3176	1	Danthonia tenuior
1434	+	Daviesia acicularis
2982	+	Dianella revoluta
3211	+	Dichelachne micrantha
1465	+	Dillwynia retorta
1210	+	Drosera peltata
3257	+	Entolasia stricta
3260	+	Eragrostis brownii
2434	+	Eucalyptus eugenioides
2504	2	Eucalyptus punctata
4073	+	Exocarpos strictus
1476	+	Glycine clandestina
1482	+	Gompholobium huegelii
1484	+	Gompholobium minus
1709	+	Goodenia bellidifolia
1718	+	Goodenia hederacea
3642	1	Grevillea linearifolia
3651	+	Grevillea mucronulata
3680	+	Hakea sericea
0436	+	Helichrysum scorpioides
1176	+	Hibbertia aspera
0889	+	Hypericum gramineum
1505	+	Jacksonia scoparia
2548	1	Kunzea ambigua
1113	+	Lepidosperma laterale
2039	+	Lindsaea microphylla
1290	+	Lissanthe strigosa
2085	+	Lomandra multiflora
2086	+	Lomandra obliqua
3694	+	Lomatia silaifolia
2604	1	Melaleuca nodosa
2101	+	Muellerina eucalyptoides
3363	+	Paspalidium gracile
1843	+	Patersonia sericea
3718	+	Persoonia linearis
3395	+	Poa affinis
3408	+	Poa labillardieri
3945	1	Pomax umbellata
2054	1	Pratia purpurascens
2903	+	Pterostylis species
1603	+	Pultenaea villosa
3013	1	Rhytidosporum procumbens
1135	1	Schoenus apogon
4265	1	Stylidium graminifolium
7066	+	Thelymitra spp.
3483	3	Themeda australis
0107	1	Tricoryne simplex
4392	+	Xanthorrhoea concava

Quadrat: 093

Number of species: 49 Date: 21 November 1996 Altitude: 180 m

Latitude: 34°04'24" Longitude: 150°58'23" Quadrat Area: 400 m^2 Collector: GL,JY

Vegetation Community: HOLS 3

2282	+	Acacia suaveolens
0113	+	Actinotus minor
3066	+	Anisopogon avenaceus
2352	+	Baeckea ramosissima
3604	2	Banksia serrata
1412	+	Bossiaea heterophylla
2366	1	Calytrix tetragona
2006	+	Cassytha pubescens
1004	+	Caustis flexuosa
1005	1	Caustis pentandra
1706	+	Dampiera stricta
1465	1	Dillwynia retorta
1204	+	Doryanthes excelsa
3991	1	Eriostemon australasius
2415	1	Eucalyptus consideniana
2446	2	Corymbia gummifera
2459	2	Eucalyptus ligustrina
2474	1	Eucalyptus multicaulis
1481	+	Gompholobium grandiflorum
3630	1	Grevillea buxifolia
3663	+	Grevillea sericea
4427	1	Grevillea sphacelata
3671	1	Hakea dactyloides
3678	+	Hakea propinqua
1185	+	Hibbertia fasciculata
1187	+	Hibbertia linearis
1189	+	Hibbertia nitida
3685	+	Isopogon anemonifolius
3690	1	Lambertia formosa
1113	+	Lepidosperma laterale
2558	1	Leptospermum arachnoides
2594	2	Leptospermum trinervium
3809	+	Lepyrodia scariosa
1267	+	Leucopogon ericoides
1281	+	Leucopogon microphyllus
2078	+	Lomandra filiformis
1296	+	Monotoca scoparia
1843	1	Patersonia sericea
3737	+	Persoonia pinifolia
3744	+	Petrophile pulchella
0154	+	Platysace linearifolia
1574	+	Pultenaea elliptica
1582	1	Pultenaea hispidula
1149	+	Schoenus turbinatus
4267	+	Stylidium lineare
4314	+	Tetratheca neglecta
1154	+	Tricostularia pauciflora
1315	2	Woollsia pungens
4403	1	Xanthorrhoea resinifera

Quadrat: 094

Number of species: 35 Date: 22 November 1996 Altitude: 80 m

Latitude: 34°05'54" Longitude: 150°50'12" Quadrat Area: 400 m^2 Collector: JY,AC

Vegetation Community: HOLS 6

2258	1	Acacia obtusifolia
0113	+	Actinotus minor
0828	1	Allocasuarina littoralis
2340	1	Austromyrtus tenuifolia
1412	+	Bossiaea heterophylla
2366	1	Calytrix tetragona
2006	+	Cassytha pubescens
0949	1	Ceratopetalum apetalum
1437	+	Daviesia corymbosa
3211	+	Dichelachne micrantha
3803	+	Empodisma minus
3257	+	Entolasia stricta
1695	+	Gleichenia microphylla
3657	1	Grevillea oleoides
3679	+	Hakea salicifolia
2573	+	Leptospermum morrisonii
2078	+	Lomandra filiformis
2079	1	Lomandra fluviatilis
3693	1	Lomatia myricoides
0769	+	*Lonicera japonica
1363	+	Micrantheum hexandrum
3325	+	Microlaena stipoides
1293	+	Monotoca elliptica
3718	+	Persoonia linearis
3743	+	Petrophile pedunculata
4009	+	Phebalium dentatum
1369	+	Phyllanthus hirtellus
1377	1	Pseudanthus pimeleoides
1145	+	Schoenus melanostachys
4186	+	Smilax glyciphylla
3746	1	Stenocarpus salignus
1697	1	Sticherus flabellatus
3466	1	Stipa pubescens
2626	2	Tristaniopsis laurina
0171	+	Xanthosia tridentata

Quadrat: 095

Number of species: 44 Date: 22 November 1996 Altitude: 60 m

Latitude: 34°05'05" Longitude: 150°50'35" Quadrat Area: 400 m^2 Collector: JY,AC

Vegetation Community: HOLS 6

2258	2	Acacia obtusifolia
2286	+	Acacia terminalis
0828	+	Allocasuarina littoralis
2341	+	Backhousia myrtifolia
2994	+	Billardiera scandens
3005	+	Bursaria spinosa
2366	+	Calytrix tetragona
2006	+	Cassytha pubescens
1005	+	Caustis pentandra
0949	+	Ceratopetalum apetalum
1022	+	*Cyperus eragrostis
1437	+	Daviesia corymbosa
2974	+	Dianella caerulea
4094	+	Dodonaea triquetra
3803	+	Empodisma minus
3257	+	Entolasia stricta
2446	+	Corymbia gummifera
4071	+	Exocarpos cupressiformis
1757	+	Gonocarpus teucrioides
3649	+	Grevillea longifolia
3657	1	Grevillea oleoides
3679	1	Hakea salicifolia
1189	1	Hibbertia nitida
0441	+	*Hypochaeris radicata
4249	+	Lasiopetalum ferrugineum var. ferrugineum
1113	+	Lepidosperma laterale
2573	2	Leptospermum morrisonii
2079	1	Lomandra fluviatilis
2082	+	Lomandra longifolia
1363	+	Micrantheum hexandrum
1296	1	Monotoca scoparia
3737	+	Persoonia pinifolia
3743	+	Petrophile pedunculata
4009	+	Phebalium dentatum
3855	+	Pomaderris intermedia
3856	+	Pomaderris lanigera
1377	+	Pseudanthus pimeleoides
1580	+	Pultenaea flexilis
1145	1	Schoenus melanostachys
4186	+	Smilax glyciphylla
3746	+	Stenocarpus salignus
2626	2	Tristaniopsis laurina
1999	1	Westringia longifolia
0171	1	Xanthosia tridentata

Quadrat: 096

Number of species: 36 Date: 24 November 1996 Altitude: 20 m

Latitude: 33°58'36" Longitude: 150°55'04" Quadrat Area: 400 m^2 Collector: JY

Vegetation Community: HOLS 1

2202	+	Acacia decurrens
0828	+	Allocasuarina littoralis
3077	+	Aristida ramosa
3081	1	Aristida vagans
0002	+	Brunoniella pumilio
3005	1	Bursaria spinosa
4180	1	Cheilanthes sieberi
3765	+	Clematis aristata
6293	+	*Conyza spp.
3143	+	Cynodon dactylon
3162	+	Danthonia linkii
1447	+	Daviesia ulicifolia
2982	+	Dianella revoluta
0915	1	Dichondra repens
2778	+	Dipodium punctatum
0863	+	Einadia hastata
2419	2	Eucalyptus crebra
2434	+	Eucalyptus eugenioides
2440	+	Eucalyptus fibrosa
2539	2	Eucalyptus tereticornis
4071	+	Exocarpos cupressiformis
1476	1	Glycine clandestina
0416	+	Gnaphalium gymnocephalum
1492	+	Hardenbergia violacea
6626	+	Lepidosperma spp.
2078	+	Lomandra filiformis
2080	+	Lomandra glauca
3325	2	Microlaena stipoides
3357	+	Panicum simile
3026	+	*Plantago lanceolata
1374	+	Poranthera microphylla
2054	+	Pratia purpurascens
0543	+	Senecio lautus
4225	+	Solanum prinophyllum
4241	+	Stackhousia viminea
3483	+	Themeda australis

Quadrat: 097

Number of species: 26 Date: 24 November 1996 Altitude: 20 m

Latitude: 33°58'35" Longitude: 150°54'55" Quadrat Area: 400 m^2 Collector: JY

Vegetation Community: HOLS 1

3081	1	Aristida vagans
3914	+	Asperula conferta
0001	1	Brunoniella australis
0002	+	Brunoniella pumilio
3005	+	Bursaria spinosa
4180	1	Cheilanthes sieberi
0364	+	*Cirsium vulgare
1704	+	Dampiera purpurea
3163	+	Danthonia longifolia
3211	+	Dichelachne micrantha
0915	1	Dichondra repens
3257	+	Entolasia stricta
2419	+	Eucalyptus crebra
2471	2	Eucalyptus moluccana
2539	+	Eucalyptus tereticornis
1084	+	Gahnia sieberiana
1476	1	Glycine clandestina
1479	+	Glycine tabacina
2081	2	Lomandra gracilis
2085	1	Lomandra multiflora
2599	+	Melaleuca decora
3325	+	Microlaena stipoides
0219	+	*Myrsiphyllum asparagoides
4225	+	Solanum prinophyllum
3483	3	Themeda australis
1650	+	Zornia dyctiocarpa

Quadrat: 098

Number of species: 40 Date: 24 November 1996 Altitude: 30 m

Latitude: 33°59'24" Longitude: 150°54'52" Quadrat Area: 400 m^2 Collector: JY

Vegetation Community: HOLS 1

2212	+	Acacia falcata
0828	+	Allocasuarina littoralis
3081	1	Aristida vagans
1418	+	Bossiaea prostrata
0001	1	Brunoniella australis
0091	1	Caesia parviflora
4180	1	Cheilanthes sieberi
3176	+	Danthonia tenuior
2982	+	Dianella revoluta
3211	+	Dichelachne micrantha
3238	+	Echinopogon caespitosus
3257	+	Entolasia stricta
2434	+	Eucalyptus eugenioides
2440	3	Eucalyptus fibrosa
2446	+	Corymbia gummifera
2539	+	Eucalyptus tereticornis
1084	+	Gahnia sieberiana
1476	1	Glycine clandestina
1756	+	Gonocarpus tetragynus
1722	+	Goodenia heterophylla
1492	+	Hardenbergia violacea
0436	+	Helichrysum scorpioides
0441	+	*Hypochaeris radicata
1505	+	Jacksonia scoparia
0446	+	Lagenifera stipitata
0097	+	Laxmannia gracilis
1113	1	Lepidosperma laterale
1290	+	Lissanthe strigosa
2068	1	Lomandra brevis
2081	1	Lomandra gracilis
3944	+	Opercularia varia
3718	+	Persoonia linearis
3945	+	Pomax umbellata
2054	+	Pratia purpurascens
1603	+	Pultenaea villosa
0543	+	Senecio lautus
3483	3	Themeda australis
0106	+	Tricoryne elatior
0753	+	Wahlenbergia gracilis
1650	+	Zornia dyctiocarpa

Quadrat: 099

Number of species: 31 Date: 24 November 1996 Altitude: 20 m

Latitude: 33°58'58" Longitude: 150°55'01" Quadrat Area: 400 m^2 Collector: JY

Vegetation Community: HOLS 1

2212	+	Acacia falcata
3081	1	Aristida vagans
0001	+	Brunoniella australis
3005	+	Bursaria spinosa
0346	+	Cassinia uncata
4180	1	Cheilanthes sieberi
3162	+	Danthonia linkii
1447	+	Daviesia ulicifolia
2982	+	Dianella revoluta
3211	+	Dichelachne micrantha
0915	1	Dichondra repens
1461	+	Dillwynia parvifolia
3256	+	Entolasia marginata
3257	1	Entolasia stricta
2419	2	Eucalyptus crebra
2440	3	Eucalyptus fibrosa
1476	1	Glycine clandestina
1718	+	Goodenia hederacea
1492	+	Hardenbergia violacea
0097	+	Laxmannia gracilis
1113	1	Lepidosperma laterale
2085	1	Lomandra multiflora
6663	1	Lomandra spp.
0841	+	Maytenus silvestris
2599	2	Melaleuca decora
3325	+	Microlaena stipoides
2941	+	Oxalis perennans
3945	+	Pomax umbellata
0543	+	Senecio lautus
3466	+	Stipa pubescens
3483	1	Themeda australis

Quadrat: 100

Number of species: 55 Date: 25 November 1996 Altitude: 250 m

Latitude: 34°08'12" Longitude: 150°51'48" Quadrat Area: 400 m^2 Collector: JY

Vegetation Community: HOLS 3

2255	+	Acacia myrtifolia
2282	1	Acacia suaveolens
0113	+	Actinotus minor
3066	+	Anisopogon avenaceus
3596	+	Banksia ericifolia
3600	+	Banksia marginata
3604	+	Banksia serrata
3607	+	Banksia spinulosa
1410	+	Bossiaea ensata
1412	1	Bossiaea heterophylla
2730	+	Caleana major
2006	+	Cassytha pubescens
1004	+	Caustis flexuosa
3610	+	Conospermum longifolium ssp. angustifolium
1012	+	Cyathochaeta diandra
1706	+	Dampiera stricta
1458	1	Dillwynia floribunda
3991	1	Eriostemon australasius
2415	2	Eucalyptus consideniana
2446	2	Corymbia gummifera
2506	2	Eucalyptus racemosa
2531	+	Eucalyptus sparsifolia
1481	1	Gompholobium grandiflorum
3630	+	Grevillea buxifolia
3632	1	Grevillea diffusa ssp. diffusa
3671	+	Hakea dactyloides
3680	+	Hakea sericea
1926	+	Hemigenia purpurea
1199	+	Hibbertia serpyllifolia
3685	1	Isopogon anemonifolius
3690	+	Lambertia formosa
1113	1	Lepidosperma laterale
2594	1	Leptospermum trinervium
2078	+	Lomandra filiformis
3694	+	Lomatia silaifolia
1539	+	Mirbelia speciosa
1296	+	Monotoca scoparia
1843	+	Patersonia sericea
3717	+	Persoonia levis
3744	1	Petrophile pulchella
1553	+	Phyllota phylicoides
4303	+	Pimelea linifolia
0152	+	Platysace ericoides
0154	+	Platysace linearifolia
1373	+	Poranthera ericifolia
2846	+	Prasophyllum flavum
1735	+	Scaevola ramosissima
4103	+	Schizaea bifida
4267	+	Stylidium lineare
4314	1	Tetratheca neglecta
0107	+	Tricoryne simplex
1154	+	Tricostularia pauciflora
4401	1	Xanthorrhoea media
0171	+	Xanthosia tridentata
3752	+	Xylomelum pyriforme

Quadrat: 101

Number of species: 42 Date: 25 November 1996 Altitude: 260 m

Latitude: 34°08'29" Longitude: 150°52'25" Quadrat Area: 400 m^2 Collector: JY

Vegetation Community: HOLS 4

0113	1	Actinotus minor
3596	2	Banksia ericifolia
3600	+	Banksia marginata
2006	+	Cassytha pubescens
1012	+	Cyathochaeta diandra
1706	+	Dampiera stricta
1458	+	Dillwynia floribunda
1252	+	Epacris microphylla
3991	+	Eriostemon australasius
2446	2	Corymbia gummifera
2506	1	Eucalyptus racemosa
1481	+	Gompholobium grandiflorum
3630	+	Grevillea buxifolia
3632	1	Grevillea diffusa ssp. diffusa
1745	+	Haemodorum corymbosum
3671	+	Hakea dactyloides
3678	+	Hakea propinqua
3682	+	Hakea teretifolia
1926	1	Hemigenia purpurea
3685	+	Isopogon anemonifolius
3690	+	Lambertia formosa
2558	1	Leptospermum arachnoides
2594	1	Leptospermum trinervium
1281	1	Leucopogon microphyllus
2078	+	Lomandra filiformis
2081	+	Lomandra gracilis
1539	+	Mirbelia speciosa
2065	+	Mitrasacme polymorpha
1843	+	Patersonia sericea
3711	+	Persoonia lanceolata
3744	1	Petrophile pulchella
0154	+	Platysace linearifolia
1563	+	Pultenaea aristata
1735	+	Scaevola ramosissima
4103	+	Schizaea bifida
1146	1	Schoenus moorei
4267	1	Stylidium lineare
1153	+	Tetraria capillaris
0107	+	Tricoryne simplex
1154	+	Tricostularia pauciflora
4401	1	Xanthorrhoea media
0170	+	Xanthosia pilosa

Quadrat: 102

Number of species: 59 Date: 27 November 1996 Altitude: 260 m

Latitude: 34°08'25" Longitude: 150°52'27" Quadrat Area: 400 m^2 Collector: GL,JY

Vegetation Community: HOLS 4

0113	2	Actinotus minor
1401	+	Almaleea paludosa
2337	+	Angophora hispida
2342	+	Baeckea brevifolia
2348	+	Baeckea imbricata
2352	+	Baeckea ramosissima
3596	+	Banksia ericifolia
3600	+	Banksia marginata
0616	1	Bauera rubioides
0628	1	Blandfordia nobilis
3102	1	Bothriochloa decipiens
3614	+	Conospermum taxifolium
1012	+	Cyathochaeta diandra
1706	1	Dampiera stricta
1212	2	Drosera spatulata
1252	1	Epacris microphylla
1254	1	Epacris obtusifolia
3260	+	Eragrostis brownii
1481	+	Gompholobium grandiflorum
1756	1	Gonocarpus tetragynus
3630	+	Grevillea buxifolia
3632	+	Grevillea diffusa ssp. diffusa
1086	+	Gymnoschoenus sphaerocephalus
1745	+	Haemodorum corymbosum
3682	+	Hakea teretifolia
1176	+	Hibbertia aspera
3686	+	Isopogon anethifolius
1875	+	Juncus continuus
1896	+	Juncus planifolius
1908	+	Juncus usitatus
2558	1	Leptospermum arachnoides
2568	+	Leptospermum juniperinum
2584	+	Leptospermum polygalifolium
2591	+	Leptospermum squarrosum
2594	1	Leptospermum trinervium
3807	1	Lepyrodia gracilis
1267	+	Leucopogon ericoides
1268	+	Leucopogon esquamatus
1281	1	Leucopogon microphyllus
2038	+	Lindsaea linearis
2078	+	Lomandra filiformis
2086	+	Lomandra obliqua
2835	+	Microtis unifolia
2065	+	Mitrasacme polymorpha
1294	+	Monotoca ledifolia
4303	+	Pimelea linifolia
0154	+	Platysace linearifolia
0520	+	Pseudognaphalium luteo-album
1563	+	Pultenaea aristata
4103	+	Schizaea bifida
1136	1	Schoenus brevifolius
4267	1	Stylidium lineare
1153	+	Tetraria capillaris
0100	+	Thysanotus juncifolius
2027	1	Utricularia dichotoma
4392	+	Xanthorrhoea concava
4401	1	Xanthorrhoea media
0171	+	Xanthosia tridentata
4407	+	Xyris gracilis

Quadrat: 103

Number of species: 64 Date: 28 November 1996 Altitude: 270 m

Latitude: 34°08'28" Longitude: 150°52'21" Quadrat Area: 400 m^2 Collector: JY,GL

Vegetation Community: HOLS 4

2255	+	Acacia myrtifolia
0113	1	Actinotus minor
1401	+	Almaleea paludosa
2337	1	Angophora hispida
3066	+	Anisopogon avenaceus
3596	+	Banksia ericifolia
3600	+	Banksia marginata
0628	1	Blandfordia nobilis
3102	+	Bothriochloa decipiens
6199	+	Calochilus spp.
1172	+	Calochlaena dubia
2004	+	Cassytha glabella
1008	+	Caustis recurvata
6293	+	*Conyza spp.
1706	1	Dampiera stricta
1210	+	Drosera peltata
1212	2	Drosera spatulata
3257	+	Entolasia stricta
1252	1	Epacris microphylla
1254	+	Epacris obtusifolia
1257	+	Epacris pulchella
2415	+	Eucalyptus consideniana
1084	+	Gahnia sieberiana
1477	+	Glycine microphylla
1756	+	Gonocarpus tetragynus
1725	+	Goodenia paniculata
3630	+	Grevillea buxifolia
3632	+	Grevillea diffusa ssp. diffusa
1745	+	Haemodorum corymbosum
3682	+	Hakea teretifolia
1926	+	Hemigenia purpurea
1199	+	Hibbertia serpyllifolia
3686	+	Isopogon anethifolius
1109	1	Lepidosperma forsythii
1113	+	Lepidosperma laterale
1114	+	Lepidosperma limicola
1116	2	Lepidosperma neesii
2558	+	Leptospermum arachnoides
2591	+	Leptospermum squarrosum
2594	+	Leptospermum trinervium
1268	+	Leucopogon esquamatus
1288	+	Leucopogon virgatus
2038	+	Lindsaea linearis
2039	+	Lindsaea microphylla
2081	+	Lomandra gracilis
2086	+	Lomandra obliqua
2109	+	Lycopodium laterale
1841	+	Patersonia glabrata
3711	+	Persoonia lanceolata
4303	+	Pimelea linifolia
1563	+	Pultenaea aristata
3810	+	Restio australis
1149	1	Schoenus turbinatus
4186	+	Smilax glyciphylla
4267	2	Stylidium lineare
1308	+	Styphelia laeta var. laeta
0100	1	Thysanotus juncifolius
0107	+	Tricoryne simplex
2027	1	Utricularia dichotoma
1649	+	Viminaria juncea
4401	1	Xanthorrhoea media
4403	+	Xanthorrhoea resinifera
0171	+	Xanthosia tridentata
4408	+	Xyris juncea

1.15.2 Species Frequencies in Quadrat Data

Species	No. quadrats	Freq (%)
Acacia binervata	1	1.0
Acacia brownii	4	3.9
Acacia decurrens	5	4.9
Acacia falcata	4	3.9
Acacia floribunda	5	4.9
Acacia hispidula	3	2.9
Acacia implexa	2	1.9
Acacia irrorata	3	2.9
Acacia linifolia	31	30.1
Acacia longifolia	7	6.8
Acacia longissima	3	2.9
Acacia mearnsii	2	1.9
Acacia myrtifolia	18	17.5
Acacia obtusifolia	10	9.7
Acacia parramattensis	1	1.0
Acacia penninervis	2	1.9
Acacia stricta	1	1.0
Acacia suaveolens	26	25.2
Acacia terminalis	34	33.0
Acacia ulicifolia	34	33.0
Acetosella vulgaris	1	1.0
Acianthus fornicatus	1	1.0
Actinotus helianthi	9	8.7
Actinotus minor	38	36.9
Adiantum aethiopicum	3	2.9
Alectryon subcinereus	1	1.0
Allocasuarina diminuta	5	4.9
Allocasuarina distyla	2	1.9
Allocasuarina littoralis	21	20.4
Allocasuarina torulosa	4	3.9
Almaleea paludosa	2	1.9
Amperea xiphoclada	4	3.9
Amphipogon strictus	3	2.9
Amyema gaudichaudii	1	1.0
Amyema miquelii	3	2.9
Andropogon virginicus	1	1.0
Angophora bakeri	16	15.5
Angophora costata	28	27.2
Angophora floribunda	1	1.0
Angophora hispida	23	22.3
Anisopogon avenaceus	20	19.4
Aotus ericoides	6	5.8
Aristida ramosa	3	2.9
Aristida vagans	24	23.3
Aristida warburgii	6	5.8
Asperula conferta	2	1.9
Asplenium flabellifolium	2	1.9
Aster subulatus	1	1.0
Astrotricha latifolia	1	1.0
Austromyrtus tenuifolia	5	4.9
Backhousia myrtifolia	3	2.9
Baeckea brevifolia	11	10.7
Baeckea diosmifolia	4	3.9
Baeckea imbricata	7	6.8
Baeckea linifolia	7	6.8
Baeckea ramosissima	14	13.6
Banksia ericifolia	26	25.2
Banksia integrifolia	1	1.0
Banksia marginata	28	27.2
Banksia oblongifolia	23	22.3
Banksia serrata	28	27.2
Banksia spinulosa	52	50.5
Bauera microphylla	1	1.0
Bauera rubioides	9	8.7
Baumea juncea	2	1.9
Baumea rubiginosa	2	1.9
Bertya pomaderroides	2	1.9
Beyeria lasiocarpa	1	1.0
Billardiera scandens	26	25.2
Blandfordia nobilis	7	6.8
Blechnum ambiguum	1	1.0
Blechnum cartilagineum	2	1.9
Boronia ledifolia	6	5.8

Boronia parviflora	5	4.9
Boronia ruppii	1	1.0
Bossiaea buxifolia	1	1.0
Bossiaea ensata	13	12.6
Bossiaea heterophylla	34	33.0
Bossiaea obcordata	1	1.0
Bossiaea prostrata	9	8.7
Bossiaea stephensonii	1	1.0
Bothriochloa decipiens	3	2.9
Brachyloma daphnoides	13	12.6
Brunoniella australis	12	11.7
Brunoniella pumilio	5	4.9
Burchardia umbellata	2	1.9
Bursaria lasiophylla	1	1.0
Bursaria spinosa	10	9.7
Caesia calliantha	1	1.0
Caesia parviflora	3	2.9
Caleana major	3	2.9
Callistemon citrinus	12	11.7
Callistemon linearis	10	9.7
Callistemon salignus	1	1.0
Callitris muelleri	1	1.0
Calochilus spp.	1	1.0
Calochlaena dubia	10	9.7
Calytrix tetragona	10	9.7
Cassinia aureonitens	1	1.0
Cassinia denticulata	1	1.0
Cassinia uncata	1	1.0
Cassytha glabella	9	8.7
Cassytha pubescens	44	42.7
Caustis flexuosa	28	27.2
Caustis pentandra	10	9.7
Caustis recurvata	2	1.9
Centaurium erythraea	3	2.9
Ceratopetalum apetalum	9	8.7
Ceratopetalum gummiferum	21	20.4
Cheilanthes distans	1	1.0
Cheilanthes sieberi	12	11.7
Chionochloa pallida	5	4.9
Chorizandra cymbaria	3	2.9
Chorizandra sphaerocephala	2	1.9
Chorizema parviflorum	3	2.9
Cinnamomum camphora	1	1.0
Cirsium vulgare	2	1.9
Clematis aristata	3	2.9
Comesperma defoliatum	3	2.9
Comesperma sphaerocarpum	3	2.9
Comesperma volubile	1	1.0
Commelina cyanea	1	1.0
Conospermum ellipticum	4	3.9
Conospermum longifolium ssp. angustifolium	11	10.7
Conospermum taxifolium	1	1.0
Conospermum tenuifolium	1	1.0
Conyza albida	6	5.8
Conyza canadensis	1	1.0
Conyza spp.	2	1.9
Cryptandra amara	4	3.9
Cryptandra ericoides	2	1.9
Cryptostylis erecta	1	1.0
Cyathochaeta diandra	52	50.5
Cymbopogon refractus	2	1.9
Cynodon dactylon	2	1.9
Cyperus eragrostis	1	1.0
Dampiera purpurea	18	17.5
Dampiera stricta	39	37.9
Danthonia linkii	2	1.9
Danthonia longifolia	7	6.8
Danthonia tenuior	3	2.9
Darwinia diminuta	7	6.8
Darwinia fascicularis	2	1.9
Darwinia grandiflora	1	1.0
Daviesia acicularis	1	1.0
Daviesia corymbosa	8	7.8
Daviesia ulicifolia	6	5.8
Dendrobium linguiforme	4	3.9
Deyeuxia contracta	1	1.0
Deyeuxia quadriseta	2	1.9
Dianella caerulea	16	15.5
Dianella longifolia	2	1.9
Dianella revoluta	32	31.1
Dichelachne micrantha	11	10.7

Dichondra repens	4	3.9
Digitaria parviflora	1	1.0
Dillwynia floribunda	14	13.6
Dillwynia juniperina	2	1.9
Dillwynia parvifolia	1	1.0
Dillwynia retorta	27	26.2
Dillwynia sericea	8	7.8
Dillwynia tenuifolia	2	1.9
Dipodium punctatum	3	2.9
Diuris aurea	1	1.0
Dodonaea triquetra	16	15.5
Doryanthes excelsa	9	8.7
Drosera peltata	4	3.9
Drosera spatulata	12	11.7
Echinopogon caespitosus	2	1.9
Echinopogon ovatus	3	2.9
Einadia hastata	1	1.0
Einadia trigonos	1	1.0
Elaeocarpus reticulatus	1	1.0
Eleocharis sphacelata	2	1.9
Empodisma minus	3	2.9
Entolasia marginata	9	8.7
Entolasia stricta	62	60.2
Epacris longiflora	5	4.9
Epacris microphylla	18	17.5
Epacris obtusifolia	7	6.8
Epacris pulchella	12	11.7
Eragrostis brownii	6	5.8
Eragrostis parviflora	1	1.0
Eriostemon australasius	36	35.0
Eriostemon scaber	5	4.9
Eucalyptus agglomerata	2	1.9
Eucalyptus beyeriana	1	1.0
Eucalyptus consideniana	8	7.8
Eucalyptus crebra	8	7.8
Eucalyptus eugenioides	8	7.8
Eucalyptus fibrosa	11	10.7
Eucalyptus globoidea	7	6.8
Corymbia gummifera	45	43.7
Eucalyptus ligustrina	1	1.0
Eucalyptus longifolia	1	1.0
Eucalyptus moluccana	2	1.9
Eucalyptus multicaulis	2	1.9
Eucalyptus oblonga	12	11.7
Eucalyptus pilularis	10	9.7
Eucalyptus piperita	17	16.5
Eucalyptus punctata	24	23.3
Eucalyptus racemosa	26	25.2
Eucalyptus resinifera	2	1.9
Eucalyptus saligna	4	3.9
Eucalyptus sclerophylla	2	1.9
Eucalyptus sieberi	2	1.9
Eucalyptus sparsifolia	5	4.9
Eucalyptus squamosa	11	10.7
Eucalyptus tereticornis	5	4.9
Exocarpos cupressiformis	3	2.9
Exocarpos strictus	9	8.7
Gahnia clarkei	3	2.9
Gahnia sieberiana	13	12.6
Geranium spp.	1	1.0
Gleichenia dicarpa	6	5.8
Gleichenia microphylla	6	5.8
Gleichenia rupestris	2	1.9
Glycine clandestina	20	19.4
Glycine microphylla	1	1.0
Glycine tabacina	9	8.7
Gnaphalium gymnocephalum	2	1.9
Gnaphalium sphaericum	1	1.0
Gompholobium glabratum	13	12.6
Gompholobium grandiflorum	27	26.2
Gompholobium huegelii	7	6.8
Gompholobium latifolium	2	1.9
Gompholobium minus	13	12.6
Gompholobium species B	1	1.0
Gonocarpus micranthus	4	3.9
Gonocarpus tetragynus	19	18.4
Gonocarpus teucrioides	21	20.4
Goodenia bellidifolia	13	12.6
Goodenia dimorpha	1	1.0
Goodenia hederacea	21	20.4
Goodenia heterophylla	1	1.0

Goodenia paniculata	4	3.9
Grevillea buxifolia	10	9.7
Grevillea diffusa ssp. *diffusa*	26	25.2
Grevillea linearifolia	6	5.8
Grevillea longifolia	6	5.8
Grevillea mucronulata	36	35.0
Grevillea oleoides	10	9.7
Grevillea sericea	20	19.4
Grevillea spacelata	20	19.4
Gymnoschoenus sphaerocephalus	5	4.9
Haemodorum corymbosum	15	14.6
Hakea dactyloides	41	39.8
Hakea gibbosa	2	1.9
Hakea propinqua	5	4.9
Hakea salicifolia	9	8.7
Hakea sericea	38	36.9
Hakea teretifolia	13	12.6
Hardenbergia violacea	23	22.3
Helichrysum collinum	3	2.9
Helichrysum elatum	1	1.0
Helichrysum scorpioides	9	8.7
Hemarthria uncinata	1	1.0
Hemigenia purpurea	5	4.9
Hibbertia acicularis	1	1.0
Hibbertia aspera	6	5.8
Hibbertia circumdans	2	1.9
Hibbertia diffusa	1	1.0
Hibbertia empetrifolia	5	4.9
Hibbertia fasciculata	1	1.0
Hibbertia linearis	4	3.9
Hibbertia monogyna	3	2.9
Hibbertia nitida	7	6.8
Hibbertia obtusifolia	4	3.9
Hibbertia riparia	18	17.5
Hibbertia sericea	2	1.9
Hibbertia serpyllifolia	14	13.6
Hovea linearis	19	18.4
Hovea longifolia	3	2.9
Hybanthus monopetalus	1	1.0
Hydrocotyle laxiflora	3	2.9
Hydrocotyle peduncularis	1	1.0
Hymenosporum flavum	1	1.0
Hypericum gramineum	10	9.7
Hypochaeris radicata	8	7.8
Hypolepis muelleri	1	1.0
Imperata cylindrica	14	13.6
Indigofera australis	1	1.0
Isolepis cernua	3	2.9
Isopogon anemonifolius	48	46.6
Isopogon anethifolius	4	3.9
Jacksonia scoparia	4	3.9
Juncus continuus	5	4.9
Juncus planifolius	4	3.9
Juncus usitatus	3	2.9
Kennedia rubicunda	3	2.9
Kunzea ambigua	10	9.7
Kunzea capitata	19	18.4
Lagenifera stipitata	4	3.9
Lambertia formosa	43	41.7
Lasiopetalum ferrugineum var. *cordatum*	1	1.0
Lasiopetalum ferrugineum var. *ferrugineum*	7	6.8
Lasiopetalum macrophyllum	2	1.9
Lasiopetalum parviflorum	2	1.9
Laxmannia gracilis	10	9.7
Lepidosperma concavum	2	1.9
Lepidosperma filiforme	5	4.9
Lepidosperma forsythii	1	1.0
Lepidosperma laterale	45	43.7
Lepidosperma limicola	3	2.9
Lepidosperma neesii	8	7.8
Lepidosperma spp.	2	1.9
Lepidosperma urophorum	1	1.0
Leptocarpus tenax	9	8.7
Leptospermum arachnoides	20	19.4
Leptospermum continentale	2	1.9
Leptospermum juniperinum	7	6.8
Leptospermum lanigerum	1	1.0
Leptospermum morrisonii	8	7.8
Leptospermum parvifolium	4	3.9
Leptospermum polygalifolium	18	17.5
Leptospermum squarrosum	4	3.9

Leptospermum trinervium	65	63.1
Lepyrodia gracilis	1	1.0
Lepyrodia scariosa	33	32.0
Leucopogon amplexicaulis	2	1.9
Leucopogon appressus	5	4.9
Leucopogon ericoides	11	10.7
Leucopogon esquamatus	8	7.8
Leucopogon juniperinus	6	5.8
Leucopogon lanceolatus	2	1.9
Leucopogon microphyllus	29	28.2
Leucopogon virgatus	1	1.0
Ligustrum sinense	2	1.9
Lindsaea linearis	26	25.2
Lindsaea microphylla	12	11.7
Liparis reflexa	2	1.9
Lissanthe strigosa	27	26.2
Lobelia alata	1	1.0
Lobelia dentata	1	1.0
Logania albiflora	4	3.9
Lomandra brevis	1	1.0
Lomandra cylindrica	12	11.7
Lomandra filiformis	38	36.9
Lomandra fluviatilis	8	7.8
Lomandra glauca	33	32.0
Lomandra gracilis	30	29.1
Lomandra longifolia	24	23.3
Lomandra multiflora	31	30.1
Lomandra obliqua	56	54.4
Lomandra spp.	1	1.0
Lomatia myricoides	11	10.7
Lomatia silaifolia	37	35.9
Lonicera japonica	1	1.0
Lycopodium laterale	2	1.9
Macrozamia communis	1	1.0
Macrozamia spiralis	3	2.9
Marsdenia suaveolens	4	3.9
Maytenus silvestris	1	1.0
Melaleuca deanei	7	6.8
Melaleuca decora	3	2.9
Melaleuca linariifolia	9	8.7
Melaleuca nodosa	5	4.9
Melaleuca squamea	1	1.0
Melaleuca thymifolia	4	3.9
Melichrus procumbens	1	1.0
Melichrus spp.	1	1.0
Melichrus urceolatus	1	1.0
Micrantheum ericoides	21	20.4
Micrantheum hexandrum	2	1.9
Microlaena stipoides	11	10.7
Microtis unifolia	1	1.0
Mirbelia rubiifolia	5	4.9
Mirbelia speciosa	9	8.7
Mitrasacme polymorpha	10	9.7
Monotoca elliptica	3	2.9
Monotoca ledifolia	1	1.0
Monotoca scoparia	29	28.2
Muellerina eucalyptoides	1	1.0
Myrsiphyllum asparagoides	2	1.9
Notelaea longifolia	3	2.9
Olax stricta	2	1.9
Olearia microphylla	1	1.0
Olearia viscidula	1	1.0
Omphacomeria acerba	2	1.9
Opercularia aspera	5	4.9
Opercularia diphylla	5	4.9
Opercularia varia	6	5.8
Oplismenus aemulus	1	1.0
Oxalis perennans	3	2.9
Oxalis radicosa	1	1.0
Oxalis spp.	5	4.9
Pandorea pandorana	3	2.9
Panicum effusum	1	1.0
Panicum simile	13	12.6
Paspalidium distans	2	1.9
Paspalidium gracile	1	1.0
Paspalum dilatatum	2	1.9
Patersonia glabrata	12	11.7
Patersonia sericea	38	36.9
Pellaea falcata	1	1.0
Persicaria praetermissa	2	1.9
Persicaria strigosa	1	1.0

Persoonia lanceolata	15	14.6
Persoonia laurina	3	2.9
Persoonia levis	55	53.4
Persoonia linearis	32	31.1
Persoonia pinifolia	24	23.3
Petrophile pedunculata	2	1.9
Petrophile pulchella	9	8.7
Petrophile sessilis	41	39.8
Phebalium dentatum	8	7.8
Phebalium diosmeum	1	1.0
Phebalium squameum	1	1.0
Phebalium squamulosum	1	1.0
Philydrum lanuginosum	1	1.0
Phyllanthus gasstroemii	1	1.0
Phyllanthus hirtellus	34	33.0
Phyllota phylicoides	14	13.6
Pimelea linifolia	47	45.6
Plantago lanceolata	4	3.9
Platysace ericoides	35	34.0
Platysace lanceolata	4	3.9
Platysace linearifolia	35	34.0
Plectranthus graveolens	1	1.0
Plinthanthesis paradoxa	1	1.0
Poa affinis	1	1.0
Poa labillardieri	6	5.8
Poa sieberiana	1	1.0
Polyscias sambucifolia	1	1.0
Pomaderris elliptica	5	4.9
Pomaderris ferruginea	3	2.9
Pomaderris intermedia	5	4.9
Pomaderris lanigera	3	2.9
Pomax umbellata	21	20.4
Poranthera ericifolia	7	6.8
Poranthera microphylla	7	6.8
Prasophyllum flavum	1	1.0
Pratia purpurascens	8	7.8
Pseudanthus pimeleoides	5	4.9
Pseudognaphalium luteo-album	2	1.9
Pteridium esculentum	27	26.2
Pterostylis species	1	1.0
Pultenaea aristata	3	2.9
Pultenaea daphnoides	6	5.8
Pultenaea elliptica	33	32.0
Pultenaea flexilis	12	11.7
Pultenaea hispidula	3	2.9
Pultenaea linophylla	2	1.9
Pultenaea scabra	4	3.9
Pultenaea stipularis	6	5.8
Pultenaea villosa	6	5.8
Rapanea variabilis	1	1.0
Restio australis	1	1.0
Restio dimorphus	1	1.0
Restio fastigiatus	2	1.9
Restio gracilis	1	1.0
Restio tetraphyllus	1	1.0
Rhytidosporum procumbens	4	3.9
Ricinocarpos pinifolius	6	5.8
Santalum obtusifolium	2	1.9
Scaevola ramosissima	13	12.6
Schizaea bifida	16	15.5
Schoenus apogon	1	1.0
Schoenus brevifolius	12	11.7
Schoenus ericetorum	17	16.5
Schoenus lepidosperma ssp. pachylepis	1	1.0
Schoenus melanostachys	8	7.8
Schoenus moorei	3	2.9
Schoenus paludosus	2	1.9
Schoenus turbinatus	6	5.8
Schoenus villosus	5	4.9
Selaginella uliginosa	4	3.9
Senecio hispidulus var. dissectus	4	3.9
Senecio lautus	5	4.9
Senecio madagascariensis	3	2.9
Setaria gracilis	1	1.0
Sigesbeckia orientalis	1	1.0
Smilax glyciphylla	17	16.5
Solanum nigrum	1	1.0
Solanum prinophyllum	3	2.9
Solanum pungetium	2	1.9
Sonchus oleraceus	1	1.0
Sonchus spp.	1	1.0

Sowerbaea juncea	1	1.0
Sprengelia incarnata	4	3.9
Stackhousia nuda	1	1.0
Stackhousia viminea	7	6.8
Stenocarpus salignus	8	7.8
Sticherus flabellatus	9	8.7
Stipa pubescens	24	23.3
Stipa ramosissima	2	1.9
Stylidium graminifolium	22	21.4
Stylidium laricifolium	2	1.9
Stylidium lineare	21	20.4
Stylidium productum	6	5.8
Styphelia laeta var. laeta	2	1.9
Styphelia spp.	1	1.0
Symphionema paludosum	2	1.9
Syncarpia glomulifera	4	3.9
Telopea speciosissima	5	4.9
Tetraria capillaris	2	1.9
Tetrarrhena juncea	3	2.9
Tetrarrhena turfosa	1	1.0
Tetratheca ericifolia	3	2.9
Tetratheca neglecta	14	13.6
Thelionema caespitosum	2	1.9
Thelymitra spp.	2	1.9
Themeda australis	33	32.0
Thysanotus juncifolius	6	5.8
Todea barbara	2	1.9
Trachymene incisa	6	5.8
Tricoryne elatior	10	9.7
Tricoryne simplex	7	6.8
Tricostularia pauciflora	10	9.7
Triglochin procerum	4	3.9
Tristania neriifolia	4	3.9
Tristaniopsis laurina	10	9.7
Utricularia dichotoma	2	1.9
Vallisneria gigantea	1	1.0
Vernonia cinerea	3	2.9
Viminaria juncea	6	5.8
Viola hederacea	9	8.7
Wahlenbergia gracilis	6	5.8
Wahlenbergia stricta	5	4.9
Westringia longifolia	1	1.0
Woollsia pungens	9	8.7
Xanthorrhoea arborea	10	9.7
Xanthorrhoea concava	22	21.4
Xanthorrhoea media	29	28.2
Xanthorrhoea resinifera	21	20.4
Xanthosia pilosa	27	26.2
Xanthosia tridentata	33	32.0
Xylomelum pyriforme	12	11.7
Xyris gracilis	9	8.7
Xyris juncea	1	1.0
Xyris operculata	1	1.0
Zieria fraseri ssp. B	1	1.0
Zieria pilosa	4	3.9
Zieria smithii	2	1.9
Zornia dyctiocarpa	3	2.9

Appendix B

Fauna

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APPENDIX B - FAUNA

Fauna survey work was carried out under the terms of Scientific Licences Sections 120 and 131 of the National Parks and Wildlife Act, 1974 (A977, A1935, A2005, A2007, A2008) issued by the New South Wales National Parks and Wildlife Service.

1.1 FIELD SURVEY

Both sites were surveyed over spring and summer 1996. Due to delays in obtaining access to the Badgerys Creek site, two separate fauna survey teams were used to undertake sampling.

1.1.1 Badgerys Creek

The maximum area considered for the Badgerys Creek site is approximately 2795 hectares. As the original airport site was surveyed in 1985 (Kinhill Stearns 1985), the present study targeted those areas not previously sampled (i.e. additional land required for Options B and C). Much of the Badgerys Creek area has been disturbed and is currently being used for agriculture or light industrial purposes; natural vegetation is restricted primarily to bushland remnants found in patches and along drainage lines The gently undulating nature of the site together with the cleared areas and a road network allowed good access to most areas of the site. Access to some areas was restricted or denied by landowners Aerial photos and 1:25 000 topographical maps were used initially to help focus the field program. Most of the field work was completed over a one week period.

In general, areas within the Badgerys Creek original proposal (Option A) were not visited. However, due to the restricted distribution of the fauna habitat and limited opportunities for surveying some faunal groups (e.g. frogs). There were two exceptions to this general rule:

- Site A, located within Option A, contained a small area of woodland habitat and a small ephemeral drainage line. This area had a slightly different vegetation structure to many of the other remnant areas of the study site because it contained Bloodwoods, and was therefore targeted for active searching.

- Badgerys Creek is a potential wildlife corridor and the riparian vegetation along it represents the most substantial habitat of this type within the study area. A section of this habitat (Site B) was actively searched and surveyed for bats.

Fauna sampling sites are shown in Figure B1. Amphibian survey sites were restricted wetlands and dams (*Figure B2* and *Table B2.4).*

1.1.2 Holsworthy

The Holsworthy site comprised approximately 15 000 ha of mostly native vegetation. Field survey therefore aimed to maximise coverage of the site and to target those areas not previously sampled. Access to most of the site was not possible due to the lack of roads and fire trails, army activities and steeply dissected country. Aerial photos and topographical maps at 1:25 000 were examined initially in order to locate suitable roads and tracks and accessible gullies. In general, field work was concentrated into two two-week blocks, with most survey activities being confined to the southern part of the study site during the first half of the field study. As a rule, AXIS/Australian Museum Business Services (1995) survey sites were not visited. However, due to the restricted distribution of some habitats and the limited opportunities for surveying some fauna groups (e.g. frogs), there was some overlap of field sites between the two studies. The seven exceptions were:

- Engineers Bridge (F42, F56) was the major accessible gorge within the study site and therefore provided good opportunities for bat detecting and spotlighting;

- Williams Creek (lower reaches) contained a *Melaleuca* community (F18, F62) which was not readily found elsewhere on the site;
- Williams Creek (upper reaches) (F52) provided good opportunities for active searching for reptiles;
- Harris Creek in the Small Arms Danger Area (F20) provided an accessible riparian community for frogging and active searching;
- Deadmans Creek (F22) provided an accessible riparian community for frogging;
- A small dam near Woolwash Junction (F59) provided good opportunities for frogging;
- Small pools near O.P. Gilday (F53) provided good opportunities for frogging;
- Small pools near Demolition 1 (F24) provided good opportunities for frogging.

Figure B3 shows the locations of these fauna sampling sites.

1.1.3 Survey Effort

Survey effort is summarised in Table B2.1below.

Table B2.1. Survey effort for each of the proposed airport sites.

Technique	**Badgerys Creek Site**	**Holsworthy Site**
Active searching	14 person-hours	108 person-hours
Hair tube nights	300 tube-nights	4540 tube-nights
Spotlight hours	4.5 hours	17.8 hours
Predator scats collected	-	approximately 150
Harp trap nights	-	39 trap-nights
Bat detector nights/hours	2 bat detector hours	11 bat detector nights
Call playback hours	-	15 hours
Frogging listening / search hours	4.25	15.5

1.1.4 Survey Techniques

The survey techniques used during the present study provided a broad coverage of most target fauna species and groups. One standard survey technique which was not used was pitfall trapping. This labour-intensive and time-consuming technique is used to target small terrestrial vertebrates such as rare reptiles, pygmy possums and dunnarts. Because pitfalls must be checked regularly, this technique is considered to be inappropriate for use at sites with restricted accessibility. The target species can be successfully located by other methods such as active searching in the case of rare reptiles and dunnarts and hair tubing or scat analysis in the case of small mammals such as feathertail gliders and pygmy possums.

Other techniques by their very nature are limited in their application. For example, the difficult terrain at the Holsworthy site restricted spotlighting activities to roadsides which were confined mainly to ridges and plateaus. We were therefore unable to do very much spotlighting in gully forest habitat. However, these areas and their associated fauna were targeted via hair tube transects, active searching and predator scat collection.

Survey techniques such as frogging and bat-trapping are most effective when applied to areas of suitable habitat for these fauna groups. Frog species tend to be more active near drainage lines or other pools of water. Similarly, bats concentrate near water or along flyways such as those created by vehicular tracks or streams. Access to suitable water bodies and drainage lines for both frog and bat work was restricted by the difficult terrain.

Specialist sub-consultants were engaged to target particular species at the Holsworthy site. Jack Baker undertook

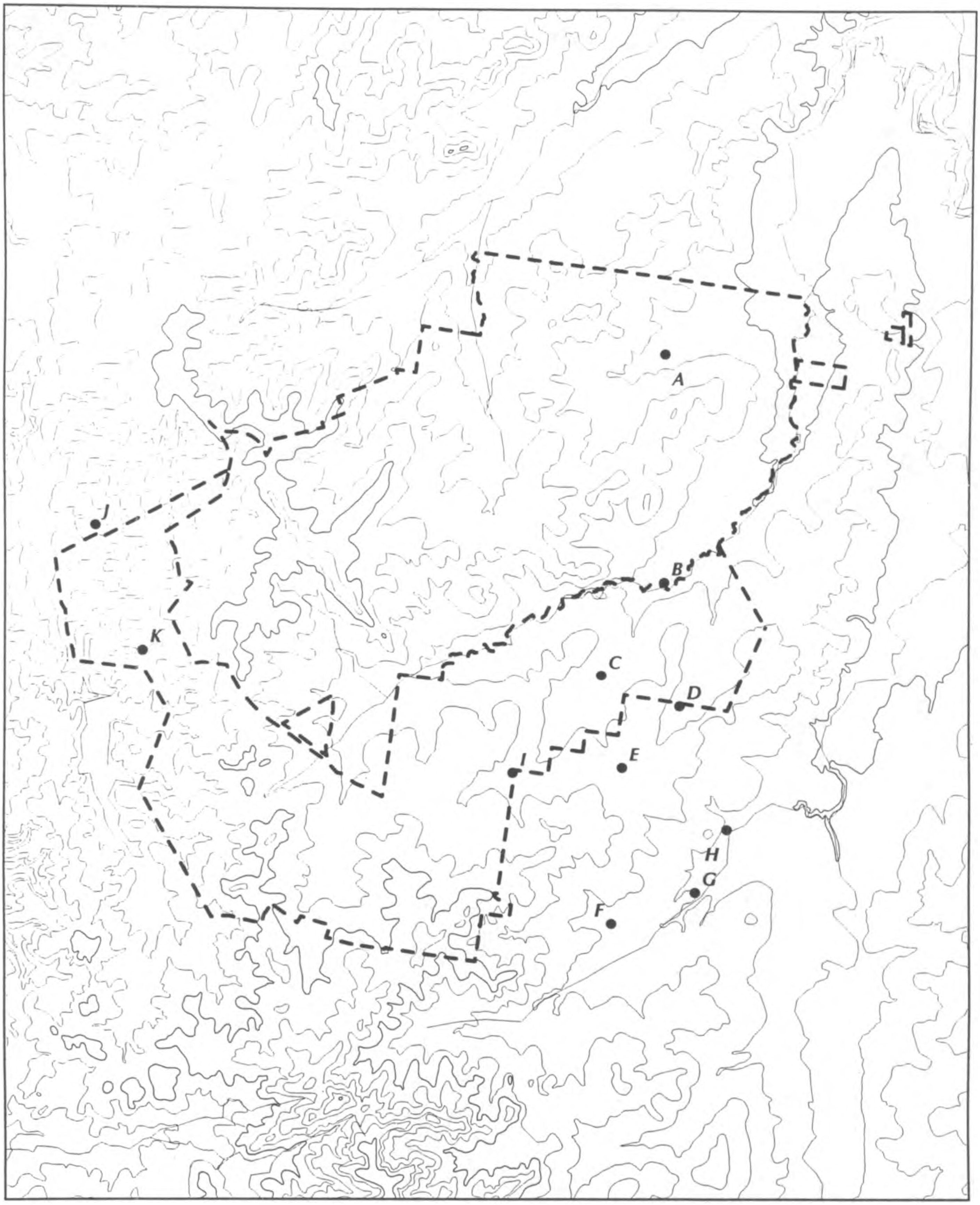


Figure B1
Badgerys Fauna Sampling Sites

28/7/97

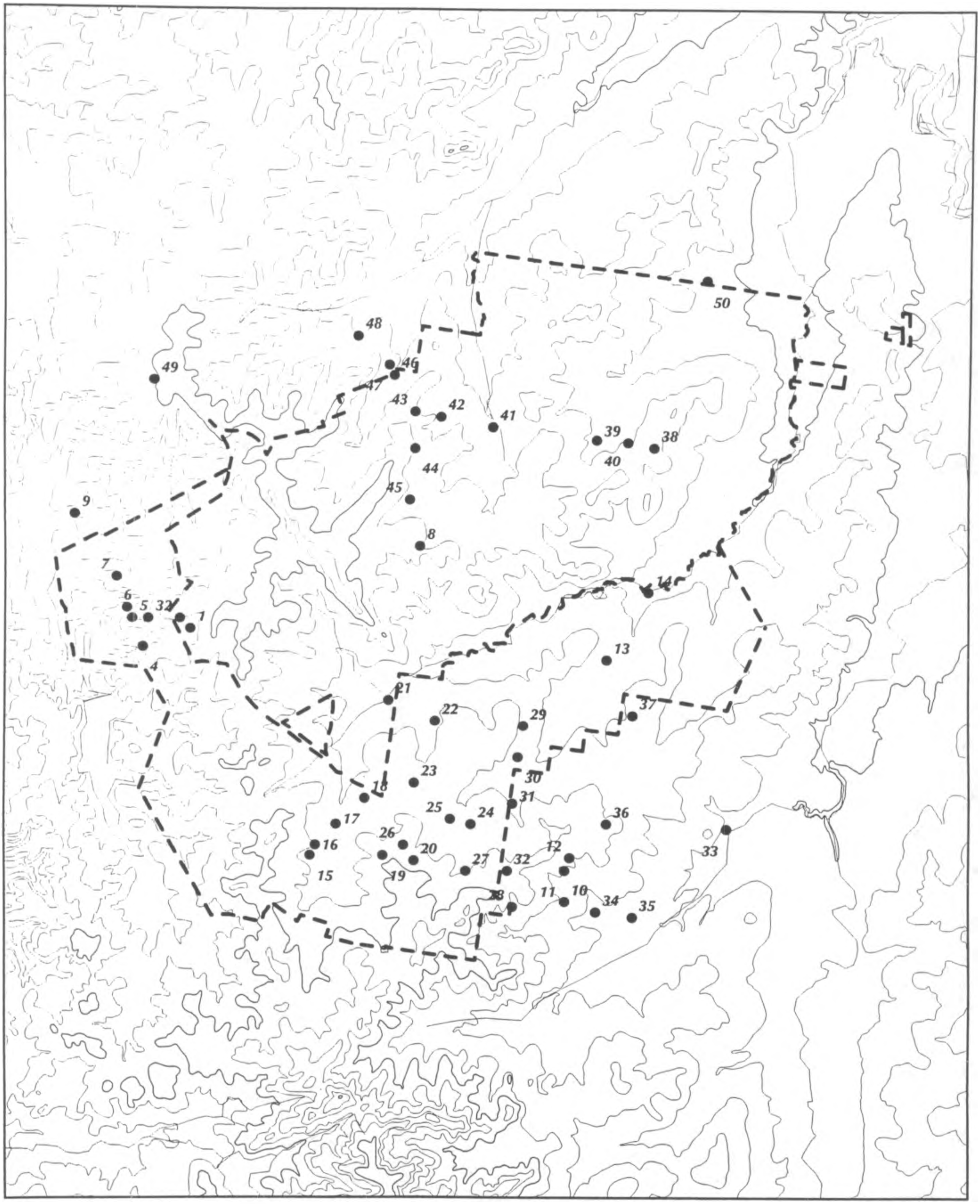
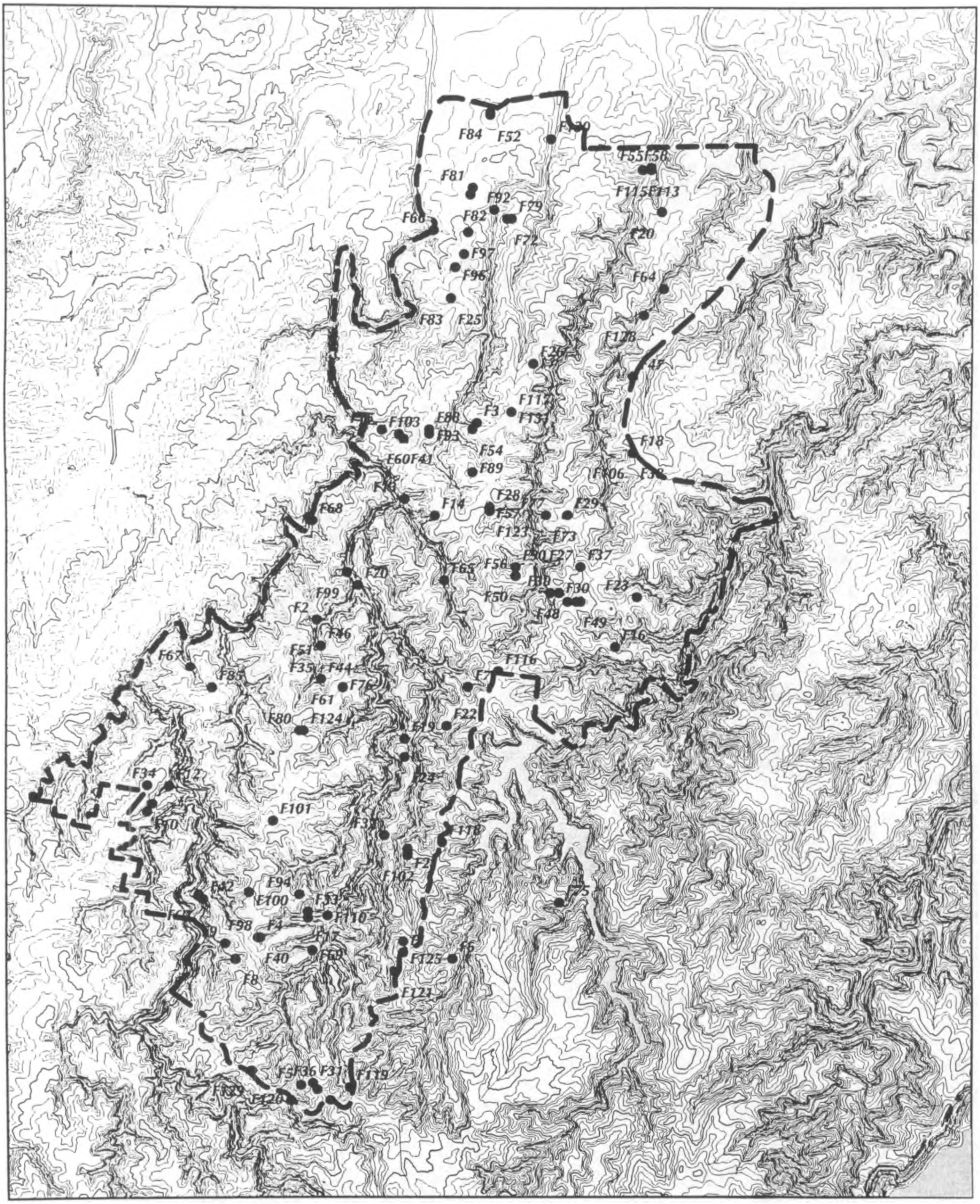


Figure B2
Badgerys Creek Frog Sampling Sites

28/7/97



Legend

- ● Holsworthy Fauna Sightings
- Military Boundary
- Rivers
- Water
- 50m contour
- 10m contour

Figure B3
Holsworthy Significant Fauna Records

1:120,000

28/7/97

Eastern Bristlebird and Ground Parrot surveys and Deryk Engel mapped Broad-headed Snake habitat.

1.1.4.1 Active Searching

Active searching targets all fauna groups. The majority of species were detected by direct observation. Birds and frogs were identified by a combination of methods. Birds were usually heard and then visually located. Detailed observations, when necessary, were made with binoculars. The majority of frogs were detected by their calls, and where possible were caught to confirm their identity. Reptiles were detected either visually as they foraged above ground or by active searching under suitable shelter sites. Active searching was concentrated on the following refuge sites: beneath surface rocks and boulders, in the base of grass tussocks, beneath exfoliating tree bark, and beneath hard litter (e g. fallen timber, corrugated iron, fence posts).

Both direct and indirect evidence of fauna was recorded. Direct evidence of fauna species includes captures, sitings or recordings of distinct vocalisations or calls (e g. birds, frogs and some nocturnal mammals). Indirect evidence of fauna species includes hair or body remains identified from predator scats The scat samples were analysed by Barbara Triggs (c/o 'Dead Finish' Genoa, Victoria).

1.1.4.2 Hair-tubing

Mammals were surveyed using hair tubes (large square section hair-tubes of dimension 100x100 mm and small circular section hair-tubes 30 mm in diameter) baited with a mixture of either rolled oats, honey and peanut butter or tuna, sardines and flour One 'tube-night' is equivalent to one hair-tube set in place for one night. Lines of twenty hair tubes were placed in pairs (one large and one small hair-tube) on the ground. Hair tubes were spaced approximately 10 - 15 m apart.

Hair tubing was considered to be the most efficient mammal survey technique for both the Badgerys Creek and Holsworthy sites. Hair tube transects provide the widest coverage over the site with a minimum of effort (since they can remain in place for up to three weeks depending on the weather). At Badgerys Creek, the traps were left out for approximately one week. All tubes were baited with a peanut butter mixture.

At Holsworthy, the traps were left out for two weeks on average. Because most of the gully locations were difficult to access, it would have been impossible to check Elliot traps placed in similar locations on a daily basis. All small tubes were baited with peanut butter; large tubes were baited alternatively with peanut butter and tuna and sardines. The large tubes of one transect line located near a suspected quoll den was baited entirely with tuna and sardines. This bait mixture has been used successfully for attracting quolls in Victoria (Chris Belcher *pers. comm.*).

1.1.4.3 Spotlighting

Nocturnal mammals and birds were surveyed by spotlight. This involved the use of 50 watt 12-volt spotlights. Trails and roads were traversed by foot during the night and trees were searched for owls and possums. Frogs were also detected at night with the aid of spotlights.

Spotlighting at the Holsworthy site was confined to suitable roads and tracks in gullies and other areas containing mature trees. If any indirect signs or arboreal mammals were noted during daytime searches (i.e. scats, feeding scars), then these sites were revisited at night.

1.1.4.4 Bird Census

Bird species identified during all other field survey activities were recorded. In addition, active searching for birds was conducted in different habitat types on a daily basis (approximately 1.5 hours per site). Point counts are not considered a suitable technique when producing a species list for an area; they are more appropriate for determioning distribution and abundance of particular species.

At the Holsworthy site, a specialist sub-consultant, Jack Baker, compiled a species list while undertaking surveys for Eastern Bristlebirds and Ground Parrots in two extensive heathland areas.

1.1.4.5 *Frog Call Identification*

Surveys for frogs generally involve the identification of species from the calls made by males. This type of survey requires extensive listening periods in habitats which are considered likely breeding habitats. Species which are difficult to identify from calls alone can often be located using triangulation and subsequently captured for identification. In addition, frogs may be located by spotlighting with head torches along water courses and dams. The eyes of frogs will often reflect back allowing them to be located and captured for identification.

A supplementary survey technique was used to identify the Red-crowned Toadlet, Giant Burrowing Frog and the Stuttering Frog. This involved the use of male frog call play-backs to induce non-calling males to respond and disclose there presence.

1.1.4.6 *Play-back of Tapes*

This technique involves playing the pre-recorded sounds of owls through a loud hailer. If the target species is within earshot of the broadcast it may respond by calling. This method relies on the fact that most species targetted are territorial and use calls as a method of defending their territory from conspecifics. Usually three species of owls, the Sooty, Masked and Powerful, are surveyed in this manner (Kavanagh and Peake 1993). This method also involved spotlighting the area immediately after the cessation of the play-back. Owls were also detected by listening for calls. Owls call most frequently at dusk on dark, still, warm nights (Kavanagh and Peake 1993, personal observations).

Taped calls from the Powerful, Sooty and Masked Owls were played for 5 minutes each (total 15 minutes call play-back). This is followed directly by a 15-minute spotlighting period and an additional 10-minute listening period to pick up any responses.

Powerful Owl call play-backs may also be used to induce audible responses from the Yellow-bellied Glider (*Petaurus australis*). This species is a favourite prey item of Powerful Owls and will often call in groups in response to taped calls in an attempt to ward off attacks.

In addition, call playback was used to detect frogs where suitable habitat was identified (see Frog Identification above). Jack Baker used playback calls to detect the Eastern Bristlebird at the Holsworthy site.

1.1.4.7 *Scat and Owl Pellet Analysis*

Carnivorous mammals and owls expel undigested remains of their prey. The faeces of carnivorous mammals contain undigested hair and bones of prey and occasionally their own grooming hairs. These residual hairs can be analysed under a microscope and identified. Hence the scats of carnivorous mammals can indicate both predator and prey species. Owls regurgitate pellets that contain undigested remains of their prey. Such pellets are usually associated with roosting sites. All scats and owl pellets were analysed by Barbara Triggs.

1.1.4.8 *Identification of Possums by Tree Incisions*

When sap-feeding, Yellow-bellied Gliders make distinctive V-shaped incisions on the trunks of food trees (Goldingay & Kavanagh 1991). Trees containing these incisions can be used to confirm the presence of glider species in large areas of forest (Goldingay & Kavanagh 1991). Incisions detected on several tree species at Holsworthy (Site M) were photographed. Photos were sent to Dr Ross Goldingay (Southern Cross University, Lismore) and to Rod Kavanagh (State Forests of NSW) for verification.

1.1.4.9 *Bat Trapping and Detection*

Bats were surveyed using both harp traps (Tideman & Woodside 1978) and ultra-sonic detectors (Anabat II - Titley Electronics). Whereas bat detectors sample those fast-flying species which tend to forage above the canopy layer, harp traps capture slower species which fly beneath the canopy. The latter technique also allows positive identification of species which are difficult to identify by calls. Harp traps are usually placed across unused tracks and fire trails or wherever there is a natural flyway to funnel flying bats towards the trap. Sites were not selected at random, but were chosen to target bat fly-ways where trapping and detecting could be maximised. Harp traps were cleared each morning and the bat(s) were released the following evening near the point of capture.

Microchiropteran bats produce ultrasonic echo location signals which are usually inaudible to the human ear. The Anabat Bat Detector has been designed to translate these signals into audible electronic signals. These sounds are usually characteristic for a particular species and hence can be used to identify the bat species present in an area. The detector is connected to a voice activated portable tape recorder via a delay switch so that a permanent record of bat signals is made. The complete system is weather-proofed by sealing it in a plastic box with only the recording microphone exposed. It is then usually placed on the ground and left on overnight. Detectors are also placed near fly-ways where bat activity is highest in order to maximise the number of bats detected.

Due to the open nature of the habitat at Badgerys Creek, harp traps could not be used. A bat detector was left out for several hours over two consecutive nights but could not be left out overnight in case of vandalism. At Holsworthy, four harp traps and two detectors were used concurrently on suitable (warm, dry) nights. At detector sites, an ultra-sonic bat detector was placed on the ground with the microphone positioned at approximately a 45° angle to remotely sample bat calls.

Tapes were later analysed by Jason Anderson (SFNSW) using zero-crossing analysis, the computer-based Anabat software

1.1.4.10 Specialist Surveys

Eastern Bristlebird and Ground Parrot surveys were conducted by J. Baker (University of Wollongong). Eastern Bristlebirds surveys were conducted by playing tapes of bristlebird calls at least every kilometre along a fixed route which transected heathland or shrubland and woodland with a heathy understorey. The tape was played at 60 locations for one minute and followed by 5-60 minutes of listening and searching. Ground Parrot surveys were conducted by using dusk and dawn aural surveys at areas of extensive heath.

Broad-headed Snake surveys were conducted by D. Engel (Lesryk Environmental Consultants). Aerial photographs and topographical maps were first examined in order to locate north to west facing rock outcrops with a woodland overstorey. Three areas which appeared to contain potential habitat were then ground-checked and assessed. The survey involved turning over most rocks on the outcrop and observing the physical conditions under each rock.

1.1.4.11 Records From Other Sources

Fauna records from the two study areas and their surrounds were obtained from the New South Wales National Parks and Wildlife Service, the Australian Museum, Sydney Water, RAOU, Bird Atlassers, Illawarra Bird Observers Club, Cumberland Plains Bird Observers Club and from a review of the literature including: AXIS/Australian Museum Business Services (1995), Dames and Moore (1983, 1991, 1993), Ecotone Ecological Consultants (1994), EDAW/Biosis Research (1996), Engel (1994a,b, 1995, 1996a,b,c), Engel and Chafer (1994), ERM Mitchell McCotter (1996a,b), Fanning (1995), Fanning and Leonard (1996), Harlow and Taylor (1995), Kevin Mills and Associates (1986, 1988, 1989, 1990b), Kinhill Stearns (1985), NPWS (unpublished), Phillips and Callaghan (1996), Phillips *et al.* (1996), Rust PPK (1993, 1995, 1996), Speight *et al.* (1995) and Speight *et al.* (1996).

1.2 HABITAT ASSESSMENT

Habitat assessment was undertaken for terrestrial vertebrate fauna. The methods used are outlined below.

A habitat type is generally formed by floristic and structural features of the vegetation which provide a set of resources to support a community of fauna species. In general, habitat types correspond to vegetation communities, however habitats may be defined by other physical attributes of the landscape. Many fauna species move between habitats or use more than one habitat.

Habitat quality was assessed using the following descriptive criteria:

High

Ground flora contains a high number of indigenous species; vegetation community structure, ground log and/or litter layer intact and undisturbed; high level of breeding, nesting, feeding and roosting resources available; high richness and diversity of native fauna species.

Moderate

Ground flora contains a moderate number of indigenous species; vegetation community structure, ground log and/or litter layer moderately intact and undisturbed; moderate level of breeding, nesting, feeding and roosting resources available, moderate richness and diversity of native fauna species.

Low

Ground flora contains a low number of indigenous species, vegetation community structure, ground log and/or litter layer disturbed and modified; low level of breeding, nesting, feeding and roosting resources available; low richness and diversity of native fauna species.

1.3 CLASSIFICATION

Common names and scientific names for vertebrates are from the Census of Australian Vertebrate Species (CAVES) ERIN Version 8.1 (1995). Additional common names for mammals follow Strahan (1995). Additional common and scientific names for reptiles and amphibians are from Cogger (1996), Ehmann (1992), Tyler (1992) and Hutchinson *et al.* (1990).

1.4 DEFINING SIGNIFICANT SPECIES

Within a given geographic context (Australia/New South Wales, region, locality) a species has a particular conservation status (extinct, endangered, vulnerable, rare). These conservation status levels are based on the International Union for the Conservation of Nature (IUCN) Red List of Threatened Animals (IUCN 1988) and are used to assess significance. Therefore species of national, state, regional and local conservation significance are those which are considered to be endangered, vulnerable or rare nationally, within a state, within a region or within a local area.

The national and state ratings for significant species were taken from published lists which are recognised by the scientific community as well as by government bodies. Because new biological information on some species is now available and lists are only published periodically, it is sometimes necessary to update significance ratings.

National significance is assessed using the following listings: ANZECC (1991) and species listed under Schedules 1 and 2 of the (Commonwealth) Endangered Species Protection (ESP) Act 1992.

State significance is assessed using recognised listings: Schedules 1 and 2 of the Threatened Species Conservation Act (1995).

Regional significance for fauna is assessed by referring to relevant government reports, by consulting experts familiar with the area, referring to the literature, and by drawing upon previous field experience of the Consultants.

Species listed under International Treaties are those listed under the Japan-Australia Migratory Birds Agreement (JAMBA) and the China-Australia Migratory birds Agreement (CAMBA).

1.5 RESULTS

Results of the literature review and field survey work are presented in this section.

1.5.1 Badgerys Creek

1.5.1.1 Overall species

A total of nine amphibian species, six reptile species, 75 bird species (65 native, 10 introduced) and 20 mammal species (10 native, 10 introduced) was recorded during the current study. Taking into account all fauna records collated from our extensive literature review, the Badgery Creek site provides or is likely to provide habitat for at least 16 amphibian species, 27 reptile species, 155 bird species (143 native, 12 introduced) and 38 mammal species (26 native, 12 introduced). A full list of species is given in Table B2.2. The locations of fauna sampling sites for Badgerys Creek are listed in Tables A2.3 and A2.4 and Frog Sampling sites are shown on *Figure B3*.

1.5.1.2 Significant species

A total of 18 significant fauna species has been recorded at the Badgerys Creek site, including two species of state significance and 16 species of regional significance. An additional two species of national significance, 11 species of state significance and 23 species of regional significance were recorded in the vicinity of Badgerys Creek and may occur within the study area. Five species listed under international agreements were also recorded in or adjacent to the study area. Species of national and state significance are discussed in detail in species profiles below. The distribution of significant species in relation to the Badgerys Creek site are listed in Table B2.6. Species of regional significance are considered in Table B2.13.

It should be noted that a further 11 significant species could possibly occur at the Badgerys Creek site but are considered to be 'unlikely' (T. Saunders, Cumberland Bird Observers Club pers. comm.). These include four species of state significance: Square-tailed Kite, Painted Snipe, Masked Owl and Bush Stone-curlew. The latter two species are known from unconfirmed records adjacent to the study area. The following species of regional significance are also unlikely to occur at the Badgerys Creek site: Black-chinned Honeyeater, Brown Cuckoo-Dove, Brown Treecreeper. Chestnut Breasted Mannikin, Glossy Ibis, Musk Duck and King Quail. Although these species may utilise the Badgerys Creek site, it is unlikely to contain critical habitat for any of them.

Table B2.2. Terrestrial vertebrate fauna known from or likely to occur within the Badgerys Creek site. Species which have no records listed are known to occur in the general area and may occur within the study site. Species lists should not be considered exhaustive.

Conservation Significance: N(e) = Listed on Schedule 1 of the Endangered Species Protection (ESP) Act (1992); N(v) = Listed on Schedule 2 of the ESP Act 1992; S(e) = Listed on Schedule 1 of the Threatened Species Conservation Act 1995; S(v) = Listed on Schedule 2 of the TSC Act 1995; R = Regional Significance; J/C = JAMBA/CAMBA International Treaties; C= CAMBA.

Type of Record: A = Identified from Hair Sample, H = Heard, I = Indirect Evidence (e.g. scats, burrows, etc), S = Seen, T = Trapped or Hand-held, X = Recorded.

Common Name	**Scientific Name**	**Status**	**Biosis**[a]	**Kinhill Stearns**[b]	**Lesryk**[c]	**NPWS**[d]	**AM**[e]
Amphibians							
Tusked Frog	*Adelotus brevis*	R					
Common Eastern Froglet	*Crinia signifera*		H		X	X	
Ornate Burrowing Frog	*Limnodynastes ornatus*						
Striped Marsh Frog	*Limnodynastes peronii*		H		X	X	
Spotted Grass Frog	*Limnodynastes tasmaniensis*		H		X	X	
Green and Golden Bell Frog	*Litoria aurea*	S(e)					
Green Tree Frog	*Litoria caerulea*	R					
Bleating Tree Frog	*Litoria dentata*						
Eastern Dwarf Tree Frog	*Litoria fallax*		H	X			
Broad-Palmed Rocket Frog	*Litoria latopalmata*		H				
Lesueur's Frog	*Litoria lesueuri*						
Peron's Tree Frog	*Litoria peronii*		H				
Laughing Tree Frog	*Litoria tyleri*		H				
Whistling Tree Frog	*Litoria verreauxii*		H		X	X	
Brown Toadlet	*Pseudophryne bibronii*	R					
Smooth/Dusky Toadlet	*Uperoleia laevigata/fusca*		H				
Reptiles							
Bar-sided Skink	*Eulamprus tenuis*		T				

Common Name	Scientific Name	Status	Biosis[a]	Kinhill Stearns[b]	Lesryk[c]	NPWS[d]	AM[e]
Bearded Dragon	*Pogona barbata*	R					
Blind Snake	*Ramphotyphlops nigrescens*						
Common Scaly-foot	*Pygopus lepidopodus*						
Copper-tailed Skink	*Ctenotus taeniolatus*						
Death Adder	*Acanthophis antarcticus*						
Diamond Python	*Morelia spilota spilota*	R					
Eastern Blue-tongued Lizard	*Tiliqua scincoides*						
Eastern Brown Snake	*Pseudonaja textilis*						
Eastern Long-necked Turtle	*Chelodina longicollis*						
Eastern Water Dragon	*Physignathus lesueurii*		S	X			
Eastern Water Skink	*Eulamprus quoyii*		S	X	X	X	
Garden Skink	*Lampropholis guichenoti*		T	X	X	X	X
Grass Skink	*Lampropholis delicata*		T		X	X	
Jacky Dragon	*Amphibolurus muricatus*						
Lace Monitor	*Varanus varius*	R		X			
Lesueur's Velvet Gecko	*Oedura lesueurii*						
Oak Skink	*Cyclodomorphus casuarinae*						
Red-bellied Black Snake	*Pseudechis porphyriacus*		S				
Red-naped Snake	*Furina diadema*						
Red-throated Skink	*Bassiana platynota*						
Southern Leaf-tailed Gecko	*Phyllurus platurus*						
Striped Skink	*Ctenotus robustus*						
Tiger Snake	*Notechis scutatus*						
Wall Lizard	*Cryptoblepharus virgatus*						
Weasel Skink	*Saproscincus mustelina*						
Wood Gecko	*Diplodactylus vittatus*						
Birds							
Australasian Bittern	*Botaurus poiciloptilus*	S(v)					
Australasian Grebe	*Tachybaptus novaehollandiae*		S	X	X	X	
Australian Hobby	*Falco longipennis*		S				
Australian King Parrot	*Alisterus scapularis*						
Australian Magpie	*Gymnorhina tibicen*		S	X	X	X	
Australian Owlet-nightjar	*Aegotheles cristatus*						
Australian Pelican	*Pelecanus conspicillatus*		S				
Australian Raven	*Corvus coronoides*		S	X	X	X	
Australian Spotted Crake	*Porzana fluminea*						
Australian White Ibis	*Threskiornis molucca*			X			
Australian Wood Duck	*Chenonetta jubata*		S	X	X	X	
Azure Kingfisher	*Alcedo azurea*		S				
Baillons Crake	*Porzana pusilla*						
Barn Owl	*Tyto alba*		S				
Bell Miner	*Manorina melanophrys*		H				
Black Bittern	*Ixobrychus flavicollis*	S(v)					
Black-faced Cuckoo-shrike	*Coracina novaehollandiae*		S	X	X	X	
Black Falcon	*Falco subniger*						
Black-fronted Dotterel	*Elseyornis melanops*		S				
Black-shouldered Kite	*Elanus axillaris*		S				
Black-winged Stilt	*Himantopus himantopus*		S	X			
Black Swan	*Cygnus atratus*			X			
Brown Falcon	*Falco berigora*		S		X	X	
Brown Songlark	*Cinclorhamphus cruralis*	R	S	X			
Brown Gerigone	*Gerygone mouki*						
Brown Goshawk	*Accipiter fasciatus*			X			
Brown Thornbill	*Acanthiza pusilla*			X			
Brown-headed Honeyeater	*Melithreptus brevirostris*						
Buff-banded Rail	*Gallirallus philippensis*						
Buff-rumped Thornbill	*Acanthiza reguloides*	R			X	X	
Cattle Egret	*Ardea ibis*	J/C			X	X	
Channel-billed Cuckoo	*Scythrops novaehollandiae*						
Chestnut Teal	*Anas castanea*						
Clamorous Reed-Warbler	*Acrocephalus stentoreus*			X			
Cockatiel	*Nymphicus hollandicus*				X	X	
Common Bronzewing	*Phaps chalcoptera*						
Common Koel	*Eudynamys scolopacea*						
Crested Pigeon	*Ocyphaps lophotes*		S	X	X	X	
Crimson Rosella	*Platycercus elegans*						
Darter	*Anhinga melanogaster*		S	X			
Diamond Firetail Finch	*Stagonopleura guttata*	R					

Common Name	**Scientific Name**	**Status**	**Biosis**[a]	**Kinhill Stearns**[b]	**Lesryk**[c]	**NPWS**[d]	**AM**[e]
Double-barred Finch	*Taeniopygia bichenovii*	R	S	X	X	X	
Dusky Moorhen	*Gallinula tenebrosa*		S	X	X	X	
Dusky Woodswallow	*Artamus cyanopterus*		S	X			
Eastern Rosella	*Platycercus eximius*		S	X		X	
Eastern Yellow Robin	*Eopsaltria australis*		S				X
Eastern Spinebill	*Acanthorhyncus tenuirostris*						
Eastern Whipbird	*Psophodes olivaceus*						
Eurasian Coot	*Fulica atra*		S	X			
Fairy Martin	*Hirundo ariel*		S		X	X	
Fan-tailed Cuckoo	*Cacomantis flabelliformis*			X			
Flame Robin	*Petroica phoenicea*	R					
Fork-tailed Swift	*Apus pacificus*	J/C					
Fuscous Honeyeater	*Lichenostomus flavescens*	R					
Galah	*Cacatua roseicapilla*		S	X	X	X	
Gang-gang Cockatoo	*Callocephalon fimbriatum*						
Glossy Black-Cockatoo	*Calyptorhynchus lathami*	S(v)					
Golden-headed Cisticola	*Cisticola exilis*			X			
Golden Whistler	*Pachycephala pectoralis*						
Great Cormorant	*Phalacrocorax carbo*		S				
Great Crested Grebe	*Podiceps cristatus*	R					
Great Egret	*Ardea alba*	R,J/C		X			
Grey Butcherbird	*Cracticus torquatus*		S	X	X	X	
Grey Fantail	*Rhipidura fuliginosa*		S	X			
Grey Shrike-thrush	*Colluricincla harmonica*						
Grey Teal	*Anas gracilis*			X			
Hardhead	*Aythya australis*						
Hoary-headed Grebe	*Poliocephalus poliocephalus*		S				
Hooded Robin	*Melanodryas cucullata*	R					
Horsfield's Bronze-Cuckoo	*Chrysococcyx basalis*						
Jacky Winter	*Microeca fascinans*	R		X			
Latham's Snipe	*Gallinago hardwickii*	R,J/C					
Leaden Flycatcher	*Myiagra rubecula*						
Laughing Kookaburra	*Dacelo novaeguineae*		S	X	X	X	
Little Black Cormorant	*Phalacrocorax sulcirostris*			X			
Little Corella	*Cacatua sanguinea*						
Little Eagle	*Hieraaetus morphnoides*	R					
Little Grassbird	*Megalurus gramineus*			X			
Little Lorikeet	*Glossopsitta pusilla*						
Little Pied Cormorant	*Phalacrocorax melanoleucos*			X		X	
Little Wattlebird	*Anthochaera chrysoptera*			X			
Long-billed Corella	*Cacatua tenuirostris*		S				
Magpie-lark	*Grallina cyanoleuca*		S	X	X	X	
Masked Lapwing	*Vanesllus miles*		S	X	X	X	
Masked Woodswallow	*Artamus personatus*						
Mistletoebird	*Dicaeum hirundinaceum*		S				
Nankeen Kestrel	*Falco cenchroides*		S				
Nankeen Night Heron	*Nycticorax caledonicus*	R	S	X			
Noisy Friarbird	*Philemon corniculatus*						
Noisy Miner	*Manorina melanocephala*		S	X	X	X	
Nutmeg Mannikin	*Lonchura punctulata*						
Olive-backed Oriole	*Oriolus sagittatus*			X			
Pacific Black Duck	*Anas superciliosa*		S	X	X	X	
Painted Button-quail	*Turnix varia*						
Pallid Cuckoo	*Cuculus pallidus*						
Peaceful Dove	*Geopelia placida*	R	S				
Peregrine Falcon	*Falco peregrinus*	R					
Pied Butcherbird	*Cracticus nigrogularis*				X	X	
Pied Cormorant	*Phalacrocorax varius*		S				
Pied Currawong	*Strepera graculina*				X	X	
Powerful Owl	*Ninox strenua*	S(v)					
Purple Swamphen	*Porphyrio porphyrio*		S	X	X	X	
Rainbow Bee-eater	*Merops ornatus*						
Red-backed Kingfisher	*Todiramphus pyrrhopygia*						
Red-browed Finch	*Neochmia temporalis*		S				
Red-capped Robin	*Petroica goodenovii*	R					
Red-rumped Parrot	*Psephotus haematonotus*		S	X	X	X	
Red Wattlebird	*Anthochaera carunculata*						

Regent Honeyeater	*Xanthomyza phrygia*	N(e), S(e)					
Restless Flycatcher	*Myiagra inquieta*	R	S		X	X	
Richard's Pipit	*Anthus novaeseelandiae*		S				
Rose Robin	*Petroica rosea*						
Royal Spoonbill	*Platalea regia*		S	X			
Rufous Fantail	*Rhipidura rufifrons*						
Rufous Songlark	*Cincloramphus mathewsi*	R					
Rufous Whistler	*Pachycephala rufiventris*		S	X			
Sacred Kingfisher	*Todiramphus sanctus*		S	X			
Scarlet Honeyeater	*Myzomela sanguinolenta*						
Shrike-tit	*Falcunculus frontatus*	R					
Silvereye	*Zosterops lateralis*		S		X	X	
Southern Boobook	*Ninox novaeseelandiae*						
Spangled Drongo	*Dicrurus bracteatus*						
Speckled Warbler	*Chthonicola sagittata*	R					
Spotted Pardalote	*Pardalotus punctatus*		S				
Straw-necked Ibis	*Threskiornis spinicollis*		S	X	X	X	
Striated Pardalote	*Pardalotus striatus*						
Striated Thornbill	*Acanthiza lineata*						
Sulphur-crested Cockatoo	*Cacatua galerita*		S	X			
Superb Fairy-wren	*Malurus cyaneus*		S	X	X	X	
Swamp Harrier	*Circus approximans*						
Swift Parrot	*Lathamus discolor*	N(v), S(v)					
Tawny Frogmouth	*Podargus strigoides*		S		X	X	
Tawny Grassbird	*Megalurus timoriensis*		S				
Tree Martin	*Hirundo nigricans*						
Varied Sittella	*Daphoenositta chrysoptera*						
Wedge-tailed Eagle	*Aquila audax*	R					
Weebill	*Smicrornis brevirostris*	R		X			
Welcome Swallow	*Hirundo neoxena*		S	X	X	X	
Western Gerygone	*Gerygone fusca*						
Whistling Kite	*Haliastur sphenurus*	R		X			
White-faced Heron	*Egretta novaehollandiae*		S	X	X	X	
White-bellied Cuckoo-shrike	*Coracina papuensis*	R					
White-browed Scrubwren	*Sericornis frontalis*						
White-browed Woodswallow	*Artamus superciliosus*						
White-fronted Chat	*Epthianura albifrons*	R					
White-naped Honeyeater	*Melithreptus lunatus*						
White-necked Heron	*Ardea pacifica*						
White-plumed Honeyeater	*Lichenostomus penicillatus*						
White-throated Gerygone	*Gergone olivacea*		S				
White-throated Needletail	*Hirundapus caudacutus*	J/C					
White-throated Nightjar	*Eurostopodus mystacalis*						
White-throated Treecreeper	*Cormobates leucophaeus*		S				
White-winged Chough	*Corcorax melanorhamphos*	R	S		X	X	
White-winged Triller	*Lalage sueurii*	R					
Willie Wagtail	*Rhippidura leucophrys*		S	X	X	X	
Yellow Thornbill	*Acanthiza nana*		S	X		X	
Yellow-billed Spoonbill	*Platalea flavipes*		S	X			
Yellow-faced Honeyeater	*Lichenostomus chrysops*						
Yellow-rumped Thornbill	*Acanthiza chrysorrhoa*	R	S		X	X	X
Yellow-tailed Black-Cockatoo	*Calyptorhynchus funereus*		S				
Zebra Finch	*Taeniopygia guttata*	R					
Introduced Birds							
Common Starling	*Sturnus vulgaris*		S	X	X	X	
Domestic Chickens	*Gallus gallus*		S				
Domestic Ducks	*Anas sp*		S				
European Goldfinch	*Carduelis carduelis*						
House Sparrow	*Passer domesticus*		S		X	X	
Common Myna	*Acridotheres tristis*		S	X	X	X	
Mallard	*Anas platyrhynchos*			X	X	X	
Ostrich	*Struthio camelus*		S				
Peacock	*Pavo cristatus*		H				
Red-whiskered Bulbul	*Pycnontus jocosus*		S				
Rock Dove	*Columba livia*		S				
Skylark	*Alauda arvensis*						

Spotted Turtle-Dove	*Streptopelia chinensis*		S	X	X	X	
Mammals							
Bush Rat	*Rattus fuscipes*						
Common Brushtail Possum	*Trichosurus vulpecula*		S	X			
Common Ringtail Possum	*Pseudocheirus peregrinus*						
Short-beaked Echidna	*Tachyglossus aculeatus*						
Sugar Glider	*Petaurus breviceps*						
Swamp Rat	*Rattus lutreolus*						
Chocolate Wattled Bat	*Chalinolobus morio*		I				
Common Bentwing Bat	*Miniopterus schreibersii*	S(v)	I		X		
Eastern Broadnosed Bat	*Scotorepens orion*						
Eastern False Pipistrelle	*Falsistrellus tasmaniensis*	S(v)	I				
Eastern Horseshoe Bat	*Rhinolophus megaphyllus*						
Eastern Little Mastiff Bat	*Mormopterus norfolkensis*	S(v)					
Gould's Long-eared Bat	*Nyctophilus gouldi*		I				
Gould's Wattled Bat	*Chalinolobus gouldii*		I		X	X	X
Greater Broadnosed Bat	*Scoteanax rueppellii*	S(v)					
Grey-headed Flying-fox	*Pteropus poliocephalus*	R	S				
Large Forest Vespadelus	*Vespadelus darlingtoni*		I				
Large-footed Myotis	*Myotis adversus*	S(v)					
Large Pied Bat	*Chalinolobus dwyeri*	S(v)					
Lesser Long-eared Bat	*Nyctophilus geoffroyi*		I				
Little Forest Bat	*Vespadelus vulturnus*		I				
Little Red flying fox	*Pteropus scapulatus*	R					
Mormopterus sp	*Mormopterus sp1*						
Southern Forest Bat	*Vespadelu regulus*						
White-striped Mastiff-bat	*Nyctinomus australis*	R			X		
Yellow-bellied Sheathtail Bat	*Saccolaimus flaviventris*	S(v)					
Introduced Mammals							
Black Rat	*Rattus rattus*		A				
Cow	*Bos taurus*		S	X			
Horse	*Equus caballus*		S	X			
Goat	*Capra hircus*		S	X			
Donkey	*Equus asinus*		S	X			
Red Deer	*Cervus elaphus*				X		
Brown Hare	*Lepus capensis*		S		X		
Cat (feral)	*Felis catus*		S	X	X		
Dingo & Dog (feral)	*Canis familiaris*		S	X	X		
Fox	*Vulpes vulpes*		S				
House Mouse	*Mus musculus*						
Rabbit	*Oryctolagus cuniculus*		S	X	X		

Note:
a. Source: Current Survey (Biosis Research Pty. Ltd.)
b. Source: Kinhill Stearns (1985)
c. Source: Engel (1996c)
d. Source: NPWS Atlas of NSW Wildlife (post-1974 records only)
e. Source: Australian Museum Database (post-1974 records only)

Table B2.3. Locations of sampling sites and trapping details for terrestial vertebrate fauna (except frogs) for the Badgerys Creek site.

Site	Location	AMG	Technique	Configuration	Date(s)	Trap effort	Weather
A	Badgerys Creek Park	290900/6248800	active searching	1 person	18/12	0.75 person hours	overcast, mild
B	Badgerys Creek	290900/6246600	active searching	2 people	17/12	2.0 person hours	cool, scattered light showers
C	Inghams	290300/6245700	active searching	2 people	17/12	1.5 person hours	cool, scattered light showers
		290370/6245870	bat detector		19/12	0.5 hours	clear, warm
D	Telstra A	291050/6245400	active searching	1 person	19/12	0.5 person hours	fine, hot
E	Telstra B	290500/6244800	active searching	2 people	19/12, 23/12	1.0 person hour	fine, hot
			hair tubes	1 line of 20 tubes (10 large, 10 small)	18/12 - 23/12	100 hair tube nights	
F	RAAF Station	290400/6243300	active searching	1 person	19/12	0.75 person hours	fine, hot
G	RAAF Station	291200/6243100	active searching	1 person	19/12	0.75 person hours	fine, hot
H	Thompsons Creek	291500/6243700	active searching	2 people	19/12, 23/12	4.0 person hours	fine, hot
			hair tubes	1 line of 20 tubes (10 large, 10 small)	18/12 - 23/12	100 hair tube nights	
		291610/6244600	bat detector		19/12	0.5 hours	clear, warm
I	Derwent Road	289450/6244750	active searching	2 people	19/12, 23/12	0.75 person hours	fine, hot
			hair tubes	1 line of 20 tubes (10 large, 10 small)	18/12 - 23/12	100 hair tube nights	
		289500/6245800	bat detector		23/12	0.25 hours	overcast, scattered showers
J	Willowdene Rd	285450/6247150	active searching	2 people	17/12, 23/12	2.25 person hours	mild, overcast
		285770/6246640	bat detector		23/12	0.75 hours	overcast, scattered showers
K	Vicar Park Lane	285900/6245950	active searching	2 people	17/12, 23/12	2.0 person hours	mild, overcast

Table B2.4. Frog survey site locations for Badgerys Creek site.

Site	Location	AMG	Water Body Type	Date	Weather
1	Vicar Park Lane	286350/6246150	dam	17/12	cool-mild, overcast
2		286250/6246250	dam		
3		285950/6246250	dam		
4	Willowdene Avenue	285900/6245975	drain		
5		285800/6246250	dam		
6		285750/6246350	dam		
7		285650/6246650	dam		
8		2885550/6246950	dam		
9		285250/6247250	drain		
10	Badgerys Creek Road	289950/6243500	dam		
11		289950/6243800	dam		
12		290000/6243925	dam		
13		290350/6245850	creek crossing		
14		290750/6246500	Badgerys Creek		
15	Dwyer Road	287500/6243950	dam	18/12	mild, overcast
16		287550/6244050	dam		
17		287750/6244250	creek crossing		
18		288025/6244500	dam		
19	Avon Road	288200/6243950	dam		
20		288500/6243900	dam		
21	Mersey Road	288250/6245450	dam		
22		288700/6245250	dam		
23		288500/6244650	dam		
24	Severn Road	289050/6244250	dam		
25		288850/6244300	dam/drain		
26	Northern Road	288400/6244050	dam		
27		28900/6243800	dam/drain		
28		289450/6243450	dam		
29	Derwent Road	289550/6245200	dam		
30		289500/6244900	dam/drain		
31		289450/6244450	dam		
32		289400/6243800	dam		
33	Retreat Road	291500/6244200	Thompsons Creek	19/12	mild, partly cloudy
34	RAAF	290250/6243400	dam		
35		290600/6243350	dam		
36		290350/6244250	dam		
37	Telstra	290600/6245300	dam		
38	Longleys Road	290800/6247900	sediment dam/dam		
39		290550/6247950	dam		
40		290250/6247975	dam		
41		289250/6248100	Oaky Creek		
42		288750/6248200	dam		
43		288500/6248250	dam		
44	Anton Road	288500/6247900	dam		
45		288450/6247400	dam/drain		
46		288300/6248600	dam		
47		288250/6248700	creek crossing		
48	Adams Road	287950/6248975	drain		
49		286000/6248550	dam/drain		
50	Elizabeth Drive	291300/6249500	dam		

Table B2.5. Locations of significant terrestrial vertebrate fauna species recorded from the Badgerys Creek site.

Type of Record: A = Identified from Hair Sample, H = Heard, I = Indirect Evidence (e.g. scats, burrows, bat detector etc), S = Seen, T = Trapped or Hand-held.

Common Name	Scientific Name	Status	AMG	Site	Record
Birds					
Brown Songlark	*Cinclorhamphus cruralis*	R	289450/6245975	I	S
Double-barred Finch	*Taeniopygia bichenovii*	R	285450/6247150	J	S
			285750/6246400	K	S
Nankeen Night Heron	*Nycticorax caledonicus*	R	289100/6244700	I	S
Peaceful Dove	*Geopelia placida*	R	285900/6245950	K	H
			285450/6247150	J	H
Restless Flycatcher	*Myiagra inquieta*	R	290700/6248900	A	S
			285450/6247150	J	S
White-winged Chough	*Corcorax melanorhamphos*	R	290900/6248850	A	S
Yellow-rumped Thornbill	*Acanthiza chrysorrhoa*	R	291550/6244250	H	S
Mammals					
Common Bentwing Bat	*Miniopterus schreibersii*	S(v)	285770/6246640	J	I
Eastern False Pipistrelle	*Falsistrellus tasmaniensis*	S(v)	291610/6244170	H	I
			285770/6246640	J	I
Grey-headed Flying-fox	*Pteropus poliocephalus*	R	290500/6246200	C	S

Table B2.6. Distribution of known or likely terrestrial vertebrate fauna species of significance in relation to the Badgerys Creek study area. Species lists should not be considered exhaustive.

Conservation Significance: N(e) = Listed on Schedule 1 of the Endangered Species Protection (ESP) Act (1992); N(v) = Listed on Schedule 2 of the ESP Act 1992; S(e) = Listed on Schedule 1 of the Threatened Species Conservation Act 1995; S(v) = Listed on Schedule 2 of the TSC Act 1995; R = Regional Significance; J/C = JAMBA/CAMBA International Treaties; C= CAMBA.

Common Name	**Scientific Name**	**Status**	**Elizabeth Drive**[a]	**Elizabeth Drive Landfill**[b]	**South Creek**[c]	**Kemps Creek**[c]	**Bents Basin**[c]	**Pemberton Gully**[d]
Amphibians								
Green and Golden Bell Frog	*Litoria aurea*	S(e)						
Green Tree Frog	*Litoria caerulea*	R						
Brown Toadlet	*Pseudophryne bibronii*	R				X		
Tusked Frog	*Adelotus brevis*	R						
Reptiles								
Bearded Dragon	*Pogona barbata*	R					X	
Diamond Python	*Morelia spilota spilota*	R						
Lace Monitor	*Varanus varius*	R			X		X	
Birds								
Australasian Bittern	*Botaurus poiciloptilus*	S(v)						
Black Bittern	*Ixobrychus flavicollis*	S(v)						
Brown Songlark	*Cinclorhamphus cruralis*	R						
Buff-rumped Thornbill	*Acanthiza reguloides*	R						
Cattle Egret	*Ardea ibis*	J/C					X	
Diamond Firetail Finch	*Stagonopleura guttata*	R						
Double-barred Finch	*Taeniopygia bichenovii*	R	X			X		
Flame Robin	*Petroica phoenicea*	R						
Fork-tailed Swift	*Apus pacificus*	J/C						
Fuscous Honeyeater	*Lichenostomus flavescens*	R						
Glossy Black-Cockatoo	*Calyptorhynchus lathami*	S(v)						
Great Crested Grebe	*Podiceps cristatus*	R						
Great Egret	*Ardea alba*	R, J/C						
Hooded Robin	*Melanodryas cucullata*	R						
Jacky Winter	*Microeca fascinans*	R						
Nankeen Night Heron	*Nycticorax caledonicus*	R						
Latham's Snipe	*Gallinago hardwickii*	R, J/C						
Little Eagle	*Hieraaetus morphnoides*	R						
Peaceful Dove	*Geopelia placida*	R					X	X

Common Name	**Scientific Name**	**Status**	**Elizabeth Drive**[a]	**Elizabeth Drive Landfill**[b]	**South Creek**[c]	**Kemps Creek**[c]	**Bents Basin**[c]	**Pemberton Gully**[d]
Peregrine Falcon	*Falco peregrinus*	R						
Powerful Owl	*Ninox strenua*	S(v)						
Red-capped Robin	*Petroica goodenovii*	R						
Regent Honeyeater	*Xanthomyza phrygia*	N(e), S(e)						
Restless Flycatcher	*Myiagra inquieta*	R						
Shrike-tit	*Falcunculus frontatus*	R						
Speckled Warbler	*Chthonicola sagittata*	R					X	
Swift Parrot	*Lathamus discolor*	N(v), S(v)						
Wedge-tailed Eagle	*Aquila audax*	R						
Weebill	*Smicrornis brevirostris*	R						
Whistling Kite	*Haliastur sphenurus*	R	X	X			X	
White-bellied Cuckoo-shrike	*Coracina papuensis*	R					X	
White-fronted Chat	*Epthianura albifrons*	R						
White-throated Needletail	*Hirundapus caudacutus*	J/C						
White-winged Chough	*Corcorax melanorhamphos*	R				X	X	
White-winged Triller	*Lalage sueurii*	R						
Yellow-rumped Thornbill	*Acanthiza chrysorrhoa*	R	X				X	
Mammals								
Common Bentwing Bat	*Miniopterus schreibersii*	S(v)					X	
Eastern Little Mastiff Bat	*Mormopterus norfolkensis*	S(v)						
Greater Broadnosed Bat	*Scoteanax rueppellii*	S(v)			X			X
Grey-headed Flying-fox	*Pteropus poliocephalus*	R					X	X
Large-footed Myotis	*Myotis adversus*	S(v)			X			
Large Pied Bat	*Chalinolobus dwyeri*	S(v)					X	
Little Red Flying Fox	*Pteropus scapulatus*	R						
White-striped Mastiff-bat	*Nyctinomus australis*	R				X	X	X
Yellow-bellied Sheathtail Bat	*Saccolaimus flaviventris*	S(v)						

Note:
a. Source: Rust PPK (1995)
b. Source: PPK Cosultants (1993)
c. Source: Ecotone Ecological Consultants (1994); Engel (1996c)
d. Source: Ecotone (1994)

1.5.2 Holsworthy

1.5.2.1 Overall species

A total of 15 amphibian species, 25 reptile species, 93 bird species (91 native, 2 introduced) and 31 mammal species (26 native, 5 introduced) was recorded during the present study. A further three species are probable records. Taking into account all fauna records collated from our extensive literature review, the Holsworthy site provides or is likely to provide habitat for at least 28 amphibian species, 48 reptile species, 151 bird species (146 native, 5 introduced) and 56 mammal species (49 native, 7 introduced). A full list of species is given in Table B2.7. The locations of fauna sampling sites at Holsworthy are listed in Table B2.8 and shown on Figure B4.

1.5.2.2 Significant species

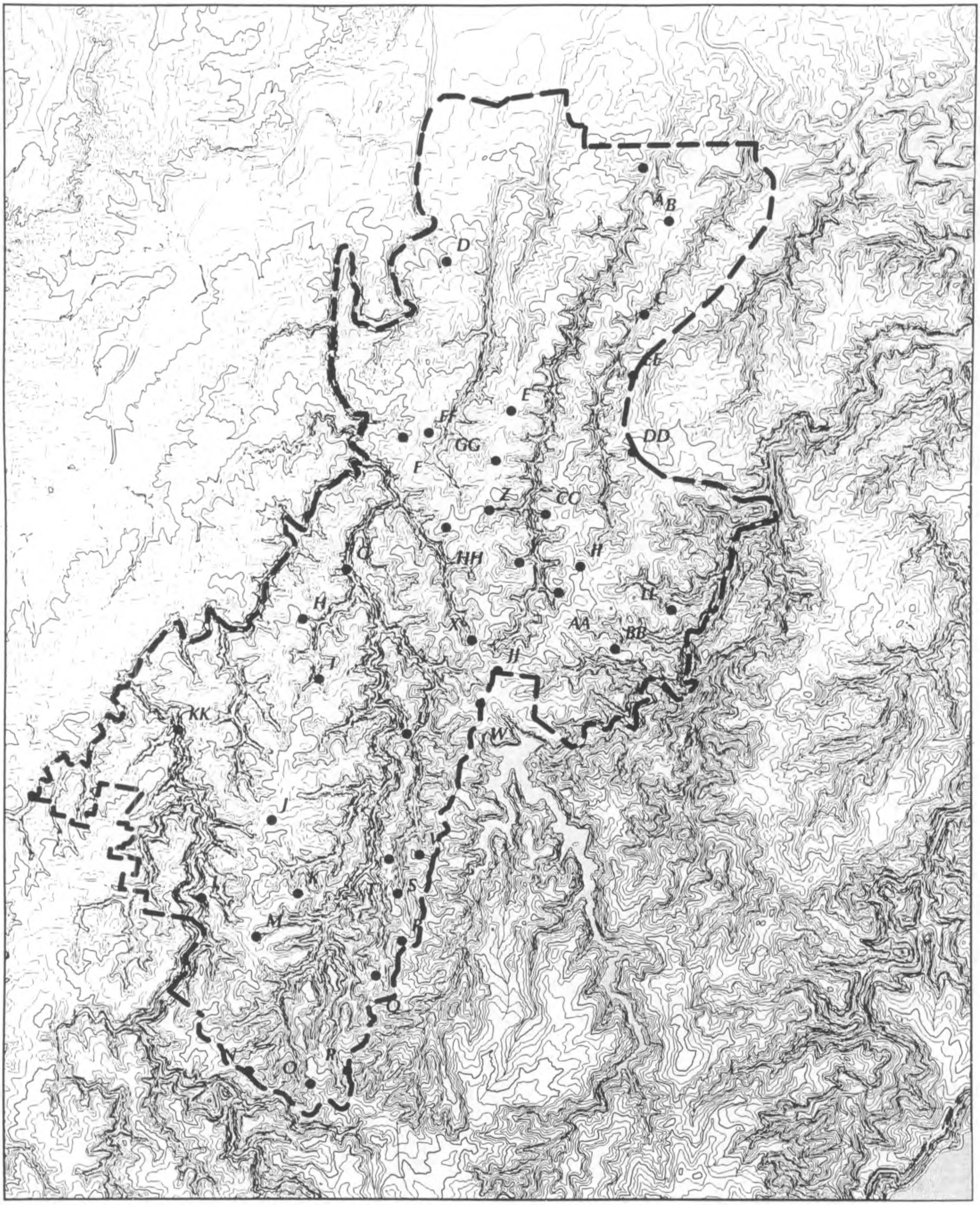
A total of 53 significant fauna species has been recorded at Holsworthy, including one species of national significance, 11 species of state significance and 41 species of regional significance (Table 9.12). An additional three species of national significance, 17 species of state significance and 17 species of regional significance were recorded in the vicinity of Holsworthy and may occur within the study area Two species listed under Australian international agreements have been recorded in or adjacent to the study area. Species of national and state significance are discussed in detail in species profiles below. The distribution of significant species in relation to the Holsworthy site are listed in Table B2.10. Species of regional significance are considered in Table B2.14. Locations for significant fauna species are shown in Figure B3 and referred to in Tble B2.9.

Table B2.7. Terrestrial vertebrate fauna known or likely to occur within the Holsworthy site. The study area covered by the Australian Koala Foundation (AKF) straddled both Wedderburn Plateau and H Range within the Holsworthy Training Area. As the Holsworthy study area contains two bioregions, all species considered to be of regional significance in Cumberland Plains Woodland and in Coastal Sandstone Plateau are included here. Species which have no records listed are known to occur in the general area and may occur within the study site. The species list should not be considered exhaustive.

Conservation Significance: N(e) = Listed on Schedule 1 of the Endangered Species Protection (ESP) Act (1992); N(v) = Listed on Schedule 2 of the ESP Act 1992; S(e) = Listed on Schedule 1 of the Threatened Species Conservation Act (TSC)1995; S(v) = Listed on Schedule 2 of the TSC Act 1995; R = Regional Significance; J/C = JAMBA/CAMBA International Treaties; C= CAMBA.

Type of Record: A = Identified from Hair Sample, H = Heard, I = Indirect Evidence (e.g. scats, burrows, etc.), S = Seen, T = Trapped or Hand-held, X = recorded, ? – unconfirmed record.

Common Name	Scientific Name	Status	Biosis[a]	AXIS/ AMBS[b]	AKF[c]	NPWS[d]	AM[e]	Other[f]
Amphibians								
Tusked Frog	*Adelotus brevis*	R						
Common Eastern Froglet	*Crinia signifera*		S	X	X	X		
Giant Burrowing Frog	*Heleioporus australiacus*	S(v)	S	X				
Eastern Banjo Frog	*Limnodynastes dumerilii*		H		X			
Ornate Burrowing Frog	*Limnodynastes ornatus*							
Striped Marsh Frog	*Limnodynastes peronii*		H		X			
Spotted Grass Frog	*Limnodynastes tasmaniensis*							
Green and Golden Bell Frog	*Litoria aurea*	S(e)						
Green Tree Frog	*Litoria caerulea*	R						
Blue Mountains Tree Frog	*Litoris citropa*	R						
Bleating Tree Frog	*Litoria dentata*				X			
Eastern Dwarf Tree Frog	*Litoria fallax*		H		X			
Wallum Rocket Frog	*Litoria freycineti*		T	X	X	X		
Dainty Tree Frog	*Litoria gracilenta*				X			
Jervis Bay Tree Frog	*Litoria jervisiensis*	R			X			
Broad-Palmed Rocket Frog	*Litoria latopalmata*		T		X	X		
Lesueur's Frog	*Litoria lesueuri*		S		X			
Heath Frog	*Litoria littlejohni*	R						
Peron's Tree Frog	*Litoria peronii*		S		X			
Leaf Green Tree Frog	*Litoria phyllochroa*		S			X		
Laughing Tree Frog	*Litoria tyleri*		T		X			
Whistling Tree Frog	*Litoria verreauxii*				X			
Haswell's Froglet	*Paracrinia haswelli*		H			X		
Red-crowned Toadlet	*Pseudophryne australis*	S(v)	S			X	X	
Brown Toadlet	*Pseudophryne bibronii*	R			X			
Dusky Toadlet	*Uperoleia fusca*						X	
Smooth Toadlet	*Uperoleia laevigata*		T		X			
Dusky/Smooth Toadlet	*Uperoleia fusca/laevigata*		H	X				
Reptiles								
Bandy-bandy Snake	*Vermicella annulata*				X	X		
Bar-sided Skink	*Eulamprus tenuis*			X	X		X	
Bearded Dragon	*Pogona barbata*	R			X			
Black-bellied Swamp Snake	*Hemiaspis signata*		S					
Black Rock Skink	*Egernia saxatilis*	R	S					
Blind Snake	*Ramphotyphlops nigrescens*			X	X			
Broad-headed Snake	*Hoplocephalus bungaroides*	N(e), S(e)		X	X	X		
Brown-tree Snake	*Boiga irregularis*							
Burton's Snake-Lizard	*Lialis burtonis*			X			X	
Common Scaly-foot	*Pygopus lepidopodus*		S	X	X	X	X	
Copper-tailed Skink	*Ctenotus taeniolatus*		S	X	X	X	X	
Cunningham's Skink	*Egernia cunninghami*				X			
Death Adder	*Acanthophis antarcticus*				X			
Diamond Python	*Morelia spilota spilota*	R	S		X		X	
Eastern Blue-tongued Lizard	*Tiliqua scincoides*				X			
Eastern Brown Snake	*Pseudonaja textilis*		S					
Eastern Long-necked Turtle	*Chelodina longicollis*		S		X			
Eastern Water Dragon	*Physignathus lesueurii*		S	X	X	X		
Eastern Water Skink	*Eulamprus quoyii*		S	X	X	X		



Legend

- ● Holsworthy Fauna Survey Sites
- ▬ ▬ Military Boundary
- Rivers
- ☐ Water
- 50m contour
- 10m contour

Figure B4
Holsworthy Fauna Sampling Sites

1:120,000

28/7/97

Common Name	Scientific Name	Status	Biosis[a]	AXIS/ AMBS[b]	AKF[c]	NPWS[d]	AM[e]	Other[f]
Garden Skink	*Lampropholis guichenoti*		S	X	X			
Golden-crowned Snake	*Cacophis squamulosus*							
Grass Skink	*Lampropholis delicata*		S	X	X	X		
Tree-base Litter Skink	*Lygisaurus foliorum*				X			
Swamp Snake	*Hemiaspis signata*				X			
Green-tree Snake	*Dendrelaphis punctulatus*		S	X				
Heath Monitor	*Varanus rosenbergi*	S(v)	S?		X			
Jacky Dragon	*Amphibolurus muricatus*		S	X	X	X	X	
Lace Monitor	*Varanus varius*	R	S	X	X	X		
Large Striped Skink	*Ctenotus robustus*		S					
Lesueur's Velvet Gecko	*Oedura lesueurii*		S	X	X	X	X	
Mountain Dragon	*Tympanocryptis diemensis*	R	S	X	X	X	X	
Oak Skink	*Cyclodomorphus casuarinae*							
Red-bellied Black Snake	*Pseudechis porphyriacus*		S		X			
Red-naped Snake	*Furina diadema*							
Red-throated Skink	*Bassiana platynota*		S		X			
She-oak Skink	*Cyclodomorphus micheali*							
Small-eyed Snake	*Rhinoplocephalus nigrescens*							
Southern Leaf-tailed Gecko	*Phyllurus platurus*				X			
Stripped Skink	*Ctenotus robustus*							
Thick-tailed Gecko	*Underwoodisaurus milii*		T		X			
Three-toed Skink	*Saiphos equalis*							
Tiger Snake	*Notechis scutatus*		S					
Wall Lizard	*Cryptoblepharus virgatus*		S	X	X		X	
Weasel Skink	*Saproscincus mustelinus*		S					
White's Skink	*Egernia whitii*		S	X	X	X	X	
Wood Gecko	*Diplodactylus vittatus*		S	X	X	X	X	
Yellow-faced Whip Snake	*Demansia psammophis*							
	Lygisaurus foliorum							
Birds								
Australasian Bittern	*Botaurus poiciloptilus*	S(v)						
Australian Ringneck	*Barnardius zonarius*				X			
Australian Hobby	*Falco longipennis*		S					
Australian King Parrot	*Alisterus scapularis*				X			
Australian Magpie	*Gymnorhina tibicen*		S	X	X	X		X
Australian Owlet-nightjar	*Aegotheles cristatus*		S					
Australian Raven	*Corvus coronoides*		S	X	X	X		X
Australian Wood Duck	*Chenonetta jubata*		S					
Azure Kingfisher	*Alcedo azurea*				X			
Bar-shouldered Dove	*Geopelia humeralis*	R			X			
Beautiful Firetail	*Stagonopleura bella*	R	S	X				
Black Bittern	*Dupetor flavicollis*	S(v)						
Black-faced Cuckoo-shrike	*Coracina novaehollandiae*		S	X	X	X		
Black-shouldered Kite	*Elanus axillaris*				X			
Brown Falcon	*Falco berigora*		S	X				X
Brown Goshawk	*Accipiter fasciatus*		S		X			
Brown Thornbill	*Acanthiza pusilla*		S	X	X	X		
Brown Treecreeper	*Climacteris picumnus*	R	S					
Brown-headed Honeyeater	*Lichenostomus brevirostris*		S	X	X	X		
Brush Bronzewing	*Phaps elegans*							X
Brush Cuckoo	*Cuculus variolosus*	R						
Buff-rumped Thornbill	*Acanthiza reguloides*	R	S	X	X	X		
Bush Stone-curlew	*Burhinus magnirostris*	S(e)				X		
Channel-billed Cuckoo	*Scythrops novaehollandiae*				X			
Chestnut Teal	*Anas castanea*		S	X		X		
Chestnut-rumped Heathwren	*Hylacola pyrrhopygia*	R	S	X	X	X		
Common Bronzewing	*Phaps chalcoptera*		S	X	X	X		X
Common Koel	*Eudynamys scolopacea*				X			
Crested Pigeon	*Ocyphaps lophapes*		S	X		X		
Crimson Rosella	*Platycercus elegans*		S	X	X	X		
Diamond Firetail Finch	*Stagonopleura guttata*	R	S					X
Dollarbird	*Eurystomus orientalis*		S		X			

Common Name	Scientific Name	Status	Biosis[a]	AXIS/ AMBS[b]	AKF[c]	NPWS[d]	AM[e]	Other[f]
Double-barred Finch	*Taeniopygia bichenovii*	R	S	X	X	X		
Dusky Woodswallow	*Artamus cyanopterus*			X	X			
Eastern Bristlebird	*Dasyornis brachypterus*	N(v), S(e)						
Eastern Rosella	*Platycercus eximius*		S	X	X	X		
Eastern Spinebill	*Acanthorhynchus tenuirostris*		S	X	X	X		X
Eastern Whipbird	*Psophodes olivaceus*		S	X	X	X		X
Eastern Yellow Robin	*Eopsaltria australis*		S	X	X	X		X
Fairy Martin	*Hirundo ariel*		S	X				X
Fan-tailed Cuckoo	*Cacomantis flabelliformis*		S	X	X	X		X
Flame Robin	*Petroica phoenicea*	R	S					
Fuscous Honeyeater	*Lichenostomus flavescens*	R			X			
Galah	*Cacatua roseicapilla*		S		X			
Gang-gang Cockatoo	*Callocephalon fimbriatum*		H		X	X		
Glossy Black-Cockatoo	*Calyptorhynchus lathami*	S(v)			X			
Golden Whistler	*Pachycephala pectoralis*		S	X	X	X		
Grey Butcherbird	*Cracticus torquatus*		S	X	X	X		X
Grey Currawong	*Strepera versicola*				X			X
Grey Fantail	*Rhipidura fuliginosa*		S	X	X	X		X
Grey Goshawk	*Accipiter novaehollandiae*	R						
Grey Shrike-thrush	*Colluricincla harmonica*		S	X	X	X		X
Ground Parrot	*Pezoporus wallicus*	S(v)						
Hooded Robin	*Melanodryas cucullata*	R						X
Horsfield's Bronze-Cuckoo	*Chrysococcyx basalis*		S					X
Jacky Winter	*Microeca fascinans*	R		X				
Large-billed Scrubwren	*Sericornis magnirostris*			X				
Laughing Kookaburra	*Dacelo novaeguineae*		S	X	X	X		X
Leaden Flycatcher	*Myiagra rubecula*		S	X	X	X		
Lewin's Honeyeater	*Meliphaga lewinii*				X			
Little Eagle	*Hieraaetus morphnoides*	R	S					
Little Lorikeet	*Glossopsitta pusilla*		S		X			
Little Pied Cormorant	*Phalacrocorax melanoleucos*				X			X
Little Raven	*Corvus mellori*	R	H					
Little Wattlebird	*Anthochaera chrysoptera*		S	X	X	X		X
Magpie-lark	*Grallina cyanoleuca*		S	X	X	X		X
Masked Lapwing	*Vanellus miles*				X			X
Masked Owl	*Tyto novaehollandiae*	S(v)						
Mistletoebird	*Dicaeum hirundinaceum*		S	X		X		X
Nankeen Kestrel	*Falco cenchroides*				X			X
Nankeen Night Heron	*Nycticorax caledonicus*	R			X			
New Holland Honeyeater	*Phylidonyris novaehollandiae*		S	X	X	X		
Noisy Friarbird	*Philemon corniculatus*		S	X	X	X		X
Noisy Miner	*Manorina melanocephala*		S	X	X	X		
Olive-backed Oriole	*Oriolus sagittatus*		S		X			
Pacific Black Duck	*Anas superciliosa*		S					
Painted Button-quail	*Turnix varia*			X	X	X		
Painted Honeyeater	*Grantiella picta*	S(v)						
Pallid Cuckoo	*Cuculus pallidus*		S		X			
Peaceful Dove	*Geopelia placida*	R			X			X
Peregrine Falcon	*Falco peregrinus*	R			X			
Pied Currawong	*Strepera graculina*		S	X		X		X
Pilotbird	*Pycnoptilus floccosus*		S	X		X		
Powerful Owl	*Ninox strenua*	S(v)		X		X		
Rainbow Lorikeet	*Trichoglossus haematodus*		S					
Red Wattlebird	*Anthochaera carunculata*		S		X	X		
Red-browed Finch	*Neochmia temporalis*		S	X	X	X		X
Red-capped Robin	*Petroica goodenovii*	R						X
Red-rumped Parrot	*Psephotus haematonotus*	R						
Regent Honeyeater	*Xanthomyza phrygia*	N(e), S(e)					X	
Restless Flycatcher	*Myiagra inquieta*	R			X			

Common Name	Scientific Name	Status	Biosis[a]	AXIS/ AMBS[b]	AKF[c]	NPWS[d]	AM[e]	Other[f]
Richard's Pipit	*Anthus novaeseelandiae*		S	X				X
Rockwarbler	*Origma solitaria*	R	S	X	X	X		
Rufous Fantail	*Rhipidura rufifrons*			X	X	X		
Rufous Whistler	*Pachycephala rufiventris*		S	X	X	X		X
Sacred Kingfisher	*Todiramphus sanctus*		S	X	X	X		
Satin Bowerbird	*Ptilonorhynchus violaceus*		S		X			
Satin Flycatcher	*Myiagra cyanoleuca*		S		X			
Scaly-breasted Lorikeet	*Trichoglossus chlorolepidotus*							X
Scarlet Honeyeater	*Myzomela sanguinolenta*				X			
Scarlet Robin	*Petroica multicolor*			X		X		
Shining Bronze-Cuckoo	*Chrysococcyx lucidus*							X
Shrike-tit	*Falcunculus frontatus*	R		X				X
Silvereye	*Zosterops lateralis*		S	X	X	X		
Sooty Owl	*Tyto tenebricosa*	S(v)				X		
Southern Boobook	*Ninox novaeseelandiae*		S	X	X			X
Southern Emu-wren	*Stipiturus malachurus*	R	S					
Speckled Warbler	*Chthonicola sagittata*	R						X
Spotted Pardalote	*Pardalotus punctatus*		S	X	X	X		X
Spotted Quail-thrush	*Cinclosoma punctatum*		S	X	X	X		
Spotted Turtle-Dove	*Streptopelia chinensis*							X
Striated Pardalote	*Pardalotus striatus*				X	X		X
Striated Thornbill	*Acanthiza lineata*		S	X	X	X		X
Sulphur-crested Cockatoo	*Cacatua galerita*		S		X			
Superb Fairy-wren	*Malurus cyaneus*		S	X	X	X		
Superb Lyrebird	*Menura novaehollandiae*		S	X	X	X		
Swift Parrot	*Lathamus discolor*	N(v), S(v)			X			
Tawny Frogmouth	*Podargus strigoides*		S	X	X			
Tawny-crowned Honeyeater	*Phylidonyris melanops*	R	S	X				X
Tree Martin	*Hirundo nigricans*							X
Turquoise Parrot	*Neophema pulchella*	S(v)						X
Varied Sittella	*Daphoenositta chrysoptera*		S					X
Variegated Fairy-wren	*Malurus lamberti*		S	X	X	X		
Wedge-tailed Eagle	*Aquila audax*	R	S	X	X			
Weebill	*Smicrornis brevirostris*	R	S	X	X	X		X
Welcome Swallow	*Hirundo neoxena*		S	X		X		X
White-bellied Sea-Eagle	*Haliaeetus leucogaster*	R, C			X			
White-browed Scrubwren	*Sericornis frontalis*		S	X	X	X		
White-browed Woodswallow	*Artamus superciliosus*							X
White-cheeked Honeyeater	*Phylidonyris nigra*		S		X			X
White-eared Honeyeater	*Lichenostomus leucotis*		S	X	X	X		X
White-fronted Chat	*Epthianura albifrons*	R	S					
White-naped Honeyeater	*Melithreptus lunatus*			X		X		
White-plumed Honeyeater	*Lichenostomus penicillatus*		S					
White-throated Gerygone	*Gergone olivacea*		S		X	X		X
White-throated Needletail	*Hirundapus caudacutus*	J/C	S					X
White-throated Nightjar	*Eurostopodus mystacalis*		S		X			
White-throated Treecreeper	*Cormobates leucophaeus*		S	X	X	X		X
White-winged Chough	*Corcorax melanorhamphos*	R	S	X		X		
Willie Wagtail	*Rhippidura leucophrys*		S	X	X			X
Wonga Pigeon	*Leucosarcia melanoleuca*				X			
Yellow Thornbill	*Acanthiza nana*				X			X
Yellow-faced Honeyeater	*Lichenostomus chrysops*		S	X	X	X		X
Yellow-rumped Thornbill	*Acanthiza chrysorrhoa*	R	S					X
Yellow-tailed Black-Cockatoo	*Calyptorhynchus funereus*		S	X	X	X		
Yellow-tufted Honeyeater	*Lichenostomus melanops*		S		X	X		
Introduced Birds								
Common Starling	*Sturnus vulgaris*			X	X			X
European Goldfinch	*Carduelis carduelis*							X
House Sparrow	*Passer domesticus*		S		X			
Common Myna	*Acridotheres tristis*		S	X	X			

Common Name	**Scientific Name**	**Status**	**Biosis**[a]	**AXIS/ AMBS**[b]	**AKF**[c]	**NPWS**[d]	**AM**[e]	**Other**[f]
Red-whiskered Bulbul	*Pycnontus jocosus*				X			
Mammals								
Brown Antechinus	*Antechinus stuartii*	R	S		X	X	X	
Brush-tailed Rock Wallaby	*Petrogale penicillata*	N(v), S(v)	?					
Bush Rat	*Rattus fuscipes*		A		X	X		
Common Brushtail Possum	*Trichosurus vulpecula*		S	X	X			
Common Dunnart	*Sminthopsis murina*	R						
Common Ringtail Possum	*Pseudocheirus peregrinus*		S	X	X	X		
Common Wombat	*Vombatus ursinus*	R	I					
Eastern Grey Kangaroo	*Macropus giganteus*	R	S	X	X	X		
Eastern Pygmy Possum	*Cercartetus nanus*		A		X			
Feathertail Glider	*Acrobates pygmaeus*		A	X		X		
Greater Glider	*Petauroides volans*	R						
Koala	*Phascolarctos cinereus*	S(v)	S	X	X	X	X	
Long-nosed Bandicoot	*Perameles nasuta*	R	T					
Long-nosed Potoroo	*Potorous tridactylus*	S(v)						
New Holland Mouse	*Pseudomys novaehollandiae*	R		X				
Platypus	*Ornithorhynchus anatinus*	R						
Red-necked Pademelon	*Thylogale thetis*	R						
Red-necked Wallaby	*Macropus rufogriseus*	R	A?		X			
Short-beaked Echidna	*Tachyglossus aculeatus*		T		X			
Squirrel Glider	*Petaurus norfolcensis*	S(v)			X			
Sugar Glider	*Petaurus breviceps*		S		X	X		
Swamp Rat	*Rattus lutreolus*		A		X			
Swamp Wallaby	*Wallabia bicolor*				X	X		
Tiger Quoll	*Dasyurus maculatus*	S(v)	A	X		X		
Wallaroo	*Macropus robustus*	R		X		X		
Water Rat	*Hydromys chrysogaster*	R						X
Yellow-bellied Glider	*Petaurus australis*	S(v)	?					
Chocolate Wattled Bat	*Chalinolobus morio*		T		X			
Common Bentwing Bat	*Miniopterus schreibersii*	S(v)			X	X		
Eastern Broadnosed Bat	*Scotorepens orion*				X			
Eastern False Pipistrelle	*Falsistrellus tasmaniensis*	S(v)	I					
Eastern Horseshoe Bat	*Rhinolophus megaphyllus*							
Eastern Little Mastiff Bat	*Mormopterus norfolkensis*	S(v)			X			
Gould's Long-eared Bat	*Nyctophilus gouldi*		T		X	X		
Gould's Wattled Bat	*Chalinolobus gouldii*		T	X	X	X		
Greater Broadnosed Bat	*Scoteanax rueppellii*	S(v)		X	X			
Grey-headed Flying-fox	*Pteropus poliocephalus*	R	S		X	X		
Large Forest Vespadelus	*Vespadelus darlingtoni*		I					
Large-footed Myotis	*Myotis adversus*	S(v)			X			
Large Pied Bat	*Chalinolobus dwyeri*	S(v)			X			
Lesser Long-eared Bat	*Nyctophilus geoffroyi*		T		X	X		
Large Forest/ Southern Forest Bat	*Vespadelus darlingtoni/ regulus*		I					
Little Forest Bat	*Vespadelus vulturnus*		T	X	X			
Little Red flying fox	*Pteropus scapulatus*	R						
Eastern Cave Bat	*Vespadelus troughtoni*	S(v)						
Unnamed Little Mastiff Bat	*Mormopterus sp.1*		I					
White-striped Mastiff-bat	*Nyctinomus australis*	R	H		X			
Yellow-bellied Sheathtail Bat	*Saccolaimus flaviventris*	S(v)	I					
Introduced Mammals								
Black Rat	*Rattus rattus*			X	X	X		
Brown Hare	*Lepus capensis*		S					
Cat (feral)	*Felis catus*		I		X			
Dingo & Dog (feral)	*Canis familiaris*		S		X			
Fox	*Vulpes vulpes*		S		X			
House Mouse	*Mus musculus*		I		X			
Rabbit	*Oryctolagus cuniculus*				X			

Note: a. Source: Current survey (Biosis Research Pty. Ltd.)

b. Source: AXIS/AMBS (1995)
c. Source: Phillips et. al. (1996)
d. Source: NPWS Atlas of NSW Wildlife (post-1974 records only)
e. Source: Australian Museum Database (post-1974 records only)
f. Source: COL. S.G.Lane (Ret.) in AXIS/AMBS (1995), CAPT. B. Gough (*pers. comm*).

Table B2.8. **Fauna sampling site locations and trapping details for the Holsworthy site (refer Figure B4)**

Site	Location	AMG	Technique	Configuration	Date(s)	Trap effort	Weather
A	Gate 12 Road	311900/6236900	hair tube	1 line of 20 tubes (10 large, 10 small)	5/11 - 11/11	200 tube nights	
		311900/6236900	harp trap	3 harp traps	14/11, 15/11, 18 - 22/11	15 trap nights	
			bat detector	delay switch	19/11	1 night	rain, cold
			owl call playback	standard	18/11	1.15 hours	cool, overcast
			active searching	3 people	14/11, 19/11 20/11 21/11	7.0 person hours	
			frogging	listening, call playback	13/11, 18/11	0.75 hours	
		309800/6237600	frogging	2 people listening, active search	13/11	0.75 hours	mild, clear
		309800/6237600	bat detector	delay switch	18/12	1 night	mild, overcast
B	National Park Road	312500/6235700	active searching	3 people	6/11	4.5 person hours	
C	Wire Bridge	311950/6233600	frogging	listening	18/11	0. 50 hours	cool, overcast, scattered showers
D	Small Arms Danger Area	307400/6234800	hair tubes	3 lines of 20 tubes (10 large, 10 small)	4/11 - 13/11	540 hair tube nights	
		307400/6234800	active searching	3 people		11.25 person hours	
		307400/6234800	frogging	listening	11/11	1.75 hours	clear, cool-cold
		309800/6237575	frogging	listening	18/11	0.17 hours	cold, overcast, light scattered showers
E	Limit	308900/6231400	active searching	3 people	13/11	5.75 person hours	clear, hot
			frogging	listening	21/11	0.25 hours	cold, rain
			bat detector	delay switch	21/11, 18/12	2 nights	
			owl call playback	Barking Owl	19/11	0.50 hours	clear, cool
F	No-Bridge Road	306400/6230800	hair tube	1 line of 20 tubes (10 large, 10 small)	5/11 - 14/11	180 tube nights	
			active search	3 people	11/11, 12/11	5.75 person hours	
			bat detector	delay switch	14/11	1 night	
			harp trap	1 trap	11/11 - 14/11	3 trap nights	
			frogging	2 people listening, active searching	7/11	1 hour	cold, wind, scattered light rain
G	Engineers Bridge	305100/6227750	owl call playback	standard	21/11, 23/11, 25/11	2.5 hours	fine, still, full moon
			frogging	listening, active searching	30/10, 5/11	1 hour	cool, overcast
			bat detector	delay switch	19/12	1 night	mild, clear
H	Old Coach Road	304100/6226600	active search	2 people	21/11	3 person hours	warm, overcast

Site	Location	AMG	Technique	Configuration	Date(s)	Trap effort	Weather
I	Mackel Landing Ground	304500/6225200	active search	3 people	15/11	6.2 person hours	fine, hot
			hair tube	1 line of 20 tubes (10 large, 10 small)	15/11 - 21/11	120 hair tube nights	
		304100/6224000	frogging	listening	5/11	0.17 hours	cold, overcast, moderate wind
J	Woolwash Road Quarry / Fire tower	303400/6221900	frogging	2 people listening, active search	5/11, 14/11 19/11	1 hour	
K	Ruins Road	304000/6220200	hair tube	3 lines of 20 tubes (10 large, 10 small)	29/10 - 8/11	600 hair tube nights	
			active search	3 people	1/11	1.75 person hours	
			frogging	2 people listening, call play back	18/11	0.75 hours	
L	O'Hares Creek	301800/6220100	hair tube	3 lines of 20 tubes (10 large, 10 small)	30/10 - 8/11	540 hair tube nights	
			active search	3 people	1/11	10.3 person hours	
			owl call playback	standard	20/11, 27/11	2.7 hours	
		302400/6219300	bat detector	delay switch	20/11	1 night	cold, moderate wind
M	Old Coach Road (south)	303050/6219200	active search	3 people	21/11	9.25 person hours	warm, partly cloudy
			owl call playback	powerful owl, yellow-bellied glider	21/11	1.0 hour	mild, scattered showers
N	Old Coach Road Gravel Pit (southern boundary)	302900/6216100	frogging	2 people listening	20/11	0.25 hours	cold, moderate wind
O	September	304300/6215800	hair tubes	3 lines of 20 tubes (10 large, 10 small)	30/10 - 8/11	540 hair tube nights	
			active search		30/10, 31/10, 6/11	7.0 person hours	mild, overcast
			frogging	2 people, listening, call playback, active search	31/10	1.0 hour	cool, overcast
			harp trap	2 traps	6/11 - 8/11	4 trap nights	
			bat detector	delay switch	20/11	1 night	cold, moderate wind
		304500/6215400	owl call playback	standard	26/11, 27/11	3.0 hours	fine, partly cloudy
P	Old Illawarra Road Trig Point	305150/6216100	owl call playback	standard	6/11	0.85 hours	cold, partly cloudy, moderate wind
Q	Old Illawarra Road	305800/6218300	owl call playback	standard	6/11	0.85 hours	cold, partly cloudy, moderate wind
R	Old Illawarra Road	306400/6219100	frogging	listening, active search	29/10	0.75 hours	cool, overcast

Site	Location	AMG	Technique	Configuration	Date(s)	Trap effort	Weather
S	Gunyah Creek	306300/6220200	active search	3 people	31/10	3.4 hours	mild, overcast
			harp trap	2 traps	29/10 - 31/11	4 trap nights	cool, overcast
		306750/6219500	Specialist Broad-headed Snake survey	1 person	29/11, 3/12, 4/12		warm-hot, fine
T	Gunyah Creek Fire Trail	306100/622100	hair tube	1 line of 20 tubes (10 large, 10 small)	29/10 - 8/11	200 hair tube nights	
U	Gunyah Creek Fire Trail	306500/6223900	hair tube	2 lines of 20 tubes (10 large, 10 small)	29/10 - 8/11	400 hair tube nights	
			active search	1 person	29/11	2.0 person hours	warm, fine
		306750/6223600	Specialist Broad-headed Snake survey	1 person	29/11, 3/12, 4/12		warm-hot, fine
V	Gilday OP	306800/6221100	active search	3 people	31/10, 6/11	2.6 person hours	mild, overcast
			harp trap	1 trap	6/11 - 8/11	2 trap nights	cold, cloudy, moderate wind
			bat detector	delay switch	6/11	1 night	cold, cloudy, moderate wind
		306500/6221400	Specialist Broad-headed Snake survey	1 person	29/11, 3/12, 4/12		warm-hot, fine
			frogging	listening, active search	29/10, 30/10,	0.6 hours	cool, overcast
W	Novice OP	308200/6224600	harp trap	1 trap	6/11 - 8/11	2 trap nights	cold, cloudy, moderate wind
			active search	2 person	3/12	0.6 person hours	mild, partly cloudy
X	90 November	308000/6226100	owl call playback	standard	19/11, 25/11	1.75 hour	mild, clear
			frogging	listening	21/11	0.17 hours	cold, scattered showers
Y	Williams Creek	309100/6227900	hair tubes	2 lines of 20 tubes (10 large, 10 small)	7/11 - 18/11	410 hair tube nights	
			active search	3 people	18/11	7.5 person hours	mild, cloudy
Z	Williams Creek	308400/6229100	hair tubes	1 line of 20 tubes (10 large, 10 small)	7/11 - 18/11	210 hair tube nights	
			active search	2 people	7/11	2 person hours	
AA	South of Eckersley Junction	310000/6227200	hair tubes	2 lines of 20 tubes (10 large, 10 small)	12/11 - 20/11	320 hair tube nights	
			active search	3 people	12/11, 19/11, 20/11	3.4 person hours	
			owl call playback	standard	12/11	0.75 hours	cold, clear
		310400/6226800	harp trap	1 trap	12/11 - 15/11	3 trap nights	
		310400/6226800	bat detector	delay switch	19/11	1 night	cold, clear

Site	**Location**	**AMG**	**Technique**	**Configuration**	**Date(s)**	**Trap effort**	**Weather**
		309750/6227250	Specialist Broad-headed Snake survey	1 person	29/11, 3/12, 4/12		warm-hot, fine
BB	DML 1	311300/6225900	frogging	listening, call playback	5/11, 12/11	0.75 hours	cool, clear
CC	Out of Bounds Road	309700/6229000	hair tube	1 line of 20 tubes (10 large, 10 small)	12/11 - 20/11	160 hair tube nights	
			active search	2 people	12/11, 20/11	4.0 person hours	
DD	Lucas Heights	311700/6230450	active search	3 people	19/11	4.5 person hours	warm, fine
EE	Heathcote Road	311700/6232200	active search	3 people	19/11	5.0 person hours	warm, fine
FF	East of Artillery Road	307000/6230900	active search	1 person	11/11	0.8 person hours	warm, sunny
			harp trap	2 traps	11/11 - 14/11	6 trap nights	
GG	Old Illawarra Road	308550/6230250	frogging	listening, active search	21/11	0.5 hours	cold, scattered showers
HH	Victor	307400/6228700	frogging	listening, active search	7/11	0.75 hours	cold, windy, light scattered rain
II	Eckersley Junction	310500/6227800	active search	1 person	20/11	2.85 person hours	hot, fine
JJ	Giles Junction	308600/6225400	bat detector	delay switch	19/12	1 night	mild, fine
KK	Woolwash Road	301250/6224000	Specialist Broad-headed Snake survey	1 person	29/11, 3/12, 4/12		warm-hot, fine
		301500/6225000	Specialist Broad-headed Snake survey	1 person	29/11, 3/12, 4/12		warm-hot, fine
		302500/6225750	Specialist Broad-headed Snake survey	1 person	29/11, 3/12, 4/12		warm-hot, fine
LL	Wallaby Gully	312600/6226800	Specialist Broad-headed Snake survey	1 person	29/11, 3/12, 4/12		warm-hot, fine

Table B2.9. Location of significant terrestrial vertebrate fauna species recorded from the Holsworthy site. As the Holsworthy study area contains two bioregions, all species considered to be of regional significance in Cumberland Plains Woodland and in Coastal Sandstone Plateau are included in the table.

Type of Record: A = Identified from Hair Sample, H = Heard, I = Indirect Evidence (e.g. scats, burrows, bat detector etc.), S = Seen, T = Trapped or Hand-held, X = recorded, ? = probable identification, ARC = Archaeologist record, TP = Tadpole, TUFT = Robyn Tuft & Associates record, PT = Identified from Photograph, ? = unconfirmed record.

Common Name	**Scientific Name**	**Status**	**AMG**	**Site**	**Record**
Amphibians					
Giant Burrowing Frog	*Heleioporus australiacus*	S(v)	306400/6218850	Q	H
			304400/6226600	H	TP
			308100/6231150	E	TP
			303100/6219200	M	TP
			304025/6215750	O	ARC, TP?
			307540/6218700	R	ARC, TP?
			307900/6225000		ARC, TP?
			302540/6218700	L	ARC, TP?
			302300/6219060		ARC, TP?
			300530/6222120		ARC, TP?
			300650/6222300		ARC, TP?
			301030/6222710		ARC, TP?
			306430/6229390		ARC, TP?
			307130/6229000		ARC, TP?
Red-crowned Toadlet	*Pseudophryne australis*	S(v)	305900/6231000	F	T
			311300/6225950	BB	H
			304200/6219650	K	H
			311700/6230450	DD	T
			306430/6223800	U	T
			312350/6235950		T
Reptiles					
Black Rock Skink	*Egernia saxatilis*	R	306500/62212500		T
Diamond Python	*Morelia spilota ssp spilota*	R	307400/6224100	X	ARC
Heath Monitor	*Varanus rosenbergi*	S(v)	311800/6227100		S?
Lace Monitor	*Varanus varius*	R	306430/6223380		S
			307500/6234000		S
			309400/6232500		S
Mountain Dragon	*Tympanocryptis diemensis*	R	310500/6227800		T
			308400/6229200	Z	T
			310200/6229000	CC	S
			310000/6227200	AA	S
			304300/6215800	O	S
			305970/6221560	T	S
			304200/6219800	K	T
			300530/6222730		ARC, PT
Birds					
Beautiful Firetail	*Stagonopleura bella*	R	304500/6225200	I	S
Brown Treecreeper	*Climacteris picumnus*	R	304300/6215800	O	S
Buff-rumped Thornbill	*Acanthiza reguloides*	R	310500/6227800		S
			311700/6230450	DD	S
			310000/6227200	AA	S
			303050/6219200	M	H
			306400/623080	FF	S
			301800/6220100	L	S
			304300/6215800	O	S
			304500/6225200	I	S
			304700/6215400	O	S
			304500/622600		S
Chestnut-rumped Heathwren	*Hylacola pyrrhopygia*	R	311700/6232200	EE	S
			310000/6227200	AA	S

Common Name	Scientific Name	Status	AMG	Site	Record
			310400/6227000	AA	S
			309000/6227600	Y	S
			304500/622600		S
Double-barred Finch	*Taeniopygia bichenovii*	R	308400/6238150		S
Flame Robin	*Petroica phoenicea*	R	310500/6227800		S
Little Eagle	*Hieraaetus morphnoides*	R	308—/6231—		S
Little Raven	*Corvus mellori*	R	312100/6236950	A	S
			309000/6227600	Y	S
			308400/6229200	Z	S
Rockwarbler	*Origma solitaria*	R	312100/6236950	A	S
			310000/6227200	AA	S
			306400/623080	FF	S
			304500/6225200	I	S
			301700/6220200	L	S
			309800/6227200	AA	S
			312400/6234200		ARC
			307350/6227500		ARC
			307100/6235550		ARC
			301500/6225500		ARC
			304300/6228900		ARC
			304300/6218900		ARC
			305350/6227400		TUFT
Southern Emu-wren	*Stipiturus malachurus*	R	304300/6215800	O	S
Tawny-crowned Honeyeater	*Phylidonyris melanops*	R	308800/6235800	D	S
			309700/6229000	CC	S
			310200/6227000	AA	S
			310—/6228–		S
			305—/6225–		S
Weebill	*Smicrornis brevirostris*	R	309700/6229000	CC	S
			310000/6227200	AA	H
White-fronted Chat	*Epthianura albifrons*	R	308900/6235800	D	S
White-throated Needletail	*Hirundapus caudacutus*	J/C	304—/6224—		S
White-winged Chough	*Corcorax melanorhamphos*	R	308000/6236500	D	S
			307950/6236350	D	S
			307500/6234000	D	S
Yellow-rumped Thornbill	*Acanthiza chrysorrhoa*	R	308400/6238200		S
			3020–/6225—		S
Mammals					
Brush-tailed Rock Wallaby	*Petrogale penicillata*	N(v), S(v)	312100/6236950	A	S?
Common Wombat	*Vombatus ursinus*	R	304400/6215650	O	I
			307000/6231000	FF	I
			308000/6230000		ARC
			309000/6227800	Y	I
			304200/6219800	K	
Eastern Grey Kangaroo	*Macropus giganteus*	R	308500/6236000		S
			307000/6230900		I
			304000/6220200	K	I
			304300/6215800	O	I
			307600/6234700	D	S
			307800/6235000	D	S
			303100/6219200	M	A
Koala	*Phascolarctos cinereus*	S(v)	305100/6227700	G	I
			302850/6220250		H
			303400/6221900	J	H
			306500/6221100	V	I
			306300/6230900	F	I
			304000/6220200	K	I
			303100/6219200	M	A
Long-nosed Bandicoot	*Perameles nasuta*	R	311700/6230450	DD	I
			303100/6219200	M	T
			307900/6235500	D	S

Common Name	Scientific Name	Status	AMG	Site	Record
			304650/6219700		ARC
Red-necked Wallaby	*Macropus rufogriseus*	R	303100/6219200	M	A?
Tiger Quoll	*Dasyurus maculatus*	S(v)	303100/6219200	M	A
Wallaroo	*Macropus robustus*	R	311900/6236900	A	I
Yellow-bellied Glider	*Petaurus australis*	S(v)	303050/6219200	M	I?
Eastern False Pipistrelle	*Falsistrellus tasmaniensis*	S(v)	311900/6236900	A	I
			308600/6225400	JJ	I
			308900/6231400	E	I
Grey-headed Flying-fox	*Pteropus poliocephalus*	R	307300/6221400	V	S
			305150/6215700		S
			303800/6215400		S
			306200/6218400	Q	S
White-striped Mastiff-bat	*Nyctinomus australis*	R	310500/6227000	AA	H
			308400/6229100	Z	H
			304100/6224000	I	H
			306400/6219100	R	H
			308500/623600	D	H
			312100/6236900	A	H
			311950/6233600	C	H
			302900/6216100	N	H
Yellow-bellied Sheathtail Bat	*Saccolaimus flaviventris*	S(v)	309800/6237600	A	I
			308900/6231400	E	I

Table B2.10. Distribution of known or likely terrestrial fauna species of significance in relation to the Holsworthy site. As the Holsworthy study area contains two bioregions, all species considered to be of regional significance in Cumberland Plains Woodland and in Coastal Sandstone Plateau are included. Species which have no records listed are known to occur in the general area and may occur within the study site. The species list should not be considered exhaustive.

Conservation Significance: N(e) = Listed on Schedule 1 of the Endangered Species Protection (ESP) Act (1992); N(v) = Listed on Schedule 2 of the ESP Act 1992; S(e) = Listed on Schedule 1 of the Threatened Species Conservation (TSC) Act 1995; S(v) = Listed on Schedule 2 of the TSC Act 1995; R = Regional Significance; J/C = JAMBA/CAMBA International Treaties; C= CAMBA. Regionally significant species was determined on the basis of the Draft Western Sydney Urban Bushland Biodiversity Study (NPWS, unpublished) and consultation with experts. Ca/Gr = Campbelltown/Georges River, W/V = Wattle Grove/Voyager Point.

Common Name	Scientific Name	Status	Wedderburn[a]	Woronora[b]	O'Hares Creek Catchment[c,g]	Royal National Park[d,g]	Heathcote National Park[g,h]	Ca/GR[e]	W/V[f]
Amphibians									
Tusked Frog	*Adelotus brevis*	R							
Giant Burrowing Frog	*Heleioporus australiacus*	S(v)		X	X	X	X		
Green and Golden Bell Frog	*Litoria aurea*	S(e)			X	X		X	
Green Tree Frog	*Litoria caerulea*	R		X	X	X			
Blue Mountains Tree Frog	*Litoris citropa*	R			X	X			
Jervis Bay Tree Frog	*Litoria jervisiensis*	R		X	X	X			
Heath Frog	*Litoria littlejohni*	R							
Red-crowned Toadlet	*Pseudophryne australis*	S(v)			X	X	X		
Brown Toadlet	*Pseudophryne bibronii*	R	X	X	X	X			
Reptiles									
Bearded Dragon	*Pogona barbata*	R							
Black Rock Skink	*Egernia saxatilis*	R							
Broad-headed Snake	*Hoplocephalus bungaroides*	N(e), S(e)	X	X	X	X	X[h]		
Diamond Python	*Morelia spilota ssp spilota*	R		X		X			
Heath Monitor	*Varanus rosenbergi*	S(v)	X			X			
Lace Monitor	*Varanus varius*	R							
Mountain Dragon	*Tympanocryptis diemensis*	R	X		X	X			
Birds									
Australasian Bittern	*Botaurus poiciloptilus*	S(v)							
Bar-shouldered Dove	*Geopelia humeralis*	R	X			X			
Beautiful Firetail	*Stagonopleura bella*	R			X	X			
Black Bittern	*Dupetor flavicollis*	S(v)							
Brown Treecreeper	*Climacteris picumnus*	R						X	
Brush Cuckoo	*Cuculus variolosus*	R						X	
Buff-rumped Thornbill	*Acanthiza reguloides*	R	X		X	X		X	
Bush Stone-curlew	*Burhinus magnirostris*	S(e)	X						
Chestnut-rumped Heathwren	*Hylacola pyrrhopygia*	R	X			X		X	
Diamond Firetail Finch	*Stagonopleura guttata*	R						X	
Double-barred Finch	*Taeniopygia bichenovii*	R	X			X		X	

Common Name	Scientific Name	Status	Wedderburn^{a}	Woronora^{b}	O'Hares Creek Catchment^{c,g}	Royal National Park$^{d\ g}$	Heathcote National Park^{gh}	Ca/GR^{e}	W/V^{f}
Eastern Bristlebird	*Dasyornis brachypterus*	N(v), S(v)		X				X	
Flame Robin	*Petroica phoenica*	R							
Fuscous Honeyeater	*Lichenostomus flavescens*	R	X			X			
Glossy Black-Cockatoo	*Calyptorhynchus lathami*	S(v)	X	X				X	
Grey Goshawk	*Accipiter novaehollandiae*	R							
Ground Parrot	*Pezoporus wallicus*	S(v)						X	
Hooded Robin	*Melanodryas cucullata*	R						X	
Jacky Winter	*Microeca fascinans*	R				X		X	
Little Eagle	*Hieraaetus morphnoides*	R				X		X	
Little Raven	*Corvus mellori*	R						X	
Masked Owl	*Tyto novaehollandiae*	S(v)				X		X	
Nankeen Night Heron	*Nycticorax caledonicus*	R	X			X		X	
Painted Honeyeater	*Grantiella picta*	S(v)							
Peaceful Dove	*Geopelia placida*	R	X			X		X	X
Peregrine Falcon	*Falco peregrinus*	R		X	X(eyrie)	X		X	
Powerful Owl	*Ninox strenua*	S(v)				X	X		
Red-capped Robin	*Petroica goodenovii*	R						X	
Red-rumped Parrot	*Psephotus haematonotus*	R							
Regent Honeyeater	*Xanthomyza phrygia*	N(e), S(e)				X		X	
Restless Flycatcher	*Myiagra inquieta*	R						X	
Rockwarbler	*Origma solitaria*	R	X		X	X		X	
Sooty Owl	*Tyto tenebricosa*	S(v)		X		X			
Southern Emu-wren	*Stipiturus malachurus*	R			X	X		X	
Speckled Warbler	*Chthonicola sagittata*	R				X		X	
Swift Parrot	*Lathamus discolor*	N(v), S(v)			X	X		X	
Tawny-crowned Honeyeater	*Phylidonyris melanops*	R			X	X		X	
Turquoise Parrot	*Neophema pulchella*	S(v)			X			X	
Weebill	*Smicrornis brevirostris*	R	X					X	
White-bellied Sea-Eagle	*Haliaeetus leucogaster*	R,C	X	X		X		X	X
White-fronted Chat	*Epthianura albifrons*	R							
White-throated Needletail	*Hirundapus caudacutus*	J/C		X	X	X			
White-winged Chough	*Corcorax melanorhamphos*	R						X	
Yellow-rumped Thornbill	*Acanthiza chrysorrhoa*	R						X	
Mammals									
Brown Antechinus	*Antechinus stuartii*	R							
Brush-tailed Rock Wallaby	*Petrogale penicillata*	N(v), S(v)		X					
Common Dunnart	*Sminthopsis murina*	R							

Common Name	Scientific Name	Status	Wedderburn[a]	Woronora[b]	O'Hares Creek Catchment[c,d]	Royal National Park[d,g]	Heathcote National Park[g,h]	Ca/GR[e]	W/V[f]
Common Wombat	*Vombatus ursinus*	R	X	X	X	X			
Eastern Grey Kangaroo	*Macropus giganteus*	R	X	X	X				X
Greater Glider	*Petauroides volans*	R	X		X	X			
Koala	*Phascolarctos cinereus*	S(v)	X	X	X	X			X
Long-nosed Bandicoot	*Perameles nasuta*	R				X			X
Long-nosed Potoroo	*Potorous tridactylus*	S(v)							
New Holland Mouse	*Pseudomys novaehollandiae*	R				X			
Platypus	*Ornithorhynchus anatinus*	R	X		X	X			
Red-necked Pademelon	*Thylogale thetis*	R				X			
Red-necked Wallaby	*Macropus rufogriseus*	R	X	X		X			X
Squirrel Glider	*Petaurus norfolcensis*	S(v)	X	X	X				
Tiger Quoll	*Dasyurus maculatus*	S(v)	?		X	X			
Wallaroo	*Macropus robustus*	R			X				
Water Rat	*Hydromys chrysogaster*	R							
Yellow-bellied Glider	*Petaurus australis*	S(v)			X				
Common Bentwing Bat	*Miniopterus schreibersii*	S(v)	X			X			
Eastern False Pipistrelle	*Falsistrellus tasmaniensis*	S(v)				X			
Eastern Little Mastiff Bat	*Mormopterus norfolkensis*	S(v)	X			X			
Greater Broadnosed Bat	*Scoteanax rueppellii*	S(v)	X			X			
Grey-headed Flying-fox	*Pteropus poliocephalus*	R	X			X			X
Large-footed Myotis	*Myotis adversus*	S(v)	X			X			
Large Pied Bat	*Chalinolobus dwyeri*	S(v)	X			X			
Little Red Flying-fox	*Pteropus scapulatus*	R							
Eastern Cave Bat	*Vespadelus troughtoni*	S(v)							
White-striped Mastiff-bat	*Nyctinomus australis*	R	X						X
Yellow-bellied Sheathtail Bat	*Saccolaimus flaviventris*	S(v)				X			

Note
- a. Scorce: Phillips et. al. (1996a), Close (1992)
- b. Source: Sydney Water database; Robinson (1985)
- c. Source: R. Close (*pers. comm.*), Database of the Register of the National Estate (AHC); Harlow & Taylor (1995); Illawarra Bird Observers Club (C. Brandis, *pers. comm.*), D. Andrew (*pers. comm*).
- d. Source: D. Andrew (*pers. comm.*)
- e. Source: Leishman (1994); ESS Consultants (1976); Sydney Pre-history Group (1983); Fanning & Leonard (1996)
- f. Source: Biosis Research (1991); ERM Mitchell McCotter (1996a,b), Engel (1994a,b)
- g. Source: NPWS Database; Australian Museum Database
- h. Source: D. Engel (*pers. comm.*)

1.5.3 Survey Efficacy

Surveys generally targeted rare or significant species, including those listed on Schedules 1 and 2 of the Threatened Species Conservation Act (1995). Surveys are, by definition, sampling processes and inevitably some species will not be detected. To overcome this sampling problem, we have incorporated results from previous field surveys conducted in the general area, the consultant's own records from the region and those held in biological databases.

Table B2.11 lists those species specifically targeted in the field surveys and assesses the efficacy of survey for all significant species discussed in this report. Survey efficacy is assessed as adequate for all targeted species. It is also assessed as adequate for most species that were not specifically targeted, as these are species that, if present, would be expected to be encountered in general surveys or whose regional distribution is so sparse and poorly known that no method of targeting is known and records are largely governed by chance. Surveys for migratory or nomadic species are considered to be inadequate due to the timing of the survey period, its short duration and the large areas under construction.

Migratory species such as the Swift Parrot and nomadic species such as the Regent Honeyeater were unlikely to be located on the site during our survey period. However, these species may still occur on the site periodically.

We therefore believe that our survey results, our extensive database and literature review for the regional area (Georges River to Royal National Park) and consultation with relevant experts give a accurate indication of the species which are known or likely to occur at the site.

Table B2.11. Assessment of the efficacy of survey for fauna species of national and state significance.

COMMON NAME	SCIENTIFIC NAME	TARGETED	EFFICACY
National Significance			
Reptiles			
Broad-headed Snake	*Hoplocephalus bungeroides*	Y	Adequate
Birds			
Regent Honeyeater	*Xanthomyza phrygia*	N	Inadequate
Swift Parrot	*Lathamus discolor*	N	Inadequate
Eastern Bristlebird	*Dasyornis brachypterus*	Y	Adequate
Mammals			
Brush-tailed Rock Wallaby	*Petrogale penicillata*	Y	Adequate
State Significance			
Amphibians			
Green and Golden Bell Frog	*Litoria aurea*	Y	Adequate
Giant Burrowing Frog	*Heleioporus australiacus*	Y	Adequate
Red-crowned Toadlet	*Pseudophryne australis*	Y	Adequate
Reptiles			
Heath Monitor	*Varanus rosenbergi*	Y	Adequate
Birds			
Australasian Bittern	*Botaurus poiciloptilus*	N	Inadequate
Black Bittern	*Ixobrychus flavicollis*	N	Inadequate
Bush Stone	*Burhinus magnirostris*	N	Adequate
Glossy Black-Cockatoo	*Calyptorhynchus lathami*	Y	Adequate
Ground Parrot	*Pezoporus wallicus*	Y	Adequate
Masked Owl	*Tyto novaehollandiae*	Y	Adequate
Painted Honeyeater	*Grantiella picta*	N	Inadequate
Powerful Owl	*Ninox strenua*	Y	Adequate
Sooty Owl	*Tyto tenebricosa*	Y	Adequate
Turquoise Parrot	*Neophema pulchella*	N	Adequate
Mammals			
Koala	*Phascolarctos cinereus*	Y	Adequate
Long-nosed Potoroo	*Potorous tridactylus*	Y	Adequate
Squirrel Glider	*Petaurus norfolcensis*	Y	Adequate
Tiger Quoll	*Dasyurus maculatus*	Y	Adequate
Yellow-bellied Glider	*Petaurus australis*	Y	Adequate
Common Bent-wing Bat	*Miniopterus schreibersii*	Y	Adequate
Eastern Cave Bat	*Vespadelus troughtoni*	Y	Adequate
Eastern False Pipistrelle	*Falsistrellus tasmaniensis*	Y	Adequate
Eastern Little Mastiff Bat	*Mormopterus norfolkensis*	Y	Adequate
Greater Broad-nosed Bat	*Scoteanax rueppelii*	Y	Adequate
Large-footed Myotis	*Myotis adversus*	Y	Adequate
Large Pied Bat	*Chalinolobus dwyeri*	Y	Adequate
Yellow-bellied Sheathtail Bat	*Saccolaimus flaviventris*	Y	Adequate

1.6 SIGNIFICANT FAUNA

Several species were identified within, or in the vicinity of, the proposed airport sites as having national, state or regional significance. Species of national and state significance for Badgerys Creek and Holsworthy are discussed in detail in species profiles in the following sections. Species listed under international treaties are discussed immediately following the species profiles. These are followed by tables discussing species of regional significance.

The Schedule 1 and 2 species known or likely to occur in the Holsworthy and Badgerys Creek study areas are listed in Table B2.12. Only those species recorded during the present study, the AXIS/Australian Museum Business Services (1996) study, the Kinhill Stearns (1985) study and from NPWS and Australian Museum Databases can be considered under Options.

Only those species with critical habitat within the study areas are considered in the profiles. At least three species of state significance and seven species of regional significance may occur on the Badgerys Creek site but are 'unlikely' (T. Saunders, *pers.comm*). Some species such as fruit-doves and some raptors (e.g Osprey, Pacific Baza) may fly over or through the Holsworthy area but they are unlikely to obtain critical resources there. These have not been considered in detail below. Other nomadic or migratory species such as the Regent Honeyeater, Swift Parrot and Painted Honeyeater may utilize feed trees within the Badgerys Creek and Holsworthy sites on an irregular basis. These have been included in the profiles set out below.

Table B2.12. List of fauna species listed on Schedule 1 and 2 of the TSC Act (1995) which have been recorded from (✓) or which may occur (blank) within the options at the Badgerys Creek and Holsworthy sites. Unconfirmed sighting is denoted by ?. This species list should not be considered exhaustive.

				Holsworthy Options			Badgerys Ck Options		
COMMON NAME	SCIENTIFIC NAME	L^1	Status^2	A	B	Other	A	B	C
National Significance									
Broad-headed Snake	*Hoplocephalus bungaroides*	Y	N(e), S(e)			✓			
Regent Honeyeater	*Xanthomyza phrygia*	N	N(e), S(e)						
Swift Parrot	*Lathamus discolor*	N	N(v), S(v)						
Eastern Bristlebird	*Dasyornis brachypterus*	N	N(v), S(e)						
Brush-tailed Rock Wallaby	Petrogale penicillata	Y	N(v), S(v)			?			
State Significance									
Green and Golden Bell Frog	*Litoria aurea*	Y	S(e)						
Giant Burrowing Frog	*Heleioporus australiacus*	Y	S(v)	✓	✓	✓			
Red-crowned Toadlet	*Pseudophryne australis*	Y	S(v)	✓	✓	✓			
Heath Monitor	*Varanus rosenbergi*	Y	S(v)			?			
Australasian Bittern	*Botaurus poiciloptilus*	Y	S(v)						
Bush Stone-curlew	*Burhinus magnirostris*	Y	S(e)						
Glossy Black-Cockatoo	*Calyptorhynchus lathami*	Y	S(v)						
Black Bittern	*Ixobrychus flavicollis*	Y	S(v)						
Turquoise Parrot	*Neophema pulchella*	Y	S(v)						
Ground Parrot	*Pezoporus wallicus*	N	S(v)						
Powerful Owl	*Ninox strenua*	Y	S(v)			✓			
Sooty Owl	*Tyto tenebricosa*	Y	S(v)						
Masked Owl	*Tyto novaehollandiae*	Y	S(v)						
Painted Honeyeater	*Grantiella picta*	N	S(v)						
Tiger Quoll	*Dasyurus maculatus*	Y	S(v)		✓	✓			
Yellow-bellied Glider	*Petaurus australis*	Y	S(v)		?				

				Holsworthy Options			Badgerys Ck Options		
COMMON NAME	SCIENTIFIC NAME	L^1	$Status^2$	A	B	Other	A	B	C
Squirrel Glider	*Petaurus norfolcensis*	Y	S(v)						
Koala	*Phascolarctos cinereus*	Y	S(v)		✓	✓			
Long-nosed Potoroo	*Potorous tridactylus*	Y	S(v)						
Yellow-bellied Sheathtail Bat	*Saccolaimus flaviventris*	Y	S(v)	✓					
Eastern Little Mastiff Bat	*Mormopterus norfolkensis*	Y	S(v)						
Greater Broadnosed Bat	*Scoteanax rueppellii*	Y	S(v)			✓			
Eastern False Pipistrelle	*Falsistrellus tasmaniensis*	Y	S(v)	✓		✓		✓	✓
Large-footed Myotis	*Myotis adversus*	Y	S(v)			✓			
Common Bentwing Bat	*Miniopterus schreibersii*	Y	S(v)			✓	✓	✓	✓
Large Pied Bat	*Chalinolobus dwyeri*	Y	S(v)			✓			
Eastern Cave Bat	*Vespadelus troughtoni*	Y	S(v)						

NOTE: 1. Abbreviation L is Licence required to harm, pick or damage habitat: Y = Yes, N = No.

2. Status: N = national, S = state significance, (e) endangered, (v) vulnerable.

1.6.1 Note on Distributions

The *statewide distributions* are summarised from maps published in Blakers *et al.* (1984), Cogger (1996), Morris *et al.* (1981), Parnaby (1992), Strahan (1995) and Swan (1990).

Regional distributions were determined from the above maps, the NPWS, RAOU and Australian Museum databases, from our field work and through consultation with the following people: T. Saunders (birds), A. Leishman (birds), F. Lemckert (amphibians, reptiles), D. Andrew (general), A. White (amphibians) and G. Swan (reptiles).

Local distribution refers to records collected within or immediately adjacent to the study area.

Several species of fauna were identified within, or in the vicinity of, the study area during the study as having **national**, **state**, or **regional** significance. These are listed below.

1.6.2 Note on Impact Assessment

Impacts on significant species are considered in terms of their habitat requirements, mobility and likely use of available habitat and the predicted effects of the airport proposal on their distribution. Guidelines used to define impacts are presented below.

High local impact occurs when the proposal affects a species which is known to occur in the study area, is mobile and has general habitat requirements and habitat is continuous and widespread.

Regional impact is considered when the proposal affects a mobile species with specific habitat requirements that is known to occur in the study area.

High regional impact occurs when the proposal affects a species that is not mobile and has specific habitat requirements.

Unknown is indicated when insufficient information is available to determine the impacts of the proposal on individual species (i.e. where use of the study area is unknown or when species have nomadic habits and may only occur there on occasions)

Not likely is indicated when consultation has revealed that a species is considered unlikely to occur in the study area.

1.7 BADGERYS CREEK

1.7.1 National Significance

1.7.1.1 Regent Honeyeater

This species underwent a dramatic decline between 1960-80 which may be due to disease, trapping, egg-collecting, timber removal and/or predation. Total population fewer than 1000 (Webster and Menkhorst 1992).

Nationally, this species is listed as Endangered (Schedule 1, *Endangered Species Protection Act 1992*; ANCA 1991). Listed in Schedule 1 of the *Threatened Species Conservation Act 1995*. Considered "endangered" by Garnett (1992).

1.7.1.1.1 Distribution

Statewide distribution: Coast, tablelands, slopes, north-west plain and Riverina; stronghold considered to be inland slopes of the Great Dividing Range in Victoria and NSW (Robinson 1994). In NSW, occurs regularly at five sites between the Northern Tablelands and the western slopes of the Great Dividing Range inland from Sydney.

Regional distribution: Possible winter visitor or local nomad to the Badgerys Creek area (N. Shedvin, Regent Honeyeater Recovery Team *pers. comm.*; A. Morris, NSW Field Ornithologists Club *pers. comm.*) and is irregularly observed (NPWS, unpublished). The species shows two activity patterns in western Sydney: feeding in flowering eucalypts and lerps in autumn and winter and foraging in River Oak and associated mistletoe species in spring and summer (A. Morris, NSW Field Ornithologists Club *pers. comm*). Generally, the birds are found in trees bordering or close to running water courses (A. Morris, NSW Field Ornithologists Club *pers. comm.*).

Local distribution and abundance: This species was not recorded during the present study. Because it is unlikely to breed in the study area (a time when Regent Honeyeaters are territorial and vocal), it was not possible to target honeyeaters during the survey period. Prior to the 1950s, Regent Honeyeaters were frequent visitors to woodlands around Kellyville, Doonside, Plumpton, Blacktown and St Marys (NPWS, unpublished).

The species has been recorded in the 1980s and early 1990s in the local area although the majority of the records occur to the south and south-west of the site. The Regent Honeyeater was recorded at Bents Basin in 1981, at Greenwattle Point Warragamba Dam in 1987, at Nattai Road Oakville in 1989 and in the Burragorang Valley in 1989 and 1991 (A. Morris, NSW Field Ornithologists Club *pers. comm*).

1.7.1.1.2 Environmental pressures

Environmental pressures on this species and its habitat include: loss and fragmentation of habitat due to clearing, decline in habitat quality, loss of large nectar-producing trees, competition with other honeyeater species.

1.7.1.1.3 Critical Habitat

The Regent Honeyeater utilises dry open forest and woodland, including forest edges, farmland and suburban areas and orchards. It is a highly specialised species which prefers box-ironbark forests, especially those occurring on wetter, more fertile soils; however, most of these have been cleared for agricultural purposes. This species prefers or reaches its highest densities in old-growth forest (Scotts 1994). Preferred trees for feeding include Red Ironbark (*Eucalyptus sideroxylon*), White Box (*E. albens*), Yellow Box (*E. melliodora*), Yellow Gum (*E. leucoxylon*), Red Gum (*E. blakelyi*) and River Red Gum (*E.camaldulensis*). Schedvin (1996) indicates in some areas at particular times nectar from mistletoe in River Oaks is an important food source. Schedvin (1996) also states that large congregations of Regent Honeyeaters have also been found in areas heavily infested with lerps.

Individuals are found feeding on nectar and insects singly or in small groups high in the canopy. Webster and Menkhorst (1992) found that local habitat selection was determined by the presence of large flowering trees, high productivity and an understorey of saplings or shrubs. The nest is constructed of eucalypt bark, grasses and other plant material. Although birds form pairs during the breeding season, they may form loose flocks during other times of the year. Honeyeaters are nomadic in their movements though they exhibit seasonal patterns of movement in relation to districts where there are flowering eucalypts and banksias.

Regent Honeyeater regularly use areas with distinct and predictable nectar production in the Sydney area (Franklin *et al.* 1989, in Robinson 1994).

1.7.1.1.4 Sensitivity to habitat modification

Past declines due to clearance of forested habitat (especially box-ironbark communities) for agriculture and other activities. Webster and Menkhorst (1992) hypothesise that a steady decline in habitat quality through the loss of habitat trees due to forestry operations, dieback and other degradation has further reduced populations of honeyeaters. Honeyeaters would be sensitive to the removal of floriferous trees. An indirect effect of habitat fragmentation may be increased competition with larger honeyeater species such as the Noisy Miner, Red Wattlebird and Noisy Friarbird. Grazing by stock and rabbits may be limiting regeneration of suitable habitat. Also the potential indirect effects of apiaries on the Regent Honeyeater are unknown.

1.7.1.1.5 Effects of proposed activities

Direct impacts of airport construction on this species are likely to be habitat loss and fragmentation, and loss of nectar-producing trees. Option A will result in the loss of 117 ha of Woodland Remnants and 4.2 ha of Riparian Woodland. Option B will result in the loss of of 197.4 ha of Woodland Remnants and 14.3 ha of Riparian Woodland. Option C will result in the loss of 168.2 ha of Woodland Remnants and 15.2 ha of Riparian Woodland. Indirect impacts of airport construction are likely to include a decline in remaining habitat quality, competition with other honeyeater species and possibly with the introduced Honey Bee.

The Regent Honeyeater has specialised habitat requirements and is highly mobile. The species is considered a possible winter visitor to the site, however the importance of the site to the Regent Honeyeater is not known.

The impact of the airport development on this species is therefore considered to be unknown.

1.7.1.1.6 Ability of species/habitat to recover

Insufficient information. The time taken for large nectar-producing trees to recover would be in excess of 100 years. The effects of habitat fragmentation and edge-related impacts on this species is unknown.

1.7.1.1.7 Amelioration measures

Minimise habitat fragmentation by careful siting of proposed transport and services corridors.

1.7.1.1.8 Known to occur in nearby conservation reserves

Because this species is nomadic and is very rare, it is not likely to be adequately represented in nearby reserves.

1.7.1.2 Swift Parrot

Nationally, it is listed as Vulnerable (Schedule 2, *Endangered Species Protection Act 1992*; ANCA 1991). Listed in Schedule 2 of the *Threatened Species Conservation Act 1995*. Considered to be "vulnerable" by Garnett (1992).

1.7.1.2.1 Distribution

Statewide distribution: Most regions but especially south-east NSW. Largely confined to box-ironbark forest and woodland on inland slopes of the Great Dividing Range in the region south of Sydney and east of Horsham, Victoria.

Regional distribution: Uncommon migrant.

Local distribution and abundance: This species was not recorded during the present study. Because the Swift Parrot is migratory and nests in Tasmania during summer, it was not possible to target this species during the survey period. Swift Parrots were not recorded in the local area by the NPWS Database or Australian Museum Database. Recent fauna surveys undertaken by the NSW NPWS in Western Sydney also failed to detect the species (NPWS, unpublished). The Swift Parrot is not common in western Sydney, but individuals are recorded each year (NPWS, unpublished).

1.7.1.2.2 Environmental pressures

Environmental pressures on this species and its habitat include: loss of hollow-bearing trees for nesting (Tasmania), loss of habitat due to clearing, loss of winter-flowering eucalypts (mainland), possibly competition for nectar resources with the introduced Honey Bee, competition for nest hollows with Starlings.

1.7.1.2.3 Critical habitat

This gregarious parrot breeds in eucalypt forests in eastern and northern Tasmania and over-winters in south-eastern mainland Australia (Garnett 1992). It is usually found in small groups (2 or more) but is associated with larger flocks (up to 30 individuals) where eucalypts are flowering in profusion. Individuals concentrate wherever winter-flowering species such as Red Ironbark, Yellow Gum, White Box, Swamp Gum and Manna Gum occur. The box-ironbark forests west of the Dividing Range are particularly favoured by parrots. They feed on nectar, pollen and lerp as well as on fruit and seeds of native and exotic plants in suburban environments. On the mainland movements are nomadic and irruptions in NSW are related to a great abundance of lerp

The majority of sightings in NSW have been in coastal eucalypt forest (NPWS Database).

1.7.1.2.4 Sensitivity to habitat modification

On the Australian mainland, this species is sensitive to the loss of winter-flowering eucalypts; loss of these may impact upon the regional viability of populations. It is especially sensitive to the removal of trees that provide copious amounts of nectar - these tend to be older trees. Garnett (1992) cautions that "even individual trees may be important" to this species The replacement of extensive woodland areas with fragmented "edge" habitats easily dominated by aggressive bird species has also probably contributed to their decline.

1.7.1.2.5 Effects from proposed activities

Direct impacts of airport construction on this species are likely to be habitat loss and fragmentation, and loss of winter-flowering eucalypts. Option A will result in the loss of 117 ha of Woodland Remnants and 4.2 ha of Melaleuca Woodland. Option B will result in the loss of of 197.4 ha of Woodland Remnants and 14.3 ha of Melaleuca Woodland. Option C will result in the loss of 168.2 ha of Woodland Remnants and 15.2 ha of Riparian and Melaleuca Woodland. Indirect impacts of airport construction are likely to include altered fire regime and competition for nectar resources with the introduced Honey Bee.

The Swift Parrot has specific habitat requirements and is highly mobile. The Swift Parrot is considered an uncommon migrant in Western Sydney but individuals are recorded there each year. The site would provide limited habitat resources for this species.

The impact of the airport development on this species is considered to be unknown.

1.7.1.2.6 Ability of species/habitat to recover

Insufficient information. As the trees which produce most nectar and flowers tend to be the largest trees, the time taken for these to regenerate may be 100+ years. Nomadic populations are likely to recover provided that suitable habitat is maintained along either side of the airport development and no significant barriers are formed.

1.7.1.2.7 Amelioration measures

Minimise habitat fragmentation by careful siting of proposed transport and services corridors.

1.7.1.2.8 Known to occur in nearby conservation reserves

As the Swift Parrot is a migratory species which breeds in Tasmania, the most critical resources for this species on the mainland are feeding trees. Due to spacial and temporal variability in eucalypt flowering, it is unlikely that Swift Parrot habitat is adequately reserved in the region.

1.7.2 State Significance

1.7.2.1 Green and Golden Bell Frog

The Green and Golden Bell Frog was once common in NSW (Cogger 1960) but has declined in recent years. The cause of this decline is unknown. Predation of tadpoles and eggs by the exotic Mosquito Fish (*Gambusia affinis)* is regarded as one possible cause (Mahoney 1993).

Listed as Endangered in Schedule 1 of the *Threatened Species Conservation Act 1995*. Recent reports (Tyler 1993, 1994; Mahony 1993) indicate a decline in a number of populations throughout its range, particularly in NSW.

1.7.2.1.1 Distribution

Statewide distribution: Eastern and south-eastern NSW.

Regional distribution: Rare and patchy. Following 1990, the species has been recorded from 21 sites in the greater Sydney area (White and Pyke 1996). The main population centres are located at Kurnell Peninsula and the Liverpool / Georges River area (White and Pyke 1996).

Local distribution and abundance: Unknown; not recorded during the present survey or from database records of the area. White and Pyke (1996) indicate that in the Liverpool region, small populations of the Green and Golden Bell Frog are known from Milperra to Hammondville. These populations are located well east of the site adjacent to the Georges River. The species was recorded north of the site at Mount Druitt in temporary ponds in 1994 (White and Pyke 1996).

1.7.2.1.2 Environmental pressures

Environmental pressures on the species and its habitat are poorly understood but may include: loss of or alteration to suitable habitat, predation of eggs and tadpoles by introduced Mosquito Fish, trampling by cattle.

1.7.2.1.3 Critical habitat

This is a largely low altitude, aquatic species which lives amongst the vegetation associated with permanent streams, dams, swamps and where low-lying areas are inundated (Cogger 1996). The Green and Golden Bell Frog is considered a rapid coloniser of suitable new locations, including artificial habitats (Ecotone Ecological Consultants 1995). Male frogs call during the summer breeding season whilst floating on the water surface amongst the submerged vegetation (Ecotone Ecological Consultants 1995). Generally this species occurs in more open sites with substantial sunlight infiltration including large permanent wetlands and large backwaters or billabongs associated with the floodplains of larger water courses. This species basks in exposed sites during the day.

The species seems to no longer occur at inland sites although a population did exist on the southern tablelands around Canberra (Osborne 1990) and on the northern tablelands (Cogger 1996). Most of the remaining known populations occur within several kilometres of the east coast. The status of all Green and Golden Bell Frog populations warrants monitoring.

1.7.2.1.4 Sensitivity to habitat modification

The Green and Golden Bell Frog is sensitive to habitat loss and modification of drainage causing excessive sedimentation in existing waterways. The species is also sensitive to the presence of Mosquito fish (*Gambusia holbrooki)* in breeding areas as they readily consume eggs or tadpoles (White and Pyke 1996).

1.7.2.1.5 Effects of proposed activities

Direct impacts of airport construction on this species are likely to be habitat loss and fragmentation. Option A will result in the loss of 5.5 km of streamline habitat. Option B will result in the loss of 9.5 km of streamline habitat. Option C will result in the loss of 12 km of streamline habitat. Indirect impacts of airport construction are likely to be polluted runoff and predation of eggs and tadpoles by the introduced Mosquito Fish.

The Green and Golden Bell Frog has specific habitat requirements but is considered a rapid coloniser of suitable habitats including artificial habitats. The species has been recorded in Western Sydney, however the significance of the site for this species is unknown. The regional distribution of this species is assessed as rare and patchy.

The impact of the airport development on this species is therefore considered to be unknown.

1.7.2.1.6 Ability of species/habitat to recover

The time taken for preferred habitat to recover is unknown. Although they have been known to inhabit disturbed habitats habitat disturbance may lead to species decline in the longer term (Ferraro and Burgin 1993a, 1993b). The disappearance of this species from many localities where it was previously recorded suggests that this species has a low recovery potential.

1.7.2.1.7 Amelioration measures

Strict adherence to erosion and sediment control measures; construction of river and stream crossings so as to maintain downstream water quality; minimise local trenching work; minimise the period that trenches are open in key habitat areas; checking of open trenches in or near suitable habitat for trapped individuals; maximise opportunities to create wetland habitat as part of stormwater management; on-site education program for construction workers in the identification of rare and vulnerable fauna species.

1.7.2.1.8 Known to occur in nearby conservation reserves

The Green and Golden Bell Frog is poorly conserved in NSW. Records since 1990 indicated that it occurs in only nine conservation reserves around the state (White and Pyke 1996). The closest of these is Botany Bay National Park. None of the known populations in Western Sydney occur within conservation reserves.

1.7.2.2 Australasian Bittern

Listed in Schedule 2 (Vulnerable) of the Threatened Species Conservation. Considered to be Insufficiently known by Garnett (1992).

1.7.2.2.1 Distribution

Statewide distributions: Most numerous in the Murray-Darling Basin (Morris *et al.* 1981).

Regional distribution. Unknown. This species is not easily observed and may be more common than expected There are records of this species from Auburn, Blacktown, Hawkesbury and Parramatta LGAs (NPWS, unpublished). It has been recorded from St Albans Common (Smith and Smith 1994).

Local distribution: This species has been recorded within 10 kilometers of the Badgerys Creek site and may occur in suitable wetlands and/or wet grasslands on the site (T. Saunders, Cumberland Bird Observers Club *pers. comm.*).

1.7.2.2.2 Environmental pressures

Environmental pressures on the species and its habitat include: loss of wetland habitats through drainage, salinisation of wetland habitats, grazing and trampling of wetlands, alteration to water quality, burning and introduced predators.

1.7.2.2.3 Critical habitat

The Australasian Bittern utilises permanent shallow, vegetated freshwater or brackish swamps dominated by reeds or sedges and may also occur in ephemeral wetlands. It prefers extensive wetlands with an abundance of vegetation, including a mixture of tall and short reeds for nesting. It is a cryptic and highly secretive species which occurs alone or in small groups in extensive dense reedbeds. It breeds in loose colonies or territorial pairs. This species feeds on insects, small fish and other aquatic life in the shallow margins of wetlands (Marchant and Higgins 1990, Emison *et al.* 1987). Nests consist of a saucer of reeds built over water. It is nomadic in its movements and requires drought refuges. Irruptions are known to occur in times of drought.

1.7.2.2.4 Sensitivity to habitat modification

This species is sensitive to drainage or salinisation of swamp habitats. It is also sensitive to grazing and trampling of wetland vegetation which it requires for shelter and to alteration or loss of drought refuges.

1.7.2.2.5 Effects of proposed activities

Direct impacts of airport construction on this species are likely to be habitat loss. Option A will result in the loss of 4.2 ha of Melaleuca Woodland and 5.5 km of streamline habitat. Option B will result in the loss of of 14.3 ha of Melaleuca Woodland and 9.5 km of streamline habitat. Option C will result in the loss of 15.2 ha of Melaleuca Woodland 12 km of streamline habitat. Indirect impacts of airport construction are likely to be a further reduction in water quality and an increase in fire frequency.

The Australasian Bittern has specific habitat requirements. The species is highly mobile and because of its secretive nature may actually be more common than expected. The regional distribution and significance of the site for this species is not known. The site provides limited habitat for this species.

The impact of the airport development on this species is therefore considered to be high local.

1.7.2.2.6 Ability of species/habitat to recover

Unknown.

1.7.2.2.7 Amelioration measures

Strict adherence to erosion and sediment control measures; construction of river and stream crossings so as to maintain downstream water quality; minimise habitat fragmentation by careful siting of proposed transport and services corridors; maximise opportunities to create wetland habitat as part of stormwater management.

1.7.2.2.8 Known to occur in nearby conservation reserves

Unknown.

1.7.2.3 Black Bittern

The Black Bittern is listed as a Vulnerable in Schedule 2 of the Threatened Species Conservation Act 1995. It is considered to be an uncommon resident in NSW by Morris *et al.* (1981).

1.7.2.3.1 Distribution

Statewide distribution: Wet coastal areas in eastern NSW.

Regional distribution: The species was considered a rare visitor to the Cumberland Plain woodlands from 1930 to 1960 (Keast 1995). The Black Bittern was a regular summer breeder in the Hawkesbury area during the 1960s (SFNSW 1995), however the species is now considered rare in the region. It was recorded in Castlereagh State Forest in 1972, 1973 and 1974 and mist-netted in 1992 and 1993 (Keast 1995).

Local distribution: Unknown, this species was not recorded during the current study; however wetland habitat may provide suitable habitat for this species periodically.

1.7.2.3.2 Environmental Pressures

Environmental pressures for this species and its habitat include habitat loss due to: clearing of woodland; draining of wetlands, grazing, burning, introduced predators and pollution of waterways. Decline in species numbers in the Hawkesbury area became apparent when the local swamp was partially drained and regular flooding ceased (SFNSW 1995), indicating that changes in the hydrological regime may impact this species.

1.7.2.3.3 Critical Habitat

The Black Bittern inhabits coastal wetlands and littoral habitats. Freshwater wetlands, fringed with dense vegetation such as *Melaleuca* and *Casuarina* are preferred (Marchant and Higgins 1990). The species will utilise billabongs, pools, and estuaries and tidal reaches of coastal creeks and rivers with fringing vegetation, which may only form a narrow band of cover (Marchant and Higgins 1990).

The species nests in trees over wetlands and watercourses in densley vegetated areas (Marchant and Higgins 1990). It will forage in low, marshy vegetation, or in shadows over shallow water and roost and rest on the ground or in leafy trees (Marchant and Higgins 1990). The species is known from woodland on the Cumberland Plain and from Castlereagh State Forest.

1.7.2.3.4 Sensitivity to Habitat Modification

Decline in species numbers have coincided with clearing for agriculture, increased salinity of rivers, grazing of waterside vegetation and siltation of wetlands (Marchant and Higgins 1990). Bitterns appear to be sensitive to changes in hydrological regimes.

1.7.2.3.5 Effects of the Proposed Activity

Direct impacts of airport construction on this species are likely to be habitat loss and fragmentation. Option A will result in the loss of 4.2 ha of Melaleuca Woodland and 5.5 km of streamline habitat. Option B will result in the loss of 14.3 ha of Melaleuca Woodland and 9.5 km of streamline habitat. Option C will result in the loss of 15.2 ha of Melaleuca Woodland and 12 km of streamline habitat. Indirect impacts of airport construction include increased predation, pollution of waterways and changes in the hydrological regime which may lead to draining of wetlands and an increase in fire frequency.

The Black Bittern has specific habitat requirements and is highly mobile. This species is considered rare in the region. The proposed development is unlikely to affect the regional distribution of this species. The site provides limited habitat for this species.

The impact of the airport development on this species is therefore considered to be high local.

1.7.2.3.6 Ability of the species / habitat to recover

The ability of the Black Bittern to recover following disturbance is unknown. Due to rarity in the region, the ability of the species to recover after disturbance is likely to be limited.

1.7.2.3.7 Amelioration Measures

Strict adherence to erosion and sediment control measures; construction of river and stream crossings so as to maintain downstream water quality; minimise habitat fragmentation by careful siting of proposed transport and services corridors; maximise opportunities to create wetland habitat as part of stormwater management.

1.7.2.3.8 Known to occur in nearby conservation reserves

Unknown; the Black Bittern was recorded in Castlereagh State Forest in the early 1990s (Keast 1995).

1.7.2.4 Glossy Black-Cockatoo

Listed as Vulnerable in the *Threatened Species Conservation Act 1995*. Considered to be "rare" by Garnett (1992).

1.7.2.4.1 Distribution

Statewide distribution: Lowland and highland forests of eastern NSW from Qld to Vic with isolated populations associated with inland mountain ranges.

Regional distribution: Distribution is patchy and localised, reflecting the distribution of this habitat type (Blakers *et al.* 1984; A. Morris, NSW Field Ornithologists Club *pers. comm.*). The species was recorded several times in north-western Sydney (NPWS unpublished). The species was not recorded in *Casuarina glauca* thickets fringing many of the streams in the South Creek catchment (NPWS unpublished).

Local distribution: Unknown; this species was not recorded during the present survey or from database records in the area. Small stands of *Casuarina glauca* are present along Badgerys Creek (G. Leonard *pers. comm.*).

1.7.2.4.2 Environmental pressures

Environmental pressures for this species and its habitat include: loss of large hollow-bearing trees for nesting, loss of casuarinas, fire.

1.7.2.4.3 Critical habitat

The Glossy Black-Cockatoo is found within a range of forests, woodlands, riparian vegetation and in partially cleared land, but prefers or reaches peak abundance in ecological old-growth forest. Its patchy distribution is due to reliance on a primary food source, the seeds from *Allocasuarina* spp. trees. *Allocasuarina torulosa, A. stricta* and *A. littoralis* are the favoured food trees in NSW. Clout (1989, in Forestry Commission of NSW 1993) showed that cockatoos actively sought out trees with greater numbers of seed cones. This species utilises hollow limbs on live or dead trees for nesting, preferring deep nest hollows with wide entrances located 10-20 m above ground. It forms permanent groups of up to 10 individuals; it may roost singly or in family groups but forms aggregations at food and water sources. Glossy Black-Cockatoos are mainly sedentary but are capable of moving long distances (more than 40 km) in order to locate suitable foraging habitat. The species is considered to be an ecological specialist.

The preferred food trees of this species in NSW do not occur at the Badgerys Creek site. Small stands of *Casuarina glauca* are present along Badgerys Creek (G. Leonard *pers. comm*).

1.7.2.4.4 Sensitivity to habitat modification

As an old-growth specialist species, the Glossy Black-Cockatoo would be highly sensitive to the removal of its preferred habitat type for the following reasons (Scotts 1994):

- It requires large contiguous areas of forest for foraging;
- It requires specialised habitat for resting and breeding (ie. tree hollows);
- It occurs naturally in low numbers

Species most sensitive to clearing are hollow-dependent species requiring a high density of the largest trees and where old-growth forest provides optimum habitat (Milledge *et al.* 1991). Because of its dependence on *Allocasuarina* spp., this species is sensitive to the loss of foraging habitat.

1.7.2.4.5 Effects of proposed activities

Direct impacts of airport construction on this species are likely to be loss of feeding and breeding resources and habitat fragmentation. Option A will result in the loss of 4.2 ha of Melaleuca Woodland. Option B will result in the loss of 14.3 ha of Melaleuca Woodland. Option C will result in the loss of 15.2 ha of Melaleuca Woodland. Indirect impacts of airport construction include cumulative impacts associated with loss of food resources and habitat and an increase in fire frequency.

The Glossy Black Cockatoo is highly mobile. Distribution of the species in the region is considered patchy and localised, reflecting the availability of suitable habitat. The site contains a limited amount of suitable habitat for this species.

The impact of the airport development on this species is therefore considered to be high local.

1.7.2.4.6 Ability of species/habitat to recover

Although *Casuarina* spp and *Allocasuarina* spp can invade cleared areas and are fast-growing, they may not be able to be used by cockatoos until 10 years post-clearing when they provide abundant seed (only cone-producing females trees can provide food for cockatoos). Suitable nest hollows may only be available after 200 years. This highly mobile species is likely to recover from impacts provided that existing suitable habitat is maintained

1.7.2.4.7 Amelioration measures

Minimise habitat fragmentation by careful siting of proposed transport and services corridors.

1.7.2.4.8 Known to occur in nearby conservation reserves

Unknown.

1.7.2.5 Powerful Owl

Listed as Vulnerable on Schedule 2 of the *Threatened Species Conservation Act 1995*. Considered to be "rare" by Garnett (1992).

1.7.2.5.1 Distribution

Statewide distributions: Coast, tablelands, south-west slope and north-west plains.

Regional distribution: Uncommon, restricted. The species has been recorded in Sydney's north-west near Maroota State Forest, at Kurrajong and on the edge of the Georges River five kilometres south of Campbelltown (NPWS unpublished). This species is considered widespread in moist gullies of the Cattai and Little Cattai catchments, the Georges River, Holsworthy and along the western boundary of the Cumberland Plain adjacent to Blue Mountains National and Wollomi National Parks (NPWS unpublished).

Local distribution and abundance: Unknown. This species was not recorded during the present survey or from database records for the area.

1.7.2.5.2 Environmental pressures

Environmental pressures on this species and its habitat include: loss of old-growth forest habitat, loss of large hollow-bearing trees, fragmentation of habitat, reduction in prey numbers due to clearing and burning.

1.7.2.5.3 Critical habitat

Breeding pairs of the Powerful Owl occupy large permanent territories (up to 1000 ha) preferably including gullies in foothill and coastal forests. This species preys primarily on arboreal mammals but also takes birds, insects and terrestrial mammals (Kavanagh 1988, 1990). The Powerful Owl inhabits both wet and dry eucalypt forest (Garnett 1992).

The Powerful Owl is found in moist and dry eucalypt forests but prefers ecological old-growth or reaches peak abundance there. Optimal habitat includes a mosaic of moist and dry hardwood on flat to undulating terrain. In north-eastern NSW, it reaches peak densities in highland hardwood forests where Greater Gliders are likely to be predominant prey species (Debus *et al.*, in prep.). It is a sedentary species with pairs occupying permanent territories from 400-1000+ ha; territory size is related to the density of prey species which in turn may be related to forest productivity. Owls hunt nocturnally in open eucalypt forest and require medium to high densities of medium-sized arboreal marsupials (eg. Sugar Gliders, Common Ringtail Possums and Greater Gliders) which comprise up to 80% of their diets. Birds and bats are also taken. They roost alone on horizontal branches generally several metres from the ground in dense old-growth vegetation often located in gullies. There may be more than one roost site but roost trees typically have a large open lower limb structure and a dense crown; Red Turpentine and Black She-oak are often selected. Powerful Owls nest in tree hollows at least 0.5 m deep (Schodde and Mason 1980), usually high (9-37 m above ground) within large eucalypts located in gullies, slopes or in the heads of minor side gullies (Kavanagh 1991). Nest site fidelity is high.

The Badgerys Creek site does not provide habitat typical of that utilised by the Powerful Owl, however the area may be used on an irregular basis as part of a much larger territory.

1.7.2.5.4 Sensitivity to habitat modification

As an old-growth specialist species, the Powerful Owl would be highly sensitive to the removal of its preferred habitat type for the following reasons (Scotts 1994):

- It requires large contiguous areas of forest for foraging;
- It is at or near the top of the food chain;
- It requires specialised habitat for resting and breeding (ie. tree hollows);

- It occurs naturally in low numbers.

Species most sensitive to clearing activities are hollow-dependent species requiring a high density of the largest trees and where old-growth forest provides optimum habitat (Milledge *et al.* 1991). It may be also be sensitive to disturbance of nest sites. Frequent burning may act to accelerate the demise of old trees and stags.

This species may be sensitive to loss of forest habitat which provides nesting/roosting trees and habitat for its prey species. However, it will switch prey species if the Greater Glider is not available (Debus *et al.*, in prep). It would also be sensitive to any activities such as grazing and frequent burning which would act to simplify the forest understorey, thereby reducing shelter and food for prey species.

1.7.2.5.5 Effects of proposed activities

Direct impacts of airport construction on this species are likely to be habitat loss and fragmentation and a reduction in prey numbers. Option A will result in the loss of 117 ha of Woodland Remnants and 4.2 ha of Melaleuca Woodland. Option B will result in the loss of 197.4 ha of Woodland Remnants and 14.3 ha of Melaleuca Woodland Option C will result in the loss of 168.2 ha of Woodland Remnants and 15.2 ha of Melaleuca Woodland. Indirect impacts of airport construction include cumulative impacts associated with habitat loss and an increase in fire frequency.

The Powerful Owl is highly mobile, occupying large territories. The Badgerys Creek site may form a very small part of a much larger home range. Regional distribution is assessed as uncommon and restricted. The airport development is unlikely to affect the regional distribution of this species.

The impact of the airport development on this species is therefore considered to be high local.

1.7.2.5.6 Ability of species/habitat to recover

The Powerful Owl is dependent on large hollows which can take from 150-200 years to form; these can be a limiting resource. However, it occurs in cleared habitat and may hunt along forest edges, in cleared land and along roads. It occurs in >70 year old regrowth and in 10-20 year old regrowth where wide corridors are retained (Debus *et al.*, in prep.). The loss of any potential habitat from the Badgerys site is unlikely to affect this wide-ranging species.

1.7.2.5.7 Amelioration measures

Minimise habitat fragmentation by careful siting of proposed transport and services corridors.

1.7.2.5.8 Known to occur in nearby conservation reserves

Unknown. Unless reserves are large, they are not likely to contain all critical resources for this species.

1.7.2.6 Yellow-bellied Sheathtail Bat

This species flies high and fast and is therefore rarely collected.

Listed as Vulnerable in Schedule 2 of the Threatened Species Conservation Act 1995.

1.7.2.6.1 Distribution

Statewide distribution: Very widespread with few records available.

Regional distribution: Unknown. Not recorded during the recent biodiversity study of Western Sydney (NPWS unpublished).

Local distribution and abundance: Unknown. The Yellow-bellied Sheathtail Bat was not recorded at Badgerys Creek during the present survey. It was not recorded on the site or in surrounding bushland remnants by Lesryk Environmental Consultants (1996) nor at South Creek by Ecotone Ecological Consultants (1994). Limited habitat for this species may be available within the Badgerys Creek study site.

1.7.2.6.2 Environmental pressures

Environmental pressures on the species and its habitat include: loss of preferred habitat through clearing for agriculture, loss of tree hollows for roosting, alteration to forest structure and consequently to insect abundance.

1.7.2.6.3 Critical habitat

The Yellow-bellied Sheathtail-bat is generally found within wet and dry sclerophyll forests and woodland <500 m in altitude, but also in mallee and open country. It is known to roost under the bark of trees, within tree hollows as well as under roof eaves and in other artificial habitats. In forested areas, it feeds on insects flying above the canopy whereas in open areas it forages closer to the ground (Austeco Pty Ltd 1994). Reports suggest that it is migratory in southern Australia, moving from cooler to warmer areas in winter (Lumsden and Menkhorst 1995). This bat is usually solitary but occurs in colonies of up to ten individuals (Strahan 1995). Habitat requirements for this species are uncertain.

1.7.2.6.4 Sensitivity to habitat modification

The Yellow-bellied Sheathtailed-bat would be highly sensitive to the removal of hollow-bearing trees, habitat fragmentation and to any alteration of forest structure. As it requires habitat complexity, it is likely to be negatively affected by frequent burning and grazing (Austeco Pty Ltd 1994, 1995).

1.7.2.6.5 Effects from proposed activities

Direct impacts of airport construction on this species are likely to be habitat loss. Option A will result in the loss of 117 ha of Woodland Remnants and 4.2 ha of Melaleuca Woodland. Option B will result in the loss of of 197.4 ha of Woodland Remnants and 14.3 ha of Melaleuca Woodland. Option C will result in the loss of of 168.2 ha of Woodland Remnants and 15.2 ha of Melaleuca Woodland. Indirect impacts of airport construction include a reduction in the abundance and diversity of insects.

The Yellow-bellied Sheathtailed-bat is highly mobile. The regional distribution of the species is unknown and likely to be rare. It is unknown if the development will have an effect on the regional distribution of this species

The impact of the airport development on this species is therefore unknown.

1.7.2.6.6 Ability of species/habitat to recover

Unable to accurately assess the ability of this species to recover based on information which is currently available. Bats are likely to have a poor recovery potential due to the following factors: high juvenile mortality, low reproductive rate and great longevity in relation to size (AXIS/Australian Museum Business Services). The ability to recover will depend largely on the ability of this species to migrate and find suitable habitat in adjacent areas. This species would be negatively affected by the removal of any preferred mature hollow-bearing trees. Suitable roosting sites are most commonly found in mature trees (80-100 years old), bats are able to use cleared areas for foraging as long as suitable roosting sites are located nearby. Due to extremely low population densities, the ability of this species to recover is likely to be low.

1.7.2.6.7 Amelioration measures

Check all sheds, buildings, culverts prior to demolition for the presence of bats and to recommend a suitable time to demolish them (i.e. when bats are absent); minimise habitat fragmentation by careful siting of proposed transport and services corridors

1.7.2.6.8 Known to occur in nearby conservation reserves

Unknown. There is little known about the distribution of bats in the Sydney region. It is unknown whether critical habitat for bats is contained with conservation reserves in the region.

1.7.2.7 Eastern Little Mastiff-bat

Listed as Vulnerable on Schedule 2 of the *Threatened Species Conservation Act 1995*. Considered to be "rare" by Strahan (1995).

1.7.2.7.1 Distribution

Statewide distribution: East of the Great Dividing Range, from southern New South Wales to south-eastern Queensland (Strahan 1995, Parnaby 1992). Known from very few localities in NSW.

Regional distribution: Unknown. Not recorded during the recent biodiversity study of Western Sydney (NPWS unpublished).

Local distribution and abundance: Unknown. The Eastern Little Mastif Bat was not recorded at Badgerys Creek during the present survey. It was not recorded on the site or in surrounding bushland remnants by Lesryk Environmental Consultants (1996) nor at South Creek by Ecotone Ecological Consultants (1994). Limited habitat for this species may be available within the Badgerys Creek study site.

1.7.2.7.2 Environmental pressures

Environmental pressures on this species and its habitat include: loss of, or disturbance to, roost sites and loss of habitat through land clearing

1.7.2.7.3 Critical habitat

Habitat preferences of the Eastern Little Mastiff Bat are unclear but it is reported to favour sclerophyll forest and woodland, particularly in sub-tropical areas (Strahan 1995). It hunts for insects above the canopy or in clearings at the edge of forest. This species may roost in small colonies of up to 50 individuals under bark, in tree hollows and under roofs and other artificial habitats. Very little is known about the ecological requirements of this species.

1.7.2.7.4 Sensitivity to habitat modification

This species would be sensitive to the removal of forest roosting and foraging habitat, to habitat fragmentation and simplification of forest structure.

1.7.2.7.5 Effects from the proposed activities

Direct impacts of airport construction on this species are likely to be habitat loss. Option A will result in the loss of 117 ha of Woodland Remnants and 4.2 ha of Riparian and Melaleuca Woodland. Option B will result in the loss of 197.4 ha of Woodland Remnants and 14.3 ha of Riparian and Melaleuca Woodland. Option C will result in the loss of 168.2 ha of Woodland Remnants and 15.2 ha of Riparian and Melaleuca Woodland. Indirect impacts of airport construction include cumulative impacts associated with habitat loss.

The Eastern Little Mastiff Bat is a mobile species. The regional distribution of the species is unknown. It is unknown if the development will have an effect on the regional distribution of this species.

The impact of the airport development on this species is unknown.

1.7.2.7.6 Ability of species/habitat to recover

Bats are likely to have a poor recovery potential due to the following factors: high juvenile mortality, low reproductive rate and great longevity in relation to size (AXIS/Australian Museum Business Services). There is insufficient information on this species to accurately predict potential impacts caused by removal of any trees containing roosting sites. Although suitable roosting sites may be most commonly found in mature trees (80-100 years old), bats are able to use cleared areas as long as suitable roosting sites are located nearby. Low population densities are likely to restrict its ability to recover.

1.7.2.7.7 Amelioration measures

Check all sheds, buildings, culverts prior to demolition for the presence of bats and to recommend a suitable time to demolish them (i.e. when bats are absent); minimise habitat fragmentation by careful siting of proposed transport and services corridors.

1.7.2.7.8 Known to occur in nearby conservation reserves

Unknown. There is little known about the distribution of bats in the Sydney region. It is unknown whether critical habitat for bats is contained with conservation reserves in the region.

1.7.2.8 Greater Broad-nosed Bat

Listed as Vulnerable in Schedule 2 of the *Threatened Species Conservation Act 1995*.

1.7.2.8.1 Distribution

Statewide distribution: Restricted to east coast and adjacent Great Dividing Range from Qld to Vic border; sparse (Parnaby 1992).

Regional distribution: Poorly known. Recorded in the LGA during the recent biodiversity study of Western Sydney (NPWS unpublished).

Local distribution and abundance: Likely to be uncommon This species was not recorded at Badgerys Creek during the present survey. It was not recorded on the site or in surrounding bushland remnants by Lesryk Environmental Consultants (1996). It was recorded at South Creek and at Pemberton Gully by Ecotone Ecological Consultants (1994).

1.7.2.8.2 Environmental pressures

Environmental pressures on this species and its habitat include: loss of rainforest, wet sclerophyll and riparian forest habitats; loss of tree hollows.

1.7.2.8.3 Critical habitat

The Greater Broad-nosed Bat forages over a range of habitats, including dry forests and woodland, but prefers wet habitats and riparian forest. This species is considered to be a specialist species which may prefer mature forest on high-fertility soils (Meredith *et al.* 1995). It requires a sparse understorey as it flies at a height of about 3-6 metres and will forage for insects at one metre over the water of creeks and small rivers (Strahan 1995). This bat feeds on large insects and possibly on small vertebrates and even other bats. It roosts mainly in tree hollows but will also use buildings. Females congregate at maternity sites during the breeding season in summer (Strahan 1995).

1.7.2.8.4 Sensitivity to habitat modification

As this species shows preference for moist forest types, the Greater Broad-nosed Bat would be sensitive to the loss of moist forest roosting and foraging habitats, riparian forest foraging habitat, and to the alteration of forest structure (Austeco Pty Ltd 1994, 1995). The foraging patterns of this bat are such that they are likely to be sensitive to reductions in water quality.

1.7.2.8.5 Effects of proposed activities

Direct impacts of airport construction on this species are likely to be habitat loss and fragmentation. Option A will result in the loss of 117 ha of Woodland Remnants and 4.2 ha of Melaleuca Woodland. Option B will result in the loss of 197.4 ha of Woodland Remnants and 14.3 ha of Melaleuca Woodland. Option C will result in the loss of 168.2 ha of Woodland Remnants and 15.2 ha of Melaleuca Woodland. Indirect impacts of airport construction include cumulative impacts associated with habitat loss.

The Greater Broad-nosed Bat is highly mobile. The regional distribution of the species is poorly known and is likely to be uncommon. It is unknown if the development will have an effect on the regional distribution of this species.

The impact of the airport development on this species is therefore unknown.

1.7.2.8.6 Ability of species/habitat to recover

Bats are likely to have a poor recovery potential due to the following factors: high juvenile mortality, low reproductive rate and great longevity in relation to size (AXIS/Australian Museum Business Services). Unable to accurately assess the ability of this species to recover based on information which is currently available. This will depend largely on its ability to locate suitable habitat in adjacent areas. This species is likely to be affected by the removal of mature hollow-bearing trees. Although it is known to forage along water courses and forest/grassland ecotones, it may require mature trees (80-100 years old) in which to roost. It is also able to use artificial roosting sites. This species is likely to recover provided existing levels of water quality are maintained and if suitable habitat, especially moist forest, riparian vegetation and large hollow-bearing trees, are conserved.

1.7.2.8.7 Amelioration measures

Check all sheds, buildings, culverts prior to demolition for the presence of bats and to recommend a suitable time to demolish them (i.e. when bats are absent); minimise habitat fragmentation by careful siting of proposed transport and services corridors; strict adherence to erosion and sediment control measures; construction of river and stream crossings so as to maintain downstream water quality;

1.7.2.8.8 Known to occur in nearby conservation reserves

Unknown. There is little known about the distribution of bats in the Sydney region. It is unknown whether critical habitat for bats is contained with conservation reserves in the region.

1.7.2.9 Eastern False Pipistrelle

Listed as Vulnerable on Schedule 2 of the *Threatened Species Conservation Act 1995*..

1.7.2.9.1 Distribution

Statewide distribution: Coast and tablelands; uncommon and localised (Parnaby 1992).

Regional distribution: Poorly known but likely to be uncommon. Not recorded during the recent biodiversity survey of Western Sydney (NPWS unpublished).

Local distribution and abundance: Uncommon. This species was recorded at two detector sites (Sites H & J) during the present survey. It was not recorded on the site or in surrounding bushland remnants by Lesryk Environmental Consultants (1996) nor at South Creek by Ecotone Ecological Consultants (1994).

1.7.2.9.2 Environmental pressures

Environmental pressures for this species and its habitat include: loss of old-growth habitat, loss of tree hollows, alteration to forest structure.

1.7.2.9.3 Critical habitat

The Eastern False Pipistrelle can be found in a range of habitats including dry woodland and wet sclerophyll forest. Scotts (1994) described this species as finding optimum habitat within old-growth forests in south-eastern Australia. It roosts in caves and abandoned buildings, but prefers tree hollows. Within the Strzelecki Ranges in Victoria, individuals were found to travel over 7-12 km to their roosting hollows located in old-growth forest or within isolated trees in farmland (Parnaby and Cherry 1992). It appears to prefer moist forest types where it hunts moths, beetles and ants below the canopy level. It possibly migrates from highland to coastal areas in winter (Parnaby 1992) and may hibernate in southern parts of its range (Strahan 1995).

1.7.2.9.4 Sensitivity to habitat modification

The main threats to this species are considered to be loss of roosting hollows and disturbance to understorey (Parnaby 1992). This is consistent with their old-growth-dependent status. This species would be sensitive to the removal of moist forest roosting and foraging habitat, to habitat fragmentation and to simplification of forest structure in foraging habitat.

As an old-growth specialist species, the Eastern False Pipistrelle would be highly sensitive to the removal of preferred habitat type for the following reasons (Scotts 1994):

- It forages over large contiguous areas of forest;
- It requires combinations of varied, specialised habitat resources for breeding, roosting and foraging;
- It is colonial or social in behaviour.

Because bats are dependent on mature hollow-bearing trees for roosting and breeding, they would be sensitive to any activities which resulted in the removal of this essential resource. Removal of or disturbance to roost sites may be critical in winter and during the breeding season when bats concentrate.

1.7.2.9.5 Effects of proposed activities

Direct impacts of airport construction on this species are likely to be habitat loss. Option A will result in the loss of 117 ha of Woodland Remnants and 4.2 ha of Melaleuca woodland Option B will result in the loss of of 197.4 ha of Woodland Remnants and 14.3 ha of Melaleuca Woodland. Option C will result in the loss of 168.2 ha of Woodland Remnants and 15.2 ha of Melaleuca Woodland. Indirect impacts of airport construction include cumulative impacts associated with habitat loss.

The Eastern False Pipistrelle is a mobile species and was recorded at the Badgerys Creek site during this study. The regional distribution of the species is poorly known, it is likely to be uncommon. It is unknown if the development will have an effect on the regional distribution of this species.

The impact of the airport development on this species is therefore unknown.

1.7.2.9.6 Ability of species/habitat to recover

Unable to accurately assess the ability of this species to recover based on information which is currently available. Bats are likely to have a poor recovery potential due to the following factors: high juvenile mortality, low reproductive rate and great longevity in relation to size (AXIS/Australian Museum Business Services). Although it is known to forage along forest/grassland ecotones, the Eastern False Pipistrelle is likely to be severely affected by the removal of mature hollow-bearing trees; these mature trees (100 years old) are essential for both roosting and breeding. The adaptability of this species to use artificial roosting sites may influence its ability to recover. The ability of this species to recover is likely to be greatest where roost sites and suitable habitat, especially riparian vegetation, is maintained.

1.7.2.9.7 Amelioration measures

Check all sheds, buildings, culverts prior to demolition for the presence of bats and to recommend a suitable time to demolish them (i.e. when bats are absent); minimise habitat fragmentation by careful siting of proposed transport and services corridors.

1.7.2.9.8 Known to occur in nearby conservation reserves

Unknown. Little is known about the distribution of bat species within the Sydney Region. It is unknown whether critical habitat for bats is contained with conservation reserves in the region.

1.7.2.10 Large-footed Myotis

The Large-footed Myotis occurs in northern, eastern and southern coastal Australia.

Listed as Vulnerable on Schedule 2 of the *Threatened Species Conservation Act 1995*.

1.7.2.10.1 Distribution

Statewide distribution: East of the Great Dividing Range; associated with water bodies.

Regional distribution: Poorly known; recorded in the Hawkesbury and Liverpool Local Government Areas (NPWS unpublished).

Local distribution and abundance: Scarce. The Large-footed Myotis was not recorded at Badgerys Creek during the present survey. It was not recorded on the site or in surrounding bushland remnants by Lesryk Environmental Consultants (1996) but was recorded at South Creek by Ecotone Ecological Consultants (1994). Limited riparian habitat for this species may be available within the Badgerys Creek study site.

1.7.2.10.2 Environmental pressures

Environmental pressures on this species and its habitat include: disturbance to colonies, particularly during the colder months (Reardon and Flavel 1987), loss of riparian habitat and alteration to hydrological regimes and water quality.

1.7.2.10.3 Critical habitat

The Large-footed Myotis inhabits a wide range of vegetation communities, always associated with permanent, usually slow-flowing water bodies. This species forages at night over bodies of fresh water, "raking" the surface with its enlarged hind feet to catch aquatic insects and small fish (Lumsden and Menkhorst 1995, Reardon and Flavel 1987).

This species roosts in caves, mines, disused railway tunnels and in some instances in dense foliage (Hall and Richards 1979). During the breeding season, maternity caves may contain colonies numbering from 10-15 to several hundred individuals (Strahan 1995). Males generally roost alone outside the breeding season. This species goes into torpor during winter and utilises caves during this period (these are separate from maternity caves). This species is considered rare is southern Australia where it is dependent on caves; it is more common in the coastal tropics where it can use dense rainforest foliage for roosting.

1.7.2.10.4 Sensitivity to habitat modification

Because this species is colonial, it would be sensitive to any disturbance at roosting or breeding sites where a significant proportion of the population may be concentrated seasonally. It would also be sensitive to any hydrological or water quality changes to the water bodies used as foraging areas. The Large-footed Myotis requires habitat complexity and would therefore be sensitive to frequent burning, grazing (Austeco Pty Ltd 1994, 1995) or selective land clearing.

1.7.2.10.5 Effects from proposed activities

Direct impacts of airport construction on this species are likely to be habitat loss and fragmentation. Option A will result in the loss of 4.2 ha of Melaleuca Woodland and 5.5 km of streamline habitat. Option B will result in the loss of 14.3 ha of Melaleuca Woodland and 9.5 km of streamline habitat. Option C will result in the loss of 15.2 ha of Melaleuca Woodland and 12 km of streamline habitat. Indirect impacts of airport construction include alteration to hydrological regimes and a reduction in water quality.

The Large-footed Myotis is a highly mobile species. The regional distribution of the species is poorly known. It is unknown if the development will have an effect on the regional distribution of this species.

The impact of the airport development on this species is therefore unknown; however if a maternity colony or a winter roost was disturbed or lost, impacts on this species would be considered of at least regional significance.

1.7.2.10.6 Ability of species/habitat to recover

Insufficient information is available to accurately assess the potential of this species to recover. Bats are likely to have a poor recovery potential due to the following factors: high juvenile mortality, low reproductive rate and great longevity in relation to size (AXIS/Australian Museum Business Services). Recovery will be dependent on retention of suitable roost sites and foraging habitats. Reduction in water quality and changes to the volume and nature of flow are likely to restrict the ability of this species to recover.

1.7.2.10.7 Amelioration measures

Check all sheds, buildings, culverts prior to demolition for the presence of bats and to recommend a suitable time to demolish them (i.e. when bats are absent); minimise habitat fragmentation by careful siting of proposed transport and services corridors; strict adherence to erosion and sediment control measures.

1.7.2.10.8 Known to occur in nearby conservation reserves

Unknown. Little is known about the distribution of bat species within the Sydney Region. It is unknown whether critical habitat for bats is contained with conservation reserves in the region.

1.7.2.11 Common Bent-wing Bat

This medium-sized insectivorous bat has restricted colonial breeding sites.

Listed as Vulnerable on Schedule 2 of the *Threatened Species Conservation Act 1995*.

1.7.2.11.1 Distribution

Statewide distribution: Coast and tablelands.

Regional distribution: Poorly known; likely to be uncommon.

Local distribution and abundance: This species was recorded from Badgerys Creek Road (Site J) during the present survey. It has also been recorded at Bents Basin by Lesryk Environmental Consultants (1996).

1.7.2.11.2 Environmental pressures

Environmental pressures on this species and its habitat include: loss of or disturbance to roosting/maternity caves, loss of or disturbance to winter roosting sites, habitat fragmentation and alteration to forest structure.

1.7.2.11.3 Critical habitat

The Common Bent-wing Bat is generally found in wet and dry sclerophyll forests and rainforest, preferring well-timbered valleys, where it forages for small insects above the tree canopy. In northern NSW, Dwyer (1965) found at least three partially discrete breeding populations which were spatially organised according to major features of physiography.

It roosts in caves, old mines, stormwater channels, rock shelters (Hall and Richards 1979, Hall *et al.* 1975) and buildings and uses different roosts according to seasonal needs, age and reproductive status It forms large colonies of up to several thousand individuals; maternity colonies may number 10,000 females (Dwyer 1965). Maternity caves are used year after year and provide a focus for colonies within a radius of several hundred kilometres. The structural characteristics of these caves are such that they enable the retention of high temperatures produced by the activity of thousands of bats and essential to the early development of young (Dwyer 1965). Juveniles disperse from maternity dens during March and may travel long distances up until May. In south-eastern Australia, roosts are used for hibernation. Numerous inconspicuous roost sites are utilised during this period.

1.7.2.11.4 Sensitivity to habitat modification

The Common Bent-wing Bat occurs in discrete populations based on maternity colonies, whose ranges are often determined by watersheds. This species is therefore particularly sensitive to the loss of or disturbance to maternity caves, particularly during the breeding season. Because roost sites are dominated by specific age/sex classes (ie. maternity, adult, juvenile), any disturbance has the potential to severely disrupt the population structure and thus the viability of regional and local populations. It would also be sensitive to disturbance of winter roosts.

Food supply, especially during winter, may be an important regulating factor for Common Bent-wing Bat populations (Dwyer 1965). Colony size is dependent on food supply. Furthermore, there may be an association between weather, number of roosting sites and food supply in determining winter survivorship. As fat supplies are critical for winter, food availability in spring and summer may also influence mortality. As this species favours habitat complexity, it is potentially sensitive to frequent burning and grazing activities (Austeco Pty Ltd 1994, 1995).

1.7.2.11.5 Effects of proposed activities

Direct impacts of airport construction on this species are likely to be habitat loss and fragmentation, disturbance or loss of maternity or roosting sites would be a significant impact on this species. Option A will result in the loss of 117 ha of Woodland Remnants and 4.2 ha of Melaleuca Woodland. Option B will result in the loss of 197.4 ha of Woodland Remnants and 14.3 ha of Melaleuca Woodland. Option C will result in the loss of 168.2 ha of Woodland Remnants and 15.2 ha of Melaleuca Woodland. Indirect impacts of airport construction include cumulative impacts associated with habitat loss.

The Common Bent-wing Bat is a highly mobile species. It forms large colonies and maternity roosts are used year after year. The species was recorded from the Badgerys Creek site, however the regional distribution of the species is poorly known. It is unknown if the development will have an effect on the regional distribution of this species.

The impact of the airport development on this species is therefore unknown; however if a maternity colony or a winter roost was disturbed or lost, impacts on this species would be considered of at least regional regional significance.

1.7.2.11.6 Ability of species/habitat to recover

The ability of this species to recover after major disturbances to its habitat is not fully understood. Bats are likely to have a poor recovery potential due to the following factors: high juvenile mortality, low reproductive rate and great longevity in relation to size (AXIS/Australian Museum Business Services). Recovery potential is likely to be greatly reduced if roost sites are destroyed. With the protection of these sites this species is likely to recover, especially where riparian vegetation and water quality are maintained.

1.7.2.11.7 Amelioration measures

Check all sheds, buildings, culverts prior to demolition for the presence of bats and to recommend a suitable time to demolish them (i.e. when bats are absent); minimise habitat fragmentation by careful siting of proposed transport and services corridors.

1.7.2.11.8 Known to occur in nearby conservation reserves

Unknown. Little is known about the distribution of bat species within the Sydney Region. It is unknown whether critical habitat for bats is contained with conservation reserves in the region.

1.7.2.12 Large Pied Bat

Listed as Vulnerable on Schedule 2 of the *Threatened Species Conservation Act 1995*.

1.7.2.12.1 Distribution

Statewide distribution: Rare. Western slopes and Dividing Range of central and northern NSW and coastal areas (Parnaby 1992).

Regional distribution: Poorly known.

Local distribution and abundance: Poorly known; this species was not recorded during the present survey. It was recorded at Bents Basin by Lesryk Environmental Consultants (1996). Suitable habitat for this species may occur along riparian corridors at Badgerys Creek.

1.7.2.12.2 Environmental Pressures

Environmental pressures on this species and its habitat include: loss of moist forest habitat and forest complexity through land clearing, loss of or disturbance to roost or maternity sites.

1.7.2.12.3 Critical Habitat

The Large Pied Bat occupies tall dry and wet forests where it forages for insects below canopy level (Strahan 1995). It was captured in wet sclerophyll forest adjacent to rainforest by Parnaby (1984, in Austeco 1994b) and in moist hardwood forest by Baverstock and Chambers (1992). Reported to favour moist forests by Richards (1991). It roosts in small colonies (>30 individuals) in caves, mine tunnels, tree hollows and even abandoned mud nest of Fairy Martins (Strahan 1995, Hall and Richards 1979). Within the shallow sandstone rock caves in which it roost this species appears to favour the brighter areas close to the entrance, this is in contrast to most other species of bat which generally prefer roosting in deeper and darker caves (Strahan 1995). Small groups of females with young remain in colonies which disband in autumn. Individuals disperse in winter and probably go into hibernation.

1.7.2.12.4 Sensitivity to Habitat Modification

This species would be sensitive to disturbance of or loss of roost sites. This would be true especially over winter and during the breeding season. This species would be sensitive to the removal of forest roosting and foraging habitat, to habitat fragmentation and to simplification of forest structure.

1.7.2.12.5 Effects of the Proposed Activity

Direct impacts of airport construction on this species are likely to be habitat loss and fragmentation. Option A will result in the loss of 4.2 ha of Melaleuca Woodland. Option B will result in the loss of 14.3 ha Melaleuca Woodland. Option C will result in the loss of 15.2 ha of Melaleuca Woodland Indirect impacts of airport construction include cumulative impacts associated with habitat loss.

The Large Pied Bat is a highly mobile species. The regional distribution of the species is poorly known. It is unknown if the development will have an effect on the regional distribution of this species.

The impact of the airport development on this species is therefore unknown; however if a maternity colony or a winter roost was disturbed or lost, impacts on this species would be considered of at least regional significance.

1.7.2.12.6 Ability of the species / habitat to recover

Bats are likely to have a poor recovery potential due to the following factors: high juvenile mortality, low reproductive rate and great longevity in relation to size (AXIS/Australian Museum Business Services). Insufficient information is available to accurately assess the recovery potential of this species this will depend largely on the amount of preferred habitat which remains in adjacent lands. Recovery potential is likely to be greatest where riparian vegetation and suitable roost sites are retained.

1.7.2.12.7 Amelioration Measures

Check all sheds, buildings, culverts prior to demolition for the presence of bats and to recommend a suitable time to demolish them (i.e. when bats are absent); minimise habitat fragmentation by careful siting of proposed transport and services corridors.

1.7.2.12.8 Known to occur in nearby conservation reserves

Unknown. Little is known about the distribution of bat species within the Sydney Region. It is unknown whether critical habitat for bats is contained with conservation reserves in the region.

1.7.2.13 Eastern Cave Bat

Listed as Vulnerable in Schedule 2 of the Threatened Species Conservation Act 1995. Considered to be "uncommon" by Strahan (1995).

1.7.2.13.1 Distribution

Statewide distribution: Uncommon. Restricted distribution along the east coast from north Queensland to south-eastern NSW; very few records for this species in NSW.

Regional distribution: Unknown; likely to be very rare.

Local distribution: The Eastern Cave Bat was not recorded at Badgerys Creek during the present survey. It was not recorded on the site or in surrounding bushland remnants by Lesryk Environmental Consultants (1996) or by Ecotone Ecological Consultants (1994). This species was not recorded during the biodiversity survey of Western Sydney (NPWS unpublished). Limited habitat for this species may be available within the Badgerys Creek study site.

1.7.2.13.2 Environmental Pressures

Environmental pressures for this species and its habitat include: habitat destruction and disturbance to forest areas. Loss or damage to subterranean roost through changes in land use or vandalism are also likely to affect this species.

1.7.2.13.3 Critical Habitat

The Eastern Cave Bat is a poorly known species, it has been recorded from a range of habitats including drier forests and tropical woodlands (Strahan 1995) where it forages mainly below the canopy. It roost in small groups, predominantly in caves and rock overhangs but also occurs in mines and buildings. At these roost sites it does not occur deep within caves or mines, instead seems to prefer well-lit areas (Strahan 1995).

1.7.2.13.4 Sensitivity to Habitat Modification

This species is likely to be sensitive to habitat fragmentation and any alteration to forest structure. In addition destruction of subterranean roost sites are likely to affect this species particularly during winter months when individuals are likely to be in torpor.

1.7.2.13.5 Effects of the Proposed Activity

Direct impacts of airport construction on this species are likely to be habitat loss and fragmentation. Option A will result in the loss of 117 ha of Woodland Remnants and 4.2 ha of Riparian and Melaleuca Woodland. Option B will result in the loss of 197.4 ha of Woodland Remnants and 14.3 ha of Melaleuca Woodland. Option C will result in the loss of 168.2 ha of Woodland Remnants and 15.2 ha of Riparian and Melaleuca Woodland. Indirect impacts of airport construction include cumulative impacts associated with habitat loss.

The Eastern Cave Bat is a highly mobile species. The regional distribution of the species is unknown, but likely to be very rare. It is unknown if the development will have an effect on the regional distribution of this species.

The impact of the airport development on this species is unknown; however if a maternity colony or a winter roost was disturbed or lost, impacts on this species would be considered of at least regional significance.

1.7.2.13.6 Ability of the species / habitat to recover

Bats are likely to have a poor recovery potential due to the following factors: high juvenile mortality, low reproductive rate and great longevity in relation to size (AXIS/Australian Museum Business Services). Insufficient information is available to accurately assess the potential of this species to recover. However, the ability of the Eastern Cave Bat to recover from the permanent destruction of roost sites is likely to be low. In addition, extremely low population densities of this species are likely to restrict its recovery potential.

1.7.2.13.7 Amelioration Measures

Check all sheds, buildings, culverts prior to demolition for the presence of bats and to recommend a suitable time to demolish them (i.e. when bats are absent); minimise habitat fragmentation by careful siting of proposed transport and services corridors.

1.7.2.13.8 Known to occur in nearby conservation reserves

Unknown Little is known about the distribution of bat species within the Sydney Region. It is unknown whether critical habitat for bats is contained with conservation reserves in the region.

1.7.3 International Agreements

The Great Egret was recorded adjacent to the study area and is listed under CAMBA. Latham's Snipe, Fork-tailed Swift and White-throated Needletail have been recorded on or in the vicinity of the Badgerys Creek site and are listed under JAMBA and CAMBA. Information presented below is summarised from Blakers *et al.* (1984) unless otherwise stated.

1.7.3.1 Great Egret

This large graceful egret is distibuted in tropical and warm temperate regions throughout the world (van Tets *et al.* 1979). It occupies terrestrial wetlands, estuarine and littoral habitats and wet grasslands (Marchant and Higgins 1990). It forages by wading in open, shallow water taking insects, crustaceans, fish and amphibians (Marchant and Higgins 1990, van Tets *et al.* 1979). The Great Egret was observed at a dam outside the Badgerys Creek site (Kinhill Stearns 1985). Suitable habitat for this species may occur at Badgerys Creek in the form of farm dams and riparian vegetation.

1.7.3.2 Cattle Egret

The Cattle Egret is native to southern Europe, Africa and Asia but probably entered Australia as part of a worldwide expansion. It is a migratory species with birds appearing to move south in the non-breeding season (winter). It is a colonial breeder and feeds on insects and other invertebrates which are disturbed by grazing cattle.

It may also feed in shallow water. The Cattle Egret first appeared on the Richmond flats in 1960 and it is now considered to be abundant in the region (NPWS unpublished). This species was recorded from the Badgerys Creek site (Lesryk Environmental Consultants 1996) and surrounds (in Rust PPK 1995).

1.7.3.3 Latham's Snipe

The Latham's Snipe breeds in Japan and spends summer in southern Australia. It prefers swampland, wet grassland and heathland and feeds by probing for invertebrates along muddy wetland margins. It lives singly or in small groups. It has been recorded in the Auburn, Blacktown, Baulkham Hills, Fairfield, Hawkesbury, Holroyd and Penrith Local Government Areas (NPWS unpublished). Latham's Snipe has been recorded within 10 kilometres of the Badgerys Creek site (T. Saunders, Cumberland Bird Observers Club *pers. comm.*, in Rust PPK 1995).

1.7.3.4 Fork-tailed Swift

The Fork-tailed Swift breeds in Asia and migrates to Australia in October each year. They fly in enormous loose flocks, eating insects and sleeping on the wing (Simpson 1979). The birds make use of thermal currents for feeding, gliding and travelling and apparently favour areas of low pressure (Simpson 1979). Fork-tailed Swifts are attracted to scrub fires, feeding around smoke columns (Simpson 1979). This species may occur in the Badgerys Creek area (Lesryk 1996).

1.7.3.5 White-throated Needletail

The White-throated Needletail migrates to eastern Australia each year in summer after breeding in Asia. It spends most of its time in the air foraging for insects and rarely, if ever, roosting. The White-throated Needletail has been recorded in the Auburn, Blacktown, Baulkham Hills, Camden, Hawkesbury, Holroyd and Penrith Local Government Areas (NPWS unpublished). It was also recorded within 10 kilometres of the Badgerys Creek site (T. Saunders, Cumberland Bird Observers Club *pers. comm.*)

1.7.4 Regional Significance

A number of species are regarded as regionally significant. These are listed in Table B2.13 below. In order to simplify discussion in Part C of this repport, regionally significant species are classified into guilds. Fauna species in the same guild are likely to be similarly impacted.

Guild codes:

Mammals and birds: Ae = Aerial forager, Aq = aquatic, Ar = arboreal mammal, B = bark forager, C = carnivore, F = flying mammal, Fo = foliage forager, Fr = frugivore, G = ground forager, Gr = granivore, He = herbivore, Ho = hollow dependent, I = insectivore, Lh = large herbivorous mammal, N= nectarivore, O = omnivore, S = shrub forager, P = predator / carrion, W = wetland bird.

Reptiles: 1 = fossorial - species which inhabitat the upper soil and litter layers; 2 = ground foraging insectivores, 3 = ground foraging carnivores, 4 = large omnivores, 5 = arboreal carnivores - carnivorous species which at least partially inhabit the tree and shrub layer, 6 = aquatic omnivores - omnivorous species which are at least partially aquatic, 7 = arboreal insectivores - insectivorous species which at least partially inhabit the tree and shrub layer.

Amphibians: 1 = wide-ranging terrestial egg-layers, 2 = wide-ranging ephemeral water egg-layers, 3 = wide-ranging permanent water egg-layers, 4 = riparian and riverine species.

Table B2.13. Regionally significant fauna species which were recorded or may occur at the Badgerys Creek site.

Species	General Habitat	Habitat Components	Guild	Known or Likely	Location	Reason for Significance
Amphibians						
Tusked Frog	gully forest, melaleuca thicket	logs, rocks, rock crevices	2	possible		southern limit of range
Green Tree Frog	gully forest, melaleuca thicket	moist environment	3	likely		declining numbers
Brown Toadlet	heath/swamp complex, melaleuca thicket, forest/woodland	rocks, leaflitter, swampy areas, emphemeral streams	2	likely		disappearing from areas where it was once known
Reptiles						
Bearded Dragon	forest, woodland	low vegetation, logs, hollows	4	possible		declining
Diamond Python	forest, woodland	rocky outcrops, arboreal hollows	5	possible		declining
Lace Monitor	woodland, forest	leaf litter	5	possible		loss of habitat
Birds						
Brown Songlark	grassland, scattered woodland	open areas, low shrubs	G	known		loss of native grassland habitat
Buff-rumped Thornbill	heath, open woodland	shrubs, hollows, loose bark (nesting)	GSI	known	Lesryk Environmental Services 1996	severe threatening processes
Diamond Firetail Finch	forest, woodland, open mallee, scrub	shrubs	GGrI	possible		significant reduction in population, severe threatening processes
Double-barred Finch	woodland, grassland	open grassy areas, shrubs	GGr	known	Sites J,K	declining
Flame Robin	woodland	open understorey, logs and leaf litter	I	known	Site II	severe threatening processes
Fuscous Honeyeater	woodland	shrubs, trees	NI	possible		significant reduction in population, severe threatening processes
Great Crested Grebe	open water, wetland	water, emergent vegetation	W	possible		loss of suitable habitat
Great Egret	open water	water, wet grass	W	likely		
Hooded Robin	heath, woodland	fallen timber, tree stumps	GI	possible		disjunct population, significant reduction in population, severe threatening processes
Jacky Winter	eco-tone of woodland and open areas, open understorey	open areas, shrubs	GAeI	known	Kinhill Stearns 1985	severe threatening processes
Nankeen Night Heron	rivers, creeks, swamps	open water	W	known	Site I	loss of habitat
Latham's Snipe	wetland, wet grass, heath	water, muddy margins	W	possible		loss of habitat
Little Eagle	forest, woodland	tall trees	P	possible		uncommon
Peaceful Dove	woodland	open areas	GGr	known	Sites K,J	severe threatening processes
Peregrine Falcon	forest, woodland	cliffs	P	possible		uncommon
Red-capped Robin	open woodland	open areas, shrubs	I			edge of range, loss of habitat
Restless Flycatcher	forest, woodland, scrubland	ground cover	Fo	possible		declining

Species	General Habitat	Habitat Components	Guild	Known or Likely	Location	Reason for Significance
Rufous Songlark	grassland, swamp edge, scrubland	longer grasses	G	possible		declining
Shrike-tit	forest, woodland	decorticating bark	BI	possible		loss of habitat
Speckled Warbler	open woodland	open understorey, leaf litter, logs	GGrI	possible		disjunct population, significant reduction in population, severe threatening processes
Wedge-tailed Eagle	open forest - grassland	tall trees	P	possible		declining
Weebill	open forest, woodland	shrubs	FoI	known	Kinhill Stearns 1985	possibly declining
Whistling Kite	forest, woodland	tall trees	P	known	Kinhill Stearns 1985	uncommon
White-bellied Cuckoo-shrike	wide variety of habitats	trees, shrubs	Fo	possible		uncommon
White-fronted Chat	heath, low woodland	low vegetation	GI	possible		ecological specialist, restricted habitat, uncommon in region
White-winged Chough	open woodland	open ground	GI	known	Site A	severe threatening processes
White-winged Triller	woodland, grassland, scrubland	fallen timber, rocks and logs	AeG	possible		
Yellow-rumped Thornbill	open woodland, lawn	shrubs,	GIGr	known	Site H	severe threatening processes
Zebra Finch	grassland, swamp margins	longer grasses, fresh water	Gr	possible		declining
Mammals						
Grey-headed Flying Fox	woodland, wet and dry sclerophyll forest,	flowering plants	FFrHe	known	Sites C	two colonies in the sydney area
Little Red Flying Fox	forest, woodland	flowering plants	FN	likely		rare
White-striped Mastiff Bat	forest, woodland, riparian vegetation	hollows, bark	ArI	likely		very low population densities throughout Sydney region

1.8 HOLSWORTHY

1.8.1 National Significance

1.8.1.1 Broad-headed Snake

Nationally, this species is listed as Endangered (Schedule 1, *Endangered Species Protection Act 1992*; ANCA 1991). Listed on Schedule 1 of the *Threatened Species Conservation Act 1995*. Considered to be "vulnerable" by Cogger *et al*. (1993).

1.8.1.1.1 Distribution

Statewide distribution: Sandstone ranges of the southern central coast, extending from Colo north of Sydney to Nowra and west to Bathurst (i.e. within a 200 km radius of the Sydney metropolitan area) (Cogger *et al*. 1993).

Regional distribution: Poorly known. Patchy; associated with sandstone ridges and dry sclerophyll forests or woodlands (Webb and Shine 1994). The species has been recorded in the region from within Royal National Park and Heathcote National Park (Webb and Shine 1994). It has also been recorded from the southern end of Dharawal State Recreation Area by C. Hamilton (amateur herpetologist *pers. comm.*), near Appin between Heathcote Road and the Georges River and within Heathcote National Park by D. Sheeram (amateur herpetologist *pers. comm.*) and off Appin Road by B. Lazell and D. Sheeram (amateur herpetologists *pers. comm.*).

Local distribution. Unknown; not recorded during this survey as it was probably too late in the year. Potential habitat within the Holsworthy site was found on north to west facing rock outcrops with a woodland overstorey which occur throughout much of the study area. There is a single record of a young snake from the AXIS/Australian Museum Business Services (1995) study. The Broad-headed Snake was recorded once in H Range (Holsworthy HTA) by Phillips *et al.* (1996) and three times in O'Hares Creek catchment by Harlow and Taylor (1995). It was also recorded at Wedderburn (Phillips *et. al.* 1996), Woronora (Sydney Water Database; Robinson 1985; B. Lazell, amateur herpetologist *pers. comm.*) and in Royal National Park (D. Andrew, NPWS *pers. comm.*, NPWS Database; Australian Museum Database).

1.8.1.1.2 Environmental pressures

Environmental pressures on the species and its habitat: loss of habitat due to clearing, habitat fragmentation, urbanisation, rock removal, trapping, human disturbance and loss of hollow-bearing trees.

1.8.1.1.3 Critical habitat

The habitat requirements of the Broad-headed Snake overlap those of the Brush-tailed Rock Wallaby, as both require north-facing sandstone escarpments which have dry sclerophyll forest or woodland on the top of the escarpment (Webb and Shine 1994, Short 1982). The species requires flat pieces of tight fitting sandstone that sit on the parent rock in unshaded areas and are lacking in organic debris for shelter during the cooler months of the year (Webb and Shine 1994, Shine *et al.* 1995). During spring and summer individuals move into the hollows of nearby eucalypts (Webb and Shine 1994). Shine (1983) examined Museum specimens and found that these snakes eat skinks, geckos and occasionally frogs. There are few published references on their ecology and habitat requirements.

The Broad-headed Snake is most likely to occur in suitable habitat throughout the southern part of the study area including areas within both options (D. Engel, Lesryk Environmental Consultants *pers. comm.*). The numbers of this species present in the study area are unknown but are likely to be low (D. Engel, Lesryk Environmental Consultants *pers. comm.*).

1.8.1.1.4 Sensitivity of species to habitat modification

This species would be sensitive to habitat loss through the destruction of cliffs and the removal of rock and mature hollow-bearing eucalypts. Because of its already patchy distribution, it may not be particularly sensitive to further minor fragmentation of its habitat, but local populations could be affected by loss of individuals (e.g. killed during construction activities). It is not known whether this species is sensitive to high levels of human disturbance.

1.8.1.1.5 Effects of proposed activities

Direct impacts of airport construction on this species are likely to be habitat loss and fragmentation, rock removal and loss of hollow-bearing trees. Option A will result in the loss of 2339.8 ha of Woodland/heath and 1454.3 ha of Gully Forest habitat. Option B will result in the loss of 1655.6 ha of Woodland/heath and 1087.5 ha of Gully Forest. Indirect impacts of airport construction are likely to include disturbance due to blasting, drilling and increased human activity.

The Broad headed Snake has: specific habitat requirements; is not highly mobile and is likely to be rare at Holsworthy. Suitable habitat is present in both Options A and B and the Holsworthy area may be a stronghold of the species in the Sydney region.

The impact of the airport development on this species is therefore considered to be high regional.

1.8.1.1.6 Ability of species/habitat to recover

Sandstone cliff habitat is not likely to recover from high levels of disturbance without active rehabilitation. Large eucalypts may take more than 100 years to recover. The large size of the proposed development means that local populations of this species may not recover from its development. Individuals of this species may recover from any impacts adjacent to the proposed airport development. However the disruption of a possible corridor linking local populations also suggests that the long-term viability of Broad-headed Snake populations in the region may be endangered by the proposed development (particularly the southern option).

1.8.1.1.7 Amelioration measures

Pre-construction surveys with the aim of undertaking monitoring studies; on site education program for construction workers in the identification of rare and vulnerable fauna species; minimise habitat fragmentation by careful siting of proposed transport and services corridors; minimise local trenching work; minimise the period that trenches are open in key habitat areas; checking of open trenches in or near suitable habitat for trapped individuals.

1.8.1.1.8 Known to occur in nearby conservation reserves

Very small, isolated populations of Broad-headed Snakes are known to occur in the nearby conservation reserves of Royal National Park and Heathcote National Park (D. Engel, Lesryk Environmental Consultants *pers. comm.*).

1.8.1.2 Regent Honeyeater

This species underwent a dramatic decline between 1960-80 which may be due to disease, trapping, egg-collecting, timber removal and/or predation. Total population fewer than 1000 (Webster and Menkhorst 1992).

Nationally, this species is listed as Endangered (Schedule 1, *Endangered Species Protection Act 1992*; ANCA 1991). Listed in Schedule 1 of the *Threatened Species Conservation Act 1995*. Considered "endangered" by Garnett (1992).

1.8.1.2.1 Distribution

Statewide distribution: Coast, tablelands, slopes, north-west plain and Riverina; stronghold considered to be inland slopes of the Great Dividing Range in Victoria and NSW (Robinson 1994). In NSW, occurs regularly at five sites between the Northern Tablelands and the western slopes of the Great Dividing Range inland from Sydney.

Regional distribution: Possible winter visitor or local nomad to the area (N. Shedvin, Regent Honeyeater Recovery Team *pers. comm.*; A. Morris, NSW Field Ornithologists Club *pers. comm.*). The species shows two activity patterns in western Sydney: feeding in flowering eucalypts and lerps in autumn and winter and foraging in River Oak and associated mistletoe species in the spring and summer (A. Morris, NSW Field Ornithologists Club *pers. comm.*). Generally the birds are found in trees bordering or close to running water courses (A. Morris, NSW Field Ornithologists Club *pers. comm.*). There are two records of the species collected in 1977 from East Hills north-east of the study area and at Warwick farm; in 1991, the species was recorded at Moorebank; and in 1995 it was recorded at Padstow (A. Morris, NSW Field Ornithologists Club *pers. comm*). The Regent Honeyeater was also recorded 21 kilometres west of Picton in October 1996 (A. Morris, NSW Field Ornithologists Club *pers. comm*). This species has been recorded in Royal National Park (D. Andrew, NPWS *pers. comm;* NPWS Database; Australian Museum Database) and in the Campbelltown area (Sydney Pre-history Group 1983).

Local distribution. This species was not recorded during the present study. Because it is unlikely to breed in the study area (a time when Regent Honeyeaters are territorial and vocal), it was not possible to target it during the survey period. There is a historical record from the Minto area (Australian Museum Database). This species has not been detected by any of the recent studies carried out in the area (AXIS/Australian Museum Business Services 1995; Phillips *et al.* 1996; Leishman 1994). It is considered to be a rare visitor in the Georges River Regional Open Space Area (ESS Consultants 1976).

1.8.1.2.2 Environmental pressures

Environmental pressures on this species and its habitat include: loss and fragmentation of habitat due to clearing, decline in habitat quality, loss of large nectar-producing trees, competition with other honeyeater species and possibly the introduced Honey Bee.

1.8.1.2.3 Critical Habitat

The Regent Honeyeater uses dry open forest and woodland, including forest edges, farmland and suburban areas and orchards It is a highly specialised species which prefers box-ironbark forests, especially those occurring on wetter, more fertile soils; however, most of these have been cleared for agricultural purposes. This species prefers or reaches its highest densities in old-growth forest (Scotts 1994). Preferred trees for feeding include Red Ironbark (*Eucalyptus sideroxylon*), White Box (*E. albens*), Yellow Box (*E. melliodora*), Yellow Gum (*E. leucoxylon*), Red Gum (*E. blakelyi*) and River Red Gum (*E.camaldulensis*). Shedvin (1996) indicates that in some areas at particular times of the year nectar from mistletoe in River Oaks is an important food source. She also states that large congregations of Regent Honeyeaters have been found in areas heavily infested with lerps.

Individuals feed on nectar and insects singly or in small groups high in the canopy. Webster and Menkhorst (1992) found that local habitat selection was determined by the presence of large flowering trees, high productivity and an understorey of saplings or shrubs. The nest is constructed of eucalypt bark, grasses and other plant material. Although birds form pairs during the breeding season, they may form loose flocks during other times of the year. Honeyeaters are nomadic in their movements though they exhibit seasonal patterns of movement in relation to districts where there are flowering eucalypts and banksias.

Regent Honeyeater regularly use areas with distinct and predictable nectar production in the Sydney area (Franklin *et al.* 1989, in Robinson 1994). Within the Holsworthy site, Regent Honeyeaters may potentially use the following species: *E. crebra*, *E. fibrosa*, *E. gummifera* (manna and lerps), *E. moluccana*, *E. oblonga*, *E. pitularis*, *E. punctata*, *E. sparsifolia*, *E. tereticornis* in association with *E. robusta*. The first three species are likely to be most important.

1.8.1.2.4 Sensitivity to habitat modification

Past declines due to clearance of forested habitat (especially box-ironbark communities) for agriculture and other activities. Webster and Menkhorst (1992) hypothesise that a steady decline in habitat quality through the loss of habitat trees due to forestry operations, dieback and other degradation has further reduced populations of honeyeaters. Honeyeaters would be sensitive to the removal of floriferous trees. An indirect effect of habitat fragmentation may be increased competition with larger honeyeater species such as the Noisy Miner, Red Wattlebird and Noisy Friarbird.

1.8.1.2.5 Effects of proposed activities

Direct impacts of airport construction on this species are likely to be habitat loss and fragmentation and loss of nectar producing trees. Option A will result in the loss of 308 ha of Grassy Forest, 2339.8 ha of Woodland/heath and 1454.3 ha of Gully Forest. Option B will result in the loss of 10.4 ha of Grassy Forest 1655.6 ha of Woodland/heath and 1087.5 ha of Gully Forest. Indirect impacts of airport construction are likely to include a decline in remaining habitat quality, competition with other honeyeater species and possibly with the introduced Honey Bee.

The Regent Honeyeater has specialised habitat requirements and is highly mobile. The importance to the site to the Regent Honeyeater is not known.

The impact of the airport development on this species is therefore considered to be unknown.

1.8.1.2.6 Ability of species/habitat to recover

Insufficient information. The time taken for large nectar-producing trees to recover would be in excess of 100 years. The effects of habitat fragmentation and edge-related impacts on this species is unknown.

1.8.1.2.7 Amelioration measures

Minimise habitat fragmentation by careful siting of proposed transport and services corridors.

1.8.1.2.8 Known to occur in nearby conservation reserves

Unknown. It is unlikely that critical resources (*i.e.* food trees) are adequately reseved anywhere within its range.

1.8.1.3 Swift Parrot

Nationally, it is listed as Vulnerable (Schedule 2, *Endangered Species Protection Act 1992*, ANCA 1991). Listed in Schedule 2 of the *Threatened Species Conservation Act 1995*. Considered to be "vulnerable" by Garnett (1992).

1.8.1.3.1 Distribution

Statewide distribution: Most regions but especially south-east NSW. Largely confined to box-ironbark forest and woodland on inland slopes of the Great Dividing Range in the region south of Sydney and east of Horsham, Victoria.

Regional distribution: Uncommon migrant. The species has been recorded in Royal National Park (D. Andrew *pers. comm;* NPWS database; Australian Museum Database). The Swift Parrot is not common in western Sydney, but individuals are recorded there each year (NPWS unpublished).

Local distribution: This species was not recorded during the present study. Because the Swift Parrot is migratory and nests in Tasmania during summer, it was not possible to target this species during the survey period. Neither AXIS/Australian Museum Business Services (1995) nor Phillips *et al.* (1996) detected this species on or adjacent to Holsworthy. However, the Swift Parrot has been recorded from O'Hares Creek catchment by the Illawarra Bird Observers Club recently (C. Brandis, Illawarra Bird Observers Club *pers. comm.*) and in Campbelltown by A. Leishman in 1983 (Leishman 1994).

1.8.1.3.2 Environmental pressures

Environmental pressures on this species and its habitat include: loss of hollow-bearing trees for nesting (Tasmania), loss of habitat due to clearing, loss of winter-flowering eucalypts (mainland), possibly competition for nectar resources with the introduced Honey Bee, competition for nest hollows with Starlings.

1.8.1.3.3 Critical habitat

This gregarious parrot breeds in eucalypt forests in eastern and northern Tasmania and over-winters in south-eastern mainland Australia (Garnett 1992). It is usually found in small groups (2 or more) but is associated with larger flocks (up to 30 individuals) where eucalypts are flowering in profusion. Individuals concentrate wherever winter-flowering species such as Red Ironbark, Yellow Gum, White Box, Swamp Gum and Manna Gum occur. The box-ironbark forests west of the Dividing Range are particularly favoured by parrots. They feed on nectar, pollen and lerp as well as on fruit and seeds of native and exotic plants in suburban environments. On the mainland movements are nomadic and irruptions in NSW are related to a great abundance of lerp.

The majority of sightings in NSW have been in coastal eucalypt forest (NPWS Database). This species may occur on the Holsworthy site between March and September where it would be restricted to feeding on autumn- and winter-flowering eucalypts such as Ironbark or Forest Red Gum and lerps. Stands of Mahogany Gum, Blue Gum and Forest Red Gum favoured by lerps are found mostly in the north-eastern corner of the study area (G. Leonard *pers. comm.*).

1.8.1.3.4 Sensitivity to habitat modification

On the Australian mainland, this species is sensitive to the loss of winter-flowering eucalypts; loss of these may impact upon the regional viability of populations. It is especially sensitive to the removal of trees that provide copious amounts of nectar - these tend to be older trees. Garnett (1992) cautions that "even individual trees may be important" to this species. The replacement of extensive woodland areas with fragmented "edge" habitats easily dominated by aggressive bird species has also probably contributed to their decline.

1.8.1.3.5 Effects of proposed activities

Direct impacts of airport construction on this species are likely to be habitat loss and fragmentation, and loss of winter flowering eucalypts. Option A will result in the loss of 308 ha of Grassy Forest habitat. Option B will result in the loss of 10.4 ha of Grassy Forest. Indirect impacts of airport construction are likely to include altered fire regime and competition for nectar resources with the introduced Honey Bee.

The Swift Parrot has specific habitat requirements, is highly mobile and nomadic. The Swift Parrot is considered an uncommon migrant in Western Sydney but individuals are recorded there each year. The significance of the Holsworthy site to this species is unknown.

The impact of the airport development on this species is therefore considered to be unknown.

1.8.1.3.6 Ability of species/habitat to recover

Insufficient information. As the trees which produce most nectar and flowers tend to be the largest trees, the time taken for these to regenerate may be 100+ years. Nomadic populations are likely to recover provided that suitable habitat is maintained around the airport development.

1.8.1.3.7 Amelioration measures

Minimise habitat fragmentation by careful siting of proposed transport and services corridors.

1.8.1.3.8 Known to occur in nearby conservation reserves

Unknown. It is unlikely that critical resources (*i.e.* food trees) on the mainland are adequately resrved within its range.

1.8.1.4 Eastern Bristlebird

No decline was noted for this species up to 1987 (Robinson 1994). Population is estimated at 5000 individuals.

Nationally, this species is listed as Vulnerable (Schedule 2, *Endangered Species Protection Act 1992*; ANCA 1991). Listed in Schedule 1 of the *Threatened Species Conservation Act 1995*. Classed as "uncommon; resident" by Morris *et al.* (1981). Considered to be "vulnerable" nationally by Garnett (1992).

1.8.1.4.1 Distribution

Statewide distribution: Patchy distribution; north-east NSW (Tweed Range), south-east NSW (Kuringai Chase NP, Barren Grounds NR/Budderoo NP, Jervis Bay NR, Nadgee to Mallacoota).

Regional distribution: Occurs in restricted habitats (heaths and heathy woodlands) on the tablelands and Illawarra coastal plains. Nearest population is at Barren Grounds Nature Reserve approximately 70 kms to the south. The species has been recorded in the Campbelltown area (Sydney Pre-history Group 1983) and in the Woronora Catchment (Sydney Water Database).

Local distribution: This species was not recorded during the present study although it was targeted using a tape call-back survey technique. Although its presence cannot be ruled out, J. Baker concluded that Holsworthy was unlikely to provide suitable habitat for this species. This species was not detected by AXIS/Australian Museum Business Services (1995) or by Phillips *et al.* (1996). Historical records exist for Maddens Plains (J. Baker, University of Wollongong *pers. comm.*).

1.8.1.4.2 Environmental pressures

Environmental pressures on this species and its habitat include: loss of habitat, unsuitable fire regimes, grazing, weed invasion and predation.

1.8.1.4.3 Critical habitat

The Eastern Bristlebird is found in a restricted area of south-eastern Australia where it is primarily associated with coastal heath (Blakers *et al.* 1984). It occurs in rank vegetation bordering on heathland in coastal and mountain environments South of Sydney, it prefers woodland with a tussocky understorey bordering heath. This species forages mainly on the ground and in the litter, taking insects and fruit. It is sedentary.

Populations of Eastern Bristlebirds in southern New South Wales have been recently studied by Baker (Baker 1992, Baker 1996). Eastern Bristlebird habitat is characterised by dense layers of ground cover and vegetation to at least one metre in tall heathland, mallee heathland, shrubland, woodland and forest (Baker 1992, Lamb *et al.* 1993, Baker 1996, Baker and Whelan 1996). Although the present study did not measure vegetation attributes, J. Baker did not consider heathland within the Holsworthy site to be dense enough for this species. However, many of the bird species detected during the study were characteristic of vegetation types occupied by Eastern Bristlebirds elsewhere (e g Chestnut-rumped Heathwren, Tawny-crowned Honeyeater).

1.8.1.4.4 Sensitivity to habitat modification

Populations of this species are small and isolated so that the probability of recolonisation is low. This species would be sensitive to removal of suitable coastal heathland habitat through clearing or inappropriate burning regimes In the longer term, it may be affected by habitat degradation through weed invasion and by predation by introduced carnivores such as the cat. As its dispersal abilities appear limited, it is probably sensitive to habitat fragmentation.

1.8.1.4.5 Effects of proposed activities

Direct impacts of airport construction on this species are likely to be habitat loss and fragmentation and unsuitable fire regimes. Indirect impacts of airport construction are likely to include weed invasion and predation.

The Eastern Bristlebird occurs in restricted habitat types with patchy distribution and is highly mobile.

The Eastern Bristlebird is not likely to occur on the site so the impact for this species is undetermined.

1.8.1.4.6 Ability of species/habitat to recover

Preferred heathland habitat would take from 2-9 years to regenerate. The species is unlikely to recover in cleared areas of the proposed airport development.

1.8.1.4.7 Amelioration measures

Minimise habitat fragmentation by careful siting of proposed transport and services corridors.

1.8.1.4.8 Adequate representation within conservation reserves

Known populations of Eastern Bristlebirds are all protected within reserves (J. Baker, University of Wollongong *pers. comm.*).

1.8.1.5 Brush-tailed Rock-wallaby

Nationally, considered to be Vulnerable (Schedule 2 - Vulnerable, *Endangered Species Protection Act 1992*; ANCA 1991). Listed in Schedule 1 of the *Threatened Species Conservation Act 1995*. Kennedy (1992) lists this rock-wallaby as "vulnerable", with a decline of 50-90% in range.

1.8.1.5.1 Distribution

Statewide distribution: Suitable habitat along the Great Divide.

Regional distribution: Restricted to steep, rocky areas. Have been recorded along the Nepean River (R. Close, University of Western Sydney *pers. comm.*). Historically recorded in the Woronora Catchment area (Sinclair

Knight 1994) but it is unknown if populations still persist here. The nearest known extant colonies are at Kangaroo Valley and Jenolan (M. Eldridge, Macquarie University *pers. comm.*).

Local distribution: This species was not recorded positively during the present survey; however, a possible sighting was made at Site A. Further searches were made in the area by Dr Robyn Delaney; scats were collected but these appeared to be from wallaroos. The Brush-tailed Rock-wallaby was not recorded from the site by AXIS/Australian Museum Business Services (1995). Phillips *et al.* (1996) recorded a 'probable' sighting of two individuals along the easterly aspect of the Georges River north-east of Kentlyn in 1994. The species has been recorded in the Woronora Catchment (Sydney Water Database). Historically, the species was recorded throughout the Hawkesbury sandstone areas of Sydney (Lunney *et al.* in press) including the upper reaches of the Georges River (Kevin Mills and Associates 1989), and in Royal National Park (R. Close, University of Western Sydney *pers. comm.*).

1.8.1.5.2 Environmental pressures

The environmental pressures on the species and its habitat include: alterations to foraging habitat through altered burning regimes, predation by introduced predators, competition from goats for refuges and food.

1.8.1.5.3 Critical habitat

The Brush-tailed Rock-wallaby occupies suitable rocky areas in inland and coastal sclerophyll forests with native or introduced grass cover. Brush-tailed Rock Wallabies require cave sites with a relatively high number of ledges, caves and routes from the cliff top onto the cliff face, usually by means of steep, narrow cracks or chimneys. Preferred sites usually have a northerly aspect (Short 1982). Brush-tailed Rock-wallabies feed predominantly on grasses and forbs but also browse on adjacent ridge and slope habitats. Male rock-wallabies defend the diurnal refuges of several females (Joblin 1983). Home ranges measure about 15 ha and overlap broadly although den sites are exclusive (Short 1982). Brush-tailed Rock-wallabies are predominantly nocturnal, returning to their shelters during the heat of the day. Juveniles of both sexes leave the natal home range within six months of independence (Joblin 1983).

The Brush-tailed Rock-wallaby possibly occurs on the Holsworthy site as some suitable habitat occurs along the rocky escarpments (R. Close, University of Western Sydney *pers. comm.*, R. Delaney *pers. comm.*).

1.8.1.5.4 Sensitivity to habitat modification

This species is potentially vulnerable to habitat alteration caused by fire or predation which acts to reduce food available adjacent to shelters (Joblin 1983). Existing populations of Brush-tailed Rock-wallabies tend to be isolated and disjunct (up to several hundred kilometres apart). Any factors which increase the isolation and/or reduce the successful migration between populations would make population extinction more likely (Hill 1991). Small populations are particularly vulnerable to stochastic events such as fire and drought. This and their poor recovery potential make this species particularly susceptible to regional extinction.

A number of species of rock-wallabies have declined in historic times and this is mainly attributed to feral predators, especially foxes (Calaby 1966, Kinnear *et al.* 1988) and cats (Spencer 1991); however foraging habitat may have been reduced due to introduced grazing competitors and changed fire regimes. Generally, the actual rocky habitat can not be physically modified because of its inaccessibility. Brush-tailed Rock-wallabies may aslo be sensitive to fire; Ecotone Ecological Consultants (1995) report that a colony in the Watagan Mountains temporarily disappeared after a moderately hot fire. Individuals were recorded at the site two years later although the exact timing of recolonisation is unknown.

1.8.1.5.5 Effects of the proposed activity

Direct impacts of airport construction on this species are likely to be alterations to foraging habitat through altered fire regimes. Option A will result in the loss of 2339.8 ha of Woodland/heath and 1454.3 ha of Gully Forest. Option B will result in the loss of 1655.6 ha of Woodland/heath and 1087.5 ha of Gully Forest. Indirect impacts of airport construction are likely to include predation and competition with introduced goats for refuges and food.

The Brush-tailed Rock Wallaby has specific habitat requirements and is mobile. Regional distribution of this species is restricted to steep rocky areas. A number of unconfirmed sightings of the species have been made at the site and the species possibly occurs at the Holsworthy in areas of suitable habitat. The significance of the Holsworthy site to this species is unknown.

The impact of the airport development on this species is therefore considered to be unknown.

1.8.1.5.6 Ability of species/habitat to recover

Little is known about the ability of the Brush-tailed Rock-wallaby to recover from disturbance.

1.8.1.5.7 Amelioration measures

Minimise habitat fragmentation by careful siting of proposed transport and services corridors; feral animal control and monitoring; pre-construction surveys with the aim of undertaking monitoring studies.

1.8.1.5.8 Adequately represented in conservation areas

Not known from any conservation reserves in the area. All known colonies in the area are on private land.

1.8.2 State Significance

1.8.2.1 Green and Golden Bell Frog

The Green and Golden Bell Frog was once common in NSW (Cogger 1960) but has declined in recent years. The cause of this decline is unknown. Predation of tadpoles and eggs by the exotic Mosquito Fish (*Gambusia affinis)* is regarded as one possible cause (Mahoney 1993).

Listed as Endangered in Schedule 1 of the *Threatened Species Conservation Act 1995*. Recent reports (Tyler 1993, 1994; Mahony 1993) indicate a decline in a number of populations throughout its range, particularly in NSW.

1.8.2.1.1 Distribution

Statewide distribution: Eastern and south-eastern NSW.

Regional distribution: Rare and patchy. Following 1990 the species has been recorded from only 21 sites in the greater Sydney area (White 1996). The main population centres are located at Kurnell Peninsula and the Liverpool / Georges River area (White 1996). Half of the known locations are from the Sydney Metropolitan Area.

Local distribution: Unknown. Likely to be rare. Not recorded from or adjacent to the Holsworthy site during the present survey or recent studies in the area (AXIS/Australian Museum Business Services 1995; Phillips *et al.* 1996; Harlow and Taylor 1995; Engel 1996a,b). It was last recorded in O'Hares Creek Catchment in 1987 by F. Lemckert and is possibly no longer extant in the catchment (Phillips *et al.* 1996). Historically it is known from Darkes Forest and Maddens Creek Crossing. This species was recorded at Williams Creek at Holsworthy in 1993 (White 1996); apparently the species was 'common' in Williams Creek (where it intersects Heathcote Road) 25 years ago (D. Sheeram, amateur naturalist *pers. comm.*). In the same year, small populations of this frog were also recorded at East Hills and Hammondville (White 1996).

1.8.2.1.2 Environmental pressures

Environmental pressures on the species and its habitat are poorly understood but may include: loss of or alteration to suitable habitat, predation of eggs and tadpoles by introduced Mosquito Fish, trampling by cattle.

1.8.2.1.3 Critical habitat

This is a largely low altitude, aquatic species which lives among the vegetation associated with permanent streams, dams, swamps and where low lying areas are inundated (Cogger 1996). The Green and Golden Bell Frog is considered a rapid coloniser of suitable new locations, including artificial habitats (Ecotone Ecological Consultants 1995). Male frogs call during the summer breeding season whilst floating on the water surface amongst the submerged vegetation (Ecotone Ecological Consultants 1995). Generally this species occurs in more open sites with substantial sunlight infiltration including large permanent wetlands and large backwaters or billabongs associated with the floodplains of larger water courses. This species basks in exposed sites during the day.

The species seems to no longer occur at inland sites although a population did exist on the southern tablelands around Canberra (Osborne 1990) and on the northern tablelands (Cogger 1996). Most of the remaining known populations occur within several kilometres of the east coast. The status of all Green and Golden Bell Frog populations warrants monitoring.

1.8.2.1.4 Sensitivity to habitat modification

Significant threats to the Green and Golden Bell Frog are the destruction of habitat and modification of drainage causing excessive sedimentation in existing waterways. Grazing may also impact upon breeding habitats of this species.

1.8.2.1.5 Effects of proposed activities

Direct impacts of airport construction on this species are likely to be habitat loss and fragmentation. Option A will result in the loss of 14.6 ha of Sedgeland and Heath/swamp complex. Option a will result in the total loss of 24 km of streamline habitat. Option B will result in the loss of 18.7 ha of Sedgeland and Heath/swamp complex. Option B will result in the total loss of 26 km of streamline habitat. Indirect impacts of airport construction are likely to be polluted runoff and predation of eggs and tadpoles by the introduced Mosquito Fish.

The Green and Golden Bell Frog has specific habitat requirements but is considered a rapid coloniser of suitable habitats including artificial habitats. The species is not highly mobile. The Green and Golden Bell Frog has been recorded on the northern edge of the Holsworthy site, however the significance of the site for this species is unknown. The regional distribution of this species is assessed as rare and patchy.

The impact of the airport development on this species is therefore considered to be unknown.

1.8.2.1.6 Ability of species/habitat to recover

The time taken for preferred habitat to recover is unknown. Although they have been known to inhabit disturbed habitats habitat disturbance may lead to species decline in the longer term (Ferraro and Burgin 1993a, 1993b). The disappearance of this species from many localities where it was once known suggests a low recovery potential.

1.8.2.1.7 Amelioration measures

Minimise habitat fragmentation by careful siting of proposed transport and services corridors; construction of river and stream crossings so as to maintain downstream water quality; on site education program for construction workers in the identification of rare and vulnerable fauna species; minimise local trenching work; strict adherence to erosion and sediment control measures; minimise the period that trenches are open in key habitat areas; checking of open trenches in or near suitable habitat for trapped individuals.

1.8.2.1.8 Known to occur in nearby conservation reserves

The Green and Golden Bell Frog is poorly conserved in NSW. Post-1990 records indicate that it occurs in only nine conservation reserves around the state (White 1996). The closest of these to Holsworthy is Botany Bay National Park. It was last recorded in Royal National Park in 1980 and in O'Hares Creek Catchment in 1987 (NPWS Database). None of the known populations in Western Sydney occur within conservation reserves.

1.8.2.2 Giant Burrowing Frog

Listed as Vulnerable in Schedule 2 of the *Threatened Species Conservation Act 1995.*

1.8.2.2.1 Distribution

Statewide distribution: Restricted distribution south of Olney State Forest, extending along coast and Great Dividing Range to the Eastern Highlands of Victoria; not found on the Cumberland Plain within the Sydney Sandstone Basin (J. Recsei, Macquarie University *pers. comm.*). Within this area, it is strongly associated with upper drainage lines and ridgetops.

Regional distribution: Very rare; patchy distribution strongly associated with sandstone substrates.

Local distribution: Positive identification of this species was made at three locations (Sites E,H,M) within the Holsworthy site. A number of unconfirmed reports of tadpoles were made by other workers on the EIS team (Sites

O,R.L) Giant Burrowing Frogs were recorded at two sites by AXIS/Australian Museum Business Services (1995); they were recorded at three sites in O'Hares Creek Catchment by Harlow and Taylor (1995). The species was not detected from Wedderburn (Phillips *et al.* 1996). It is likely to inhabit perched wetlands within the Holsworthy site as it was recorded by R. Payne in this habitat type on the Central Coast (in Phillips *et al.* 1996). Records of this species also exist for Royal and Heathcote National Parks (NPWS Database; Australian Museum Database) and for the Woronora Catchment area (Sydney Water Database).

1.8.2.2.2 Environmental pressures

Environmental pressures on this species and its habitat include: housing and other development, forest clearance, high frequency of fires, urban runoff, road maintenance and road kills (J. Recsei, Macquarie University *pers. comm.*).

1.8.2.2.3 Critical habitat

The Giant Burrowing Frog can be found in a range of habitat types including wet sclerophyll forest and tall open forest. In these areas it inhabits hanging swamps and perennial non-flooding creeks (Webb 1993). This species is also known to occupy ephemeral to permanent artificial drainage lines and culverts along roads (J. Recsei, Macquarie University *pers. comm.*). Population densities of breeding colonies are likely to be extremely low and may consist of as few as two or three breeding pairs (J. Recsei, Macquarie University *pers. comm.*). Males call from burrows constructed in sandy banks and egg masses are deposited in standing or flowing water (Gillespie 1990).

This species appears to consist of two geographically distinct populations (Gillespie 1990). The northern population ranges from the Watagan Mountains to Narooma Recently, several breeding populations (based on the identification of tadpoles) have been detected in Morton National Park on the western edge of 12 Mile Road (Meredith *et al.* 1995). The northern population of the Giant Burrowing Frog occurs in heath and woodland growing on sandstone; this habitat type is common throughout the Holsworthy site.

1.8.2.2.4 Sensitivity to habitat modification

This species would be sensitive to loss of or alteration to its stream and breeding habitats. It is also sensitive to removal of forest cover and a high frequency of fires. Urban runoff accompanied by its associated pollutants have been recorded to impact of breeding sites of this species. Tadpoles are now absent from drainage lines affected by urban runoff and siltation (NPWS unpublished).

1.8.2.2.5 Effects of proposed activities

Direct impacts of airport construction on this species are likely to be habitat loss and fragmentation and increased fire frequencey Option A will result in the loss of 308 ha of Grassy forest, 2339.8 ha of Woodland/heath, 14.6 ha of Heath/swamp Complex and 1454.3 ha of Gully Forest. Option A will result in the loss of 24 km of streamline habitat. Option B will result in the loss of 10.4 ha of Grassy forest, 1655.6 ha of Woodland/heath, 18.7 ha of Heath/swamp Complex and 1087.5 ha of Gully Forest. Option B will result in the loss of 26 km of streamline habitat. Indirect impacts of airport construction are likely to be polluted runoff and roadkills.

The Giant Burrowing Frog occupies heath and woodland habitats both of which are widespread at Holsworthy. The species is not highly mobile and has been recorded in both options within the Holsworthy site. The regional distribution of this species is considered very rare and patchy associated with sandstone substrates.

The impact of the airport development on this species is therefore considered to be high regional.

1.8.2.2.6 Ability of species/habitat to recover

Unknown. Due to the very low population densities, recovery potential of this species is likely to be extremely limited (J. Recsei, Macquarie University *pers. comm.*).

1.8.2.2.7 Amelioration measures

Minimise habitat fragmentation by careful siting of proposed transport and services corridors; construction of river and stream crossings so as to maintain downstream water quality; on site education program for construction workers in the identification of rare and vulnerable fauna species; minimise local trenching work; strict adherence to erosion and sediment control measures; minimise the period that trenches are open in key habitat areas; checking of open trenches in or near suitable habitat for trapped individuals.

1.8.2.2.8 Known to occur in nearby conservation reserves

The Giant Burrowing Frog is found in Royal and Heathcote National Parks (NPWS unpublished).

1.8.2.3 Red-crowned Toadlet

Listed as Vulnerable in Schedule 2 of the *Threatened Species Conservation Act 1995*. Ecological specialist which requires ephemeral streams in Sydney Sandstone.

1.8.2.3.1 Distribution

Statewide distribution: Restricted; the core of the range generally considered to be confined to Hawkesbury Sandstone within a radius of 160 km of Sydney (Cogger 1996; Heatwole *et al.* 1995; K. Thumm, University of Newcastle, *pers. comm.*). May be more widespread than core range suggests with populations peripheral to the Sydney region being rare (Heatwole *et al.* 1995).

Regional distribution: Patchy distribution throughout Sydney; associated with upper laterals of ephemeral creeks and sandstone substrates.

Local distribution: This species has been recorded during the present survey on six occasions (including Sites DD, BB, U, K, F). It was recorded at Holsworthy by AXIS/Australian Museum Business Services (1995), in O'Hares Creek Catchment by Harlow and Taylor (1995) and in the Mill Creek area by C. Hamilton (amateur herpetologist *pers. comm.*). It was not detected in Wedderburn (Phillips *et al.* 1996). The Red-crowned Toadlet is likely to be uncommon to moderately common within its preferred habitat.

1.8.2.3.2 Environmental pressures

Environmental pressures on this species and its habitat include: housing developments, weed infestation, stormwater runoff, depletion of bush rock, fire trail maintenance, fire hazard reduction and turbo mowing (K. Thumm, University of Newcastle *pers. comm.*).

1.8.2.3.3 Critical habitat

The Red-crowned Toadlet appears to be almost totally confined to Hawkesbury Sandstone habitats (Robinson 1994). In these areas, it is most often encountered in dry sclerophyll forest. Breeding aggregations of male Red-crowned Toadlets are found in leaf litter, grass and other debris beside ephemeral creeks and drainage lines, generally in sandstone areas (Cogger 1996). Dispersing and foraging individuals are found under surface debris such as rocks and logs.

Apart from an outlier population at Point Lookout in northern NSW, this species is restricted to an area within about 200 kilometres of Sydney (NPWS Database, Australian Museum Database). The south-easternmost record of this species is from Barren Grounds Nature Reserve (K Thumm, University of Newcastle *pers. comm.*).

1.8.2.3.4 Sensitivity to habitat modification

Erosion, siltation and pollution of lateral creeks is likely to reduce the availability of breeding sites for this species. In addition a frequent fire regime may impact upon local population as this species lives in leaf litter. Disturbance through the removal of bushrock is likely to greatly reduce the capacity of a habitat to support breeding populations.

1.8.2.3.5 Effects of proposed activities

Direct impacts of airport construction on this species are likely to be habitat loss and fragmentation and increased fire frequencey. Option A will result in the loss of 308 ha of Grassy Forest, 2339.8 ha of Woodland/heath and 14.6 ha of Heath/swamp Complex. Option B will result in the loss of 10.4 ha of Grassy Forest, 1655.6 ha of Woodland/heath and 18.7 ha of Heath/swamp Complex. Indirect impacts of airport construction are likely to be polluted runoff and associated reduction in breeding sites.

The Red-crowned Toadlet has very specific habitat requirements and is widespread at the Holsworthy site. The species is not highly mobile. Regional distribution of this species is considered patchy and associated with specific habitat requirements.

The impact of the airport development on this species is therefore considered to be high regional.

1.8.2.3.6 Ability of species/habitat to recover

Reproductive success of the Red-crowned Toadlet is extremely low (K.Thumm University of Newcastle *pers. comm*.). In addition, its restricted distribution and regional rarity indicate that its ability to recover after disturbance is likely to be severely limited.

1.8.2.3.7 Amelioration measures

Minimise habitat fragmentation by careful siting of proposed transport and services corridors; construction of river and stream crossings so as to maintain downstream water quality; on site education program for construction workers in the identification of rare and vulnerable fauna species; minimise local trenching work; strict adherence to erosion and sediment control measures; minimise the period that trenches are open in key habitat areas; checking of open trenches in or near suitable habitat for trapped individuals; pre-construction surveys with the aim of undertaking monitoring studies.

1.8.2.3.8 Known to occur in nearby conservation reserves

Unknown. Records exist for Royal and Heathcote National Parks (NPWS Database; Australian Museum Database).

1.8.2.4 Heath Monitor

Listed as Vulnerable in Schedule 2 of the *Threatened Species Conservation Act 1995*. Considered to be "rare or insufficiently known" by Cogger *et al.* (1993).

1.8.2.4.1 Distribution

Statewide distribution: Currently the population within NSW is considered to be more isolated than that of the other states (Cogger 1996). The species has been found at restricted localities from just north of the Hawkesbury River to Cooma (Swan 1990; Shea 1994).

Regional distribution: Heath Monitors have been found in Morton National Park (Meredith *et al.* 1995), in Kurringai-Chase National Park (G. Swan, Australian Museum *pers. comm.*), and in Royal National Park (D. Andrew, NPWS *pers. comm*.). A Heath Monitor has been recorded from the southern end of Dharawal State Recreation Area by C. Hamilton (amateur herpetologist *pers. comm.*).

Local distribution: Unknown; this species was noted as a possible record AMG 311800/6227100 during the present survey by Deryk Engel. The Heath Monitor was recorded by Phillips *et al.* (1996) just outside the Wedderburn study area and was considered likely to occur at Wedderburn. It has also been recorded in Heathcote National Park (D. Engel, Lesryk Environmental Consultants *pers. comm.*) and between Heathcote Road and the Georges River (D. Sheeram, amateur herpetologist *pers. comm.*). Harlow and Taylor (1995) did not record this species in the O'Hares Creek Catchment but concluded that it was likely to occur there in low numbers.

1.8.2.4.2 Environmental pressures

Environmental pressures on this species and its habitat include: loss of habitat through clearing or excessive use of fire, loss of termite mounds.

1.8.2.4.3 Critical habitat

The distribution of this species ranges from south-west Western Australia along the coast to South Australia, Victoria and NSW (Cogger 1996). Heath Monitors are largely restricted to heath (G. Swan, Australian Museum *pers. comm.*) and have a large home range of between 1.7 - 43.7 ha (Green and King 1993). Eggs are laid in termite mounds and it has been suggested that the female returns to the oviposition site and digs out the eggs to release the fully developed young (Ehmann *et al.* 1991). Hence termite mounds are a critical component of the habitat of this species.

Suitable woodland/heath habitat occurs throughout the Holsworthy study area.

1.8.2.4.4 Sensitivity to habitat modification

This species would be sensitive to removal of its preferred habitat.

1.8.2.4.5 Effects of proposed activities

Direct impacts of airport construction on this species are likely to be habitat loss and fragmentation and an increase in fire frequency. Option A will result in the loss of 2339.8 ha of Woodland/heath and 14.6 ha of Heath/swamp Complex. Option B will result in the loss of 1655.6 ha of Woodland/heath and 18.7 ha of Heath/swamp Complex. Indirect impacts of airport construction are likely to be loss of termite mounds.

The Heath Monitor has general habitat requirements. The species is moderately mobile and an unconfirmed sighting has been made at the Holsworthy site. Regional distribution of this species is not known.

The impact of the airport development on this species is therefore considered to be unknown.

1.8.2.4.6 Ability of species/habitat to recover

Preferred heathland habitat would take from 3-5 years to regenerate where this was allowed. This species is likely to recover provided that suitable habitat is maintained around the development area and links to other natural areas such as Heathcote and Royal National Park are maintained.

1.8.2.4.7 Amelioration measures

Minimise habitat fragmentation by careful siting of proposed transport and services corridors; on site education program for construction workers in the identification of rare and vulnerable fauna species; minimise local trenching work; minimise the period that trenches are open in key habitat areas; checking of open trenches in or near suitable habitat for trapped individuals.

1.8.2.4.8 Known to occur in nearby conservation reserves

Unknown. Heath Monitors are known to occur in Heathcote and Royal National Parks (D. Engel Lesryk Environmental Consultants *pers. comm.*; D. Andrew, NPWS *pers. comm*).

1.8.2.5 Australasian Bittern

Listed as vulnerable on Schedule 2 of the *Threatened Species Conservation Act 1995*. Considered to be Insufficiently known by Garnett (1992).

1.8.2.5.1 Distribution

Statewide distributions: Most numerous in the Murray-Darling Basin (Morris *et al.* 1981).

Regional distribution: This species is not easily observed and may be more common than expected. It has been recorded from the Sutherland/Kurnell Peninsula area (NPWS Database).

Local distribution: This species has not been recorded within or adjacent to the study site but may occur there where suitable habitat exists.

1.8.2.5.2 Environmental pressures

Environmental pressures on the species and its habitat include: loss of wetland habitats through drainage, salinisation of wetland habitats, grazing and trampling of wetlands, alteration to water quality, burning and introduced predators.

1.8.2.5.3 Critical habitat

The Australasian Bittern utilises permanent shallow, vegetated freshwater or brackish swamps dominated by reeds or sedges and may also occur in ephemeral wetlands. It prefers extensive wetlands with an abundance of vegetation, including a mixture of tall and short reeds for nesting. It is a cryptic and highly secretive species which occurs alone or in small groups in extensive **dense** reedbeds. It breeds in loose colonies or territorial pairs. This species feeds on insects, small fish and other aquatic life in the shallow margins of wetlands (Marchant and Higgins 1990, Emison *et al.* 1987). Nests consist of a saucer of reeds built over water. It is nomadic in its movements and requires drought refuges. Irruptions are known to occur in times of drought.

1.8.2.5.4 Sensitivity to habitat modification

This species is sensitive to drainage or salinisation of swamp habitats. It is also sensitive to grazing and trampling of wetland vegetation which it requires for shelter and to alteration or loss of drought refuges

1.8.2.5.5 Effects of proposed activities

Direct impacts of airport construction on this species are likely to be habitat loss and an increase in fire frequency. Option A will result in the loss of 14.6 ha of Sedgeland. Option B will result in the loss of 18.7 ha of Sedgeland. Indirect impacts of airport construction are likely to be a reduction in water quality.

The Australasian Bittern has specific habitat requirements. The species is highly mobile and due to its secretive habits, may be more common than expected Limited areas of suitable habitat occur on the Holsworthy site Regional distribution of this species is not known.

The impact of the airport development on this species is therefore considered to be unknown.

1.8.2.5.6 Ability of species/habitat to recover

Unknown.

1.8.2.5.7 Amelioration measures

Construction of river and stream crossings so as to maintain downstream water quality; strict adherence to erosion and sediment control measures; minimise habitat fragmentation by careful siting of proposed transport and services corridors.

1.8.2.5.8 Known to occur in nearby conservation reserves

Unknown.

1.8.2.6 Bush Stone-curlew

Listed as Endangered (Schedule 1 on the *Threatened Species Conservation Act 1995*). Considered to be "endangered" by Garnett (1992). Classified as Priority 1 (Threatened) because of its dramatic decline in numbers and distribution by Smith (1991).

1.8.2.6.1 Distribution

Statewide distribution: Mainly east and south, west to the Barwon River and Darling River; along Murray-Darling system, generally absent from coast and tablelands.

Regional distribution: Poorly known.

Local distribution: Not known; this species was not recorded during the present study. Furthermore, it was not recorded on the Holsworthy site or adjacent to it during recent surveys (AXIS/Australian Museum Business Services 1995; Phillips *et al.* 1996; Leishman 1994). It was recorded in the Wedderburn area by NPWS in 1990. There are also recent (last five years) records from west of Liverpool (A. Leishman, Royal Botanic Gardens *pers. comm.*) This species could possibly occur on the Holsworthy site.

1.8.2.6.2 Environmental pressures

Environmental pressures for this species and its habitat include: loss of woodland habitat through clearing, predation by foxes, alteration of nesting habitat through grazing and burning, removal of leaf litter and fallen timber.

1.8.2.6.3 Critical habitat

The Bush Stone-curlew occupies open forests and woodlands with grassy understoreys. Optimum habitat often includes short and sparse ground cover, no shrub layer and abundant leaf litter and fallen timber (Johnson and Baker-Gabb 1994). It feeds nocturnally on seeds, fruits, insects and spiders, invertebrates and small vertebrates. It often drinks, wades and forages in water where available. It nests and forages on the ground in habitats containing abundant grasses and leaf litter (Schodde and Tidemann 1986). It occurs in small flocks during the non-breeding season and forms breeding pairs generally at the same sites year after year. It requires fallen timber or tree cover for daytime roosting (camping) sites. Bush Stone-curlews are sedentary and monogamous; breeding pairs may occupy 10-20 ha territories while non-breeding groups range over 100 sq km (Schodde and Mason 1980, in Smith 1991). Eggs are laid in a shallow scrape on bare ground, usually sheltered or partly concealed amid fallen timber but with a clear view of the surrounding area. Nesting sites may be used year after year.

Suitable Grassy Woodland habitat occurs in the north-west of the Holsworthy study area.

1.8.2.6.4 Sensitivity to habitat modification

Although the Bush Stone-curlew was once widespread and abundant, there has been a dramatic decline in its numbers in southern Australia during historical times (Smith 1991). It is sensitive to loss of woodland, grassland and wetland habitats. It is highly sensitive to the removal of fallen timber; in northern Victoria, Thick-knees deserted sites where they had previously occurred regularly after green timber and fallen debris had been removed (Johnson and Baker-Gabb 1994). It is also sensitive to any activities which facilitate predation by foxes. Any activities which increase levels of human disturbance may be detrimental.

1.8.2.6.5 Effects of proposed activities

Direct impacts of airport construction on this species are likely to be habitat loss and an increase in fire frequency. Option A will result in the loss of 308 ha of Grassy Forest. Option B will result in the loss of 10.4 ha of Grassy Forest. Indirect impacts of airport construction include increased predation.

The Bush Stone-curlew has specific habitat requirements, it is highly mobile but is sensitive to habitat loss. Regional distribution of this species is not known.

The impact of the airport development on this species is therefore considered to be unknown.

1.8.2.6.6 Ability of the species/habitat to recover

The amount of time required for regeneration of suitable habitat for this species is unknown. This species can occur in highly disturbed habitats subject to intensive agriculture, silviculture or other development such as golf courses. It is also a highly mobile species and is able to use cleared habitats for foraging.

In the longer term, this species may be affected by increased access of introduced predators such as the fox. Individuals are apparently able to persist in many wheat-growing areas and in areas where there is a high density of foxes; whereas adults are able to escape predation, chicks and eggs are vulnerable (Johnson and Baker-Gabb 1994).

1.8.2.6.7 Amelioration measures

Minimise habitat fragmentation by careful siting of proposed transport and services corridors.

1.8.2.6.8 Known to occur in nearby conservation reserves

Unknown.

1.8.2.7 Black Bittern

The Black Bittern is listed as a Vulnerable in Schedule 2 of the *Threatened Species Conservation Act 1995*. It is considered an uncommon resident in NSW by Morris *et al.* (1981).

1.8.2.7.1 Distribution

Statewide distribution: Wet coastal areas in eastern NSW.

Regional distribution: The species was considered a rare visitor to Cumberland Plain woodlands from 1930 to 1960 (Keast 1995). The Black Bittern was a regular summer breeder in the Hawkesbury area during the 1960s (SFNSW 1995), however the species is now considered rare in the region. It was recorded in Castlereagh Sate Forest in 1972, 1973 and 1974 and mist netted in 1992 and 1993 (Keast 1995).

Local distribution: Unknown, this species was not recorded during the current study, however wetland habitat not surveyed during this study may provide suitable habitat for this species. The Black Bittern was recorded in Mill Creek catchment near the Georges River and close to the eastern boundary of the Holsworthy site in 1994 (Engel and Chafer 1994). It is considered to be rare in Royal National Park (D. Andrew, NPWS *pers. comm*).

1.8.2.7.2 Environmental Pressures

Environmental pressures for this species and its habitat include habitat loss due to: clearing of woodland; draining of wetlands; grazing; burning; increased introduced predators; and pollution of waterways. Decline in species numbers in the Hawkesbury area were recognised when the local swamp was partially drained and regular flooding ceased (SFNSW 1995), indicating that changes in the hydrological regime may impact this species.

1.8.2.7.3 Critical Habitat

The Black Bittern inhabits coastal wetlands and littoral habitats. Freshwater wetlands, fringed with dense vegetation such as Melaleuca and Casuarina are preferred (Marchant and Higgins 1990). The species will utilise billabongs, pools, and estuaries and tidal reaches of coastal creeks and rivers with fringing vegetation, which may only form a narrow band of cover (Marchant and Higgins 1990).

The species nests in trees over wetlands and watercourses in densely vegetated areas (Marchant and Higgins 1990). It will forage in low, marshy vegetation, or in shadows over shallow water and roost and rest on the ground or in leafy trees (Marchant and Higgins 1990). The species is known from woodland on the Cumberland Plain and from Castlereagh State Forest.

1.8.2.7.4 Sensitivity to Habitat Modification

Decline in species numbers have coincided with clearing for agriculture, increased salinity of rivers, grazing of waterside vegetation and siltation of wetlands (Marchant and Higgins 1990). Decline in species numbers in the Hawkesbury area were recognised when the local swamp was partially drained and regular flooding ceased (SFNSW 1995).

1.8.2.7.5 Effects of the Proposed Activity

Direct impacts of airport construction on this species are likely to be habitat loss and fragmentation and an increase in fire frequency. Option A will result in the loss of 308 ha of Grassy Forest and 14.6 ha of Sedgeland. Option B will result in the loss of 10.4 ha of Grassy Forest and 18.7 ha of Sedgeland. Indirect impacts of airport construction include increased predation, pollution of waterways and changes in the hydrological regime which lead to draining of wetlands.

The Black Bittern has specific habitat requirements and is highly mobile. Limited areas of suitable habitat occur on the Holsworthy site. This species is considered rare in the region.

The impact of the airport development on this species is therefore considered to be unknown.

1.8.2.7.6 Ability of the species / habitat to recover

The ability of the Black Bittern to recover following disturbance is unknown. Due to rarity in the region, the ability of the species to recover after disturbance is likely to be limited.

1.8.2.7.7 Amelioration Measures

Construction of river and stream crossings so as to maintain downstream water quality; strict adherence to erosion and sediment control measures; minimise habitat fragmentation by careful siting of proposed transport and services corridors.

1.8.2.7.8 Known to occur in nearby conservation reserves

Unknown; the Black Bittern has been recorded in Castlereagh State Forest in the early 1990s (Keast 1995) and has recently been recorded in Mill Creek catchment adjacent to the Holsworthy study site (Engel and Chafer 1994).

1.8.2.8 Glossy Black-Cockatoo

Listed as Vulnerable in the *Threatened Species Conservation Act 1995*. Considered to be "rare" by Garnett (1992).

1.8.2.8.1 Distribution

Statewide distribution: Lowland and highland forests of eastern NSW from Qld to Vic with isolated populations associated with inland mountain ranges.

Regional distribution: Distribution is patchy and localised, reflecting the distribution of this habitat type (Blakers *et al.* 1984; A. Morris, NSW Field Observers Club *pers. comm*).

Local distribution: Unknown; this species was not recorded during the present survey. It was not recorded by AXIS/Australian Museum Business Services (1995) but was recorded feeding on *Allocasuarina littoralis* on the Wedderburn Plateau by Phillips *et al.* (1996). The species has also been recorded from the Woronora Catchment area (Sydney Water Database). It has been recorded from the Georges River National Park (NPWS unpublished). It was not recorded in the recent biodiversity survey of Western Sydney (NPWS unpublished). Glossy Black-Cockatoos are considered to be uncommon visitors in the Campbelltown area (Leishman 1994).

1.8.2.8.2 Environmental pressures

Environmental pressures for this species and its habitat include: loss of large hollow-bearing trees for nesting, loss of casuarinas, fire.

1.8.2.8.3 Critical habitat

The Glossy Black-Cockatoo is found within a range of forests, woodlands, riparian vegetation and in partially cleared land, but prefers or reaches peak abundance in ecological old-growth forest. Its patchy distribution is due to reliance on a primary food source, the seeds from *Allocasuarina* spp. trees. *Allocasuarina torulosa, A. stricta* and *A. littoralis* are the favoured food trees in NSW. Clout (1989, in Forestry Commission of NSW 1993) showed that cockatoos actively sought out trees with greater numbers of seed cones. This species uses hollow limbs on live or dead trees for nesting, preferring deep nest hollows with wide entrances located 10-20 m above ground. It forms permanent groups of up to 10 individuals; it may roost singly or in family groups but gather into aggregations at food and water sources. Glossy Black-Cockatoos are mainly sedentary but are capable of moving long distances (more than 40 km) in order to locate suitable foraging habitat. The species is considered to be an ecological specialist.

Glossy Black-Cockatoos may occur at Holsworthy. There are extensive stands of *A. distyla* and *A. littoralis* on the site (G. Leonard *pers. comm.*) which could provide suitable habitat for Glossy Black-Cockatoos. The greatest concentrations of these stands are located on ridgetops and plateaus at Wild Cat Ridge and Wallaby Ridge in D Range, and in B, E and H Ranges, although scattered individual trees are found throughout Holsworthy.

1.8.2.8.4 Sensitivity to habitat modification

As an old-growth specialist species, the Glossy Black-Cockatoo would be highly sensitive to the removal of its preferred habitat type for the following reasons (Scotts 1994):

- It requires specialised habitat for foraging (ie. casuarinas);
- It requires specialised habitat for resting and breeding (ie. tree hollows);
- It occurs naturally in low numbers

Those species most sensitive to clearing are hollow-dependent species requiring a high density of the largest trees and where old-growth forest provides optimum habitat (Milledge *et al.* 1991). Because of its dependence on *Allocasuarina* spp., the Glossy Black Cockatoo is sensitive to the loss of foraging habitat.

1.8.2.8.5 Effects of proposed activities

Direct impacts of airport construction on this species are likely to be loss of feeding and breeding resources, habitat fragmentation and an increase in fire frequency. Option A will result in the loss of 2339.8 ha of Woodland/heath and 1454.3 ha of Gully Forest. Option B will result in the loss of 1655.6 ha of Woodland/heath and 1087.5 ha of Gully Forest. Indirect impacts of airport construction include cumulative impacts associated with loss of food resources and habitat.

The Glossy Black Cockatoo is a highly mobile species. Distribution of the species in the region is considered patchy and localised, reflecting the availability of suitable habitat. This species has been recorded from areas adjacent to Holsworthy. Large areas of suitable habitat occur at the site and the species is likely visit the area

The impact of the airport development on this species is therefore considered to be regional.

1.8.2.8.6 Ability of species/habitat to recover

Although casuarinas can invade cleared areas and are fast-growing, they may not be able to be used by cockatoos until 10 years post-clearing when they provide abundant seed (only cone-producing female trees can provide food for cockatoos). Suitable nest hollows may only be available after 200 years. This highly mobile species may recover from impacts provided that habitat is maintained around the proposed development area and if rehabilitation of casuarina habitat is undertaken.

1.8.2.8.7 Amelioration measures

Minimise habitat fragmentation by careful siting of proposed transport and services corridors.

1.8.2.8.8 Known to occur in nearby conservation reserves

Unknown.

1.8.2.9 Turquoise Parrot

This species suffered a serious population decline, especially in NSW, between 1900-1920 when it disappeared entirely from many areas The cause of the decline is not known but may have been due to disease.

Listed as Vulnerable on Schedule 2 of the *Threatened Species Conservation Act 1995*. Considered to be "rare" by Garnett (1992).

1.8.2.9.1 Distribution

Statewide distribution: Tablelands, central and south coast, western slopes.

Regional distribution: Poorly known.

Local distribution: Unknown; not recorded during this study or during recent surveys on, or adjacent to the site (AXIS/Australian Museum Business Services 1995; Phillips *et al.* 1996). Historical records from Macquarie Fields (A. Leishman, Royal Botanic Gardens *pers. comm*). The Turquoise Parrot was recorded from Holsworthy in the 1960s by Col S.G. Lane, from Ingleburn Reserve in the 1970s by A. Leishman (A. Leishman, Royal Botanic Gardens *pers. comm.*; ESS Consultants 1976) and in the upper catchment of O'Hares Creek (Illawarra Bird Observers Club 1986, in Kevin Mills and Associates 1989). The species was also recorded at Wedderburn (Phillips *et al.* 1996) and at Mount Annan Botanic Gardens (Leishman 1996).

1.8.2.9.2 Environmental pressures

Environmental pressures on this species and its habitat include: loss of nesting hollows through clearing, livestock and rabbit grazing, changes to burning regimes, predation, competition for nest hollows.

1.8.2.9.3 Critical habitat

The Turquoise Parrot is found on the edges of eucalypt woodland adjoining clearings and on timbered ridges and creeks in farmland. It is often detected at the edge of forests in native grassland and open woodland (Crome and Shields 1992; Blakers *et al.* 1984). It is usually found in small groups of 5-30 individuals but winter groups may include 100-200 birds (Quin and Baker-Gabb 1993). It forages on the ground for seed of grasses and herbs, both native and introduced (Crome and Shields 1992) and prefers to feed in shade. In Victoria, it may feed on flowers, flower parts, nectar, fruit, seeds, leaf and insect scale (Quin and Baker-Gabb 1993). It requires water on a daily basis. It nests in hollows which are generally <0.5 m deep and approximately vertical within eucalypt trees or stumps. There is no evidence of large-scale movements but it is moderately nomadic in winter. In Chiltern State Park, Victoria, parrots form winter roosting groups in dense vegetation which may include young eucalypts, coppicing stumps or wattles (Quin and Baker-Gabb 1993).

The Turquoise Parrot may occur at very low densities in the Holsworthy study area.

1.8.2.9.4 Sensitivity to habitat modification

This species is sensitive to the loss of nesting hollows. It may also be sensitive to grazing-induced or fire-induced changes to seed availability, especially during breeding season.

1.8.2.9.5 Effects of proposed activities

Direct impacts of airport construction on this species are likely to be habitat loss and fragmentation and an increase in fire frequency. Option A will result in the loss of 308 ha of Grassy. Option B will result in the loss of 10.4 ha of Grassy Forest. Indirect impacts of airport construction include increased predation and competition for nest hollows.

The Turquoise Parrot is a mobile species and can be nomadic during winter. Its distribution in the region is poorly known, however it is considered the species may occur in very low densities at Holsworthy. Limited areas of suitable habitat are available for this species at the site.

The impact of the airport development on this species is therefore considered to be unknown.

1.8.2.9.6 Ability of species/habitat to recover

Insufficient information. This species is able to exploit disturbed habitats and can use colonising plant species as food. It is likely to recover provided that suitable habitat is maintained around the airport development.

1.8.2.9.7 Amelioration measures

Minimise habitat fragmentation by careful siting of proposed transport and services corridors.

1.8.2.9.8 Known to occur in nearby conservation reserves

Unknown. Likely to be poorly represented in conservation reserves.

1.8.2.10 Ground Parrot

This species has undergone a significant reduction in range since European settlement.

Listed as Vulnerable in Schedule 2 of the *Threatened Species Conservation Act 1995*. Classed as "scarce" by Morris *et al.* (1981). Considered to be "vulnerable" by Garnett (1992).

1.8.2.10.1 Distribution

Statewide distribution: Scattered records from the far north coast to the far south coast.

Regional distribution: Nearest known population to Holsworthy is Barren Grounds Nature Reserve, approximately 70 kms to the south.

Local distribution: This species was not recorded during the present study although it was targeted using dawn and dusk aural surveys in suitable heathlands. This species was not detected during recent surveys on, and adjacent to the site but is known historically from Maddens Plain (J. Baker, University of Wollongong *pers. comm.*) and from Appin (A. Leishman, Royal Botanic Gardens *pers. comm*). There is a recent record of this species from the Maddens Plains area (Anon 1989, in Kevin Mills and Associates 1989).

1.8.2.10.2 Environmental pressures

Environmental pressures on this species and its habitat include: loss of habitat through clearing and/or drainage, unsuitable fire regimes, predation.

1.8.2.10.3 Critical habitat

The Ground Parrot is restricted mainly to coastal heaths, estuarine flats and swamps. It is a granivore (McFarland 1989; Bryant 1991) and has specialised habitat requirements. In eastern Australia, it is largely restricted to heathlands and sedgelands with very dense cover (>80%) and a high density of food plants (Meredith *et al.* 1984). Parrots feed on a variety of small seeds and fruits, preferring the seeds of Cyperaceae and Restionaceae. Pairs nest beneath very dense vegetation and are probably sedentary and territorial. Post-breeding dispersal of up to 120 km may occur.

The nearest known locations of the Ground Parrot are those of disjunct populations which occur at Bherwerre Peninsula, Barren Grounds Nature Reserve and Morton National Park (J. Baker, University of Wollongong *pers. comm*). Vegetation characteristics of ground parrot habitat have been summarised by Bryant (1994) as: low (60-100 cm) closed (FPC > 70%) sedgeland and wet and dry heathland with high species richness (typically 20 to 40 spp per 5m x 5m plot). Jack Baker concluded that Holsworthy was unlikely to provide suitable habitat for this species; heathland within the site was not considered dense enough for Ground Parrots even though many of the bird species detected during the study are characteristic of vegetation types occupied by Ground Parrots elsewhere (ie. Chestnut-rumped Heathwren, Tawny-crowned Honeyeater). Wet heathland at the site was not considered to be extensive enough for Ground Parrots considering their home range size (J. Baker, University of Wollongong *pers. comm*).

1.8.2.10.4 Sensitivity to habitat modification

Because of its specialised dietary requirements, this species is sensitive to removal of habitat through clearing, drainage or unsuitable fire regimes. It may also be sensitive to predation.

1.8.2.10.5 Effects of proposed activities

Direct impacts of airport construction on this species are likely to be habitat loss and fragmentation and unsuitable fire regimes. An indirect impact may be increased predation.

The Ground Parrot occurs in restricted habitat types with patchy distribution and is sedentary and territorial.

The Ground Parrot is not likely to occur on the site so the impact for this species is undetermined.

1.8.2.10.6 Ability of species/habitat to recover

Preferred heathland habitat would take from 3-5 years to regenerate where this was allowed. The species is likely to recover provided that suitable habitat is maintained around the development area.

1.8.2.10.7 Amelioration measures

Minimise habitat fragmentation by careful siting of proposed transport and services corridors.

1.8.2.10.8 Known to occur in nearby conservation reserves

All known Ground Parrot populations in the area are found in reserves (J. Baker, University of Wollongong *pers. comm.*).

1.8.2.11 Powerful Owl

Listed as Vulnerable on Schedule 2 of the *Threatened Species Conservation Act 1995*. Considered to be "rare" by Garnett (1992).

1.8.2.11.1 Distribution

Statewide distributions: Coast, tablelands, south-west slope and north-west plains.

Regional distribution: Uncommon, restricted. Recorded from Royal National Park in 1996 and from Heathcote National Park in 1991 (NPWS Database). The species has been recorded in Sydney's north-west near Maroota State Forest (M. Chidel, *pers. obs.*)and at Kurrajong. (NPWS unpublished). This species is considered widespread in moist gullies of the Cattai and Little Cattai catchments, the Georges River, Holsworthy and along the western boundary of the Cumberland Plain adjacent to Blue Mountains and Wollomi National Parks (NPWS unpublished).

Local distribution: Unknown; this species was not recorded during the present survey despite targeted survey effort. The Powerful Owl was recorded by AXIS/Australian Museum Business Services (1995) and on the NPWS Database in the southern part of the study area. It was not detected at Wedderburn despite spotlighting and call playback survey (Phillips *et al.* 1996). It is known from Campbelltown (Sydney Pre-history Group 1983) and from Macquarie Fields (Australian Museum Database). This species has been recorded from Browns Bush, adjacent to the Georges River five kilometres south of Campbelltown. A breeding record occurs in the Georges River National Park and the species is widespread in moist gullies of the Georges River and Holsworthy area (NPWS unpublished).

1.8.2.11.2 Environmental pressures

Environmental pressures on this species and its habitat include: loss of old-growth forest habitat, loss of large hollow-bearing trees, fragmentation of habitat, reduction in prey numbers due to clearing and burning.

1.8.2.11.3 Critical habitat

Breeding pairs of the Powerful Owl occupy large permanent territories (up to 1000 ha) preferably including gullies in foothill and coastal forests. This species preys primarily on arboreal mammals but also takes birds, insects and terrestrial mammals (Kavanagh 1988, 1990).

The Powerful Owl is found in moist and dry eucalypt forests but prefers ecological old-growth or reaches peak abundance there (Garnett 1992). Optimal habitat includes a mosaic of moist and dry hardwood on flat to undulating terrain. It is a sedentary species with pairs occupying permanent territories from 400-1000+ ha; territory size is related to the density of prey species which in turn may be related to forest productivity. Owls hunt nocturnally in open eucalypt forest and require medium to high densities of medium-sized arboreal marsupials (eg. Sugar Gliders, Common Ringtail Possums and Greater Gliders) which comprise up to 80% of their diets. Birds and bats are also taken. They roost alone on horizontal branches generally several metres from the ground in dense old-growth vegetation often located in gullies. There may be more than one roost site but roost trees typically have a large open lower limb structure and a dense crown; Red Turpentine and Black She-oak are often selected. Powerful Owls nest in tree hollows at least 0.5 m deep (Schodde and Mason 1980), usually high (9-37 m above ground) within large eucalypts located in gullies, slopes or in the heads of minor side gullies (Kavanagh 1991). Nest site fidelity is high.

Although recent surveys in Holsworthy and surrounds have specifically targeted the large owls, very few have been detected. This is to be expected considering their large home ranges and the fact that the Holsworthy site may comprise only part of a pair's home range. We would expect Powerful Owls to occur at low densities at Holsworthy; this is likely to be related to the low densities of arboreal mammals. They are likely to be associated with deep forested gullies on the site.

1.8.2.11.4 Sensitivity to habitat modification

As an old-growth specialist species, the Powerful Owl would be highly sensitive to the removal of its preferred habitat type for the following reasons (Scotts 1994):

- It requires large contiguous areas of forest for foraging;
- It is at or near the top of the food chain;
- It requires specialised habitat for resting and breeding (ie. tree hollows);

- It occurs naturally in low numbers.

Species most sensitive to clearing activities are hollow-dependent species requiring a high density of the largest trees and where old-growth forest provides optimum habitat (Milledge *et al.* 1991). It may be also be sensitive to disturbance of nest sites. Frequent burning may act to accelerate the demise of old trees and stags.

This species may be sensitive to loss of forest habitat which provides nesting/roosting trees and habitat for its prey species. However, it will switch prey species if the Greater Glider is not available (Debus *et al.*, in prep.). It would also be sensitive to any activities such as grazing and frequent burning which would act to simplify the forest understorey, thereby reducing shelter and food for prey species.

1.8.2.11.5 Effects of proposed activities

Direct impacts of airport construction on this species are likely to be habitat loss and fragmentation, a reduction in prey numbers and an increase in fire frequency. Option A will result in the loss of 2339.8 ha of Woodland/heath Complex and 1454.3 of Gully Forest Option B will result in the loss of 1655.6 ha of Woodland/heath Complex and 1087.5 ha of Gully Forest. Indirect impacts of airport construction include cumulative impacts associated with habitat loss.

The Powerful Owl is highly mobile, occupying large territories. The Holsworthy site may only form part of a much larger home range for several pairs Suitable habitat for the species is widespread throughout the Holsworthy site. Regional distribution is assessed as uncommon and restricted.

The impact of the airport development on this species is therefore considered to be high local.

1.8.2.11.6 Ability of species/habitat to recover

The Powerful Owl is dependent on large hollows which can take from 150-200 years to form; these can be a limiting resource. However, it occurs in cleared habitat and may hunt along forest edges, in cleared land and along roads. It occurs in greater than 70-year old regrowth and in 10-20 year old regrowth where wide corridors are retained (Debus *et al.*, in prep). It is unknown whether the large scale of this development may affect this wide-ranging species.

1.8.2.11.7 Amelioration measures

Minimise habitat fragmentation by careful siting of proposed transport and services corridors.

1.8.2.11.8 Known to occur in nearby conservation reserves

This species has been extensively recorded in Royal National Park and in Heathcote National Park (NPWS Database). As forest owl home ranges are very large, it is unlikely that all critical resources would be adequately protected in reserves.

1.8.2.12 Sooty Owl

Listed as Vulnerable on Schedule 2 of the *Threatened Species Conservation Act 1995*. Considered to be "rare" by Garnett (1992). This species is difficult to detect.

1.8.2.12.1 Distribution

Statewide distribution: Coast and northern, central and southern tablelands, west to upper Cataract River, upper Manning River, Berrima and upper Murrah River (Morris *et al.* 1981).

Regional distribution: Poorly known; have been found moving between Woronora Catchment and Royal National Park (D. Andrew, NPWS *pers. comm.*).

Local distribution: Not known; not recorded during this study. It has been recorded in Royal National Park (NPWS Database; Australian Museum Database) and in the Woronora Catchment (Sydney Water Database).

1.8.2.12.2 Environmental pressures

Environmental pressures on this species and its habitat include: loss of rainforest habitat, loss of or alteration to riparian vegetation, loss of nesting hollows, fire.

1.8.2.12.3 Critical habitat

The Sooty Owl prefers tall, wet old-growth forest on fertile soils with a dense understorey and emergent tall eucalypts (Garnett 1992). It is a habitat specialist utilising dry subtropical and warm temperate rainforest and wet eucalypt gullies with dense understoreys (NPWS 1995). A survey of the habitat requirements of this species on the far south coast of New South Wales indicates that it prefers low altitude (<300 metres), sheltered south-east facing sites which contain rainforest with a dense understorey layer (Kavanagh & Peake 1993).

It is sedentary and territorial occupying territories measuring 400-600 ha/pair. It hunts alone, taking ground-dwelling mammals (eg. rats, marsupial mice, bandicoots) and arboreal species (eg. ringtail possum and Sugar Glider) and birds. Individuals roost alone in very large hollows (40-50 cm deep and 40-60 cm diameter) located high (16-31 m) in trees 150 years or older, amongst the aerial roots of figs, in caves and under overhanging banks (Kavanagh 1991). Roosting and nesting habitat is likely to be found in the heads of gullies and along minor gullies (NPWS 1995). Sooty Owls exhibit high nest site fidelity.

Rod Kavanagh (State Forests of NSW) has recorded Sooty Owls moving between Woronora Catchment and Royal National Park (D. Andrew, NPWS *pers. comm*). In this area, they are typically associated with rainforest but are also found in sclerophyll forest and in deep gullies. They are most likely to be found in the moister gullies in the eastern part of Holsworthy. As this species may be more likely to call in winter (D. Andrew, NPWS *pers. comm.*), this may be a more appropriate time to survey.

1.8.2.12.4 Sensitivity to habitat modification

As an old-growth specialist species, the Sooty Owl would be highly sensitive to the removal of its preferred habitat type for the following reasons (Scotts 1994):

- It requires large contiguous areas of forest for foraging;
- It is at or near the top of the food chain;
- It requires specialised habitat for resting and breeding (ie. tree hollows);
- It occurs naturally in low numbers.

The species most sensitive to clearing activities are hollow-dependent species requiring a high density of the largest trees and where old-growth forest provides optimum habitat (Milledge *et al.* 1991). It may be sensitive to disturbance of nest sites. Furthermore, frequent burning may act to accelerate the demise of old trees and stags. The Australian race of this species may be broken into several regional populations and may therefore be vulnerable to habitat fragmentation at a regional level (Debus *et al*, in prep). This species would also be sensitive to removal of habitat for prey species.

1.8.2.12.5 Effects of proposed activities

Direct impacts of airport construction on this species are likely to be habitat loss and fragmentation, a reduction in prey numbers and an increase in fire frequency. Option A will result in the loss of 2339.8 ha of Woodland/heath and 1454.3 ha of Gully Forest. Option B will result in the loss of 1655.6 ha of Woodland/heath and 1087.5 ha of Gully Forest. Indirect impacts of airport construction include cumulative impacts associated with habitat loss.

The Sooty Owl is highly mobile, occupying large territories. Regional distribution is poorly known; however suitable habitat is widespread in moist gullies at the Holsworthy site.

The impact of the airport development on this species is therefore considered to be high local.

1.8.2.12.6 Ability of species/habitat to recover

The Sooty Owl is dependent on large hollows which can take from 150-200 years to form; these can be a limiting resource. However, it is able to use logged habitat and hunts along forest edges, in cleared land and along roads. This development is unlikely to greatly affect this wide-ranging species.

1.8.2.12.7 Amelioration measures

Minimise habitat fragmentation by careful siting of proposed transport and services corridors.

1.8.2.12.8 Known to occur in nearby conservation reserves

Unknown. The Sooty Owl has been recorded in Royal National Park (NPWS Database; Australian Museum Database). As forest owl home ranges are very large, it is unlikely that all critical resources would be adequately protected in reserves.

1.8.2.13 Masked Owl

The Masked Owl is amongst the least known of Australia's owl species.

Listed as Vulnerable on the *Threatened Species Conservation Act 1995*. Considered to be "rare" by Garnett (1992).

1.8.2.13.1 Distribution

Statewide distribution: Throughout the state, mainly in the east (Morris *et al.* 1981).

Regional distribution: Poorly known; associated with deep moist gullies between Holsworthy and Royal National Park. Masked Owls have been recorded from Royal National Park (NPWS Database, Australian Museum Database).

Local distribution: Unknown, this species was not recorded during the present survey. It was not recorded during the AXIS/Australian Museum Business Services (1995) survey but was possibly heard during the Phillips *et al.* (1996) Wedderburn survey. The Masked Owl was recorded in Spotted Gum Forest west of the Georges River (Leishman 1994; ESS Consultants 1976). Alan Leishman (Royal Botanic Gardens *pers. comm.*) also reports recent records of Masked Owls from Padstow and Appin.

1.8.2.13.2 Environmental pressures

Environmental pressures on the species and its habitat include: loss of hollow-bearing trees, loss or fragmentation of habitat, alteration to forest understorey.

1.8.2.13.3 Critical habitat

The Masked Owl occurs in eucalypt forest and woodland and uses riparian forest types and partially cleared land and forest edges for hunting. Debus (1993) stated that this species is "...an opportunistic generalist, widespread in coastal and sub-coastal open forests and woodlands". It reaches peak densities in dry forest types on gentle to undulating terrain; important habitat types may be those dominated by Spotted Gum, Red Forest Gum, Manna Gum and River Red Gum (Debus *et al.*, in prep.). In south-eastern NSW, the Masked Owl occupied mixed age or mid-successional (>60 years) open forest and woodland of high structural diversity (Debus *et al.*, in prep.).

It feeds opportunistically on a wide range of prey species from insects to birds and mammals, preferring to hunt ground-dwelling mammals (eg. rats, *Antechinus* spp., *Sminthopsis* spp., bandicoots and rabbits). It is a sedentary species with pairs occupying permanent territories from 400-600 ha/pair. Individuals appear to have traditional roost sites in dense vegetation in wet sclerophyll gullies or in caves. Pairs nest in tree hollows in large trees (dead or alive) often within tall forest; they require large, roomy vertical hollows (0.4-5 m deep X 0.5 m wide) located 10-30 m above ground (Schodde and Mason 1980). Owls may roost and nest on forested ridges and mid-slope areas (Kavanagh and Peake 1993). Its densities appear to be positively associated with diversity of woodland and forest structure (Debus and Rose 1994).

This species was not detected despite targeted survey effort. It may occur at Holsworthy at low densities; as for Powerful Owls, its distribution and abundance may be related to the availability of arboreal mammal prey species. It is also likely to be associated with deep moist gullies to the east of the Holsworthy site.

1.8.2.13.4 Sensitivity to habitat modification

This species would be sensitive to loss of ridgetop forest habitat which provides nesting/roosting trees and habitat for prey species. It is able to survive and breed in disturbed areas and can feed on introduced animals (Debus *et al.*, in prep).

1.8.2.13.5 Effects of proposed activities

Direct impacts of airport construction on this species are likely to be habitat loss and fragmentation, a reduction in prey numbers and an increase in fire frequency. Option A will result in the loss of 2339.8 ha of Woodland/heath and 1454.3 ha of Gully Forest. Option B will result in the loss of 1655.6 ha of Woodland/heath and 1087.5 ha of Gully Forest. Indirect impacts of airport construction include cumulative impacts associated with habitat loss.

The Masked Owl is a widespread generalist, occupying large permanent territories. Regional distribution is poorly known, but the species is associated with moist gullies which are widely distributed at the Holsworthy site.

The impact of the airport development on this species is therefore considered to be high local.

1.8.2.13.6 Ability of species/habitat to recover

The Masked Owl is dependent on large hollows which can take from 150-200 years to form; these can be a limiting resource. However, it is able to use partly cleared habitat for foraging. Despite the large scale of this proposed development, it is unlikely to affect this wide-ranging and mobile species.

1.8.2.13.7 Amelioration measures

Minimise habitat fragmentation by careful siting of proposed transport and services corridors.

1.8.2.13.8 Known to occur in nearby conservation reserves

Unknown. The Masked Owl is known to occur in Royal National Park (NPWS Database, Australian Museum Database). As forest owl home ranges are very large, it is unlikely that all critical resources would be adequately protected in reserves.

1.8.2.14 Painted Honeyeater

Listed as Vulnerable on the Threatened Species Conservation Act 1995.

1.8.2.14.1 Distribution

Statewide distribution: Mainly western slopes and plains of Great Dividing Range (Blakers *et al.* 1984).

Regional distribution: Poorly known.

Local distribution: Unknown; not recorded during this survey and no known records from on, or adjacent to, the Holsworthy study area.

1.8.2.14.2 Environmental pressures

Environmental pressures for this species and its habitat include: loss of habitat through clearing, fragmentation of habitat, reduced regeneration due to rabbit and sheep grazing, possible competition with Mistletoebird.

1.8.2.14.3 Critical habitat

The Painted Honeyeater prefers dry open forest and woodland. It occurs in pairs or small groups, feeding almost exclusively on mistletoe berries which are parasitic on eucalypts and acacias, but also taking nectar and insects. It is migratory, breeding in southern Australia and moving north in the winter. It nests at the ends of drooping branches in a cup-shaped woven nest located 3-20 m above ground. During the breeding season, honeyeaters may inhabit Melaleuca, Eucalyptus, Casuarina and Acacia woodland infested with the mistletoe Amyema Movement patterns are nomadic and are related to the flowering and fruiting of mistletoe (Garnett 1992).

1.8.2.14.4 Sensitivity to habitat modification

Insufficient information. Species has always been regarded as rare. Sensitive to loss of mistletoe and breeding habitat by clearing and to competition with Mistletoebird.

1.8.2.14.5 Effects of proposed activities

Direct impacts of airport construction on this species are likely to be habitat loss and fragmentation. Option A would result in the loss of 308 ha of Grassy Forest, 2339.8 ha of Woodland/heath and 1454.3 ha of Gully Forest. Option B would result in the loss of 10.4 ha of Grassy Forest, 1655.6 ha of Woodland/heath and 1087.5 ha of Gully Forest. Indirect impacts of airport construction include increased competition with the Mistletoebird.

The Painted Honeyeater prefers dry open forest and woodland which are widespread at Holsworthy. It has now been previously recorded within the study site. The species is migratory and its regional distribution is poorly known.

The impact of the airport development on this species is therefore considered to be unknown.

1.8.2.14.6 Ability of species/habitat to recover

Insufficient information. The time taken for critical habitat to recover is unknown. However, this species is likely to recover provided that suitable habitat is maintained around the development area.

1.8.2.14.7 Amelioration measures

Minimise habitat fragmentation by careful siting of proposed transport and services corridors.

1.8.2.14.8 Known to occur in nearby conservation reserves

Unknown. Unlikely as this is a highly migratory species, known to breed in southern Australia and move north during winter (Blakers *et al.* 1984).

1.8.2.15 Tiger Quoll

This species is the largest extant marsupial carnivore on the mainland, being the size of a domestic cat at maturity. The Tiger Quoll is a nocturnal predator hunting a variety of prey from birds and small arboreal mammals to reptiles and insects. The range of this species has halved in the last 150 years (Mansergh 1984).

This species has been nominated for listing on Schedule 2 (Vulnerable) of the revised *Endangered Species Protection Act* 1992 (Kim Brebach, Threatened Species Network, *pers. comm*). It is also recommended in the 1996 Action Plan for Australian Marsupials and Monotremes (Maxwell *et al.* 1996) that the Tiger Quoll be listed as vulnerable under the *Endangered Species Protection Act* 1992. Presently listed as vulnerable in the *Threatened Species Conservation Act 1995*. Strahan (1995) lists this species as "common to sparse", Kennedy (1992) as "potentially vulnerable" with a probable decline in population of 50-90%.

1.8.2.15.1 Distribution

Statewide distribution: Coast and tablelands. The stronghold for the species in NSW appears to include Barrington Tops and escarpment and gorges of New England tablelands (Benson and Andrew 1990). These areas are centred on high rainfall areas with high-nutrient soils.

Regional distribution: Widely distributed from Holsworthy to Royal National Park; prefers wetter forests. Robinson (1985) reported Tiger Quoll to be present in Wedderburn.

Local distribution: This species was recorded during the present study via a well-established feeding site at Site M. It was also recorded by AXIS/Australian Museum Business Services (1995) at Engineers Bridge and there is an unconfirmed record of Tiger Quoll at Site CC (Corporal R. Thompson *pers. comm.*). It was not recorded by Phillips *et al.* (1996). The species has been recorded in the O'Hares Creek Catchment (R. Close University of

Western Sydney *pers. comm.*, Register of the National Estate Database) and from along the Woronora River (C. Hamilton, amateur herpetologist *pers. comm.*). The species is likely to be thinly distributed in sandstone areas.

1.8.2.15.2 Environmental pressures

Environmental pressures on the species and its habitat include: loss of old-growth forest, fragmentation of preferred habitats, loss of prey habitat through grazing and burning, competition with introduced carnivores, poison baiting and destruction by pastoralists.

1.8.2.15.3 Critical Habitat

In NSW, the Tiger Quoll inhabits a range of forest types from closed forest to woodland, and also occasionally coastal heathland, although it is most abundant in wetter forests. It occurs in high numbers in large unfragmented areas of forest in northern NSW and reaches peak abundance in ecological old-growth forests (Osborne 1982, Scotts 1991). Maintaining the continuity of riparian corridors is essential for this species (Scotts 1991). Debbie Andrew (South Metropolitan District, NPWS) undertook a long-term study of Tiger Quolls at Limeburners Creek in Royal National Park. She found that quolls occupied a range of habitats from Scribbly Gum with dense Banksia understorey to rainforest

The quoll is nocturnal and solitary, resting in rocky caves or crevices, in hollow logs or in tree hollows during the day. It is scansorial and preys upon a wide variety of small to medium-sized arboreal and terrestrial animals such as birds, rats, gliders, small macropods, reptiles and arthropods. It is also a scavenger.

AXIS/Australian Museum Business Services (1995) recorded this species in gully forest characterised by good ground cover, rocky outcrops and the presence of hollow logs. This species is likely to occur within such gullies throughout Holsworthy. During the course of this study a Tiger Quoll feeding site was discovered. Prey included Echidnas, Long-nosed Bandicoots, Swamp Wallabys, Ring-tailed Possums and a variety of small mammals.

1.8.2.15.4 Sensitivity to habitat modification

The Tiger Quoll appears to be declining throughout its range. It is extinct in SA, rare in Victoria and declining in NSW (Lunney and Leary 1988).

As an old-growth specialist species, the quoll will be highly sensitive to the removal of its preferred habitat type for the following reasons (Scotts 1994):

- It requires large contiguous areas of forest;
- It is at the top of the food chain;
- It requires specialised habitat for resting and breeding (i.e. caves, tree hollows, fallen logs);
- It naturally occurs at low densities.

Habitats where quolls have been observed are characterised by high soil fertility, a minimum of disturbance and an absence or low abundance of foxes (Braithwaite, in Forestry Commission of NSW 1993). Quolls are negatively affected by frequent burning and by competition with foxes (Catling 1991).

1.8.2.15.5 Effects of proposed activities

Direct impacts of airport construction on this species are likely to be habitat loss and fragmentation, loss of prey species and an increase in fire frequency. Option A would result in the loss of 2339.8 ha of Woodland/heath and 1454.3 ha of Gully Forest. Option B would result in the loss of 1655.6 ha of Woodland/heath and 1087.5 ha of Gully Forest. Indirect impacts of airport construction include increased competition with introduced carnivores. The Tiger Quoll is a CWR species so is particularly susceptible to indirect impacts which may lead to local extinction.

The Tiger Quoll inhabits a range of forest types present at the Holsworthy site, but is most abundant in wetter forests. The species is mobile and is considered likely to be thinly distributed in sandstone areas in Holsworthy.

The impact of the airport development on this species is therefore considered to be high local.

1.8.2.15.6 Ability of species/habitat to recover

The amount of time required for regeneration of suitable habitat for this species is unknown. Although old-growth forest may be preferred habitat and requires several hundred years to regenerate, quolls can persist in logged forests and other disturbed habitats and will scavenge on dead livestock and raid chicken coops in rural areas. They are capable of traversing large distances and may use cleared land adjacent to forests for feeding. However the large size of the proposed development means that local populations of this species may not recover from its development.

In the longer term, surviving local populations of the Tiger Quoll may be affected by increased access of potentially competitive species such as fox and feral cat. Opening up of forests by clearing habitats may assist in the dispersal of these exotic species into areas where they were previously unknown.

1.8.2.15.7 Amelioration measures

Minimise habitat fragmentation by careful siting of proposed transport and services corridors; pre-construction surveys with the aim of undertaking monitoring studies; feral animal control and monitoring; on site education program for construction workers in the identification of rare and vulnerable fauna species; minimise the period that trenches are open in key habitat areas.

1.8.2.15.8 Known to occur in nearby conservation reserves

Tiger Quolls can be found in Royal National Park, Dharawal SRA, Heathcote National Park and in the Woronora Catchment.

1.8.2.16 Yellow-bellied Glider

Listed as Vulnerable in Schedule 2 of the *Threatened Species Conservation Act 1995*. Kennedy (1992) classes the glider as "potentially vulnerable" with a 10% decline in population status.

1.8.2.16.1 Distribution

Statewide distribution: Coastal NSW and tablelands.

Regional distribution: Poorly known; appears to be uncommon in the region.

Local distribution: A possible record for this species was determined during the present study. Feeding incisions were observed on three different species of trees in a localised area (Site M). Photos were taken and sent to Ross Goldingay and Rod Kavanagh for verification. The results are inconclusive but suggest most incisions are unlikely to be those of Yellow-bellied Gliders. In addition, although the area was surveyed by spotlighting and by owl-playback, no Yellow-bellied Gliders were recorded. The Yellow-belled Glider was not recorded for Holsworthy or its surrounds by AXIS/Australian Museum Business Services (1995) or by Phillips *et al.* (1996) but it was recorded in O'Hares Catchment (R. Close, University of Western Sydney *pers. comm.*, Register of the National Estate Database). However suitable habitat occurs there.

1.8.2.16.2 Environmental pressures

Environmental pressures on the species and its habitat include: loss of old-growth forest hollow-bearing trees and feed trees, alteration to forest structure through clearing, burning and grazing.

1.8.2.16.3 Critical habitat

Within its range, the Yellow-bellied Glider inhabits a variety of forest types, from dry sclerophyll forest with a xeric understorey to moist forest types. As for other species of arboreal mammals, gliders prefer forest habitats occurring on high-nutrient soils. This species reaches its highest densities in old-growth forest (Milledge *et al.* 1991, Lindenmeyer 1994).

The Yellow-bellied Glider is closely associated with the distribution of preferred food (sap and nectar) trees and tends to be patchily distributed throughout its forest habitat. Kavanagh (1987) found that in south eastern NSW, preferred habitat is likely to be characterised by a mosaic of tree species associations, including those that flower in winter. He also found that gliders selected trees with the most flowers to forage for nectar and that these were at least 200 years old. It appears that tree phenology is an important habitat characteristic as gliders forage for ephemeral food sources and show seasonal patterns in the use of tree species, particularly smooth-barked and winter-flowering eucalypts (Goldingay and Kavanagh 1991).

Yellow-bellied Gliders require large tree hollows. Such suitable hollows do not develop until a tree is 150-200 years old (Mackowski 1984). Gliders line their nests with twigs and leaves from live branches, therefore requiring live den trees (Gibbons 1994). The Yellow-bellied Glider feeds on nectar, pollen, plant and animal exudates and invertebrates. Sap forms a central part of the diet (Goldingay 1987, 1991) and is tapped from smooth-barked tree trunks via readily identified V-shaped incisions.

In preferred habitat, Yellow-bellied Gliders occur at very low densities of 0.05-0.14 gliders/ha (Goldingay and Kavanagh 1991). They are sociable, forming small groups of 3-4 individuals. Each group shares nest hollows and uses a common home range. Exclusive home ranges are large enough (30-65 ha) to accommodate microhabitat preferences which may vary seasonally according to patterns of flowering, bark shedding and availability of other food resources (Kavanagh 1984).

The Holsworthy site contains favoured food trees of this species, including Grey Gum and Red Bloodwood. The species containing possible Yellow-bellied Glider incisions included Grey Gum, Smooth-barked Apple and ?? However, it is now considered unlikely that these incisions were made by Yellow-bellied Gliders (R. Goldingay, R. Kavanagh, SFNSW *pers. comm*.). Despite this, Yellow-bellied Gliders may occur in suitable habitat at Holsworthy.

1.8.2.16.4 Sensitivity to habitat modification

As an old-growth specialist species, the Yellow-bellied Glider would be highly sensitive to the removal of its preferred habitat type for the following reasons (Scotts 1994):

- It requires large contiguous areas of forest;
- It requires specialised habitat for resting and breeding (eg tree hollows);
- It naturally occurs at low densities,
- It is colonial or social in population structure.

The Yellow-bellied Glider is dependent on large hollows which can take from 150-200 years to form; these can be a limiting resource. A decrease in the number of hollows available may also result in the exposure of individuals to increased predation by owls. Gliders would also be sensitive to removal of feed trees or to any activities which altered the forest structure with consequent effects on the distribution and abundance of food trees and insect prey.

Yellow-bellied Gliders are highly mobile and may travel long distances while foraging. However, removal or fragmentation of habitat may increase foraging distances leading to energetic fitness costs.

1.8.2.16.5 Effects of proposed activities

Direct impacts of airport construction on this species are likely to be habitat loss and fragmentation and increased fire frequencey. Option A would result in the loss of 2339.8 ha of Woodland/heath and 1454.3 ha of Gully Forest. Option B would result in the loss of 1655.6 ha of Woodland/heath and 1087.5 ha of Gully Forest. Indirect impacts of airport construction include cumulative impacts associated with habitat loss, including increased predation by owls.

The Yellow-bellied Glider inhabits a range of forest types, is highly mobile and may travel large distances while foraging. The regional distribution of this species is not well understood, however suitable habitat for this species is present at the Holsworthy site. There is an unconfirmed record for Holsworthy.

The impact of the airport development on this species is therefore considered to be unknown.

1.8.2.16.6 Ability of species/habitat to recover

The Yellow-bellied Glider has a low breeding potential. The amount of time required for regeneration of suitable hollow-bearing trees for this species is from 150-200 years. However, local populations of this highly mobile species outside the main development area may recover from any impacts provided that habitat is maintained around the proposed airport area.

1.8.2.16.7 Amelioration measures

Minimise habitat fragmentation by careful siting of proposed transport and services corridors; provide aerial walkways in areas of fragmented, significant habitat.

1.8.2.16.8 Known to occur in nearby conservation reserves

Unknown. Possibly conserved in Dharawal SRA.

1.8.2.17 Squirrel Glider

This is one of the least studied arboreal marsupials.

Listed as Vulnerable in the *Threatened Species Conservation Act 1995*. Strahan (1995) considers the species to be "rare". Kennedy (1992) classes the glider as "potentially vulnerable" with a 10-50% decline in population status.

1.8.2.17.1 Distribution

Statewide distribution: Throughout the tablelands of NSW, not usually associated with the coast.

Regional distribution: Poorly known; low densities, associated with well-watered, high quality open forest.

Local distribution: Unknown; not recorded in the present study. The Squirrel Glider was possibly recorded from a scat collected as part of the Phillips *et al.* (1996) study in the Wedderburn. It has also been recorded from the western side of O'Hares Creek Catchment (Robinson 1985).

1.8.2.17.2 Environmental pressures

Environmental pressures on the species and its habitat include: habitat clearing, loss of hollow-bearing and nectar-producing trees, alterations to habitat structure.

1.8.2.17.3 Critical habitat

Generally inhabits dry sclerophyll forest and woodlands which have mature or mixed-age stands of more than one eucalypt species. Studies on the Squirrel Glider indicate that it inhabits sclerophyll forest composed of mixed-species stands including gum bark and high nectar-producing species, some which flower in winter (Menkhorst *et al.* 1988). This species reaches peak abundance in forest >100 years old and finds optimal habitat in old-growth forest (Scotts 1991).

The Squirrel Glider is dependent on tree hollows for shelter and nesting. In north-eastern Victoria, gliders were found to use hollows located in tree stumps in areas where mature trees were a limited resource (Traill 1994). In Chiltern State Park, nest group size was 1-10 and consisted of one adult male, two or more adult females and their offspring (Traill 1994). Home ranges measured 6-17 ha and gliders spent most of their time foraging within 400 m of their nest hollow (Traill 1994). Dietary studies indicate a preference for insects, honeydew, pollen and nectar and plant exudates, especially *Eucalyptus* sap and *Acacia* gum (Menkhorst & Collier 1987). It appears that in years of poor flowering in northern Victoria, gliders switch to plant exudates and insects (Traill 1994). They may require mature *Acacia* spp. as a source of carbohydrate in winter while *Acacia* seeds may form a significant part of the diet in late spring (Traill 1994).

Information about habitat requirements and distribution of this species is inadequate for New South Wales. Robinson (1987) detected this species close to Morton National Park.

1.8.2.17.4 Sensitivity to habitat modification

As an old-growth specialist species, the Squirrel Glider would be highly sensitive to the removal of its preferred habitat. A decrease in the number of hollows available may result in the exposure of individuals to increased predation by owls.

Gliders would also be sensitive to removal of feed trees, especially winter-flowering species, or to any activities which altered the forest structure with consequent effects on the distribution and abundance of food trees and insect prey. Austeco Pty Ltd (1994) reports that this species may be sensitive to the removal of nectar and pollen sources, particularly Spotted Gum and Ironbark forests with banksia understoreys.

This species is known from logged forests and other disturbed habitats. It is found in *Eucalyptus* plantations and in remnant forest where hollows did not appear to be abundant (Ecotone Ecological Consultants 1995). In Chiltern, Traill (1991) found that in addition to the use of tree hollows located in tree crowns, Squirrel Gliders used hollows in dead stumps left from timber cutting, and hollows formed at the rotting base of trees that have regrown from coppicing stumps.

1.8.2.17.5 Effects of proposed activities

Direct impacts of airport construction on this species are likely to be habitat loss and fragmentation and alteration of the undersytorey due to increased fire frequencey. Option A would result in the loss of 308 ha of Grassy Forest, 2339.8 ha of Woodland/heath and 1454.3 ha of Gully Forest. Option B would result in the loss of 10.4 ha of Grassy Forest, 1655.6 ha of Woodland/heath and 1087.5 ha of Gully Forest. Indirect impacts of airport construction include cumulative impacts associated with habitat loss, including increased predation by owls.

The Squirrel Glider is a highly mobile species. Regional distribution of this species is poorly known; however large areas of potential habitat occur at the Holsworthy site.

The impact of the airport development on this species is therefore considered to be high local.

1.8.2.17.6 Ability of species/habitat to recover

The Squirrel Glider is considered to have a narrow ecological tolerance, thus leading to concern about the combined effects of fragmentation and commercial use of habitat (Menkhorst *et al.* 1988). Although the amount of time required for regeneration of optimal habitat (old-growth) for this species may be 100 years or more, it is able to use disturbed habitats. Acacias, which provide another important food source for this species, would require at least 10 years to regenerate. Local populations of this highly mobile species living outside the main development area may recover from any impacts of the airport development provided that habitat is maintained on either side of the airport area. Being a mobile and agile species, any Squirrel Gliders that fall into craters in construction areas may be able to get themselves out, although they can become trapped after falling into narrow fence-post holes (C. Meredith, *pers. obs.*).

1.8.2.17.7 Amelioration measures

Minimise habitat fragmentation by careful siting of proposed transport and services corridors; provide aerial walkways in areas of fragmented, significant habitat.

1.8.2.17.8 Known to occur in nearby conservation reserves

Unknown.

1.8.2.18 Koala

This large arboreal folivore was once widespread in eastern Australia but its range has since declined. It is restricted to areas where suitable eucalypt trees occur as a food source.

Listed as Vulnerable in Schedule 2 of the *Threatened Species Conservation Act 1995*. It is considered to be "common, limited" (Strahan 1995) and "potentially vulnerable" with a 50-90% decline in population status (Kennedy 1992). The Koala population at Wedderburn is presently being considered by the NSW Scientific Committee for listing as an Endangered Population under Part 2 of Schedule 1 of the Threatened Species Conservation Act (1995) (Chris Dickman, Chairman NSW Scientific Committee *pers. comm.*).

1.8.2.18.1 Distribution

Statewide distribution: Widespread at low densities or with patches of local abundance. In 1995, a separate State Environmental Planning Policy (SEPP 44) was introduced as a conservation measure.

Regional distribution: Low densities from Holsworthy to Royal National Park (NPWS Database). The Georges River acts as an important regional corridor for this species.

Local distribution: Patchy and very sparse throughout Holsworthy; the Koala was observed at two locations (Site G) and indirect evidence was recorded at a further three locations (Sites F, O and V) during the present study. It has previously been recorded at Holsworthy by AXIS/AMBS (1995), by Army personnel (M. Peterson Department of Defence *pers. comm.*, R. Close, University of Western Sydney *pers. comm.*) and by the NPWS Database. It has also been recorded adjacent to the site along the Georges River in Campbelltown, at Wedderburn, and at Voyager Point (Phillips and Callaghan 1996; Phillips *et al.* 1996; R. Close, University of Western Sydney *pers. comm.*), adjacent to the study area at the intersection of Deadmans Creek and Heathcote Road (Engel 1996a) and in the Woronora Catchment (Sinclair Knight 1994).

1.8.2.18.2 Environmental pressures

Environmental pressures on the species and its habitat include: loss and fragmentation of habitat through clearing for agriculture, land development and forestry; road kills; predation by domestic dogs; lowered fertility due to *Chlamydia* infection.

1.8.2.18.3 Critical habitat

On a state-wide basis, the distribution of Koalas is well-documented (Reed and Lunney 1990). Koalas are found in areas where there are suitable food trees and these range from dense forest to open woodland. Like other folivores, this species tends to be associated with forests growing on high-nutrient soils along river flats and drainage lines, most of which have been cleared for farmland (Reed and Lunney 1990, Braithwaite *et al.* 1983). They are unlikely to be found on low-nutrient soils or on steep slopes typical of many of our reserved areas (Austeco Pty Ltd 1992). Altogether, 55 species of eucalypts and 11 species of non-eucalypts are known to be used and eaten by Koalas (Reed *et al.* 1990).

Koalas are nocturnal, resting within the fork of a tree or on a sturdy branch during the daytime. They are solitary except during the breeding season. Home range size is related to density of large trees and possibly to population density and can vary from several hectares to 15 ha in area (Mitchell 1990). Male and female home ranges overlap extensively. Adult Koalas are sedentary but young males (2-3 years) emigrate from natal areas. In Victorian populations, adults only left an area when food resources became severely depleted (Mitchell and Martin 1990).

R. Close (University of Western Sydney) has undertaken extensive survey and radio-tracking studies in the Campbelltown area and in O'Hares Creek Catchment in particular. Based on survey transects carried out from Victoria Road to Woolwash, he has estimated koala densities at 1 per 10 ha. These densities would have been typical for the Sydney Basin and are expected for the Holsworthy Training Area as well. Movement patterns are less well understood; one individual collared in Campbelltown crossed the Holsworthy area and was detected again in Heathcote National Park. AXIS/Australian Museum Business Services (1995) described the western side of Holsworthy between 34^0 01'and 34^0 06'as prime habitat for koalas although they have been recorded from Heathcote Road, Menai and Royal National Park.

The Australian Koala Foundation compiled a Koala Habitat Atlas for the Campbelltown Local Government Area in 1996 (Phillips and Callaghan 1996). They found that habitat utilisation by koalas was principally determined by the distribution of two species of trees, Grey Gum and Blue-leaved Stringybark, particularly when these occurred on higher-nutrient soils (i.e. shale). The authors found that two habitat types within the LGA could be considered to provide critical or core habitat for koalas. Primary habitat contained preferred floristic associations as the dominant component of the overstorey. Secondary habitat contained these associations as a sub-dominant component of the overstorey or bushland/cleared areas supporting low densities of preferred tree species. At Holsworthy, primary habitat is confined to the north-western part of the site (i.e. Cumberland Plain Woodland) while secondary habitat covers the rest of it. Overall, these two habitat types comprised an estimated 5877 ha (37%) of the remaining forested areas within the LGA. Phillips and Callaghan (1996) estimated the local koala population at 30-90 individuals and concluded that it was highly vulnerable and under threat of localised extinction.

Phillips and Callaghan (1996) also commented on the consistency of State Environmental Planning Policy 44 with respect to the protection of the Campbelltown LGA koala population. The policy aims to "encourage the proper conservation and management of areas of natural vegetation that provide habitat for koalas to ensure permanent free-living populations over their present range and to reverse the current trend of koala population decline". It applies to a development application involving land of more than one hectare which occurs in a nominated local government area identified in Schedule 1 of State Environmental Planning Policy 44. When determining a DA, the consent authority must ensure that consent is not issued without investigation of potential and core koala habitat. Potential koala habitat is defined as "areas of native vegetation where the trees of the types listed in Schedule 2 constitute at least 15% of the total number of trees in the upper or lower strata of the tree component". As pointed out by Phillips and Callaghan (1996), a critical habitat tree in the Campbelltown area, the Blue-leaved Stringybark, is not included in Schedule 2.

Core koala habitat is defined as "an area of land with a resident population of koalas, evidenced by attributes such as breeding females (that is, females with young) and recent sightings of and historical records of a population". According to the Koala Atlas, the entire Holsworthy site constitutes core habitat for koalas even though generally low activity levels were recorded. This is to be expected in low-density populations and must be taken into account when assessing koala populations in the area; the authors suggested that any koala faecal pellet evidence be considered significant in the Campbelltown LGA.

1.8.2.18.4 Sensitivity to habitat modification

The most serious threat to the Koala is the removal of food trees (Whitehouse 1990, Reed and Lunney 1990). Although the optimal habitat for this species, forests growing on nutrient-rich soils, has been mainly cleared due to agriculture and forestry activities, the Koala still finds large areas of suitable habitat on private and rural leasehold land (Reed and Lunney 1990). It is thus highly vulnerable to habitat loss and/or disturbance. In particular, isolated populations may be highly vulnerable to drought unless they have access to refuge areas; drought may exacerbate the impacts of activities such as logging and burning (Reed and Lunney 1990). Furthermore, Koalas in fragmented habitats are probably often nutritionally stressed (Hume 1990).

Koalas will occupy disturbed habitats such as residential developments with a varying degree of success, provided that there are food trees and low levels of disturbance. Other human-associated impacts such as traffic and dogs (Prevett *et al.* 1992) can affect Koalas as they are prone to stress-related diseases such as *Chlamydia*. According to Lunney *et al.* (1990), over-browsing and consequent starvation as well as disease- and drought-induced mortality are the result of loss of optimum habitat.

1.8.2.18.5 Effects of proposed activities

Koala habitat at Holsworthy has been assessed as primary habitat (roughly corresponds to Grassy Forest habitat) and secondary habitat (roughly corresponds to Woodland/heath Complex and Gully Forest habitats). Direct impacts of airport construction on this species are likely to be habitat loss and fragmentation. Option A would result in the loss of 308 ha or around 14 % of the total primary habitat available at Holsworthy. A total of 3794 ha or around 25 % of available secondary habitat would also be lost in Option A. Option B would result in the loss of approximately 10.4 ha or 0.5% of total primary habitat and a total of 2743 ha or around 18% of secondary habitat. Indirect impacts of airport construction include predation by dogs, roadkills and increased transmission of disease.

The Wedderburn Koala population is often referred to by local residents as the healthiest population in the Sydney area. Although individuals show no clinical signs of *Chlamydia*, the disease is no doubt present in the population (R. Close, University of Western Sydney *pers. comm.*) and could become apparent if individuals within the population become stressed. Prior to 1986, there was no recognised population in the area; similarly, there were no records for Royal National Park nor roadkills recorded on Heathcote Road. An increase in the number of Koala sightings or roadkills near Audley, Camden, Picton and along Heathcote Road may be the result of a resurgent Campbelltown population dispersing along the Georges and Nepean Rivers and across the Holsworthy HTA (R. Close, University of Western Sydney *pers. comm.*). This population is presently being considered by the Scientific Committee as an endangered population under Part 2 of Schedule 1 of the TSC Act (1995).

The impact of the airport development on this species is therefore considered to be at least regional.

1.8.2.18.6 Ability of species/habitat to recover

This species has a low reproductive rate and may not be able to recover quickly from major disturbances. However, Koalas are able to tolerate change in the species which they feed on and will feed on species with which they are not familiar (Lee and Martin 1988). Although the amount of time required for regeneration of optimal habitat (old-growth) for koalas may be 100 years or more, sedentary breeding females have been located in 40-year old regrowth in northern NSW (C. Mackowski, *pers. obs.*, in Forestry Commission of NSW 1993). Individuals not directly affected by the airport development may recover. However the disruption of a corridor linking local populations suggests that the long-term viability of koala populations in the region may be endangered by the proposed development (particularly the southern option).

1.8.2.18.7 Amelioration measures

Minimise habitat fragmentation by careful siting of proposed transport and services corridors; pre-construction surveys with the aim of undertaking monitoring studies; feral animal control and monitoring; on site education program for construction workers in the identification of rare and vulnerable fauna species; ensure that construction vehicles are driven responsibly and safely to avoid roadkills; minimise the period that trenches are open in key habitat areas; checking of open trenches in or near suitable habitat for trapped individuals

1.8.2.18.8 Known to occur in nearby conservation reserves

This species is found in low densities in Woronora Catchment, Dharawal SRA and Royal National Park (before the 1994 fires).

1.8.2.19 Long-nosed Potoroo

Listed as Vulnerable on Schedule 2 of the *Threatened Species Conservation Act 1995*. Kennedy (1992) classes the potoroo as "potentially vulnerable" with a 10-50% decline in population status.

1.8.2.19.1 Distribution

Statewide distribution: Patchy distribution along the coast.

Regional distribution: Poorly known; possibly associated with moist forest in deep gullies.

Local distribution: Unknown; not recorded from the study area or adjacent areas. This species is difficult to record and if present at Holsworthy, is likely to be restricted to deep gullies. Its presence at Holsworthy is likely to be restricted by the overly frequent burning regime which reduces the density of ground cover. Known historically from Darkes forest.

1.8.2.19.2 Environmental pressures

Environmental pressures on the species and its habitat include: removal of rainforest or dense understorey habitat, alteration to habitat by frequent fire, and predation by introduced carnivores and grazing by stock.

1.8.2.19.3 Critical habitat

Preferred habitat for the Long-nosed Potoroo ranges from woodland with dry heathy understorey to wet heaths, dense coastal scrubs and mixed species open forest and rainforest (Seebeck *et al.* 1989). It requires thick ground cover and light, sandy soil. On a microhabitat scale, it requires a vegetation mosaic containing dense cover for predator protection and more open areas of floristically diverse vegetation for foraging (Bennett 1993). In general, the optimum habitat of this species is a mosaic of regenerating dense understorey vegetation produced as a result of a patchwork of periodic and severe fires (Catling 1991).

The Long-nosed Potoroo feeds on roots, tubers, fruit, plant tissue and arthropods; however a major part of its diet consists of hypogeal fungi. These fungi are eaten more frequently in autumn and winter when soil moisture levels are higher (Claridge *et al.* 1993). The potoroo will forage within open cleared areas but will seldom venture far from dense understorey cover. In unlogged areas in Victoria, Claridge *et al.* (1993) found that potoroos used midslope and gully areas for feeding and for nesting (although the latter were dependent on seasonal factors). This species is solitary with home ranges measuring approximately 2-20 ha.

In Holsworthy the Long-nosed Potoroo is most likely to occur in deeper, moist gullies such as those occuring in greater frequency towards the southern part of the study area.

1.8.2.19.4 Sensitivity to habitat modification

The Long-nosed Potoroo is sensitive to predation by foxes and feral dogs. As such, it will be sensitive to activities such as clearing, frequent burning and grazing which remove dense understorey vegetation required for shelter (Catling 1991). Potoroos will also be sensitive to the loss of hypogeal fungi even though these can persist in highly disturbed areas (Claridge *et al.* 1993). The Long-nosed Potoroo has been found to persist in isolated forest fragments (<80 ha in size) at Naringal, Victoria (Bennett 1987).

1.8.2.19.5 Effects of proposed activity

Direct impacts of airport construction on this species are likely to be habitat loss and fragmentation and alteration of the understorey due to increased fire frequencey. Option A would result in the loss of 1454.3 ha of Gully Forest. Option B would result in the loss of 1087.5 ha of Gully Forest. Indirect impacts of airport construction include increased predation.

The Long-nosed Potoroo has specialist habitat requirements. Regional distribution of this species is poorly known, it is most likely to occur in deep moist gullies with a low fire frequencey which are widespread at the Holsworthy site. However, this species has not been previously recorded from Holsworthy.

The impact of the airport development on this species is therefore considered to be unknown.

1.8.2.19.6 Ability of species/habitat to recover

As potoroos use forest edges for feeding, the ecotone between cleared and uncleared moist forests could be beneficial to this species in the medium-term. Schlager (1981, in Ecotone Ecological Consultants 1995) found that potoroos actually preferred regenerating forest on the edges of rainforest to undisturbed rainforest.

The probability of populations remaining in the long-term may be dependent on maintaining a dense enough understorey to provide protection from predators. Undergrowth would regenerate within a period of 2-3 years if left undisturbed. While periodic burning may create suitable habitat for this species, frequent fire will disadvantage it by simplifying the forest structure.

1.8.2.19.7 Amelioration measures

Minimise habitat fragmentation by careful siting of proposed transport and services corridors; feral animal control and monitoring; on site education program for construction workers in the identification of rare and vulnerable fauna species; ensure that construction vehicles are driven responsibly and safely to avoid roadkills; minimise the period that trenches are open in key habitat areas.

1.8.2.19.8 Known to occur in nearby conservation reserves

Unknown. Known from Nadgee National Park and at least one reserve in northern coastal New South Wales (J. Seebeck, Department of Natural Resources and Environment, VIC *pers. comm.*).

1.8.2.20 Yellow-bellied Sheathtail Bat

This species flies high and fast and is therefore rarely collected.

Listed as Vulnerable in Schedule 2 of the *Threatened Species Conservation Act 1995*.

1.8.2.20.1 Distribution

Statewide distribution: Very widespread with few records available.

Regional distribution: Unknown; likely to be rare.

Local distribution: Rare; detected at two Sites (A, E) during the present study although it was not recorded within the study area by AXIS/Australian Museum Business Services (1995) or adjacent to it by Phillips *et al.* (1996)

However it has been recorded from Stanwell Park and the Sutherland Shire (Phillips *et al.* 1996) and from Royal National Park (Australian Museum Database).

1.8.2.20.2 Environmental pressures

Environmental pressures on the species and its habitat include: loss of preferred habitat through clearing for agriculture, loss of tree hollows for roosting, alteration to forest structure and consequently to insect abundance

1.8.2.20.3 Critical habitat

The Yellow-bellied Sheathtail-bat is generally found within wet and dry sclerophyll forests and woodland <500 m in altitude, but also in mallee and open country. It is known to roost under the bark of trees, within tree hollows as well as under roof eaves and in other artificial habitats. In forested areas, it feeds on insects flying above the canopy whereas in open areas it forages closer to the ground (Austeco Pty Ltd 1994). Reports suggest that it is migratory in southern Australia, moving from cooler to warmer areas in winter (Lumsden and Menkhorst 1995). This bat is usually solitary but occurs in colonies of up to ten individuals (Strahan 1995). Habitat requirements for this species are uncertain.

1.8.2.20.4 Sensitivity to habitat modification

The Yellow-bellied Sheathtail-bat would be highly sensitive to the removal of hollow-bearing trees, habitat fragmentation and to any alteration of forest structure. As it requires habitat complexity, it is likely to be negatively affected by frequent burning and grazing (Austeco Pty Ltd 1994, 1995).

1.8.2.20.5 Effects of proposed activities

Direct impacts of airport construction on this species are likely to be habitat loss and fragmentation and alteration of the understorey due to increased fire frequencey. Option A would result in the loss of 308 ha of Grassy Forest, 2339.8 ha of Woodland/heath and 1454.3 ha of Gully Forest. Option B would result in the loss of 10.4 ha of Grassy Forest, 1655.6 ha of Woodland/heath and 1087.5 ha of Gully Forest. Indirect impacts of airport construction include a reduction in the abundance of insects.

The Yellow-bellied Sheathtail-bat is highly mobile. The regional distribution of the species is unknown and likely to be rare.

The impact of the airport development on this species is therefore considered to be unknown.

1.8.2.20.6 Ability of species/habitat to recover

Unable to accurately assess the ability of this species to recover based on information which is currently available. Bats are likely to have a poor recovery potential due to the following factors: high juvenile mortality, low reproductive rate and great longevity in relation to size (AXIS/Australian Museum Business Services). The ability to recover will depend largely on the ability of this species to migrate and find suitable habitat in adjacent areas. This species would be negatively affected by the removal of any preferred mature hollow-bearing trees. Suitable roosting sites are most commonly found in mature trees (80-100 years old), bats are able to use cleared areas for foraging as long as suitable roosting sites are located nearby. Due to extremely low population densities, the ability of this species to recover is likely to be low.

1.8.2.20.7 Amelioration measures

Minimise habitat fragmentation by careful siting of proposed transport and services corridors; check all sheds, buildings, culverts prior to demolition for the presence of bats and to recommend a suitable time to demolish them (i.e. when bats are absent).

1.8.2.20.8 Known to occur in nearby conservation reserves

Unknown. This species has been recorded in Royal National Park (Australian Museum Database). Little is known about the distribution of bat species in the Sydney Region. It is unknown whether critical habitat for bats is protected within conservation reserves in the region.

1.8.2.21 Eastern Little Mastiff-bat

Listed as Vulnerable on Schedule 2 of the *Threatened Species Conservation Act 1995*. Considered to be "rare" by Strahan (1995).

1.8.2.21.1 Distribution

Statewide distribution: East of the Great Dividing Range, from southern New South Wales to south-eastern Queensland (Strahan 1995, Parnaby 1992). Known from very few localities.

Regional distribution: Unknown.

Local distribution: Unknown; this species was not recorded during the present survey It was not recorded by AXIS/Australian Museum Business Services (1995) but was considered likely to inhabit the site. It was recorded from Wedderburn (Phillips *et al.* 1996) and possibly from Royal National Park (D. Andrew, NPWS *pers. comm.*).

1.8.2.21.2 Environmental pressures

Environmental pressures on this species and its habitat include: loss of, or disturbance to, roost sites and loss of habitat through land clearing.

1.8.2.21.3 Critical habitat

Habitat preferences of the Eastern Little Mastiff Bat are unclear but it is reported to favour sclerophyll forest and woodland, particularly in sub-tropical areas (Strahan 1995). It hunts for insects above the canopy or in clearings at the edge of forest. This species may roost in small colonies of up to 50 individuals under bark, in tree hollows and under roofs and other artificial habitats. Very little is known about the ecological requirements of this species.

1.8.2.21.4 Sensitivity to habitat modification

This species would be sensitive to the removal of forest roosting and foraging habitat, to habitat fragmentation and simplification of forest structure.

1.8.2.21.5 Effects of the proposed activities

Direct impacts of airport construction on this species are likely to be habitat loss and fragmentation and alteration of the understorey due to increased fire frequencey. Option A would result in the loss of 308 ha of Grassy Forest, 2339.8 ha of Woodland/heath and 1454.3 ha of Gully Forest. Option B would result in the loss of 10.4 ha of Grassy Forest, 1655.6 ha of Woodland/heath and 1087.5 ha of Gully Forest. Indirect impacts of airport construction include cumulative impacts associated with habitat loss.

The Eastern Little Mastiff Bat is a mobile species. The regional distribution of the species is unknown.

The impact of the airport development on this species is therefore considered to be unknown.

1.8.2.21.6 Ability of species/habitat to recover

Bats are likely to have a poor recovery potential due to the following factors: high juvenile mortality, low reproductive rate and great longevity in relation to size (AXIS/Australian Museum Business Services). There is insufficient information on this species to accurately predict potential impacts caused by removal of any trees containing roosting sites. Although suitable roosting sites may be most commonly found in mature trees (80-100 years old), bats are able to use cleared areas as long as suitable roosting sites are located nearby. Low population densities are likely to greatly restrict the recovery potential of this species.

1.8.2.21.7 Amelioration measures

Minimise habitat fragmentation by careful siting of proposed transport and services corridors; check all sheds, buildings, culverts prior to demolition for the presence of bats and to recommend a suitable time to demolish them (i.e. when bats are absent).

1.8.2.21.8 Known to occur in nearby conservation reserves

Unknown. This species may occur in Royal National Park (D. Andrew, NPWS *pers. comm.*). Little is known about the distribution of bat species in the Sydney Region. It is unknown whether critical habitat for bats is protected within conservation reserves in the region.

1.8.2.22 Greater Broad-nosed Bat

Listed as Vulnerable in Schedule 2 of the *Threatened Species Conservation Act 1995.*

1.8.2.22.1 Distribution

Statewide distribution: Restricted to east coast and adjacent Great Dividing Range from Qld to Vic border; sparse (Parnaby 1992).

Regional distribution: Poorly known

Local distribution: Unknown. This species was not recorded during the present survey. It was recorded from Holsworthy by AXIS/Australian Museum Business Services (1995), from Wedderburn by Phillips *et al.* (1996) and from Waterfall by Fanning (1995). The Greater Broad-nosed Bat is known from Royal National Park (D. Andrew, NPWS *pers. comm*). It is likely to be sparsely distributed throughout the study area.

1.8.2.22.2 Environmental pressures

Environmental pressures on this species and its habitat include: loss of rainforest, wet sclerophyll and riparian forest habitats; loss of tree hollows.

1.8.2.22.3 Critical habitat

The Greater Broad-nosed Bat forages over a range of habitats, including dry forests and woodland, but prefers wet habitats and riparian forest. This species is considered to be a specialist species which may prefer mature forest on high-fertility soils (Meredith *et al.* 1995). It requires a sparse understorey as it flies at a height of about 3-6 metres and will forage for insects at one metre over the water of creeks and small rivers (Strahan 1995). This bat feeds on large insects and possibly on small vertebrates and even other bats. It roosts mainly in tree hollows but will also use buildings. Females congregate at maternity sites during the breeding season in summer (Strahan 1995).

1.8.2.22.4 Sensitivity to habitat modification

As this species shows preference for moist forest types, the Greater Broad-nosed Bat would be sensitive to the loss of moist forest roosting and foraging habitats, riparian forest foraging habitat, and to the alteration of forest structure (Austeco Pty Ltd 1994, 1995). The foraging patterns of this bat are such that they are likely to be sensitive to reductions in water quality.

1.8.2.22.5 Effects of proposed activities

Direct impacts of airport construction on this species are likely to be habitat loss and fragmentation. Option A would result in the loss of 308 ha of Grassy forest, 2339.8 ha of Woodland/heath, 1454.3 ha of Gully Forest and 24 km of streamline habitat. Option B would result in the loss of 10.4 ha of Grassy Forest, 1655.6 ha of Woodland/heath, 1087.5 ha of Gully Forest and 26km of streamline habitat. Indirect impacts of airport construction include cumulative impacts associated with habitat loss.

The Greater Broad-nosed Bat is a mobile species. The regional distribution of the species is poorly known and is likely to be sparsely distributed throughout the Holsworthy site.

The impact of the airport development on this species is therefore considered to be unknown.

1.8.2.22.6 Ability of species/habitat to recover

Unable to accurately assess the ability of this species to recover based on information which is currently available. Bats are likely to have a poor recovery potential due to the following factors: high juvenile mortality, low reproductive rate and great longevity in relation to size (AXIS/Australian Museum Business Services). This will depend largely on its ability to locate suitable habitat in adjacent areas. This species is likely to be affected by the removal of mature hollow-bearing trees. Although it is known to forage along water courses and forest/grassland ecotones, it may require mature trees (80-100 years old) in which to roost. It is also able to use artificial roosting sites. This species is likely to recover provided existing levels of water quality are maintained and if suitable habitat, especially moist forest, riparian vegetation and large hollow-bearing trees, are conserved.

1.8.2.22.7 Amelioration measures

Minimise habitat fragmentation by careful siting of proposed transport and services corridors; check all sheds, buildings, culverts prior to demolition for the presence of bats and to recommend a suitable time to demolish them (i.e. when bats are absent); strict adherence to erosion and sediment control measures; construction of river and stream crossings so as to maintain downstream water quality.

1.8.2.22.8 Known to occur in nearby conservation reserves

Unknown. The species is known to occur in Royal National Park (D. Andrew, NPWS *pers. comm.*). Little is known about the distribution of bat species in the Sydney Region. It is unknown whether critical habitat for bats is protected within conservation reserves in the region.

1.8.2.23 Eastern False Pipistrelle

Listed as Vulnerable on Schedule 2 of the *Threatened Species Conservation Act 1995*..

1.8.2.23.1 Distribution

Statewide distribution: Coast and tablelands; uncommon and localised (Parnaby 1992).

Regional distribution: Poorly known. Likely to be uncommon.

Local distribution: Uncommon. This species was detected at three wetland sites (Sites A,E,JJ) during the present survey; it was not detected in or adjacent to the study area by AXIS/Australian Museum Business Services (1995) or by Phillips *et al.* (1996). This species is known from Royal National Park (D. Andrew, NPWS *pers. comm.*). It most likely inhabits ridge and gully habitats throughout the study site.

1.8.2.23.2 Environmental pressures

Environmental pressures for this species and its habitat include: loss of old-growth habitat, loss of tree hollows, alteration to forest structure.

1.8.2.23.3 Critical habitat

The Eastern False Pipistrelle can be found in a range of habitats including dry woodland and wet sclerophyll forest. Scotts (1994) described this species as finding optimum habitat within old-growth forests in south-eastern Australia. It roosts in caves and abandoned buildings, but prefers tree hollows. Within the Strzelecki Ranges in Victoria, individuals were found to travel over 7-12 km to their roosting hollows located in old-growth forest or within isolated trees in farmland (Parnaby and Cherry 1992). It appears to prefer moist forest types where it hunts moths, beetles and ants below the canopy level. It possibly migrates from highland to coastal areas in winter (Parnaby 1992) and may hibernate in southern parts of its range (Strahan 1995).

1.8.2.23.4 Sensitivity to habitat modification

The main threats to this species are considered to be loss of roosting hollows and disturbance to understorey (Parnaby 1992). This is consistent with their old-growth-dependent status. This species would be sensitive to the removal of moist forest roosting and foraging habitat, to habitat fragmentation and to simplification of forest structure in foraging habitat.

As an old-growth specialist species, the Eastern False Pipistrelle would be highly sensitive to the removal of preferred habitat type for the following reasons (Scotts 1994):

- It forages over large contiguous areas of forest;
- It requires combinations of varied, specialised habitat resources for breeding, roosting and foraging;

- It is colonial or social in behaviour.

Because bats are dependent on mature hollow-bearing trees for roosting and breeding, they would be sensitive to any activities which resulted in the removal of this essential resource. Removal of or disturbance to roost sites may be critical in winter and during the breeding season when bats concentrate.

1.8.2.23.5 Effects of proposed activities

Direct impacts of airport construction on this species are likely to be habitat loss and fragmentation and changes to understorey through increased fire frequency. Option A would result in the loss of 2339.8 ha of Woodland/heath, 1454.3 ha of Gully Forest and 24 km of streamline habitat. Option B would result in the loss 1655.6 ha of Woodland/heath, 1087.5 ha of Gully Forest and 26 km of streamline habitat. Indirect impacts of airport construction include cumulative impacts associated with habitat loss.

The Eastern False Pipistrelle is a highly mobile species. The regional distribution of the species is poorly known, it is likely to be uncommon.

The impact of the airport development on this species is therefore considered to be unknown.

1.8.2.23.6 Ability of species/habitat to recover

Unable to accurately assess the ability of this species to recover based on information which is currently available. Bats are likely to have a poor recovery potential due to the following factors: high juvenile mortality, low reproductive rate and great longevity in relation to size (AXIS/Australian Museum Business Services). Although it is known to forage along forest/grassland ecotones, the Eastern False Pipistrelle is likely to be severely affected by the removal of mature hollow-bearing trees; these mature trees (100 years old) are essential for both roosting and breeding. The adaptability of this species to use artificial roosting sites may influence its ability to recover. The ability of this species to recover is likely to be greatest where roost sites and suitable habitat, especially riparian vegetation, is maintained.

1.8.2.23.7 Amelioration measures

Minimise habitat fragmentation by careful siting of proposed transport and services corridors; check all sheds, buildings, culverts prior to demolition for the presence of bats and to recommend a suitable time to demolish them (i.e. when bats are absent).

1.8.2.23.8 Known to occur in nearby conservation reserves

Little is known about the distribution of bat species within the Sydney Region. It is unknown whether critical habitat for bats is contained with conservation reserves in the region.

1.8.2.24 Large-footed Myotis

The Large-footed Myotis occurs in northern, eastern and southern coastal Australia.

Listed as Vulnerable on Schedule 2 of the *Threatened Species Conservation Act 1995*.

1.8.2.24.1 Distribution

Statewide distribution: East of the Great Dividing Range; associated with water bodies.

Regional distribution: Poorly known.

Local distribution: Scarce; this species was not recorded during the present survey. It was not recorded from the study site by AXIS/Australian Museum Business Services (1995) but the authors reported that it had been recorded along the Georges River near Wedderburn. It was trapped by Phillips *et al.* (1996) and is expected to occur along creek systems within the Holsworthy site. This species has also been recorded in Royal National Park (NPWS Database).

1.8.2.24.2 Environmental pressures

Environmental pressures on this species and its habitat include: disturbance to colonies, particularly during the colder months (Reardon and Flavel 1987), loss of riparian habitat and alteration to hydrological regimes and water quality.

1.8.2.24.3 Critical habitat

The Large-footed Myotis inhabits a wide range of vegetation communities, always associated with permanent, usually slow-flowing water bodies. This species forages at night over bodies of fresh water, "raking" the surface with its enlarged hind feet to catch aquatic insects and small fish (Lumsden and Menkhorst 1995, Reardon and Flavel 1987).

This species roosts in caves, mines, disused railway tunnels and in some instances in dense foliage (Hall and Richards 1979).It is known to utlise Hawkesbury Sandstone caves, fissures and overhangs for roosting 9NPWs Unpublishred). During the breeding season, maternity caves may contain colonies numbering from 10-15 to several hundred individuals (Strahan 1995). Males generally roost alone outside the breeding season. This species goes into torpor during winter and utilises caves during this period (these are separate from maternity caves). This species is considered rare is southern Australia where it is dependent on caves; it is more common in the coastal tropics where it can use dense rainforest foliage for roosting.

1.8.2.24.4 Sensitivity to habitat modification

Because this species is colonial, it would be sensitive to any disturbance at roosting or breeding sites where a significant proportion of the population may be concentrated seasonally. It would also be sensitive to any hydrological or water quality changes to the water bodies used as foraging areas. The Large-footed Myotis requires habitat complexity and would therefore be sensitive to frequent burning, grazing (Austeco Pty Ltd 1994, 1995) or selective land clearing.

1.8.2.24.5 Effects of proposed activities

Direct impacts of airport construction on this species are likely to be habitat loss and fragmentation. Option A would result in the loss of 2339.8 ha of Woodland/heath, 1454.3 ha of Gully Forest and 24 km of streamline habitat. Option B would result in the loss of 1655.6 ha of Woodland/heath, 1087.5 ha of Gully Forest and 26 km of streamline habitat. Indirect impacts of airport construction include alteration to hydrological regimes and a reduction in water quality..

The Large-footed Myotis is a highly mobile species. The regional distribution of the species is poorly known.

The impact of the airport development on this species is unknown; however if a maternity roost or winter roost is lost or disturbed, the impacts may be of at least regional significance.

1.8.2.24.6 Ability of species/habitat to recover

Insufficient information is available to accurately assess the potential of this species to recover. Bats are likely to have a poor recovery potential due to the following factors: high juvenile mortality, low reproductive rate and great longevity in relation to size (AXIS/Australian Museum Business Services). Recovery will be dependent on retention of suitable roost sites and foraging habitats. Reduction in water quality and changes to the volume and nature of flow are likely to restrict the ability of this species to recover.

1.8.2.24.7 Amelioration measures

Pre-construction surveys to target likely maternity roost sites; minimise habitat fragmentation by careful siting of proposed transport and services corridors; check all sheds, buildings, culverts prior to demolition for the presence of bats and to recommend a suitable time to demolish them (i.e. when bats are absent); strict adherence to erosion and sediment control measures; construction of river and stream crossings so as to maintain downstream water quality.

1.8.2.24.8 Known to occur in nearby conservation reserves

This species has been recorded in Royal National Park (NPWS Database). Little is known about the distribution of bat species within the Sydney Region. It is unknown whether critical habitat for bats is contained with conservation reserves in the region.

1.8.2.25 Common Bent-wing Bat

This medium-sized insectivorous bat has restricted colonial breeding sites.

Listed as Vulnerable on Schedule 2 of the *Threatened Species Conservation Act 1995*.

1.8.2.25.1 Distribution

Statewide distribution: Coast and tablelands.

Regional distribution: Poorly known; likely to be uncommon.

Local distribution: This species was not recorded during the present survey. Unconfirmed records exist for Holsworthy (AXIS/Australian Museum Business Services 1995) and for Wedderburn (Phillips *et al.* 1996). It has been recorded at Holsworthy (NPWS Database) and at Waterfall (Fanning 1995). This species has also been recorded at Royal National Park (NPWS Database; D. Andrew, NPWS *pers. comm*).

1.8.2.25.2 Environmental pressures

Environmental pressures on this species and its habitat include: loss of or disturbance to roosting/maternity caves, loss of or disturbance to winter roosting sites, habitat fragmentation and alteration to forest structure.

1.8.2.25.3 Critical habitat

The Common Bent-wing Bat is generally found in wet and dry sclerophyll forests and rainforest, preferring well-timbered valleys, where it forages for small insects above the tree canopy. In northern NSW, Dwyer (1965) found at least three partially discrete breeding populations which were spatially organised according to major features of physiography.

It roosts in caves, old mines, stormwater channels, rock shelters (Hall and Richards 1979, Hall *et al* 1975) and buildings and uses different roosts according to seasonal needs, age and reproductive status. The species is known to utilise hawkesbury Sandstone caves, overhangs and fissures for roosting (NPWS Unpublished). It forms large colonies of up to several thousand individuals; maternity colonies may number 10,000 females (Dwyer 1965). Maternity caves are used year after year and provide a focus for colonies within a radius of several hundred kilometres. The structural characteristics of these caves are such that they enable the retention of high temperatures produced by the activity of thousands of bats and essential to the early development of young (Dwyer 1965). Juveniles disperse from maternity dens during March and may travel long distances up until May. In south-eastern Australia, roosts are used for hibernation. Numerous inconspicuous roost sites are utilised during this period.

1.8.2.25.4 Sensitivity to habitat modification

The Common Bent-wing Bat occurs in discrete populations based on maternity colonies, whose ranges are often determined by watersheds. This species is therefore particularly sensitive to the loss of or disturbance to maternity caves, particularly during the breeding season. Because roost sites are dominated by specific age/sex classes (ie. maternity, adult, juvenile), any disturbance has the potential to severely disrupt the population structure and thus the viability of regional and local populations. It would also be sensitive to disturbance of winter roosts.

Food supply, especially during winter, may be an important regulating factor for Common Bent-wing Bat populations (Dwyer 1965). Colony size is dependent on food supply. Furthermore, there may be an association between weather, number of roosting sites and food supply in determining winter survivorship. As fat supplies are critical for winter, food availability in spring and summer may also influence mortality. As this species favours habitat complexity, it is potentially sensitive to frequent burning and grazing activities (Austeco Pty Ltd 1994, 1995).

1.8.2.25.5 Effects of proposed activities

Direct impacts of airport construction on this species are likely to be habitat loss and fragmentation and alteration of forest structure due to increased fir frequency. Disturbance or loss of maternity or roosting sites would be a significant impact on this species. Option A would result in the loss of 2339.8 ha of Woodland/heat, 1454.3 ha of Gully Forest and 24 km of streamline habitat. Option B would result in the loss of 1655.6 ha of Woodland/heath, 1087.5 ha of Gully Forest and 26km of streamline habitat. Indirect impacts of airport construction include cumulative impacts associated with habitat loss.

The Common Bent-wing Bat is a highly mobile species. It forms large colonies and maternity roosts are used year after year. The regional distribution of the species is poorly known and likely to be uncommon. It is unknown if the development will have an effect on the regional distribution of this species.

The impact of the airport development on this species is unknown, however if a maternity roost or winter roost is lost or disturbed, the impacts may be of at least regional significance.

1.8.2.25.6 Ability of species/habitat to recover

The ability of this species to recover after major disturbances to its habitat is not fully understood. Bats are likely to have a poor recovery potential due to the following factors: high juvenile mortality, low reproductive rate and great longevity in relation to size (AXIS/Australian Museum Business Services). Recovery potential is likely to be greatly reduced if roost sites are destroyed. With the protection of these sites this species is likely to recover, especially where riparian vegetation and water quality are maintained.

1.8.2.25.7 Amelioration measures

Pre-construction surveys to target likely maternity roost sites; minimise habitat fragmentation by careful siting of proposed transport and services corridors; check all sheds, buildings, culverts prior to demolition for the presence of bats and to recommend a suitable time to demolish them (i.e. when bats are absent).

1.8.2.25.8 Known to occur in nearby conservation reserves

This species has been recorded in Royal National Park (Australian Museum Database; D. Andrew, NPWS *pers. comm.*). Little is known about the distribution of bat species within the Sydney Region. It is unknown whether critical habitat for bats is contained with conservation reserves in the region.

1.8.2.26 Large Pied Bat

Listed as Vulnerable in Schedule 2 of the *Threatened Species Conservation Act 1995*

Reasons for Schedule 2 listing: *Population and distribution suspected to be reduced; concentrates; threatening processes severe; ecological specialist.*

1.8.2.26.1 Distribution

State distribution: Rare. Western slopes and Dividing Range of central and northern NSW and coastal areas (Parnaby 1992)

Regional distribution: Poorly known.

Local distribution: Poorly known. This species was not recorded during the present survey. It was not recorded from the study site by AXIS/Australian Museum Business Services (1995). It was trapped by Phillips *et al.* (1996) and is expected to occur within the study area. This species has also been recorded in Royal National Park (D. Andrew, NPWS *pers. comm.*).

1.8.2.26.2 Environmental Pressures

Environmental pressures on this species and its habitat include: loss of moist forest habitat and forest complexity through land clearing, loss of or disturbance to roost or maternity sites.

1.8.2.26.3 Critical Habitat

The Large Pied Bat occupies tall dry and wet forests where it forages for insects below canopy level (Strahan 1995). It was captured in wet sclerophyll forest adjacent to rainforest by Parnaby (1984, in Austeco 1994b) and in moist hardwood forest by Baverstock and Chambers (1992). Reported to favour moist forests by Richards (1991). It roosts in small colonies (>30 individuals) in caves, mine tunnels, tree hollows and even abandoned mud nest of Fairy Martins (Strahan 1995, Hall and Richards 1979). Within the shallow sandstone rock caves in which it roost this species appears to favour the brighter areas close to the entrance, this is in contrast to most other species of bat which generally prefer roosting in deeper and darker caves (Strahan 1995). Small groups of females with young remain in colonies which disband in autumn. Individuals disperse in winter and probably go into hibernation.

1.8.2.26.4 Sensitivity to Habitat Modification

This species would be sensitive to disturbance of or loss of roost sites. This would be true especially over winter and during the breeding season. This species would be sensitive to the removal of forest roosting and foraging habitat, to habitat fragmentation and to simplification of forest structure

1.8.2.26.5 Effects of proposed activities

Direct impacts of airport construction on this species are likely to be habitat loss and fragmentation and changes in understorey due to increased fire regime. Option A would result in the loss of 2339.8 ha of Woodland/heath, 1454.3 ha of Gully Forest and 24 km of streamline habitat. Option B would result in the loss of 1655.6 ha of Woodland/heath, 1087.5 ha of Gully Forest and 26km of streamline habitat. Indirect impacts of airport construction include cumulative impacts associated with habitat loss.

The Large Pied Bat is a highly mobile species. The regional distribution of the species is poorly known.

The impact of the airport development on this species is therefore considered to be unknown; however if a maternity roost or winter roost is lost or disturbed, the impacts may be of at least regional significance.

1.8.2.26.6 Ability of the species / habitat to recover

Bats are likely to have a poor recovery potential due to the following factors: high juvenile mortality, low reproductive rate and great longevity in relation to size (AXIS/Australian Museum Business Services). Insufficient information is available to accurately assess the recovery potential of this species this will depend largely on the amount of preferred habitat which remains in adjacent lands. In addition, extremely low population densities are likely to restrict recovery potential.

1.8.2.26.7 Amelioration Measures

Minimise habitat fragmentation by careful siting of proposed transport and services corridors; check all sheds, buildings, culverts prior to demolition for the presence of bats and to recommend a suitable time to demolish them (i.e. when bats are absent).

1.8.2.26.8 Known to occur in nearby conservation reserves

Unknown. This species is known to inhabit Royal National Park (D. Andrew, NPWS *pers. comm.*). Little is known about the distribution of bat species within the Sydney Region. It is unknown whether critical habitat for bats is contained with conservation reserves in the region.

1.8.2.27 Eastern Cave Bat

Listed as Vulnerable in Schedule 2 of the *Threatened Species Conservation Act 1995*. Considered to be "uncommon" by Strahan (1992).

1.8.2.27.1 Distribution

State distribution: Uncommon. Restricted distribution along the east coast from north Queensland to south-eastern NSW; very few records for this species in NSW.

Regional distribution: Unknown; likely to be very rare.

Local distribution: This species was not recorded at Holsworthy during the present survey; it was not recorded during the environmental audit by AXIS/Australian Museum Business Services (1995) nor at Wedderburn by Phillips *et al.* (1996). It has not been recorded in Heathcote National Park, Royal National Park or in O'Hares Creek Catchment (NPWS Database; Australian Museum Database). Broad habitat attributes of the Holsworthy study area indicate that this species may inhabit the site.

1.8.2.27.2 Environmental Pressures

Environmental pressures for this species and its habitat include: habitat destruction and disturbance to forest areas. Loss or damage to subterranean roost through changes in land use or vandalism are also likely to affect this species.

1.8.2.27.3 Critical Habitat

The Eastern Cave Bat is a poorly known species, it has been recorded from a range of habitats including drier forests and tropical woodlands (Strahan 1995) where it forages mainly below the canopy. It roost in small groups, predominantly in caves and rock overhangs but also occurs in mines and buildings. At these roost sites it does not occur deep within caves or mines, instead seems to prefer well-lit areas (Strahan 1995).

1.8.2.27.4 Sensitivity to Habitat Modification

This species is likely to be sensitive to habitat fragmentation and any alteration to forest structure. In addition destruction of subterranean roost sites are likely to affect this species particularly during winter months when individuals are likely to be in torpor.

1.8.2.27.5 Effects of proposed activities

Direct impacts of airport construction on this species are likely to be habitat loss and fragmentation and changes in understorey due to increased fire regime. Option A would result in the loss of 308 ha of Grassy Forest, 2339.8 ha of Woodland/heath, 1454.3 ha of Gully Forest and 24 km of streamline habitat. Option B would result in the loss of 10.4 ha of Grassy Forest, 1655.6 ha of Woodland/heath, 1087.5 ha of Gully Forest and 26km of streamline habitat Indirect impacts of airport construction include cumulative impacts associated with habitat loss.

The Eastern Cave Bat is a highly mobile species. The regional distribution of the species is unknown, but likely to be very rare.

The impact of the airport development on this species is unknown; however if a maternity roost or winter roost is lost or disturbed, the impacts may be of at least regional significance.

1.8.2.27.6 Ability of the species / habitat to recover

Bats are likely to have a poor recovery potential due to the following factors: high juvenile mortality, low reproductive rate and great longevity in relation to size (AXIS/Australian Museum Business Services). Insufficient information is available to accurately assess the potential of this species to recover. However, the ability of the Eastern Cave Bat to recover from the permanent destruction of roost sites is likely to be low. In addition, low population densities are likely to greatly restrict the recovery potential of this species.

1.8.2.27.7 Amelioration Measures

Minimise habitat fragmentation by careful siting of proposed transport and services corridors; check all sheds, buildings, culverts prior to demolition for the presence of bats and to recommend a suitable time to demolish them (i.e. when bats are absent).

1.8.2.27.8 Known to occur in nearby conservation reserves

Unknown. Little is known about the distribution of bat species within the Sydney Region. It is unknown whether critical habitat for bats is contained with conservation reserves in the region.

1.8.3 International Agreements

The White-throated Needletail, recorded within the Holsworthy site during this study is listed under both JAMBA and CAMBA. The White-bellied Sea-eagle recorded from the local area (Phillips *et al.* 1996) is listed under the China-Australia Migratory Bird Agreement. Information presented below is summarised from Blakers *et al.* (1984) unless otherwise stated.

1.8.3.1 White-throated Needletail

The White-throated Needletail migrates to eastern Australia each year in summer after breeding in Asia. It spends most of its time in the air foraging for insects and rarely, if ever, roosting. The White-throated Needletail has been recorded in the Woronora Catchment (Sinclair Knight 1994), at Waterfall (Fanning 1995), in O'Hares Creek Catchment (Illawarra Bird Observers Club database) and at Anzac Creek, Holsworthy (Engel 1994b).

1.8.3.2 White-bellied Sea-eagle

This large soaring raptor is distributed throughout India, south-east Asia, New Guinea and Australia. In Australia, it is found along the coast and inland rivers and lakes, particularly in the east of the country. The White-bellied Sea-eagle preys on birds, reptiles and carrion and has also been known to take bandicoots. Breeding pairs are thought to be sedentary; traditional breeding areas are utilised although several different nest sites may be used within such an area. The White-bellied Sea-eagle has been recorded adjacent to the study area (Phillip *et al.* 1996) and in the vicinity of Voyager Point and Picnic Point on the Georges River (Engel 1994a; Speight *et al.* 1995).

1.8.4 Regional Significance

A number of species are regarded as regionally significant. These are listed in Table B2.14 below. In order to simplify discussion in Part C of this report, regionally significant species are classified into guilds. Fauna species in the same guild are likely to be similarly impacted.

Table B2.14. Regionally significant fauna species which were recorded from or may occur at the Holsworthy site As the Holsworthy study area contains two bioregions, all species considered to be of regional significance in Cumberland Plains Woodland and in Coastal Sandstone Plateau are included. Species lists should not be considered exhaustive.

Guild codes:

Mammals and birds: Ae = Aerial forager, Aq = aquatic, Ar = arboreal mammal, B = bark forager, C = carnivore, F = flying mammal, Fo = foliage forager, Fr = frugivore, G = Ground forager, Gr = granivore, He = herbivore, Ho = hollow dependent, I = insectivore, Lh = large herbivorous mammal, N= nectarivore, O = omnivore, S = shrub forager, P = predator / carrion, W = wetland bird.

Reptiles: 1 = fossorial - species which inhabitat the upper soil and litter layers; 2 = ground foraging insectivores, 3 = ground foraging carnivores, 4 = large omnivores, 5 = arboreal carnivores - carnivorous species which at least partially inhabit the tree and shrub layer, 6 = aquatic omnivores - omnivorous species which are at least partially aquatic, 7 = arboreal insectivores - insectivorous species which at least partially inhabit the tree and shrub layer.

Amphibians: 1 = wide-ranging terrestial egg-layers, 2 = wide-ranging ephemeral water egg-layers, 3 = wide-ranging permanent water egg-layers, 4 = riparian and riverine species.

Species	General Habitat	Habitat Components	Guild	Known or Likely	Location	Reason for Significance
Amphibians						
Tusked Frog	gully forest, melaleuca thicket	logs, rocks, rock crevices	2	possible		southern limit of range
Green Tree Frog	gully forest, melaleuca thicket	moist environment	3	likely		declining numbers
Blue Mountains Tree Frog	woodland, sclerophyll forest	permanent - semi-permanent rocky creeks	3	likely		status unknown in Sydney region
Jervis Bay Tree Frog	wet & dry sclerophyll forest, woodland/heath complex	streamline vegetation	4	known	Phillips et. al. (1996)	edge of range
Heath Frog	wet & dry sclerophyll forest, woodland/heath complex	permanent - semi-permanent water bodies	2	likely		habitat under threat
Brown Toadlet	heath/swamp complex, melaleuca thicket, forest/woodland	rocks, leaflitter, swampy areas, emphemeral streams	2	likely		disappearing from areas where it was once known
Reptiles						
Bearded Dragon	forest, woodland	low vegetation, logs, hollows	4	known	Phillips et. al. (1996)	declining in Cumberland Plain Woodland
Black Rock Skink	rock outcrops	boulder slopes, rock faces	7	known	306500/62212500	uncommon in region
Diamond Python	forest, woodland	rocky outcrops, arboreal hollows	5	known	Site X	declining
Lace Monitor	forest, woodland	trees	5			loss of habitat in Cumberland Plain Woodland
Mountain Dragon	dry sclerophyll forest, heath	rocks, ground litter	2	known	Sites AA, CC, K, O, T, Z	restricted to heath in Sydney area
Birds						
Bar-shouldered Dove	woodland, gardens	open areas	GGr	known	Phillips et. al. (1996)	near limit of distribution

Species	General Habitat	Habitat Components	Guild	Known or Likely	Location	Reason for Significance
Beautiful Firetail	riparian, woodland, heath	shrubs, dense undergrowth	GSGr	known	Site I	ecological specialist, near limit of distribution, uncommon in region
Brown Treecreeper	woodland, gully forest	fallen timber, old dead trees and stumps	GBI	known	Site O	rare possibly due to removal of fallen timber and paucity of old dead trees.
Brush Cuckoo	woodland, gully forest	fallen timber, old dead trees and stumps	FoI	possible		significant reduction in population
Buff-rumped Thornbill	heath, open woodland	shrubs, hollows, loose bark (nesting)	GSI	known	Sites I, L, M, O, AA, DD, FF	severe threatening processes
Chestnut-rumped Heathwren	heath, heathy woodland	shrubs	GIGr	known	Sites Y, AA, EE	ecological specialist, restricted habitat
Diamond Firetail Finch	forest, woodland, open mallee, scrub	shrubs	GGrI	known	recorded by Lane in AXIS/AMBS (1995)	significant reduction in population, severe threatening processes
Double-barred Finch	woodland, grassland	open grassy areas, shrubs	GGr	known	range control	significant decline in population
Flame Robin	woodland	open understorey, logs and leaf litter	I	known	Site II	severe threatening processes
Fuscous Honeyeater	forest, woodland	flowering shrubs, nectar, insects	NI	known	Phillips et. al. (1996)	significant reduction in population, severe threatening processes
Hooded Robin	heath, woodland	fallen timber, tree stumps	GI	possible		disjunct population, significant reduction in population, severe threatening processes
Grey Goshawk	open woodland, forest	tall trees	P	possible		rare in Cumberland Plains Woodland
Jacky Winter	eco-tone of woodland and open areas, open understorey	open areas, shrubs	GAeI	known	AXIS/AMBS (1995) near range control	severe threatening processes
Little Eagle	woodland, dry forest	trees with perches	P	known	308000/6231000	uncommon
Little Raven	woodland, open forest	trees with perches	O	known	Sites A,Y,Z	disjunct population, rare
Nankeen Night Heron	rivers, creeks, swamps	open water	W	known	Phillips et. al. (1996)	
Peaceful Dove	woodland	open areas	GGr	known	Phillips et. al. (1996)	severe threatening processes
Peregrine Falcon	forest, woodland	cliffs	P	known	Phillips et. al. (1996)	uncommon
Red-capped Robin	woodland	open understorey, leaf litter, logs	I	known	recorded by Lane (in AXIS/AMBS)	disjunct population, significant reduction in population, severe threatening processes

Species	General Habitat	Habitat Components	Guild	Known or Likely	Location	Reason for Significance
Restless Flycatcher	forest, woodland, scrubland	ground cover	Fo	known	Phillips et. al. (1996)	significant decline in population
Rockwarbler	gully forest	rocky gullies with open water	GIGr	known	Sites A, AA, FF, I, L	significant proportion of population contained within the region
Shrike-tit	forest, woodland, riparian	decorticating bark	B	likely		loss of habitat
Southern Emu-wren	woodland heath complex	dense vegetation	SI	known	Site O	ecological specialist, restricted habitat, uncommon in region
Speckled Warbler	open woodland	open understorey, leaf litter, logs	GGrI	known	Phillips et. al. (1996)	disjunct population, significant reduction in population, severe threatening processes
Tawny-crowned Honeyeater	heath/woodland ecotone	flowering shrubs, bare ground	N	known	Site D	ecological specialist, uncommon in region
Wedge-tailed Eagle	open woodland, open forest	tall trees	P	possible		declining
Weebill	open forest, woodland	shrubs	FoI	known	Sites AA, CC	possibly declining
White-bellied Cuckoo-shrike	wide variety of habitats	trees, shrubs	IFr	possible		rare
White-bellied Sea-eagle	open forest, coastal	tall trees	P	possible		loss of habitat, uncommon
White-fronted Chat	heath, low woodland	low vegetation	GI	known	Site D	ecological specialist, restricted habitat, uncommon in region
White-winged Chough	open woodland	open ground	GI	known	Site D	severe threatening processes
Yellow-rumped Thornbill	open woodland, lawn	shrubs,	GIGr	known	range control	severe threatening processes
Mammals						
Brown Antechinus	gully forest, heathy woodland, woodland	ground cover, logs, rocky areas	I	known	Sites A, M, U	loss of habitat in Cumberland Plains Woodland
Common Dunnart	grassland, heathland, woodland	logs	I	possible		unknown, difficult to trap
Common Wombat	woodland, forest, heathland	grass, dense cover	Lh	known	Sites O, FF, Y, K	restricted habitat
Eastern Grey Kangaroo	open woodland and forest, grass	grass, cover, water	Lh	known	Sites D, O, K	restricted habitat east of hume highway
Greater Glider	tall forest	hollows, mature forest	ArHeHo	possible		restricted habitat, sparsely distributed
Long-nosed Bandicoot	heath, shrubland, heathy woodland, forest/grass ecotone	dense ground cover, shrubby cover, grasses	I	known	Sites D, DD, M	sparsely distributed
New Holland Mouse	heathland	dense cover	O	known	AXIS/AMBS (1995) - F7	restricted habitat, sparsely distributed

Species	General Habitat	Habitat Components	Guild	Known or Likely	Location	Reason for Significance
Platypus	flowing waterbodies	water, stabilised banks	Aq	known	Punchbowl Creek, Deadmans Creek, Williams Creek	declining habitat
Red-necked Pademelon	rainforest, wet sclerophyll forest	dense cover	Lh	possible		restricted habitat, sparse distribution
Red-necked Wallaby	open woodland and forest, grass	grass, cover	Lh	known	Site M, AFK, 1996	restricted habitat
Wallaroo	woodland, forest on shale	rocky outcrops	Lh	known	Site A, AXIS/AMBS (1995) F16	restricted habitat, sparse distribution
Water Rat	wetland, riparian	water	AqO	probable	Site G	restricted distribution in the Sydney area
Grey-headed Flying Fox	woodland, wet and dry sclerophyll forest,	flowering plants	FFrHe	known	Sites P, Q, R, V	two colonies in the Sydney area
Little Red Flying Fox	forest, woodland	flowering plants	FN	likely		rare
White-striped Mastiff Bat	forest, woodland, riparian vegetation	hollows, bark	ArI	known	Sites A,C,D,I,N,R,Z,AA	very low population densities throughout Sydney region

1.9 SUMMARY OF IMPACTS

This section provides a summary of impacts on significant species at a national and state level. Detailed impact assessment for each species has been presented in species profiles in Sections 1.7 and 1.8.

Table B2.15 Summary of impacts on species of national and state significance

High regional impact occurs when the proposal affects a species that is not mobile and has specific habitat requirements.

Regional impact is considered when the proposal affects a mobile species with specific habitat requirements that is known to occur in the study area.

High local impact occurs when the proposal affects a species which is known to occur in the study area, is mobile and has general habitat requirements and habitat is continuous and widespread.

Unknown is indicated when insufficient information is available to determine the impacts of the ptoposal on indivdual species.

Not likely is indicated when consultation has revealed that a species is considered unlikely to occur in the study area.

Table B2.15. Summary of impacts for significant species known or likely to occur within the Badgerys Creek and Holsworthy sites.

Species	**Impacts**				
	High Regional	**Regional**	**High Local**	**Unknown**	**Not Likely**
Badgerys Creek					
Regent Honeyeater N(e),S(e)				✓	
Swift Parrot N(v), S(v)				✓	
Green and Golden Bell Frog S(e)				✓	
Australasian Bittern			✓		
Black Bittern S(v)			✓		
Glossy Black-Cockatoo S(v)			✓		
Powerful Owl S(v)			✓		
Yellow-bellied Sheathtail Bat S(v)				✓	
Eastern Little Mastiff Bat S(v)				✓	
Greater Broadnosed Bat S(v)				✓	
Eastern False Pipistrelle S(v)				✓	
Large-footed Myotis S(v)				✓	

Species	**Impacts**				
	High Regional	**Regional**	**High Local**	**Unknown**	**Not Likely**
Common Bentwing Bat S(v)				✓	
Large Pied Bat S(v)				✓	
Eastern Cave Bat S(v)				✓	
Total			4	11	
Holsworthy					
Broad-headed Snake N(e), S(e)	✓				
Regent Honeyeater N(e),S(e)				✓	
Swift Parrot N(v),S(v)				✓	
Eastern Bristlebird N(v), S(v)					✓
Brush-tailed Rock Wallaby N(v), S(v)				✓	
Green and Golden Bell Frog S(e)				✓	
Giant Burrowing Frog S(v)	✓				
Red-crowned Toadlet S(v)	✓				
Heath Monitor S(v)				✓	
Australasian Bittern S(v)				✓	
Bush Stone-curlew S(e)				✓	
Black Bittern S(v)				✓	
Glossy Black-Cockatoo S(v)		✓			
Turquoise Parrot S(v)				✓	
Ground Parrot S(v)					✓
Powerful Owl S(v)			✓		
Sooty Owl S(v)			✓		
Masked Owl S(v)			✓		
Painted Honeyeater S(v)				✓	
Tiger Quoll S(v)			✓		
Yellow-bellied Glider S(v)				✓	
Squirrel Glider S(v)				✓	

Species	Impacts				
	High Regional	Regional	High Local	Unknown	Not Likely
Koala S(v)		✓			
Long-nosed Potoroo S(v)				✓	
Yellow-bellied Sheathtail Bat S(v)				✓	
Eastern Little Mastiff Bat S(v)				✓	
Greater Broadnosed Bat S(v)				✓	
Eastern False Pipistrelle S(v)				✓	
Large-footed Myotis S(v)				✓	
Common Bentwing Bat S(v)				✓	
Large Pied Bat S(v)				✓	
Eastern Cave Bat S(v)				✓	
Total	3	2	4	21	2

Footnote: Status: N(e) = Listed on Schedule 1 of the Endangered Species Protection (ESP) Act (1992); N(v) = Listed on Schedule 2 of the ESP Act 1992; S(e) = Listed on Schedule 1 of the NSW Threatened Species Conservation Act 1995; S(v) = Listed on Schedule 2 of the NSW TSC Act 1995.

Appendix C

Freshwater Fish and Crayfish

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1. APPENDIX C - FRESHWATER FISH AND CRAYFISH

1.1 METHODS

Fieldwork for the following research was carried out under the terms of Section 37 of the Fish Management Act 1994 (F89/18) issued by NSW Fisheries.

1.2 CHARACTERISING FRESHWATER HABITAT

It should be noted that only fish and crayfish habitats were considered throughout this study. Technical Paper No 7 considers water quality and macroinvertebrates. As similar methodology was used for both Badgerys Creek and Holsworthy, the methodology for both sites is combined below.

1.2.1 Desktop Study

To broadly characterise the diversity of stream habitats present, the following attributes were described in selected stream/river sections using 1:25 000 scale topographic maps and aerial photographs. Standard colour 1:25 000 aerial photographs taken on 4/10/94 for Badgerys Creek and on 4/1/94 for Holsworthy were used.

Stream elevation: Longitudinal profiles of stream elevation were derived from contouring on 1:25 000 topographic maps.

Stream gradient: Profiles of stream gradient were derived from the above stream elevation profile data. Stream gradient strongly influences the abundance, size and depth/velocity characteristics of the pool habitats. The occurrence of riffles/runs and fish passage restrictions is also closely controlled by stream gradient.

Stream width: Stream widths give an indication of a key habitat feature of streams, the volume of habitat. Stream widths also give an indication of the stream's exposure to sunlight (i.e. the potential for water heating and aquatic plant growth). The width of the visible river surface was recorded (riparian vegetation canopy edge-to-edge distance, minimum resolution ca.2.5 metres) for each 100 metres of the river/stream where aerial photographs were made available.

Riparian vegetation canopy width: This width gives an indication, albeit not definitive, of the integrity of river bank vegetation. This in turn provides an indication of the likelihood that the vegetation can buffer impacts on the river arising from adjacent terrestrial disturbances and provide refuge areas for water-associated fauna. Riparian vegetation has also been shown to be important in structuring fish communities in the Nepean River (Gehrke and Harris 1996). Koehn and O'Conner (1990) and Burchmore (1993) noted the great importance of riparian vegetation to stream ecosystems. It could be argued that riparian vegetation communities are a critical component of stream ecosystems given that they provide nutrients, food and shelter for the biota, and strongly influence the physical environment by stabilising water temperatures (through shading) and limiting the input of sediment.

As above, standard colour 1:25 000 aerial photographs were used as the data source. The width of the riparian vegetation canopy on each bank was recorded (minimum resolution ca.2.5 metres) for each 100 metres of the river/stream where aerial photographs were made available. Widths equal to or greater than 125 metres were recorded as 125 metres.

Where widths were less than or equal to 125 metres, an assessment was made as to whether this was a result of natural conditions (e.g. rock outcrops), or due to gross human disturbance (e.g. roading, clearing for agriculture, etc). A stream/river section with a low level of gross disturbance in the riparian zone clearly has greater value than one with a high level of disturbance. The level of disturbance was expressed as the occurrence rate (percentage) within all the 100 metre riparian samples (left and right banks are considered as separate samples) examined in a particular stream/river section.

Habitat diversity index: Apart from characterising fundamental features of the stream/river environments, the above physiographic/riparian analysis provided the basis for the development of a measure of habitat diversity for the various stream/river sections. It was assumed that variation in elevation, stream gradient, stream width and riparian vegetation width, strongly (and positively) influences aquatic habitat diversity. A stream/river with high habitat diversity clearly has higher value than one with low habitat diversity. Variation in the above four variables was defined by calculating the standard deviations from the samples gathered (the 100 metre samples for river width and riparian vegetation width together with at least 20 randomly chosen measurements made from the profiles of stream elevation and stream gradient). The derived standard deviations were standardised to have a mean value of 1.0 in order to give equal weight to the variables when calculating the index. The sum of these adjusted standard deviations was the index of habitat diversity.

1.2.2 Field Work

All field work was conducted during summer 1996/7. Badgerys Creek was surveyed between 27 and 30 January 1997 while Holsworthy between 17 December 1996 and 8 January 1997. The location of survey sites at Badgerys Creek are shown in Figure C1; survey sites at Holsworthy are on Figure C2. Figures A3.1 and A3.2 show sampling locations from this and other previous studies.

Habitat attributes were characterised to varying degrees depending on logistical constraints (e.g. size, complexity and access) of the stream reach being examined. Particular emphasis was placed on locating fish migration obstacles (e.g. weirs, waterfalls, etc.) and assessing the quality of habitat and its susceptibility to degradation. Field assessments in the Holsworthy area also focused on determining the suitability of habitat for 'Macquarie' Perch, a species predicted to be present in the Georges River system. As this species was known to be abundant in the adjacent Loddon River (Figure C3.2; feeder stream of Cataract Dam), a habitat assessment was made at this locality to develop an understanding of the species'environmental requirements.

1.3 CHARACTERISING FISH AND CRAYFISH COMMUNITIES

Desktop Study

Data on fish/crayfish occurrences in the Badgerys Creek and Holsworthy areas was initially derived from the literature and through contact with a limited number of biologists who had undertaken surveying in or about the areas. This information was later augmented by the results of interviews with landholders and anglers, and fishing club questionnaires contained in Attachment 1.

Field Work

The range of sampling techniques used at a particular site was a function of site suitability. Where possible, a similar range of sampling techniques was used in the two study areas. For both areas, the information obtained was very important in augmenting existing data and in turn deriving the conservation index defined below. In and about the Badgerys Creek area, no sampling was undertaken in the lower Nepean

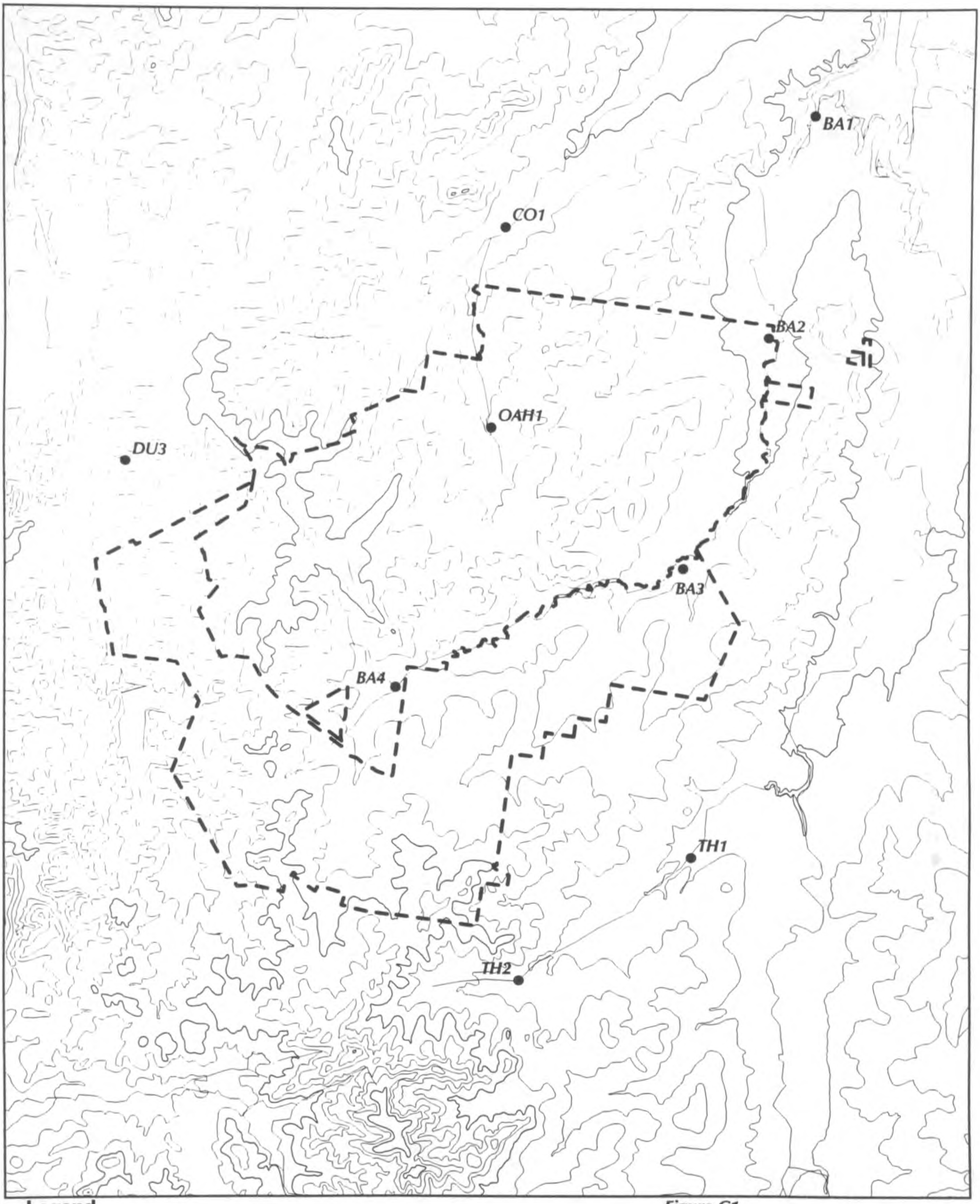

Figure C1
Badgerys Creek Aquatic Sampling Sites

28/7/97

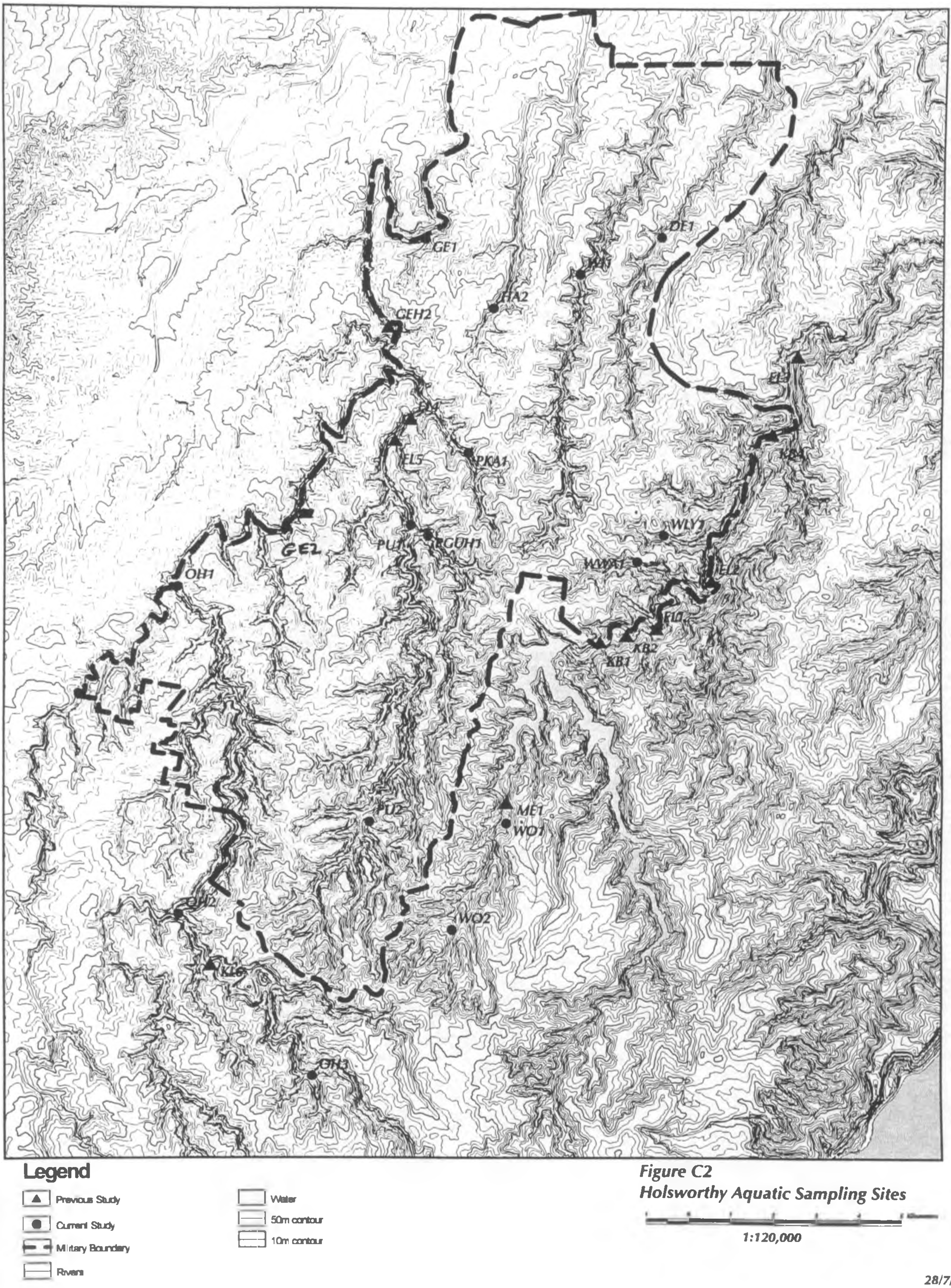

Figure C2
Holsworthy Aquatic Sampling Sites

1:120,000

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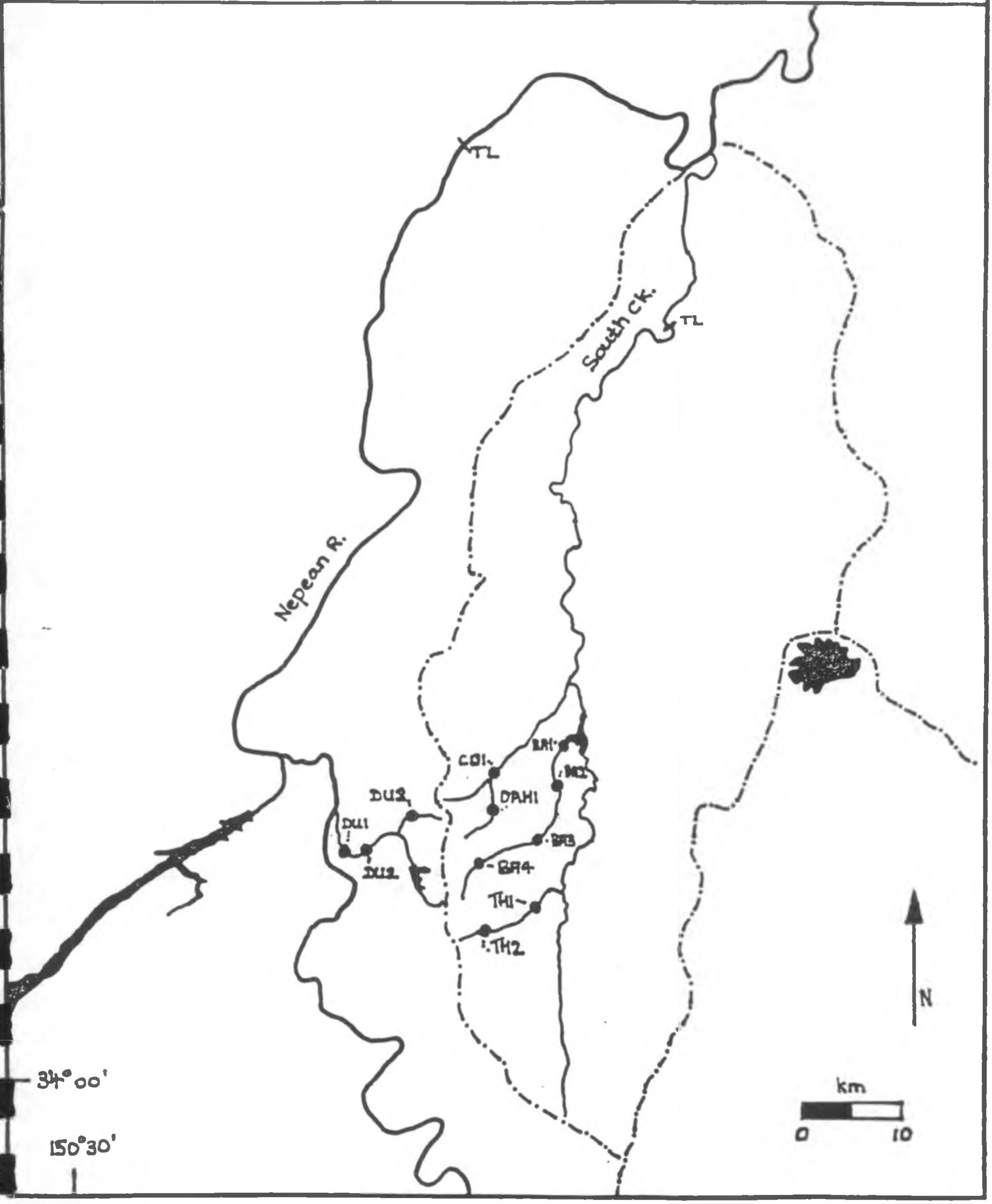
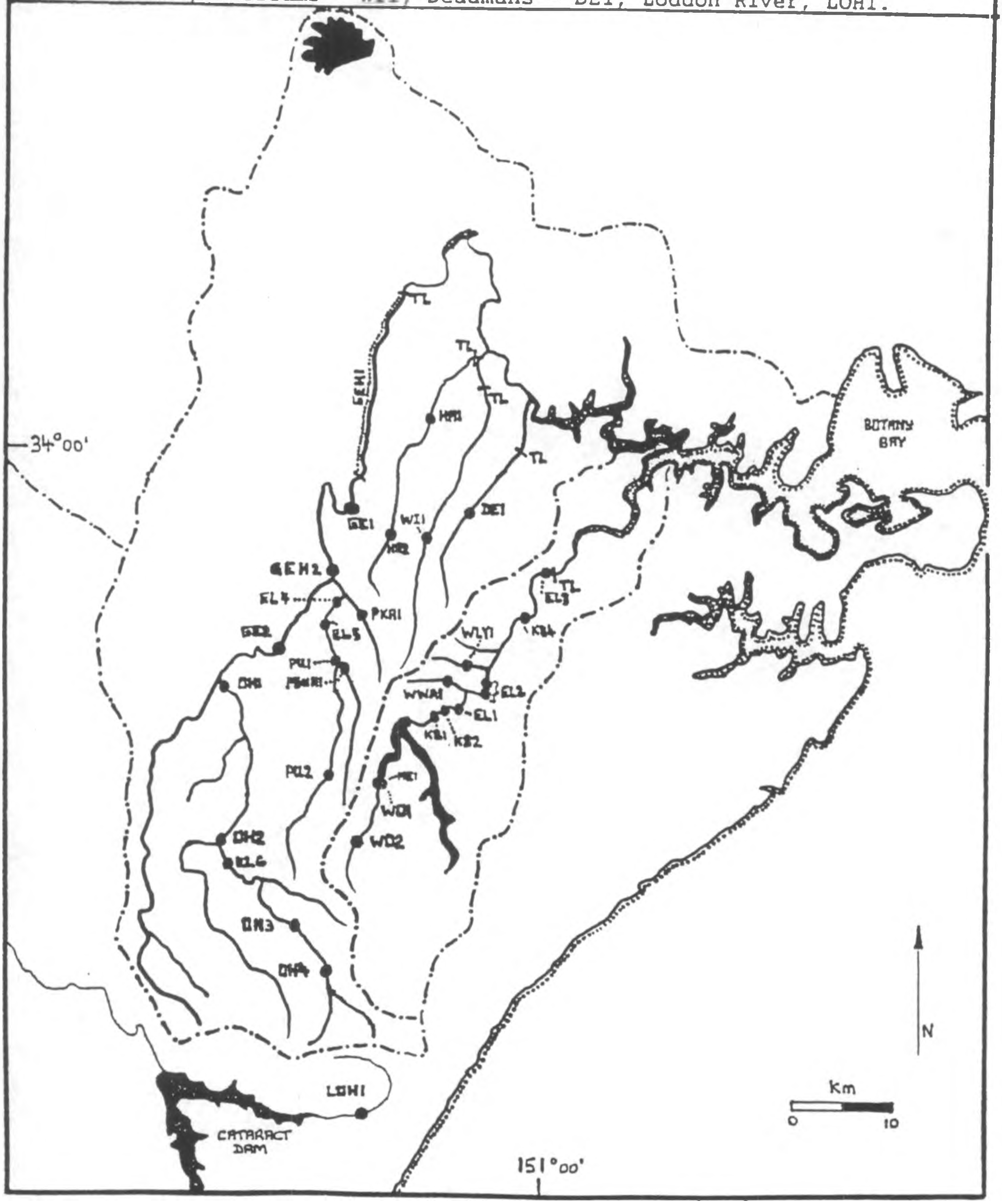
FIGUREA3.1SOUTH CREEK CATCHMENT SHOWING STREAMS OF INTEREST. Duncans Ck., a tributary of the Nepean River, is also shown. South Creek catchment boundary = _._; Tidal limit = TL; Stream names are indicated in relation to coded sampling sites: Cosgroves Creek: CO1 (trib: Oaky, OAH1); Badgerys Creek: BA1, BA2, BA3 and BA4; Thompsons Creek: TH1 and TH2; Duncans Creek: DU1, DU2 (trib: unnamed, DU3).



FIGUREA3.2THE GEORGES RIVER CATCHMENT SHOWING MAJOR STREAMS. Catchment boundaries = _._ (includes Woronora R. sub-catchment); TL = tidal limit; estuary & ocean shores = ...; Stream names are indicated in relation to coded sampling sites: Georges River: GEH1 (Liverpool Weir), GE1, GEH2, GE2; Punchbowl Creek: EL4, EL5 (TG1 not incl.), PU1, PU2 (tribs: Kalibucca, PKA1; Gunya, PGUH1); O'Hares Creek: OH1, OH2, EL6, OH3 (EL7 not incl.), OH4; Woronora River: EL3, KB4, EL2, EL1, KB2, KB1, WO1, WO2 (tribs: Lyretail, WLY1; Wappa, WWA1); Northern streams: Harris - HA1 & HA2, Williams - WI1, Deadmans - DE1; Loddon River, LOH1.



River or the upper Hawkesbury River estuary because of intensive sampling recently undertaken by NSW Fisheries.

In the Holsworthy area, 'Macquarie' Perch and crayfish were primarily targeted, although a wide range of other taxa were also effectively sampled. No sampling was undertaken in the Woronora River downstream of Woronora Dam because of recent, reasonably intensive sampling undertaken by the Ecology Lab for Sydney Water (see sites prefixed 'EL' in Figure C3.2). Sampling extended up O'Hares Creek beyond the Holsworthy area in order to substantiate the predictions of 'Macquarie' Perch occurring in the Georges River system. The alignment of O'Hares Creek and the nearby Loddon River (Figure C3.2) indicates the possibility of river capture occurring in recent geological history. Given the occurrence of 'Macquarie' Perch in the Loddon River (T. Marsden, NSW Fisheries *pers. comm*), river capture may be a mechanism for the transfer of the species to the Georges River system.

The following surveying methods were used:

- Six-hour sets (three hours before sunset to three hours after sunset) of monofilament surveying gillnets: 35 x 2 metre multiple-meshed sized incorporating seven 5 metre panels, each with different mesh size (26, 44, 58, 76, 100, 132, 150 millimetre meshes, knot to knot) arranged sequentially by increasing mesh size;

- Six-hour sets (as per gillnets) of four 'Operahouse' fish/crayfish traps (baited with tinned catfood);

- Collections in shallow areas (less than 1.0 metre) with a 10 metre long seine net; mesh size 10 millimetres (knot to knot), depth 1.5 metres;

- Collections in shallow areas (less than 1.0 metre) with a Japanese push seine; mesh size 2 millimetres (knot to knot);

- Observing/dipnetting fish at night with the aid of a 50 W underwater spotlight (approximately one hour of observation at each site). This technique, which is very effective in detecting 'Macquarie' Perch (*pers. obs.*, J. Harris, NSW Fisheries *pers. comm*), was possible because of the generally high water clarity, particularly in the Holsworthy area. It has further advantages in that it is non-destructive.

- Recording the occurrence of fish/crayfish during the day by visual observation using polarising glasses;

- Collections during the day by attracting fish/crayfish with a bait and scooping them with a dipnet, polarising glasses were also used;

- Collections in the day with a dipnet.

Fish were identified using keys in McDowall (1996). The keys were not adequate for galaxiids and so specimens were sent to a taxonomic specialist (Dr A. Sanger, Tasmanian Inland Fisheries Commission) for identification. The lengths of all captured larger fish (i.e. catfish, bass, etc) were recorded to the nearest 5 millimetres (length to caudal fork [LCF]) or total length [TL] depending on the shape of the tail). Efforts were made to return all native fish back alive to the river. Pest fishes were destroyed.The maximum and minimum lengths of samples of smaller fish were recorded to the nearest 1 millimetre (LCF or TL depending on the shape of the tail). Generally these fish were preserved in 10% formalin solution for later sorting and identification in the laboratory. Crayfish were either identified in the field or later in the laboratory after being preserved in 10% formalin. Keys in Merrick (1993) and Morgan (in press) were used in combination. Where difficulties were encountered with the keys, specimens were sent to a taxonomic specialist (Dr P. Horwitz, Edith Cowan University) for identification. Carapace lengths were recorded to the nearest mm.

1.4 CLASSIFICATION

Common and scientific names for fish are taken from McDowall (1996). Taxonomic classification for crayfish is from Merrick (1993).

1.5 CONSERVATION VALUE ASSESSMENT

1.5.1 Conservation Index Derivation

Index derivation followed the procedure used by Bishop (in Meredith *et al.* 1995) for a sample of 1032 streams in south-eastern Australia Accordingly, information was gathered with the aim of developing an index which would collectively reflect the occurrence of the following features:

1. recognised valuable areas in which diminished integrity of stream ecosystems would diminish intrinsic values;
2. the naturalness of fish communities;
3. high conservation value fish species;
4. high recreational value fish species;
5. high conservation freshwater crayfish species;
6. valuable areas for scientific research.

Emphasis was placed on fish and crayfish for two reasons: information on the conservation status for these taxa is reasonably adequate and the general public are familiar with them. The index was determined for streams on which major land disturbance impacts are expected to occur as a result of the various airport options. The index is determined for a specific point on the streams and this was taken to be where airport option boundaries cross them. This boundary is referred to as the 'impact edge'. The six components above formed the basis of the derived index. The method by which scores were attributed to each component is described below:

- **Recognised valuable areas**. The occurrence of these areas was determined by reference to the following: Australian Heritage Commission (1996) - areas listed and nominated for listing on the Register of the National Estate; Department of Water Resources (1987) - proposed NSW wild and scenic rivers; State Pollution Control Commission (1980) - protected, controlled and specially protected NSW waters; Smith & Smith (1994) - significant wetlands in the Hawkesbury-Nepean River valley. The scores were attributed as follows:

DISTANCE FROM IMPACT EDGE	SCORE
Area 0 to 1 km downstream (by stream) of impact edge	2
Area 1 to 50 km downstream of impact edge	1
Area greater than 50 km downstream or no area present	0

The scores were summed if more than one area was present downstream.

- **Naturalness of fish communities**. Fish communities with few introduced species are becoming increasingly rare in south-eastern Australia. Accordingly, such communities should be recognised as having a higher conservation status than those dominated by introduced taxa. Information on the known occurrence of introduced fish taxa was derived from literature review and field sampling. Assumptions were made regarding the distribution of fish species present based on limited sampling. The scores were attributed as follows:

0-1 km downstream of impact edge:

PRESENCE OF INTRODUCED SPECIES	SCORE
No introduced species	6
One introduced species	4
Two-four introduced species	2
Greater than 4 introduced species	0

1 - 50 km downstream of impact edge:

PRESENCE OF INTRODUCED SPECIES	SCORE
No introduced species	3
One introduced species	2
Two-four introduced species	1
Greater than four introduced species	0

The scores were halved for situations where large impoundments were located between the impact edge and the downstream stream section (the impoundments would buffer any impacts in these sections). Scores were summed across areas.

- **High conservation-value fish taxa**. High conservation value fish taxa were identified as those listed at the national and state levels. All species with a status of 'Indeterminate' or greater as listed by Jackson (1995) are considered to be of national significance. No clear guidelines for listing exist in NSW; however, Jackson (1994) and Wagner and Jackson (1993) note that there are bans and proposed bans on captures for a number of species.

  Information on known occurrences was derived from literature review, field sampling, interviews and fishing club questionnaires. Assumptions regarding fish distributions were made based on limited sampling. The scores were attributed as follows:

0-1 km downstream of impact edge:

FISH TAXA	SCORE
Number of high value species present	2

1-50 km downstream of impact edge:

FISH TAXA	SCORE
Number of high value species present	1

The scores were halved for situations where large impoundments were located between the impact edge and the downstream stream section. Scores were summed across areas.

- **High recreational value fish taxa**. These are taken to be large-bodied species (weight greater than 0.5 kilograms) which can readily be taken by angling and are highly prized by anglers. Indices were determined using the same methodology as for *High conservation value fish taxa* described above. Estuarine areas were not included.

- **High conservation value freshwater crayfish**. Information on occurrences of species was derived from literature review, field sampling, interviews and fishing club questionnaires. Assumptions regarding fish distributions were made based on limited sampling. All crayfish taxa were considered to have high conservation value. The scores were attributed as follows:

0 - 1 km downstream of impact edge:

CRAY FISH TAXA	SCORE
Number of species	2

1 - 50 km downstream of impact edge:

CRAY FISH TAXA	SCORE
Number of species	1

The scores were halved for situations where large impoundments were located between the impact edge and the downstream stream section. Scores were summed across areas.

Valuable areas for scientific research. These areas were identified by the occurrence of reference sites currently being used for the long-term monitoring of freshwater fauna. Such monitoring is extremely valuable as it provides a direct measure of ecosystem integrity and produces information crucial to stream managers. Because of the long-term nature of monitoring systems, large amounts of money have already been invested in order to obtain data. A range of research organisations was approached in order to determine the locations of monitoring points, particularly those involved in the Commonwealth Government's 'Monitoring River Health Initiative'. Scores were attributed as follows:

0-0.1 km downstream of impact edge:

MONITORING SITES	SCORE
Number of sites	4

0.1-1 km downstream of impact edge:

MONITORING SITES	SCORE
Number of sites	2

1-50 km downstream of impact edge:

MONITORING SITES	SCORE
Number of sites	1

The scores were halved for situations where large impoundments were between the impact edge and the downstream stream section. Scores were summed across areas.

1.5.2 Calculation of the Conservation Index

The data from the Badgerys Creek and Holsworthy areas was analysed along with the 1032 samples taken by Bishop (in Meredith *et al.* 1995). To give equal weighting to the six components (variables) defined above, scores for each component variable were standardised so that their mean value was 1.0. These standardised scores were then summed across the six components. The resultant variable was then standardised so that its mean value was 1.0 (i.e. the resultant scores were divided by 6).

1.5.3 Contact with Recreational Fishers

Representatives from a number of recreational fishing clubs (see Table C3.1) were contacted and asked to indicate their use of various stream/river sections relevant to investigations in the Badgerys Creek and Holsworthy areas. They were also asked to give an indication of the extent to which they valued the fisheries in these sections (Table C3.2 and A3.3). A copy of the correspondence sent to clubs indicating that they had a reasonable level of experience in the stream/river sections, is given in Attachment 1.

1.6 RESULTS

1.6.1 Badgerys Creek

1.6.1.1 Fish

A list of the fish species recorded in waters in the Badgerys Creek area are given in Table C3.4. Site occurrences from the present study are given in Table C3.5. Only the Eastern Gambusia, an introduced pest species, was found within the study site. European Carp, Goldfish and some native gudgeon species are also expected to occur there.

Considering downstream areas through South Creek and its upper tributaries, a total of ten native and three introduced species were recorded in freshwaters. Downstream through Duncans Creek to the lower Nepean River, a total of sixteen native and three introduced species were recorded.

1.6.1.1.1 High conservation value (HCV) fish

No HCV fish species were recorded within the Badgerys Creek study area. Downstream of the site, in the lower Nepean River (connection through Duncans Creek), one HCV species, the 'Macquarie' Perch, is present. Another HCV species, the Australian Grayling (*Prototroctes maraena)* is no longer expected to occur in the Hawkesbury-Nepean River system. It was recorded in the Grose River early this century and a senior fisheries inspector indicated that grayling were common in the Grose River in the 1950s (Bell *et al.* 1980). There was an unsubstantiated record in this river in the early 1980s (D. Pollard, NSW Fisheries *pers. comm.*). However, specific surveys by NSW Fisheries and intensive sampling of the lower Nepean River in 1992-95 by NSW Fisheries have yielded no grayling.

'Macquarie' Perch

'Macquarie' Perch (*Macquaria australasica* [?]) are listed as a protected species in NSW (Fisheries Management Act 1994). It is presently listed nationally (Jackson 1995) as having 'Indeterminate' status in the classification of Australian threatened species by the Australian Society for Fish Biology. This status category includes taxa which are likely to fall into endangered, vulnerable or potentially threatened categories, but for which insufficient data are presently available to make an assessment.

Quotes are used around 'Macquarie', and a question mark appears after the specific name to distinguish this small variety of perch-like fish found in the Nepean River from the better known Macquarie Perch present in rivers west of the Great Dividing Range. Dufty (1986) found major phenotypic and genotypic differences between these forms indicating that the perch in the Nepean River was a separate species. Dufty has not yet formally described this new species. It is considered to be potentially threatened in the upper Nepean River by dam-induced low stream flows and associated degradation (Gehrke and Harris 1996; Sammut and Erskine 1995).

The 'Macquarie' Perch occurs upstream and downstream of the upper Nepean dams and within Warragamba Dam and some of its tributaries. It appears sporadically as far downstream as the Penrith Weir on the lower Nepean River (J. Sammut *pers. comm.*). This occurrence is associated with floods which presumably displace individuals from nearby steep gradient, pristine streams which drain the Blue Mountains National Park (e.g. they are present in Erskine and Glenbrook Creeks; T. Marsden, NSW Fisheries *pers. comm.*). 'Macquarie' Perch were not collected during intensive sampling of the lower Nepean River during 1992-95 by NSW Fisheries.

1.6.1.1.2 High recreational value (HRV) fish

No HRV fish species were recorded within the Badgerys Creek study site. Downstream of the site, a number of HRV species are present.

In the lower Nepean River (connection through Duncans Creek), three HRV species are present: Australian Bass, Eel-tailed catfish and 'Macquarie' Perch. Given that 'Macquarie' Perch are a protected species, all captured fish are required to be returned to the water unharmed. Although Estuary Perch are present in the Hawkesbury River estuary, none have been recorded in the lower Nepean River. European Carp are also sought in the area but these are considered a 'trash' species.

In South Creek (connection through Cosgroves, Badgerys or Thompsons Creeks), the only HRV species likely to be present is the Australian Bass. Again, European Carp are sought in the area but these are considered a 'trash' species. Landholders indicate that Golden Perch, a translocated native HRV species, are present in farm dams in the area. However, this has not been verified.

Australian Bass

Australian Bass (*Macquaria novemaculeata*), a sportsfish highly valued by recreational fishers, occurs in the Hawkesbury River estuary, along the Nepean River up to Maldon Weir (a major migration obstacle) and in tributary streams such as South Creek. This species must migrate from freshwaters to the estuary to breed (i.e. it is a catadromous species).

The most upstream recording of this species in South Creek is 20 kilometres by creek downstream of the Badgerys Creek study area. Landholders living near the proposed site indicate that bass used to occur up into the local area 20-30 years ago. Pollard *et al.* (1994) noted a decreased abundance of bass in the eutrophic zones downstream of sewage treatment works (STW) release points in the Nepean River. STW releases into the lower reaches of South Creek in the last 10-20 years may account for apparent reductions in the distribution of bass in the system.

Eel-tailed catfish

Eel-tailed catfish (*Tandanus tandanus*), a fish valued by recreational fishers, occurs along the Nepean River up to and within Maldon Weir. Limited electrophoretic analysis of enzymes in tissues of catfish from the river suggest that the species present is *Tandanus tandanus*, a species which is widespread west of the Great Dividing Range (T. Marsden, NSW Fisheries *pers. comm.*). Further electrophoretic analysis undertaken by Southern Cross University (Animal Conservation Genetics Department) for the present study confirmed this result.

1.6.1.2 *Crayfish*

No crayfish species were recorded within or downstream of the Badgerys Creek study site. However, it is predicted that the Common Yabby could occur in some downstream areas after escaping from surrounding farm dams where they had been stocked. Table C3.6 indicates the site occurrences of crayfish in the Badgerys Creek and Holsworthy areas.

Common Yabby

The Common Yabby (*Cherax destructor*), is the most widely distributed species of crayfish in Australia and occurs in streams, rivers, billabongs, and other water bodies. Its high value in the aquaculture industry has led to its extensive translocation. Common Yabbies are not considered endangered, but populations have been greatly reduced in some areas (Merrick 1993).

1.6.1.3 *Habitat*

Summary statistics of stream variables used to calculate habitat diversity index values for selected streams in the area are given in Table C3.7. Elevation and stream gradient profiles of selected streams are shown in Attachment 1 (Figures 1-14). Except for South Creek, the streams (excluding man-made water bodies) are all very narrow All have, at best, only narrow corridors of riparian vegetation. Mean elevations range from only 37 to 79 metres and stream gradients are generally low. Excluding Thompsons Creek, the gradients show only small variation.

The calculated habitat-diversity index values are shown in Figure C3.3. These indicate low to possibly moderate habitat diversity.

Major habitat degradation was apparent in all streams examined. Some of the forms of degradation included:

- siltation,
- terrestrial weed invasion;
- aquatic weed invasion;
- eutrophication;
- bank destabilisation caused by cattle/horse access;
- dumping of rubbish in streams;
- damage and major reductions in the surrounding riparian vegetation.

The frequency of gross disturbance in the riparian zone of selected streams is shown in Figure C3.4. All of the streams had a ca. 100% frequency of gross disturbance.

1.6.1.4 *Recreational Fishing Survey*

A total of six recreational fishing clubs, representing ca. 580 anglers, were contacted in relation to their members' fishing experience within and downstream of the Badgerys Creek site (Table C3.1). Only the Emmaus College Fishing Club (ECFC) and the Campbelltown City Sport Fishing Club (CCSC) had members who had recently fished in at least some areas about the site. The Panthers Club contact indicated that members didn't fish South Creek because it is now polluted due to releases from sewerage treatment works (STW). For similar reasons, the contact from the Nepean Fishing Club stated that it was extremely rare for club members to fish the area. This contact indicated that children currently take European Carp and eels from the South Creek System, but in the past (20 - 30 years ago), good catches of Australian Bass were common.

Members of the CCSC only had experience in the lower reaches of South Creek and in Duncans creek. The fishing quality was regarded as poor in both areas (Table C3.2). Although CCSC members rarely fished the lower reaches of South Creek (Attachment 1), it was noted that 20 fishers could be seen using the area on weekends and five on weekdays (Attachment 1). Carp and eels were seen as the main catch in this area (Attachment 1). In Duncans Creek, on average only one member fished the area on weekends and none on weekdays. Generally two other fishers were seen on weekends along this creek. Typically bass and eels were caught.

Members of the ECFC only had experience along south Creek and in Badgerys Creek. In the lower reaches of South Creek quality of the fishery was considered very good in summer (Table C3.2) with up to 20 members using the area on weekends and on two weekdays (Attachment 1). Typically four to five other fishers would be seen on weekends and one to two on weekdays (Attachment 1). Four native and one introduced fish species could be caught (Attachment 1). In the upper reaches of South Creek the quality of the fishery was regarded as good with up to ten members using the area on weekends and one on weekdays (typically two to three and one to two other fishers were respectively seen during these periods). The same array of fish species could be caught as in the lower reaches, however catches of bass, Herring and Mullet would be much less, and in contrast, greater catches of European carp and eels. In Badgerys Creek the quality of the fishery was considered reasonable with up to eight members fishing the area on weekends and one on weekdays (typically one to two and 0 to one other fishers were respectively seen during these periods). European Carp and eels were the species primarily caught, although bass and Mullet occasionally occur in catches Pollution and access were seen to be problems in all places fished by the club members.

Bishop (1996) undertook a similar recreational fishing survey for the Nepean River. For the Nepean River downstream of Duncan's Creek confluence, the quality of the fishery was viewed as ranging from "very good" to "excellent" by a number of fishing club representatives.

1.6.2 Holsworthy

1.6.2.1 Fish

1.6.2.1.1 Georges River and tributaries

Up until very recently, no formal fish surveys have been undertaken in freshwaters of this system. Surveys were undertaken in the upper estuary in 1978-81 by NSW Fisheries. Nineteen fish species were recorded (Table C3.8), and thirteen of these are known to enter freshwaters in other systems. The presence of the Liverpool Weir would restrict entry to the river upstream to brief periods of moderate to high river flows.

A list of fish species recorded in the Georges River and tributaries relevant to the present study are given in Table C3.9. Site occurrences from the present study and recent nearby surveys are given in Table C3.5. Eleven native species were recorded in the system, and all can be expected to occur within or on the borders of the Holsworthy site. Two translocated native species, Golden Perch and Murray Cod, have been reported in an impoundment on Brennans Creek, a tributary of the upper Georges River beyond the Holsworthy site. These reports have not been verified. Two introduced fish species, European Carp and Eastern Gambusia, have only been recorded on the borders of the Holsworthy site (i.e. in the Georges River).

A considerable number of catadromous and marine-vagrant species are notably absent in samples from fresh waters of the Georges River system (see Table C3.8, particularly freshwater herring, Bullrout, Bream, Roach, freshwater mullet and Bully Mullet). These apparent absences, and the consequent overall depression of species richness in the system, would primarily be due to Liverpool Weir blocking fish passage between the estuary and freshwaters. Fish passage is further inhibited upstream due to the occurrence of natural migration blocks such as waterfalls and cascades.

1.6.2.1.2 Woronora River and tributaries

Eleven native species were recorded in the system, all of which can be expected to occur within or bordering on the Holsworthy site (Tables A3.5 and A3.9). One translocated native species, the Silver Perch, has been reported in Woronora Dam. Only one introduced species, the Eastern Gambusia, has been recorded. This was on the border of the site.

1.6.2.1.3 Northern streams

Eight native species were recorded in the streams, all within the Holsworthy site (Tables A3.6 and A3.9). Only one introduced species, the Eastern Gambusia, was recorded in the lower reaches of Harris Creek.

1.6.2.1.4 High conservation value (HCV) Fish.

One HCV fish species was recorded The 'Macquarie' Perch, has been recorded upstream in O'Hares Creek in the Georges River system and within the lower Woronora River. These reports have not been verified, although the possibility exists that this species is present, albeit in low numbers, along the borders of and within the Holsworthy site. Another HCV species, the Silver Perch, has been recorded in Woronora Reservoir, a waterbody which borders the Holsworthy site on the eastern side.

'Macquarie' Perch

'Macquarie' Perch (*Macquaria australasica [?]*) are listed as a protected species in NSW (Fisheries Management Act 1994). It is presently listed nationally (Jackson 1995) as having 'Indeterminate' status in the classification of Australian threatened species by the Australian Society for Fish Biology. This status category includes taxa which are likely to fall into endangered, vulnerable or potentially threatened categories, but for which insufficient data are presently available to make an assessment.

Quotes are used around 'Macquarie', and a question mark appears after the specific name in order to bring attention to the possibility that the perch-like fish apparently found in the Georges and Woronora River systems, may not be the same as the better known Macquarie Perch present in rivers west of the Great Dividing Range. Like the perch-like fish in the Nepean River, a separate species may exist in the Georges Rivers system.

Stead (1906) noted the possibility of 'Macquarie' Perch being present in the Georges River system early this century. Macquarie perch were listed as being present in O'Hares Creek (Georges River system) in a Register of the National Estate Database Place Report for the O'Hares Creek catchment (AHC 1996). Discussions with the author of the report yielded no clear source for the origin of the listing. Two suggested leads were futile.

Another listing arose from a fishing club questionnaire returned on 15/2/97 by the Campbelltown City Sportsfishing Club. Only one of the 150 members of the club had experience with 'Macquarie' Perch in the area. The particular member was contacted and he indicated that:

- a number of 'Macquarie' Perch (approximately 200 millimetres total length) were caught while bait fishing in the lower Woronora River two years ago. He had not returned to the site since. He described key characteristics of 'Macquarie' Perch accurately. (Note that Anon. (1975) indicated that 'Macquarie' Perch were present in Woronora Reservoir.)

- ten years ago he was informed of a record of 'Macquarie' Perch in O'Hares Creek. He had great confidence in the identification skills of the fisher involved.

- some local fishers translocate fish from Cataract Reservoir to the Georges River system, particularly to an impoundment on Brennnans Creek. As 'Macquarie' Perch are abundant in Cataract Reservoir, this raises the possibility that records in the Georges River system are a result of translocations of the Nepean River species.

- there are records from a number of sources of 'Macquarie' Perch being present in the 1960-70s in Fishers Ghost Creek (Campbelltown), a tributary of the now highly degraded Bunbury Curran Creek.

The questionnaire returned by Bass Sydney (23/2/97) indicated that 'Macquarie' Perch were present in the upper Georges River and O'Hares Creek. This record was based on information supplied by NSW Fisheries personnel. Dr J. Harris of NSW Fisheries was contacted and it was indicated that he had heard of records of 'Macquarie' Perch in the Georges River system, but their follow up surveying did not provide verification.

Silver Perch

Silver Perch are a translocated native species. The record for this species in the Woronora Reservoir has not been verified. It is presently listed nationally (Jackson 1995) as having "Potentially Threatened' status in the classification of Australian threatened fishes by the Australian Society for Fish Biology.

1.6.2.1.5 High Recreational Value (HRV) Fish

One HRV fish species, the Australian Bass, was found within the Holsworthy site (northern streams and Punchbowl Creek in the Georges River system) and on its borders (Georges River and Woronora River). Another two HRV species, the Eel-tailed Catfish and 'Macquarie' Perch, have been recorded on the site's borders. It is possible that both of these species may occur within the site. Estuary Perch occur in the Georges River estuary (Table C3.9) and it is likely that, at times, they enter the section of Liverpool Weir which borders the Holsworthy site. Similarly, Silver Perch are found in a water body which borders the site. Golden Perch and Murray Cod, the two translocated native species which are reported to be present in the upper Georges River catchment, are also HRV species.

Australian Bass

Australian Bass, a sportsfish highly valued by recreational fishers, occurs in the Woronora River up to the Woronora Dam, the closest remaining bass stream to the Sydney CBD. Many rivers in the Sydney area have been degraded as a result of urban and industrial impacts. Bishop (1993) noted that population densities in the adjacent Georges and Hacking Rivers have been strongly depressed because weirs without effective fishways are present in their lower reaches (Liverpool and Audley Weirs, respectively). Recently major funding has been approved for the construction of fishways on these structures.

Dr J. Harris of the Fisheries Research Institute, Cronulla, has indicated that recruitment in the Georges River may be dependent upon spawning success in the Woronora River estuary (bass are catadromous). This condition is likely to be the same for the northern streams of the Holsworthy site which enter the Georges River estuary.

Unconfirmed reports indicate that bass have been recorded as far upstream as Appin in the Georges River. It is acknowledged that this occurs rarely and numbers are very low. Waterfalls and cascades along the Georges River are likely to greatly restrict up-river movement. A waterfall three metres high, immediately upstream of the Punchbowl Creek confluence, would limit upstream passage to periods of flooding out at very high flows. Bass were only caught downstream of this barrier in the present study (downstream =site GE1, upstream=sites GE2, OH1, OH2, OH3 and OH4).

As no major migration obstacles are present in the lower reaches of Punchbowl Creek, it is expected that the virtually all bass moving upstream in the Georges River would be diverted into this tributary which drains the Holsworthy site. Large catches of bass have been made in this stream at sites EL4, EL5, TG1 and PU1. Clearly, Punchbowl Creek is an important stream for bass of the Georges River system during the freshwater phase of their lifecycle.

Australian Bass

Eel-tailed catfish (*Tandanus tandanus*), a fish valued by recreational fishers, was recorded in the Georges River. Electrophoretic analysis of enzymes taken from captured individuals was undertaken by Southern Cross University (Animal Conservation Genetics Department) for the present study to confirm the species identity. This species is widespread west of the Great Dividing Range.

1.6.2.2 Crayfish

All crayfish species are considered to have high conservation value. A list of crayfish recorded in waters relevant to the study area is given in Table C3.9. Site occurrences are given in Table C3.6.

Two species, the Sydney Crayfish and the Australian Crayfish, were recorded within and around the Holsworthy site. Potentially, another species of spiny crayfish *(Eustacus* sp.A) may also be present within the site. A further species, the Common Yabby, is present in a water body bordering of the site.

Sydney crayfish

The Sydney Crayfish (*Eustacus spinifer*) (a spiny species) was the most widely distributed and abundant species found within and about the Holsworthy site. It occurred in small to large streams in the Georges and Woronora River systems. It also occurred in each of the northern streams. Its abundance was reduced in more accessible areas, suggesting that its populations are readily depleted when fishing pressure is applied.

Merrick (1993) indicated that this species has a limited range in the Hawkesbury-Nepean, Parramatta, Georges, Hacking and Shoalhaven River systems. Its populations are now greatly reduced or absent from areas of dense development such as most of the Parramatta River system.

Australian Crayfish

The Australian Crayfish (*Eustacus australasiensis*), another spiny species, was found in the Woronora River and its tributaries. It was also recorded in Deadmans Creek and is likely to occur in the other northern streams within the Holsworthy site.

Merrick (1993) indicates that this species has limited range from Mount Ousley (north of Wollongong), through the upper Hawkesbury system, and north to the coastal Gosford district. The status of this species is unclear.

Unidentified spiny crayfish

One spiny crayfish (*Eustacus* sp.) collected in Deadmans Creek within the Holsworthy site had very unusual spination - one spine on the carpus. No other spiny crayfish species has this spination. As the specimen collected was small, it is possible that this spination may be within normal variation for juveniles of a common crayfish species. In analyses of conservation significance which follow, it has been conservatively assumed that the specimen represents a separate species.

Common Yabby

Common Yabbies are the most widely crayfish distributed species in Australia occurring in streams, rivers, billabongs and other water bodies. It was recorded only in Woronora Reservoir, a water body which borders the Holsworthy site to the east. Its high value in the aquaculture industry has led to its extensive translocation. This would explain its occurrence in the Woronora River system. Common Yabbies are not considered endangered, but populations have been greatly reduced in some areas (Merrick 1993). Elevation and stream gradient profiles of selected streams are shown in Attachment 1 (Figures 1-14).

1.6.2.3 Habitat

Summary statistics of stream variables used to calculate habitat diversity index values for the selected streams (excluding man-made water structures) in the area are given in Table C3.7

The streams varied greatly in their mean width from 0.3 - 0.7 metres for the small tributary streams such as Wappa and Lyretail Creeks to 10.5-13.0 metres for the major predominantly sandstone-based Woronora and Georges Rivers. A wide corridor of riparian vegetation surrounds most of the streams. Mean elevations range considerably between streams, from 37-67 metres for the northern streams up to 193-257 metres for some of the Georges and Woronora River catchment streams. Stream gradients are generally moderate to high and vary considerably within streams.

The calculated habitat-diversity index values are shown in Figure C3.3. High to very high habitat diversity is indicated by the resultant values

High quality fish habitat was abundant in most of the streams. Prime habitat for 'Macquarie' Perch (i.e. as typified by the Loddon River at site LOHI [Figure C3.2]) occurs in the Georges River, Punchbowl Creek, Gunya Creek, O'Hares Creek, the lower Woronora River, Deadmans Creek and Williams Creek. However, natural migration barriers such as cascades and waterfallls are common in the streams (e.g. on the Georges River just upstream of the confluence of Punchbowl Creek; on Gunya Creek where it enters Punchbowl Creek at site PGUH1; on O' Hares Creek at site OH2; on the lower Woronora River between sites KB1 and KB2). Man-made barriers include Woronora Dam on the Woronora River and Liverpool Weir on the Georges River.

The extent of degraded habitat was generally quite limited, although three areas are noteworthy:

- in the upper O'Hares Creek near site OH4 the creek has gone underground for approximately one kilometre in an area of fractured bedrock. Major habitat degradation is apparent where the creek emerges (thick adherent algae and iron-rich bacterial slimes). Mine subsidence is a probable cause.

- the lower reaches of Harris and Williams Creek show impacts of urban development and roading

- Liverpool Weir (site GEH1) downstream of Bunbury-Curren Creek entry point and the Glenfield STW is degraded through:

    - siltation (the longitudinal depth profile of the weir pool (Figure 15, Attachment 1) shows rise in bed level downstream of the creek entry point suggesting siltation arising from the creek's highly urbanised catchment);

    - aquatic weed invasion (*Salvinia* is abundant);

    - eutrophication (background details are given in NSW NPWS (1996));

    - terrestrial weed invasion (Table C3.10 shows the occurrence of bank types along the weir and the dramatic increase in the occurrence of introduced riparian flora downstream of the creek entry point);

    - damage and major reductions in the surrounding riparian vegetation.

NSW NPWS (1996) also note severe degradation downstream of Glenfield. It is indicated that upstream, the Georges River is healthy and requires a high degree of protection because of its high value for education use and as a reference stream for monitoring.

The frequency of gross disturbance in the riparian zone of the selected streams is shown in Figure C3.4. Virtually no gross disturbance was apparent in seven of the streams. Five streams had a low level of disturbance: Georges River, Woronora River and the three northern streams. This disturbance was focused on these streams' lower reaches.

1.6.2.4 Recreational Fishing Survey

Two recreational fishing clubs, representing ca. 190 anglers, were contacted in relation to their members' fishing experience within and downstream of the Holsworthy site (Table C3.1).

Members of the Campbelltown City Sportfishing Club (CCSC) only had experience in five out of nine nominated stream sections, a result of access restrictions (Sydney Water and Military Reserve). The fishery in the Georges River was considered to be fair downstream and poor upstream (Table C3.3). The lack of a fish ladder on Liverpool Weir and poor access was given as the basis for these quality ratings. It was noted that on average that three club members would fish the river on weekends and only one on weekdays (Attachment 1). However, it was stated that 110 other fishers would typically be seen on weekends and 12 on weekdays (Attachment 1). Bass and 'Macquarie' Perch were caught in the upper and lower reaches of river (attachment 1). Additionally, European Carp were only caught in lower reaches of the river and eels and Spiny Crayfish only in the upper reaches.

Fishing in O'Hares Creek and tributaries was viewed as poor by CCSC members. Due to poor access this tributary was rarely fished by members, although two other fishers were seen on average during weekends and one on weekdays. eels and Spiny Crayfish were typically caught.

CCSC members indicated that fishing in Deadmans Creek to be of good quality. The species composition of fish caught indicated that estuarine rather than freshwater reaches were considered by members who filled out the questionnaire Freshwater reaches of Deadmans Creek are entirely enclosed in Holsworthy Military Reserve.

Fishing in the Woronora River downstream of Woronora Dam was considered by CCSC members to be of poor quality, a result of poor access. On average one club member fishes in this river section on a weekend. Ten other fishers are typically seen on weekends and two are seen on weekdays. Australian Bass is the main species caught. 'Macquarie' Perch rarely occur in catches.

Members of the Bass Sydney Club (BS) also had experience in five out of nine nominated stream section, again a result of access restrictions The fishery in the Georges River was considered poor to fair, again a result of poor access for fishers and the fish (ie. the latter a result of the absence of a fish ladder on Liverpool Weir). Fish typically caught in the lower reaches include Australian Bass, European Carp, Long-finned Eels and possibly Catfish. In the upper reaches (upstream of Punchbowl Creek confluence), Long-finned Eels, 'Macquarie' Perch and possibly Australian Bass are caught.

Fishing in Punchbowl and O'Hares Creek is also viewed by BS members as poor to fair. Restricted access is a major factor influencing this rating. Bass and Long-finned Eels and possibly Catfish and European Carp are typically caught in Punchbowl Creek. In O'Hares Creek, Long-finned Eels, Australian Bass and 'Macquarie' Perch are possibly caught.

Fishing in the Woronora River downstream of Woronora Dam was also viewed as poor to fair by BS members. Long-finned Eels, Australian Bass and Bully Mullet were typically caught. BS members also indicate the possibility of European Carp occurring in catches.

1.7 CONSERVATION SIGNIFICANCE

There is no formalised method for assessing the conservation significance of streams. For this study, conservation value assessments were determined by comparing conservation index values for the streams/positions in the study areas with those similarly calculated for a sample of 1032 streams/positions from south-eastern Australia (Bishop, in Meredith *et al.* 1996). Conservation index values for the Badgerys Creek and Holsworthy areas are shown in Figure C3.5. Table C3.11 provides a summary of the criteria and assumptions which form the basis of the six components used to determine the index values. The frequency distributions of index values for the two study areas and for the south-eastern Australian sample are given in Figure C3.6.

1.7.1 Overall Significance of Streams Draining the Badgerys Creek Site

Low conservation index values were obtained for each of the six streams/positions examined (Figure C3.5). All were placed in the second lowest conservation index interval within the frequency distribution (Figure C3.6). Most of the streams in south-eastern Australia fall into the same interval (mode=54%). There is therefore no obvious difference between six streams in the Badgerys Creek area and 1032 streams in south-eastern Australia.

The streams sampled at Badgerys Creek are therefore considered to be of local significance. Although the streams provide locally significant freshwater habitat, they are generally degraded.

1.7.2 Overall Significance of Streams Draining the Holsworthy Site

Two sets of streams/positions can be distinguished in the Holsworthy area based on differences in conservation index values obtained:

- moderate value set includes Kalibucca Creek (Hd in Figure C3.5) and the three northern areas (Hg, Hh, Hi);

- high to very high value set includes Punchbowl Creek (Ha), Gunya Creek (Hb), O'Hares Creek (Hc), Lyretail Creek (He) and Wappa Creek (Hf).

The frequency distribution of the south-eastern Australian sample spanned six intervals (Figure C3.6). All streams/positions in the moderate value set from the Holsworthy site had index values in the third highest interval of the distribution As only twenty percent of the 1032 streams/positions within the south-eastern Australian sample were located in the top three intervals, the results indicate that the moderate set of Holsworthy streams is at least of state significance.

All streams/positions in the high to very high value set had index values greater than any determined for the sample from south-eastern Australia (Figure C3.6). The high to very high value sets of Holsworthy streams are therefore considered to be of national significance.

Table C3.1. Recreational fishing clubs contacted during the study.

Fishing Club	**Contact**	**Area of Relevance**
Bass Sydney (40 members)	Trevor Mills	Holsworthy
Campbelltown City Sportfishing Club (*ca.* 150 members)	John Cordin	Holsworthy & Badgerys Ck
Blue Mountains and Nepean District Angling Association (54 members)	Noel Brown	Badgerys Ck
Nepean Fishing Club (100 members)	Ray Stockton	Badgerys Ck
Panthers Fishing Club (200 members)	Garry Kaast	Badgerys Ck
Emmaus College Fishing Club (35 members)	Philip Matar	Badgerys Ck

Table C3.2. Fishing clubs' perceived value of fisheries in and around the Badgerys Creek site.

Fishing Club	Stream					
	B1	B2	B3	B4	B5	B6
Emmaus College Fishing Club	very good (in summer)	good	reasonable	unknown	unknown	unknown
Campbelltown City Sportfishing Club	fair	unknown	unknown	unknown	unknown	poor

Key to Streams

B1 = South Creek from St Marys downstream to Richmond

B2 = South Creek from St Marys upstream to headwaters

B3 = tributary of South Creek: Badgerys Creek

B4 = tributary of South Creek: Cosgroves Creek

B5 = tributary of South Creek: Thompsons Creek

B6 = Nepean River tributary: Duncans Creek

Table C3.3. Fishing clubs' perceived value of fisheries in and around the Holsworthy site

Fishing Club	Stream								
	H1	H2	H3	H4	H5	H6	H7	H8	H9
Bass Sydney	poor to fair	poor to fair	poor to fair	poor to fair	not known	not known	not known	poor to fair	not known
Campbelltown City Sportfishing Club	fair	poor	not known	poor	not known	not known	good	poor	not known

Key to Streams

H1 = Georges River from Liverpool to in line with Campbelltown

H2 = Georges River from ~Campbelltown to headwaters (~Appin)

H3 = tributary of Georges River: Punchbowl Creek and tributaries

H4 = tributary of Georges River: O'Hares Creek and tributaries

H5 = tributary of Georges River estuary: Harris Creek

H6 = tributary of Georges River estuary: Williams Creek

H7 = tributary of Georges River estuary: Deadmans Creek

H8 = Woronora river and tributaries from dam to tidal limit

H9 = Woronora Reservoir and River upstream from the dam

Table C3.4. List of fish species recorded in waters relevant to investigations in the Badgerys Creek area: pre-survey and present survey. Pre-survey list based on an examination of the literature, interviews and fishing club questionnaires to fishing clubs. The Hawkesbury River becomes the Nepean River upstream of the Grose River confluence, a short distance upstream of the tidal limit. The letter given identifies the following information sources:

Pre-survey: A P. Gehrke, NSW Fisheries *pers. comm.* (results of NSW Fisheries' surveys from late spring 1992 to late winter 1993 in the Hawkesbury River near Windsor),
B AMBS (1994)
C Pollard and Growns (1993)
D P. Matar, Emmaus College Fishing Club (*pers. comm.*)
E J. Cordon Campbelltown City Sportfishing Club (*pers. comm.*)
F J. Sammut (*pers. comm.*)
G AMBS (1992)
H T. Marsden, NSW Fisheries (*pers. comm.*)
\- not recorded.
Present survey: P

		Freshwaters		
Taxa	**Upper Hawkesbury River estuary**	**South Creek & tributaries**	**Lower Nepean**	**Duncans Creek**
Native species				
Longfinned Eel (*Anguilla reinhardtii*)	A	B,P,G	C	-
Shortfinned Eel (*Anguilla australis*)	-	P	-	-
Unidentified eels	-	D	-	E
Freshwater Herring (*Potamalosa richmondia*)	A	D	C	-
Australian Smelt (*Retropinna semoni*)	A	B,P,G	C	-
Common Galaxias (*Galaxias maculata*)	A	-	C	-
Freshwater Catfish (*Tandanus tandanus*)	A	-	C	-
Bullrout (*Notesthes robusta*)	A	-	C	-
'Macquarie' Perch (*Macquaria australasica*[?])	-	-	C,F	-
Australian Bass (*M. novemaculeata*)	A	D,H	C	E
Bully Mullet (*Mugil cephalus*)	A	H	C	-
Freshwater Mullet (*Myxus petardi*)	A	-	C	-
Unidentified Mullet	-	D	-	-
Striped gudgeon (*Gobiomorphus australis*)	A	B	C	-
Cox's Gudgeon (*G. coxii*)	A	-	C	-

		Freshwaters		
Taxa	**Upper Hawkesbury River estuary**	**South Creek & tributaries**	**Lower Nepean**	**Duncans Creek**
Carp Gudgeon (*Hypseleotris compressa*)	A	B	C	-
Firetail Gudgeon (*H. galii*)	A	P	C	-
Flathead Gudgeon (*Philypnodon grandiceps*)	A	P	C	-
Dwarf Flathead Gudgeon (*Philypnodon* sp.)	A	-	C	-
Largemouth Goby (*Redigobius macrostoma*)	A	-	-	-
Non-native species				
Goldfish (*Carassius auratus*)	-	P	C	-
European Carp (*Cyprinus carpio*)	A	D,P,H	C	P
Eastern Gambusia (*Gambusia holbrooki*)	A	B,P,G	C	P

Table C3.5. Site occurrences of fish and other taxa in the Badgerys Creek and Holsworthy areas: results of the present study and other adjacent surveys. Sites sampled during the present study are indicated with an asterisk (*) after the site codes The location of sites are shown in Figure 3.4 (Hawkesbury-Nepean River catchment = Badgerys Creek area and in Figure 3.5 (Georges River catchment, Woronora River catchment, northern streams = Holsworthy area). The location of sites in relation to distance from the estuary (tidal limit), elevation and stream gradient are shown in Figures 1 - 14 (Attachment 1). Present = +, not recorded = -.

Taxa codes:

Ang rei = *Anguilla reinhardtii* (Longfinned Eel)
Ang ? = *Anguilla* sp. (unidentified eel)
Gal oli = *Galaxias olidus* (Mountain Galaxias)
Ret sem = *Retropinna semoni* (Australian Smelt)
Mac nov = *Macquaria novemaculeata* (Australian Bass)
Myx pet = *Myxus petardi* (Freshwater Mullet)
Gob aus = *Gobiomorphus australis* (Striped Gudgeon)
Phi ? = *Philypnodon* sp. (unidentified *Philypnodon*)
Hyp com = *Hypseleotris compressa* (Empirefish)
Cyp car = *Cyprinus carpio* (European Carp)
Gam hol = *Gambusia holbrooki* (Eastern Gambusia)
Tad pol = Tadpoles

Ang aus = *Anguilla australis* (Shortfinned Eel)
Gal mac = *Galaxias maculatus* (Common Jollytail)
Gal bre = *Galaxias brevipinnis* (Climbing Galaxias)
Tan tan = *Tandanus tandanus* (Eel-tailed Catfish)
Bid bid – *Bidyanus bidyanus* (Silver Perch)
Gob cox = *Gobiomorphus coxii* (Cox's Gudgeon)
Phi gra = *Philypnodon grandiceps* (Flathead Gudgeon)
Hyp gal = *Hypseleotris galii* (Firetail Gudgeon)
Hyp ? = *Hypseleotris* sp. (unidentified *Hypseleotris*)
Car aur = *Carassius auratus* (Goldfish)
Par ? = *Paratya* sp (unidentified *Paratya* shrimp)

River/Stream Sampling Site	**Native Fish**																		**Introduced Fish**			**Other Taxa**	
Badgerys Creek area	***Ang rei***	***Ang aus***	***Ang ?***	***Gal mac***	***Gal oli***	***Gal bre***	***Ret sem***	***Tan tan***	***Mac nov***	***Bid bid***	***Myx pet***	***Gob cox***	***Gob aus***	***Phi gra***	***Phi ?***	***Hyp gal***	***Hyp com***	***Hyp ?***	***Cyp car***	***Car aur***	***Gam hol***	***Par ?***	***Tad pol***
Hawkesbury-Nepean River catchment:																							
Duncans Creek.																							
DU1*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-
DU2*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	+	-	-
DU3*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
South Creek system:																							
Cosgroves Creek																							
CO1*	+	+	-	-	-	-	+	-	-	-	-	-	-	-	-	+	-	-	+	+	+	+	-
Badgerys Creek																							
BA1*	+	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	+	-	+	+	-
BA2*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	+	-	-
BA3*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-
BA4*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-
Thompsons Creek																							
TH1*	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	+	-	-
TH2*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Holsworthy area	*Ang rei*	*Ang aus*	*Ang ?*	*Gal mac*	*Gal oli*	*Gal bre*	*Ret sem*	*Tan tan*	*Mac nov*	*Bid bid*	*Myx pet*	*Gob cox*	*Gob aus*	*Phi gra*	*Phi ?*	*Hyp gal*	*Hyp com*	*Hyp ?*	*Cyp car*	*Car aur*	*Gam hol*	*Par ?*	*Tad pol*
Georges River catchment:																							
Georges River																							
GE1*	+	-	+	-	-	-	+	+	+	-	-	-	+	+	-	-	-	-	-	-	-	-	-
GE2*	+	-	+	-	-	-	+	+	-	-	-	+	-	-	-	-	-	+	-	-	+	+	+
Punchbowl Creek																							
EL4	-	-	-	+	-	-	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
EL5	-	-	-	+	-	-	+	-	+	-	-	+	+	-	-	-	-	-	-	-	-	-	-
TG1	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PU1*	+	-	+	-	-	-	+	-	+	-	-	+	-	-	-	-	-	-	-	-	-	+	-
PU2*	+	-	+	-	-	-	+	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
(Kalibucca Creek)																							
PKA1*	+	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
O'Hares Creek																							
OH1*	+	-	-	-	-	-	+	-	-	-	-	+	-	-	-	-	-	-	-	-	-	+	+
OH2*	+	-	+	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	+	+
EL6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OH3*	+	-	+	-	+	+	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	+	+
EL7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OH4*	+	-	-	-	+	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	+	+
Woronora River catchment (Georges River estuary):																							
Woronora River																							
EL3	-	-	-	+	-	-	+	-	+	-	+	+	+	+	+	-	+	-	-	-	+	-	-
KB4	+	-	-	-	-	-	+	-	+	-	-	+	+	+	-	-	-	-	-	-	-	-	-
EL2	-	-	-	-	-	-	+	-	+	-	-	-	-	-	-	-	-	-	-	-	+	-	-
KB3	+	-	-	-	-	-	+	-	+	-	-	+	+	+	-	-	-	-	-	-	-	-	-
EL1	-	-	-	-	-	-	+	-	+	-	-	+	-	-	+	-	-	-	-	-	-	-	-
KB2	+	-	-	+	-	-	+	-	+	-	-	+	+	+	-	-	-	-	-	-	-	-	-
KB1	-	-	-	-	-	-	+	-	+	-	-	+	+	+	-	-	-	-	-	-	-	-	-
ME1	+	-	-	-	-	-	+	-	-	+	-	-	-	+	-	-	-	-	-	-	-	-	-
WO1*	+	-	-	-	-	-	+	-	-	-	-	+	-	-	-	-	-	-	-	-	-	+	-
WO2*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lyretail Creek																							
WLY1*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
Wappa Creek																						+	
WWA1*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-

Holsworthy area	*Ang rei*	*Ang aus*	*Ang ?*	*Gal mac*	*Gal oli*	*Gal bre*	*Ret sem*	*Tan tan*	*Mac nov*	*Bid bid*	*Myx pet*	*Gob cox*	*Gob aus*	*Phi gre*	*Phi ?*	*Hyp gal*	*Hyp com*	*Hyp ?*	*Cyp car*	*Car aur*	*Gam hol*	*Par ?*	*Tad pol*
Northern streams (Georges R. estuary):																							
Harris Creek																							
HA1*	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	+	-	-
HA2*	+	-	-	+	-	-	-	-	-	-	-	-	+	-	-	+	-	-	-	-	-	-	-
Williams Creek																							
WI1*	+	-	-	-	-	-	+	-	+	-	-	+	-	-	-	-	-	-	-	-	-	+	-
Deadmans Creek																							
DE1*	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
TG2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table C3.6. Site occurrences of crayfish in the Badgerys Creek and Holsworthy areas: results of the present study and other adjacent surveys. Sites sampled during the present study are indicated with an asterisk (*) after the site codes. The location of sites are shown in Figure 3.4 (Hawkesbury-Nepean River catchment = Badgerys Creek area) and in Figure 3.5 (Georges River catchment, Woronora River catchment, northern streams = Holsworthy area). The location of sites in relation to distance from the estuary (tidal limit), elevation and stream gradient are shown in Figures 2-15 (Attachment 1). Present = +, not recorded = -.

Taxa codes:

Che des = *Cherax destructor* (Common Yabby)
Eua spi = *Euastacus spinifer* (Sydney Crayfish)
Eua spi = *Euastacus australasiensis* (Australian Crayfish)
Eua spa = *Euastacus* sp. A
Eua ? = *Euastacus* sp. (unidentified *Euastacus*)

	Crayfish Taxa				
River/Stream & Sampling Site	***Che des***	***Eus spi***	***Eua aus***	***Eua spa***	***Eua ?***
Badgerys Creek area					
Hawkesbury-Nepean River catchment					
Duncans Creek					
DU1*	-	-	-	-	-
DU2*	-	-	-	-	-
DU3*	-	-	-	-	-
South Creek system					
Cosgroves Creek					
CO1*	-	-	-	-	-
Badgerys Creek					
BA1*	-	-	-	-	-
BA2*	-	-	-	-	-
BA3*	-	-	-	-	-
BA4*	-	-	-	-	-
Thompsons Creek					
TH1*	-	-	-	-	-
TH2*	-	-	-	-	-
Holsworthy area					
Georges River catchment					
Georges River					
GE1*	-	-	-	-	-
GE2*	-	+	-	-	-
Punchbowl Creek					
EL4	-	-	-	-	-
EL5	-	-	-	-	-
TG1	-	-	-	-	+
PU1*	-	+	-	-	-
PU2*	-	+	-	-	-
(Kalibucca Creek)					
PKA1*	-	-	-	-	-
O'Hares Creek					
OH1*	-	-	-	-	-
OH2*	-	+	-	-	-
EL6	-	-	-	-	-
OH3*	-	+	-	-	-
EL7	-	-	-	-	-
OH4*	-	+	-	-	-

	Crayfish Taxa				
River/Stream & Sampling Site	*Che des*	*Eus spi*	*Eua aus*	*Eua spa*	*Eua ?*
Woronora River catchment (Georges R. estuary)					
Woronora River					
EL3	-	-	-	-	-
KB4	-	-	-	-	-
KB3	-	-	-	-	-
EL1	-	-	-	-	-
KB2	-	+	-	-	-
KB1	-	-	-	-	-
ME1	-	-	-	-	-
WO1*	+	+	-	-	-
WO2*	-	-	+	-	-
Lyretail Creek					
WLY1*	-	+	+	-	+
Wappa Creek					
WWA1*	-	+	-	-	+
Northern streams (Georges R. estuary)					
Harris Creek					
HA1*	-	-	-	-	-
HA2*	-	+	-	-	-
Williams Creek					
WI1*	-	+	-	-	-
Deadmans Creek					
DE1*	-	+	+	+	+
TG2	-	-	-	-	-

Table C3.7. Summary statistics of stream variables used to calculate the habitat-diversity index. Variables are as defined and explained in the text. Stream codes are given in parentheses after the stream names. N = sample size, S.D. = standard deviation.

Area/stream system	Stream width (m)			Riparian veg width (m)			Elevation (m)			Stream gradient (m/km)		
	N	Mean	S.D.	N	Mean	S.D	N	Mean	S.D.	N	Mean	S.D.
Holsworthy area												
Georges River catchment:												
Georges River (H1)	524	13.0	13.3	1048	66.5	46.5	20	75.8	79.6	20	7.0	8.8
Punchbowl Ck (H2)	216	3.1	4.5	432	65.8	47.8	20	170.6	130.8	24	24.4	39.8
Kalibucca Ck (H3)	41	0.7	4.7	82	90.7	39.7	20	102.1	48.7	20	41.1	23.8
Gunya Ck (H4)	94	1.6	5.1	188	55.6	48.7	26	143.9	48.3	26	31.6	24.7
O'Hares Ck (H5)	215	5.3	6.2	40	53.9	51.3	26	193.3	88.8	26	15.6	18.2
Woronora River catchment (Georges R. estuary)												
Woronora River downstream (H6)	163	10.5	11.8	326	38.9	43.8	20	53.6	38.9	20	6.7	3.9
Lyretail Ck (H7)	33	0.7	2.4	66	35.5	35.2	20	136.3	48.4	20	64.7	48.6
Wappa Ck (H8)	49	0.3	1.2	98	46.7	40.5	20	148.6	44.9	20	49.7	29.6
Woronora River upstream (H9)	62	1.7	3.9	124	54.7	44.6	20	257.3	76.8	20	33.9	38.0
Northern streams (Georges R. estuary):												
Harris Ck (H10)	158	1.7	4.3	316	67.1	45.1	20	37.9	39.3	20	11.7	21.0
Williams Ck (H11)	190	1.7	4.5	380	67.3	41.2	23	55.2	51.2	23	14.4	22.3
Deadmans Ck (H12)	130	1.7	2.8	260	87.7	40.7	20	66.6	49.1	20	21.3	25.7
Badgerys Creek area:												
Hawkesbury-Nepean River catchment:												
Duncans Ck (B1)	88	0.5	1.3	176	15.2	19.6	21	49.4	17.1	21	6.0	9.1
Unnamed Ck (B2)	23	0.2	1.0	46	18.4	17.8	20	66.6	11.6	20	8.5	4.4
South Creek catchment:												
South Ck (B3)	274	2.8	6.0	548	20.8	22.2	24	36.7	29.0	24	1.4	1.5
Cosgroves Ck (B4)	123	0.5	3.5	246	13.7	10.1	20	58.5	19.6	20	7.8	9.8
Badgerys Ck (B5)	128	0.7	1.0	256	23.7	18.4	20	57.1	12.3	20	4.6	3.5
Thompsons Ck (B6)	77	0.0	0.0	154	18.2	17.2	20	79.3	23.7	20	15.8	28.8

Table C3.8 List of fish species recorded in the Georges River upper estuary in 1978-81 (P. Gibbs, NSW Fisheries pers. comm). Sampling was undertaken with a range of gillnets (1.5-4.5"), a small seine net and a beam trawl. The lower sampling limit was Milpera Bridge. The upper sampling limit was Meadowbank Ponds, a short distance downstream of Liverpool Weir.

	Years			
Taxa	**1978**	**1980**	**1981**	**Known to enter Freshwater**
Anguilla reinhardtii (Longfinned Eel)	+	+	-	yes
Elops machnata (Giant Herring)	-	-	+	yes
Harengula abbreviata (Southern Herring)	+	+	+	no
Potamalosa richmondia (Freshwater Herring)	+	+	+	yes
Cnidoglanis macrocephalus (Estuary Catfish)	-	+	+	no
Notesthes robusta (Bullrout)	-	+	+	yes
Platycephalus fuscus (Dusky Flathead)	+	-	+	no
Ambassis jacksoniensis (Port Jackson Perchlet)	+	-	-	no
Macquaria novemaculeata ^A^ (Australian Bass)	+	+	+	yes
Macquaria colonorum ^A^ (Estuary Perch)	+	+	+	yes
Acanthopagrus australis (Yellowfin Bream)	+	+	+	no
Pomatomus saltator (Tailor)	-	+	-	no
Gerres subfasciatus (Roach)	+	+	+	yes
Myxus elongatus (Sand Mullet)	+	+	-	yes
Myxus petardi (Freshwater Mullet)	+	+	+	yes
Liza argentia (Flat-tail Mullet)	+	+	+	yes
Mugil cephalus (Bully Mullet)	+	+	+	yes
Philypnodon grandiceps (Flatheaded Gudgeon)	+	-	-	yes
Afurcagobius tamarensis (Tamar River Goby)	+	-	-	yes

+, present; -, not recorded; A, also recorded by Harris (1985)

Table C3.9. List of fish and crayfish recorded in freshwaters relevant to investigations in the Holsworthy area: pre- survey and present survey. Pre-survey list based on an examination of the literature, interviews and fishing club questionnaires The letter given identifies the following information sources:

Pre-survey:

Pre-survey:	A	Bishop (1993)
	B	J. Cordon, Campbelltown City Sportfishing Club (*pers. comm.*)
	C	M. Lincoln-Smith, Ecology Lab (*pers. comm.*)
	D	Merrick and Rimmer (1984)
	E	T. Grant (*pers. comm.*)
	F	B. Young, Campbelltown City Sportfishing Club (*pers. comm.*)
	G	Merrick (1993)
	-	not recorded.
Present survey:	P	

Taxa	**Georges River & tributaries**	**Woronora River & tributaries**	**Northern Streams**
Native fish species			
Longfinned Eel (*Anguilla reinhardtii*)	P	A,D,P	P
Unidentified eels	B,P	-	P
Australian Smelt (*Retropinna semoni*)	C,P	A,C,D,P	P
Common Galaxias (*Galaxias maculata*)	C	A,C	P
Mountain Galaxias (*Galaxias olidus*)	P	-	-
Climbing Galaxias (*Galaxias brevipinnis*)	P	-	-
Eel-tailed catfish (*Tandanus tandanus*)	P	-	-
'Macquarie' Perch (*Macquaria australasica*[?])	B	B	-
Australian Bass (*M. novemaculeata*)	B,C,E,P	A,B,C	B,P
Freshwater Mullet (*Myxus petardi*)	-	C	-
Unidentified Mullet	-	-	B
Striped Gudgeon (*Gobiomorphus australis*)	C,P	A,C	P
Cox's Gudgeon (*G. coxii*)	C,P	A,C,D	P
Carp Gudgeon (*Hypseleotris compressa*)	-	C	-
Firetail Gudgeon (*H. galii*)	-	-	P
Flathead Gudgeon (*Philypnodon grandiceps*)	P	A,C,D	-
Unidentified Flathead Gudgeon (*Philypnodon* sp.)	-	C	-
Translocated native fish species			
Silver Perch (*Bidyanus bidyanus*)	-	D	-
Golden Perch (*Macquaria ambigua*)	F	-	-
Murray Cod (*Maccullochella peeli*)	F	-	-
Non-native fish species			
European Carp (*Cyprinus carpio*)	B,P	-	-
Eastern Gambusia (*Gambusia holbrooki*)	P	C	P
Crayfish species			
Common Yabby (*Cherax destructor*)	-	P	-
Sydney Crayfish (*Euastacus spinifer*)	G,P	A,P	P
Australian Crayfish (*Euastacus australasiensis*)	-	P	P
Euastacus sp.A	-	-	P
Unidentified Spiny Crayfish (*Euastacus* sp.)	B,E	-	-

Table C3.10. The occurrence of bank types along Liverpool Weir. The bank type dimensions used were slope, substrate and (riparian) vegetation. Values are the percentage of samples (randomly selected 10 metres of bank) in which the bank type occurred. I = introduced riparian flora present.

Bank type	**Position in relation to Bunbury Curran Creek confluence**	
	Upstream	**Downstream**
Number of samples	9	13
Near vertical clay/sand & boulder banks with:		
Rainforest flora	4.5	0.0
Near vertical clay/sand banks with		
Acacia	4.5	0.0
Eucalyptus	9.1	0.0
Acacia & Eucalyptus	0.0	4.5
Privet (I)	0.0	4.5
Willow & *Lantana* (I)	0.0	4.5
Steep clay/sand banks with:		
Rainforest flora	4.5	0.0
Rainforest & *Lomandra*	4.5	0.0
Acacia	4.5	0.0
Eucalyptus	4.5	0.0
Privet & *Lomandra* (I)	4.5	0.0
Privet & *Eucalyptus* (I)	0.0	9.1
Acacia, privet & balloon vine (I)	0.0	4.5
Eucalyptus & Lantana (I)	0.0	4.5
Balloon vine on trees (I)	0.0	13.6
Grasses (I)	0.0	9.1
Shallow sloped banks with:		
Grasses (I)	0.0	4.5

Table C3.11. Stream/position summary of information/assumptions which form the basis of the six components used to determine conservation index values. The components are: 1) recognised valuable areas; 2) naturalness of fish communities; 3) high conservation-value fish taxa; 4) high recreational-value fish taxa; 5) high conservation-value crayfish taxa; and 6) valuable areas for scientific research. See text for details.

BADGERYS CREEK AREA

Duncans Creek (relevant to options A & B), coded Ba

1) Controlled waters (SPCC 1980) beyond 1 km
2) Potentially three introduced fish species (*Gambusia*, European Carp and possibly Goldfish) up to and beyond 1 km
3) One high conservation-value fish species (Macquarie Perch) beyond 1 km. It is highly likely that Australian grayling are no longer present in the Nepean River system
4) Three high recreational-value fish species (Australian Bass, Macquarie Perch and Eel-tailed Catfish [*Tandanus tandanus*]) beyond 1 km
5) Potentially one high conservation-value crayfish species (Common Yabby) beyond 1 km
6) No biological monitoring sites downstream.

Cosgroves Creek (relevant to options A & B), coded Bb

1) Two significant wetlands (Smith and Smith 1994) beyond 1 km
2) No native fish species up to 1 km; three introduced fish species (*Gambusia*, European Carp and Goldfish) beyond 1 km
3) No high conservation-value fish species
4) One high recreational-value fish species (Australian Bass) beyond 1 km
5) Potentially one high conservation-value crayfish species (Common Yabby) beyond 1 km
6) No biological monitoring sites downstream.

Cosgroves Creek (relevant to options C), coded Bc

1) Two significant wetlands (Smith and Smith 1994) beyond 1 km
2) Three introduced fish species (Gambusia, European Carp and Goldfish) up to and beyond 1 km
3) No high conservation-value fish species
4) One high recreational-value fish species (Australian Bass) beyond 1 km
5) Potentially one high conservation-value crayfish species (Common Yabby) beyond 1 km
6) No biological monitoring sites downstream.

Badgerys Creek (relevant to option A), coded Bd

1) Two significant wetlands (Smith and Smith 1994) beyond 1 km
2) No native fish species up to 1 km; potentially three introduced fish species (*Gambusia*, European Carp and possibly Goldfish) beyond 1 km
3) No high conservation-value fish species
4) One high recreational-value fish species (Australian Bass) beyond 1 km
5) Potentially one high conservation-value crayfish species (Common Yabby) beyond 1 km
6) No biological monitoring sites downstream.

Badgerys Creek (relevant to options B & C), coded Be

1) Two significant wetlands (Smith and Smith 1994) beyond 1 km
2) Three introduced fish species (*Gambusia*, European Carp and Goldfish) up to and beyond 1 km
3) No high conservation-value fish species
4) One high recreational-value fish species (Australian Bass) beyond 1 km
5) Potentially one high conservation-value crayfish species (Common Yabby) beyond 1 km
6) No biological monitoring sites downstream

Thompsons Creek (relevant to options C), coded Bf

1) Two significant wetlands (Smith and Smith 1994) beyond 1 km
2) Three introduced fish species (*Gambusia*, European Carp and Goldfish) up to and beyond 1 km
3) No high conservation-value fish species
4) One high recreational-value fish species (Australian Bass) beyond 1 km
5) Potentially one high conservation-value crayfish species (Common Yabby) beyond 1 km
6) No biological monitoring sites downstream.

HOLSWORTHY AREA

Punchbowl Creek (relevant to the southern option), coded Ha

1) Controlled waters (SPCC 1980) up to and beyond 1 km; proposed wild and scenic river (DWR 1987, Georges River) beyond 1 km
2) No introduced fish species up to 1 km; two introduced fish species (*Gambusia* and European Carp in Liverpool Weir) beyond 1 km
3) Potentially one high conservation-value fish species ('Macquarie' Perch, *Macquaria australasica* [?]) up to and beyond 1 km

4) Potentially three high recreational-value fish species (Australian Bass, Macquarie Perch and Eel-tailed Catfish) up to and beyond 1 km; potentially one high recreational-value fish species (Estuary Perch) beyond 1 km

5) One high conservation-value crayfish species (Sydney Crayfish) potentially up to and beyond 1km

6) Four monitoring sites beyond 1 km sampled for fish by the Ecology Lab for Sydney Water.

Gunya Creek (relevant to the southern option), coded Hb

1) Controlled waters (SPCC 1980) up to and beyond 1 km; proposed wild and scenic river (DWR 1987, Georges River) beyond 1 km

2) No introduced fish species up to 1 km; two introduced fish species (*Gambusia* and European Carp in Liverpool Weir) beyond 1 km

3) Potentially one high conservation-value fish species ('Macquarie' Perch) beyond 1 km

4) Potentially four high recreational-value fish species (Australian Bass, Estuary Perch, Macquarie Perch and Eel-tailed Catfish) beyond 1 km

5) One high conservation-value crayfish species (Sydney Crayfish) potentially up to and beyond 1km

6) Four monitoring sites beyond 1 km sampled for fish by the Ecology Lab for Sydney Water.

O'Hares Creek (relevant to the southern option), coded Hc

1) Controlled waters (SPCC 1980) up to and beyond 1 km; proposed wild and scenic river (DWR 1987, Georges River) beyond 1 km; catchment, including creek, listed as a heritage area (Australian Heritage Commission)

2) No introduced fish species up to 1 km; two introduced fish species (*Gambusia* and European Carp in Liverpool Weir) beyond 1 km

3) Potentially one high conservation-value fish species ('Macquarie' Perch) up to and beyond 1 km

4) Potentially two high recreational-value fish species (Australian Bass and Macquarie Perch) up to and beyond 1 km; potentially two high recreational-value fish species (Eel-tailed Catfish and Estuary Perch) beyond 1 km

5) One high conservation-value crayfish species (Sydney Crayfish) potentially up to and beyond 1 km

6) Two monitoring sites beyond 1 km sampled for macro-invertebrates by AWT-Ensight for Sydney Water.

Kalibucca Creek (relevant to the northern option), coded Hd

1) Controlled waters (SPCC 1980) up to and beyond 1 km; proposed wild and scenic river (DWR 1987, Georges River) beyond 1 km

2) No introduced fish species up to 1 km; two introduced fish species (*Gambusia* and European Carp in Liverpool Weir) beyond 1 km

3) Potentially one high conservation-value fish species ('Macquarie' Perch) beyond 1 km

4) Potentially four high recreational-value fish species (Australian Bass, Estuary Perch, Macquarie Perch and Eel-tailed Catfish) beyond 1 km

5) One high conservation-value crayfish species (Sydney Crayfish) beyond 1km

6) No biological monitoring sites downstream.

Lyretail Creek (relevant to the northern option), coded He

1) Controlled waters (SPCC 1980) up to and beyond 1 km

2) No introduced fish species up to 1 km; one introduced fish species (*Gambusia*) beyond 1 km

3) Potentially one high conservation-value fish species ('Macquarie' Perch) beyond 1 km

4) Potentially two high recreational-value fish species (Australian Bass and Macquarie Perch) beyond 1 km

5) Two high conservation-value crayfish species (Sydney Crayfish and Australian Crayfish) up to and beyond 1km

6) Seven monitoring sites beyond 1 km sampled for fish and macroinvertebrates by the Ecology Lab for Sydney Water.

Wappa Creek (relevant to the northern option), coded Hf

1) Controlled waters (SPCC 1980) up to and beyond 1 km

2) No introduced fish species up to 1 km; one introduced fish species (*Gambusia*) beyond 1 km

3) Potentially one high conservation-value fish species ('Macquarie' Perch) beyond 1 km.

4) Potentially two high recreational-value fish species (Australian Bass and Macquarie Perch) beyond 1 km

5) Two high conservation-value crayfish species (Sydney Crayfish and Australian Crayfish) up to and beyond 1km

6) Nine monitoring sites beyond 1 km sampled for fish and macroinvertebrates by the Ecology Lab for Sydney Water.

Harris Creek (relevant to the northern option), coded Hg

1) Controlled waters (SPCC 1980) up to and beyond 1 km; estuarine area (Voyager Point) > 1 km downstream nominated as a heritage area (Australian Heritage Commission)

2) No introduced fish species up to 1 km; one introduced fish species (*Gambusia*) beyond 1 km

3) No high conservation-value fish species

4) One high recreational-value fish species (Australian Bass) potentially beyond 1 km

5) Potentially two high conservation-value crayfish species (Sydney Crayfish and Australian Crayfish) up to and beyond 1km

6) No biological monitoring sites downstream.

Williams Creek (relevant to the northern option), coded Hh

1) Controlled waters (SPCC 1980) up to and beyond 1 km - estuarine area (Voyager Point) > 1 km downstream nominated as a heritage area (Australian Heritage Commission)

2) No introduced fish species up to and beyond 1 km

3) No high conservation-value fish species

4) One high recreational-value fish species (Australian Bass) potentially up to and beyond 1 km

5) Potentially two high conservation-value crayfish species (Sydney Crayfish and Australian Crayfish) up to and beyond 1km

6) No biological monitoring sites downstream

Deadmans Creek (relevant to the northern option), coded Hi

1) Controlled waters (SPCC 1980) up to and beyond 1 km

2) No introduced fish species up to and beyond 1 km

3) No high conservation-value fish species

4) One high recreational-value fish species (Australian Bass) beyond 1 km

5) Potentially three high conservation-value crayfish species (Sydney Crayfish, Australian Crayfish and the unidentified *Euastacus* sp A) up to and beyond 1km

6) No biological monitoring sites downstream.

1.8 IMPACT ANALYSIS

1.8.1 Methodology

Impact assessment is based on the Construction Plan and Master Plans for five airport options incorporating mitigation measures detailed (Airplan 1997) and on water quality assessment presented in Technical Paper No. 5. Taking a conservative approach, impact assessment takes into account the occurrence of a number of major rainfall events, human error and inappropriate or inadequate impact mitigation measures. The latter can only be determined once construction is underway.

1.8.1.1 Construction impacts

A list of airport construction activities which may lead to impacts on freshwater fish and crayfish fauna is given in Table C3.12. This list, which is not necessarily exhaustive, provides a generalised checklist to be considered when assessing impacts. Only some of these may be relevant to each airport option.

A minimum of 31 activities were identified:

- 6 causing habitat destruction/removal
- 4 initiating habitat degrading processes
- 9 causing sediment inputs to streams
- 5 causing nutrient inputs to streams
- 7 causing miscellaneous contaminant inputs to streams

For each of the activities listed in Table C3.12, the following was considered for each stream to be directly affected:

Three time frames: -
short-term (about one month, coded 'S')
medium-term (up to one to two years, coded 'M')
long-term (beyond three to four years, coded 'L')

Likely spatial extent of stream impacts (coarse estimates): -

0 = no impact likely
1 = localised impact likely (up to one km downstream)
2 = moderately extensive (1-10 km downstream)
3 = very extensive (beyond 10 km downstream)
4 = unknown, unsupplied or unable to predict in the coarsest terms

Likely intensity of stream impacts (coarse estimates) -

0 = no impact likely
1 = low intensity
2 = moderate intensity
3 = high intensity
4 = very high intensity (e.g. habitat removal)

Unknown, unsupplied or unable to predict in the coarsest terms

For each activity, stream, and time frame category, the product of the scores (impact extent X impact intensity) was determined. These provided a measure of the scale of impact. These products were then summed across activities to provide a measure of the scale of impact for each stream and time frame. The scale of impact for each stream is described as follows.

minor:	0-10 (summed products)
major:	10-50
very major:	50-100
severe:	100-150
very severe:	greater than 150

These also represent a sliding scale of impacts for fish and crayfish inhabiting these streams. A minor scale of impacts indicates the following changes to the fish and crayfish species inhabiting these streams: subtle reductions in the abundance of sensitive native fish and crayfish taxa; associated subtle community composition changes favouring pollution tolerant taxa; and slight reductions in reproductive success. A very severe scale of impacts indicates virtual elimination of the majority of native fish taxa down affected tributaries and well into trunk streams, elimination of all crayfish taxa and cessation of reproduction.

1.8.1.2 Operational impacts

A list of airport operational activities/installations which may lead to impacts on freshwater fish and crayfish fauna is given in Table C3.13. As for construction activities, this list, which is not necessarily exhaustive, provides a generalised checklist to be considered when assessing impacts. Only some of these may be relevant to each airport option.

A minimum of 28 activities/installations were identified:

- 3 causing habitat destruction/removal
- 4 initiating habitat degrading processes
- 1 causing sediment inputs to streams
- 1 causing biological contaminants to streams
- 6 causing nutrient inputs to streams
- 13 causing miscellaneous contaminant inputs to streams

The primary differences in the shift from construction activities to operational activities/installations are a reduction of activities involving sediment inputs (9 goes to 1), an increase in activities causing miscellaneous contaminant inputs (7 goes to 13) and the introduction of activities causing biological contaminant inputs (0 goes to 1). The effects of activities causing habitat destruction/removal and habitat degrading processes essentially carry on through from the construction to the operational period.

As for the construction activities, the prediction of impacts resulting from operational activities/installations is clearly difficult given the number of activities, the large scale of the development and a general lack of quantitative information on the likely input of operational-derived materials into streams. Again, a very high level of complexity is apparent when the range of possible impact mechanisms are considered for each group of operational activities (see some impact mechanisms in Tables 7 and 8, Attachment 1).

Assessment for operational impacts was similar to that for construction impacts, with the following exceptions:

- activities/installations in Table C3.13 are relevant for operational impacts;
- an important external issue - the release of treated sewerage effluent into the Georges River (Holsworthy options) - was considered in relation to operational impacts;
- surrounding streams not hydrologically connected to those draining the airport sites had to be considered in operational impacts because of the liklihood of atmospheric fallout (gaseous pollutants) from aircraft and increased vehicular traffic.

1.8.1.2.1 Limitations

Impact assessment for stream biota impacts is clearly difficult given the number of activities and a general lack of quantitative information regarding the likely input of construction derived materials to the streams. It is recognised that most of these inputs will be influenced by unpredictable factors such as the occurrence of intense rainfall events, human error, protocols found to be inappropriate in hindsight and others.

Considering the link between the physical/chemical impacts and stream biota impacts, a very high level of complexity is apparent when the range of possible impact mechanisms is examined for each group of activities. For example, for each activity involving sediment inputs, there are at least 11 stream-biota impact mechanisms (see Attachment 1, Appendix 3) and there is a high probability of interactions between some of these mechanisms Similarly, for each activity involving nutrient inputs, there are at least nine impact mechanisms (Attachment 1, Appendix 3); interactions between mechanisms are likely.

Because of the complexity, the key initial task of impact assessment procedure was to simplify or reduce the number of impacts and their interactions. The overall objective was to derive a measure of the scale of impacts likely to occur for each airport option for comparative purposes

1.8.2 Analysis and Results

1.8.2.1 Badgerys Creek Option A

1.8.2.1.1 Construction impacts

Estimates used to derive the measure stream impacts caused by construction activities at the Badgerys Creek Option-A site are given in Table C3.14. The summed products of these estimates per affected stream and time-frame category are given below:

Cosgroves Ck and tribs.:	S = 72(4?)	M = 71(4?)	L = 28(4?)
Oaky Ck and tribs.:	S = 72(4?)	M = 71(4?)	L = 28(4?)
Badgerys Ck and tribs.:	S = 62(4?)	M = 61(4?)	L = 21(4?)
Duncans Ck and tribs.:	S = 46(3?)	M = 46(4?)	L = 14(4?)

In the short- and medium-term, it is likely that fish and crayfish within Cosgroves, Oaky and Badgerys Creeks (and their downstream trunk streams such as South Creek) will be subject to major impacts. These impacts are likely to persist in the long-term. Duncans Creek is likely to suffer major impacts in the short- and long-term.

This assessment is made without being able to consider the impacts of three to four construction activities for each stream (the number activities in which impacts could not be coarsely predicted are given above: '_?')

1.8.2.1.2 Operation impacts

Estimates used to derive the measure stream impacts caused by operational activities/installations at the Badgerys Creek Option-A site are given in Table C3.15. The summed products of these estimates per affected stream and time-frame category are given below:

Cosgroves Ck and tribs.:	S =	M =	L = 26(12?)
Oaky Ck and tribs.:	S =	M =	L = 26(8?)
Badgerys Ck and tribs.:	S =	M =	L = 27(12?)
Thompsons Ck and tribs.:	S =	M =	L = 0(2?)
Duncans Ck and tribs.:	S =	M =	L = 12(12?)
Surrounding streams:	S =	M =	L = 0(2?)

For all time frames, it is likely that fish and crayfish within Cosgroves, Oakey, Badgerys and Duncan Creeks (and their downstream trunk streams such as South Creek) will be subject to major impacts. No impacts are predicted in Thompsons Creek and its tributaries and surrounding streams as they are not hydrologically connected to the airport site. This assessment is made without being able to consider the impacts of 8 to 12 operational activities/installations for each stream.

No impacts were predicted in Thompsons Creek and tributaries, and the surrounding streams, as they are not hydrologically connected to the airport site. However, no information was available to assess the impacts of atmospheric fallout on these streams.

1.8.2.2 Badgerys Creek Option B

1.8.2.2.1 Construction impacts

Estimates used to derive the measure stream impacts caused by construction activities at the Badgerys Creek Option-B site are given in Table C3.16. The summed products of these estimates per affected stream and time-frame category are given below:

Cosgroves Ck and tribs :	S = 68(4?)	M = 67(4?)	L = 26(4?)
Oaky Ck and tribs.:	S = 72(4?)	M = 71(4?)	L = 28(4?)
Badgerys Ck and tribs :	S = 86(4?)	M = 85(4?)	L = 31(4?)
Thompsons Ck and tribs.:	S = 8(3?)	M = 8(3?)	L = 0(3?)
Duncans Ck and tribs.:	S = 62(3?)	M = 61(3?)	L = 22(3?)

In the short- and medium-term, it is likely that fish and crayfish in Cosgroves, Oakey, Badgerys and Duncans Creeks (and their downstream trunk streams such as South Creek) will be subject to very major impacts. Major impacts are likely to persist in the long-term. Fish and crayfish within Thompsons Creek are likely to be subject to minor impacts in the short- and medium-term. This assessment is made without being able to consider the impacts of three to four construction activities for each stream.

1.8.2.2.2 Operation impacts

Estimates used to derive the measure stream impacts caused by operational activities/installations at the Badgerys Creek Option-B site are given in Table C3.17. The summed products of these estimates per affected stream and time-frame category are given below:

Cosgroves Ck and tribs.:	S =	M =	L = 26(8?)
Oaky Ck and tribs.:	S =	M =	L = 26(12?)
Badgerys Ck and tribs.:	S =	M =	L = 37(12?)
Thompsons Ck and tribs.:	S =	M =	L = 3(4?)
Duncans Ck and tribs.:	S =	M =	L = 22(11?)
Surrounding streams:	S =	M =	L = 0 (2?)

For all time frames considered, it is likely that fish and crayfish in Cosgroves, Oakey, Badgerys and Duncans Creeks will be subject to major impacts. Minor impacts are likely in Thompsons Creek and its tributaries and no impacts are likely in surrounding streams as their hydrological connection to the airport option is limited. This assessment is made without being able to consider the impacts of 8 to 12 operational activities/installations for each stream. However, no information was available to assess the impacts of atmospheric fallout on these streams.

1.8.2.3 Badgerys Creek Option C

1.8.2.3.1 Construction impacts

Estimates used to derive the measure stream impacts caused by construction activities at the Badgerys Creek Option-C site are given in Table C3.18. The summed products of these estimates per affected stream and time-frame category are given below:

Cosgroves Ck and tribs.:	S = 21(3?)	M = 20(3?)	L = 4(3?)
Oaky Ck and tribs.:	S = 71(4?)	M = 70(4?)	L = 28(4?)
Badgerys Ck and tribs.:	S = 83(4?)	M = 82(4?)	L = 29(4?)
Thompsons Ck and tribs.:	S = 51(4?)	M = 51(4?)	L = 13(4?)
Duncans Ck and tribs.:	S = 19(3?)	M = 19(3?)	L = 4(3?)

In the short- and medium-term, it is likely that fish and crayfish in Cosgroves, Oakey, Badgerys, Duncans and Thompsons Creeks (and their downstream trunk streams such as South Creek) will be subject to very major impacts. Major impacts are likely to persist in the long-term in Oakey, Badgerys and Thompsons Creeks. Fish and crayfish in Cosgroves and Duncans Creeks are likely to be subject to minor impacts in the long-term. This assessment is made without being able to consider the impacts of three to four construction activities for each stream

1.8.2.3.2 Operation impacts

Estimates used to derive the measure stream impacts caused by operational activities/installations at the Badgerys Creek Option-C site are given in Table C3.19. The summed products of these estimates per affected stream and time-frame category are given below:

Cosgroves Ck and tribs.:	S =	M =	L = 4(5?)
Oaky Ck and tribs.:	S =	M =	L = 26(12?)
Badgervs Ck and tribs.:	S =	M =	L = 35(12?)
Thompsons Ck and tribs.:	S =	M =	L = 13(4?)
Duncans Ck and tribs :	S =	M =	L = 3(4?)
Surrounding streams:	S =	M =	L = 0 (2?)

For all time frames, it is likely that Oakey, Badgerys and Thompsons Creeks (and their downstream trunk streams such as South Creek) will be subject to major impacts. Minor impacts are likely in Cosgroves Creek and Thompsons Creeks and their tributaries. No impacts are likely for surrounding streams as they have no hydrological connection to the airport site. This assessment is made without being able to consider the impacts of 4 to 12 operational activities/installations for each stream. However, no information was available to assess the impacts of a limited number of ground activities and/or atmospheric fallout on these streams.

1.8.2.4 Badgerys Creek Overall Impacts

Given the existing degraded stream conditions, and the associated low conservation value of the streams, the predicted major stream impacts from the Badgerys Creek airport options are unlikely, in an absolute sence, to result in profound deleterious changes to the stream biota. It is highly likely that the fish fauna will become even more dominated by pollution-tolerant pest species.

The scale of impacts expected from each airport option is quite similar. This is well illustrated in Figures A3.7 to A3.9 where the conservation value of selected streams is respectively plotted against the scale of short-term and medium-term construction impacts, long term construction impacts and long term operational impacts (note the overlapping stream data points). However, in terms of minimising of the number of streams to be affected, Option A is desirable - only four stream systems are to be directly affected compared with five in both of the other options.

1.8.2.5 Holsworthy Option A

1.8.2.5.1 Construction impacts

Estimates used to derive the measure stream impacts caused by construction activities at the Holsworthy Option-A site are given in Table C3.20. The summed products of these estimates per affected stream and time-frame category are given below:

Harris Ck and tribs.:	S =	M = 106(4?)	L = 42(4?)
Williams Ck and tribs.:	S =	M = 125(4?)	L = 61(4?)
Deadmans Ck and tribs.:	S =	M = 71(4?)	L = 27(3?)
Lyretail Ck and tribs.:	S =	M = 97(4?)	L = 45(4?)
Wappa Ck and tribs.:	S =	M = 93(3?)	L = 40(3?)
Kalibucca Ck and tribs.:	S =	M = 89(4?)	L = 34(4?)
Punchbowl Ck and tribs.:	S =	M = 67(3?)	L = 25(3?)

In the short- and medium-term, it is likely that fish and crayfish in Harris and Williams Creeks (and their downstream trunk streams) will be subject to severe impacts. Major to very major impacts are likely to persist in the long-term. It is likely that fish and crayfish in Deadmans, Lyretail, Wappa, Kalibucca and Punchbowl Creeks (and their downstream trunk streams such as the Georges River and the Woronora River) are likely to be subject to very major impacts in the short- and medium-term. Major impacts are likely to persist in these streams in the long-term. No assessment was undertaken for four other sets of streams: Complete Creek, Wallaby Creek, miscellaneous lower Woronora River tributaries and miscellaneous Woronora Reservoir feeder streams. It is predicted that minor impacts would occur in these streams (see Table C3.20, Appendix 3). This assessment is made without being able to consider the impacts of 3 to 4 construction activities for each stream.

1.8.2.5.2 Operation impacts

Estimates used to derive the measure stream impacts caused by operational activities/installations at the Holsworthy Option-A site are given in Table C3.21. The summed products of these estimates per affected stream and time-frame category are given below:

Harris Ck and tribs.:	S =	M =	L = 35(12?)
Williams Ck and tribs.:	S =	M =	L = 54(12?)
Deadmans Ck and tribs.:	S =	M =	L = 20(4?)
Lyretail Ck and tribs.:	S =	M =	L = 38(4?)
Wappa Ck and tribs.:	S =	M =	L = 34(4?)
Kalibucca Ck and tribs.:	S =	M =	L = 26(12?)
Punchbowl Ck tribs.:	S =	M =	L = 18(4?)
Georges R. and tribs.:	S =	M =	L = 16 (2?)
Surrounding streams:	S =	M =	L = 0 (2?)

For all time frames, it is likely that fish and crayfish in Harris, Williams, Deadmans, Lyretail, Wappa, Kalibucca and Punchbowl Creeks would be subject to major impacts. Minor long-term impacts are expected for the four unassessed streams. No impacts are likely for the surrounding streams as they have no hydrological connection to the airport site. However, no information was available to assess the impacts of atmospheric fallout on these streams. This assessment is made without being able to consider the impacts of 2 to 12 operational activities/installations for each stream.

1.8.2.6 Holsworthy Option B

1.8.2.6.1 Construction

Estimates used to derive the measure stream impacts caused by construction activities at the Holsworthy Option-B site are given in Table C3.22. The summed products of these estimates per affected stream and time-frame category are given below:

Punchbowl Ck and tribs.:	S =	M = 152(4?)	L = 82(4?)
Gunya Ck and tribs.:	S =	M = 58(3?)	L = 12(3?)
O'Hares Ck and tribs.:	S =	M = 104(3?)	L = 36(3?)
upper Woronora R. tribs.:	S =	M = 17(3?)	L = 5(3?)
Dahlia Ck tribs:	S =	M = 18(3?)	L = 5(3?)

In the short- and medium-term, it is likely that fish and crayfish in Punchbowl and O'Hares Creek (and their downstream trunk stream the Georges River) would be subject to severe to very severe impacts. Major to very major impacts are likely to persist in these two streams in the long-term. Fish and crayfish in Gunya, Upper Woronora River tributaries and Dahlia Creek tributaries (and their downstream trunk stream the Georges River) would be subject to major to very major impacts in the short- and medium term. Minor to major impacts are likely to persist in these three streams in the long-term. This assessment is made without being able to consider the impacts of three to four construction activities for each stream.

1.8.2.6.2 Operation impacts

Estimates used to derive the measure stream impacts caused by operational activities/installations at the Holsworthy Option-B site are given in Table C3.23. The summed products of these estimates per affected stream and time-frame category are given below:

Punchbowl Ck and tribs.:	S =	M =	L = 64(12?)
Gunya Ck and tribs.:	S =	M =	L = 10(4?)
O'Hares Ck and tribs :	S =	M =	L = 37(4?)
upper Woronora R. tribs :	S =	M =	L = 8(4?)
Dahlia Ck tribs:	S =	M =	L = 8(4?)
Georges R. and tribs.:	S =	M =	L = 16 (2?)
Surrounding streams:	S =	M =	L = 0 (2?)

For all time frames, fish and crayfish in Punchbowl Creek and its tributaries (and its downstream trunk stream the Georges River) would be subject to very major impacts. It is likely that Gunya Creek and its tributaries, O'Hares Creek and its tributaries and the Georges River and its tributaries would be subject to major impacts for all time frames. Minor impacts are expected for the upper Woronora River and its tributaries, Dahlia Creek and its tributaries. No impacts are expected for the surrounding streams as they have no hydrological connection to the airport option. However, no information was available to assess the impacts of atmospheric fallout on these streams. This assessment is made without being able to consider the impacts of 2 to 12 operational activities/installations for each stream.

1.8.2.7 Holsworthy Overall Impacts

Given the existing high-quality stream conditions, and the associated high conservation value of the streams (state to national significance), the predicted major to very severe stream impacts from the Holsworthy airport options are likely, in an absolute sence, to result in profound deleterious changes to the stream biota, including fish and crayfish fauna. It is likely that many of the streams will become highly degraded with their conservation value being severely compromised.

Compared with the Badgerys Creek airport options, major stream-environment losses are expected with the Holsworthy options - generally the scale of impacts is predicted to be larger and, because of the stream's high conservation value, more can be lost. This is well illustrated in Figures A3.7 to A3.9 (plots of conservation value vs. scale of impacts).

The scale of impacts expected from each Holsworthy airport option is generally similar (Figures A3.7 to A3.9). However, the most severe impacts on a particular stream are expected from Option B (southern). Unfortunately, the stream system affected (Punchbowl Creek) is large, has a very high conservation value, and is an important stream for Australian bass (a recreationally valuable fish species) within the Georges River system.

In terms of minimising of the number of streams to be affected, Option B is the most desirable - only six stream systems are to be directly affected compared with twelve in Option B.

Table C3.12. Checklist of airport construction activities which may lead to impacts on freshwater fish or crayfish fauna.

Activity (construction of....) and primary impacts:

Habitat destruction/removal (HDR):

- temporary water storages (HDR1): habitat & passage loss
- permanent detention ponds (HDR2): habitat & passage loss
- temporary stream diversions (HDR3): habitat loss
- temporary stream excavations (HDR4): habitat & passage loss
- infilling of streams (HDR5): habitat & passage loss
- temporary & permanent drainage works (HDR6): habitat loss

Habitat degrading processes (HDP):

- blasting (HDP1): fracturing of stream beds then loss of low stream flows
- impervious and well-drained surfaces without detention ponds (HDP2): greater stream-flow energy peaks leading to the destabilisation of stream and riparian substrates; increased duration of low flows
- impervious and well-drained surfaces with detention ponds (HDP3): increased duration of low flows: reduced peak flows (reducion in flow variability)
- catchment severing (HDP4): reduction of stream flows

Sediment inputs (SI):

- temporary water storages (SI1): sediment inputs during construction - see Attachment 1 for possible impacts
- permanent detention ponds (SI2): sediment inputs during construction - see Attachment 1
- temporary stream diversions (SI3): sediment inputs particularly during the first flush - see Attachment 1
- temporary stream excavations (SI4): sediment inputs during works & flushes - see Attachment 1
- infilling of streams (SI5): sediment inputs if surface flow occurs during works - see Attachment 1
- temporary and permanent drainage works (SI6): sediment inputs particularly during the first flush - see Attachment 1
- clearing of vegetation (SI7): sediment inputs until stabilised - see Attachment 1
- major earthworks (SI8): sediment inputs until stabilised - see Attachment 1
- dust generation & deposition (SI9): sediment inputs through washoff - see Attachment 1

Nutrient inputs (NI):

- sediments inputs (NI1): sediments arising from all earthworks above (including dust generation) will variously have nutrients attached; sediment inputs will therefore lead to nutrient inputs - see Appendix 6 (nutrient component) for possible impacts
- water percolation through disturbed soils (NI2): this may lead to nutrient leaching and hence nutrient inputs through runoff or seepage - see Attachment 1 (nutrient component)
- fertilisers for revegetation (NI3): water runoff leading to nutrient inputs - see Attachment 1 (nutrient component)
- water percolation through mulch piles (NI4): this may lead to nutrient leaching and hence nutrient inputs through runoff or seepage - see Attachment 1 (nutrient component)
- water percolation through material within filled ravines (NI5): this may lead to nutrient leaching (particularly under anoxic conditions) and hence nutrient inputs at seepage output points - see Attachment 1 (nutrient component)

Miscellaneous contaminant inputs (MCI):

- fuel/oil spills (MCI1): direct toxicity & habitat degradation
- drilling fluid spills (MCI2): direct toxicity & habitat degradation
- leachates from blast furnace slag (MCI3): possible direct toxicity
- cement slurry spills (MCI4): direct toxicity and habitat degradation
- water percolation through material within filled ravines (MCI5): this may lead to the leaching of toxic substances such as metal salts (particularly under anoxic conditions), and hence toxicant inputs at seepage output points
- runoff from bitumenised areas (MCI6): possible direct toxicity
- inappropriate dosing of floculating agents (MCI7): direct toxicity and habitat degradation

Table C3.13. *Checklist of airport operational activities and/or installations which may lead to impacts on freshwater fish or crayfish fauna. STW = sewerage treatment works.*

Activity/installation and primary impacts

Habitat destruction/removal (HDR):
- permanent detention ponds (HDR1): habitat & passage loss
- infilled streams (HDR2): habitat & passage loss
- permanent drainage system (HDR3): habitat loss

Habitat degrading processes (HDP):
- post-construction blasting effects (HDP1): fractures in stream beds continue to result in the loss of low stream flows
- impervious and well-drained surfaces without detention ponds (HDP2): greater stream-flow energy peaks leading to the destabilisation of stream and riparian substrates; increased duration of low flows
- impervious and well-drained surfaces with detention ponds (HDP3): increased duration of low flows: reduced peak flows (reduction in flow variability)
- catchment severing (HDP4): reduction of stream flows

Sediment inputs (SI):
- erosion from sloped grounds either not fully revegetated or vegetation cover reduced due to drought conditions (SI1): sediment inputs - see Appendix 5 for possible impacts

Nutrient inputs (NI):
- sediments inputs (NI1): sediments arising from erosion (see above) will variously have nutrients attached; sediment inputs will therefore lead to nutrient inputs - see Attachment 1 (nutrient component) for possible impacts
- fertilisers for maintenance of grounds (NI2): water runoff leading to nutrient inputs - see Attachment 1 (nutrient component)
- water percolation through material within filled ravines (NI3): this may lead to nutrient leaching (particularly under anoxic conditions) and hence nutrient inputs at seepage output points - see Attachment 1 (nutrient component)
- releases from permanent STW (NI4): nutrient inputs - see Attachment 1 (nutrient component)
- detergents from aircraft washdown sites (NI5): runoff containing nutrient-rich detergents may be significant nutrient inputs to streams - see Attachment 1 (nutrient component)
- atmospheric fallout including nitrogenous constituents such as NOx (NI6): coupled with rain events, this fallout may result in nutrient inputs - see Attachment 1 (nutrient component)

Biological contaminant inputs (BCI):
- releases from permanent STW (BCI1): microbiological contaminant inputs - see Attachment 1 (pathogen component)

Miscellaneous contaminant inputs (MCI):
- fuel/oil spills (MCI1): direct toxicity & habitat degradation
- leachates from blast furnace slag (MCI2): possible direct toxicity
- water percolation through material within filled ravines (MCI3): this may lead to the leaching of toxic substances such as metal salts (particularly under anoxic conditions), and hence toxicant inputs at seepage output points
- runoff from bitumenised areas (MCI4): possible direct toxicity
- inappropriate dosing of floculating agents (MCI5): direct toxicity and habitat degradation
- releases from permanent STW (MCI6): it is possible that a variety of substances may be released which are either directly toxic, have chronic effects, or result in habitat degradation - see Attachment 1 (toxicants, miscellaneous substances and oils/greases components)
- pesticides/herbicides for maintenance of grounds (MCI7): runoff from grounds may result in significant inputs of these toxicants
- runoff containing oils, greases, solvents from maintenance areas (MCI8): direct toxicity and habitat degradation
- runoff containing detergents from aircraft washdown sites (MCI9): potential for habitat degradation

- runoff containing paint, paint strippers and solvents from maintenance areas (MCI10): direct toxicity and habitat degradation
- runoff containing substances used in fire fighting training (acids, fluorocarbon & solvents (MCI11): direct toxicity and habitat degradation
- runoff containing rubber detritus from aircraft touchdowns (MCI12): possible habitat degradation
- atmospheric fallout (MCI13): it is possible that a variety of substances may be released which are either directly toxic (e.g. hydrocarbons) or result in habitat degradation (e.g. ozone affecting plants, Nox coupled with rainfall or fog resulting in increased acidity)

***Table C3.14.** Extent and intensity estimates used to derive a measure of the scale of stream impacts caused by construction activities at the Badgerys Creek Option A site. Activity codes are given in Table C3.12.*

Activity	**Cosgroves Ck & tribs**			**Oaky Ck & tribs**			**Badgerys Ck & tribs**			**Thompsons Ck & tribs**			**Duncans Ck & tribs**		
	S	**M**	**L**	**S**	**M**	**L**	**S**	**M**	**L**	**S**	**M**	**L**	**S**	**M**	**L**
Habitat destruction/removal (HDR):															
HDR1	1x4	1x4	0x0	1x4	1x4	0x0	1x4	1x4	0x0	0x0	0x0	0x0	1x4	1x4	0x0
HDR2	1x4	1x4	1x4	1x4	1x4	1x4	1x4	1x4	1x4	0x0	0x0	0x0	0x0	0x0	0x0
HDR3	1x4	1x4	0x0	1x4	1x4	0x0	1x4	1x4	0x0	0x0	0x0	0x0	1x4	1x4	0x0
HDR4	1x4	1x4	0x0	1x4	1x4	0x0	1x4	1x4	0x0	0x0	0x0	0x0	1x4	1x4	0x0
HDR5	2x4	2x4	2x4	2x4	2x4	2x4	1x4	1x4	1x4	0x0	0x0	0x0	1x4	1x4	1x4
HDR6	2x4	2x4	2x4	2x4	2x4	2x4	1x4	1x4	1x4	0x0	0x0	0x0	1x4	1x4	1x4
Habitat degrading processes (HDP):															
HDP1	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
HDP2	0x0	0x0	0x0	0x0	0x0	0x0	1x1	1x1	1x1	0x0	0x0	0x0	1x1	1x1	1x1
HDP3	1x1	1x1	1x1	1x1	1x1	1x1	1x1	1x1	1x1	0x0	0x0	0x0	0x0	0x0	0x0
HDP4	1x1	1x1	1x1	1x1	1x1	1x1	1x1	1x1	1x1	0x0	0x0	0x0	1x1	1x1	1x1
Sediment inputs (SI):															
SI1	2x1	2x1	0x0	2x1	2x1	0x0	2x1	2x1	0x0	0x0	0x0	0x0	2x1	2x1	0x0
SI2	2x1	2x1	0x0	2x1	2x1	0x0	2x1	2x1	0x0	0x0	0x0	0x0	0x0	0x0	0x0
SI3	2x1	2x1	0x0	2x1	2x1	0x0	2x1	2x1	0x0	0x0	0x0	0x0	2x1	2x1	0x0
SI4	2x1	2x1	0x0	2x1	2x1	0x0	1x1	1x1	0x0	0x0	0x0	0x0	1x1	1x1	0x0
SI5	2x1	2x1	0x0	2x1	2x1	0x0	1x1	1x1	0x0	0x0	0x0	0x0	1x1	1x1	0x0
SI6	2x1	2x1	0x0	2x1	2x1	0x0	1x1	1x1	0x0	0x0	0x0	0x0	1x1	1x1	0x0
SI7	3x2	3x2	3x1	3x2	3x2	3x1	3x2	3x2	3x1	0x0	0x0	0x0	2x2	2x2	2x1
SI8	3x2	3x2	3x1	3x2	3x2	3x1	3x2	3x2	3x1	0x0	0x0	0x0	2x2	2x2	2x1
SI9	2x1	2x1	0x0	2x1	2x1	0x0	2x1	2x1	0x0	0x0	0x0	0x0	1x1	1x1	0x0
Nutrient inputs (NI):															
NI1	3x1	3x1	0x0	3x1	3x1	0x0	3x1	3x1	0x0	0x0	0x0	0x0	2x1	2x1	0x0
NI2	3x1	3x1	0x0	3x1	3x1	0x0	3x1	3x1	0x0	0x0	0x0	0x0	2x1	2x1	0x0
NI3	3x1	3x1	0x0	3x1	3x1	0x0	3x1	3x1	0x0	0x0	0x0	0x0	2x1	2x1	0x0
NI4	1x1	1x1	0x0	1x1	1x1	0x0	1x1	1x1	0x0	0x0	0x0	0x0	1x1	1x1	0x0
NI5	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
Miscellaneous contaminant inputs (MCI):															
MCI1	1x2	1x2	0x0	0x0	1x2	1x1	1x2	1x1	0x0	0x0	0x0	0x0	1x1	1x1	0x0
MCI2	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
MCI3	?	?	?	?	?	?	?	?	?	0x0	0x0	0x0	?	?	?
MCI4	?	?	?	?	?	?	?	?	?	0x0	0x0	0x0	?	?	?
MCI5	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
MCI6	?	?	?	?	?	?	?	?	?	0x0	0x0	0x0	?	?	?
MCI7	?	?	?	?	?	?	?	?	?	0x0	0x0	0x0	0x0	0x0	0x0

Table C3.15. Extent and intensity estimates used to derive a measure of the scale of stream impacts caused by operational activities/installations at the Badgerys Creek Option A site. Activity/installation codes are given in Table C3.13.

Activity	Cosgroves Ck & tribs			Oaky Ck & tribs			Badgerys Ck & tribs			Thompsons Ck & tribs			Duncans Ck & tribs			Surrounding Streams		
	S	M	L	S	M	L	S	M	L	S	M	L	S	M	L	S	M	L
Habitat destruction/removal (HDR):																		
HDR1	1x4	1x4	1x4	1x4	1x4	1x4	1x4	1x4	1x4	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
HDR2	2x4	2x4	2x4	2x4	2x4	2x4	1x4	1x4	1x4	0x0	0x0	0x0	1x4	1x4	1x4	0x0	0x0	0x0
HDR3	2x4	2x4	2x4	2x4	2x4	2x4	1x4	1x4	1x4	0x0	0x0	0x0	1x4	1x4	1x4	0x0	0x0	0x0
Habitat degrading processes (HDP):																		
HDP1	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
HDP2	0x0	0x0	0x0	0x0	0x0	0x0	1x1	1x1	1x1	0x0	0x0	0x0	1x1	1x1	1x1	0x0	0x0	0x0
HDP3	1x1	1x1	1x1	1x1	1x1	1x1	1x1	1x1	1x1	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
HDP4	1x1	1x1	1x1	1x1	1x1	1x1	1x1	1x1	1x1	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
Sediment inputs (SI):																		
SI1	1x1	1x1	1x1	1x1	1x1	1x1	1x1	1x1	1x1	0x0	0x0	0x0	1x1	1x1	1x1	0x0	0x0	0x0
Nutrient inputs (NI):																		
NI1	1x1	1x1	1x1	1x1	1x1	1x1	1x1	1x1	1x1	0x0	0x0	0x0	1x1	1x1	1x1	0x0	0x0	0x0
NI2	2x1	2x1	2x1	2x1	2x1	2x1	2x1	2x1	2x1	0x0	0x0	0x0	1x1	1x1	1x1	0x0	0x0	0x0
NI3	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
NI4	0x0	0x0	0x0	0x0	0x0	0x0	2x2	2x2	2x2	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
NI5	?	?	?	0x0	0x0	0x0	?	?	?	0x0	0x0	0x0	?	?	?	0x0	0x0	0x0
NI6	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Biological contaminant inputs (BCI):																		
BCI1	0x0	0x0	0x0	0x0	0x0	0x0	2x1	2x1	2x1	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
Miscellaneous contaminant inputs (MCI):																		
MCI1	?	?	?	?	?	?	?	?	?	0x0	0x0	0x0	?	?	?	0x0	0x0	0x0
MCI2	?	?	?	?	?	?	?	?	?	0x0	0x0	0x0	?	?	?	0x0	0x0	0x0
MCI3	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
MCI4	?	?	?	?	?	?	?	?	?	0x0	0x0	0x0	?	?	?	0x0	0x0	0x0
MCI5	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
MCI6	0x0	0x0	0x0	0x0	0x0	0x0	2x1	2x1	2x1	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
MCI7	?	?	?	?	?	?	?	?	?	0x0	0x0	0x0	?	?	?	0x0	0x0	0x0
MCI8	?	?	?	0x0	0x0	0x0	?	?	?	0x0	0x0	0x0	?	?	?	0x0	0x0	0x0
MCI9	?	?	?	0x0	0x0	0x0	?	?	?	0x0	0x0	0x0	?	?	?	0x0	0x0	0x0
MCI10	?	?	?	0x0	0x0	0x0	?	?	?	0x0	0x0	0x0	?	?	?	0x0	0x0	0x0
MCI11	?	?	?	?	?	?	?	?	?	0x0	0x0	0x0	?	?	?	0x0	0x0	0x0
MCI12	?	?	?	?	?	?	?	?	?	0x0	0x0	0x0	?	?	?	0x0	0x0	0x0
MCI13	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?

Table C3.16. Extent and intensity estimates used to derive a measure of the scale of stream impacts caused by construction activities at the Badgerys Creek Option B site. Activity codes are given in Table C3.12.

Activity	Cosgroves Ck & tribs			Oaky Ck & tribs			Badgerys Ck & tribs			Thompsons Ck & tribs			Duncans Ck & tribs		
	S	M	L	S	M	L	S	M	L	S	M	L	S	M	L
Habitat destruction/removal (HDR):															
HDR1	1x4	1x4	0x0	1x4	1x4	0x0	1x4	1x4	0x0	0x0	0x0	0x0	1x4	1x4	0x0
HDR2	1x4	1x4	1x4	1x4	1x4	1x4	1x4	1x4	1x4	0x0	0x0	0x0	0x0	0x0	0x0
HDR3	1x4	1x4	0x0	1x4	1x4	0x0	2x4	2x4	0x0	0x0	0x0	0x0	1x4	1x4	0x0
HDR4	1x4	1x4	0x0	1x4	1x4	0x0	2x4	2x4	0x0	0x0	0x0	0x0	1x4	1x4	0x0
HDR5	2x4	2x4	2x4	2x4	2x4	2x4	2x4	2x4	2x4	0x0	0x0	0x0	2x4	2x4	2x4
HDR6	2x4	2x4	2x4	2x4	2x4	2x4	2x4	2x4	2x4	0x0	0x0	0x0	2x4	2x4	2x4
Habitat degrading processes (HDP):															
HDP1	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
HDP2	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	1x1	1x1	1x1
HDP3	1x1	1x1	1x1	1x1	1x1	1x1	2x2	2x2	2x2	0x0	0x0	0x0	0x0	0x0	0x0
HDP4	1x1	1x1	1x1	1x1	1x1	1x1	1x1	1x1	1x1	0x0	0x0	0x0	1x1	1x1	1x1
Sediment inputs (SI):															
SI1	2x1	2x1	0x0	2x1	2x1	0x0	2x1	2x1	0x0	0x0	0x0	0x0	2x1	2x1	0x0
SI2	2x1	2x1	0x0	2x1	2x1	0x0	2x1	2x1	0x0	0x0	0x0	0x0	0x0	0x0	0x0
SI3	2x1	2x1	0x0	2x1	2x1	0x0	2x1	2x1	0x0	0x0	0x0	0x0	2x1	2x1	0x0
SI4	2x1	2x1	0x0	2x1	2x1	0x0	2x1	2x1	0x0	0x0	0x0	0x0	2x1	2x1	0x0
SI5	2x1	2x1	0x0	2x1	2x1	0x0	2x1	2x1	0x0	0x0	0x0	0x0	2x1	2x1	0x0
SI6	2x1	2x1	0x0	2x1	2x1	0x0	2x1	2x1	0x0	0x0	0x0	0x0	2x1	2x1	0x0
SI7	2x2	2x2	2x1	3x2	3x2	3x1	3x2	3x2	3x1	1x1	1x1	0x0	2x2	2x2	2x1
SI8	2x2	2x2	2x1	3x2	3x2	3x1	3x2	3x2	3x1	1x1	1x1	0x0	2x2	2x2	2x1
SI9	2x1	2x1	0x0	2x1	2x1	0x0	2x1	2x1	0x0	1x1	1x1	0x0	2x1	2x1	0x0
Nutrient inputs (NI):															
NI1	3x1	3x1	0x0	3x1	3x1	0x0	3x1	3x1	0x0	1x1	1x1	0x0	3x1	3x1	0x0
NI2	3x1	3x1	0x0	3x1	3x1	0x0	3x1	3x1	0x0	1x1	1x1	0x0	3x1	3x1	0x0
NI3	3x1	3x1	0x0	3x1	3x1	0x0	3x2	3x2	0x0	1x1	1x1	0x0	3x1	3x1	0x0
NI4	1x1	1x1	0x0	1x1	1x1	0x0	1x1	1x1	0x0	1x1	1x1	0x0	1x1	1x1	0x0
NI5	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
Miscellaneous contaminant inputs (MCI):															
MCI1	1x2	1x1	0x0	1x2	1x1	0x0	1x2	1x1	0x0	1x1	1x1	0x0	1x2	1x1	0x0
MCI2	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
MCI3	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
MCI4	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
MCI5	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
MCI6	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
MCI7	?	?	?	?	?	?	?	?	?	0x0	0x0	0x0	0x0	0x0	0x0

Table C3.17. *Extent and intensity estimates used to derive a measure of the scale of stream impacts caused by operational activities/installations at the Badgerys Creek Option B site. Activity/installation codes are given in Table C3.13.*

Activity	**Cosgroves Ck & tribs**			**Oaky Ck & tribs**			**Badgerys Ck & tribs**			**Thompsons Ck & tribs**			**Duncans Ck & tribs**			**Surrounding Streams**		
	S	**M**	**L**	**S**	**M**	**L**	**S**	**M**	**L**	**S**	**M**	**L**	**S**	**M**	**L**	**S**	**M**	**L**
Habitat destruction/removal (HDR):																		
HDR1	1x4	1x4	1x4	1x4	1x4	1x4	1x4	1x4	1x4	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
HDR2	2x4	2x4	2x4	2x4	2x4	2x4	2x4	2x4	2x4	0x0	0x0	0x0	2x4	2x4	2x4	0x0	0x0	0x0
HDR3	2x4	2x4	2x4	2x4	2x4	2x4	2x4	2x4	2x4	0x0	0x0	0x0	2x4	2x4	2x4	0x0	0x0	0x0
Habitat degrading processes (HDP):																		
HDP1	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
HDP2	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	1x1	1x1	1x1	0x0	0x0	0x0
HDP3	1x1	1x1	1x1	1x1	1x1	1x1	2x2	2x2	2x2	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
HDP4	1x1	1x1	1x1	1x1	1x1	1x1	1x1	1x1	1x1	0x0	0x0	0x0	1x1	1x1	1x1	0x0	0x0	0x0
Sediment inputs (SI):																		
SI1	1x1	1x1	1x1	1x1	1x1	1x1	1x1	1x1	1x1	1x1	1x1	1x1	1x1	1x1	1x1	0x0	0x0	0x0
Nutrient inputs (NI):																		
NI1	1x1	1x1	1x1	1x1	1x1	1x1	1x1	1x1	1x1	1x1	1x1	1x1	1x1	1x1	1x1	0x0	0x0	0x0
NI2	2x1	2x1	2x1	2x1	2x1	2x1	2x1	2x1	2x1	1x1	1x1	1x1	2x1	2x1	2x1	0x0	0x0	0x0
NI3	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
NI4	0x0	0x0	0x0	0x0	0x0	0x0	2x2	2x2	2x2	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
NI5	0x0	0x0	0x0	?	?	?	?	?	?	0x0	0x0	0x0	?	?	?	0x0	0x0	0x0
NI6	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Biological contaminant inputs (BCI):																		
BCI1	0x0	0x0	0x0	0x0	0x0	0x0	2x1	2x1	2x1	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
Miscellaneous contaminant inputs (MCI):																		
MCI1	?	?	?	?	?	?	?	?	?	0x0	0x0	0x0	?	?	?	0x0	0x0	0x0
MCI2	?	?	?	?	?	?	?	?	?	0x0	0x0	0x0	?	?	?	0x0	0x0	0x0
MCI3	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
MCI4	?	?	?	?	?	?	?	?	?	0x0	0x0	0x0	?	?	?	0x0	0x0	0x0
MCI5	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
MCI6	0x0	0x0	0x0	0x0	0x0	0x0	2x1	2x1	2x1	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
MCI7	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	0x0	0x0	0x0
MCI8	0x0	0x0	0x0	?	?	?	?	?	?	0x0	0x0	0x0	?	?	?	0x0	0x0	0x0
MCI9	0x0	0x0	0x0	?	?	?	?	?	?	0x0	0x0	0x0	?	?	?	0x0	0x0	0x0
MCI10	0x0	0x0	0x0	?	?	?	?	?	?	0x0	0x0	0x0	?	?	?	0x0	0x0	0x0
MCI11	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	0x0	0x0	0x0
MCI12	?	?	?	?	?	?	?	?	?	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
MCI13	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?

Table C3.18. Extent and intensity estimates used to derive a measure of the scale of stream impacts caused by construction activities at the Badgery Creek Option C site. Activity codes are given in Table C3.12.

Activity	Cosgroves Ck & tribs			Oaky Ck & tribs			Badgerys Ck & tribs			Thompsons Ck & tribs			Duncans Ck & tribs		
	S	M	L	S	M	L	S	M	L	S	M	L	S	M	L
Habitat destruction/removal (HDR):															
HDR1	0x0	0x0	0x0	1x4	1x4	0x0	1x4	1x4	0x0	1x4	1x4	0x0	0x0	0x0	0x0
HDR2	0x0	0x0	0x0	1x4	1x4	1x4	1x4	1x4	1x4	1x4	1x4	1x4	0x0	0x0	0x0
HDR3	0x0	0x0	0x0	1x4	1x4	0x0	2x4	2x4	0x0	1x4	1x4	0x0	0x0	0x0	0x0
HDR4	0x0	0x0	0x0	1x4	1x4	0x0	2x4	2x4	0x0	1x4	1x4	0x0	0x0	0x0	0x0
HDR5	0x0	0x0	0x0	2x4	2x4	2x4	2x4	2x4	2x4	0x0	0x0	0x0	0x0	0x0	0x0
HDR6	0x0	0x0	0x0	2x4	2x4	2x4	2x4	2x4	2x4	1x4	1x4	1x4	0x0	0x0	0x0
Habitat degrading processes (HDP):															
HDP1	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
HDP2	0x0	0x0	0x0	0x0	0x0	0x0	1x1	1x1	1x1	0x0	0x0	0x0	0x0	0x0	0x0
HDP3	0x0	0x0	0x0	1x1	1x1	1x1	1x1	1x1	1x1	1x1	1x1	1x1	0x0	0x0	0x0
HDP4	0x0	0x0	0x0	1x1	1x1	1x1	1x1	1x1	1x1	0x0	0x0	0x0	0x0	0x0	0x0
Sediment inputs (SI):															
SI1	0x0	0x0	0x0	2x1	2x1	0x0	2x1	2x1	0x0	2x1	2x1	0x0	0x0	0x0	0x0
SI2	0x0	0x0	0x0	2x1	2x1	0x0	2x1	2x1	0x0	2x1	2x1	0x0	0x0	0x0	0x0
SI3	0x0	0x0	0x0	2x1	2x1	0x0	2x1	2x1	0x0	2x1	2x1	0x0	0x0	0x0	0x0
SI4	0x0	0x0	0x0	2x1	2x1	0x0	2x1	2x1	0x0	2x1	2x1	0x0	0x0	0x0	0x0
SI5	0x0	0x0	0x0	2x1	2x1	0x0	2x1	2x1	0x0	0x0	0x0	0x0	0x0	0x0	0x0
SI6	0x0	0x0	0x0	2x1	2x1	0x0	2x1	2x1	0x0	2x1	2x1	0x0	0x0	0x0	0x0
SI7	2x2	2x2	2x1	3x2	3x2	3x1	3x2	3x2	3x1	2x2	2x2	2x1	2x2	2x2	2x1
SI8	2x2	2x2	2x1	3x2	3x2	3x1	3x2	3x2	3x1	2x2	2x2	2x1	2x2	2x2	2x1
SI9	1x1	1x1	0x0	1x1	1x1	0x0	1x1	1x1	0x0	1x1	1x1	0x0	1x1	1x1	0x0
Nutrient inputs (NI):															
NI1	3x1	3x1	0x0	3x1	3x1	0x0	3x1	3x1	0x0	3x1	3x1	0x0	3x1	3x1	0x0
NI2	3x1	3x1	0x0	3x1	3x1	0x0	3x1	3x1	0x0	3x1	3x1	0x0	3x1	3x1	0x0
NI3	3x1	3x1	0x0	3x1	3x1	0x0	3x2	3x2	0x0	3x1	3x1	0x0	3x1	3x1	0x0
NI4	1x1	1x1	0x0	1x1	1x1	0x0	1x1	1x1	0x0	1x1	1x1	0x0	1x1	1x1	0x0
NI5	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
Miscellaneous contaminant inputs (MCI):															
MCI1	1x2	1x1	0x0	1x2	1x1	0x0	1x2	1x1	0x0	1x1	1x1	0x0	1x1	1x1	0x0
MCI2	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
MCI3	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
MCI4	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
MCI5	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
MCI6	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
MCI7	0x0	0x0	0x0	?	?	?	?	?	?	?	?	?	0x0	0x0	0x0

Table C3.19. *Extent and intensity estimates used to derive a measure of the scale of stream impacts caused by operational impacts/installations at the Badgerys Creek Option C site. Activity/installation codes are given in Table C3.13.*

Activity	**Cosgroves Ck & tribs**			**Oaky Ck & tribs**			**Badgerys Ck & tribs**			**Thompsons Ck & tribs**			**Duncans Ck & tribs**			**Surrounding Streams**		
	S	M	L	S	M	L	S	M	L	S	M	L	S	M	L	S	M	L
Habitat destruction/removal (HDR):																		
HDR1	0x0	0x0	0x0	1x4	1x4	1x4	1x4	1x4	1x4	1x4	1x4	1x4	0x0	0x0	0x0	0x0	0x0	0x0
HDR2	0x0	0x0	0x0	2x4	2x4	2x4	2x4	2x4	2x4	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
HDR3	0x0	0x0	0x0	2x4	2x4	2x4	2x4	2x4	2x4	1x4	1x4	1x4	0x0	0x0	0x0	0x0	0x0	0x0
Habitat degrading processes (HDP):																		
HDP1	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
HDP2	0x0	0x0	0x0	0x0	0x0	0x0	1x1	1x1	1x1	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
HDP3	0x0	0x0	0x0	1x1	1x1	1x1	1x1	1x1	1x1	1x1	1x1	1x1	0x0	0x0	0x0	0x0	0x0	0x0
HDP4	0x0	0x0	0x0	1x1	1x1	1x1	1x1	1x1	1x1	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
Sediment inputs (SI):																		
SI1	1x1	1x1	1x1	1x1	1x1	1x1	1x1	1x1	1x1	1x1	1x1	1x1	1x1	1x1	1x1	0x0	0x0	0x0
Nutrient inputs (NI):																		
NI1	1x1	1x1	1x1	1x1	1x1	1x1	1x1	1x1	1x1	1x1	1x1	1x1	1x1	1x1	1x1	0x0	0x0	0x0
NI2	2x1	2x1	2x1	2x1	2x1	2x1	2x1	2x1	2x1	2x1	2x1	2x1	1x1	1x1	1x1	0x0	0x0	0x0
NI3	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
NI4	0x0	0x0	0x0	0x0	0x0	0x0	2x2	2x2	2x2	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
NI5	0x0	0x0	0x0	?	?	?	?	?	?	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
NI6	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Biological contaminant inputs (BCI):																		
BCI1	0x0	0x0	0x0	0x0	0x0	0x0	2x1	2x1	2x1	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
Miscellaneous contaminant inputs (MCI):																		
MCI1	0x0	0x0	0x0	?	?	?	?	?	?	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
MCI2	?	?	?	?	?	?	?	?	?	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
MCI3	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
MCI4	0x0	0x0	0x0	?	?	?	?	?	?	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
MCI5	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
MCI6	0x0	0x0	0x0	0x0	0x0	0x0	2x1	2x1	2x1	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
MCI7	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	0x0	0x0	0x0
MCI8	0x0	0x0	0x0	?	?	?	?	?	?	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
MCI9	0x0	0x0	0x0	?	?	?	?	?	?	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
MCI10	0x0	0x0	0x0	?	?	?	?	?	?	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
MCI11	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	0x0	0x0	0x0
MCI12	0x0	0x0	0x0	?	?	?	?	?	?	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
MCI13	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?

Table C3.20. Extent and intensity estimates used to derive a measure of the scale of stream impacts caused by construction activities at the Holsworthy Option A site. Activity codes are given in Table C3.12.

Activity	Harris Ck & tribs			Williams Ck & tribs			Deadmans Ck & tribs			Lyretail Ck & tribs			Wappa Ck & tribs			Kalibucca Ck & tribs			Punchbowl Ck & tribs		
	S	M	L	S	M	L	S	M	L	S	M	L	S	M	L	S	M	L	S	M	L
Habitat destruction/removal (HDR):																					
HDR1	1x4	1x4	0x0	1x4	1x4	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
HDR2	1x4	1x4	1x4	1x4	1x4	1x4	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	1x4	1x4	1x4	0x0	0x0	0x0
HDR3	1x4	1x4	0x0	1x4	1x4	0x0	1x4	1x4	0x0	1x4	1x4	0x0	1x4	1x4	0x0	1x4	1x4	0x0	1x4	1x4	0x0
HDR4	1x4	1x4	0x0	1x4	1x4	0x0	1x4	1x4	0x0	1x4	1x4	0x0	1x4	1x4	0x0	1x4	1x4	0x0	1x4	1x4	0x0
HDR5	2x4	2x4	2x4	3x4	3x4	3x4	1x4	1x4	1x4	2x4	2x4	2x4	1x4	1x4	1x4	1x4	1x4	1x4	0x0	0x0	0x0
HDR6	2x4	2x4	2x4	3x4	3x4	3x4	1x4	1x4	1x4	1x4	1x4	1x4	1x4	1x4	1x4	1x4	1x4	1x4	1x4	1x4	1x4
Habitat degrading processes (HDP):																					
HDP1	1x1	1x1	1x1	1x2	1x2	1x2	1x2	1x2	1x2	1x2	1x2	1x2	1x2	1x2	1x2	1x2	1x2	1x2	1x2	1x2	1x2
HDP2	0x0	0x0	0x0	0x0	0x0	0x0	1x1	1x1	1x1	2x2	2x2	2x2	2x2	2x2	2x2	0x0	0x0	0x0	1x1	1x1	1x1
HDP3	1x1	1x1	1x1	2x2	2x2	2x2	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	1x1	1x1	1x1	0x0	0x0	0x0
HDP4	1x1	1x1	1x1	2x2	2x2	2x2	0x0	0x0	0x0	2x2	2x2	2x2	2x2	2x2	2x2	1x1	1x1	1x1	1x1	1x1	1x1
Sediment inputs (SI):																					
SI1	2x2	2x2	0x0	2x2	2x2	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
SI2	2x2	2x2	0x0	2x2	2x2	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	2x2	2x2	0x0	0x0	0x0	0x0
SI3	2x2	2x2	0x0	2x2	2x2	0x0	2x1	2x1	0x0	2x2	2x2	0x0	2x2	2x2	0x0	2x2	2x2	0x0	2x1	2x1	0x0
SI4	2x2	2x2	0x0	2x2	2x2	0x0	2x1	2x1	0x0	2x2	2x2	0x0	2x2	2x2	0x0	2x2	2x2	0x0	2x1	2x1	0x0
SI5	2x2	2x2	0x0	2x2	2x2	0x0	2x1	2x1	0x0	2x2	2x2	0x0	2x2	2x2	0x0	2x2	2x2	0x0	0x0	0x0	0x0
SI6	2x2	2x2	0x0	2x2	2x2	0x0	2x1	2x1	0x0	2x2	2x2	0x0	2x2	2x2	0x0	2x2	2x2	0x0	2x1	2x1	0x0
SI7	3x3	3x3	3x2	3x3	3x3	3x2	3x3	3x3	3x2	3x3	3x3	3x2	3x3	3x3	3x2	3x3	3x3	3x2	3x3	3x3	3x2
SI8	3x3	3x3	3x2	3x3	3x3	3x2	3x3	3x3	3x2	3x3	3x3	3x2	3x3	3x3	3x2	3x3	3x3	3x2	3x3	3x3	3x2
SI9	2x1	2x1	0x0	2x1	2x1	0x0	2x1	2x1	0x0	2x1	2x1	0x0	2x1	2x1	0x0	2x1	2x1	0x0	2x1	2x1	0x0
Nutrient inputs (NI):																					
NI1	3x2	3x2	1x1	3x2	3x2	1x1	3x2	3x2	1x1	3x2	3x2	1x1	3x2	3x2	1x1	3x2	3x2	1x1	3x2	3x2	1x1
NI2	3x2	3x2	1x1	3x2	3x2	1x1	3x2	3x2	1x1	3x2	3x2	1x1	3x2	3x2	1x1	3x2	3x2	1x1	3x2	3x2	1x1
NI3	3x2	3x2	1x1	3x2	3x2	1x1	3x2	3x2	1x1	3x2	3x2	1x1	3x2	3x2	1x1	3x2	3x2	1x1	3x2	3x2	1x1
NI4	1x1	1x1	0x0	1x1	1x1	0x0	1x1	1x1	0x0	1x1	1x1	0x0	1x1	1x1	0x0	1x1	1x1	0x0	1x1	1x1	0x0
NI5	1x2	1x2	1x2	2x2	2x2	2x2	1x1	1x1	1x1	2x2	2x2	2x2	2x2	2x2	2x2	1x1	1x1	1x1	1x1	1x1	1x1
Miscellaneous contaminant inputs (MCI):																					
MCI1	1x2	1x2	0x0	1x2	1x2	0x0	1x2	1x2	0x0	1x2	1x2	0x0	1x2	1x2	0x0	1x2	1x2	0x0	1x2	1x2	0x0
MCI2	1x2	1x2	0x0	1x2	1x2	0x0	1x2	1x2	0x0	1x2	1x2	0x0	1x2	1x2	0x0	1x2	1x2	0x0	1x2	1x2	0x0
MCI3	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
MCI4	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
MCI5	1x2	1x2	1x2	2x2	2x2	2x2	0x0	0x0	0x0	2x2	2x2	2x2	2x2	2x2	2x2	1x1	1x1	1x1	1x1	1x1	1x1
MCI6	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
MCI7	?	?	?	?	?	?	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	?	?	?	0x0	0x0	0x0

Table C3.21. *Extent and intensity estimates used to derive a measure of the scale of stream impacts caused by operational activities/installations at the Holsworthy Option A site. Activity/installation codes are given in Table C3.13.*

Activity/ Install.	Harris Ck & tribs			Williams Ck & tribs			Deadmans Ck & tribs			Lyretail Ck & tribs			Wappa Ck & tribs			Kalibucca Ck & tribs			Punchbowl Ck & tribs			Georges R. Ck & tribs			Surrounding streams		
	S	M	L	S	M	L	S	M	L	S	M	L	S	M	L	S	M	L	S	M	L	S	M	L	S	M	L
Habitat destruction/removal (HDR):																											
HDR1	1x4	1x4	1x4	1x4	1x4	1x4	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	1x4	1x4	1x4	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
HDR2	2x4	2x4	2x4	3x4	3x4	3x4	1x4	1x4	1x4	2x4	2x4	2x4	1x4	1x4	1x4	1x4	1x4	1x4	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
HDR3	2x4	2x4	2x4	3x4	3x4	3x4	1x4	1x4	1x4	1x4	1x4	1x4	1x4	1x4	1x4	1x4	1x4	1x4	1x4	1x4	1x4	0x0	0x0	0x0	0x0	0x0	0x0
Habitat degrading processes (HDP):																											
HDP1	1x1	1x1	1x1	1x2	1x2	1x2	1x2	1x2	1x2	1x2	1x2	1x2	1x2	1x2	1x2	1x2	1x2	1x2	1x2	1x2	1x2	0x0	0x0	0x0	0x0	0x0	0x0
HDP2	0x0	0x0	0x0	0x0	0x0	0x0	1x1	1x1	1x1	2x2	2x2	2x2	2x2	2x2	2x2	0x0	0x0	0x0	1x1	1x1	1x1	0x0	0x0	0x0	0x0	0x0	0x0
HDP3	1x1	1x1	1x1	2x2	2x2	2x2	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	1x1	1x1	1x1	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
HDP4	1x1	1x1	1x1	2x2	2x2	2x2	0x0	0x0	0x0	2x2	2x2	2x2	2x2	2x2	2x2	1x1	1x1	1x1	1x1	1x1	1x1	0x0	0x0	0x0	0x0	0x0	0x0
Sediment inputs (SI):																											
SI1	2x1	2x1	2x1	2x1	2x1	2x1	2x1	2x1	2x1	2x1	2x1	2x1	2x1	2x1	2x1	2x1	2x1	2x1	2x1	2x1	2x1	0x0	0x0	0x0	0x0	0x0	0x0
Nutrient inputs (NI):																											
NI1	2x1	2x1	2x1	2x1	2x1	2x1	2x1	2x1	2x1	2x1	2x1	2x1	2x1	2x1	2x1	2x1	2x1	2x1	2x1	2x1	2x1	0x0	0x0	0x0	0x0	0x0	0x0
NI2	2x2	2x2	2x2	2x2	2x2	2x2	2x2	2x2	2x2	2x2	2x2	2x2	2x2	2x2	2x2	2x2	2x2	2x2	2x2	2x2	2x2	0x0	0x0	0x0	0x0	0x0	0x0
NI3	1x2	1x2	1x2	2x2	2x2	2x2	1x1	1x1	1x1	2x2	2x2	2x2	2x2	2x2	2x2	1x1	1x1	1x1	1x1	1x1	1x1	0x0	0x0	0x0	0x0	0x0	0x0
NI4	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	3x3	3x3	3x3	0x0	0x0	0x0
NI5	?	?	?	?	?	?	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	?	?	?	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
NI6	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Biological contaminant inputs (BCI):																											
BCI1	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	3x1	3x1	3x1	0x0	0x0	0x0
Miscellaneous contaminant inputs (MCI):																											
MCI1	?	?	?	?	?	?	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	?	?	?	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
MCI2	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	0x0	0x0	0x0	0x0	0x0	0x0
MCI3	1x2	1x2	1x2	2x2	2x2	2x2	0x0	0x0	0x0	2x2	2x2	2x2	2x2	2x2	2x2	1x1	1x1	1x1	1x1	1x1	1x1	0x0	0x0	0x0	0x0	0x0	0x0
MCI4	?	?	?	?	?	?	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	?	?	?	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
MCI5	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
MCI6	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	2x2	2x2	2x2	0x0	0x0	0x0
MCI7	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	0x0	0x0	0x0	0x0	0x0	0x0
MCI8	?	?	?	?	?	?	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	?	?	?	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
MCI9	?	?	?	?	?	?	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	?	?	?	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0

MCI10	?	?	?	?	?	?	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	?	?	?	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
MCI11	?	?	?	?	?	?	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	?	?	?	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
MCI12	?	?	?	?	?	?	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	?	?	?	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
MCI13	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?

Table C3.22. *Extent and intensity estimates used to derive a measure of the scale of stream impacts caused by construction activities at the Holsworthy Option B site. Activity codes are given in Table C3.12.*

Activity	**Punchbowl Ck & tribs**			**Gunya Ck & tribs**			**O'Hares Ck & tribs**			**Woronora Rv (up) tribs**			**Dahlia Ck & tribs**		
	S	M	L	S	M	L	S	M	L	S	M	L	S	M	L
Habitat destruction/removal (HDR):															
HDR1	1x4	1x4	0x0	0x0	0x0	0x0	1x4	1x4	0x0	0x0	0x0	0x0	0x0	0x0	0x0
HDR2	2x4	2x4	2x4	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
HDR3	2x4	2x4	0x0	1x4	1x4	0x0	1x4	1x4	0x0	0x0	0x0	0x0	0x0	0x0	0x0
HDR4	2x4	2x4	0x0	1x4	1x4	0x0	1x4	1x4	0x0	0x0	0x0	0x0	0x0	0x0	0x0
HDR5	3x4	3x4	3x4	0x0	0x0	0x0	2x4	2x4	2x4	0x0	0x0	0x0	0x0	0x0	0x0
HDR6	3x4	3x4	3x4	1x4	1x4	0x0	2x4	2x4	2x4	0x0	0x0	0x0	0x0	0x0	0x0
Habitat degrading processes (HDP):															
HDP1	1x2	1x2	1x2	1x2	1x2	1x2	1x2	1x2	1x2	0x0	0x0	0x0	0x0	0x0	0x0
HDP2	1x2	1x2	1x2	0x0	0x0	0x0	1x2	1x2	1x2	0x0	0x0	0x0	0x0	0x0	0x0
HDP3	2x2	2x2	2x3	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
HDP4	2x2	2x2	2x2	1x1	1x1	1x1	1x1	1x1	1x1	0x0	0x0	0x0	0x0	0x0	0x0
Sediment inputs (SI):															
SI1	2x2	2x2	0x0	0x0	0x0	0x0	2x2	2x2	0x0	0x0	0x0	0x0	0x0	0x0	0x0
SI2	2x2	2x2	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
SI3	2x2	2x2	0x0	2x1	2x1	0x0	2x2	2x2	0x0	0x0	0x0	0x0	0x0	0x0	0x0
SI4	2x2	2x2	0x0	2x1	2x1	0x0	2x2	2x2	0x0	0x0	0x0	0x0	0x0	0x0	0x0
SI5	2x2	2x2	0x0	0x0	0x0	0x0	2x2	2x2	0x0	0x0	0x0	0x0	0x0	0x0	0x0
SI6	2x2	2x2	0x0	2x1	2x1	0x0	2x2	2x2	0x0	0x0	0x0	0x0	0x0	0x0	0x0
SI7	3x3	3x3	3x2	3x2	3x2	3x1	3x3	3x3	3x2	2x2	2x2	1x1	3x2	3x2	1x1
SI8	3x3	3x3	3x2	3x2	3x2	3x1	3x3	3x3	3x2	2x2	2x2	1x1	3x2	3x2	1x1
SI9	2x1	2x1	0x0	2x1	2x1	0x0	2x1	2x1	0x0	1x1	1x1	0x0	1x1	1x1	0x0
Nutrient inputs (NI):															
NI1	3x3	3x3	2x2	3x2	3x2	1x1	3x2	3x2	1x1	2x1	2x1	1x1	2x1	2x1	1x1
NI2	3x3	3x3	2x2	3x2	3x2	1x1	3x2	3x2	1x1	2x1	2x1	1x1	2x1	2x1	1x1
NI3	3x3	3x3	2x2	3x2	3x2	1x1	3x2	3x2	1x1	2x1	2x1	1x1	2x1	2x1	1x1
NI4	1x1	1x1	0x0	1x1	1x1	0x0	1x1	1x1	0x0	1x1	1x1	0x0	1x1	1x1	0x0
NI5	2x3	2x3	2x3	0x0	0x0	0x0	2x2	2x2	2x2	0x0	0x0	0x0	0x0	0x0	0x0
Miscellaneous contaminant inputs (MCI):															
MCI1	1x2	1x2	0x0	1x2	1x2	0x0	1x2	1x2	0x0	1x1	1x1	0x0	1x1	1x1	0x0
MCI2	1x2	1x2	0x0	1x2	1x2	0x0	1x2	1x2	0x0	0x0	0x0	0x0	0x0	0x0	0x0
MCI3	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
MCI4	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
MCI5	2x3	2x3	2x3	0x0	0x0	0x0	2x2	2x2	2x2	0x0	0x0	0x0	0x0	0x0	0x0
MCI6	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
MCI7	?	?	?	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0

Table C3.23. *Extent and intensity estimates used to derive a measure of the scale of stream impacts caused by operational activities/installations at the Holsworthy Option B site. Activity/installation codes are given in Table C3.13.*

Activity/ install.	Punchbowl Ck & tribs			Gunya Ck & tribs			O'Hares Ck & tribs			Woronora R (up) & tribs			Dahlia Ck & tribs			Georges R & tribs			Surrounding Streams		
	S	M	L	S	M	L	S	M	L	S	M	L	S	M	L	S	M	L	S	M	L
Habitat destruction/removal (HDR):																					
HDR1	2x4	2x4	2x4	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
HDR2	3x4	3x4	3x4	0x0	0x0	0x0	2x4	2x4	2x4	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
HDR3	3x4	3x4	3x4	0x0	0x0	0x0	2x4	2x4	2x4	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
Habitat degrading processes (HDP):																					
HDP1	1x2	1x2	1x2	1x2	1x2	1x2	1x2	1x2	1x2	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
HDP2	1x2	1x2	1x2	0x0	0x0	0x0	1x2	1x2	1x2	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
HDP3	2x2	2x2	2x3	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
HDP4	2x2	2x2	2x2	1x1	1x1	1x1	1x1	1x1	1x1	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
Sediment inputs (SI):																					
SI1	2x1	2x1	2x1	2x1	2x1	2x1	2x1	2x1	2x1	2x1	2x1	2x1	2x1	2x1	2x1	0x0	0x0	0x0	0x0	0x0	0x0
Nutrient inputs (NI):																					
NI1	2x1	2x1	2x1	2x1	2x1	2x1	2x1	2x1	2x1	2x1	2x1	2x1	2x1	2x1	2x1	0x0	0x0	0x0	0x0	0x0	0x0
NI2	2x2	2x2	2x2	2x2	2x2	2x2	2x2	2x2	2x2	2x2	2x2	2x2	2x2	2x2	2x2	0x0	0x0	0x0	0x0	0x0	0x0
NI3	2x3	2x3	2x3	0x0	0x0	0x0	2x2	2x2	2x2	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
NI4	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	3x3	3x3	3x3	0x0	0x0	0x0
NI5	?	?	?	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
NI6	?	?	?	?	?	?	?	?	?	?	?	?	??		?	?	?	?	?	?	?
Biological contaminant inputs (BCI):																					
BCI1	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	3x1	3x1	3x1	0x0	0x0	0x0
Miscellaneous contaminant inputs (MCI):																					
MCI1	?	?	?	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
MCI2	?	?	?	?	?	?	?	?	?	?	?	?	??		?	0x0	0x0	0x0	0x0	0x0	0x0
MCI3	2x3	2x3	2x3	0x0	0x0	0x0	2x2	2x2	2x2	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
MCI4	?	?	?	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
MCI5	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
MCI6	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	2x2	2x2	2x2	0x0	0x0	0x0
MCI7	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	0x0	0x0	0x0	0x0	0x0	0x0
MCI8	?	?	?	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0

MCI9	?	?	?	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
MCI10	?	?	?	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
MCI11	?	?	?	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
MCI12	?	?	?	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0	0x0
MCI13	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?

2. ATTACHMENT 1

ATTACHMENT 1

*** DR K.A. BISHOP *** FRESHWATER BIOLOGY CONSULTANT ** SPECIALISING IN BIOLOGICAL MONITORING AND FISH ECOLOGY ***

Dr Keith Bishop
Sugar Creek Rd.
Bungwahl 2423
(Tele/fax: 049 976193)
My ref: CONSULTX/AIRPORT
/RECFISH.LET

TO:

FAX: (pages only)

RE: SECOND SYDNEY AIRPORT: FRESHWATER FISH

Dear Mr ,

As discussed over the telephone, I have been commissioned by BIOSIS RESEARCH to undertake a study of freshwater fish in the Badgerys Creek and Holsworthy areas. This is part of a process of preparing an Environmental Impact Statement (EIS) to assess possible options for Sydney's Second Airport.

An important component of my work is to assess the impact on the existing recreational fisheries in the vicinity of the proposed airport sites. This is why I have made contact - to obtain your perceptions of the relative value of the freshwater fisheries in these areas:

- Holsworthy site (Figure 1)
  - Georges River from Liverpool to in line with Campbelltown
  - Georges River from ~Campbelltown to headwaters (~Appin)
  - tributary of Georges R.: Punchbowl Creek and tribs
  - tributary of Georges R.: O'Hares Creek and tribs
  - tributary of Georges R. estuary: Harris Creek
  - tributary of Georges R. estuary: Williams Creek
  - tributary of Georges R. estuary: Deadmans Creek
  - Woronora River and tributaries from dam to tidal limit
  - Woronora Res. and River upstream from dam

- Badgerys Creek site (Figure 2)
  - South Creek from St Marys downstream to Windsor
  - South Ck. from St Marys upstream to headwaters (~Narellan)
  - tributary of South Ck.: Badgerys Creek
  - tributary of South Ck.: Cosgroves Creek
  - tributary of South Ck.: Thompsons Creek
  - Nepean River tributary: Duncans Creek

ATTACHMENT 1 cont.

Accordingly, for each of the areas listed in the attached form, could you please provide me with indications of the following:

- Quality of fishery: e.g. "excellent, good, reasonable, poor"
- Likely fish catch & species: e.g. "generally 2 bass per hour"
- Member usage on a weekend or holiday: e.g. "averages 2 per day"
- Member usage on week days: e.g. "averages 1 per week (5 days)"
- Number of fisherman seen on weekend or holiday: e.g. as above
- Number of fishermen seen on week days: e.g. as above
- Difficulties: e.g. accessibility (e.g. gorge country, prohibited access, fishing not allowed)

I am interested mostly in your perceptions, not necessarily highly accurate data. In situation where you have great uncertainty, simply please put a dash, or "haven't been there", or "too hard", etc.

For your information, please find enclosed a copy of the summary from my Picton STW EIS report. I thank you for the valuable information your group provided on that job.

Yours sincerely,

K.A. Bishop

APPENDIX 1 cont.

SURVEY OF RECREATIONAL FISHING INTEREST IN STREAMS OF THE GEORGES/WORONORA CATCHMENTS: page 1

CLUB NAME OR FISHERMAN'S NAME:

CONTACT ADDRESS:

CONTACT TELEPHONE NUMBER(S):

NUMBER OF CLUB MEMBERS (if appropriate):

Georges River from Liverpool to in line with Campbelltown

- Quality of fishery:
- Likely fish catch and species:

- Member usage on a weekend or holiday:
- Member usage on week days:
- Number of fisherman seen on weekend/holiday:
- Number of fishermen seen on week days:
- Difficulties:

Georges River from ~Campbelltown to headwaters (~Appin)

- Quality of fishery:
- Likely fish catch and species:

- Member usage on a weekend or holiday:
- Member usage on week days:
- Number of fisherman seen on weekend/holiday:
- Number of fishermen seen on week days:
- Difficulties:

Tributary of Georges R.: Punchbowl Creek and tribs

- Quality of fishery:
- Likely fish catch and species:

- Member usage on a weekend or holiday:
- Member usage on week days:
- Number of fisherman seen on weekend/holiday:
- Number of fishermen seen on week days:
- Difficulties:

Tributary of Georges R.: O'Hares Creek and tribs

- Quality of fishery:
- Likely fish catch and species:

- Member usage on a weekend or holiday:
- Member usage on week days:
- Number of fisherman seen on weekend/holiday:
- Number of fishermen seen on week days:
- Difficulties:

APPENDIX 1 cont.

SURVEY OF RECREATIONAL FISHING INTEREST IN STREAMS OF THE GEORGES/WORONORA CATCHMENTS: page 2

CLUB NAME OR FISHERMAN'S NAME:

Tributary of Georges R. estuary: Harris Creek

- Quality of fishery:
- Likely fish catch and species:

- Member usage on a weekend or holiday:
- Member usage on week days:
- Number of fisherman seen on weekend/holiday:
- Number of fishermen seen on week days:
- Difficulties:

Tributary of Georges R. estuary: Williams Creek

- Quality of fishery:
- Likely fish catch and species:

- Member usage on a weekend or holiday:
- Member usage on week days:
- Number of fisherman seen on weekend/holiday:
- Number of fishermen seen on week days:
- Difficulties:

Tributary of Georges R. estuary: Deadmans Creek

- Quality of fishery:
- Likely fish catch and species:

- Member usage on a weekend or holiday:
- Member usage on week days:
- Number of fisherman seen on weekend/holiday:
- Number of fishermen seen on week days:
- Difficulties:

Woronora River and tributaries from dam to tidal limit

- Quality of fishery:
- Likely fish catch and species:

- Member usage on a weekend or holiday:
- Member usage on week days:
- Number of fisherman seen on weekend/holiday:
- Number of fishermen seen on week days:
- Difficulties:

cont/-

APPENDIX 1 cont.

SURVEY OF RECREATIONAL FISHING INTEREST IN STREAMS OF THE GEORGES/WORONORA CATCHMENTS: page 3

CLUB NAME OR FISHERMAN'S NAME:

Woronora Res. and River upstream from dam

*Quality of fishery:
*Likely fish catch and species:

*Member usage on a weekend or holiday:
*Member usage on week days:
*Number of fisherman seen on weekend/holiday:
*Number of fishermen seen on week days:
*Difficulties:

General comments:

APPENDIX 1 cont.

SURVEY OF RECREATIONAL FISHING INTEREST IN SELECTED STREAMS OF SOUTH CREEK and NEPEAN RIVER CATCHMENTS: page 1

CLUB NAME OR FISHERMAN'S NAME:

CONTACT ADDRESS:

CONTACT TELEPHONE NUMBER(S):

NUMBER OF CLUB MEMBERS (if appropriate):

South Creek from St Marys downstream to Windsor

- Quality of fishery:
- Likely fish catch and species:

- Member usage on a weekend or holiday:
- Member usage on week days:
- Number of fisherman seen on weekend/holiday:
- Number of fishermen seen on week days:
- Difficulties:

South Ck. from St Marys upstream to headwaters (~Narellan)

- Quality of fishery:
- Likely fish catch and species:

- Member usage on a weekend or holiday:
- Member usage on week days:
- Number of fisherman seen on weekend/holiday:
- Number of fishermen seen on week days:
- Difficulties:

Tributary of South Ck.: Badgerys Creek

- Quality of fishery:
- Likely fish catch and species:

- Member usage on a weekend or holiday:
- Member usage on week days:
- Number of fisherman seen on weekend/holiday:
- Number of fishermen seen on week days:
- Difficulties:

Tributary of South Ck.: Cosgroves Creek

- Quality of fishery:
- Likely fish catch and species:

- Member usage on a weekend or holiday:
- Member usage on week days:
- Number of fisherman seen on weekend/holiday:
- Number of fishermen seen on week days:
- Difficulties:

APPENDIX 1 cont.

SURVEY OF RECREATIONAL FISHING INTEREST IN SELECTED STREAMS OF SOUTH CREEK and NEPEAN RIVER CATCHMENTS: page 2

CLUB NAME OR FISHERMAN'S NAME:

Tributary of South Ck.: Thompsons Creek

- Quality of fishery:
- Likely fish catch and species:

- Member usage on a weekend or holiday:
- Member usage on week days:
- Number of fisherman seen on weekend/holiday:
- Number of fishermen seen on week days:
- Difficulties:

Nepean River tributary: Duncans Creek

- Quality of fishery:
- Likely fish catch and species:

- Member usage on a weekend or holiday:
- Member usage on week days:
- Number of fisherman seen on weekend/holiday:
- Number of fishermen seen on week days:
- Difficulties:

General comments:

Table 1. Fishing clubs' member usage in and around the Badgerys Creek site.

Fishing Club	Stream					
	B1	B2	B3	B4	B5	B6
Emmaus College Fishing Club						
Weekend/ Holiday	up to 20	up to 10	up to 8	0	0	0
Week day	2	1	1	0	0	0
Campbelltown City Sportfishing Club						
Weekend/ Holiday	0	0	0	0	0	1
Weekday	0	0	0	0	0	0

Key to Streams

B1 = South Creek from St Marys downstream to Richmond

B2 = South Creek from St Marys upstream to headwaters

B3 = tributary of South Creek: Badgerys Creek

B4 = tributary of South Creek: Cosgroves Creek

B5 = tributary of South Creek: Thompsons Creek

B6 = Nepean River tributary: Duncans Creek

Table 2. Fishing clubs' member usage in and around the Holsworthy site.

Fishing Club	Stream								
	H1	H2	H3	H4	H5	H6	H7	H8	H9
Campbelltown City Sportfishing Club									
Weekend/holiday	2	1	0	0	0	0	2	1	0
Week day	1	0	0	0	0	0	0	0	0

Key to Streams

H1 = Georges River from Liverpool to in line with Campbelltown

H2 = Georges River from ~Campbelltown to headwaters (around Appin)

H3 = tributary of Georges River: Punchbowl Creek and tributaries

H4 = tributary of Georges River: O'Hares Creek and tributaries

H5 = tributary of Georges River estuary: Harris Creek

H6 = tributary of Georges River estuary: Williams Creek

H7 = tributary of Georges River estuary: Deadmans Creek

H8 = Woronora River and tributaries from dam to tidal limit

H9 = Woronora Reservoir and River upstream from the dam

Table 3. Fishing clubs' estimates of the number of fishers typically observed in and around the Badgerys Creek site.

Fishing Club	Stream					
	B1	B2	B3	B4	B5	B6
Emmaus College Fishing Club						
Weekend/ Holiday	4-5	2-3	1-2	?	?	?
Weekday	1-2	1-2	0=1	?	?	?
Campbelltown City Sportfishing Club						
Weekend/ Holiday	20	?	?	?	?	2
Weekday	5	?	?	?	?	0

Key to Streams

B1 = South Creek from St Marys downstream to Richmond

B2 = South Creek from St Marys upstream to headwaters

B3 = tributary of South Creek: Badgerys Creek

B4 = tributary of South Creek: Cosgroves Creek

B5 - tributary of South Creek: Thompsons Creek

B6 = Nepean River tributary: Duncans Creek

Table 4. Fishimg clubs' estimates of the number of fishers typically observed in and around the Holsworthy site.

Fishing Club	Stream								
	H1	H2	H3	H4	H5	H6	H7	H8	H9
Campbelltown City Sportfishing Club									
Weekend/ Holiday	100	10	?	2	?	?	20	10	?
Weekday	10	2	?	1	?	?	6	2	?

Key to Streams

H1 = Georges River from Liverpool to in line with Campbelltown

H2 - Georges River from ~Campbelltown to headwaters (around Appin)

H3 = tributary of Georges River. Punchbowl Creek and tributaries

H4 = tributary of Georges River: O'Hares Creek and tributaries

H5 = tributary of Georges River estuary: Harris Creek

H6 = tributary of Georges River estuary: Williams Creek

H7 = tributary of Georges River estuary: Deadmans Creek

H8 = Woronora River and tributaries from dam to tidal limit

H9 = Woronora Reservoir and River upstream from the dam

Table 5 Fishing club members' typical catch in and around the Badgerys Creek site.

Fishing Club	Stream					
	B1	B2	B3	B4	B5	B6
Emmaus College Fishing Club	Bass 4-5/outing Mullet 8/hr Herring 10/hr Carp 2/hr Eels 3/hr	Bass 1-2/outing Carp 8/hr Mullet 5/hr Herring 4/hr Eels 5/hr	Carp 8/hr Eels 8/hr Bass occas Mullet occas	?	?	?
Campbelltown City Sport Fishing Club	Eels Carp	?	?	?	?	Bass Eels

Key to Streams

B1 = South Creek from St Marys downstream to Richmond

B2 = South Creek from St Marys upstream to headwaters

B3 = tributary of South Creek: Badgerys Creek

B4 = tributary of South Creek: Cosgroves Creek

B5 = tributary of South Creek: Thompsons Creek

B6 = Nepean River tributary: Duncans Creek

Table 6. Fishing club members' typical catch in and around the Holsworthy site

Fishing Club	Stream								
	H1	H2	H3	H4	H5	H6	H7	H8	H9
Bass Sydney	Bass Carp I/F Eels Catfish?	Macquarie Perch I/F Eels Bass?	Bass I/F Eels catfish? Carp?	I/F Eels? Bass Macquarie Perch?	/	?	?	I/F Eels Bass Bully Mullet Carp?	?
Campbelltown City Sportfishing Club	Bass Carp Macquarie Perch	Bass Eels Macquarie Perch Spiny Cray	?	Eels Spiny Crays	?	?	Bass Mullet Crabs Sting Rays Bream Flathead	Bass Macquarie Perch	

Key to Streams

H1 = Georges River from Liverpool to in line with Campbelltown

H2 = Georges River from ~Campbelltown to headwaters (around Appin)

H3 – tributary of Georges River: Punchbowl Creek and tributaries

H4 = tributary of Georges River: O'Hares Creek and tributaries

H5 = tributary of Georges River estuary: Harris Creek

H6 = tributary of Georges River estuary: Williams Creek

H7 = tributary of Georges River estuary: Deadmans Creek

H8 = Woronora River and tributaries from dam to tidal limit

H9 = Woronora Reservoir and River upstream from the dam

Table 7. Major mechanisms by which increased levels of (inert) suspended solids, settling of these solids and increased bedload could lead to harmful effects on stream biota.

SUSPENDED SOLIDS - Direct impacts

Creek plants:

Mechanism SSD1: reductions in primary production caused by damage to plant tissues as a result of leaf abrasion following exposure to high concentrations of suspended solids in flowing waters.

Severe leaf damage caused by abrasion by suspended solids to a freshwater moss was observed at 500 mg/l after one week and at 100 mg/l after three weeks (Lewis [1973] in Alabaster and Lloyd [1982]).

Macroinvertebrates:

Mechanism SSD2: reductions in invertebrate production caused by direct impacts as a result of high concentrations of suspended solids.

Suspended solids may be expected to have its greatest effect on filter feeding invertebrates. In streams high concentrations of particles may clog nets and damage filtering mechanisms by which these organisms feed (Campbell and Doeg 1989). Densities of filter- feeding invertebrates are often reduced in streams receiving high concentrations of suspended solids (e.g. Gammon [1970], Nuttall and Bielby 1973, Mayack and Waterhouse [1983]; all in Campbell and Doeg [1989]).

Fish:

Mechanism SSD3: Exposure of fish to high levels of suspended solids causing physiological stress through, for example, damage to gill tissue. Death, reduced growth rates or increased susceptibility to disease may result.

Following an extensive literature survey on the subject, Alabaster and Lloyd (1982) stated that suspended solids concentrations from 200 to several thousand mg/l have been the minimum levels which have caused deaths among fish exposed for several weeks or months. The only information on Australian freshwater fishes (Koehn et al. [1991], Koehn pers. comm.) indicates that concentrations as low as 600 mg/l caused deaths for the three species studied. These differences are probably partially due to the fact that not all species of fish are equally resistant.

Reduced growth rates in trout have been shown to occur in 50 mg/l of suspended solids an exposure of several months (Herbert and Richards [1963] in Alabaster and Lloyd [1982]). In terms of resistance to disease, these authors found that 100 mg/l suspended solids was the lowest concentration at which trout showed symptoms of fin-rot after 8 months exposure. Reduced growth rates of eastern freshwater cod (*Maccullochella ikea*) have been recorded in hatchery ponds in which the turbidity was much higher than in the cod's riverine environment (S. J. Rowland pers. comm.).

SUSPENDED SOLIDS - Indirect impacts:

Creek plants

Mechanism SSI1: reductions in primary production (i.e. plant growth) caused by reduced photosynthesis as a result of reduced light penetration following high concentrations of suspended solids. In the long term this has flow-on effects to invertebrate production.

Table 7 (cont'd)

Normally rich lakes have been rendered unproductive by (long-term) turbidity problems because photosynthesis is reduced drastically (Ryder 1978). Light penetration and hence photosynthesis is frequently temporarily halted during floods where concentrations of suspended solids are elevated (e.g. Schmitz [1961] in Hynes [1970]). Photosynthesis plays only a minor role in primary production in lotic environments (i.e. streams vs lakes) because foodchains are primarily based on detrital material arising from terrestrial environments (Odum 1971).

Fish

Mechanism SSI2: exposure of fish to high levels of suspended solids causing behavioural changes which may be important in, for example, reproduction, feeding, migration or the establishment of territories. Reduced growth rates or reproductive success may result.

Where given a choice, fish have been observed to avoid turbid waters resulting in the loss of use of lengths of river. Alabaster and Lloyd (1982) cite a number of studies in which fish have been observed avoiding turbid tributaries.

Bachmann (1958; in Alabaster and Lloyd [1982]) observed trout subjected to 35 mg/l suspended solids concentration were unharmed but sought cover and stopped feeding.

SUSPENDED SOLIDS - SETTLING (- direct impacts)

Fish

Mechanism SSSD1: Smothering eggs or larvae with a layer of silt (particularly those within the interstitial space of substrates) causing increased mortality by, for example, physiological stress due to reduced oxygen availability. Reproductive success is reduced by increased mortality of eggs or larvae.

Alabaster and Lloyd (1982) indicate spawning grounds of some fish species are very vulnerable to finely divided solids. Concentrations of suspended solids lower than 25 mg/l resulting in the deposition of a fine layer sediment may prevent the successful development of deposited eggs.

SUSPENDED SOLIDS - SETTLING (- indirect impacts)

Macroinvertebrates

Mechanism SSSI1: reductions in invertebrate production caused by indirect impacts such as, for example, habitat change as a result of hard substrates or organic matter (as food) being smothered, and/or interstitial spaces being filled by deposited silt.

The deposition of silt or sand on and in stony substrates has been shown to reduce the abundance and emergence of mayflies, caddis-flies and stoneflies, even when deposits remain for only part of the year (Hynes 1970). Research in the Mitta Mitta River (Blyth [1980] and Blyth et al. [1984]; both in Blyth and Jackson [1985]) and the Thompson River (Davey et al. [1982] in Blyth and Jackson [1985]) has shown that even where total blanketing of the bed doesn't occur, alteration of the bed structure by deep penetration of fine material, and by coating of solid surfaces with slit/algal mats, can reduce invertebrate species richness and biomass by 50% or more.

Platts and Magahan (1975; in Blyth and Jackson [1985]) examined the recovery of a sediment polluted stream in Idaho, USA. Restoration of streambed particle composition to pre-pollution levels took at least nine years after cessation of activities which generated the sediment. While surface sediment may be quickly flushed by ensuing spates, major floods are probably necessary to flush out fine sediment trapped deep within the streambed (Campbell and Doeg 1989).

Table 7 (cont'd)

It is now known that large populations of invertebrates live deep within the streambed (Hynes, Williams and Williams [1976], Pugsley and Hynes [1983]; both in Blyth and Jackson [1985]). It is possible that filling spaces in the river bed may have a critical effect upon seasonal movement and life-cycle patterns, so that long-term reductions in diversity and abundance of streambed fauna results (Blyth and Jackson 1985).

In a study of the impacts of forestry operations on the benthic invertebrates in a coastal stream in southern NSW, Richardson (1985) showed that the composition of these communities was altered up to 7 km downstream of these operations for at least 9 months after associated siltation and elevated turbidity first occurred.

Hogg and Norris (1991) have documented reductions in species richness and densities of macroinvertebrate fauna as a result of the settling of sediments on pool substrates. The sediments were inputted from cleared land adjacent to the river studied.

Mechanism SSSD2: The presence of deposited silt causing fish to avoid areas which may be important, for example, in breeding or feeding. Trout have been observed to not spawn in gravel beds choked with silt, even when surface silt is cleared (Stuart [1953] in Alabaster and Lloyd [1982]). Courtship displays of fishes could readily be thwarted if underwater visibility is significantly reduced.

BEDLOAD - Direct impacts

Creek plants

Mechanism BLD1: the elimination of freshwater plants by the smothering or abrasive effect of excessive bedload.

BEDLOAD - Indirect impacts

Macroinvertebrates

Mechanism BLI1: habitat change through increased bedload (sand-gravel fraction) which reduces sheltering habitat.

Hynes (1970) indicates that in general the larger the stones, and hence the more complex the substratum, the more diverse is the invertebrate fauna. Accordingly, increases in the sand-gravel component in the bedload will fill spaces between larger stones and hence reduce the diversity of the invertebrate fauna.

Fish

Mechanism BLI2: habitat change through increased bedload which results in the loss of sheltering habitat and migration routes.

For adult fish, sheltering habitat may be in the form of deep pools, space under submerged timber or undercut banks, all of which could be reduced with increased bedload. Larval and juvenile fish, and small species in general, may use the interstitial space in rock/cobble substrates which may be reduced with increased bedload (sand-gravel fraction).

Excessive bedload, or sedimentation, is usually the major damage to the freshwater environment in Australia (Koehn and O'Conner 1990). Large changes in the distribution of North American fishes have been documented due to such impacts (Gerking [1945] and Lachner [1956]; both in Hynes [1970]).

Passage along creeks and rivers may be reduced by excessive bedload in situations where water percolates through the deposited sediments rather than flowing over the surface.

Table 7 (cont'd)

IMPORTANT NOTE CONCERNING TROPHIC RELATIONSHIPS

Mechanisms affecting the freshwater invertebrates will in turn impact the fish because the invertebrates are a major food item for the fish.

Table 8. *Possible mechanisms by which the release of sewage effluents can impact freshwater fish and recreational fisheries. (Note that this table provides a generalised checklist of mechanisms which need to be considered when assessing impacts - only some of these may be applicable.)*

D = direct impacts; I = indirect impacts.

Nutrients (N):

N-I1: nutrient enrichment causing major growth of microalgae; the presence of the algae in the water may result in physical abrasion of fish gills, stress or mortality results; stressed fish are more susceptible to disease

N-I2: nutrient enrichment causing major growth of microalgae; breakdown products of the algae may be directly toxic to fish, causing stress or mortality; stressed fish are more susceptible to disease

N-I3: nutrient enrichment causing major growth of microalgae; dissolved oxygen (DO) levels may be greatly reduced when the algae die and decay, thus resulting in stress or mortality for fish, stressed fish are more susceptible to disease

N-I4: nutrient enrichment causing major growth of microalgae; reduced light penetration results in the loss of macrophyte beds, which subsequently impacts fish because of the habitat loss, or lowered DO levels when beds decay

N-I5: nutrient enrichment causing major growth of adherent algae on macrophytes; this results in the loss of macrophyte beds, which subsequently impacts fish because of the habitat loss, or lowered DO levels when the beds decay

N-I6: nutrient enrichment causing major growth of adherent algae on substrates; this results in the degradation of physical habitat for substrate-associated fish species

N-I7: nutrient enrichment causing major growth of macrophytes; DO levels may be greatly reduced when macrophytes die and decay, thus resulting in stress or mortalilty for fish; stressed fish are more susceptible to disease

N-I8: nutrient enrichment causing major growth of macrophytes, thus reducing recreational fishers ability to fish waters (e.g. reduced open water for fishing, and/or decreased access caused by vegetation blocking boating routes)

N-I9: Nutrient enrichment creating favourable conditions for micro-organisms (e.g. bacteria), including fish pathogens, which results in an increased occurrence of fish diseases

The above nine mechanisms could be repeated for food organisms. Reductions in the abundance of food organisms could clearly impact fish.

Toxicants (T):

T-D1: the release of toxic substances (e.g. pesticides, metals, chlorine, etc), causing stress or mortality to fish

T-I1: the release of toxic substances (e.g. pesticides, metals, etc), causing stress or mortality to food organisms, which subsequently impacts fish

T-I2: the accumulation of toxic substances in fish tissues may render them unsuitable for consumption by recreational fishers

Table 8 (cont'd)

Miscellaneous substances having chronic effects (M):

M-D1: the release of substances which in the medium to long term have chronic effects on fish (e.g. the release of breakdown products of plastics which may lead to alterations in oestrogen activity leading to sterility)

M-I1: the release of substances which in the medium to long term have chronic effects on food organisms which subsequently impacts fish

Oils/greases (O):

O-D1: coating of fish tissues, particularly gills, causing stress or mortality to fish; stressed fish are more susceptible to disease

O-I1: coating of food-organism's tissues, particularly gills, causing stress or mortality to the organisms, which subsequently impacts fish

O-I2: production of surface films on water which reduces air-to-water oxygen exchange; lowered DO levels cause stress or mortality to fish; stressed fish are more susceptible to disease

O-I3: production of surface films which reduces air-to-water oxygen exchange; lowered DO levels cause stress or mortality to food organisms, which subsequently impacts fish

O-I4: production of surface films on substrates which degrades physical habitat and impacts substrate-associated fish

O-I5: production of surface films on substrates which degrades physical habitat and impacts substrate-dwelling food organisms, which subsequently impacts fish

Pathogens (P):

P-D1: the release of pathogens which can directly affect fish

P-I1: the release of pathogens which activate benign fish pathogens already present in the wild

Appendix D

Floristic Table

HOLSWORTHY

Floristic Classification

```
                                        HOLS 1       HOLS 2                 HOLS 3                       HOLS 4       HOLS 5               HOLS 6     HOLS7
                                        00000000000  000000000000000000000  000000000100000000000000000  00000111000  0000000000000000000  000000000  00000
                                        19991129178  218609110407570678780  755444334088990616152533233  53443000455  3342026560646797772  888968965  21202
                                        27865649851  198542303872662732435  020947313007316079197726378  84159132631  0529868429401109788  456439565  04512

2440    Eucalyptus fibrosa              + 3+++13312   +
1447    Daviesia ulicifolia             +  + + +++
2419    Eucalyptus crebra               1+ 2 2 2 23    +
3325    Microlaena stipoides             + 2  ++ 11                                                                                     +     +       ++ +
1       Brunoniella australis           111 ++++2+   11                 +
1479    Glycine tabacina                1+   12 1+    1+                                                                                                +
3005    Bursaria spinosa                2+ 1+ ++ 2         +                                                              +                      +
4180    Cheilanthes sieberi             +1111  11    + +   + 1                                                                  +
1492    Hardenbergia violacea             +++2+++    +++      1                                                       ++++    +++ ++ +  +          +
3211    Dichelachne micrantha            ++    ++ 1  +    + +     +                                                           +               +
2443    Eucalyptus globoidea                + 2 + 2  21 1
3081    Aristida vagans                 +111+++11+1  ++ 31 +21  +1   +  +                                                     + +
3357    Panicum simile                  +  ++ +  ++  +  2+           +                 +                                      +     +
1476    Glycine clandestina             +1112  1+ +  ++ +++++ +   +                                                       +   +                       +
2085    Lomandra multiflora             +1  2 11+++  +1 + +++ 2++   ++  +   + +                 +   1                     +++ + ++      +
2982    Dianella revoluta               + ++2 1+1++  12+2+++1++  1  +1 +++                                               ++   +++ ++
3483    Themeda australis               233+3331222  231+232+3133112  111              +                                              ++                2
1718    Goodenia hederacea                  + 1+1 +  11  2+++++   +   +++                                                 +     +     +
2332    Angophora bakeri                    + + + 1   +1  11 2  1 1    1                                                            + 1 1
3718    Persoonia linearis                + +   + +  ++ +++ +     + ++++++     +  +                                    ++1+ + +++ ++          +    +   +
2504    Eucalyptus punctata                       1  2111 2+1   1+3 +2222+                                                  + +    + 1 2        1      +
97      Laxmannia gracilis                +    +  +  ++    + +                +
4073    Exocarpos strictus                           ++ 1++ +                  +                                           +       2
889     Hypericum gramineum                  +    +  ++   ++  +         +                                                             ++
1484    Gompholobium minus                        +  +    +1++  +  +    +1  +                                                   +  +
436     Helichrysum scorpioides           +      +   +    ++1 ++       +
2548    Kunzea ambigua                                 2+ 1            +      +        1 1    2  +                                           1
3260    Eragrostis brownii                             ++ +           1+                                        +
162     Trachymene incisa                              +   1 +    +1                   +
2434    Eucalyptus eugenioides          + ++     2        +           221
1290    Lissanthe strigosa                + + + 1++  111 +++1 + +   1+   1  1 ++  1 +           ++                              +  +
3257    Entolasia stricta                ++ + 211+1  11 31++ 22221  21   2  + 1  1+ + +   21+ ++ 1  +     + 1  + +    ++123111++1 22   +2    ++ +1+   + 2 2
1113    Lepidosperma laterale             1 + 11 +     ++ ++   ++ +     +1   1  +  2 1  + 1 +     + + 1        +      + 1++1+++  1+ ++  2  + + +++1+
2078    Lomandra filiformis                +    2 +  11 12 ++  11+  +  ++1        ++ ++ + 1     +   ++        + +      +++ ++    +11++       +
2081    Lomandra gracilis               21              +     +   +  2 +    + 1          1 ++ +              ++      211+1  1+1+ 11++  1         +
2903    Pterostylis species                 + + 2 +  +   1+ + +322   1 + 1   + 1  2 1  + 12 21 12 23222  222+2                     +
1843    Patersonia sericea                      + +  ++   ++++  1     +  +   + 1 1 +++++1+++1 + 1 11++1   +++ +                      ++
3717    Persoonia levis                         +    +   +    +++ + ++++++  ++++++++++ + +++ + +    +++  + +++        1++ +++++++++11 +++  +   1  +
2594    Leptospermum trinervium                 +1+  ++    ++++++1+++++1 1  2 3212+2+1112+2++2++111121+  +++++1+1     +++  ++ + ++ 11 1 +
1012    Cyathochaeta diandra                     ++  11+  +++1 211 +21 + 1  2122 12++++1 +21++2+2132211  2231 + +          +    ++ 1
1756    Gonocarpus tetragynus             +     + +  ++    ++ +         +      +                    +      + +  +1                   ++ +
4303    Pimelea linifolia                        +   +     ++++ 2 +++ +1++  +  1+1 +++ +  1++1 + ++++ +  ++ ++ +++++   +   +       1   ++              +
162     Platysace ericoides                      +   +     ++ ++    +1      +122+2+ +++   ++ 1+ + ++11     +           + + +     +++   +
4403    Xanthorrhoea resinifera                   +   +  1  ++ ++     +                 1   1   1  + 1   +12++ ++ 2        +
2086    Lomandra obliqua                          +  ++  +++++1+21 +1++++1   +11   ++ ++ +1+ ++112 +2+   +     ++ +   +++2+1+ + + 21 +++1
3671    Hakea dactyloides                              +       +121    1++   + +++++++1 11+1+++++++1++2  +1++ +   +           +  +    1
3680    Hakea sericea                                  ++ +  +1+1+  + + 1   +1++++ +++1 11+ + + 1  +       1          +    + ++1  +     +        1 +
3737    Persoonia pinifolia                            1          +           +  +     +         +  ++    ++          +   1+ +   +   ++ +  +1+  1+ +
2357    Callistemon linearis                           +  + 1  +         +            1  +                 +     +               1
3711    Persoonia lanceolata                           +                       +   + 1+ 1    +  +  +       +   ++                    1 + +
2480    Eucalyptus oblonga                              1    +              11 2+1        1        1+     +                        1
2282    Acacia suaveolens                                +  +    +  ++       1+ + + 1  + +    +    ++      + +    +   +++   +     + 1 +          +
4265    Stylidium graminifolium                           1+   +   +  + +   ++  +  +    +     ++   2     +   2  1+2        + 1
3600    Banksia marginata                                 +           1 1   1+1 +1 2+11 1   1    ++ 2+    + + +++            1 + +      +
3066    Anisopogon avenaceus                              +  1   2            + 1   +  +  12   + +1+++    +   +        +   1            2
2255    Acacia myrtifolia                                 + + +1  ++   1     ++ ++ +++             +          +                       +
4392    Xanthorrhoea concava                +             ++       +     +  +++ 1++     1   +    +             +      21 1     +  1+ +
```

```
3632    Grevillea diffusa                                              1  +     +  ++   +2++ + +1+ 1+  1+11      +    1++    1             ++
3685    Isopogon anemonifolius                                         ++1 ++1++1+++1+  +22++++1+1+++1+11++1 +++++1   + +++               +       ++   +
2506    Eucalyptus racemosa                                            +  2+ +1    12     +2    ++ 21    2    12 + ++1   1 + 1                  +  2 2
154     Platysace linearifolia                                         ++               2112 +2+ +  ++      +  +  1+  +++ ++ + +   2  2 21+++ 2++   1
1296    Monotoca scoparia                                               ++    +++     +  +1++++++1 +  +      +  +  +              +++++      +     +
3663    Grevillea sericea                                               ++  + +                  +  +      11+1  111 1     +      + +   1+
2550    Kunzea capitata                                                 +  ++1     +             1  1+1 +112 1 +  ++                         ++
3745    Petrophile sessilis                                              + + + +1    +  2++++1  2 ++ 111+221+2+21++  +3+++    +    ++      +  ++     +
2006    Cassytha pubescens                                               1+ +2  ++    +  +++++1+1+++ ++++ 1++ + +    + ++ +   ++      + 1 +++ +
3690    Lambertia formosa                                                1   +1+  1 +  1++++++11 +1+11+2++ +1+++1+1  +  +++      ++  ++    1   1 2 +
1267    Leucopogon ericoides                                             +  ++ +                 +         +         +    ++                1
1257    Epacris pulchella                                                 + +       +    1  + +            +          +     1        +         +
4401    Xanthorrhoea media                                                +  ++ 1+      1++11  1+1++  11 ++  +1 2        111 +              + 1      +
2244    Acacia linifolia                                                  1++1  +2 + 1  +1+  +   +1 1+     +  +    +           + +1 ++++  +11  1
1362    Micrantheum ericoides                                              + ++   + ++           ++   +1 ++ +  1    +1                   +    ++ ++
4103    Schizaea bifida                                                    2             + ++ ++         ++++       + + +    +         +1
1574    Pultenaea elliptica                                                1 +  + + +  1++ +++  ++++2 1 + ++111+1  ++2+1              +         + +
1199    Hibbertia serpyllifolia                          +                 +      +        +  ++  +  + +      2  +  +  +                    +
1481    Gompholobium grandiflorum                                   +  + +++   2+ +++ 1 1  +         +1+      + +           +     ++  +1+
1706    Dampiera stricta                                            +  +      +111+1 1+++ +++++++++++ +++   +++1+11++3                + + +
1735    Scaevola ramosissima                                        +   ++ ++  +   ++ +                     +   +        +          +
3991    Eriostemon australasius                                     ++ +1+    21111+++ 1++1  1 ++1 ++ 11+       +         + +  + +++++ +
4267    Stylidium lineare                                +                   +    +         ++ ++ + + + +   11 22   12  121                      +
1412    Bossiaea heterophylla                                         ++      2+++ 1+1+1 ++  ++1 ++             +    +  1+++ +1  +++++  + +
1194    Hibbertia riparia                                              + +    1+  +2 ++  + +++ +    1+ +      2            +
1154    Tricostularia pauciflora                              +        +         +++     +     +  +                     +
1281    Leucopogon microphyllus                                            +   1++ 1+++ + + ++  + 1+11++2  +1++21 1 1                  +
1841    Patersonia glabrata                                                +      +           +  1          +       + ++1+       +   +
4427    Grevillea sphacelata                                                  1+ ++2+1    1  ++1+++ +  11  +                       ++
3630    Grevillea buxifolia                                                      + 1   +  1+         +       +++              +
2065    Mitrasacme polymorpha                                  +          +    +++       +    +                 + + +
2038    Lindsaea linearis                                   +   +  + +              + + ++ +1+ 1+ 1++1+12   +  1 +++
1480    Gompholobium glabratum                                   +  ++          +  + +      +  +  +1+1   1
1553    Phyllota phylicoides                                        + +                 ++  + ++ + + ++11   1
2352    Baeckea ramosissima                                                    +   + +     ++   +++    +      +                    +
2342    Baeckea brevifolia                                                         +  +    +  +      21     +                 ++1
2446    Eucalyptus gummifera                           +         1+  +  1 1 +22 1+   1  +122+21+122 2  +   ++++ 1+      2     ++ ++2 +  2+1 1 2 +
3607    Banksia spinulosa                                        + 1 1 1+222+2+1+11 11  ++1 + + ++11 +2111 +1+  +    +           +++1 ++1+1+ 111 11+
1369    Phyllanthus hirtellus                                  + 1+  1 1+11 +1+ 1+ + +  1 1 + +      +   +    1                  +11 + +++++1    1
2290    Acacia ulicifolia                                    ++   + ++  + +++ + ++ + 1  +   ++  +     +      +  +    +           +++++++ + +  +    +
2994    Billardiera scandens                                     + +  +++ +    + +      +     +    +   +            1               +  ++ +++ +    +
3945    Pomax umbellata                                +    +      +1 1+ + +  +++++++   +                +                     ++       ++
112     Actinotus helianthi                                        +         +                  +                                 1   + +  + ++
1465    Dillwynia retorta                                Ž         +          2++    +1   1+   2   1+   ++    1          +1               +  + 1++ 1 ++1 +  +
1757    Gonocarpus teucrioides                                   + +          2 +  12+                                  +    ++              +21 +  2 +        1
1709    Goodenia bellidifolia                                    2            +  + ++     +  +         +    + 1+  +      +
3466    Stipa pubescens                                             +          ++  2 +  1   1  ++  + + +  +  1+   112                 2  + +  +    1
1496    Hovea linearis                                                         +1+   + +++   +     +  ++        +         ++              +  ++ +    +
2080    Lomandra glauca                                       +  +     +         ++  +2      1  223+++12  ++   111++1+2++12                           ++2
3752    Xylomelum pyriforme                                                     +     +  +     1   + +  +                                         + 1    + +
2074    Lomandra cylindrica                                                     +   +  +       1+1+                    +                      ++  +   1
1138    Schoenus ericetorum                                                      +             +111 + 1    + +    ++1+++                                +   +
1004    Caustis flexuosa                                                          1     +      2112+1+++++ +  +          1 +               ++ + 1+ + ++ 1  +
4314    Tetratheca neglecta                                                                +     ++ 11+1  +         ++1+                   +  1
106     Tricoryne elatior                                      +                     +   +++               + +                                      ++ +
1005    Caustis pentandra                                                                       +    1   1           2+                   + 1
2533    Eucalyptus squamosa                                                        1   ++             + 1  1  1 +  +1  1
1236    Brachyloma daphnoides                                                         +++     ++  + +1        +     ++ + +
3610    Conospermum longifolium                                                        +      +++++1++ +             +
1410    Bossiaea ensata                                                                 ++ +    + + + +++           ++++
2366    Calytrix tetragona                                                                               11           +1                          11 +
2370    Darwinia diminuta                                                                                         +  ++   1+ +                    +
113     Actinotus minor                                                                       + +2 1++ +++++22 2222232122  2 21 1121+   +   1         ++2
3809    Lepyrodia scariosa                                                         2           21 ++2+  ++++11 ++1++2122+  223+2    22  +    +           1
2558    Leptospermum arachnoides                                                                         11+    ++ +++1+  21+ 21+1 2                    + +
2337    Angophora hispida                                                           +                     223121121++122  1++3+ 1+                      1
3601    Banksia oblongifolia                                                       1  +                 + 1++1  21+121+   22213   1                     1  2
1252    Epacris microphylla                                                                      + +                1 +++  +++1 +11111     1         +
3682    Hakea teretifolia                                                                                         +1  +  +2122++++ 1
```

```
3596  Banksia ericifolia                                +              1+ 2+2++            1+++  1124+2++++1            +      1         +
1136  Schoenus brevifolius                           +                                        2 22+2    1133                   +               1
1745  Haemodorum corymbosum                                                2            +   ++ +      ++++++1+           +   +
3805  Leptocarpus tenax                              +                  1                           42   433                +      +
1254  Epacris obtusifolia                                                             +                     + +11 2                +
 628  Blandfordia nobilis                                                         +                         1 11+ + +
2348  Baeckea imbricata                                                                 +                 1 3  +122
1458  Dillwynia floribunda                             +       +     1        1  + + 1 + +       +  + +  2 2
1212  Drosera spatulata                                                                         +    222 2 +                + +++  +  +
1204  Doryanthes excelsa                                                          +    +                            1133+               1    1
2039  Lindsaea microphylla                            +            +                                    +      ++ + +++ + +                +
2974  Dianella caerulea                                     +                 +                 +                ++++++++1       +        +     +  +
4390  Xanthorrhoea arborea                                                                                             + 22+   ++2+     +          +
4186  Smilax glyciphylla                                       +                                         +      +++  +++++++        +  +  +++
2333  Angophora costata                           2  +1  + +  2 +    +    +   +  2                       +      12322 +121++++2         +1  1
3694  Lomatia silaifolia                             +   2   ++ ++++  ++++ ++  +   +    +    1+   +  +        1++++++1++++++ ++
 170  Xanthosia pilosa                            +   +           +   +  + 21+                        +       11+211+++ +++1+  ++  +   +
2494  Eucalyptus piperita                         1                     +                                     +12  +++2+ 1  12 12      1        +
3604  Banksia serrata                             +                   +212+ ++ + 2      +    +++              11+  + +++12+ ++1 +
 950  Ceratopetalum gummiferum                    +          +   +                                            +++  2+3+213  111   1++    1+
1171  Pteridium esculentum                        +         11    1                                      +    +11+++++22+ 1 12  +      1 +   2+1++
2584  Leptospermum polygalifolium                 2   1     1+                                       +  +     2    + 1++    221+    1    +1
2286  Acacia terminalis                           1++1  1  + +  ++++            +            +       +   +    +++  ++++++ ++  ++  + +  ++1+
3651  Grevillea mucronulata                          +  2  ++ 1+++ 1    1 +     ++                            ++1 +1+2++ 21+11+1+ +1+  + +1
1704  Dampiera purpurea                             +                +                        +                               +++  +1+ +  2 + ++  ++  +      +
4094  Dodonaea triquetra                                   +         +                                                           2 1 + +2 2   ++  ++  1+1    +
 171  Xanthosia tridentata                                                  ++     2   +  ++ +         ++  + +   ++      1+  1++ + + 1+++ 1  ++ +++1++
2493  Eucalyptus pilularis                                                2                                                 + + 2+2     12     1    +
2355  Callistemon citrinus                        +                               +              +   2                      + ++   ++ +      1 1
 616  Bauera rubioides                                                                                   1                  +  11  111  1  +
2349  Baeckea linifolia                                                                                                       + 1+  +++    +
1580  Pultenaea flexilis                                                                                            +2  21        +   +++ +1+ +
3693  Lomatia myricoides                                                                                                  +       ++  2211+1 +2
1695  Gleichenia microphylla                                                                                                      1   1 1++1
3679  Hakea salicifolia                                                                                         +               1   222++ 1      +
2258  Acacia obtusifolia                                                                                                          11  11112121
1697  Sticherus flabellatus                                                                                                +        +  1111+1  2
3657  Grevillea oleoides                                                                                     +    1                     +  +1+1111
 949  Ceratopetalum apetalum                                                                                                             +  21+1+ +12
 828  Allocasuarina littoralis       ++           + 1   +  1                      +                            2++  1 +     1    +11111+1
4009  Phebalium dentatum                                                                                                   +           ++++ +++
3746  Stenocarpus salignus                                                                                                                 11+1 1++  +
2573  Leptospermum morrisonii                                                                                                              111+122+
2079  Lomandra fluviatilis                           +                                                                         +  1++1+ 1
1437  Daviesia corymbosa                                                 +  +                                           +           ++ +2 +
2626  Tristaniopsis laurina                                                                                                                222221222  +
2082  Lomandra longifolia                  2    +   ++  + 22   1+                                               ++1+   +++               2+++  ++ 11
1172  Calochlaena dubia                                                                                           +      + +   12                  1+   +1+
2603  Melaleuca linariifolia                      +  1      +                                                               1           +    2433
 365  *Conyza albida                                   1                                                             +                +     ++ +
1084  Gahnia sieberiana               ++                                +  +                             +            +        1+          +   +211
2568  Leptospermum juniperinum                   +                                                      +                    1           +   3+1
2054  Pratia purpurascens             ++  +       +  1                                                                                        1 ++
4371  Viola hederacea               1   ++   1        +                                                                                       1211
3307  Imperata cylindrica                    1    1+1 + 3    1+   1                                                                    1     +++ +
2522  Eucalyptus saligna                           3                                                                                          3 1 +
2902  Pterostylis species           2    +  + +2    1   +       +                                                 +
2471  Eucalyptus moluccana          +2
2539  Eucalyptus tereticornis       +++2         +
3163  Danthonia longifolia           +  +   + + +      +                                                                    +
1603  Pultenaea villosa               + + 2 ++       +
1418  Bossiaea prostrata              + 1 + 1   ++  +   1             +
3944  Opercularia varia               +             + +   +                                                   +                               +
 753  Wahlenbergia gracilis           +        S      +  +           S                           S         + S      +  +         S          S
 441  *Hypochaeris radicata           + +                     +                                                       + +               + +  +
1374  Poranthera microphylla           ++                       +++             +                                                            +
4241  Stackhousia viminea              +  +     +                                             +               +      +   +
1176  Hibbertia aspera                     +            ++                                                 +                  +                  +
3256  Entolasia marginata                  +      +          +  + 1             +                                                      +      11
```

```
1116    Lepidosperma neesii                 +                                      +               2     2 1                         + +  +
2512    Eucalyptus resinifera                  +   1
3082    Aristida warburgii                        1     21      +               +       +
2531    Eucalyptus sparsifolia                     1  +            2           + 1
3408    Poa labillardieri                          +           + +                +                                                               +
1482    Gompholobium huegelii                      +       +   ++               +                                              ++
3642    Grevillea linearifolia                     1    2       +                  2                                     +            +
107     Tricoryne simplex                          1+                         +                +       ++ +
1145    Schoenus melanostachys                        +                                                          +     +                 ++ 12+
1466    Dillwynia sericea                             +  1                  +     1   1 1  +      +
1649    Viminaria juncea                              +                                              + +   +                 + +
1570    Pultenaea daphnoides                          +                                                       2+2  +        1
1539    Mirbelia speciosa                               ++  +        + +++   +                        +
4268    Stylidium productum                             +                                                     11+1     2
1379    Ricinocarpos pinifolius                           +               +                                    +   +        ++
2245    Acacia longifolia                                  1 +                                                       + 1                   +    + 1
2526    Eucalyptus sclerophylla                            +                   1
2598    Melaleuca deanei                                    +               + +  +   +1    +
1274    Leucopogon juniperinus                               +++        +      +                 +
1373    Poranthera ericifolia                                        +        ++                               +    +   +                +
2415    Eucalyptus consideniana                                      2   +1 1+2  1                      +
1149    Schoenus turbinatus                                           + + + +    +                      1
2529    Eucalyptus sieberi                                            + 1
1315    Woollsia pungens                                                + 1 +    2            1                     +        ++          +
4407    Xyris gracilis                                                  +                  2+ ++   +1 1  +
1599    Pultenaea stipularis                                              1 2                                         +   2    +    +
1189    Hibbertia nitida                                                   +     +                              1            1 +    +     1
2474    Eucalyptus multicaulis                                             2     1
3744    Petrophile pulchella                                                1 1  +            +        1              +      +      +   +
100     Thysanotus juncifolius                                              +          + +              1+  +
1268    Leucopogon esquamatus                                                  +            +         + ++1                  + +
2004    Cassytha glabella                                                                +  ++   +  + +                    +          +
3966    Boronia ledifolia                                                                    +                     ++  +    + +
1694    Gleichenia dicarpa                                                                                +             +        1          1    2+
1403    Aotus ericoides                                                                                    1    2+              1   ++
4249    Lasiopetalum ferrugineum                                                                                      +         + +      + ++    +
2384    Eucalyptus agglomerata                                                                                        +                +
3649    Grevillea longifolia                                                                                           2         12       ++     +

                                  00000000000  000000000000000000000  000000000100000000000000000  00000111000  0000000000000000000  000000000  00000
                                  19991129178  218609110407570678780  755444334088990616152531233  53443000455  3342026560646797772  888968965  21202
                                  27865649851  198542303872662732435  020947313007316079197726378  84159132631  0529868429401109788  456439565  04512
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Quadrats are read vertically on the table, for example the first quadrat in HOLS 1 is 012.

Vegetation community

HOLS 1	Grey Box Ironbark Woodland
HOLS 2	Shale/sandstone Forest
HOLS 3	Sydney Sandstone Ridgetop Woodland
HOLS 4	Woronora Plateau Upland Swamp
HOLS 5	Sydney Sandstone Gully Forest
HOLS 6	Riparian Scrub
HOLS 7	River-flat Forest

Cover-abundance value

+	cover <5%, uncommon/rare
1	cover <5%, common
2	cover 5-20%, <5%, abundant
3	cover 20-50%
4	cover 50-75%
5	cover 75-100%

Quadrats 92-101 have 25% as 2-3 boundary

Appendix E

Australian Heritage Commission Statement of Significance of Holsworthy Military Area

AUSTRALIAN HERITAGE
COMMISSION

Cubbitch Barta National Estate Area

Statement of Significance

Cubbitch Barta National Estate Area is a large area with outstanding cultural and natural values. It is very significant as a cultural and natural landscape which demonstrates relationships between the environment and human occupation through time. Its significance is emphasised by its proximity to Sydney, the nation's largest metropolitan centre.

Cubbitch Barta National Estate Area is an integral component of the Woronora Ramp area, stretching south-west from Sydney, together with Royal National Park, Heathcote National Park, the Woronora catchment and O'Hares Creek Catchment. Major parts of the Woronora Ramp region are included in the Register of the National Estate. This region, together with the other tracts of undeveloped areas to the west and north of the metropolitan area, are essential in defining the character of the broader Sydney region.

In the network of gullies which criss-cross the area, many of the natural values remain undisturbed, and the indigenous heritage is impressively retained. Over 500 Aboriginal sites provide a glimpse of the relationship between people and the land prior to 1788. The sites, and the area's long-term and more recent connections with Aboriginal people, combine to form a landscape of great significance for its indigenous heritage. The landscape also provides important illustrations of European settlement, agriculture and Australia's military history.

It is unusual to find landscapes in this region so intact. This provides a rare opportunity to understand both the natural and cultural history of the region. It is remarkable that this landscape has survived on the margins of the nation's earliest and largest urban centre.

INDIGENOUS VALUES

The Cubbitch Barta National Estate Area is highly valued by members of the Tharawal Local Aboriginal Land Council and the Dharawal people for its symbolic, cultural, educational and social associations. (Criterion G.1) The Aboriginal cultural landscape of the area reflects the past lifestyle of Aboriginal people in this region, and its preservation enables Aboriginal people to maintain cultural links to the area. These connections with the past are particularly important, because Aboriginal people in this part of Australia were among the earliest impacted by European settlement of this continent, and their culture has since been disrupted by war, disease and urban development. Throughout the environments of the area, the Dharawal see evidence of the relationship between their people and the land. The Tharawal Local Aboriginal Land Council is also concerned about maintaining the area's natural environment.

The area contains a large and diverse collection of Aboriginal sites, which represent a complex Aboriginal cultural landscape. (Criterion A.3) Over 530 sites are known from the area, and a further 509 potential archaeological sites have been documented. It is highly likely that the area contains many hundreds more sites. Sites include rock paintings and drawings, engravings, open scatters of artefacts, grinding grooves and scarred trees. The survival of a significant number of scarred trees within the area is important as this is a rare type of site within the Sydney Basin. (Criterion B.2) While rock art sites are well-represented in the Sydney Basin, other types of sites are less so. The preservation within the area of scarred trees, open artefact scatters and archaeological sites in particular, offer considerable potential for further developing a picture of day-to-day activities of Aboriginal people in the Sydney Basin prior to 1788. (Criterion C.2)

This large number of sites, and the stories they may tell, form a landscape in which Aboriginal life prior to 1788 is recorded without the large-scale impact of European settlement. There is also a high density of sites in the area. This is particularly important because sites are found in groups or clusters with their relationship to one another largely intact. By examining where they are located in the landscape and their relationship to other types of sites, a more complete picture of the lifestyle of Aboriginal people could be established. (Criterion C.2)

The Georges River, which bounds the national estate area on the west, and is close to the north, has been identified as an important north-south Aboriginal cultural boundary within the Sydney Basin. The cultural landscape of the national estate area is representative of the southern social unit of the Sydney Basin. (Criterion D.2) This unit has been characterised by the presence of a number of distinctive traits within the art and by complex analyses which show that the art sites of this region are significantly different from those north of the Georges River. The large number of sites, the relatively high site density, the condition of sites and the preservation of the landscape as a whole makes the area important in terms of the further definition of this southern unit.

The area also offers considerable research potential in terms of the analysis and interpretation of small-scale groups. (Criterion C.2) There is evidence to suggest that this area formed the cultural landscape of a single residence group whose territory extended over the Georges River and Williams/Mill Creek drainage basins. In this region, it is uncommon to have such a landscape preserved in this way, and particularly important, as knowledge of local groups from enthnohistory is often incomplete and problematic.

The rich collection of more than 300 rock art sites within the area is regionally significant as a group in the Sydney Basin and representative of rock art south of the Georges River. (Criterion D.2) The rock art sites are diverse in terms of technique (paintings, drawings and engravings) and motifs depicted. (Criterion A.3) The art in the area contains a number of motifs which are rare within the Sydney region, such as the engraving of a pregnant woman. The site where this occurs is considered important, as female motifs and gender-specific evidence of this kind are relatively rare. (Criterion B.2) The long history of recording the rock art sites by voluntary groups and individuals indicates that they are aesthetically important to groups within the broader community. (Criteria E.1) The aesthetic value of these sites is enhanced by their excellent condition and lack of graffiti.

The Cubbitch Barta National Estate Area is important as an illustration of a landscape in which changes in the relationship between Aboriginal people and early settlers took place (Criterion A.4). This is a phase in the cultural history of Australia for which traditional documentation is often poor. The area is associated with Governor Macquarie's war against the Aboriginal people of the Liverpool, Campbelltown and Appin areas from April to November 1816. Despite efforts to mov_ indigenous people away from this country, documentation indicates Aboriginal people were still visiting sites within the area in the 1830s. Within the area, it is the evidence of the strong

Aboriginal presence combined with the nineteenth century history and landuse without much twentieth century development, which makes this area unusual for the way it can illustrate this period of history. Potential exists for further research to shed light on this era through research relating to exploration, settlements within the area and information about the adjacent Aboriginal reserve. (Criterion C.2)

NATURAL VALUES

This area contains a diversity of natural landscapes and vegetation types in a relatively unmodified condition, in an area otherwise greatly altered by urban development. Vegetation communities include plateau forest (covering forest and woodland on both tertiary alluvium soils and on shale), gully forest, woodland/heath complex, riparian forest, sedgeland, heath/swamp complex and melaleuca thickets. The laterite ridgetops are almost entirely intact and are significant reference sites which demonstrate the formation of laterite caps and the occupying vegetation communities. (Criterion A.2)

Diversity of plant species is high, with more than 400 species recorded in the area. At least seven different plant communities have been distinguished in the area, indicating high community diversity. (Criterion A.3)

At least eight plant species considered rare nationally occur here: DARWINIA DIMINUTA, D. GRANDIFLORA, EUCALYPTUS LUEHMANNIANA, GREVILLEA LONGIFOLIA, HIBBERTIA NITIDA, LOMANDRA FLUVIATILIS, MELALEUCA DEANEI and TETRATHECA NEGLECTA. A rare and undescribed species of greenhood orchid PTEROSTYLIS sp. E has also been recorded here. The area contains a substantial remnant of Cumberland Plain woodlands, a vegetation type growing mainly on Wianamatta shale. Only 6% of the original area of Cumberland Plain woodlands remains. This community has been listed as an endangered ecological community under the NSW Threatened Species Conservation Act 1995. LEUCOPOGON EXOLASIUS, found here, is listed as vulnerable under the Commonwealth Endangered Species Protection Act 1992. Regionally significant plants include E. SQUAMOSA, GREVILLEA DIFFUSA and ZORNIA DYCTIOCARPA. (Criterion B.1)

The broad-headed snake HOPLOCEPHALUS BUNGAROIDES, found in this area, is listed under the Commonwealth Endangered Species Protection Act 1992. The koala PHASCOLARCTOS CINEREUS population found locally is considered one of the few remaining viable populations in southern NSW. The area also contains a significant population of the spotted-tailed quoll DASYURUS MACULATUS. Both the koala and quoll are listed as vulnerable under the NSW Threatened Species Conservation Act, together with the giant burrowing frog HELEIOPORUS AUSTRALIACUS, red-crowned toadlet PSEUDOPHRYNE AUSTRALIS, powerful owl NINOX STRENUA, and greater broad-nosed bat SCOTEANAX RUEPPELLII, all of which are recorded in the area. The New Holland mouse PSEUDOMYS NOVAEHOLLANDIAE, considered to be regionally rare, is also found here together with a number of other fauna species of regional or state conservation significance. (Criterion B.1)

The area has areas of significant aesthetic values, particularly the forested creek gorges. (Criterion E.1)

HISTORIC VALUES

The settlement sites and transport routes in the area are associated with the history of nineteenth century European settlement and the development of agriculture in the Liverpool region, including the wine industry and subsistence farming in a bushland