COMMONWEALTH DEPARTMENT OF
TRANSPORT AND REGIONAL DEVELOPMENT

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Geology, Soils and Water

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.

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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.

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Introduction

1 INTRODUCTION

1.1 INTRODUCTION

This technical paper addresses the potential impacts of the previously proposed development of the Second Sydney Airport at either Badgerys Creek or Holsworthy Military Area on surface water and groundwater. It also examines the soil characteristics and geology of the sites of the airport options, in relating to their potential impacts on water quality. 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:

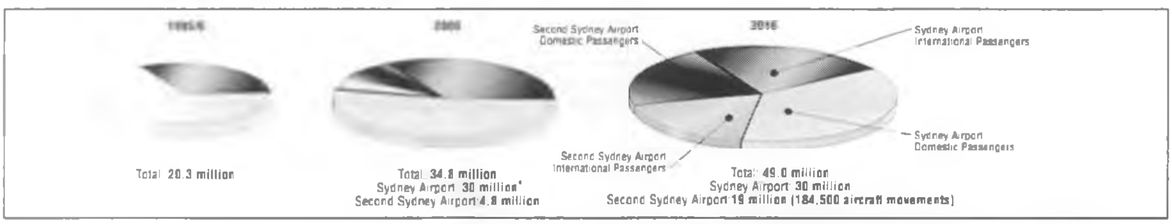
- Badgerys Creek Option A which has been developed to be generally consistent with the planning for this site undertaken since 1986. The airport would be developed within land presently owned by the Commonwealth with two parallel runways constructed on an approximate north-east to south-west alignment;
- 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.

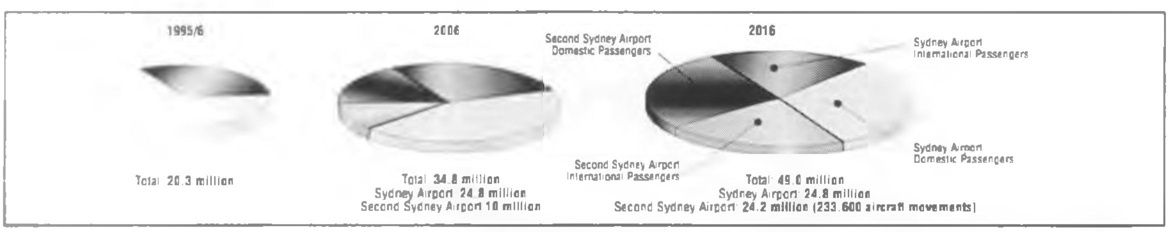
The number of flights into and out of the proposed Second Sydney Airport would depend on a number of factors including the types of aircraft that would use the airport and the associated numbers of passengers in each aircraft. The proposal put forward by the Government anticipates a major

Figure 1.1

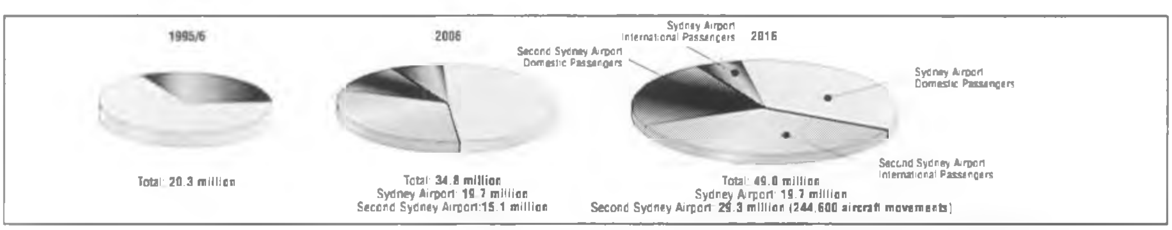
Potential Airport Sites Considered in the Draft EIS



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

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.

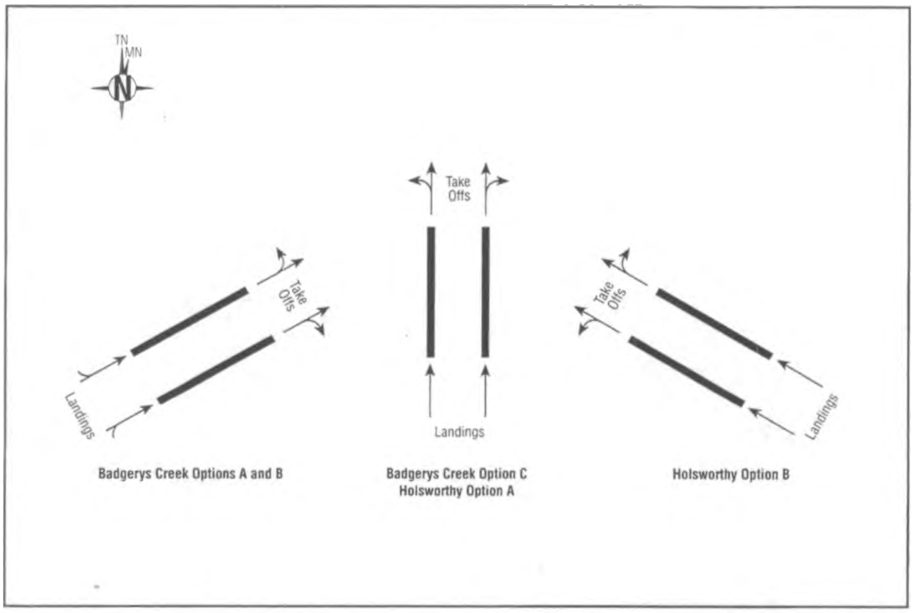


Figure 1.3

Predominant Directions of Movement of Aircraft for Airport Operation 1

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

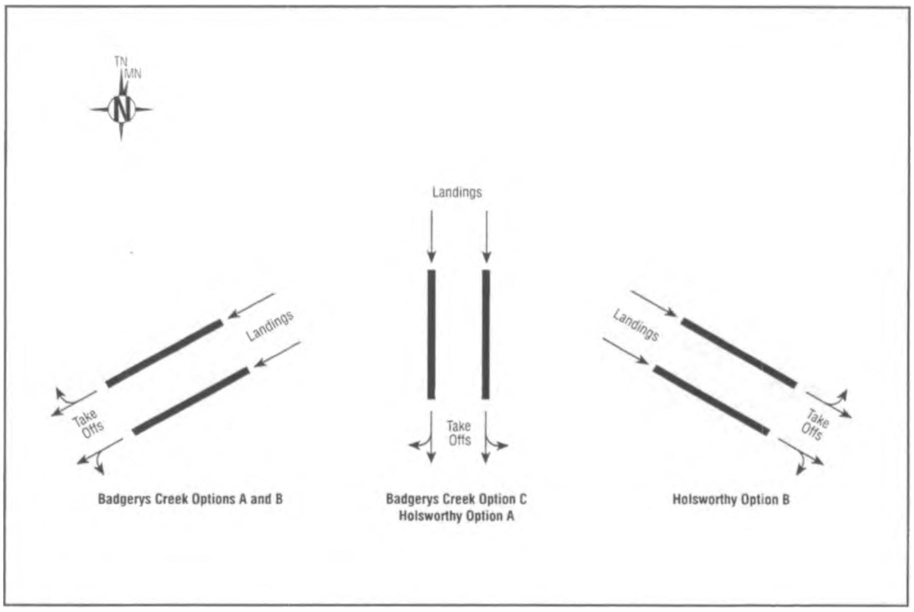


Figure 1.4

Predominant Directions of Movement of Aircraft for Airport Operation 2

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

2 CONSULTATION

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

Consultation was undertaken with various organisations, community groups and government departments to gain information and to determine concerns.

Organisations and groups that were consulted included:

- Georges River Catchment Management Committee;
- South Creek Catchment Management Committee;

- Department of Urban Affairs and Planning,
- Department of Land and Water Conservation;
- National River Health Initiative;
- Sydney Water Corporation;
- Australian Water Technologies;
- Environment Protection Authority;
- Australian Heritage Commission;
- Bureau of Meteorology;
- Other consultants in the EIS and Airport Design Teams;
- The Department of Mineral Resources;
- Department of Education;
- Waste Recycling and Processing Service of NSW;
- Penrith City Council;
- Liverpool City Council;
- Campbelltown City Council;
- Coffey Partners International Pty Ltd;
- DJ Douglas & Partners Pty Ltd;
- Dames & Moore;
- Pacific Waste Management; and
- Private landowners.

3 METHODOLOGY

3.1 AIMS AND SCOPE OF WORK

This technical paper has a number of aims:

- to provide baseline data on surface water quality in the vicinity of the proposed airport sites at Badgerys Creek and Holsworthy;
- to characterise the existing groundwater environment at the proposed airport sites; and
- to assess impacts of the development of the airport options on the quality of surface water and groundwater in the surrounding environments.

The paper also covers aspects of topography, hydrology, soils and geology relevant to surface water and groundwater. An examination of health aspects of drinking water pollution has also been made.

Major issues of concern relate to the supply of water, sewerage and drainage facilities, soil erosion and flood mitigation devices, and their impacts over a short and long term period. There are also issues relating to drinking water supply reservoirs, rainwater tanks and water supply pipelines.

The primary objectives of the study are as follows:

Existing Environment

- identify soil types at each of the sites of the airport options, their potential for erosion and the likelihood of acid sulphate soils in areas which would be disturbed;
- establish the current water quality of streams which may be affected by the proposed Second Sydney Airport;
- identify and characterise groundwater occurrence at the proposed airport sites;
- identify the existing levels of relevant pollutants in surface waters and groundwater as a baseline for monitoring; and
- identify sensitive areas that would be impacted by construction and operation of the proposed Second Sydney Airport.

Impact Assessment

- assess potential impacts of airport construction and operation on water quality in reservoirs, streams and aquifers as well as domestic rain water tanks;
- examine the potential for flooding, upstream and downstream of the sites, as a result of developing the Second Sydney Airport; and
- determine potential health impacts of air pollutants in relation to drinking water in reservoirs and domestic rain water tanks.

Environmental Management

- identify mitigation measures and control mechanisms to reduce or prevent identified impacts; and
- prepare proposals for monitoring of water quality (surface and groundwater) during construction and operation of the airport.

3.2 STUDY TEAM

The various studies associated with this technical paper were undertaken as follows:

- Surface Water Quality and Health - Robyn Tuft and Associates;
- Soils and Groundwater - PPK Environment & Infrastructure; and
- Hydrology - Second Sydney Airport Planners.

3.3 INFORMATION SOURCES

Surface water quality data and other catchment information, groundwater data and other relevant information about water issues was obtained from a number of organisations that were consulted. A broad outline of some of the information obtained is shown in *Table 3.1*:

TABLE 3.1 INFORMATION OBTAINED FROM VARIOUS ORGANISATIONS

Organisation	Information Obtained
Australian Heritage Commission	National Trust and heritage listings
Australian Water Technologies	Water quality monitoring data Hydrological data
Department of Health	Monitoring of rainwater tanks
Department of Land and Water Conservation	Locations of existing groundwater bores. Prescribed Streams (Soil Conservation Act 1938)
Department of Urban Affairs and Planning	State Environmental Planning Policy 14 Wetlands
Environment Protection Authority	Effluent management including details of existing Bubble License (South Creek Sewage Treatment Operations)
NSW Fisheries	Commercial fishing and shellfish harvesting
NSW National Parks and Wildlife Service	Warragamba Catchment Nature Reserves and National Parks
Roads and Traffic Authority of NSW	Water quality data for Elizabeth Drive
Sydney Water Corporation	Catchment and Reservoir management issues
	Water filtration plants
	Sewerage programs
	Ecological and human health assessment
	Water quality monitoring data
	Emergency situation consequences
Campbelltown Council	Water Monitoring data
Leichhardt Council	Fuel dumping complaints
Georges River Catchment Management Trust	References on water quality issues concerning airport options, particularly Holsworthy options
Hawkesbury Nepean Catchment Management Trust	References on water quality issues concerning Badgerys Creek proposals
South Creek Catchment Management Committee	References on water quality issues concerning Badgerys Creek proposals

In addition, geotechnical data was obtained from the following sources:

- Soil Conservation Service of NSW; and
- Dames & Moore.

3.4 REVIEW OF PREVIOUS WORK

3.4.1 TOPOGRAPHY, GEOLOGY AND SOILS

Soil types at the sites of each of the airport options were identified and the potential for soil erosion and acid sulphate soils was assessed. Information on geology and soil characteristics was obtained from standard references. This is discussed in *Section 4*.

3.4.2 HYDROLOGY

Stormwater runoff from the existing Oaky Creek and Badgerys Creek catchments, together with flood levels in Badgerys Creek, were investigated in a previous conceptual design for the proposed airport of Badgerys Creek (Snowy Mountains Engineering Corporation, 1991). The hydrological model used in that study was based on an earlier model for the South Creek catchment by the Department of Water Resources (1990). Both models were developed to simulate catchment characteristics and were calibrated using recorded rainfall and stream flow data.

At Holsworthy, existing hydrological information which adequately defines expected flowrates and runoff volumes was not available.

3.4.3 SURFACE WATER

There have been a number of water quality studies in the vicinity of both Badgerys and Holsworthy sites. At Badgerys Creek this has included surveys of Badgerys Creek at Elizabeth Drive, South Creek as far as the Hawkesbury River, Kemps Creek and various sites on the Nepean River. In 1991, Snowy Mountains Engineering Corporation undertook water quality testing at six locations within the Badgerys Creek site. For Holsworthy, surveys have been identified for the Georges River and Woronora River and sites in the lower sections of Williams and Harris Creeks.

Although much of this data is useful for the regional perspective, additional field information on specific parameters associated with construction or operation of an airport was collected as part of preparation of the Draft EIS. It was also important to identify the current status of streams and water bodies within the immediate vicinity of the sites of the proposed airport options.

3.4.4 GROUNDWATER

Badgerys Creek

In 1991, Coffey Partners International undertook a geotechnical investigation of the original site for the proposed airport at Badgerys Creek (Coffey Partners International, 1991). The works program included drilling 55 boreholes, excavating 44 testpits, and conducting a geophysical survey comprising five seismic sections. Water levels were recorded in 20 of the boreholes and groundwater electrical conductivities were obtained from four of the boreholes.

AGC Woodward Clyde Pty Ltd undertook geological, hydrogeological and leachate studies on behalf of Pacific Waste Management at the Elizabeth Drive Landfill located approximately one kilometre north-east of the proposed airport site. This work is reported in "Elizabeth Drive Landfill, Proposal to Accept General Solid Waste, Environmental Impact Statement" (PPK, 1993). The study provides background groundwater level and chemistry data obtained prior to the excavation of cell B4.

Snowy Mountains Engineering Corporation/Gutteridge Haskins & Davey (1994) undertook a geotechnical investigation consisting of the excavation of 56 testpits to shallow (less than 6.5 metres) depths. One test pit encountered groundwater seepage at a depth of 4.1 metres. Details of this study are reported in *Sydney West Airport - Development Option for Major Airport Operation - Concept Design Report* (Coffey Partners International, 1991).

Dames and Moore (1996) undertook a desktop review of geotechnical issues as part of the Sydney Airport Master Plan Study. This report summarised available geotechnical information from reports relating to the currently proposed airport sites. The study identified a deficiency in available information relating to the Holsworthy options.

Holsworthy

Only one study relevant to groundwater issues at the Holsworthy sites was able to be located. DJ Douglas and Partners in conjunction with Coffey Partners International undertook an investigation of the hydrogeology at the Lucas Heights Waste Depot for the Waste Service of NSW (Douglas Partners and Coffey Partners International 1994). The investigation included drilling twenty boreholes, geological mapping, groundwater sampling, test pumping, and geophysical testing.

3.5 FIELD SURVEY

3.5.1 SURFACE WATER

Sampling Strategy

Stream monitoring sites were selected in the vicinity of the proposed airport sites at Badgerys Creek and Holsworthy. Site selection was based primarily on proximity to the proposed airport sites and included sites both upstream and downstream of all proposed areas of disturbance. In addition, observations were made of catchment characteristics and water quality within relevant water bodies, including farm dams.

Badgerys Creek sampling sites were:

- Badgerys Creek (three sites);
- Cosgroves Creek (two sites);
- Duncans Creek; and
- Thompsons Creek.

These sites are shown on *Figure 3.1*.

Holsworthy sampling sites were:

- O'Hares Creek (two sites);
- Punchbowl Creek (three sites);
- Williams Creek (two sites);
- Harris Creek;
- Deadmans Creek (two sites);
- Georges River;
- Wappa Creek; and
- Gunyah Creek.

These sites are shown on *Figure 3.2*.

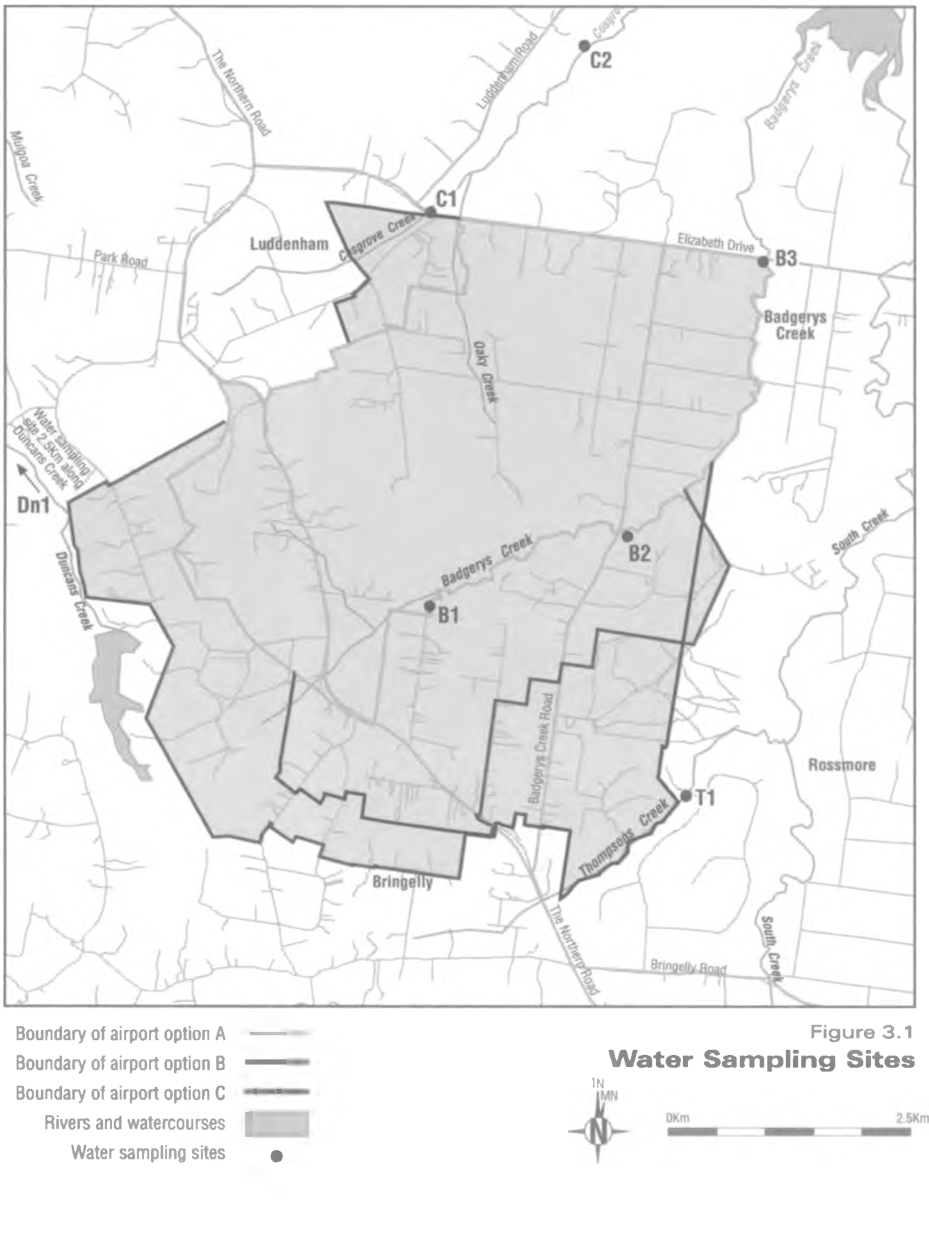


Figure 3.1
Water Sampling Sites

Figure 3.2
Water Sampling Sites at Holsworthy Options

Holsworthy Military Area Boundary
Airport Option Boundary
Rivers and Watercourses
Water Sampling Sites

TN MN N
0Km 5Km

Historical data was also obtained for the following sites:

- Badgerys Creek Streams:
  - Badgerys Creek;
  - Oaky Creek;
  - South Creek; and
  - Cosgrove Creek.
- Holsworthy Streams:
  - Harris Creek;
  - Williams Creek; and
  - Georges River.

Parameters Recorded

Water samples were analysed for the following physical and chemical parameters:

- Suspended Solids;
- Turbidity;
- Grease and Oil;
- Total Phosphate;
- Nitrite;
- Nitrate;
- Ammonia as N;
- Total Kjeldahl Nitrogen;
- Methylene Blue Active Substances (a measure of detergents);
- Total Organic Carbon;
- Mercury;
- Metals (iron, nickel, copper, chromium, zinc, lead, cadmium);
- Phenolics as Phenols;
- Total Petroleum Hydrocarbons;

- Volatile Aromatic Compounds (including benzene, xylene, toluene);
- Polynuclear Aromatic Hydrocarbons (including naphthalene, pyrene); and
- Volatile Halogenated Compounds (including vinyl chloride, chloroform, carbon tetrachloride, chlorobenzene, bromoform).

Descriptions of these physical and chemical parameters are provided in *Appendix A*.

Ecological indicators of water quality measure the biological state of a water body. Water quality indicators include measures of types and abundance of algae, aquatic plants and aquatic fauna. The purpose of monitoring biological characteristics is firstly to have a direct measure of ecological impact and secondly to provide an indicator which can integrate water quality over a period of time to determine impacts which may not be detected by snapshot" chemical sampling.

Aquatic plants include native and introduced species which are partially or wholly submerged. They include species which can be rooted or free-floating and either submerged, emergent or floating. A large number of aquatic plants, particularly introduced weeds, can indicate excessive nutrients in the water.

Algae are non-vascular plants which may be single celled, colonial or arranged in filaments. In freshwater systems, algae can be suspended in the water column (phytoplankton), attached to rocks, sticks or aquatic plants (periphyton) or form part of bottom silts (benthic algae).

Aquatic fauna include vertebrates such as fish, amphibia and reptiles as well as invertebrates. Although vertebrate fauna were recorded when observed, these organisms were not specifically targeted as they form part of the faunal assessment (refer *Technical Paper No. 8 - Flora and Fauna*). The water quality survey specifically involved collecting macroinvertebrates which are indicative of water quality. These include insect larvae, beetles, snails, worms, shrimps, mites and spiders.

Survey Method

At each site, in-situ measurements were taken of water temperature, pH, dissolved oxygen and conductivity. Samples for laboratory analysis of remaining parameters were collected five centimetres below the surface in specially prepared bottles, kept cool and transported to a National Association of Testing Authorities registered laboratory within 24 hours. Sampling containers were prepared in accordance with standard procedures and samples collected in strict order to minimise cross contamination. The laboratory analyses incorporated quality control procedures, including analysis of blanks, spikes, percentage recoveries and duplicate testing.

At each site aquatic plants were identified and distributions mapped. Periphyton, benthic algae and (where relevant) phytoplankton were collected. Phytoplankton were collected from surface water, preserved in Lugols iodine, settled to 10 percent volume and quantified using a Lund cell to give cell count per millilitre. Other types of algae were collected from rock and vegetation scrapes and in bottom silts. These were identified to genus level and given abundance scores within the algal sample collected. These were then put into context by integrating with the proportion of algal coverage on stream substrates. The abundance of algae was rated using the following scale:

1. Extremely abundant;
2. Abundant;
3. Common;
4. Occasional; and
5. Few.

For macroinvertebrates, sweep samples using a 0.3 millimetre mesh net were collected from pool habitats over a 15 minute period. Samples were then sorted in the field and abundances of each family recorded on a four point scale:

1. Rare (1 to 3 individuals);
2. Present (4 to 10 individuals);
3. Common (11 to 50 individuals); and
4. Very Common (greater than 50 individuals).

A small number of each type of macroinvertebrates were placed in ethanol for subsequent identification to family level classification using a dissecting microscope. The number of discrete taxa (species") were also scored for each family.

Results Analysis

Macroinvertebrate data was entered into a database which calculated the total number of taxa and a water quality index (SIGNAL index). The SIGNAL index (Chessman, 1995) is a measure of water quality using the factors of indicator animals and abundance which has been developed specifically for Australian waters.

Animals are identified to family level classification, with each family assigned a grade between one and 10 depending on the tolerance to common pollutants (higher values represent lower levels of tolerance). Each species is then assessed for abundance on a four point scale.

The Index is derived from the sum of scores divided by the sum of abundances. This provides a comprehensive ecological indicator that takes into account the number and abundance of pollutant sensitive animals.

SIGNAL indices are classified into four levels:

- less than 4 – probable severe pollution;
- 4-5 – probable moderate pollution;
- 5-6 – doubtful quality, possible mild pollution; and
- greater than 6 – clean water.

The index for each site was compared to the index for a "pristine" reference site by calculating the ratio of the two values. Ratios below 1.0 indicated poorer water quality, whereas ratios exceeding 1.0 suggested higher water quality.

Algae and aquatic plants were identified to genus level. This data, together with relative abundance and percentage cover at the sampling site was entered into a data base. The data was then analysed for dominant types as well as for the presence or absence of specific indicator groups or genera.

3.5.2 GROUNDWATER

Locations of licensed borehole locations within three kilometres of the proposed Badgerys Creek sites and the Holsworthy Military Area were obtained from the Department of Land and Water Conservation. Borehole locations were plotted onto basemaps using co-ordinates supplied by the Department of Land and Water Conservation, and landowners determined from local council records. Where possible, the landowners were contacted to ascertain the status of the licensed boreholes, and to gain access permission.

Located boreholes were manually dipped to static water levels. The bores were purged either manually or using existing wellhead pumps, and groundwater pH, electrical conductivity, dissolved oxygen, redox potential, and temperature were determined. Licensed borehole locations within three kilometres of the proposed Badgerys Creek sites and the Holsworthy Military

Area were obtained from the Department of Land and Water Conservation. Borehole locations were plotted onto basemaps using co-ordinates supplied by the Department of Land and Water Conservation, and landowners determined from local council records. Where possible, the landowners were contacted to ascertain the status of the licensed boreholes, and to gain access permission.

Located boreholes were manually dipped to static water levels. The bores were purged either manually or using existing wellhead pumps, and groundwater pH, electrical conductivity, dissolved oxygen, redox potential, and temperature were determined.

Part B

Existing Environment

4 EXISTING ENVIRONMENT

4.1 STATUTORY CONTEXT

Clean Waters Act, 1972

The *Clean Waters Act, 1972* (which is currently under review) makes provision for the classification of waters, the broad objectives being to describe the degree of protection required for particular waterways, so as to preserve their quality consistent with the needs of users.

In the Act, certain waters have been classified in accordance with specific protection classes (Atlas of Classified Waters):

- Class C waters can accept treated effluent provided the quality meets specific criteria;
- Class S waters (which include water supply reservoirs) do not permit any discharges; and
- Class P waters include waters flowing into potable supplies, waters flowing through public lands, waters which merit a high level of protection and those containing sensitive aquatic environments. For Class P, any discharge must comply with Schedules 2 and 3 of the Clean Waters Act, which lists substances likely to be harmful to human health and aquatic health.

Under the Act, approval is required from the Environment Protection Authority for construction of any structure which will contain or create pollution. Any effluent or runoff discharged would have to conform to requirements in Clause 16 of the Act which prohibits the pollution of waters.

Water Board Corporatisation Act, 1994

Under this Act, Sydney Water must be notified of proposed developments within areas zoned Special Areas" and Outer Catchment Areas". Within these areas under Sections 78 (4) and section 84 (1) and (4) Sydney Water requires notification of development within Special Areas prior to determination of development approval (Sydney Water, 1996).

The reservoir catchment areas of Woronora, Cataract, Cordeaux, Nepean, Avon and Warragamba are designated as Special Areas. O'Hares Creek catchment area near Holsworthy is also designated.

Catchment Management Act, 1989

The *Catchment Management Act, 1989* establishes committees to co-ordinate the sustainable use and management of the land on a catchment basis. The Catchment Management Committee has the responsibility of developing Catchment Management Plans to ensure the natural resources of a catchment are not degraded. Consultation must be made with these committees to ensure any proposals are in accordance with Management Plans.

State Environmental Planning Policy No. 14 Coastal Wetlands

Under this Act, an Environmental Impact Statement must be prepared for clearing, filling, draining or the construction of levees in mapped wetlands (Department of Urban Affairs and Planning, 1996b). Additionally the *Environmental Impact Assessment Advisory Paper No. 1* (Department of Environment and Planning, 1987) outlines procedures to be followed and legislative requirements for development of *State Environmental Planning Policy No. 14 wetlands. State Environmental Planning Policy No. 14* generally applies to wetlands beyond the Sydney Metropolitan Area and as such there are no wetlands within the Study sites that are affected by this legislation (pers comm, Susan Harrison, Department of Urban Affairs and Planning).

NSW Fisheries and Oysters Farms Act, 1935 (amended 1979)

The *Fisheries and Oyster Farms Act, 1935* gives NSW Fisheries the responsibility for the protection, development and regulation of fisheries within NSW. These guidelines have been devised to improve freshwater habitat management in NSW.

Sections 90 E-L of the Fisheries and Oyster Farms Act deal with dredging and reclamation. Before carrying out or authorising dredging or reclamation works, authority must be obtained from the Minister. Proposed alterations to streambeds fish habitat need to be approved from the Minister (NSW Fisheries, 1993). Works which potentially may alter habitat or food resources would need to conform with this Act.

Under Section 34 of the *Fisheries and Oyster Farms Act, 1935* penalties can arise for introduction of substances injurious to fish (NSW Fisheries, 1993). This has implications for diffuse and point source pollution control and mitigation.

Australian Heritage Commission Act, 1975

As a component of the *Australian Heritage Commission Act, 1975* a national inventory is maintained of places identified as components of the National

Estate. Entry in the register gives some protection to a place under Section 30 of the Act. According to the Australian Heritage Commission Section 30 of the Act only applies to the Federal Government, and listing a place in the register does not provide any direct legal constrains or controls over the actions of State or local governments (Australian Heritage Commission, 1994).

An action is considered to have an adverse affect on a place in the Register if it diminishes or destroys any of the National Estate values which have led to its inclusion in the register.

Australia and New Zealand Environment Conservation Council Australian Water Quality Guidelines, 1992.

These guidelines are an important reference tool for determining an acceptable water quality standard. Although not statutory, they are used for comparative purposes in assessing water quality for human and aquatic health. Within NSW the Environment Protection Authority has incorporated these guidelines to determine acceptable levels for pollution discharge and subsequent licensing requirements to maintain or improve water quality.

National Water Quality Management Strategy - Guidelines for Groundwater Protection in Australia, 1995.

These guidelines provide a framework enabling State, Territory and Commonwealth governments to develop policies and strategies for protecting groundwater from contamination. The framework involves identification of specific beneficial uses and values for every major aquifer, and development of policies to ensure the groundwater is not degraded. A polluter pays principle applies.

4.2 ENVIRONMENTAL CONTEXT

4.2.1 BADGERYS CREEK

Topography, Geology and Soils

The proposed airport site is located in the south-west portion of the Cumberland Plain, on the eastern side of the elevated ridge system dividing the catchments of the Nepean River and South Creek. The Cumberland Plain has an average elevation of about 20 metres above sea level in the north, rising to about 150 metres in the south around Bringelly, Camden and Campbelltown, a distance of about 50 kilometres. The elevated ridge system on which the site is located begins to rise at Orchard Hills in the north and extends to Bringelly and Cobbitty, where it broadens into an elevated plain. *Figure 4.1* shows the slope classes which occur at the sites.

Reference to the 1:100,000 Geological Series Sheet for Penrith, indicates that most of the site is underlain by Triassic rocks (Bringelly Shale) and unconsolidated Quaternary sediments.

The Bringelly Shale is the uppermost unit of the Wianamatta Group and underlies the surface soils under the majority of the site. Bringelly Shale is interpreted as a coastal alluvial plain which grades up from a lagoonal-coastal marsh sequence at the base to a more increasingly terrestrial, alluvial plain sediments to the top of the formation. Lithology's which comprise the Bringelly Shale are:

- claystone and siltstone;
- laminite;
- sandstone;
- coal and highly carbonaceous claystone; and
- tuff.

Quaternary alluvium appears as accumulated surficial deposits along the main creeks in the area. These creeks include Cosgrove Creek to the north and Badgerys Creek to the south of the airport. The alluvium typically comprises fine grained sand, silt and clay.

A major dyke, known as the Luddenham Dyke outcrops along the top of a ridge at the site. The dyke consists of olivine basalt carrying analcite, and intrudes Wianamatta Shale (H.J. Audova, 1956). The dyke forms the spine of the prominent north-west trending ridge located in the south-west of the site. It is approximately two to three metres wide, about eight kilometres long and has a maximum depth of about 10 to 12 metres at the ridge. The dyke dips to the south-west at about 85 degrees.

Circular mass slides and flow-type landslips occur where highly plastic clayey soils have developed on extremely weathered Bringelly Shale and coincide where a sufficient thickness of soil and a steep land slope exist. These conditions occur along parts of the ridge line that extends southward from Luddenham. However, the potential for landslip generally only occurs following periods of heavy rainfall (due to a rise in groundwater levels and, hence, soil pore water pressures).

The area covered by the Penrith 1:100,000 Geological Sheet has not, in its 200 years of recorded history, suffered from a major earthquake associated with zones of significant crustal weakness. It does, however, suffer occasional tremors. The origin of the strongest of these events is inferred to be a zone of weakness in the south-western Sydney Basin, south of the Penrith 1:100,000 sheet. Accurate earthquake record data has only been collected since 1909. Some "felt" intensity record data extend back to the

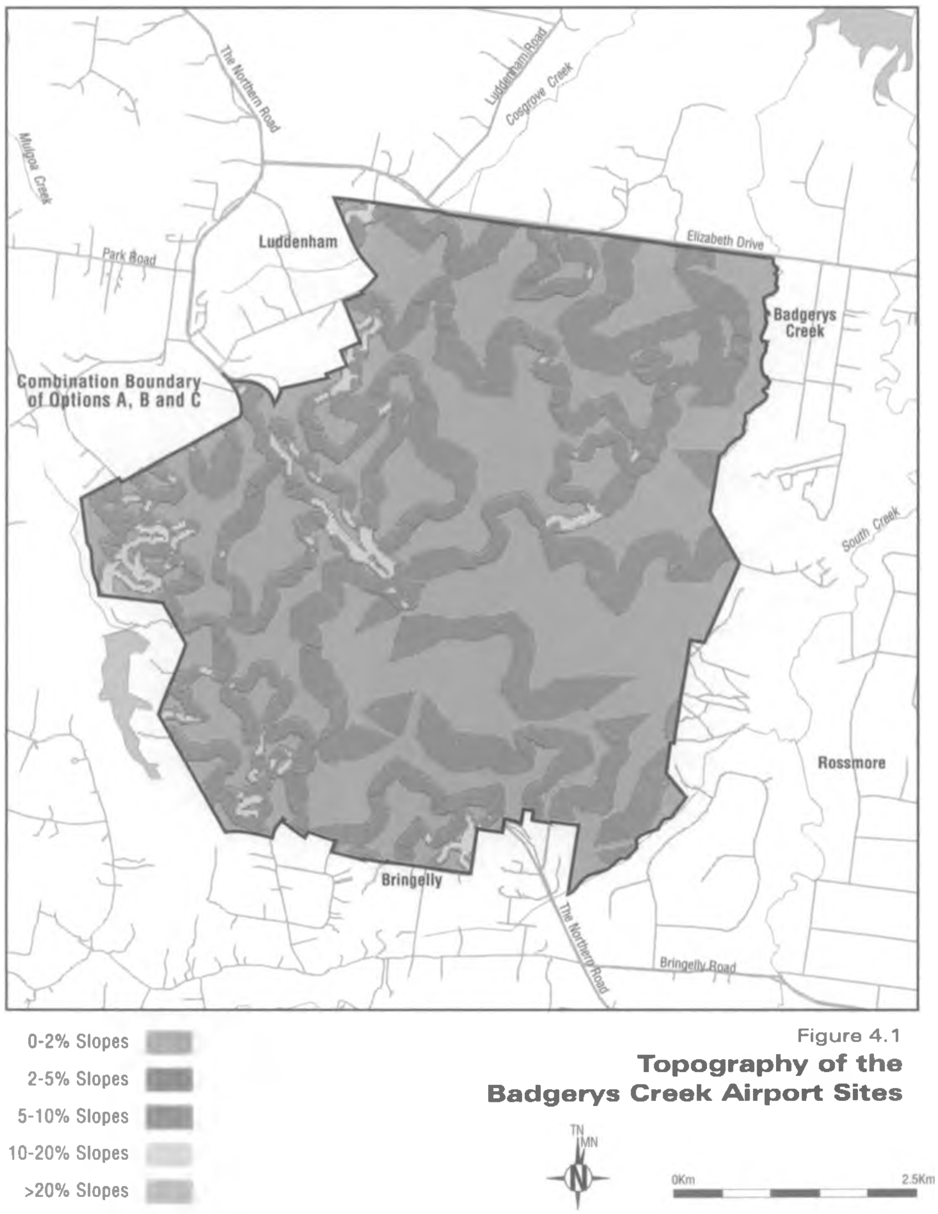


Figure 4.1
Topography of the Badgerys Creek Airport Sites

early 19th century. While 70 years of records cannot be considered a long period in term of natural geological processes, it is considered sufficient to indicate that the region is probably not in or near a strongly seismic active zone.

The proposed Badgerys Creek airport site is underlain by three soil landscapes as identified by the NSW Soil Conservation Service (Bannerman and Hazelton, 1990). Soil landscapes are defined as areas of land that have recognisable and describable topography and soils, that are capable of being represented on a map, and of being described by concise statements. The three soil landscape units identified within the area comprise:

- Luddenham;
- Blacktown; and
- South Creek.

Table 4.1 indicates the general extent of the various soil landscapes within the study area, while *Figure 4.2* illustrates these soil types.

Hydrology

Badgerys Creek and South Creek have the potential to cause flooding. Areas adjacent to the sites of the airport options, and downstream are within the one in 100 year flood zone, and are considered as flood liable land (Taskforce on Planning, 1995). Accepted planning criterion in Sydney is to exclude development from such flood prone land unless protective measures are put in place and the impact on the creek system is understood.

The sites of the Badgerys Creek airport options are part of the South Creek Catchment, a subcatchment of the Hawkesbury-Nepean Catchment. Major tributaries which enter South Creek from the east in the Badgerys Creek study area include Rileys Creek, Kemps Creek, Ropes and Eastern Creek. Other tributaries are Thompson Creek, Badgerys Creek, Cosgrove Creek and Blaxland Creek which enter South Creek from the west.

Daily flows in South Creek are measured at Richmond Road by Sydney Water Corporation (Site HYDAY V25). Flows of up to 30,000 megalitres per day have been recorded in South Creek at Richmond Road during floods, but typical flows are considerably less. The minimum and 50 percentile flows were about 20 and 42 megalitres per day, respectively, for the period of record between 1990 and 1994, according to the *Second Sydney Airport - Planning and Design Study* Report (Second Sydney Airport Planner, 1997a) Low flows lasted for periods of up to two months during this period.

Peak runoff values and flood levels are shown in *Tables 4.2* and *4.3*.

TABLE 4.1 - CHARACTERISTICS OF SOIL LANDSCAPE UNITS AT BADGERYS CREEK

Soil Landscape Unit	Topography	Local Relief	Slopes	Soil Types	Dominant Soil Material	Soil Depths	Intrinsic Fertility	Existing Erosion	Erosion Hazard
Luddenham Erosional Soil Landscape Unit	Low rolling to steep low hills	50 to 120 metres	5 to 20 percent	Dark podsolic and massive. earthy clays on crests; red podsolic soils on upper slopes; yellow podsolic and prairie soils on lower slopes and drainage lines	Loam and/or clay loam A Horizon, light to medium clay B Horizon	less than 150 cm	Moderate to high	minor gully and moderate sheet erosion	Moderate to very high
Blacktown Residual Soil Landscape Unit	Gently undulating rises	Less than 30 metres	Less than 10 percent	Red and brown podsolic soils on crests; yellow podsolic soils on slopes and drainage lines	Loam and/or clay loam A Horizon, light mottled clay B Horizon	less than 100 cm	Moderate to high	Minor sheet and gully erosion	Slight to moderate for non-concentrated flows; moderate to high for concentrated flows
South Creek Fluvial Soil Landscape Unit	Flat terrace tops dissected by small drainage lines	less than 10 metres	less than 5 percent	Red and yellow podsolic soils on terraces, structured plastic clays	Loam and or clay loam A Horizon, light to medium clay B Horizon	Often very deep (>2 metres)	Low to moderate	Stream bank and sheet erosion of floodplain	Potentially very high to extreme

Source: Bannerman & Hazelton (1990).

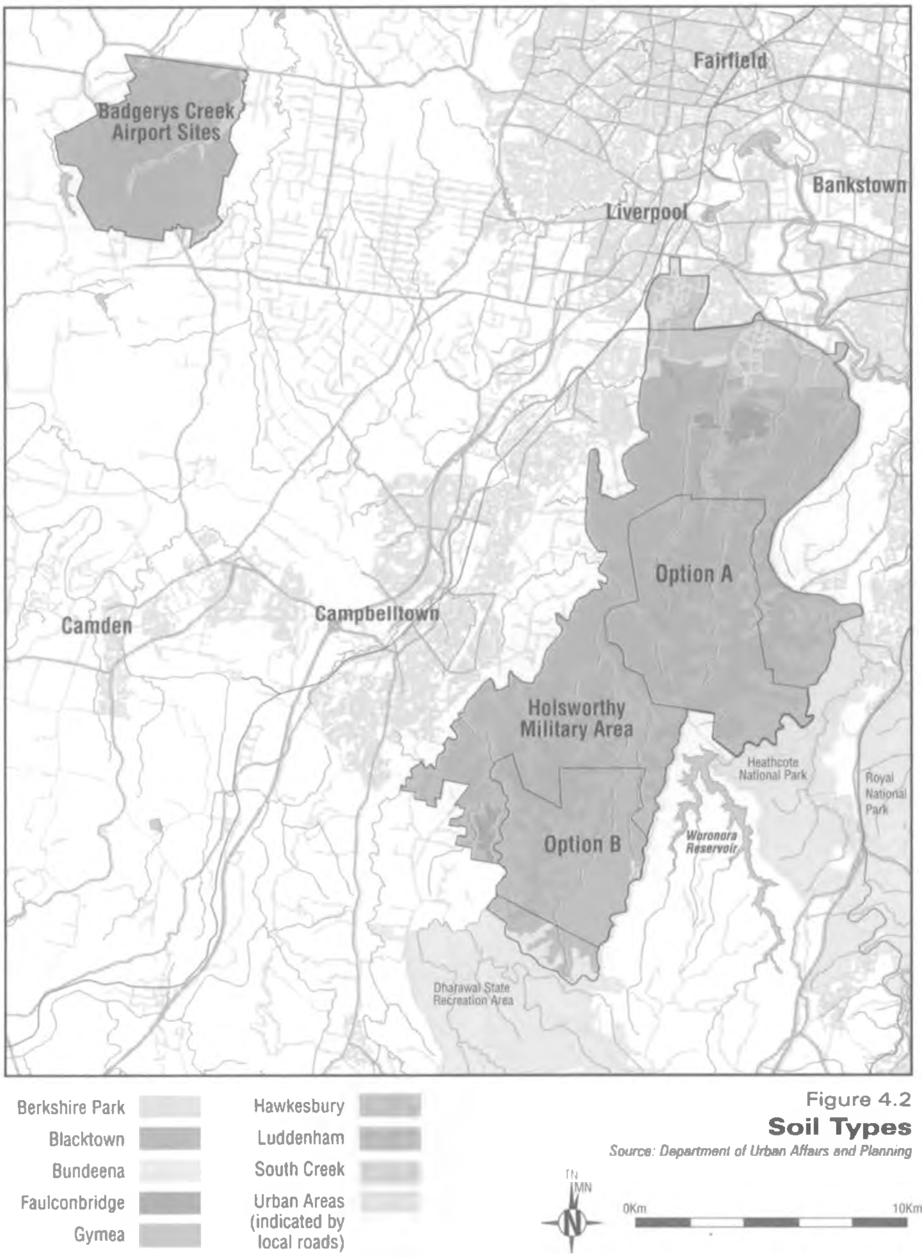


Figure 4.2
Soil Types
Source: Department of Urban Affairs and Planning

TABLE 4.2 PRE-DEVELOPMENT PEAK DISCHARGES AT ELIZABETH DRIVE

Water Course	10 year Average Return Interval (cubic metres per second)	100 year Average Return Interval (cubic metres per second)
Oaky Creek	25	39
Badgerys Creek	91	153

Source: Badgerys Creek hydrological model, Snowy Mountains Engineering Corporation 1991

TABLE 4.3 PRE-DEVELOPMENT 100 YEAR AVERAGE RETURN INTERVAL FLOOD LEVELS IN BADGERYS CREEK

Location	Water Level, RL (m AHD)
300 metres downstream of Elizabeth Drive	45.0
5 metres upstream of Elizabeth Drive	46.7
Gardiner Road	49.7
Upstream of Pitt Street	50.9
Leggo Street	54.1
Upstream of Badgerys Creek Road	58.7
1,240 metres upstream of Badgerys Creek Road	62.8
2,300 metres upstream of Creek Road	66.8

Source: Badgerys Creek Hydrological model, Snowy Mountains Engineering Corporation 1991

Rivers and Streams

Major tributaries which enter South Creek from the east in the Badgerys Creek study area include Rileys Creek, Kemps Creek, Ropes and Eastern Creek. Other tributaries are Thompsons Creek, Badgerys Creek, Cosgrove Creek, Oaky Creek and Blaxland Creek. These enter South Creek from the west.

General descriptions of the original Badgerys Creek airport site (Snowy Mountains Engineering Corporation, 1995) state that the surrounding land use is predominantly agricultural with much of the area being used for grazing beef, dairy cattle and sheep. Poultry and pig farming combined with vegetable cropping form minor industries in the area. Currently there are no water supply or sewerage systems influencing water quality in the area. However, rural industries and the presence of a high number of dams (over 100) have adversely affected water quality. None of the farm dams have sufficient storage to affect flood behaviour, but could be a source of algal blooms.

Reservoirs

Lake Burragorang is the predominant water supply for Sydney and parts of the Blue Mountains and was created by the construction of Warragamba Dam. Currently the lake provides approximately 70 percent of the water for over 3.7 million people, it is one of the largest water supply storages in the world, holding 2,057,000 million litres of water (Sydney Water and National Parks and Wildlife Service, 1997a).

Potential issues affecting the management of Lake Burragorang in terms of water quality include:

- public health;
- soil erosion;
- fire;
- land use and development;
- recreation and access; and
- aircraft movements over the water catchment.

Lake Burragorang forms part of the Warragamba catchment area that is currently managed jointly by Sydney Water and the National Parks and Wildlife Service and is designated as a "Special Area". The waters within Lake Burragorang and the Kowmung River are classified Class S - Specially Protected Waters under the Clean Waters Act 1970 which prohibits the discharge of any waste to these waters. All other tributaries are Class P - Protected waters. Discharges to these waters must be licensed and must comply with the Clean Waters Regulation 1972. These classifications reflect the significance of the storage and its tributaries for water supply purposes (Sydney Water and National Parks and Wildlife Service, 1997a).

The quality of the water entering Lake Burragorang is usually worse than water extracted from the outflow (Sydney Water and National Parks and Wildlife Service, 1997a). The reason for this difference is attributed to the topography, which allows a long residence time for the water. This permits sedimentation and the assimilation of nutrients by organisms.

The Australian and New Zealand Environment and Conservation Council has recommended that, notwithstanding any treatment the water may receive, catchments of water storages should be protected to prevent the deterioration of the raw water quality (Australia and New Zealand Environment Conservation Council, 1992). Currently the quality criteria for drinking water is the National Health and Medical Research Council guidelines.

The quality of water taken from the dam has consistently achieved compliance with the Australia and New Zealand Environment Conservation Council guidelines for Raw Water for Drinking Water Supply, with the exception of iron, manganese, faecal coliforms and turbidity (Sydney Water and National Parks and Wildlife Service, 1997a). High levels of iron, aluminium and manganese are associated with runoff from the surrounding geological strata and soils. High faecal coliforms and turbidity are the result of surrounding land use activities and correlate with flood events. However, these "exceptions" are later removed through filtration and disinfection processes before drinking water enters the water supply system.

Giardia and Cryptosporidium have been detected at near zero levels which are comparable to other protected water storages and supplies around the world (Sydney Water and National Parks and Wildlife Service, 1997a).

Sydney Water's monitoring of the storage indicates that Lake Burragorang currently has a mesotrophic nutrient status which is an intermediate state between oligotrophic (low nutrient enrichment) and eutrophic (high nutrient enrichment) (Sydney Water and National Parks and Wildlife Service, 1997a). Therefore, maintaining current nutrient levels is essential in controlling algal blooms.

Prospect Reservoir until recently has been operated as an intermediate water supply storage reservoir. However, Prospect Reservoir currently operates as an emergency supplier of water, with Prospect Water Filtration Plant connected direct to the Warragamba pipeline. Approximately 85 percent of the Sydney Metropolitan area is serviced from this water treatment plant. This water storage area is utilised during periods when water supply from Lake Burragorang is interrupted for maintenance if water quality is poor. Therefore the water quality is maintained at a level suitable for drinking water (pers comm Paul Freeman, Sydney Water Corporation).

Potential issues concerning the management of Prospect reservoir include:

- public health;
- soil erosion;
- fire;
- noxious weeds and feral animals;
- recreational use and public access;
- land use and development;

- recreation and access; and
- aircraft movements over the water catchment .

The waters within the Prospect Catchment are classified Class S - Specially Protected Waters under the *Clean Waters Act 1970*, which prohibits the discharge of any waste to these waters. In addition, under the *Sydney Water Corporatisation Act (1994)* catchment regulations, it is classified as a Schedule 1 Area. This limits activities within the catchment.

Protected Areas or Areas of Special Concern

The Hawkesbury-Nepean River, downstream of its confluence with the Warragamba River and several of the Hawkesbury-Nepean tributaries, have not been classified in accordance with the Atlas of Classified Waters (1980).

Lake Burragorang, Prospect Reservoir, Duncans Creek and the Nepean River upstream of Warragamba River are classified as Class S waters.

Currently the Hawkesbury-Nepean catchment is undergoing an independent assessment by the Healthy Rivers Commission. A final report is planned for the end of 1997. Development of the airport would need to be consistent with the outcomes of the Commission's assessment.

A licensing system has been developed between Sydney Water and the Environment Protection Authority called the South Creek Bubble Licence which covers three sewage treatment plants (Riverstone, Quakers Hill and St Mary's) in the South Creek area. The "bubble" licence aims to limit the total load of nutrients within South Creek but allows licensees flexibility in operating sewage treatment plants. Under this licence system it is hoped to firstly reduce Total Phosphorus concentrations in the Hawkesbury-Nepean River, initially to 0.01 to 0.03 milligrams per litre, and then reduce Total Nitrogen levels to 0.1 to 0.5 milligrams per litre (Environment Protection Authority, 1996). Exports from stormwater quality structures and effluent treatment systems within the proposed Badgerys Creek airport site may need to be accommodated within the "bubble licence".

The draft *Sydney Regional Environmental Plan No. 20 Hawkesbury-Nepean River* replaces the original *Sydney Regional Environmental Plan No. 20 Hawkesbury-Nepean River* and amendments to that Plan. It also incorporates amendments to *Sydney Regional Environmental Plan No. 20 Hawkesbury-Nepean River* exhibited in 1995 as draft amendment No. 2 (Department of Urban Affairs and Planning, 1996c). *Sydney Regional Environmental Plan No. 20* was gazetted in September 1989 to guide planning and development within the Hawkesbury-Nepean River. Under this plan, no wetlands of significance have been identified for the Badgerys Creek Study Site (Department of Urban Affairs and Planning, 1996b).

No natural heritage listings, such as wetlands or outstanding natural features are documented for the Badgerys Creek site.

External to the site there are heritage listings for:

- Bents Basin State Recreation Area and adjacent areas; and
- Kemps Creek Natural Area.

The Hawkesbury-Nepean Catchment Management Trust has particular interest in the Badgerys Creek site especially in the context of the Trust's goal of achieving a healthy, productive and diverse Hawkesbury-Nepean Catchment.

More specifically, the Trust's policy on water quality and quantity outlines that any development on the site must not lead to a deterioration of the ecosystem or compromise its environmental values. The Trust has also stated that on-site and off-site issues should also be assessed. Of particular concern are the potential issues of fuel fall-out on the Hawkesbury-Nepean catchment and the Warragamba Dam reservoir and the impacts of any new sewage treatment plants.

The Trust has identified the following environmental values for water:

- any water flow or changes in flow from the area should not alter the downstream natural hydrology (frequency or peaks) for all events up to the one in two year storm event (30 minute event), and should not alter the downstream peak levels for the events up to the one in 100 year even;
- surface runoff should not compromise the:
  - Australia and New Zealand Environment Conservation Council Guidelines Standard for Healthy Rivers - Aquatic Ecosystems, Irrigation for Non-commercial Crops; and
  - National Health and Medical Research Council Guidelines for recreational water quality - visual amenity and secondary contact recreation.
- groundwater should be protected from the impacts of any contaminated surface waters.

The South Creek Catchment Management Committee (Catchment Management Act, 1989) has identified six zones for environmental values for water for the South Creek Catchment (Hawkesbury-Nepean Catchment Management Trust, 1996). These zones also reflect potential changes in land use including the construction of the Second Sydney Airport.

Construction of a Second Sydney Airport would occur within the upper sections of the South Creek Catchment. Therefore the South Creek Catchment Management Committee has significant interest in the effects of the airport construction both on-site and downstream. The South Creek Catchment Management Committee has decided that an acceptable quality of water would be the standard for primary recreation and fishing as defined by the Australia and New Zealand Environment Conservation Council water quality guidelines (1992). Also the South Creek Catchment Management Committee has concerns about the operation of a sewage treatment plant in this area as there are currently no sewage treatment plants operating in the upper catchment.

Other areas of special concern include features such as dams and drainage basins which alter the flow and quality of surface run-off. Within the Badgerys Creek site there are approximately 115 dams which provide for the local water supply, in particular for agricultural purposes. Additionally there are drainage basins including Duncans Creek, Cosgroves Creek and Badgerys Creek.

There are also recreational areas and wetlands associated with the downstream section of South Creek.

Groundwater

The Badgerys Creek airport site overlies Mid Triassic sedimentary rocks belonging to the Bringelly Shale, the uppermost unit of the Wianamatta Group. The Wianamatta Group attains a maximum thickness of approximately 140 metres beneath the site (Penrith 1:100,000 Geology Map).

Quaternary alluvium overlies the Bringelly Shale along Badgerys Creek and Cosgroves Creek - the two main water courses on the site. The alluvium typically consists of sand, silt, and clay.

The Luddenham Dyke transects the western side of the site, forming an elevated ridge that extends south east from Luddenham. The dyke is 2 to 3 metres wide, 8 kilometres long and dips to the south west at around 85 degrees. It is composed of olivine basalt and is commonly weathered to a depth of 15 metres (Dames and Moore, 1996).

The sedimentary rocks of the Wianamatta Group generally have extremely low matrix porosity, and groundwater storage and transmission is facilitated through secondary structures such as fracture and joints. Salinity information for bores completed within the Wianamatta Group (Old, 1942) indicates that groundwater is generally too saline (up to 31,750 milligrams per litre of Total Dissolved Solids) for most practical uses, particularly within the centre of the Cumberland Basin.

The source of the salt is most likely the marine lithology of the Group. Reported yields from boreholes are generally extremely low (Jones and Clark, 1991). Most successful water bores drilled within the Wianamatta Group are either located on the elevated margins of the Cumberland Basin, or penetrate through to the underlying Hawkesbury Sandstone where water quality is better.

4.2.2 HOLSWORTHY

Topography, Geology and Soils

The Holsworthy Military Area comprises steep, rugged terrain ranging from above 200 metres in the south to below 50 metres in the north and west. The landform consists of a series of ridges and gullies containing deep entrenched creek systems. This is illustrated in *Figure 4.3* which shows slope classes within the Holsworthy Military Area. Drainage is generally north via the Georges River.

Reference to the 1:100,000 Geological Series Sheet for Wollongong - Port Hacking and Penrith, indicates that the majority of the site is underlain by Triassic rocks (Hawkesbury Sandstone and Ashfield Shale) and with some Quaternary and Tertiary sediment deposits to the north of the site.

Hawkesbury Sandstone consists of about 95 percent quartoze sandstone, with the remaining five percent consisting of siltstone/fine sandstone laminite, siltstone, and claystone interbeds. The sandstone varies from fine to coarse grained with the major part being medium grained. Angular clusts of dark grey claystone and siltstone are common near claystone and siltstone interbeds, and in places form an apparent interforational breccia.

The interbeds of laminite, siltstone, and claystone generally occurs as lenses within the sandstone and are commonly referred to as "shale lenses". They are usually mid to dark grey in colour, lensoidal in shape, and grade into the overlying sandstone or have sharp boundaries. These lenses vary in thickness from a few millimetres to more than 10 metres. Their lateral extent can sometimes exceed a kilometre, although most are much smaller.

The Ashfield Shale rests within an apparent disconformity on either the Mittagong Formation, or where this is absent, the Hawkesbury Sandstone. This unit forms the basal unit of the Wianamatta Group and where present varies in thickness from 40 metres to 60 metres. The unit consists of dark grey to blue black siltstone with interbedded laminite horizons. The bedding is usually uniform and less than 50 millimetres thick, although sporadic siderite concentrations and beds up to 300 millimetres thick are present in some places. The sandstone content of the unit increases towards the top, but no significant lateral variation has yet been detected.

The Mittagong Formation consists of fine grained quartzose sandstone interbedded with dark grey siltstone and laminite in beds up to 1m in thickness. The thickness of the unit varies from nil to up 6m with an average thickness of 2 metres. The base of the unit is taken to be the base of the lowermost persistent siltstone, while the top is taken as the top of the uppermost, laterally persistent quartzose sandstone bed.

Quaternary alluvium appears as accumulated surficial deposits along the Williams Creek, in the north-eastern corner of the airport site. The alluvium typically comprises fine grained sand, silt and clay.

Alluvial sediments, probably of Tertiary age occur as river terraces adjacent to the Georges River in the Holsworthy - Liverpool area. These sediments consist of up to 15 metres of clayey sand, silt and clay. In general, the clay is extremely plastic and consists of quartz, kaolinite, illite, and mixed-layered clay, while the sand consists of subrounded quartz grains. A well developed lateritic soil profile, developed on the alluvium, consists of bands of lateritic ironstone pebbles and red-grey mottled zones.

Circular mass slides and flow-type landslips occur due to the presence of large thicknesses of potentially slip-prone soil. Highly plastic, clayey soils developed on extremely weathered Ashfield of Bringelly Shale are potentially capable of slip where sufficient thickness of soil and a steep land slope coincide. Significant landslip phenomena are also present where Narrabeen Group strata are exposed. In all these case the instability is directly associated with a benched or terraced morphology, generated by the presence of resistant sandstones interbedded with more easily weathered shales and clays.

The common feature in all landslip areas is the presence of generally thick soil profiles, which are in places highly plastic or have poor cohesion. These areas commonly experience high subsoil pressures generated by the poor drainage characteristics of the surficial soils, especially at aquifer emergent sites such as at the tops of shale units. The tops of shale units are commonly weathered in part to clay, thus providing readymade slip surfaces for overlying soil, especially when they are lubricated with groundwater. Following periods of heavy sustained rainfall, raised groundwater levels provide the necessary conditions for the generation of high pore pressures. Such pressures have the potential to overcome the normal inherent restraining forces within the slope and trigger downslope soil movement.

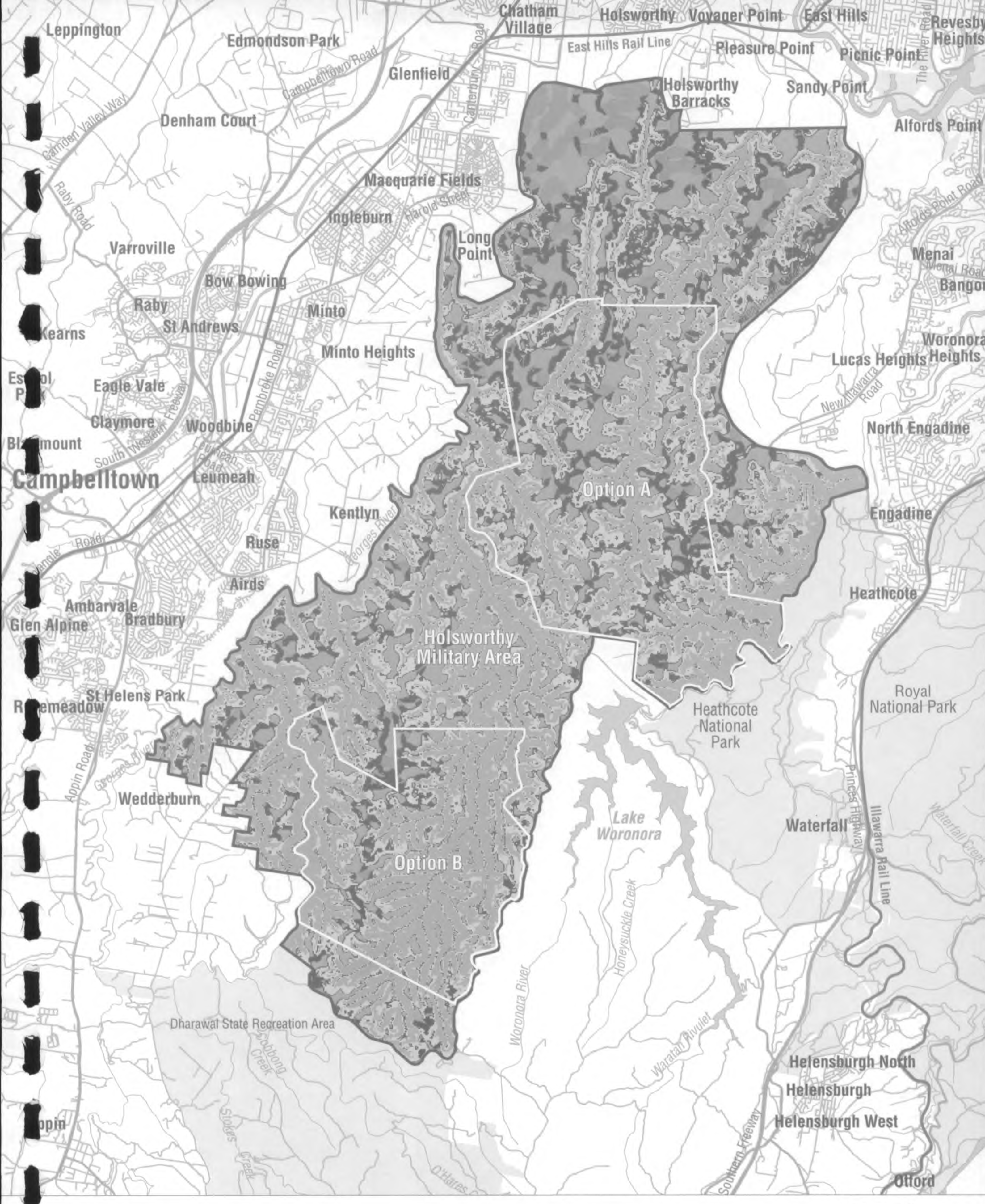


Figure 4.3

Slope Classes within Holsworthy Military Area

0-2% Slopes
2-5% Slopes
5-10% Slopes
10-20% Slopes
>20% Slopes

A systematic appraisal of seismicity in the Sydney Basin was not possible before 1958-1959 when a network of seismograph stations was established. Because of the short time of operation of the seismic network, no accurate projections of seismic activity in the Sydney Basin can be made. However, the data collected so far indicates that Sydney itself and the south coast of New South Wales have a relatively low seismicity, with most earthquakes occurring outside the Wollongong-Port Hacking 1:100,000 Geological Sheet area.

During the time that seismic activity has been recorded, none of the earth tremors/earthquakes originating in the Wollongong-Port Hacking sheet area is reported to have caused damage at the surface.

The sites of the Holsworthy airport options are underlain by five soil landscapes as identified by the NSW Soil Conservation Service (Bannerman and Hazelton, 1990). The five soil landscape units identified within the area comprise:

- Blacktown;
- Lucas Heights;
- Hawkesbury;
- Gymea; and
- Berkshire.

Figure 4.1 indicates the various extent of the various soil landscapes within the study area, the characteristics of which are shown in *Table 4.6*.

TABLE 4.6 - CHARACTERISTICS OF SOIL LANDSCAPE UNITS AT HOLSWORTHY

Soil Landscape Unit	Topography	Local Relief	Slopes	Soil Types	Dominant Soil Material	Soil Depths	Intrinsic Fertility	Existing Erosion	Erosion Hazard
Blacktown Residual Soil Landscape Unit	Gently undulating rises	Less than 30 metres	Less than 10 percent	Red and brown podsolic soils on crests; yellow podsolic soils on slopes and drainage lines.	Loam and/or clay loam A Horizon, light mottled clay B Horizon.	less than 100cm	Moderate to high	Minor sheet and gully erosion.	Slight to moderate for non-concentrated flows; moderate to high for concentrated flows.
Lucas Heights Residual Soil Landscape Unit	Gently undulating plateau.	Less than 30 metres	Less than 30 percent	Yellow podsolic soils and yellow soloths.	Dark brown to yellowish brown sandy loam A Horizon, yellowish brown sandy clay loam and clay B Horizon.	50 - 150cm	Low	Minor sheet and gully erosion.	Generally moderate for non-concentrated flows, but ranges from slight to extreme, high for concentrated flows.
Hawkesbury Colluvial Soil Landscape Unit	Steep, rugged slopes and ridges.	40-200 metres	Greater than 25 percent	Lithosols, earthy sands, yellow earths, yellow podsolic soils and siliceous sands.	Coarse quartz sands A Horizon, yellowish brown sandy clay loam and light clay B or C Horizon.	Less than 50cm	Low	Minor to severe sheet erosion.	Generally very high for non-concentrated flows, but ranges from moderate to high.
Gymea Erosional Soil Landscape Unit	Undulating to rolling low hills.	20-80 metres	10-25 percent	Yellow earths, siliceous sands and lithosols, earthy sands, gleyed and yellow podsolic soils, earthy sands and leached sands.	Coarse sandy loam A Horizon, yellowish brown clayey sand B Horizon, yellowish sandy clay and yellowish brown clay B Horizon.	30-300 cm	Low	Minor gully and severe sheet erosion.	Generally high to very high for non-concentrated flows, but ranges from moderate to extreme, high to extreme for concentrated flows.
Berkshire Park Fluvial Soil Landscape Unit	Flat terrace tops dissected by small drainage lines	Less than 10 metres	Less than 5 percent	Solods, yellow and red podsolic and chocolate soils.	Heavy clays and clayey soils, often mottled and containing ironstone nodules.	less than 450cm	Marginal	minor sheet, rill and wind erosion.	Low to moderate for non-concentrated flows; high for concentrated flows.

Source: Bannerman & Hazelton (1990).

Hydrology

The Holsworthy site represents 15 per cent of the catchment of the Georges River. The Georges River has its source near Cataract and flows north towards Liverpool before looping generally to the south and east.

Major tributaries in and around the sites of the airport options include Williams Creek, Deadmans Creek and Harris Creek which drain north to the Georges River near East Hills. Punchbowl Creek, O'Hares Creek, and Stokes Creek flow to the upper reaches of the Georges River. Wappa Creek, Lyretail Gully and Wallaby Creek drain to the Woronora River.

Existing hydrological information which adequately defines expected flowrates and runoff volumes is not available for Holsworthy. From field observation it is clear that the streams in the area have low average flows but are subject to occasional significant flood flows (Second Sydney Airport Planners, 1997a).

Simplified hydrological models have been used by the airport planners to estimate both pre and post development flows (Airplan, 1997).

Reservoirs

Woronora Dam and storage (Lake Woronora) supply water to southern areas of Sydney via the Woronora and two Helensburgh pipelines. (Sydney Water and National Parks and Wildlife Service, 1997b). Depending on demand, the reservoir can supply the southern suburbs of Helensburgh, Engadine, Lucas Heights, Sutherland and Penshurst/Allawah.

The dam, storage areas and tributaries have been classified under the Clean Waters Act, 1970. All waters within the Woronora Special Area are given the highest classification, Class S, Specially Protected, prohibiting discharge of waste to these waters. O'Hares Creek and tributaries of the Woronora storage are Class P - Protected Waters and discharges must be licensed in accordance with the Clean Waters Regulation 1972.

To date, water quality has generally met Australia and New Zealand Environment Conservation Council water quality guidelines for Raw Water for Drinking Water Supply and the Guidelines for Protection of Aquatic Ecosystems (Sydney Water and National Parks and Wildlife Service, 1997b). The only exceptions have been iron, manganese and aluminium and occasionally faecal coliforms or turbidity which were associated with rainfall events. However, current filtration processes remove these impurities. The high aluminium content of this water supply is considered to be due to natural influences.

Sydney Water operates four reservoirs, Cataract, Cordeaux, Nepean and Avon on the Upper Nepean River system.

Generally water quality within Cataract, Cordeaux and Avon storages has met the Australia and New Zealand Environment Conservation Council Guidelines for Raw Water Supply and Guidelines for Protection of Aquatic Ecosystems. Although iron, manganese and aluminium levels exceeded guidelines, water filtration provides protection to the drinking water supply (Sydney Water and National Parks and Wildlife Service, 1997b).

The Nepean storage has high aluminium levels. Turbidity has, in the past, been high but has improved in recent years. Chlorophyll a, indicative of algal growth, has exceeded concentrations recommended by the Australian Council for reservoirs (Sydney Water and National Parks and Wildlife Service, 1997b). Poorer water quality is attributed to agricultural activities and highly erodible soils in the upper sections of the catchment.

Water release from Lake Nepean, Cordeaux Reservoir and Cataract Reservoir are for supply requirements and are therefore intermittent, with the release flow and frequency being determined by supply requirements (Sydney Water and National Parks and Wildlife Service, 1997b).

The upper Nepean reservoirs supply water to suburbs including Camden, Campbelltown and parts of the Wollondilly via the Macarthur water filtration plant. In addition the reservoirs supply water to areas in the Illawarra region (in particular the Wollongong, Kiama and Shoalhaven Local Government Areas) via the Illawarra filtration plant. At the Nepean dam potable water is supplied to rural areas which include Bargo, Picton, Thirlmere, Tahmoor, The Oaks, Buxton and Oakdale. Water can also be provided from these dams to Prospect Reservoir via the upper canal (Sydney Water and National Parks and Wildlife Service, 1997b).

Protected Areas or Areas of Special Concern

O'Hares Creek has been identified as a Special Area (75 square kilometres), which includes land that drains to the confluence of O'Hares and Stokes Creeks. Sydney Water has no current or future interest in developing the O'Hares Creek Special Area for water supply purposes and will be pursuing deproclamation of this special area. (Sydney Water and National Parks and Wildlife Service, 1997b).

Currently Sydney Water and National Parks and Wildlife Service have agreed to negotiate the divestment of Sydney Water owned and managed lands within the O'Hares Creek Special Area. These lands were intended to be incorporated in the Dharawal State Recreation or Dharawal Nature Reserve and managed by National Parks and Wildlife Service. Approximately 83 percent of the O'Hares Creek Special Area is gazetted as the Dharawal

Nature Reserve and Dharawal State Recreation Area under *the National Parks and Wildlife Act 1974*.

The *Soil Conservation Act, 1938*, Sections 21 a and b identifies prescribed streams and protected land which is currently being administered by the Department of Land and Water Conservation. Whilst no protected lands were identified, O'Hares Creek was identified as a Prescribed Stream. Prescribed Streams are areas mapped as being environmentally sensitive, or affected by or liable to erosion, siltation or degradation." (Soil Conservation Service, 1938). This places restrictions on the removal of riparian vegetation which may affect water quality.

Within Holsworthy Military Area, the following creeks are classified as Class C (Controlled Waters) under the *Clean Waters Act, 1972*:

- Deadmans Creek;
- Williams Creek;
- Harris Creek;
- Georges River;
- Punchbowl Creek; and
- O'Hares Creek (also Class P in upstream sections above the junction with Stokes Creek).

This level of classification permits discharges subject to approved treatment for the removal of contaminants and to adequate dilution of the discharge being available in the receiving waters." (State Pollution Control Commission, 1980).

In addition there are several other classifications within the Holsworthy Military Area, which include the following:

- O'Hares Creek Class P (Protected Waters) - Discharges of effluents into Class P' waters are limited to those with a quality similar to that required as a 'raw' source of potable water." (State Pollution Control Commission, 1980); and
- Woronora Dam and a small section of O'Hares Creek (approximately one kilometre upstream from Junction with Stokes Creeks) are classified as Class S (Specially Protected Waters). Within this classification no effluents may be discharged and all waters flowing to Class S' waters are classified as Class P' (State Pollution Control Commission, 1980). Therefore, special measures need to be implemented to control land use within the catchments of Class S' Waters.

There are no wetlands within the Study sites that are affected by State Environmental Planning Policy No. 14 Coastal Wetlands (pers comm, Susan Harrison, Department of Urban Affairs and Planning). However, the Voyager Point wetlands on the Georges River is on the Register for the National Estate as administered by the Australian Heritage Commission.

As a component of the *Australian Heritage Commission Act* a national inventory is maintained of places identified as components of the National Estate. Entry in the register gives some protection to a place under Section 30 of the Act. Section 30 only applies to the Federal Government, and listing a place in the register does not provide any direct legal constrains or controls over the actions of State or local governments. (Australian Heritage Commission, 1994).

An action is considered to have an adverse affect on a place in the register if it diminishes or destroys any of the national estate values which have led to its inclusion in the register.

Within the Holsworthy Military Area the following listings occur:

- O'Hares Creek Catchment (Class Natural) approximately 7,500 hectares; and
- Holsworthy Army Camp (Class Historic).

External to the site are:

- Voyager Point Wetlands.
- Other non-listed areas of concern are:
- Chipping Norton Lakes; and
- Lake Moore.

The Australian Heritage Commission decided on 24 July 1997 to place the 18,000 hectares of the Holsworthy Military Area on the Interim Listing of the Register of the National Estate. It is to be described as the Cubbitch Barta National Estate Area.

Groundwater

Both of the sites of Holsworthy airport options are located on the Woronora Plateau, a geomorphological unit that is tilted towards the north and deeply incised by northward flowing creeks. Surface rocks belong to the Middle Triassic Hawkesbury Sandstone.

The Hawkesbury Sandstone has a relatively low matrix permeability and as such aquifer (water yielding) potential is dependant upon fractures and other structural features which enhance permeability. The yields from bores in the sandstone range from 0.2 to 11.3 litres per second, with an average yield of 1.3 litres per second. Water is generally of good quality, ranging in salinity from 100 to 1,000 milligrams per litre total solids. Pumping tests from coal mines in the Tahmoor area gave transmissivities between five and 50 square metres per day, but these are thought to represent higher yielding parts of the formation (Sherwin and Holmes, 1986).

5 RESULTS OF SURVEYS

5.1 SURVEY RESULTS

5.1.1 BADGERYS CREEK

Surface Water

Physical and chemical constituents of surface water were sampled by Robyn Tuft and Associates at seven sites from four streams across the Badgerys Creek site. Site descriptions are provided in *Table 5.1*. Survey result data for chemical and physical constituents is provided in *Appendix A*. Site locations are shown in *Figure 3.1*.

TABLE 5.1 SITE LOCATIONS - BADGERYS CREEK

Site Name	Site Description	Grid Reference
Duncans Creek, Dn1	300 metres upstream of Bridge along Greendale Road, Greendale	462 821, Warragamba
Thompsons Creek, T1	Sample point is 500 metres upstream of bridge crossing via a newly constructed road called 'The Retreat'	437 914, Warragamba
Cosgroves Creek, C1	100 metres upstream from Bridge near the junction of Adams Road and Elizabeth Drive	498 888, Warragamba
Cosgroves Creek, C3	Access via Bangalla Research Station 516 903	514 904, Warragamba
Badgerys Creek, B1	Sample site approximately 200 metres from the end of Mersey Road 457 888	457 887, Warragamba
Badgerys Creek, B2	Sample site approximately 200 metres upstream from bridge at Badgerys Creek road intersection with Badgerys Creek	466 906, Warragamba
Badgerys Creek, B3	Sample site upstream of bridge at Elizabeth Drive Intersection with Badgerys Creek	489 923, Liverpool

Duncans Creek (Dn1) samples were taken at a large and deep pool section with thick stands of macrophytes along the banks, which included *Potamogeton tricaninates, Typha, Azolla* and *Alisma*. Pasture grasses were the dominant riparian vegetation as the creek passed through open grazing land. Although the banks and adjacent areas were quite stable at the time of sampling, the creek was channelised forming a series of deep pools with connecting shallower reaches, suggesting that erosion had occurred during periods of high rainfall. Erosion was probably exacerbated by cattle.

Sediments from this erosion were evident in the creek bed with a high proportion of fine substrate fractions such as sands, silts and clays being present. These fractions, particularly clays, probably contributed to the brown and turbid appearance of the water. There was no apparent flow and a sulphurous odour was detected indicating low oxygen and/or anoxic conditions. This was also reflected by observations of carp coming to the surface for air. Other animals recorded at the site included an eel, two types of frogs, one identified as *Crinia sp* (common Eastern Froglet) and an Eastern Water Dragon.

Thompsons Creek (T1) was characterised by deeply eroded banks supporting small patches of vegetation. The banks were stabilised to some degree by the roots of *Casuarinas* which were the major riparian plant. These trees grew quite thickly, casting shadows across the creek at the site. Despite these shady conditions, macrophytes including *Potamogeton crispus* were present with the emergent *Typha* growing upstream of the site. The creek had diminished into a series of pools with very little or no flow in the adjacent riffle zones.

Low oxygen conditions were apparent as a sulphurous odour was evident when the bottom sediments were disturbed and an extensive iron and sulphur bacterial slick was observed. This slick contributed to the poor water clarity which was also influenced by the presence of clays in suspension. These clays as well as silts were the main substrate fractions, suggesting that the creek receives eroded material.

Also present in the stream bed were moderate levels of decaying vegetation and instream logs which probably contributed to the oxygen demand of the creek. Carp and mosquito fish (*Gambusia*), both introduced species, were the only fish observed.

Cosgroves Creek (C1 and C3) flows in a north easterly direction through predominantly agricultural land. The site at C1 is further upstream than site C3. At the time of sampling there was no flow and the creek had receded to a series of intermittent pools. The stream bed itself was channelised possibly indicating that high eroding flows have occurred. The upstream site had stable banks, covered in patches with reeds (*Typha*) and grasses. Riparian vegetation consisted predominantly of Casuarina trees.

Bedrock and clays were the main stream substrate fractions, suggesting in the upper reaches of the creek at least, that clays are the dominant soil type. Water was clear at this site, possibly due to the lack of rainfall. this had enabled sediments to settle out of the water column. In addition, sulphurous odours were not apparent, despite a fair coverage of decaying vegetation and logs in the stream bed. These conditions were not repeated downstream at site C3, where Casuarina needles lined a predominantly clay and silt stream bed, probably creating a considerable oxygen demand. This oxygen demand was evident, as sulphurous odours were detected upon disturbing sediments.

Water clarity was very poor and no fish or frogs were observed or heard. Conversely, the introduced fish, carp and *Gambusia* were evident at C1. Macrophytes were present along the creek, with the rooted floating *Triglochin* observed at site C1. Plants such as *Nitella* which are more characteristic of slow flowing waters were recorded at the downstream site.

Badgerys Creek (B1, B2 and B3) drains a rural/semi rural area where cattle grazing and intensive agriculture such as poultry farming and market gardening dominate the land use. Although the creek had relatively little or no flow at the time of sampling, eroded banks in the lower reaches at sites B2 and B3 suggested that high scouring flows do occur. The creek consisted of a series of intermittent pools. Riparian and bank vegetation alternated from closed shady areas dominated by Casuarinas to open sunny sections covered with grasses and at site B3, weeds such as *Tradescantia albiflora*.

Macrophytes were present at all sites, with rooted emergents such as *Typha* and *Trichglochin* abundant in the shallower reaches of the pools and floating types including *Lemna* (duckweed), *Azolla, Salvinia* and *Potamogeton* evident in the deeper sections. Water clarity was poor to very poor, probably a result of the predominantly clay stream bed substrate and high sediment loads.

Sulphurous odours were detected at all sites, indicating low oxygen conditions. Instream decaying detritus and logs were probably contributing to this oxygen demand. Fauna observed during sampling included the introduced *Gambusia* at site B1 and Carp at site B3. A native frog, *Crinia signifera*, was present at site B2.

Water quality assessment was based on the results of chemical analyses which are summarised in *Table 5.2* (full analyses are provided in *Appendix B*).

Results of analysis reflect nitrogen enriched systems, with generally poor levels of dissolved oxygen. Badgerys Creek at sites B2 and B3 appeared to be the most impacted, with high levels of ammonia and total phosphorus detected. In addition, high numbers of algal cells were apparent at site B2 and probably were responsible for the supersaturated dissolved oxygen concentrations and slightly alkaline pH.

TABLE 5.2 WATER QUALITY COMPLIANCE - BADGERYS CREEK

		Water Sampling Locations						
	ANZECC Guideline	**B1**	**B2**	**B3**	**C1**	**C3**	**T1**	**D1**
Total Nitrogen (mg/L)	0.5-0.75	0.6	3.3	0.9	0.5	1.01	0.6	✓
Total Phosphorus (mg/L)	0.01-0.05	✓	1.2	0.26	✓	✓	✓	✓
Ammonia Nitrogen (mg/L)	1.4	✓	✓	✓	✓	✓	✓	✓
Dissolved Oxygen (mg/L) /Percent Saturation	6(80-90%)	4.5 (63%)	12.2 (150%)	2.2 (24%)	3.1 (34%)	2.2 (25%)	2.2 (23%)	1.3 (15%)
Nickel (mg/L)	0.015-0.15	✓	✓	✓	✓	✓	✓	✓
Copper (mg/L)	0.002-0.005	0.005	✓	✓	✓	✓	✓	✓
Chromium (mg/L)	0.01	✓	0.01	✓	0.05	✓	✓	✓
Zinc (mg/L)	0.005-0.05	0.013	<0.01	<0.01	<0.01	0.018	0.018	<0.01
Lead (mg/L)	0.001-0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cadmium (mg/L)	0.0002-0.002	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Iron (mg/L)	1.0	✓	1.8	1.1	✓	✓	4.9	✓
Mercury (mg/L)	0.0001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

Waters in these catchments were generally more neutral in pH than that observed in the Holsworthy streams. Conductivities were higher than at Holsworthy, reflecting the local shale geology. It is also likely that the geology is influencing turbidity, in the form of fine clays. These clays are not represented by the suspended solids analysis. Higher levels of suspended solids are probably due to algal cells and/or larger sized sediment particles. These particles may arise as a result of farming practices. It is also probable that some farming activities could be contributing to dissolved salt concentrations.

The majority of nitrogen was in the organic form, with the oxidised forms remaining undetected at all sites except Thompsons Creek, where low levels of nitrate were recorded. Although ammonia toxicity concentrations were below Australia and New Zealand Environment Conservation Council Guidelines for the Protection of Aquatic Ecosystems, its presence, along with generally low dissolved oxygen levels suggests the streams were tending towards a reduced (anaerobic) state. Concentrations were highest in Badgerys Creek at B2 and B3, where total phosphorus and nitrogen results were near or above the maximum Australia and New Zealand Environment Conservation Council guidelines values. This is probably due to agricultural activities in the surrounding area.

Heavy metals within the catchment, apart from iron, were restricted to low concentrations of copper, chromium and zinc. In most instances, levels were at or below the relevant Australia and New Zealand Environment Conservation Council guidelines. However, chromium was elevated at four sites, Badgerys Creek at sites B2 and B3, Cosgroves Creek at site C1 and Thompsons Creek (T1).

Chromium is no longer used widely in agricultural chemicals, which suggests this contamination is likely to be historical (possibly from copper chromium arsenite). Conversely, copper is still widely used, particularly as an ingredient in fungicides which are extensively used in market gardens. It is therefore not unexpected for copper to be detected in a semi rural waterway. Zinc is a fairly ubiquitous metal and levels may be attributed to numerous sources including galvanised iron from building structures.

Zinc, copper and lead have also been identified in stormwater runoff from roads, both in particulate and soluble forms (Hogan et al 1995). It is therefore possible that air borne pollutants from roadways may fall back to the ground. In a recent study/series of studies, air borne lead was found to be a significant source of this metal. (Victorian Environment Protection Authority pers. com.).

Significant levels of iron were recorded in Badgerys Creek at sites B2 and B3 and in Thompsons Creek. Again the passage of groundwater into surface waters may increase iron concentrations through leaching processes. A sheen similar to that caused by iron/sulphur bacteria was apparent at most of these sites, particularly at Thompsons Creek. This suggests groundwater ingress. In addition, sulphurous odours were apparent once the sediments were disturbed. This also implies that the water was in a reduced state, consequently favouring the movement of iron into the system.

Trace amounts of anionic surfactants such as detergents occurred in Badgerys Creek, at sites B2 and B3 and at Cosgroves Creek at site C1. At such low levels it is difficult to attach any significance to the results. This analysis may detect other compounds which are not necessarily attributable to man made surfactants.

Total organic carbon levels were elevated, which is not unexpected given the increased productivity of these catchments. Although results show that most of the total organic carbon was not derived directly from organic chemicals such as aromatic and halogenated hydrocarbons, the increased nutrient concentrations responsible for higher productivity were the result of human activities. The highest level of total organic carbon, 25 milligrams per litre, was recorded at site B2 where an oily scum was observed on the surface of the water. This may well have contributed to the higher result.

Petroleum hydrocarbons, volatile aromatic and halogenated compounds, phenolics and polyaromatic hydrocarbons were not detected at any site.

There are approximately 115 farm dams in the Badgerys Creek area. A selection of dams were observed. The largest of these, Bringelly Dam, is over 1.5 kilometres in length when full. As the dam was situated in a feed lot area the banks of the dam were well worn by cattle and only very few riparian plants were observed. Erosion was evident around the sides of the dam and in the adjacent fields where extensive gullies had formed. Water clarity was poor with a high proportion of clays present.

The dams in the poultry research station Oroolong" consisted of smaller turbid reservoirs, with several larger clearer dams towards the east of the property. Water clarity in the smaller dams was poor, and iron and sulphur bacterial scums were apparent on the surface of some of the waterbodies. Rooted emergent macrophytes were present and periphyton (attached algae) covered submerged sections of the plants. This indicated that favourable conditions for algal growth, such as adequate nutrient levels, existed.

Longneck turtles, fish and tadpoles were recorded. The larger dams were located in grassy fields where no grazing was observed. Considerable stands of macrophytes bordered these water bodies and water clarity was high. Periphyton growth on macrophytes did not appear to be as extensive as in the western dams, suggesting that nutrient levels may be lower.

The "Green Acres" dams consist of approximately seventeen dams to the west of Bringelly. Although there were no cattle in the immediate area during the site inspection, grazing was evident in fields upstream of the dams. These waterbodies had large stands of macrophytes around the edges, with little sign of erosion. Water clarity was good.

Ecological health assessments were based on the types and abundance of aquatic flora and fauna detailed in *Appendix C*. Signal Indices and taxa for all sites are provided in *Figures 5.1* and *5.2*. *Figure 5.3* demonstrates the proportion of each sample within three pollutant tolerant groups.

Between 14 and 37 taxa were identified at each site, although diversity was found not to be correlated with SIGNAL index. SIGNAL Indices varied from 4.4 to 5.3 with Badgerys Creek at Elizabeth Drive showing the poorest ecological water quality (*Table 5.3*). An average of 32 percent of animals were from the most sensitive category (grades 7 to 10) and only 22 percent of animals were from the pollutant tolerant group (grades 1 to 3). This suggests

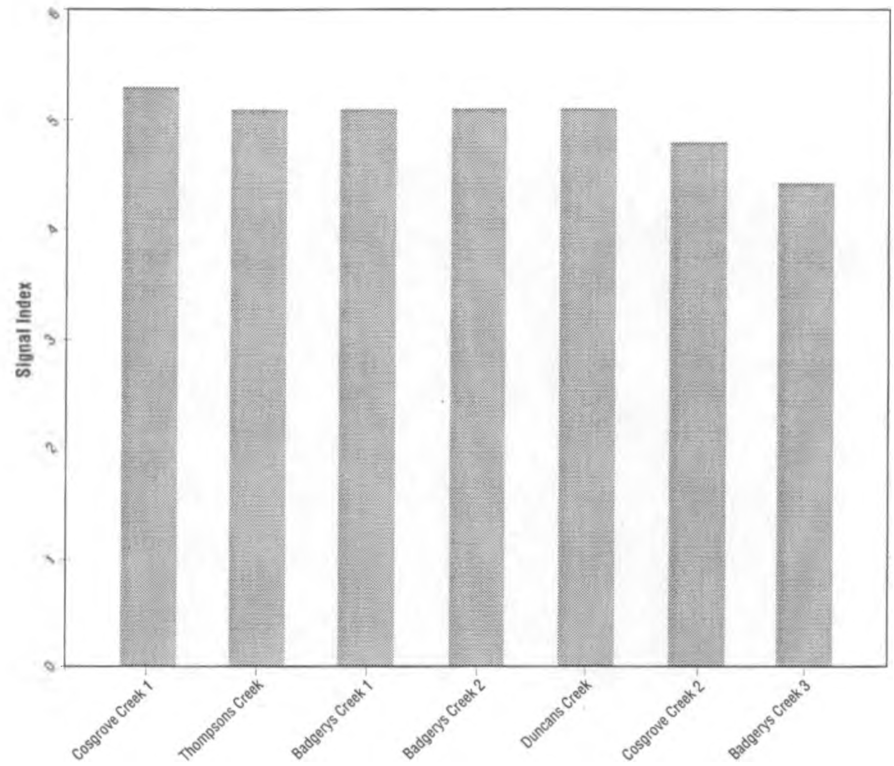


Figure 5.1
Macroinvertebrate - Signal Indices
Badgerys Creek

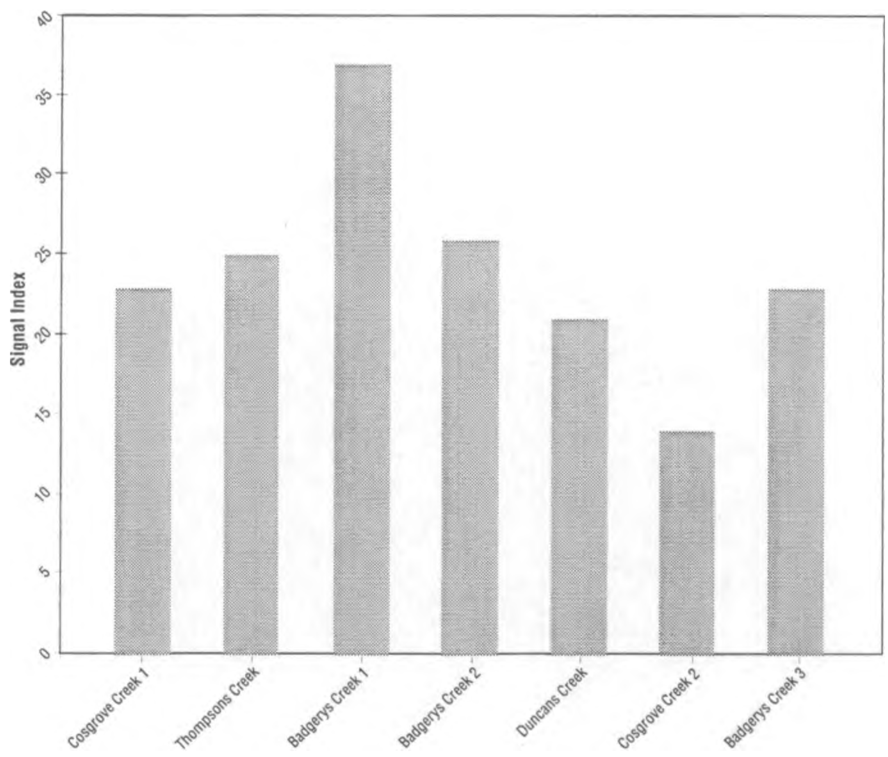


Figure 5.2
Macroinvertebrate - Number of Taxa
Badgerys Creek

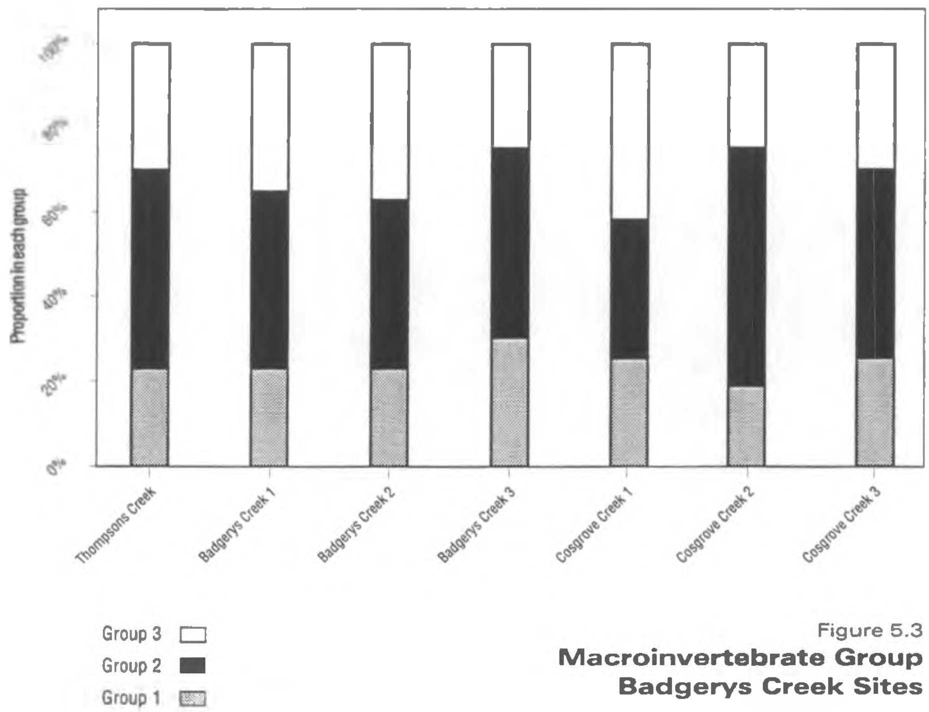


Figure 5.3
Macroinvertebrate Group
Badgerys Creek Sites

that the ecosystem is slightly impoverished but still allows development of sensitive fauna.

Both suspended and attached algae were analysed in the Badgerys Creek study. High numbers of phytoplankton were recorded in most of the streams except for Cosgrove Creek at site C1. The very shady nature of this site probably restricted algal growth. Other sites recorded as many as 5,900 cells per millilitre and diversity was large and typical of nutrient rich conditions. Most sites had one to three dominant organisms with smaller levels of other algae.

The most abundant organism was *Trachelomonas*, an alga associated with high concentrations of nitrogen, phosphorus and organic content (Round, 1977). Coverage of attached algae was usually extensive, growing on instream logs, detritus, sediments and macrophytes. At Cosgroves Creek, site C3, the bottom of the stream was covered with *Oscillatoria*. This blue-green algae is ubiquitous, however the combination of low light conditions and no flow may have allowed this organism to dominate over non blue-green algae.

TABLE 5.3 MACROINVERTEBRATE DATA - BADGERYS CREEK

Site Name	Number of Taxa	SIGNAL Index	Pollution Indicated	Ratio to Reference Site	Classification band
Badgerys Creek, B3	23	4.4	moderate pollution	0.7	mildly impaired
Cosgroves Creek, C3	14	4.8	moderate pollution	0.76	transition
Thompsons Creek, T1	25	5.1	mild pollution	0.81	transition
Badgerys Creek, B2	26	5.1	mild pollution	0.81	transition
Badgerys Creek, B1	37	5.1	mild pollution	0.81	transition
Duncans Creek, Dn1	21	5.1	mild pollution	0.81	transition
Cosgroves Creek, C1	23	5.3	mild pollution	0.84	transition

Groundwater

The Department of Land and Water Conservation licensed bore database search (limited to within three kilometres of the site) identified only four boreholes in the vicinity of the site. Coordinates were not supplied by the Department of Land and Water Conservation for one backfilled borehole (GW100136). Access consent could not be obtained for bores GW063062 and GW073533 to the south of the site and therefore the status of these bores is unknown. The bore licence for GW072774 applies to monitoring bores at the Elizabeth Drive Landfill. Licensed bore records are provided in *Appendix D.*

No groundwater chemistry data was located by the Department of Land and Water Conservation, although the bore record for the backfilled borehole (GW100136) reports salty groundwater. Limited chemical data was obtained from the Coffey Partners International (1991) study, as well as from the Elizabeth Drive Landfill EIS (PPK, 1993).

Water level information was obtained from twenty of the geotechnical holes drilled on the site by Coffey Partners International (1991), and from the ten monitoring bores located at the Elizabeth Drive Landfill. The Coffey Partners International boreholes are too widely spaced to enable accurate groundwater level contours to be generated. However, the Coffey Partners International data and the background Elizabeth Drive data indicate that the water table geometry is similar to the topography though in a subdued manner.

Table 5.4 summarises the Coffey Partners International borehole information. Reference to this table shows groundwater was encountered between 3.0 and 9.6 metres below ground level. The water levels in some holes were reported to fluctuate after rainfall.

TABLE 5.4 SUMMARY OF BOREHOLE INFORMATION AND GROUNDWATER LEVELS FROM COFFEY PARTNERS INTERNATIONAL (1991)

Borehole	Easting (mAMG)	Northing (mAMG)	Drilled Depth (mBGL)	Ground RL (mAHD)	SWL (mBGL)	Water RL (mAHD)
D1	286840	6245879	15.2	104.2	7.9	96.3
D2	287065	6246834	9.9	97.6	3.7	93.9
D3	287295	6247189	10.0	105.7	3.4	102.3
D4	287114	6247801	15.1	98.8	2.95	95.9
D5	288139	6247480	20.2	102.5	3.9	98.6
D6	287790	6246539	25.1	112.9	7.4	105.5
D7	288158	6245894	10.4	79.4	3.9	75.5
D8	289089	6246504	10.1	92.1	7.95	84.2
D9	289486	6247149	10.2	87.5	4.2	83.3
D10	289772	6247874	10.0	88.0	4.7	83.3
D11	289470	6248482	10.1	74.1	4.0	70.1
D12	291163	6249365	10.5	59.0	3.2	55.8
D13	290718	6247897	10.4	73.5	3.05	70.5
D14	292129	6248648	10.1	55.2	3.8	51.4
D19	288395	6248129	15.0	88.9	5.5	83.4
D22	287250	6246322	20.0	103.2	9.1	94.1
D23	287118	6247517	20.7	105.6	9.6	96.0
D29	288388	6247031	10.1	95.1	7.6	87.5

Source: Coffey Partners International, 1991.
Notes: mAMG = metres Australian Map Grid

mBGL – metres Below Ground Level
mAHD – metres Australian Height Datum
RL – relative level

Groundwater levels obtained from the Coffey Partners International (1991) data indicate that the elevated topography associated with the Luddenham Dyke acts as a local recharge area, and a groundwater divide. Groundwater flow is westerly to the west of the dyke, and north-easterly to the east of the dyke. Insufficient data exists to determine whether the dyke and likely associated jointing act as a feature of enhanced groundwater transmission.

Measured hydraulic conductivities at the Elizabeth Drive Landfill range from 5.2×10^{-5} to 1.7 metres per day with a geometric mean of 3.5×10^{-3} metres per day (PPK, 1993). The data indicate that rock mass permeability decreases with depth, and confirms that joints and fractures govern groundwater movement. Horizontal bedding planes and joints are reported to prevail over vertical and subvertical joints, giving an anisotropic rock mass where horizontal hydraulic conductivity is greater than vertical. Nested piezometers at the landfill also indicate that an upward pressure gradient exists at the landfill site.

The amount of groundwater seeping to Badgerys Creek from the airport sites is likely to be low given the low hydraulic conductivities of the bedrock and clayey soils.

Electrical conductivities for four groundwater samples obtained from the site are presented in *Table 5.5* (Coffey Partners International, 1991) along with baseline groundwater quality data from the Elizabeth Drive Landfill (PPK, 1993). Reference to the table shows the electrical conductivities values from the site range from 1350 microsiemens per centimetre to 14810 microsiemens per centimetre. Baseline groundwater quality data obtained at the Elizabeth Drive Landfill prior to cell excavation is consistent with the highly saline character of water within the Wianamatta Group.

TABLE 5.5 SUMMARY OF GROUNDWATER CHEMICAL PARAMETERS

Borehole	Electricity Conductivity (microsiemens per centimetre)	TDS (milligrams per litre)
D8	3010	2000 *
D9	14290	9400 *
D11	14810	9800 *
D13	1350	900 *
G1a	17700	9907
G3a	22190	10449
G4a	36600	17290
G5	31200	14695
G6	28000	13466
G7	28800	13479

Notes: * approximate values calculated from electrical conductivity values

D" series boreholes drilled by Coffey Partners International at the Badgerys Creek site
G" series boreholes drilled by AGC Woodward Clyde at Elizabeth Drive

All six Elizabeth Drive analyses returned electrical conductivities values in excess of 17700 microsiemens per centimetre, and values were observed to increase with depth. The highest value obtained was 36600 microsiemens per centimetre.

The relatively low salinities recorded for bores D8 and D13 are likely to reflect recent infiltration.

5.1.2 HOLSWORTHY

Surface Water

Physical and chemical Constituents were sampled by Robyn Tuft and Associates at thirteen sites, from eight streams within the Holsworthy Military Area. Site descriptions are provided in *Table 5.6* and sampling locations are shown in *Figure 3.2*.

TABLE 5.6 WATER SAMPLING LOCATIONS - HOLSWORTHY

Site Name	Site Description	Grid Reference
Harris Creek, H2	Sample point below creek junction	083 334, Campbelltown
Punchbowl Creek, P0	500 metres upstream of Engineers Bridge	063 295, Campbelltown
Punchbowl Creek, P1	500 metres upstream junction with Gunyah Creek	058 263, Campbelltown
Punchbowl Creek, P2	Access via the ruins' 042 202 of the Old Coach Road. Sample point is below the creek junction	047 196, Appin
Wappa Creek, Wa1	Access is via the 4WD road. Head south from 117 258 between the south facing escarpments	118 255, Campbelltown
O'Hares Creek, OH1	Downstream site. Approximately 700 metres upstream of Pheasant Creek intersection	017 224, Campbelltown
O'Hares Creek, OH2	Upstream site. Access via road heading roughly WNW off the Old Coach Road at 009 173	003 173, Appin
Georges River, Ge1	Site at the intersection of Old Coach Road and Georges River at Freres Crossing	042 289, Campbelltown
Deadmans Creek, D2	Downstream site. Located at the intersection of Deadmans Creek and National Park Road	119 337, Campbelltown
Deadmans Creek, D3	Upstream site. Located approximately 1 kilometre east off National Park Road	108 311, Campbelltown

Site Name	Site Description	Grid Reference
Gunyah Creek, G1	500 metres upstream of junction with Punchbowl Creek	061 264, Campbelltown
Williams Creek, W2	Downstream site	098 324, Campbelltown
Williams Creek, W3	Located approximately 1 kilometre west from National Park Road	094 284, Campbelltown

Harris Creek (H2) samples were taken at a long slow flowing pool bordered by reeds, grasses, ferns and Casuarinas. These trees cast considerable shadows across the water, possibly inhibiting the growth of macrophytes. The banks appeared to be quite stable although flood debris in adjacent riparian vegetation indicated that the creek experiences high flows. Stream substrates were mainly sands, reflecting the sandstone catchment. This sand was covered with significant proportions of detritus which probably exerted an oxygen demand at least in the bottom waters and sediments. This low oxygen condition was evident from the sulphurous odour emitted when decaying vegetation was disturbed. Turbidity was high, possibly from suspended algae and fine detritus. Aquatic macro-fauna such as fishes and frogs were not observed.

Punchbowl Creek (P0, P1 and P2) catchment is wholly contained within the Holsworthy Military Area and drains a large area of pristine or near pristine bushland. Erosion is minimal with virtually no smaller substrate fractions such as clays and sands being present. Water clarity also reflects this low sediment load with very little turbidity observed.

Relatively steep valleys characterise the surrounding area. No introduced riparian plants were evident. The creek consisted of a series of long slow flowing pools, often deep, with shorter riffle zones. Small amounts of detritus kept instream oxygen demand to a minimal level. Surface scums and odours were not detected. A low percentage cover, approximately 10 percent of macrophytes were present at sites P0 and P1. These were *Trichglochin*. Native fish were also recorded at these sites.

Wappa Creek (Wa 1) flows in an easterly direction on the eastern boundary of the Holsworthy Military Area. Although the stream was quite shallow at the time of sampling, approximately 20 centimetres average depth, bent riparian trees indicate that high scouring flows do occur. The ribbon like macrophyte *Triglochin* was recorded. The stream bed consisted mainly of sandstone bedrock with intermittent patches of sand, reflecting both the sandstone parent material and the low sediment load.

Apart from army exercises the catchment area is undisturbed. Consequently, water clarity was very high. Sulphurous odours were not detected, despite a fair proportion of detritus being present, indicating a low instream oxygen demand. The site consisted of a long pool approximately 50 metres in length. Riffle zones were not observed, however it is likely that such features were present further upstream and downstream. Fish and frogs were not observed.

Williams Creek (W2 and W3) was typical of the creeks within the Holsworthy Military Area, flowing through pristine sandstone bushland. Stream bed substrates were characterised by at least 50 percent sandstone bedrock, interspersed with patches of sand. The upstream site, W2 had lower amounts of sand probably a result of its location in the headwaters where steeper stream gradients encourage scouring. Sediments removed in the upper reaches were evident at site W3 were deposition of instream solids was found.

Water clarity was extremely high, again reflecting the low solid load in the water column. Both sites consisted of long shallow open pools with a small coverage of detritus. This decaying vegetation did not appear to create a large oxygen demand as sulphurous odours, an indicator of anoxic conditions, were not detected. Macrophytes were not observed , possibly as these may have been removed in high flows which had occurred several weeks prior to sampling.

Deadmans Creek (D2 and D3) appeared to have a high proportion (approximately 75 percent) of sand in the stream bed, suggesting the site is in a depositional zone. Some undercutting of the banks was also evident. Water clarity remained high despite the increased sediment load, as sand tends to fall to the bottom of the water column during periods of low to moderate flow. Native vegetation including ferns and Gymea lilies were the main riparian understorey plants, with eucalyptus dominating the canopy.

Some grasses were apparent on the sandbanks at site D3, whilst macrophytes including *Myriophylium, Phragmites, Beumea* and *Potamogeton* were observed at D2 in low numbers. A low coverage of detritus was recorded at both sites and although no sulphurous odours were detected, a ferrous iron deposit was observed at D3, which would create an instream oxygen demand. Fauna included an unidentified species of fish at D2 and a rat, probably native, at D3.

Gunyah Creek (G1) samples were taken at a location where the creek was reduced to a long narrow riffle flowing slowly along the edge of a broad flat area of sandstone bedrock. However flood debris indicated that flows can fill the entire bedrock area. Sand and silt deposits covered approximately 20 percent of the stream bed and adjacent banks. A platypus burrow was observed on one of these sandy sections, along with the common eastern froglet or *Crinia*. Sulphurous odours were not evident, indicating the relatively low coverage of instream detritus was not exerting a large oxygen demand. Water clarity was high, reflecting the undisturbed bushland catchment as well as the sandstone geology of the area. Macrophytes were not observed.

Georges River (Ge1) at the sampling site consisted of an open channelised system, slowly flowing through a mainly sandstone bed. Boulders and cobbles were present, as well as sand deposits. These were probably a result of erosion in the upper catchment. The river was at least two metres deep, however water clarity was high as the bottom could be easily observed. Macrophytes were not apparent, although periphyton coverage of algae was extensive. Riparian and stream bank vegetation was confined to native species. No fauna were recorded.

O'Hares Creek (OH1 and OH2) flowed through a broad open valley, in a series of very long pools, approximately 75 to 100 metres in length connected by short riffles. The depth in the pools was fairly shallow, between 30 to 50 centimetres. Stream substrates consisted mainly of the larger rock particles such as boulders, cobbles, pebbles and gravel. Small patches of sand were also evident. This wide array of substrates indicates the creek in these reaches carries sufficient flow to transport heavier rock fractions.

Macrophytes were restricted to very low numbers of *Triglochin* at site OH2. Flood debris in the trees along the river indicate that high flows are experienced in this creek. Water clarity was high and the lack of sulphurous odours indicate good levels of dissolved oxygen. Tadpoles were observed at OH1.

Water quality compliance is summarised in *Table 5.7*. *Appendices B* and *C* contain the full data set.

All streams had very good to excellent water quality, with low levels of nutrients, suspended solids and dissolved salts. Dissolved oxygen concentrations were within or near the Australia and New Zealand Environment Conservation Council Guidelines for the Protection of Aquatic Ecosystems and the acidic pHs were typical of sandstone catchments (Australia and New Zealand Environment Conservation Council 1992).

For the majority of sites, anthropogenic chemicals such as heavy metals, phenols, volatile aromatic and halogenated compounds and detergents were either not detectable or present at trace levels. Harris Creek, Wappa Creek and Punchbowl Creek, at site PO recorded the highest occurrences of detectable chemicals.

TABLE 5.7 WATER QUALITY COMPLIANCE - HOLSWORTHY

		Water Sampling Locations												
	ANZECC Guideline	Wa1	D2	D3	W2	W3	H2	G1	Ge1	P0	P1	P2	OH1	OH2
Total Nitrogen (mg/L)	0.05-0.75	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Total Phosphorus (mg/L)	0.1-0.05	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Ammonia Nitrogen (mg/L)	1.4	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Dissolved Oxygen (mg/L) Percent Saturation	6 (80-90%)	11.7 (122%)	7.6 (78%)	6.8 (73%)	8.3 (91%)	8.0 (86%)	2.2 (24%)	7.6 (90%)	9.2 (112%)	9.3 (100%)	8.2 (95%)	8.4 (100%)	8.6 (100%)	6.7 (77%)
Nickel (mg/L)	0.015-0.15	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Copper (mg/L)	0.002-0.005	0.014	✓	✓	✓	✓	0.005	✓	✓	0.02	✓	✓	✓	✓
Chromium (mg/L)	0.01	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Zinc (mg/L)	0.005-0.05	0.022	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.014	<0.01	<0.01	<0.01	<0.01
Lead (mg/L)	0.001-0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cadmium (mg/L)	0.002-0.002	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Iron (mg/L)	1.0	✓	✓	✓	✓	✓	2.3	✓	✓	✓	✓	✓	✓	✓
Mercury (mg/L)	0.0001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

Trace levels of Methylene Blue Active Substances (anionic surfactants, detergents rather than soaps) were found at Harris and Punchbowl Creek at PO. This may not be significant as this technique will detect natural anionic surfactants such as saps as well as other non detergent type compounds (American Public Health Association, 1995).

Low levels of heavy metals, apart from iron were detected at Harris, Punchbowl (at PO) and Wappa Creeks and at Georges River. These were copper, nickel, chromium and zinc. It is likely that these metals originated from military munitions, such as shells and bullet casings, which were observed at nearly all sites within the Reserve. The toxicity of most of these metals is related to water hardness.

Although the hardness of the waterways was not measured, conductivity and catchment morphology indicate soft waters. Levels of zinc may not therefore be significant as toxicity decreases with increasing softness.

The toxicity of copper is more complex and concentrations at Punchbowl Creek at PO and Wappa Creek were above the upper Australia and New Zealand Environment Conservation Council limit for the Protection of Freshwater Ecosystems. Chromium and nickel were also detected, however results comply with Australia and New Zealand Environment Conservation Council Guidelines.

Iron was detected at all sites throughout the Holsworthy Military Area, which would be expected given the catchment geology. Levels were below Australia and New Zealand Environment Conservation Council Guidelines for the Protection of Aquatic Ecosystems, with the exception of Harris Creek. Although there were no apparent ferrous flocs at this site, is it possible that a groundwater lens could join the creek at this point. Groundwaters are usually in a reduced state, favouring the movement of certain metals including iron. Such groundwater lenses are common in the Sydney area and were observed downstream of at least one other site.

One or more of the aromatic compounds benzene, toluene, xylene, ethyl benzene and 1,2 dichlorobenzene were present at trace levels at Harris Creek, all sites along Punchbowl Creek, Wappa Creek, Gunyah Creek, O'Hares Creek at OH1 and the Georges River. This is not unexpected as these chemicals, particularly toluene, are major components of some explosives (Australia and New Zealand Environment Conservation Council 1992).

At present there is insufficient data to set guidelines for the non chlorinated aromatics in Australian ecosystems. Levels of 1, 2 dichlorobenzene were below the recommended Australia and New Zealand Environment Conservation Council guideline value. Aromatic compounds are usually more toxic than aliphatic petroleum hydrocarbons, are more likely to dissolve in water (although overall solubility in water for both remains low) and are more persistent in the environment (Connell, 1993). However, without details of army munitions use, it is not possible to comment upon the likely age of such contamination.

Total Organic Carbon levels were depressed, reflecting the pristine nature of these streams. Results of analysis suggest that most or all of the organic carbon originates from natural sources.

Occasional traces of petroleum hydrocarbons were detected at Harris Creek, Punchbowl Creek at PO and P1 and Gunyah Creek. These were generally the lighter fractions, indicating explosives as the likely source rather than vehicle emissions or lubricants (Australia and New Zealand Environment Conservation Council, 1992). The very rugged terrain, in particular at Punchbowl Creek at PO and Gunyah Creek, would also restrict the passage of vehicles. This again implies that petroleum traces are derived from munitions.

The macroinvertebrate data for Holsworthy shown in *Table 5.8* indicates that most sites' SIGNAL scores were above or close to the threshold for clean water (Chessman, 1995) and not significantly different to the reference site (*Figure 5.4*). Possible mild pollution was indicated for the Georges River at Freres Crossing and for the lower site in Deadmans Creek. Between 11 and 33 taxa were identified at each site (*Figure 5.5*), although again, diversity was not correlated with SIGNAL index. As shown in *Figure 5.6*, an average of 53 percent of animals were from the most sensitive category (grades 7 to 10) and only 13 percent of animals were from the pollutant tolerant group (grades 1 to 3). The bias towards sensitive species is more apparent at the Holsworthy sites than in the streams near Badgerys Creek.

Algal data was restricted to the analysis of periphyton. Phytoplankton samples were not collected as algae were predominantly in attached forms and water clarity and colour indicated minimal suspended algal growth. In the neighbouring Woronora River, a recent two year study of suspended algae revealed very low concentrations of organisms. Generally, attached algae were limited to the riffle zones of the Holsworthy streams with occasional large sections of growth in smaller pools immediately downstream from a riffle area.

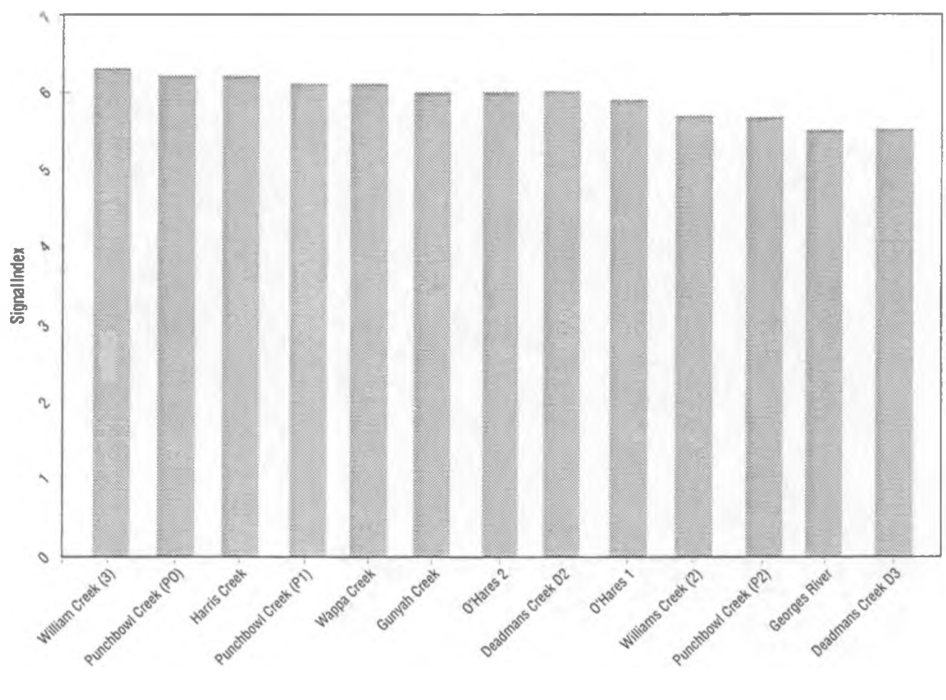


Figure 5.4

Macroinvertebrate - Signal Indices
Holsworthy Sites

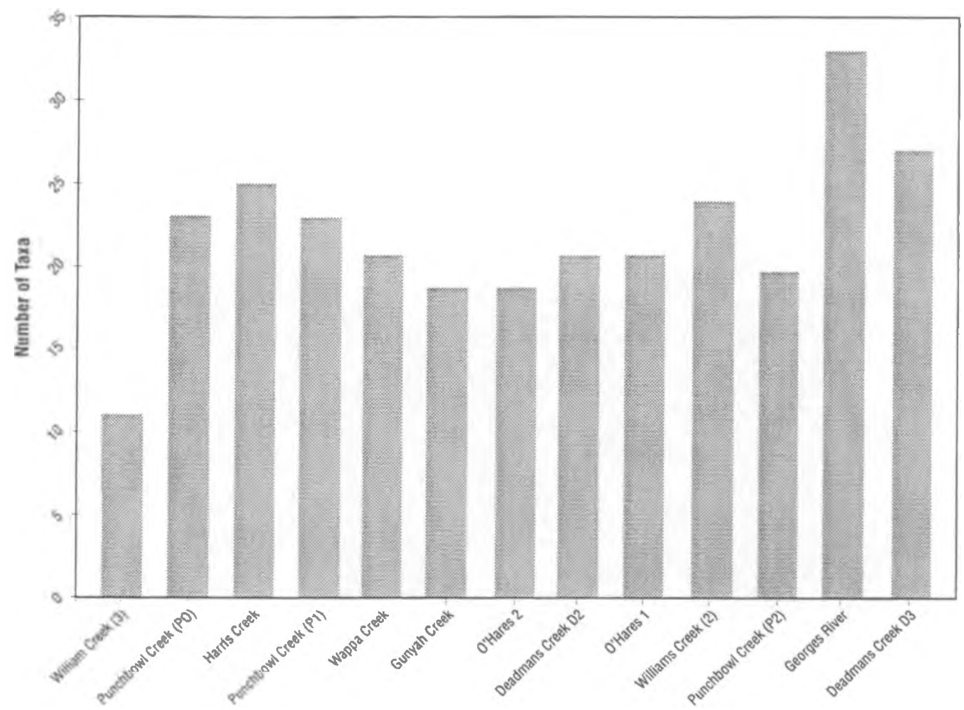


Figure 5.5
Macroinvertebrate - Number of Taxa
Holsworthy Sites

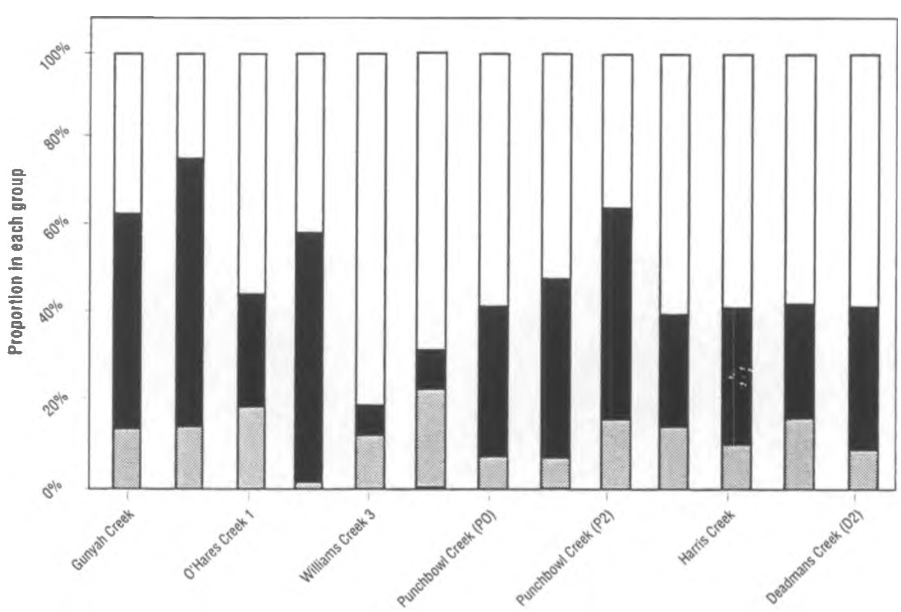


Figure 5.6
Macroinvertebrate Group
Holsworthy Sites

TABLE 5.8 MACROINVERTEBRATES - HOLSWORTHY

Site Name	Number of Taxa	SIGNAL Index	Pollution Indicated	Ratio to Reference Site	Classification Band
Deadmans Creek, D2	27	5.5	mild pollution	0.87	transitional
Georges River, Ge1	33	5.5	mild pollution	0.87	transitional
Deadmans Creek, D3	20	5.5	mild pollution	0.9	similar to reference
Punchbowl Creek, P2	24	5.7	mild pollution	0.9	similar to reference
Williams Creek, W2	21	5.7	mild pollution	0.94	similar to reference
O'Hares Creek, OH1	21	5.9	mild pollution	0.95	similar to reference
Gunyah Creek, G1	19	6.0	clean water	0.95	similar to reference
O'Hares Creek, OH2	19	6.0	clean water	0.95	similar to reference
Punchbowl Creek, P1	21	6.1	clean water	0.97	similar to reference
Wappa Creek, Wa1	23	6.1	clean water	0.97	similar to reference
Harris Creek, H2	25	6.2	clean water	0.98	similar to reference
Punchbowl Creek, P0	23	6.2	clean water	0.98	similar to reference
Williams Creek, W3	11	6.3	clean water	1.0	Reference

In the majority of cases benthic algae consisted of a very thin and patchy areas of diatomaceous silts, reflecting the pristine, sandstone nature of the Holsworthy Military Area. The dominant filamentous organism was *Zygenopsis Zygenopsis*, a common algae also recorded in the Woronora River catchment. There was minimal or no growth observed on instream logs and macrophytes and diversity was very low, again indicating the depressed concentrations of nutrients in the streams.

Groundwater

The Department of Land and Water Conservation licensed bore database search identified only three boreholes within three kilometres of the Holsworthy Military Area. All three bores were located in Parish Wedderburn, west of Option B. Anecdotal evidence obtained from discussions with local residents suggests that a number of unregistered bores may exist in this area. No groundwater level information was obtained from the database search. Licensed bore records are provided in *Appendix D*.

Groundwater levels and contours could not be determined at the sites of either of the Holsworthy options due to the lack of water level data. However, it is likely that the groundwater system at both sites is similar to the area around the Lucas Heights Landfill. Here, groundwater flow is generally to the north, and the water table geometry is similar to the topography, though in a subdued manner. Ridges act as recharge areas while groundwater discharges to creeks. Locally, hydraulic gradients may be strongly influenced by structural features.

The database search provided limited chemical data for one bore (GB032310), indicating the water quality is likely to be good with an electrical conductivity of 297 microsiemens per centimetre and a pH of 6.5. All bores recorded lithological information indicating that the thickness of the Hawkesbury Sandstone may exceed 150 metres.

Private land access consent for field sampling could only be obtained for one of the Department of Land and Water Conservation registered bores (GW072454). Field sampling was undertaken at this bore and the chemical parameter results are summarised in *Table 5.9* along with average groundwater chemistry data from the hydrogeological study undertaken at Lucas Heights Waste Depot (Douglas and Partners and Coffey Partners International, 1994).

TABLE 5.9 SUMMARY OF GROUNDWATER CHEMICAL PARAMETERS

Borehole	pH	Electrical Conductivity (microsiemens per centimetre)	Total Dissolved Solids (milligrams per litre)
GW032310	6.5	297	
GW072454	5.12	335	158
Lucas Heights average[1]	5.83	345.5	255[2]

Notes: 1. Coffey Partners International and Douglas and Partners 1994 data for first sampling round.
2. Sum of analysed ions.

Discussions with the Department of Mineral Resources (Coal Branch) indicated that records of coal exploration bores drilled by the Department throughout the Sydney Basin contained sparse groundwater information, and that all holes would have been backfilled with cement.

5.2 REGIONAL CONTEXT OF SURFACE WATER SURVEY RESULTS

5.2.1 BADGERYS CREEK

Sydney Water, South Creek Investigations 1990 to 1995

South Creek is a major tributary of the Hawkesbury-Nepean River, draining 626 square kilometres in Sydney's west and south-west. From 1990 to 1995, Sydney Water sampled 17 to 19 sites within the creek's catchment. Samples were usually collected either weekly, fortnightly or monthly. Results were used to characterise patterns in water quality through the South Creek system. Of particular interest are the sites to the south of the suburb of St Clair. These sites lie within the proposed South Creek Valley Sector Development, which includes the sites of the Badgerys Creek airport options.

Sydney Water produced two reports, the first covering the period January 1990 to April 1994 and the second, May 1994 to April 1995. Compliance figures quoted below are based upon the larger data set contained in the first document. Conclusions from the second report show no significant change in water quality for sites south of St Clair occurring during this period.

Flow regimes in the upper catchment were found to be highly variable, with long periods of little or no flow to relatively brief intervals of high flow. Concentrations of suspended solids, (turbidity) dissolved solids, total phosphorus and faecal coliforms were generally elevated during or immediately after wet weather.

Generally, nutrient levels were high, particularly in the upper tributaries such as Badgerys Creek and Kemps Creek and compliance rates with Australia and New Zealand Environment Conservation Council Guidelines for the Protection of Aquatic Ecosystems were poor to fair. In Badgerys Creek at Elizabeth Drive, approximately 80 percent of samples contained greater than 0.75 milligrams per litre of total nitrogen, the upper level recommended by Australia and New Zealand Environment Conservation Council. South Creek at Elizabeth Drive and Kemps Creek at Elizabeth Drive also scored a low compliance rate for total nitrogen with only 10 percent of samples meeting the appropriate Australia and New Zealand Environment Conservation Council limit.

Nearly all of the total nitrogen in South Creek at Elizabeth Drive consisted of organic nitrogen, indicating a productive ecosystem. In the neighbouring Badgerys Creek and Kemps Creek, approximately 80 percent of total nitrogen was comprised of organic nitrogen, with oxidised nitrogen and even ammonia nitrogen contributing on some occasions. This may be due to influences such as agricultural runoff, discharge from intensive farming and possibly on sites, however Sydney Water was not able to accurately identify these sources.

Total phosphorus compliance for all the Elizabeth Drive sites was poor to fair with a figure of approximately 30 percent in Kemps Creek, 40 percent in Badgerys Creek and 60 percent in South Creek. Contributions from filterable phosphorus were greatest in Badgerys Creek where this parameter accounted for 38 percent of the total phosphorus. This ratio was lower in South Creek and Kemps Creek where 29 percent of total phosphorus consisted of filterable phosphorus. This difference may be attributed to the potential sources mentioned above.

Algal growth measured as chlorophyll a was excessive in all creeks at Elizabeth Drive, with a compliance rate of only 20 percent for Kemps Creek and 30 percent for South Creek and Badgerys Creek. Elevated levels of nutrients were likely to be contributing to this high algal activity. Despite these high levels of chlorophyll a, dissolved oxygen concentrations remained low on occasions, with all sites scoring a compliance rate between 65 to 70 percent. The elevated productivity in these systems combined with low flow rates may have contributed to these results. This would have occurred through poor oxygenation and/or the creation of a oxygen demand from decaying material.

Faecal coliform levels were influenced by wet weather with elevated concentrations recorded after rainfall. In addition, isolated high results were obtained during dry weather, suggesting contamination from water fowl or other animals. Compliance rates with Australia and New Zealand Environment Conservation Council Guidelines for Recreational Waters were higher in Badgerys Creek, with 67 percent for primary contact such as swimming and 90 percent for secondary contact including wading and fishing.

South Creek and Kemps Creek both scored only 50 percent compliance for primary contact. Compliance for secondary recreational purposes was slightly better at Kemps Creek, whereas for South Creek the result was 84 percent. Runoff from agricultural areas and intensive rural industries may be contributing factors.

Environment Protection Authority, Water Quality, Hawkesbury-Nepean River System, June 1990-June 1993

During these three years, the NSW Environment Protection Authority conducted an extensive survey of the Hawkesbury-Nepean River, from Maldon weir (its headwaters) to Lion Island at Broken Bay. This included a site at Bents Basin Recreation area. Of interest to this EIS are the sites north of the rivers confluence with Mulgoa Creek. West Camden Sewage

Treatment Plant discharge enters the Hawkesbury-Nepean River in this upper reach at Matahil Creek.

The sites above Matahil Creek were characterised by a high water quality with median scores for Total Nitrogen, Total Phosphorus, Chlorophyll a, Dissolved Oxygen and Faecal Coliforms all falling below the appropriate Australia and New Zealand Environment Conservation Council guidelines.

Sites below Matahil Creek were influenced by sewage treatment plant discharge, with median Total Nitrogen levels double the upper maximum Australia and New Zealand Environment Conservation Council value. Oxidised Nitrogen contributed to over half of this high concentration of nitrogen, again reflecting contribution from effluent. Total Phosphorus levels only exceeded Australia and New Zealand Environment Conservation Council guidelines during wet weather.

Median faecal coliform concentrations were 260 per 100 millilitres in Matahil Creek, which is in exceedance of guidelines for primary contact but well within secondary contact criteria. Sites on the Hawkesbury-Nepean River complied with both contact values, based on median scores. Dissolved oxygen remained within Australia and New Zealand Environment Conservation Council guidelines except in Matahil Creek on isolated occasions.

There was little response from algae to these increased nutrient levels with chlorophyll a concentrations only slightly elevated at sites downstream of Matahil Creek, however values remained under 20 micrograms per litre. Turbidity and suspended solid levels reflected this trend.

Environment Protection Authority, Hawkesbury-Nepean Recreational Studies

The NSW Environment Protection Authority has been investigating recreational water quality in the Hawkesbury-Nepean River, using as the assessment criteria the Australia and New Zealand Environment Conservation Council Guidelines for Recreational Water Quality and Aesthetics as well as the National Health and Medical Research Council , Australian Guidelines for Recreational Use of Water.

The studies were undertaken during 1993 to 1995, and results were analysed and interpreted every six months. Faecal coliforms, enterococci, algal counts, pH, temperature, conductivity and turbidity were performed along with a series of field observations. These observations noted the presence of oily films, floating debris or grease, odours and frothing.

Sites of interest with respect to this Draft EIS include the Nepean River at Macquarie Grove Road at Camden, the Nepean River at Menangle Road

Bridge and the Nepean River at Bents Basin State Recreation Area. Sampling at the Macquarie Grove Road site was discontinued in March 1994 due to the lack of recreational use and transferred upstream to a new site at Menangle Bridge.

Compliance at both the Macquarie Grove Road site and the Menangle Bridge site was sporadic, with bacteriological levels occasionally in exceedance of the recommended values. The Macquarie Road site had a worse compliance rate with four out of the six samples containing high levels of faecal bacteria. Oily films were also observed on five occasions at this site. Water quality at Menangle Bridge was better, with only one high recording of faecal coliforms. No oily films were detected.

Bents Basin Reserve had excellent compliance rates for the duration of the study. No oily films were observed although the water often had a slightly turbid appearance.

5.2.2 HOLSWORTHY

Sydney Water, Georges River, Ingleburn Weir to Chipping Norton Lakes

This Sydney Water study was undertaken over a period of at least one year, usually on a monthly basis from four sites along the Georges River at Ingleburn Weir, Cambridge Causeway, Liverpool Weir and Chipping Norton Lake. The majority of these samples were collected between August 1995 to August 1996. The samples were analysed for nutrients, chlorophyll a, faecal coliforms and conductivity. Nutrient levels (total phosphorus and total nitrogen) increased from quite low concentrations at Ingleburn Weir (well within the upper maximum Australia and New Zealand Environment Conservation Council guidelines for the Protection of Aquatic Ecosystems) to several high levels (especially total nitrogen) measured at Chipping Norton Lakes.

Compliance rates for total nitrogen and total phosphorus ranged from 100 percent for both nutrients at Ingleburn Weir to 88 percent for total phosphorus and 75 percent for total nitrogen at Chipping Norton Lakes. The majority of nitrogen present was in organic form, indicating a healthy and productive system. Ammonia levels were also within recommended Australia and New Zealand Environment Conservation Council toxicity limits. As expected, algal activity measured as chlorophyll a also increased along with the elevation in nutrient levels.

Concentrations of faecal coliforms at Ingleburn Weir were usually within the range expected for a non polluted rural river. Occasional large amounts of bacteria were recorded, possibly as a result of wet weather or livestock/

waterfowl contamination. There were more occurrences of such elevated levels at the Liverpool Weir site, probably as a result of stormwater runoff from the adjacent urban areas.

As the faecal coliform data was not collected in accordance with the sampling timetable outlined in the Australia and New Zealand Environment Conservation Council guidelines for recreational water quality and aesthetics, it is not possible to meaningfully compare results. Results consistently over 150 organisms per 100 millilitres, such as were recorded at Liverpool Weir, are a cause for concern. Contact with such water, particularly bodily immersion, is not recommended.

Sydney Water Corporation, Georges River, Harris Creek and Williams Creek, Hammondville

A 27 month survey by Australian Water Technologies for Sydney Water was conducted at three sites at Hammondville between January 1991 to March 1993. The Georges River site had 52 samples collected during this period, with 41 from Williams Creek and only 15 from Harris Creek. Samples were analysed for nutrients, suspended solids, turbidity, chlorophyll a and faecal coliforms. As the Georges River site was located downstream from Liverpool and Bankstown urban areas as well as downstream from the Army Sewage Treatment Plant at Holsworthy, water quality was depressed when compared to the Ingleburn Weir site above.

Compliance rates for the protection of aquatic ecosystems decreased to 71 percent for total phosphorus and 38 percent for total nitrogen. Approximately one third to one half of the total nitrogen at the Georges River site consisted of oxidised nitrogen. Filterable phosphorus concentrations attributed to total phosphorous levels in a similar ratio. These nutrient patterns are probably as a result of effluent from the sewage treatment plant.

Ammonia levels were within Australia and New Zealand Environment Conservation Council toxicity guidelines. Both the Harris Creek and Williams Creek site were approximately one to two kilometres upstream of the Harris Creek/Williams Creek junction. Nutrient levels were low in both Harris and Williams Creeks.

Relative levels of oxidised nitrogen and filterable phosphorous were also low, in keeping with a waterway not receiving sewage treatment plant discharge. Compliance rates for nutrients and ammonia toxicity were excellent for both streams with only one elevated total nitrogen recording at Williams Creek during the sampling period.

Chlorophyll a measurements were all under 20 microgram per litre, the level often used to qualify eutrophic conditions. There appeared to be no relationship between an increase in nutrients and an increase in algal levels within these three waterways. Turbidity levels generally did rise with an elevation in chlorophyll a suggesting that algae were contributing to the worsening water clarity. Suspended solids levels were usually below 40 milligram per litre, with occasional high concentrations. These may be related to rainfall patterns.

Sydney Water Corporation, Woronora River, Macroinvertebrates, 1996

A study of macroinvertebrates along the Woronora River, downstream of the Woronora Dam was performed in June 1995 and November 1995. The Woronora River predominantly experiences a stable flow regime, with sporadic periods of high flow. The investigation compared data from two habitat types from three sampling locations, from sites within each location and between the two sampling dates. A rainfall event during one of the sampling occasions also allowed for comparison of organisms before and after rain. A series of statistical analysis was performed to identify trends within and across data sets.

Chiromonidae larvae (non-biting midges) were the most abundant family of organisms from both habitat types, comprising of 54 percent of the total from the leaf litter habitat and 38 percent of the total from pool rocks. A total of 37 different taxa (groups) were identified at the pool rock sites, with Caenidae (mayfly larvae) comprising 14 percent of organisms and Hydropsychidae caddis flies, 9.4 percent.

The leaf litter habitat had a greater diversity of macroinvertebrates, with 50 different taxa recorded. Following Chironomidae, Oligochaetae (a variety of segmented worm) were the next abundant organism at 10 percent and Sphaeridae, a freshwater mussel, at 8 percent. Both habitat types were typical of coastal drainage rivers from eastern Australia (Sydney Water, 1997). No rare or endangered organisms were identified.

The assemblages of organisms were examined to reveal trends across the three sampling locations. These locations were chosen to represent areas in the upper, middle and lower reaches of the river. Significant differences between locations were apparent for the rock pool habitats and at the upper leaf litter location.

Rainfall did not appear to greatly influence the communities in the rock pool habitats, however considerable differences in assemblages were recorded for the leaf litter habitats. Increased numbers of Chironomidae (non-biting midges), Elmidae (a variety of small beetle) and Sphaeridae (a variety of freshwater mussel) were found in most leaf litter sites after rain.

Campbelltown City Council, 1976-1996

Campbelltown City Council has been investigating water quality at nine sites along the Georges River and Nepean River and some of their tributaries from 1976. Sites extend from Menangle Park Bridge at Menangle on the Nepean River to Simmos Beach Recreation Reserve at Macquarie Fields on the Georges River. Although analysis was not been performed in a National Association of Testing Authorities registered laboratory, results indicate some trends over the past ten years.

Faecal pollution was usually elevated at all sites after rain although occasional isolated high levels were recorded in dry weather. This may have been due to localised contamination from water fowl, animals or even sewage overflow.

Dissolved oxygen concentrations were generally very good, falling above, the range Australia and New Zealand Environment Conservation Council recommends for the Protection of Freshwater Ecosystems.

One site, Harold Street Bridge on Bunbury Curran Creek, consistently scored higher results for nutrients, colour, turbidity, dissolved salts and faecal coliforms. In addition, dissolved oxygen levels were often depressed. These results remained outstanding in dry weather indicating influences other than stormwater runoff. As this creek receives drainage from the majority of the Campbelltown area, this depressed water quality probably reflects urban runoff.

Sydney Water - Macroinvertebrate Investigation, 1995

A two month study of macroinvertebrates in the Georges River and O'Hares Creek was conducted during Autumn and Spring 1995. Dominant macroinvertebrates in O'Hares Creek, upstream of the Georges River were Trichopterans (a type of Caddis fly), Aytidae (fresh water shrimp) as well as a variety of Diptera (fly larvae), bugs, beetles and dragon flies. In the headwater sections of O'Hares Creek, mayfly larvae were more abundant and diverse and a wide variety of organisms from other major groups were also represented.

5.3 ASSESSMENT OF SIGNIFICANCE

The following section integrates the chemical and biological data presented above and compares the status of local streams and groundwater aquifers and regional water bodies to recognised water quality criteria. Water quality in rain water tanks in individual dwellings is discussed in *Sections 6.2.1* and *7.2.1*.

5.3.1 ASSESSMENT CRITERIA

The assessment of the significance of water bodies in the context of the proposed Second Sydney Airport takes into account the aquatic chemistry and ecology of each system. Human uses of the water for potable supply, recreation or agricultural extraction are also relevant. In assessing water quality the following published criteria have been used:

- Australia and New Zealand Environment Conservation Council (1992) guidelines for ecosystem protection;
- Australia and New Zealand Environment Conservation Council (1992) guidelines for recreation;
- Australia and New Zealand Environment Conservation Council (1992) guidelines for potable supplies;
- National Health and Medical Research Council guidelines for recreation; and
- Australian Drinking Water Guidelines (National Health and Medical Research Council and Agriculture and Resources Management Council of Australia and New Zealand, 1996).

In addition indicators such as macroinvertebrate indices, abundances of pollutant tolerant/intolerant biota, algal coverage or concentration and levels of nuisance organisms has been used to determine the status of existing water bodies.

5.3.2 BADGERYS CREEK

Surface Water

Local streams within the Badgerys Creek sites are Badgerys Creek, Cosgroves Creek, Thompsons Creek and Duncans Creek.

Badgerys Creek exhibits extreme fluctuations in flow, with associated variable water quality. High flows have facilitated bank erosion and carry high loads of suspended solids which render the stream turbid with colloidal particles. The field survey undertaken by Robyn Tuft and Associates for preparation of the Draft EIS corresponded to a prolonged dry warm period. As such, it recorded the stream in a relatively stressed condition.

Nitrogen is often excessive in Badgerys Creek, with organic nitrogen predominant, as expected in a biologically productive system. On occasions, ammonia has exceeded the toxic threshold. Phosphorus compliance with Australia and New Zealand Environment Conservation

Council guidelines is low (40 percent). Phosphorus mostly contained the more bio-available orthophosphate. Loadings of phosphorus in wet weather tend to be extreme, particularly when suspended solid loads are high.

In response to these nutrients, and where light is available, phytoplankton levels tend to be elevated with concentrations and genera indicative of eutrophic (nutrient enriched) conditions. There is also extensive coverage of attached algae and development of aquatic vascular plants, ranging from floating forms such as *Lemna* and *Salvinia* to reeds such as *Phragmites* and *Typha*. Algal genera also included a high concentration of the nuisance blue-green "alga" *Anabaena*.

Dissolved oxygen concentrations were often found to be below the level recommended for support of aquatic fauna, presumably from processes of organic decay and algal respiration. Anaerobic bacterial activity is evidenced by sulphurous odours when sediments are disturbed. Low oxygen is exacerbated by low flow.

Stream fauna consist of a wide variety of invertebrates, but a high proportion are tolerant of pollution. Introduced nuisance fish including *Gambusia* and Carp are common. One native frog species was found during the field survey.

Cosgroves Creek has similar characteristics to Badgerys Creek, being nutrient enriched, productive and containing tolerant fauna. There were elevated heavy metals detected which exceeded recommended ecosystem protection levels. These may have been derived from agricultural or aerial sources.

Thompsons Creek was very stagnant when sampled. High levels of iron and elevated zinc were recorded. The fauna and floral characteristics were typical of a eutrophic, low flowing stream.

Duncans Creek has relatively high water quality, with all parameters except dissolved oxygen complying with ecosystem protection criteria. The stream carried moderate levels of attached and suspended algae. Fauna consisted of diverse invertebrates, many of which were pollutant tolerant, and fish such as eels and carp. Two native species of frogs were observed.

The Badgerys Creek study area drains predominantly into South Creek and ultimately into the Hawkesbury River.

South Creek is the receiving stream for Badgerys Creek, Thompsons Creek and Cosgroves Creek. The creek then travels some 50 kilometres before joining the Hawkesbury River near Windsor. South Creek is generally a depauperate system, high in nutrients and often turbid. It receives runoff from agricultural and urban land and below St Marys receives treated effluent from three treatment plants.

At the Luddenham Road monitoring site on South Creek 70 percent of samples complied with Australia and New Zealand Environment Conservation Council guidelines for total phosphorus and 25 percent compliance was found for total nitrogen. Over 50 percent of samples exceeded primary contact guidelines for faecal coliforms, which increase markedly with wet weather.

The Nepean River, west of the Badgerys site, is an important water body for a wide range of activities including swimming, boating, fishing and passive recreation. The river is also a water supply for agriculture and potable supply for North Richmond Water Treatment Plant.

Above West Camden, the Nepean water quality is high with all parameters complying fully with Australia and New Zealand Environment Conservation Council guidelines. Below West Camden Sewage Treatment Plant nitrogen levels are approximately double Australia and New Zealand Environment Conservation Council guidelines. Phosphorus and faecal coliform levels tended to increase in wet weather. By the recreational area at Bents Basin, nutrients are still elevated but recreational guidelines for swimming are met.

Reservoirs and dams in the vicinity of Badgerys Creek including a large number of small to medium private farm dams or water storages. These are used for agriculture or drainage purposes. Water quality in these dams, although not specifically tested, appears to satisfy criteria for these activities.

The two Sydney Water storages of Lake Burragorang and Prospect are also relevant to the airport options as they lie under potential flight paths. The more remote reservoirs of Avon, Nepean, Cataract and Cordeaux may also be overflown. Lake Burragorang is the primary source of potable water for Sydney and presently contains a high quality of water, due mostly to its protected catchment. Prospect Reservoir is now used as only an emergency supply source for Sydney's water, with the Warragamba pipeline directly supplying the water treatment plant at Prospect.

Groundwater

No beneficial users or uses for groundwater within the Wianamatta Group have been identified at the Badgerys Creek airport sites. With the exception of shallow groundwater sampled from D13 and D8 (Coffey Partners International, 1991) the available chemical data indicates that the groundwater has only limited applications for stock watering, and Total Dissolved Solids values for all holes except D13 are well above levels recommended for the protection of freshwater aquatic ecosystems. The poor quality of the groundwater coupled with low yields indicate no beneficial uses of the groundwater are likely to exist in the future that is, the groundwater within the Wianamatta Group is of low value.

Furthermore, records show that successful bores located near the centre of the Cumberland Basin usually need to be drilled through the Wianamatta Group to access groundwater in the underlying Hawkesbury Sandstone. Aquifers capable of yielding a useful water supply are generally at least 50 metres beneath the base of the Wianamatta Group (Jones and Clark, 1991). At Badgerys Creek, this equates to a depth in the order of 150 metres, which generally makes drilling for groundwater uneconomic.

5.3.3 HOLSWORTHY

Surface Water

The Holsworthy options potentially directly affect the major streams of O'Hares Creek, Williams Creek, Punchbowl Creek, Harris Creek, Deadmans Creek and the upper Georges River. There are also a number of tributaries of the Woronora River such as Wappa Creek and Lyretail gully. When surveyed, these streams showed virtually pristine water quality with most parameters conforming with water quality criteria. There were elevated concentrations of copper and zinc at Punchbowl Creek. These exceeded Australia and New Zealand Environment Conservation Council Protection of Aquatic Ecosystems criteria. Metals are presumed to be from munitions sources.

Munitions were also presumed to be the source of trace organic chemicals at a number of sites, although levels were well within criteria. The poorest water quality was exhibited by Harris Creek, where high iron and low dissolved oxygen were observed. In the lower sections of Williams and Harris Creeks, water quality is currently impacted by treated effluent from the Holsworthy Sewage Treatment Plant.

The regional streams of significance are the Georges River and Woronora River.

The Georges River has its source near Cataract. The river flows north to near Liverpool before looping generally to the south and east. It almost completely surrounds the Holsworthy base site. The river is used extensively for swimming, recreational fishing and boating. Chipping Norton Lakes has been developed specifically for recreation. The Department of Fisheries advises that there are no operating oyster leases or commercial fisheries above Tom Ugly's Bridge.

Upstream of Bunburry Curran Creek at Glenfield the water quality is good, with high compliance with Australia and New Zealand Environment Conservation Council guidelines. Macroinvertebrates at Freres Crossing were diverse and indicative of low pollution. Below Glenfield the water quality deteriorates, particularly during wet weather when loads of nutrients and faecal coliforms increase. The river below Williams and Harris Creek is currently impacted by effluent discharged from Holsworthy Sewage Treatment Plant, with approximately 30 percent of river nutrient concentrations attributable to the discharge. The river at this point is tidal and tends to be saline.

Woronora River headwaters have been impounded since 1931. Below the dam wall the river receives a small volume of baseflow from leakages in the dam and overflows once the storage is full. Above Heathcote Creek water quality is relatively high and stream ecosystems healthy. Algae are predominantly attached to rocks with diatoms dominant. Algal genera typical of slow flowing streams are common.

Reservoirs in the vicinity of Holsworthy are Woronora and Upper Nepean Reservoirs.

Woronora Reservoir is to the south of the Holsworthy site and supplies water to suburbs in southern Sydney. Water quality is relatively good apart from elevated levels of iron and manganese. Water filtration before supply is effective in controlling these parameters.

The Upper Nepean Reservoirs comprise Cataract, Cordeaux, Nepean and Avon reservoirs. Generally water quality within Cataract, Cordeaux and Avon storages has met the Australia and New Zealand Environment Conservation Council Guidelines for Raw Water Supply and Guidelines for Protection of Aquatic ecosystems. At the Nepean storage, although iron, manganese and aluminium levels exceeded guidelines, water filtration provides protection to the drinking water supply.

Groundwater

The groundwater within the Hawkesbury Sandstone is of good quality with electrical conductivities and Total Dissolved Solids levels below recommended criteria for stock watering, irrigation, raw water for drinking, and protection of freshwater aquatic ecosystems.

Information from all sources indicates there are no users of groundwater within three kilometres down hydraulic gradient of either site. Groundwater users have been identified at Wedderburn, due west of the southern option, however it is noted that O'Hares Creek is located in a deeply incised valley that separates the site from the groundwater users. As such, any groundwater impacts due to the site are unlikely to affect the groundwater users at Wedderburn.

Part C

Assessment of Impacts

6 IMPACTS OF BADGERYS CREEK OPTIONS

6.1 CONSTRUCTION

6.1.1 SOIL EROSION AND ACIDITY

The potential for, and severity of erosion is a function of velocity and the volume of run-on/run-off, slope gradient, extent of land disturbance and soil erodability.

The potential erosion hazard for the soil landscape for the proposed Badgerys Creek airport, as assessed by the NSW Soil Conservation Service (Bannerman and Hazelton 1990) is summarised *Table 6.1*:

TABLE 6.1 POTENTIAL FOR SOIL EROSION AT BADGERYS CREEK

Soil Landscape Unit	Potential Erosion Hazard
Luddenham	Moderate to Very High
Blacktown	Low to High
South Creek	Very High to Extreme

The potential for the existence of acid sulphate soils has also been assessed.

Acid sulphate soils are generally likely to be present in sediments of the recent (Holocene) geological age; in soils not more than five metres above high tide level; and in marine or estuarine settings (Environment Protection Authority, 1995). These sediments show traces of pyrite which, upon exposure to air, can oxidise to form sulphuric acid. The acid reacts with the clay minerals and dissolves metal particles in the soil such as iron and aluminium. The resulting acid and dissolved metals that leach from the soil are often toxic to flora and fauna.

As long as the pyritic sediment remains below the water table where it cannot be oxidised, it poses no problems. It is when pyritic sediment is exposed to air such as in periods of prolonged drought, or when the sediment is drained, excavated or after dredging, that problems can occur.

The sites of the Badgerys Creek airport options are unlikely to contain acid sulphate soils, because of the elevation of the sites (above 10 metres Australian Height Datum) and the absence of marine or estuarine sediments.

6.1.2 SURFACE WATER

Streams within Airport Sites

Table 6.2 summarises estimates of the length of each stream which would be infilled or taken up with stormwater detention structures. These estimates are based upon information provided by Second Sydney Airport Planners.

TABLE 6.2 ESTIMATED LENGTHS OF CREEKS WHICH WOULD BE INFILLED OR TAKEN UP WITH STORMWATER DETENTION STRUCTURES

Stream	**Estimated Length (kilometres)**		
	Option A	**Option B**	**Option C**
Badgerys Creek	0	5.4	5.7
Cosgrove Creek	1.8	1.5	0
Oaky Creek	3.0	3.0	3.9
Total	**4.8**	**9.9**	**9.6**

Diversion of three major creeks is described in Second Sydney Airport Planners, (1997a). Badgerys Creek carries the highest flow of the three creeks. Creek diversions would involve temporary excavations to the dimensions and standards required by the Environment Protection Authority. Work is proposed to commence on the north side of the airport site and progress in a southerly direction. Once the permanent stormwater drainage is completed, the temporary creek diversions filled in and water would be allowed to flow through the permanent system.

A major impact of these works would be complete removal of habitat and stream biota in all the infill areas. It is estimated that between two and three hectares of wetland habitat would be lost.

The airport proposal for this site includes the construction of reed beds for stormwater quality control, which would cover an area of approximately 10 hectares for Option A and 20 hectares for Options B and C. This would to some extent replace wetland habitat for the area, particularly if local species are used for the artificial wetlands.

Downstream and Regional Impacts

The streams potentially impacted by an airport at Badgerys Creek are Badgerys Creek, Cosgroves Creek, Oaky Creek, Duncans Creek and the South Creek system. All of these streams are affected by all airport options and stages, except that Duncans Creek has minimal impact from Option A and Option C.

In principle, downstream of infill areas there should be no adverse water quality impacts provided sediment control is adequate and stream flow maintained to approximate pre-existing patterns. However, with the large scale earthwork program (with approximately 1,000 hectares disturbed at any time) it may be difficult to fully control sediment export from the site.

Several factors contribute to erosion and sediment movement:

- rainfall erosivity;
- soil erodability;
- slope length/gradient; and
- ground cover.

Appendix E provides the calculation basis for the Universal Soil Loss Equation (potential soil loss measure) and derivation of Soil Loss Class. Calculations have been done for average terrain over the site. The estimated export of sediment from an exposed hectare of soil is 65 tonnes per year. This places the site in the Soil Class 1 where standard sediment control measures are generally adequate to limit sediment pollution to acceptable levels (Department of Housing, 1993). The large areas of disturbed land, however, would require erosion controls such as hay bales and filter fences and the construction of a large capacity of sedimentation.

Current designs for Badgerys Creek options include three to six large ponds which would receive drainage from the entire site. The ponds would form the permanent stormwater basins once the airport is operational and have been sized to cater for the volume of a one year Average Return Interval, two hour storm. They are designed to drain gradually over a period of approximately 20 days via a low capacity pipeline. Due to the dispersive nature of soils of the region, these sediment basins will also incorporate chemical flocculation to prevent the escape of fine material. They would have road access for dosing of flocculants and sediment removal.

In the event of a large storm (in either intensity or duration) or if a minor storm occurs when the pond water level is high, these structures would overflow. Detention times in the ponds would be of the order of an hour or so even under major storm conditions, and coarser sediments (sands etc) would be retained. However some finer fractions of sediment would not be fully trapped on these occasions. Streams and rivers partially impacted by sediments are shown in *Figures 6.1* and *6.2*.

Storms of intermediate magnitude (high volume of turbid runoff but no overflow) may also contribute sediment via drainage of turbid water through the low capacity pipes. This discharge should gradually clear as the sediment in the pond settled.

Given the extended construction period there is a significant risk of finer sediment escaping detention during storm events. The transfer of fine sediment to the receiving streams and ultimately South Creek would have potential stream impacts including:

- changes in stream flow characteristics (from siltation);
- direct smothering of fauna (0.1 metres sufficient to smother benthic fauna - Rooney 1991);
- interference with gill function in fish, filter feeding mechanisms (Hardwick et al, 1995);
- reduction in the euphotic (lighted) zone and retardation of aquatic plant function;
- increased turbidity interfering with visual feeding; and
- siltation and reduction in stream habitat and removal of water sources for riparian fauna.

These streams however already frequently experience high turbidity due to runoff over the dispersive soils of the catchment as well as resuspension of fine benthic sediments. Hence the aquatic ecosystems are to some extent adapted to influxes of sediment, although construction runoff would exacerbate existing turbidity.

A major release of sediment would be expected to occur during a major storm event when stream flows would be elevated. With high flow the fine sediment will be transported well into the South Creek system. It may take more than one major storm to flush this sediment through South Creek and into the Hawkesbury River.

The pollutants attached to sediment particles are also of concern. Nutrients such as phosphorus tend to adsorb to particles such as clays and can be incorporated into downstream sediments, supplying a nutrient source for later stimulation of aquatic plants and algae.

If Duncans Creek is affected there is a high probability that sediment would be transferred to the Nepean River near Wallacia. This would increase river turbidity and transfer attached pollutants such as nutrients, potentially impairing both recreational activities and aquatic viability. Duncans Creek and this section of the river are classified as Class S under the Clean Waters Act 1970 (that is, discharge of any waste is prohibited).

Creeks impacted by sewage treatment plant discharge

Creeks impacted by stormwater runoff

Optional sewage treatment plant discharge points

Option A Boundary

Option B boundary

Figure 6.1
Potential Water Quality Impacts of Badgerys Creek Options A and B

Creeks impacted by sewage treatment plant discharge

Creeks impacted by stormwater runoff

Optional sewage treatment plant discharge points

Figure 6.2
Potential Water Quality Impacts of Badgerys Creek Option C

The proposed mulching of vegetation on site could provide a rich nutrient source if not adequately controlled. The proposed covering of these piles to reduce rainfall infiltration should control this source, although diversion of drainage away from piles will also be necessary.

Another consideration is the control of pollutants such as those generated from concrete washings and truck wash-down areas. During the construction of the F3 freeway, serious water quality problems occurred when alkaline concrete dust water was discharged into poorly buffered streams (Rooney 1991). It is proposed to provide a valved delivery system for cement dust with collection systems incorporated for any spilled material. The truck wash areas would be bunded and drained to the stormwater system via local sediment traps and oil interceptors. Any hazardous materials stored on the site would also incorporate safety provisions, such as bunding, according to Australian regulations.

At Badgerys Creek, the construction activity would also generate dust which could be transported into nearby water courses and dams. This source should be controlled adequately with dust suppression, using collected stormwater.

The impact from storage areas for fuels and other hazardous materials would be controlled through bunding to prevent the escape of any spills and specific drainage collection. Wastewater generated during the construction period is proposed to be treated using a septic tank with pump out and sludge removal to St Marys Sewage Treatment Plant. There would be no discharge to streams or groundwater during this period.

Reservoirs

The major water supply reservoirs of Prospect and Lake Burragorang are not expected to be impacted by construction activity. Most of the farm dams in the vicinity of the site should not be impacted provided dust control is adequate. Dams (including the large storages on the headwaters of Duncans Creek) could potentially receive sediment from the construction of Option B.

These are currently used for agricultural purposes such as stock watering. Siltation or nutrient inflows to these storages could affect water clarity and encourage algal growth. The large dams at the junction of Badgerys Creek and South Creek, which are mostly used for agricultural purposes, may be similarly affected.

6.1.3 GROUNDWATER

Coffey Partners International (1991) data indicates that elevated groundwater levels correspond to the ridge formed by the Luddenham Dyke. Earthworks to level the ridge will result in groundwater being encountered. Experience at the Elizabeth Drive Landfill (PPK, 1993) indicates that the volume of groundwater encountered is likely to be very low and conventional pump and sump methods should be sufficient to deal with seepage during construction. Furthermore, the ridge acts as a local elevated recharge area, and its removal and subsequent airport development of an airport would result in decreased infiltration and a general lowering of groundwater levels.

The runways where groundwater is likely to be encountered during construction are summarised in *Table 6.3*.

TABLE 6.3 SUMMARY OF RUNWAYS INTERSECTING GROUNDWATER

Airport Option	Runway	Likely Impact Area
A	05L-23R	western end
	05R-23L	-
B	05L-23R	western end
	05R-23L	insufficient data
	15-33	northern end
C	18R-36L	possible centre
	18L-36R	-
	09-27	possible western end

Groundwater encountered during construction is likely to be highly saline and potential exists for a reduction in surface water runoff quality as a result of evaporative concentrations of salts.

Impacts to the groundwater environment due to airport construction are considered to be minimal. The absence of identified beneficial uses of groundwater at the Badgerys Creek sites, and the recognition of the low value of the groundwater means that changes in groundwater quality would not have a major impact.

6.2 OPERATIONAL

Stormwater from the airport, after detention and water quality treatment, would discharge into Badgerys Creek for all options and to Cosgrove/Oaky Creek for Options A and B.

6.2.1 HYDROLOGY

As the developed airport would contain large areas of paved or impervious surfaces and an efficient drainage system, site runoff would have a quicker response time and losses by infiltration would be lower than at present. Therefore post development runoff would exceed pre-development runoff.

Preliminary design of airport drainage infrastructure at Badgerys Creek has been based upon sizing of detention ponds so that they can temporarily detain stormwater produced by severe storm events up to one in 100 years Average Recurrence Interval.

This is based on the assumption that to prevent increased flooding, the rate of volume discharge should be limited to 20 percent less than existing peak values (Second Sydney Airport Planners, 1997a). To verify this assumptions, it would be necessary to carry out flood modelling for the whole of South Creek catchment. This work is yet to be undertaken.

6.2.2 SURFACE WATER QUALITY

Stormwater Discharges

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.

Stormwater management proposed for the options would limit the export of oil, grease and fire fighting chemicals through bunding and interception. The detention basins include surface booms for trapping any oils which escape the interception pits. Contaminants entering the water quality reed beds would include nutrients, suspended solids, trace metals and trace organics washed off pavements and other surfaces.

Water quality ponds and reed beds can typically remove approximately 60 percent of phosphorus and 50 percent of nitrogen (Lawrence 1996). Phosphorus removal is also facilitated by chemical dosing of water quality ponds. Where full detention is available, this allows essentially complete capture of metals and sediments.

A predicted residual annual nutrient loading on Badgerys Creek has been calculated as part of this impact assessment. This is based on applying nitrogen and phosphorus loadings consistent with a commercial/industrial land use and allowing for runoff from the remainder of the catchment at existing loading rates (calculations in *Appendix E*). Streams and rivers potentially impacted by stormwater are shown in *Figures 6.1* and *6.2*.

For phosphorus, the predicted load from the full development of the airport is approximately 1,900 kilograms per year. this is essentially the same as the existing load of 1,857 kilograms per year (Cuddy, 1994). For nitrogen, the predicted annual loads for Badgerys Creek are 9,000 to 10,000 kilograms per year as compared to 11,500 for the existing land use.

Sewage Treatment Plant Discharges

The major downstream impacts relate to potential discharge of treated effluent. One option is to provide an on site sewage treatment plant for an airport at Badgerys Creek. Wastewater would be treated to tertiary level and incorporate disinfection and a high level of nutrient removal.

The resultant effluent quality (50th percentile) is predicted to be as follows:

Biochemical Oxygen Demand	10 milligrams per litre
Suspended Solids	10 milligrams per litre
Total Nitrogen	5 milligrams per litre
Total Phosphorus	0.3 milligrams per litre
Faecal Coliforms	less than 200 colony forming units per 100 millilitres

Effluent reuse would be incorporated wherever practicable. This would include a dual reticulation system supplying recycled effluent for toilets and outside watering applications. Fire fighting and irrigation are also proposed to use recycled effluent. Incorporation of water demand management could potentially reduce the volume of wastewater requiring treatment. It is estimated that in dry weather approximately 50 percent of effluent can be reused at the airport both for outside purposes and within facilities. Wet weather reuse would be predominantly within facilities where 25 percent of total effluent is expected to be utilised.

It is proposed to discharge treated effluent to Badgerys Creek at a rate of 7.5 megalitres per day (dry weather average) for Stage 1 and 22.5 megalitres per day for the ultimate load. (Second Sydney Airport Planners, 1997c). However if effluent reuse is adopted this rate could probably be halved. Discharges would be downstream of the airport facility. They would alter the flow characteristics of the existing stream from a highly variable regime with predominantly low flow to a perennial, medium flow situation.

Given that tertiary treatment and disinfection processes would reduce Biochemical Oxygen Demand Suspended Solids and Faecal Coliforms, the major aquatic impacts from the discharge would be due to nutrient additions. During dry weather, where the stream offers virtually no dilution, effluent discharge would result in a concentration of 0.3 milligrams per litre of phosphorus and 5 milligrams per litre of nitrogen (as compared to existing total phosphorus and nitrogen concentrations ranging from 0.3 to 3.3 and 1.2 to 12 milligrams per litre respectively) in the streams. Estimated annual loads for nutrients are given in *Table 6.4*. Streams and rivers potentially impacted by discharge from a sewage treatment plant are shown in *Figures 6.1* and *6.2*.

TABLE 6.4 ESTIMATED POLLUTANT LOADINGS FOR BADGERYS CREEK DOWNSTREAM OF EFFLUENT DISCHARGE POINTS (ANNUAL AVERAGE)

	Existing loading (tonnes/year)	Stage 1 contribution (tonnes/year)	Masterplan contribution (tonnes/year)
Nitrogen	11.5	13.7	41
Phosphorus	1.9	0.8	2.5

Implications of increased nutrient loads to the South Creek system would be the exacerbation of existing eutrophication processes. This would result in increased levels of in-stream algae or aquatic plants. Streams within the sites of the airport options drain into South Creek via a series of large storage dams. Although there has not been any monitoring of these dams, it is thought that they can lead to temporarily high nutrient levels in the streams when sediments are scoured during wet weather (pers com James Rivarovski, Sydney Water Corporation). Discharge of additional nutrients to the dams would add to the store of nutrients.

Eutrophication of the streams would potentially lead to changes in aquatic fauna to more tolerant forms, particularly if dissolved oxygen becomes limiting. There would also be aesthetic impacts. There are expected to be no direct human health implications as the upper catchment is not considered suitable for harvesting of fish, shellfish or for primary contact recreation (Hawkesbury Nepean Catchment Management Trust, 1996).

The issue of cumulative Impact of pollutants in the Hawkesbury River through South Creek is expected to be minor given the existing loads from South Creek of 9,600 and 400,000 kilograms per year phosphorus and nitrogen respectively (Environment Protection Authority, 1994). However, with the introduction of improved nutrient removal at Sydney Water's treatment plants would reduce existing loads. This would increase the proportion of nutrients from the airport discharges, although the total nutrient load entering the Hawkesbury River would decline. However, further nutrient contributions could be expected due to increased residential and commercial development, either associated with the airport or in urban developments, such as the South Creek Valley Sector.

As outlined above, treated effluent and stormwater would be conveyed into South Creek via large storage dams. The large residence time afforded by these dams could exacerbate nutrient enrichment and result in increased algal or aquatic plant growth in the streams.

Effects of Air Pollutants on Reservoirs

The impact of aerial pollutants from aircraft operation on receiving streams was also investigated and the predicted concentrations compared to ecological guidelines for aquatic biota (Australia and New Zealand Environment Conservation Council, 1992).

Major reservoirs near the Badgerys Creek airport site include the potable water supplies of Warragamba, Prospect and the more distant Nepean system reservoirs. The risk of aircraft emissions contaminating water supplies has been examined as part of the preparation of the Draft EIS. This involved estimating the transfer and solubility of key contaminants into waters near offtakes for given ground level concentrations of air pollutants. These levels are derived from the air quality modelling studies which are reported in *Technical Paper No. 6 - Air Quality*.

The effect of aerial pollutants on water quality was assessed for potable water reservoirs, domestic water tanks and aquatic ecosystems. Predicted concentrations were compared against drinking water guidelines (National Health and Medical Research Council, 1996) and ecosystem protection guidelines (Australia and New Zealand Environmental Conservation Council, 1992). The drinking water guidelines are based on maximum concentrations considered not to pose any significant risk to the health of the consumer over a lifetime of a consumer. The ecosystem guidelines are based on chronic and acute toxicity data for aquatic test organisms.

The concentrations in water were determined for benzene and benzo(a)pyrene (a polycyclic aromatic hydrocarbon). These were chosen as representing the more toxic of constituents potentially generated by an airport. Benzene also represents the behaviour of gaseous emissions such as formaldehyde, toluene and xylene. Benzo(a)pyrene is an indicator of those non gaseous compounds which can attach to particles in the atmosphere. The calculations were simplified as there was insufficient data to enable modelling of the full range of meteorological conditions. A conservative approach has therefore been taken.

The situation where short-term meteorological conditions may result in localised high pollutant concentrations was also considered, such as during atmospheric inversion. Microclimatic studies reported in *Technical Paper No. 5 - Meteorology* indicated that these concentrated pollutants are unlikely to be transferred into the water column due to isolating effect of the cold air flowing down over a reservoir in the late afternoon from the side of the catchment.

For benzene, maximum predicted ground level concentrations were provided by the air quality monitoring predictive models for each airport options. The worst case contour was used for the calculations. The concentration in a water body was then determined by applying a partitioning coefficient (Henry's constant). Levels of benzene for all options at Badgerys Creek were more than ten thousand times lower than the drinking water guideline of one gram per litre and more than 10 million times lower than ecosystem protection guidelines. It should also be noted that gases such as benzene which are dissolved in water are in a state of equilibrium with atmospheric concentrations and hence do not accumulate over time.

The polycyclic aromatic hydrocarbon, benzo(a) pyrene was not able to be assessed due to a lack of data on aircraft emissions and subsequent incorporation into water by partitioning or adsorption to particulates. Those compounds which adhere to particulates are of concern due to the potential for accumulation of deposits in the environment. However, it should be noted that airports are not identified as a major source of benzo(a) pyrene. The major environmental sources of all polycyclic aromatic hydrocarbons in Sydney have been identified as commercial and industrial incinerators, motor vehicles, burning off and bushfires (Environment Protection Authority, 1991).

Furthermore, settling filtration and coagulation processes in water filtration plants in the Sydney Water system are capable of reducing the concentration of benzo(a) pyrene to less than 1 nanogram per litre (ten times lower than the recommended guideline) even if the influent concentration is high. It is likely that other polycyclic aromatic hydrocarbons would be similarly reduced (National Health and Medical Research Council, 1996). This removal efficiency was confirmed in prototype trials of the Prospect Water Filtration System which reported 99 percent removal of particles for articles between 2 and 350 micrometres (Murray, 1995).

The situation in the aquatic environment concerning polycyclic aromatic hydrocarbons was not able to be quantified. The guideline for benzo(a) pyrene ecosystem protection is three micrograms per litre, but this needs to be applied cautiously given the lack of toxicity data on some other polycylcic aromatic hydrocarbons. The guideline, however, does take into account bioconcentration factors which can be significant for compounds such as benzo(a) pyrene.

Monitoring of the Parramatta River showed benzo(a) pyrene to be in the range of 0.3 to 0.9 nanograms per litre (Smith et al, 1991) which is three orders of magnitude lower than recommended guidelines. It should be noted that the Parramatta River is typical of an industrial and urbanised watercourse, receiving considerable road runoff. Road runoff has been identified as a major source of polycyclic aromatic hydrocarbons in aquatic systems (Sydney Water 1995). Even for highly contaminated rivers such as the Rhine River at Mainz and the Thames River in London the concentrations of benzo(a) pyrene range between 0.05 to 0.1 micrograms per litre (Smith et al, 1991). If these rivers, which would have a far higher exposure to sources of polycyclic aromatic hydrocarbons still satisfy ecosystem guidelines then it is reasonable to conclude that the increased exposure from aircraft sources would not be sufficient to raise aquatic concentrations to undesirable levels.

In summary, it would be appear from the above evidence that polycyclic aromatic hydrocarbons are not considered a risk to Sydney's filtered water supply or to natural waterways. It is recommended that the concentrations of airborne polycyclic aromatic hydrocarbons from the airport operation and their subsequent transfer to water be quantified and assessed for both human health and ecosystem risk.

Effects of Air Pollutants on Rainwater Tanks

The potential for aircraft emissions to contaminate rain water supplies was examined by estimating the transfer and solubility of key air pollutants onto roofs in areas near Badgerys Creek not supplied by mains water (data supplied by Sydney Water Corporation). Ground level concentrations of pollutants were derived from the air quality modelling studies, (refer *Technical Paper No. 6 - Air Quality*). The analysis took into account compounds likely to absorb to particulates.

Rainwater tanks can provide a reliable source of water but water collected in such tanks can be subject to quality problems. These arise from contamination of roof surfaces, from sources such as aerial pollutants as well as from animal droppings and leaching of roof materials. Contaminants can potentially accumulate in bottom sediments within rainwater tanks.

This study was not able to identify any monitoring data for contaminants of concern in rainwater tanks, although there was limited data available on faecal coliforms available from the Department of Health.

The western area of Sydney has been identified as a region of poor air quality. Consequently significant contaminant background levels would be expected. Background concentrations within rainwater tanks in the vicinity of the sites of the airport options were not evaluated for this study. This was partly because limitations in analytical methods mean that it is difficult to detect low enough concentrations for health impacts to occur (as was identified in a study by Sydney Water, pers com Peter Schneider). A large number of variables affect water quality in tanks, such as roof material, water consumption, animal contamination, age of the system and rainfall patterns.

Given the existing potential water quality problems from roof contamination, it is advisable for water to be either filtered or a first flush diversion system installed, where rainwater tanks are used for potable water supply.

The potential risk to domestic rainwater tanks was also not able to be fully quantified. For gaseous emissions the equilibrium concentrations determined for reservoirs would also apply to rainwater tanks. These predicted worse case concentrations for benzene at Badgerys Creek were more than ten thousand times lower than the drinking water guideline of one micro gram per litre.

The situation for particulate emissions such as polycyclic aromatic hydrocarbons is more complex due to the lack of data on these compounds in aircraft emissions as well as the effects of microclimatic factors in transfer particles into water. However, given the potential for particulates and associated pollutants from various sources to accumulate in rainwater tanks it would be desirable for any rainwater tanks utilised for potable purposes to have appropriate filtration or other treatment prior to use. Further data would need to be collected and modelling undertaken into the transfer of particulate emissions into water tanks to assess the relative importance of aircraft emissions.

Fuel Discharges from Aircraft

The likely incidence of fuel dumping, which is required in emergency situations, and accidental venting of fuel, are discussed in *Technical Paper No. 6 - Air Quality*.

The constituents of aircraft fuel are petroleum derived and are light weight and insoluble in water. Therefore any dumped fuel reaching the surface would be likely to float on the surface of waterbodies such as Lake Burragorang or Woronora Dam. If accidental fuel venting occurred over Warragamba Dam, water could be drawn off at a lower depth to minimise any risk of contamination.

Aircraft Crashes

The other area of concern with either Sydney Water reservoirs or smaller storages is the potential affects of aircraft fuel discharges or aircraft crashes.

Sydney Water Corporation provided risk and hazard information on the possible consequences of aircraft crashes effecting major infrastructure or populations. In general, any aircraft crash scenario affecting Sydney Water infrastructure would have implications for water supply, supply of sewerage services as well as the potential for pollution from sewerage system damage or aircraft fuel. The likelihood of aircraft crashes has been assessed in *Technical Paper No. 10 - Hazards and Risks*.

At Warragamba, dam break failure studies have been carried out for probable maximum flooding impacts (Mitchell McCotter, 1996). One potential impact identified was the case of failure of one or more of the dam gates. Consequences of this event would be the loss of an estimated 35 percent of total storage. Although the gates could be repaired within a couple of months, Sydney Water may have to wait several years for recovery of stored water via rainfall. The impact of the downstream flooding resulting from such an event has not been assessed, although failure of a dam gate is less catastrophic event than dam collapse.

A plane crash within the catchment area of dams such as Lake Burragorang has the potential to cause bushfires. Such events can add to nutrients and other pollutants within the lake after rainfall and lead to reduced runoff yields due to regrowth for several years.

No studies have been undertaken on other dams, although probable maximum flood assessments are underway or planned for Woronora, Cordeaux and Cataract.

Aircraft crashes into storage waters or catchments would have the potential to affect raw water quality, particularly if near offtake points. Sydney Water has the ability to adjust vertical offtake level and could control floating material such as fuel by booms. It does not have the facilities for treating or removing fuel spills. The water filtration plants drawing water from these reservoirs do not have processes for fuel removal.

Sydney Water Corporation has also identified other infrastructure potentially at risk from an aircraft crash, including water filtration plants, pumping stations, service reservoirs, pipelines and canals and sewerage treatment plants. Damage to the Prospect Water Filtration Plant would result in severe consequences for Sydney's water supply as Prospect supplies 75 to 80 percent of drinking water. Damage to the Warragamba-Prospect pipeline could disrupt services from both Orchard Hills and Prospect. Depending on the location of the break, only minimal water supplies could be possible from the Blue Mountains system, the Upper Canal or Woronora.

Damage to the sewerage system could occur if a plane crashed into a sewage treatment plant or above ground sewer such as the South Western Suburbs Ocean Outfall Sewer (SWSOOS). In either case, large volumes of untreated sewage would discharge to local waterways and possibly surcharge through domestic fittings. Damage to the sewerage system would be expected to have environmental impacts as well as potential human health implications.

External Issues

Although this assessment is primarily concerned with the direct impacts on water quality from airport operations, it is recognised that there may be additional impacts from access roads, fuel, water supply and sewerage pipelines and railway lines. As well as this, there are potential long-term impacts from associated commercial/industrial or residential development. Additional traffic volumes would also increase aerial pollutants and stormwater pollutant levels. Issues associated with external infrastructure would be subject to additional environmental assessment.

The preferred option for water supply to the proposed airport sites is to connect in to the Warragamba pipeline and provide a new water filtration plant to service the airport. The route would essentially follow the Old Northern Road. No creek crossings are anticipated. Sewage effluent would be treated on-site and discharged near to the airport. Alternative options of transferring raw sewage either to a new South Creek Sewage Treatment Plant or to St Marys Sewage Treatment Plant.

6.2.3 GROUNDWATER

The airport development would reduce the amount of groundwater recharge, resulting in a lowering of groundwater levels. This effect may be locally counteracted by mounding beneath detention dams.

While potential exists for groundwater contamination from a number of sources, properly engineered surface water drainage facilities should protect groundwater from obvious sources such as fuel spillages and washdown bay runoff. Fuel storage and delivery systems would be designed to minimise the risk of leakages, through the use of double containment with interstitial monitoring systems. Similarly, wet stock reconciliation practices would be maintained.

Impacts to groundwater due to airport operations are considered of minimal magnitude and importance due to the absence of identified beneficial uses of groundwater at the Badgerys Creek sites, and the recognition of the low value of the groundwater.

7 IMPACTS OF HOLSWORTHY OPTIONS

7.1 CONSTRUCTION

7.1.1 SOIL EROSION AND ACIDITY

The potential erosion hazard for the soil landscape for the proposed Holsworthy airport, as assessed by the NSW Soil Conservation Service (Bannerman and Hazelton, 1990) is summarised in the following table:

TABLE 7.1 POTENTIAL FOR SOIL EROSION AT HOLSWORTHY

Soil Landscape Unit	Potential Erosion Hazard
Blacktown	Low to High
Lucas Heights	Slight to Extreme
Hawkesbury	Moderate to Very High
Gymea	Moderate to Extreme
Berkshire Park	Low to High

The potential for the existence of acid sulphate soils has also been assessed.

Acid sulphate soils are generally likely to be present in sediments of the recent (Holocene) geological age; in soils not more than five metres above high tide level; and in marine or estuarine settings (Environment Protection Authority, 1995). These sediments show traces of pyrite which, upon exposure to air, can oxidise to form sulphuric acid. The acid reacts with the clay minerals and dissolves metal particles in the soil such as iron and aluminium. The resulting acid and dissolved metals that leach from the soil are often toxic to flora and fauna.

As long as the pyritic sediment remains below the water table where it cannot be oxidised, it poses no problems. It is when pyritic sediment is exposed to air such as in periods of prolonged drought, or when the sediment is drained, excavated or after dredging, that problems can occur.

Reference to the 1:25,000 Acid Sulphate Soil Risk Map for Liverpool indicates that the northern end of the Holsworthy Military Area has potential acid sulphate soils along the Georges River, Harris, Williams and Tudera Creeks. The creeks have a low probability of occurrence of acid sulphate materials, which if encountered, are likely to occur between one and three metres depth and below three metres depth depending on the location.

Along the Georges River there is a low probability that acid sulphate materials occur in the alluvial sediments adjacent to the river channel. If encountered, these acid sulphate materials are likely to occur below a depth of three metres. However, there is a high probability that acid sulphate materials occur in the bottom sediments (below the water table) of the river. The Risk Map indicates that there is a severe risk if these bottom sediments are disturbed by activities such as dredging.

7.1.2 SURFACE WATER

Streams within Airport Sites

Estimated lengths of streams within the airport sites that would be infilled or taken up with stormwater detention structures are shown. Streams potentially affected by the borrow pits and obstacle limitation works are described in *Tables 7.3*. This is based upon information provided by Second Sydney Airport Planners (1997a). Streams would also be affected by dams constructed in the headwaters to provide water storage (500 megalitres) for construction activities such as compaction and dust suppression. At this stage the particular creeks to be dammed have not been specified.

TABLE 7.2 ESTIMATED LENGTHS OF CREEKS WHICH WOULD BE INFILLED OR TAKEN UP WITH STORMWATER DETENTION STRUCTURES.

Stream	**Estimated Length (Kilometres)**	
	Option A	**Option B**
Punchbowl Creek (plus tributaries)	n/a	16
Harris Creek	4.5	n/a
Williams Creek	8.1	n/a
Complete Creek	0	n/a
Deadmans Creek	0.6	n/a
O'Hares Creek (tributaries only)	n/a	4.8
Gunyah Creek	0	0.6
Total	**13.2**	**21.4**

TABLE 7.3 POTENTIAL IMPACTS OF CLEARING AND BORROW AREAS

Stream	Other Potential Impacts
Option A	
Harris Creek	Fuel Storage
Punchbowl Creek (plus tributaries)	Runoff from obstacle limitations for 1km length
Dingo Creek	Runoff from borrow pit
Williams Creek	Runoff from borrow pit, 2.5 km affected
Deadmans Creek	Runoff from borrow pit, 2 km affected
Lyretail Gully	Runoff from cut earthworks and obstacle limitation works
Wappa Creek	-
Lake Woronora Catchment	Tree cutting and minor surface cutting activities
Gunyah Creek	3 km length adjacent to obstacle limitation works
Option B	
Punchbowl Creek and Major Tributaries	Runoff from borrow pit, 3 km affected
Gunyah Creek	Tree felling and surface cut in headwaters 3 km length adjacent to obstacle limitation works. Borrow area on adjacent ridges for 3km
O'Hares Creek	Obstacle limitation and cut adjacent ridges. Access road construction.
Dahlia Creek	Obstacle limitation on adjacent ridges
Woronora River Tributaries	Obstacle limitation on adjacent ridges

As shown in the tables, airport construction will involve substantial filling of gullies, completely removing habitat and aquatic biota. There may also be more long term impacts from leaching of salts from fill. These salts, including iron compounds can cause oxygen depletion in downstream surface waters.

Downstream Impacts

In principle, downstream of infill areas there should be no adverse water quality impacts, provided sediment control is adequate and stream flow is maintained to approximate pre-existing patterns. However with the large scale 'mining operation' necessary of Holsworthy, it may be difficult to fully control sediment export from the site. It is proposed that over 70 percent of the site would be disturbed at any one time. There would be a need to clear most of the vegetation in the early stages to allow for unexploded ordnance removal.

The sites of the Holsworthy options are considered to pose relatively high risks due to the steep terrain and high rainfall erosivity of the area. Several factors contribute to erosion and sediment movement:

- rainfall erosivity;
- soil erodability;
- slope length/gradient; and
- ground cover.

Appendix E provides the calculation basis for the Universal Soil Loss Equation (potential soil loss measure) and derivation of Soil Loss Class. Calculations have been done for both steep terrain and ridge tops.

On the more level ridge lines the estimated export of sediment from an exposed hectare of soil is 44 tonnes per year. This places the ridge lines in the Soil Class 1 where standard sediment control measures are generally adequate to limit sediment pollution to acceptable levels (Department of Housing, 1993). For gully sides the expected sediment export is calculated to be 2,300 tonnes per hectare per year, which places this zone in the Soil Class 3. Development of Class 3 lands "should only proceed where very stringent erosion and sediment control measures are implemented, but such measures are likely to be expensive and could render works uneconomic." (Department of Housing, 1993).

Sediment export is to be controlled primarily by the permanent water detention basins, which would be put in place during the earliest stages of construction. These basins are designed cater for the volume for a 1 year Average Return Interval storm and to drain gradually over a period of approximately 20 days via a low capacity pipe.

The location of these basins in gullies and streams would result in further removal of stream habitat. Construction and maintenance of such basins would also incur land disturbance and stringent sediment control would be required to prevent impacts to streams.

In the event of a large storm (in either intensity of duration) of if a minor storm occurs when the pond water level is high, the detention ponds would overflow. Detention times in the ponds would be of the order of an hour or so even under major storm conditions, and coarser sediments (sands etc) would be retained. However some finer fractions of sediment would not be fully trapped on these occasions.

Storms of intermediate magnitude (high volume of turbid runoff but no overflow) may also contribute sediment via drainage of turbid water through the low capacity pipes. This discharge should gradually clear as the sediment in the pond settles.

Given the extended construction period for the Airport options, there is a significant risk of finer sediment escaping detention during storm events.

Greatest release of sediment would be expected to occur during a major storm event when stream flows would be elevated. With this high flow the fine sediment would be transported well into the creek systems (or into the Woronora River for creeks such as Wappa). It may take more than one major storm to scour this sediment through to the Georges River or, for the Woronora River streams, into Port Hacking. *Figures 7.1* and 7.2 show rivers and streams potentially impacted by sediments.

The transfer of fine sediment to the receiving streams and ultimately to the Georges or Woronora Rivers would have potential stream impacts including:

- changes in stream flow characteristics;
- direct smothering of fauna (0.1 metre sufficient to smother benthic fauna - Rooney 1991);
- interference with gill function in fish, filter feeding mechanisms (Hardwick et al, 1995);
- reduction in the euphotic zone and retardation of aquatic plant function;
- increased turbidity interfering with visual feeding; and
- siltation and reduction in stream habitat, removal of water sources for riparian fauna.

Pollutants attached to sediment particles are also of concern. Nutrients such as phosphorus tend to absorb to particles such as clays and can be incorporated into downstream sediments, supplying a nutrient source for later stimulation of aquatic plants and algae.

Given the highly pristine nature of the streams draining the two site options at Holsworthy, any increase in sediment load and associated pollutants would be expected to have a large impact on stream water quality and ecology. This would occur Over virtually the full length of the streams to their confluence with the Georges River and for a high proportion of the Woronora River. The diversity of habitats available could decline, leading to changes in in-stream and riparian fauna.

Reservoirs

The construction area for Option A does not directly intrude into the catchment for Woronora Reservoir. There are plans, however, for obstacle limitation works on an adjacent ridge. There would be a need for careful control of sediment and vegetation clearance to prevent runoff to sediment into the reservoir catchment.

Transfer of airborne dust to the Woronora Reservoir is also an area of concern. With the proximity of Option A and to a lesser extent Option B, construction would need to incorporate an efficient dust suppression program using water sprays and covering or stabilising of stockpiles.

7.1.3 GROUNDWATER

There is insufficient data available to identify specific impacts to groundwater due to construction. Generally, however the main physical impact of construction on groundwater will be a temporary increase of groundwater level. Clearing of vegetation, quarrying and surface water storage/detention ponds all have potential to increase the amount of infiltration at various locations. This could result in localised mounding of the groundwater beneath the disturbed areas. Groundwater levels however, would be constrained by the deeply incised regional surface water drainage features, and levels are likely to fall, following completion of the construction phase.

The potential exists for impacts to surface water quality via the transportation of contaminants in groundwater discharging to the creeks as baseflow. Possible contaminant sources include salt leached from fill material, contaminated water from detention dams, and accidental spillages of fuel and chemicals such as ammonium nitrate.

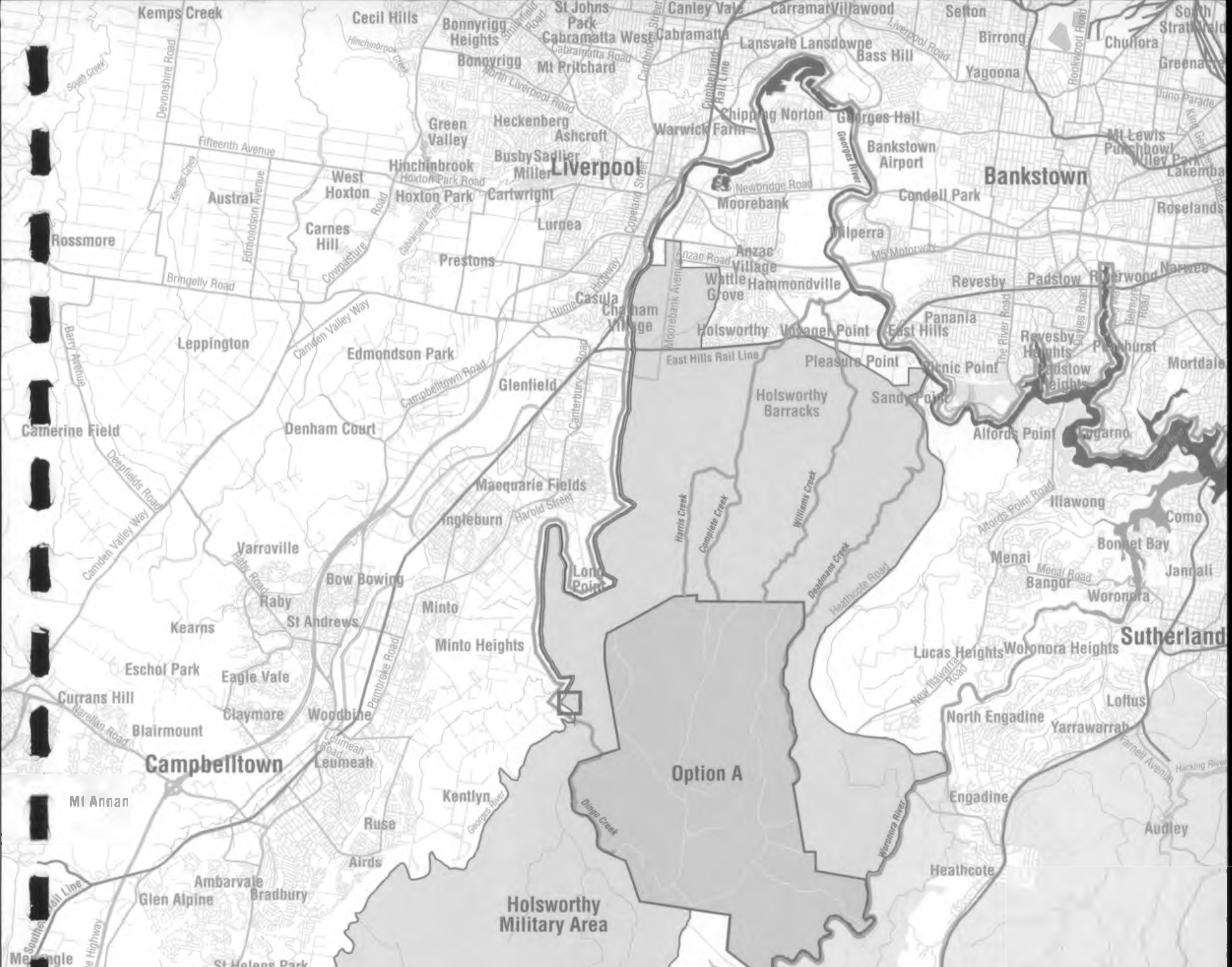
While a detailed hydrogeological study would be necessary to accurately identify impacts to specific creeks, potential for surface water contamination from groundwater exists for all named creeks within the sites of the airport options.

7.2 OPERATIONAL

Treated stormwater would be discharged into Williams, Harris and Punchbowl Creek for Option A and Punchbowl Creek for Option B.

7.2.1 HYDROLOGY

As the developed airport will contain large areas of paved or impervious surfaces and an efficient drainage system, site runoff would have a quicker



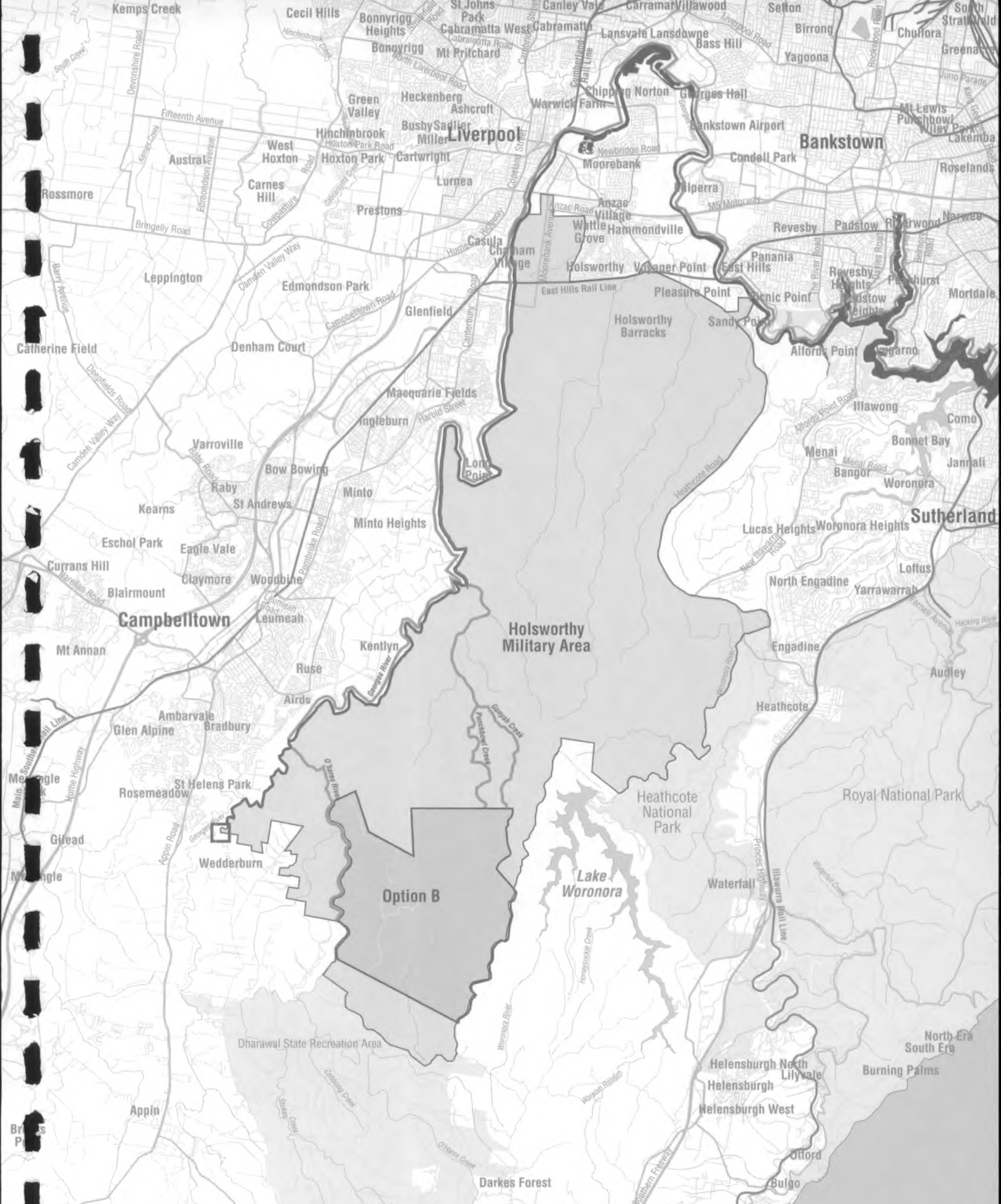
Creeks and rivers impacted by sewage treatment plant discharge

Creeks impacted by stormwater runoff

Optional Sewage treatment plant discharge point

Figure 7.1

Potential Water Quality Impacts of Holsworthy Option A



Creeks and rivers impacted by sewage treatment plant discharge

Creeks impacted by stormwater runoff

Sewage treatment plant discharge point

Figure 7.2

Potential Water Quality Impacts of Holsworthy Option B

response time and losses by infiltration will be lower than at present. Therefore post development runoff would exceed pre-development runoff.

Preliminary design of airport drainage infrastructure at Holsworthy has been based upon sizing of detention ponds so that they can temporarily detain stormwater produced by severe storm events up to one in 100 years Average Recurrence Interval. This was based upon the assumption that to prevent increased flooding the volume rate of discharge should be limited to 20 percent less than existing peak values (Second Sydney Airport Planners, 1997a). To verify this assumption, it would be necessary to carry out flood modelling for the whole catchment to Georges River. This work is yet to be undertaken.

7.2.2 SURFACE WATER

Stormwater Discharges

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.

Stormwater management proposed for the site would limit the export of oil, grease and fire fighting chemicals through bunding and interception. Detention basins include surface booms for trapping any oils which escape the interception pits. Contaminants entering the water quality reed beds would include nutrients, suspended solids, trace metals and trace organics washed off pavements and other surfaces.

Water quality ponds and reed beds can typically remove approximately 60 percent of phosphorus and 50 percent of nitrogen (Lawrence, 1996). Phosphorus removal is also facilitated by chemical dosing of water quality ponds. Where full detention is available, this allows essentially complete capture of metals and sediments.

A predicted residual annual nutrient loading at Holsworthy has been calculated based on applying nitrogen and phosphorus loadings consistent with a commercial/industrial land use and allowing from runoff from the remainder of the catchment at existing loading rates.

The estimated annual nutrient loading from the existing bushland catchments and predicted loads once the airport is fully operational are given in *Table 7.4* (calculations in *Appendix E*). Discharge of treated stormwater is expected to result in a seven fold increase in the phosphorus loads and a doubling of the nitrogen exports. Streams and rivers potentially impacted by stormwater are shown in *Figures 7.1* and *7.2*.

TABLE 7.4 PREDICTED NUTRIENT LOADS FROM STORMWATER DISCHARGES

		Option A	Option B
Total Nitrogen	Current load (kg/yr)	6,375	4,207
	Post airport load (kg/yr)	12,750	8,415
Total Phosphorus	Current load (kg/yr	425	280
	Post airport load (kg/yr)	3,060	2,020

Sewage Treatment Plant Discharges

Major downstream impacts are also predicted for potential treated effluent discharges. One option proposed is to provide an on-site sewage treatment plant for an airport at Holsworthy. Wastewater would be treated to tertiary level and incorporate disinfection and a high level of nutrient removal. The resultant effluent quality (50th percentile) would be:

Biochemical Oxygen Demand	10 milligrams per litre
Suspended Solids	10 milligrams per litre
Total Nitrogen	5 milligrams per litre
Total Phosphorus	0.3 milligrams per litre
Faecal Coliforms (assumed)	< 200 colony forming units per 100 millilitres

Effluent reuse would be incorporated wherever practicable. This would include a dual reticulation system supplying recycled effluent for toilets and outside water applications. Fire fighting and irrigation are also proposed to use recycled effluent. Incorporation of water demand management could reduce the volume of wastewater requiring treatment. It is estimated that in dry weather approximately 50 percent of effluent can be reused at the airport both for outside purposes and within facilities. Wet weather reuse would be predominantly within facilities where 25 percent of total effluent would be expected to be utilised.

For both Options A and B, it is proposed to pipe treated effluent to the Georges River for discharge. The locations of discharge points are shown in *Figures 7.1* and 7.2. The Georges River was selected as the receiving zone as local streams were considered to be a higher risk of degradation from discharge, unless a very high level of treatment was provided. This was considered uneconomic.

With 50 percent reuse, the volume requiring discharge during dry weather is estimated to be 3.75 megalitres per day for Stage 1 and 11.25 megalitres per day for the Master Plan. This discharge was used to predict river pollutant concentrations during dry weather. For annual loading calculations where higher discharges would occur in wet weather, the full average daily flow was used for calculations (for example, 7.5 and 22.5 megalitres per day for Stage 1 and Master Plan respectively).

The proposed discharge point for Option A is just downstream of Punchbowl Creek and Option B upstream of O'Hares Creek and west of Mt Giliad.

To estimate impacts, flow data was obtained from Australian Water Technologies for the gauge at Liverpool Weir. The flow at the discharge points is predicted to be lower than that recorded at Liverpool Weir as the two potential discharge points are upstream of this gauge and upstream of Bunbury Curran Creek (a major tributary). In addition, the data covered only a five year period from August 1992 to February 1997. The 90th percentile and 50th percentile flows for Liverpool Weir for the period are 22.4 and 40.7 megalitres per day respectively. Existing water quality data was taken from Ingleburn Weir (Sydney Water data, August 1995 to August 1996).

Using the lower flow regime represented by the 90th percentile (when the aquatic ecology is under greater stress), the resultant concentrations of nitrogen, phosphorus and faecal coliforms in the Georges River from an airport sewage treatment plant discharge are given in *Table 7.5*.

TABLE 7.5 WATER QUALITY PREDICTIONS FOR THE GEORGES RIVER, DOWNSTREAM AND EFFLUENT DISCHARGE POINTS (DRY WEATHER FLOW)

	Existing water quality (median) milligrams per litre	**Stage 1 predication** milligrams per litre	**Master Plan predication** milligrams per litre	**ANZECC guidelines** milligrams per litre
Total Nitrogen	0.2	0.6	1.8	0.5-0.75
Total Phosphorus	0.01	0.04	0.1	0.01-0.1
Faecal Coliforms	16	42	78	150

Annual loads of constituents were calculated and compared to data developed for Sydney Water (Water board, 1991). The results are shown in *Table 7.6*.

TABLE 7.6 POLLUTANT LOADINGS FOR THE GEORGES RIVER, DOWNSTREAM AND EFFLUENT DISCHARGE POINTS (ANNUAL AVERAGE)

	Existing loading (tonnes/year)	**Stage 1 contribution (tonnes/year)**	**Masterplan contribution (tonnes/year)**
Nitrogen	36	13.7	41
Phosphorus	1.2	0.8	2.5
Suspended Solids	730	27	82
Biochemical oxygen demand	40	27	82

The impact of this effluent on aquatic ecosystems would largely be to stimulate aquatic plant and algal growth, particularly as this section of river is generally of low plant productivity. *Table 7.5* indicates that, with the ultimate flow, concentrations of nutrients in the river would be within the range where eutrophication is enhanced. Of higher concern is the potential loading of conserved substances such as phosphorus. As phosphorus can accumulate in sediments and become a long-term supplier of nutrient, the predicted increase in nearly 200 percent in phosphorus loading is significant. An increase in algal or plant productivity may adversely influence other ecosystem components such as habitat and faunal species composition.

There are not expected to be any acute or chronic toxicological problems given the proposed treatment process and effluent quality. Suspended solids loads from the discharge are not considered problematical nor is any depression in dissolved oxygen expected from discharged biochemical oxygen demand.

Faecal coliform concentrations conform to primary contact recreational guidelines.

However, deterioration in water quality could have detrimental effects on recreational use of the river, including swimming and fishing. Of particular concern is the potential for further eutrophication of recreational lakes at Lake Moore and Chipping Norton Lakes.

Commercial fishing is not an issue for this discharge as commercial fishing is currently deemed non productive above Tom Ugly's Bridge. No new or renewed commercial leases are envisaged unless water quality and productivity improves dramatically (pers com John Diplock, NSW Fisheries).

Effects of Air Pollutants on Reservoirs

The impact of aerial pollutants from aircraft operation on receiving streams was also investigated and the predicted concentrations compared to ecological guidelines for a quality biota (Australia and New Zealand Environment Conservation Council, 1992).

Reservoirs near the sites of the Holsworthy options include the potable water supplies of Woronora and the more distant Nepean system, Prospect and Warragamba reservoirs. The risk of aircraft emissions contaminating water supplies was examined by estimating the transfer and solubility of key contaminants into waters near offtakes given ground level concentrations and pollutants derived from the air quality modelling studies and reported in *Technical Paper No. 6 - Air Quality*.

The effect of aerial pollutants on water quality was assessed for potable water reservoirs, domestic water tanks and aquatic ecosystems. Predicted concentrations were compared against drinking water guidelines (National Health and Medical Research Council, 1996) and ecosystem protection guidelines (Australia and New Zealand Environment Conservation Council, 1992). The drinking water guidelines are based on maximum concentrations considered not to pose any significant risk to the health of the consumer over a lifetime of a consumer. The ecosystem guidelines are based on chronic and acute toxicity data for aquatic test organisms.

The impacts of aerial pollutants in water were determined for benzene and benzo(a)pyrene (a polycyclic aromatic hydrocarbon). These were chosen as representing the more toxic of constituents potentially generated by an airport. Benzene also represents the behaviour of gaseous emissions such as formaldehyde, toluene and xylene. Benzo(a)pyrene is an indicator of those non gaseous compounds which can attach to particles in the atmosphere. The calculations were simplified as there was insufficient data to enable modelling of the full range of meteorological conditions. A conservative approach has therefore been taken.

The assessment was based on maximum annual emission contours (predicted from the air quality assessment *refer Technical Paper No. 6-Air Quality*). The situation where short-term meteorological conditions may result in localised high pollutant concentrations was also considered, such as during atmospheric inversion. Microclimatic studies reported in *Technical Paper No. 5 - Meteorology* indicated that these pollutants are unlikely to be transferred into the water column due to isolating effect of the cold air flowing down over a reservoir in the late afternoon from the side of the catchment.

For benzene, maximum predicted ground level concentrations were provided by the air quality monitoring predictive models for each airport options. The worst case contour was used for calculations which are contained in *Appendix E*. The concentration in a water body was then determined by applying a partitioning coefficient (Henry's constant). These concentrations would be relevant to potable water reservoirs, domestic water tanks and natural water courses.

Levels of benzene for both options at Holsworthy were more than a thousand times lower than the drinking water guideline of one gram per litre and more than one million times lower than ecosystem protection guidelines. It should be noted that gases such as benzene which are dissolved in water are in a state of equilibrium with atmospheric concentrations and hence do not accumulate over time.

The polycyclic aromatic hydrocarbon, benzo(a) pyrene was not able to be assessed due to a lack of data on aircraft emissions and subsequent incorporation into water by partitioning or adsorption to particulates. Those compounds which adhere to particulates are of concern due to the potential for accumulation of deposits in the environment. However, it should be noted that airports are not identified as a major source of benzo(a) pyrene. The major environmental sources of all polycyclic aromatic hydrocarbons in Sydney have been identified as commercial and industrial incinerators, motor vehicles, burning off and bushfires (Environment Protection Authority, 1991).

Furthermore, settling filtration and coagulation processes in water filtration plants in the Sydney Water system are capable of reducing the concentration of benzo(a) pyrene to less than 1 nanogram per litre (ten times lower than the recommended guideline) even if the influent concentration is high. It is likely that other polycyclic aromatic hydrocarbons would be similarly reduced (National Health and Medical Research Council, 1996).

The situation in the aquatic environment concerning polycyclic aromatic hydrocarbons was not able to be quantified. The guideline for benzo(a) pyrene ecosystem protection is 3 micrograms per litre, but this needs to be applied cautiously given the lack of toxicity data on some other polycyclic aromatic hydrocarbons. The guideline, however, does take into account bioconcentration factors which can be significant for compounds such as benzo(a) pyrene.

Monitoring of the Parramatta River showed benzo(a) pyrene to be in the range of 0.3 to 0.9 nanograms per litre (Smith et al, 1991) which is three orders of magnitude lower than recommended guidelines. It should be noted that the Parramatta River is typical of an industrial and urbanised watercourse, receiving considerable road runoff. Road runoff has been identified as a major source of polycyclic aromatic hydrocarbons in aquatic systems (Sydney Water 1995). Even for highly contaminated rivers such as the Rhine River at Mainz and the Thames River in London the concentrations of benzo(a)pyrene range between 0.05 to 0.1 micrograms per litre (Smith et al, 1991). If these rivers, which would have a far higher exposure to sources of polycyclic aromatic hydrocarbons still satisfy ecosystem guidelines then it is reasonable to conclude that the increased exposure from aircraft sources would not be sufficient to raise aquatic concentrations to undesirable levels.

In summary, it would be appear from the above evidence that polycyclic aromatic hydrocarbons are not considered a risk to Sydney filtered water supply or to natural waterways. The data is not clear for tank water quality. It is recommended that the concentrations of airborne polycyclic aromatic hydrocarbons from the airport operation and their subsequent transfer to water be quantified and assessed for both human health and ecosystem risk.

Rainwater Tanks

The potential for aircraft emissions contaminating tank water supplies was examined by estimating the transfer and solubility of key air pollutants onto roofs in areas near Holsworthy not supplied by mains water (data supplied by Sydney Water Corporation). Ground level concentrations of pollutants were derived from the air quality modelling studies (refer *Technical Paper No. 6 - Air Quality*).

Rainwater tanks can provide a reliable source of water but water collected in such tanks can be subject to quality problems. These arise from contamination of roof surfaces from sources such as aerial pollutants as well as from animal droppings and leaching of roof materials. Contaminants can potentially accumulate In bottom sediments within rainwater tanks.

This study was not able to identify any monitoring data for contaminants of concern in rainwater tanks, although there was some limited data available from the Department of Health on faecal coliforms.

Background concentrations within rainwater tanks in the vicinity of the sites of the airport options were not evaluated for this study. This was partly because limitations in analytical methods mean that it is difficult to detect low enough concentrations where health impacts occur (as was identified in a study by Sydney Water, pers com Peter Schneider). A large number of variables affect water quality in tanks, such as roof material, water consumption, animal contamination, age of the system and rainfall patterns.

Given the existing potential water quality problems from roof contamination, it is advisable for water to be either filtered or a first flush diversion system installed, where rainwater tanks are used for potable water supply.

The potential risk to domestic rainwater tanks was also not able to be fully quantified. For gaseous emissions the equilibrium concentrations determined for reservoirs would also apply to rainwater tanks. These predicted worse case concentrations for benzene at Badgerys Creek were more than ten thousand times lower than the drinking water guideline of one gram per litre.

The situation for particulate emissions such as polycyclic aromatic hydrocarbons is more complex due to the lack of data on these compounds in aircraft emissions as well as the effects of microclimatic factors in transfer particles into water. However, given the potential for particulates and associated pollutants from various sources to accumulate in rainwater tanks it would be desirable for any rainwater tanks utilised for potable purposes to have appropriate filtration or other treatment prior to use. It is recommended that further data be collected and modelling undertaken into the transfer of particulate emissions into water tanks to assess the relative importance of aircraft emissions.

Fuel Discharges from Aircraft

The likely incidence of deliberate fuel dumping, which is required in emergency situation, and accidental venting of fuel, are discussed in *Technical Paper No. 6 - Air Quality*.

The constituents of aircraft fuel are petroleum derived and are light weight and insoluble in water. This would ensure that any dumped fuel reaching the surface would stay on the surface of waterbodies such as Lake Burragorang or Woronora Dam. Should fuel dumping occur over Warragamba Dam, then water could be drawn off at a lower depth to minimise any risk of contamination. It may also be possible for Air Traffic Controllers to set a specified track for dumping away from reservoirs.

Aircraft Crashes

The other area of concern with either Sydney Water reservoirs or smaller storages is the potential effects of aircraft fuel discharges from aircraft crashes.

Sydney Water Corporation provided risk and hazard information on the consequences of aircraft crashes effecting major infrastructure or populations. In general, any aircraft crash scenario affecting Sydney Water infrastructure would have implications for water supply, supply of sewerage services as well as the potential for pollution from sewerage system damage or aircraft fuel.

At Warragamba, dam break failure studies have been carried out for probable maximum flooding impacts (Mitchell McCotter, 1996). One potential impact identified was the case of failure of one or more of the dam gates. The likelihood of aircraft crashes is covered in *Technical Paper No. 10 - Hazards and Risks*. The consequences of this event would be the loss of an estimated 35 percent of total storage. Although the gates could be repaired within a couple of months, Sydney Water may have to wait several years for recovery of stored water via rainfall. The impact of the downstream flooding resulting from such an event has not been assessed, although failure of a dam gate is less catastrophic event than dam collapse.

A plane crash within the catchment area of dams such as Lake Burragorang has the potential to cause bushfires. Such events can add to nutrients and other pollutants within the lake after rainfall and lead to reduced runoff yields due to regrowth for several years.

No studies have been undertaken on other dams, although probable maximum flood assessments are underway or planned for Woronora, Cordeaux and Cataract.

Aircraft crashes into storage waters or catchments would have the potential to affect raw water quality, particularly if near offtake points. Sydney Water has the ability to adjust vertical offtake level and could control floating material such as fuel by booms. It does not have the facilities for treating or removing fuel spills. The water filtration plants drawing water from these reservoirs do not have processes for fuel removal.

Sydney Water Corporation has also identified other infrastructure potentially at risk from an aircraft crash, including water filtration plants, pumping stations, service reservoirs, pipelines and canals and sewerage treatment plants. Damage to the Prospect Water Filtration Plant would result in severe consequences for Sydney's water supply as Prospect supplies 75 to 80 percent of drinking water. Damage to the Warragamba-Prospect pipeline could disrupt services from both Orchard Hills and Prospect. Depending on the location of the break, only minimal water supplies could be supplied from the Blue Mountains system, the Upper Canal or Woronora.

Damage to the sewerage system could occur if a plane crashed into a sewage treatment plant or above ground sewer such as the South Western Suburbs Ocean Outfall Sewer (SWSOOS). In either case, large volumes of untreated sewage would discharge to local waterways and possibly surcharge through domestic fittings. Damage to the sewerage system would be expected to have environmental impacts as well as potential human health implications.

External Issues

Although this assessment is primarily concerned with the direct impacts on water quality from airport operations, it is recognised that there may be additional impacts from access roads, fuel, water supply and sewerage pipelines and railway lines. As well as this, there are potential long-term impacts from associated commercial/industrial development. Additional traffic volumes would also increase aerial pollutants and stormwater pollutant levels. Issues associated with external infrastructure would be subject to additional environmental assessment.

The access roads into the Holsworthy Option A would require construction of bridges over the Georges River and Harris Creek for access from the south Western Freeway or alternatively, eastern access from the Princes Highway which would require bridges over the Woronora River, Mill Creek, Deadmans Creek and Williams Creek. The rail corridor is proposed to link to the East Hills line, travelling south before crossing Harris Creek.

For Option B, the road options are to link the South Western Freeway via either O'Hares Creek and the Georges River or from the north near Moorebank Avenue and crossing Punchbowl Creek. Another option is to link the airport to Heathcote Road with the route following the Old Illawarra

Road. Rail access would be from the west and follow the road route from the Freeway.

Bridges over gorges are likely to be constructed using cantilevered or incrementally launched methods which involve minimal disturbance to the base of gorges other than localised areas at the piers. As noted above, the steep terrain and erodability of soils would require extreme caution and rigorous sediment management to avoid sediment runoff to streams during construction. The upgrading of the Old Illawarra Road would need to prevent any sediment runoff into Lake Woronora or the catchment area.

The effluent transfer pipeline from Option A is proposed to follow the ridgeline to the Georges River. For Option B, crossings of O'Hares Creek and Pheasants Creek would be required. Water supply pipelines for Option A could either come from Macarthur Water Purification Plant, crossing Georges River, O'Hares Creek and Punchbowl Creek or from the Prospect system to the north. In the latter, the pipeline would follow the ridge or from Woronora Water Purification Plant. For Option B, water could be supplied from Macarthur South, crossing the Georges River and O'Hares Creek, connection to an existing main near Appin Road with crossings of the Georges River and Pheasants Creek or from Woronora Treatment Plant, following a route below Woronora Dam and Old Illawarra Road.

7.2.3 GROUNDWATER

Operations at the airport sites would generally impact on groundwater due to an increase in the amount of impervious ground, and the increase in surface water runoff rates. Both factors will reduce the retention time and amount of water available for infiltration, ultimately resulting in reduced groundwater level. This affect may be locally counteracted by the removal of trees and in the presence of retention basins, where local groundwater mounding would occur.

While potential exists for groundwater contamination from a number of sources, properly engineered surface water drainage facilities should protect groundwater from obvious sources such as fuel spillages and washdown bay runoff. Fuel storage and delivery systems should be designed to minimise the risk of leakages, through the use of best practice measures such as double containment with interstitial monitoring. Similarly, wet stock reconciliation procedures should be maintained.

The use of fertilisers on tended vegetated areas could add nutrients to the groundwater and ultimately the creeks around the sites. However, the risk of such contamination is low and would be minimised through good management practices.

Part D

Environmental Management

8 ENVIRONMENTAL MANAGEMENT - BADGERYS CREEK OPTIONS

The airport concept designs and construction plans detail the mitigation measures planned to control impacts from construction activity as well as the impacts from an operating airport. The predicted impacts of these proposals at Badgerys Creek are given in Chapter 6. This section examines the requirements for environmental management to mitigate these impacts and monitoring to enable impacts to be measured.

8.1 MITIGATION OF CONSTRUCTION IMPACTS

8.1.1 SOIL MANAGEMENT

Measures to control soil erosion and sedimentation would need to be implemented to ensure that soil erosion does not occur and thus threaten engineering works and the environment, and to ensure that sedimentation of both on site and off site areas is minimised during construction.

An erosion and sedimentation control plan would need to be prepared prior to the commencement of construction. Preparation of such a plan would need to be undertaken in consultation with the Department of Land and Water Conservation. Likely measures that would need to be implemented include:

- phasing the construction to confine disturbance to areas of workable size and minimise the duration of the disturbance;
- clearing vegetation initially along drains and erosion/sedimentation control structures. Where possible, natural vegetation should be maintained to act as buffer zones to minimise erosion and sedimentation;
- stockpiling stripped topsoils and chipped vegetation for later use in revegetation. Stockpiles should be protected by temporary vegetation or mulching, and located away from drainage lines and upstream of sedimentation structures. Diversion banks and/or catch drains would need to be constructed to protect stock piles from erosion by surface flows;
- the use of staked strawbales or siltation fences to restrict sediment movements within the site and to prevent any movements off site;
- revegetation of constructed areas as soon as possible. Stockpiled topsoil and chipped vegetation should be spread and vegetated initially with

fast growing species and ultimately with permanent vegetation. This operation should be undertaken progressively during construction;

- installation of drainage works early in the program to protect construction areas from run-on. Flow velocities should be minimised and flows dispersed, rather than concentrated. Energy dissipaters such as rip-rap gabions or mattressing may be required to control flows and, erodible areas should be provided with scour protection;
- construct sediment ponds to minimise total volumes and peak discharge rates of run-off. Controls may need to be provided for accumulated and accidental pollution; and
- construct any culverts early (that is, following clearing and prior to embankment construction) in natural watercourses. Flows would need to be minimised by rip-rap gabions or mattressing.

If acid sulphate soils are located during construction, further investigation would be required to define its extent, together with the formulation of an Acid Sulphate Soil Management Plan. Should future soil investigations within the airport sites reveal the likelihood of acid sulphate soils, reference should be made to the Environment Protection Authority and the NSW Roads and Traffic Authority Guidelines for assessing and managing acid sulphate soils.

8.1.2 STORMWATER MANAGEMENT

The dispersive soil properties at Badgerys Creek, together with the large area of expected disturbance requires diligent adherence to soil and sediment control to minimise export of sediment into receiving streams. Dosing of flocculants for turbidity control in sediment basins would need to be undertaken as well as adequate desludging of basins. Sediment control near to the source of disturbance is recommended using measures such as drainage diversion or interception. All sediment control structures should be regularly inspected and maintained.

Dust control should be managed through the diligent use of water sprays and stabilising or covering of stockpiles.

Storages for materials such as chemicals, fuel or concrete components should be bunded to contain any spills. Procedures should be implemented to promptly clean up any spillages and to dispose of soiled clean-up equipment or materials.

8.1.3 WASTEWATER MANAGEMENT

Provided that the temporary sewage treatment plant is carefully managed to avoid overflow and procedures are implemented to clean-up overflows (if they occur), there should be no need for additional mitigation measures.

8.2 MONITORING OF CONSTRUCTION IMPACTS

8.2.1 SURFACE WATER MONITORING

Further baseline monitoring of receiving streams should be undertaken prior to construction activity. During construction, regular monitoring should occur. This would include three locations on Badgerys Creek and two locations on Cosgroves Creek. Parameters to be measured include:

- flow rate and cumulative discharge;
- suspended solids;
- turbidity;
- total phosphorus;
- total nitrogen;
- oil and grease;
- pH;
- conductivity;
- dissolved oxygen;
- total hydrocarbons; and
- metals (copper, zinc, lead, cadmium, aluminium, iron).

Sampling should be undertaken once per month during dry weather, and during rain events to capture peak flow from the site. A rainfall event is classified as over 10 millimetres of rainfall in the preceding 24 hours. The program should aim to capture about 12 events per year.

Monitoring should also include inspection and regular reporting on the integrity of structures such diversion drains, sediment ponds or filter fences.

8.2.2 GROUNDWATER MONITORING

Pre-construction

A thorough understanding of the hydrogeological environment at the sites is required in order to identify the risks to groundwater from the airport construction and operation. To this end, a groundwater monitoring network should be installed, ideally 12 months prior to the onset of construction activities. The monitoring bores would be constructed to accepted international standards and surveyed to determine elevation and location.

The required number and locations of groundwater monitoring bores is site specific. Bores would be placed so as to confirm the regional groundwater flow direction, and provide strategically located monitoring sites. Areas which will ultimately have potential to act as contamination sources would have a sufficient density of groundwater monitoring sites to ensure reasonable understanding of hydraulic properties.

The monitoring network would provide data on the baseline conditions and indicate the natural variations of the groundwater system prior to development. Hydraulic properties of the aquifers would be determined by test pumping, and a monitoring program instigated to record water levels and chemical parameters on a quarterly basis. Parameters to be measured would include:

- pH;
- electrical conductivity;
- dissolved oxygen;
- redox potential;
- major cations (calcium, magnesium, sodium, potassium);
- major anions (chloride, sulphate, carbonate, bicarbonate, nitrate);
- metals (lead, copper, zinc, cadmium, aluminium, iron);
- total phosphorus;
- total nitrogen;
- total petroleum hydrocarbons;
- volatile organic compounds (including benzene, toluene, ethyl benzene and xylene); and
- polycyclic aromatic hydrocarbons.

Monitoring would include a report on the integrity of the monitoring boreholes.

Construction Phase

Given the low level of impacts to groundwater identified during the construction phase at the Badgers Creek options, no additional mitigation measures are necessary. The pre-construction groundwater monitoring program however, should be continued on a quarterly basis to identify any unforeseen groundwater contamination, should it occur.

Groundwater monitoring would utilise the bores installed prior to the commencement of construction. Parameters to be measured would be the same as for the pre-construction phase (see above):

- pH;
- electrical conductivity;
- dissolved oxygen;
- redox potential;
- major cations (calcium, magnesium, sodium, potassium);
- major anions (chloride, sulphate, carbonate, bicarbonate, nitrate);
- metals (lead, copper, zinc, cadmium, aluminium, iron);
- total phosphorus;
- total nitrogen;
- total petroleum hydrocarbons;
- volatile organic compounds (including benzene, toluene, ethyl benzene and xylene); and
- polycyclic aromatic hydrocarbons.

Monitoring would include inspection and reporting on the integrity of the monitoring bores.

8.3 MITIGATION OF OPERATIONAL IMPACTS

8.3.1 STORMWATER MANAGEMENT

The potential for stormwater pollution from the operation of an airport and ancillary services has been recognised in the proposed airport design. This section examines the efficacy of storm water quality measures.

The following measures are proposed to control stormwater quality or discharge volumes once the airport is operational:

- bunding of storage facilities;
- flame/fuel traps;
- gross pollutant traps;
- extended detention ponds;
- gravel filter beds; and
- flocculent dosing.

Pollutants such as suspended solids, heavy metals, oils and greases, detergents and gross pollutants such as litter should be adequately controlled through the processes operating in flame/fuel traps, gross pollutant traps, stormwater settling basins and reed gravel filters.

As discussed in *Section* 6, nutrient removal processes in the settling basins and wetland reed filters would not completely remove nitrogen and phosphorus in the stormwater. It is proposed to provide additional dosing of flocculants to enhance sediment and nutrient removal. This would occur in the detention basins when monitoring detects excessive nutrients escaping from the system. Although flocculants will assist phosphorus removal by adsorption processes, they are unlikely to fully remove phosphorus and would have minimal effect on dissolved nitrogen.

Adequate management and maintenance programs are essential for the continued efficacy of these measures. This includes regular cleaning of traps and desilting of sediment basins. The reed beds need to be monitored for clogging and short-circuiting and replacement of reed plants as required.

The discharges from the system should be measured (rate of flow and cumulative discharge) and monitored for the following parameters:

- suspended solids;
- total phosphorus;

- total nitrogen;
- faecal coliforms;
- oils and grease;
- polycyclic aromatic hydrocarbons;
- total petroleum hydrocarbons;
- volatile organic compounds; and
- metals (copper, zinc, lead, cadmium, aluminium, iron).

Monitoring should be undertaken at the same frequencies as recommended for the construction monitoring.

8.3.2 WASTEWATER MANAGEMENT

The proposed wastewater treatment system for the airport incorporates tertiary processes, including disinfection and a high level of nutrient removal. To achieve a higher effluent quality would require processes such as reverse osmosis filtration with a substantially higher cost and generation of sidestreams such as brine.

To ensure maximum efficiency from the treatment process, it would be necessary to optimise and monitor plant operation, to provide sufficient redundancy for essential plant components and to develop an appropriate contingency response plan.

8.3.3 AIRCRAFT CRASHES

This section outlines the emergency responses to aircraft crashes into reservoirs or sewage system infrastructure. It should be remembered, however, that the probability of such emergencies is not high (refer *Technical Paper No. 10 - Hazards and Risks*).

Emergencies within the airport would be dealt with under the standard emergency response procedures. In terms of water quality this would involve containment and clean-up of spills.

An aircraft crash into water supply or sewerage system infrastructure would be responded to by emergency services and invoke the relevant Sydney Water emergency procedure.

In the case of a crash into a water supply reservoir most contaminants would either settle or float. Booms would be introduced to limit the spread of surface contaminants. The level of water offtake could also be adjusted to avoid these contaminants. Filtration plants provide treatment for some contaminants but would not remove fuel or dissolved chemicals.

Damage to dam walls, supply pipelines, service reservoirs or filtration plants would require the arrangement of alternative water supplies where possible. Water restrictions may need to be applied if large volumes of water are lost or if repairs are lengthy.

If sewerage systems were severely damage there would be a need for rapid response to prevent environmental or human health impacts. Where possible, discharges would be contained within receiving streams and warnings issued. There would also need to be rapid repairs to the infrastructure to minimise overflows.

8.3.4 FIRE TRAINING

It is proposed to provide fire fighting training twice a week at the Second Sydney Airport. For Badgerys Creek this would take place at a facility would be located beside Badgerys Creek, just upstream of the drainage pond for Option A, the facility for Option B would be between Cosgroves Creek and Oaky Creek and for Option C, beside Cosgroves Creek.

It is estimated that approximately 400 litres of kerosene and between 20 to 40 litres petrol would be used in each training session. These fires would be extinguished using a biodegradable aqueous film forming foam and potassium bicarbonate. Under the Draft Airports Environment Protection Regulations, Schedule 2, such chemicals are collected and partially treated on site before discharging to sewer. Although these regulations are in draft form, advice from the Federal Airports Corporation is that the water quality limits, Schedule 2, would be adopted for future fire fighting operations. The resultant drainage works and fuel interceptors should prevent runoff from the fire fighting entering the local waterways (pers com. T. McGuiness, Federal Airports Corporation). It is recommended that the collected drainage should be transferred to sewer.

In addition to the routine fire drills, a "Hot Fire" and LPG training area may also be incorporated into the new airport. Sydney Airport does not have this facility due to the proximity of surrounding dwellings and factories. Again the operation of this training area would be in accordance with the Draft Airports Environment Protection Regulations, Schedule 2 (pers com. T. McGuiness, Federal Airports Corporation).

8.3.5 FLIGHT PATH IMPACT MANAGEMENT

The present flight paths associated with Badgerys Creek airport options include a number of take-off and landing flight paths which pass over lake

Burragorang near the offtake point and dam wall. For options A and B, Prospect Reservoir is under a number of landing and take-off flight paths.

For minimising the risk of aircraft crash or accidental fuel release it is recommended that flight paths avoid the regions of the lake close to the dam wall. This would also reduce any potential water quality impacts.

8.4 MONITORING OF OPERATIONAL IMPACTS

8.4.1 SURFACE WATER MONITORING

A licence for discharge to receiving waters would need to be issued by the Environment Protection Authority. This would specify effluent quality requirements and a monitoring regime. It is recommended that the monitoring program incorporate biological assessment of Badgerys Creek to provide a direct measurement of any ecosystem impacts as well as additional water quality information.

8.4.2 GROUNDWATER MONITORING

In principle, groundwater contamination will only result from infiltration of contaminants from the surface. If surface water contamination mitigation measures are adequately implemented during airport operations, contamination of groundwater is unlikely to occur except beneath detention dams where expected impacts have been identified as low.

The permanent fuel storage facilities will incorporate bunding and impervious basins within confining walls. Monitoring bores should however be installed around fuel storage facilities to ensure that the integrity of containment measures is maintained. These bores should be added to the ongoing groundwater monitoring program, and sampled on a quarterly basis, along with the monitoring bores installed prior to the commencement of the construction phase.

The parameters to be measured would be the same as for the pre-construction phase (refer *Section 8.2.2*).

The monitoring results should be reviewed after 12 months, at which time the range of chemical parameters sampled may be reduced if no changes in groundwater chemistry are identified. If at any time contamination were detected, the full monitoring program would be reinstated.

9 ENVIRONMENTAL MANAGEMENT - HOLSWORTHY OPTIONS

The airport concept designs and construction plans detail the mitigation measures planned to control impacts from construction activity as well as the impacts from an operating airport. The predicted impacts of these proposals at Holsworthy is given in Chapter 7. This section examines the requirements for environmental management to mitigate these impacts and monitoring to enable impacts to be measured.

9.1 MITIGATION OF CONSTRUCTION IMPACTS

9.1.1 SOIL MANAGEMENT

Measures to control soil erosion and sedimentation would need to be implemented to ensure that soil erosion does not occur and thus threaten engineering works and the environment, and to ensure that sedimentation of both on site and off site areas is minimised during construction.

An erosion and sedimentation control plan would need to be prepared prior to the commencement of construction. Preparation of such a plan would need to be undertaken in consultation with the Department of Land and Water Conservation. Likely measures that would need to be implemented include:

- phasing the construction to confine disturbance to areas of workable size and minimise the duration of the disturbance;
- clearing vegetation initially along drains and erosion/sedimentation control structures. Where possible, natural vegetation should be maintained to act as buffer zones to minimise erosion and sedimentation;
- stockpiling stripped topsoils and chipped vegetation for later use in revegetation. Stockpiles should be protected by temporary vegetation or mulching, and located away from drainage lines and upstream of sedimentation structures. Diversion banks and/or catch drains would need to be constructed to protect stock piles from erosion by surface flows;
- the use of staked strawbales or siltation fences to restrict sediment movements within the site and to prevent any movements off site;
- revegetation of constructed areas as soon as possible. Stockpiled topsoil and chipped vegetation should be spread and vegetated initially with

fast growing species and ultimately with permanent vegetation. This operation should be undertaken progressively during construction;

- installation of drainage works early in the program to protect construction areas from run-on. Flow velocities should be minimised and flows dispersed, rather than concentrated. Energy dissipaters such as rip-rap gabions or mattressing may be required to control flows and, erodible areas should be provided with scour protection;
- construct sediment ponds to minimise total volumes and peak discharge rates of run-off. Controls may need to be provided for accumulated and accidental pollution; and
- construct any culverts early (that is, following clearing and prior to embankment construction) in natural watercourses. Flows would need to be minimised by rip-rap gabions or mattressing.

If acid sulphate soils are located, further investigation would be required to define its extent, together with the formulation of an Acid Sulphate Soils Management Plan. Should future soil investigations within the airport sites reveal the likelihood of acid sulphate soils, reference should be made to the Environment Protection Authority and the NSW Roads and Traffic Authority Guidelines for assessing and managing acid sulphate soils.

9.1.2 STORMWATER MANAGEMENT

The steep terrain at this site together with the very large areas of disturbance would require diligent adherence to soil and sediment control, to minimise export of sediment into receiving streams. Dosing of flocculants for turbidity control in sediment basins would need to be undertaken as well as adequate desludging of basins. Sediment control near to the source of disturbance is recommended using measures such as drainage diversion or interception. All sediment control structures should be regularly inspected and maintained.

Dust control should be managed largely through diligent use of water sprays and stabilising or covering of stockpiles.

Storages of materials such as chemicals, fuel or concrete components would be bunded to contain any spills. Procedures should be in place to promptly clean up any spillages.

9.1.3 WASTEWATER MANAGEMENT

Provided that the temporary sewage treatment plant is carefully managed to avoid overflow and procedures are implemented to clean-up overflows (if they Occur), there should be no need for additional mitigation measures.

9.2 MONITORING OF CONSTRUCTION IMPACTS

9.2.1 SURFACE WATER MONITORING

Further baseline monitoring of receiving streams should be undertaken prior to construction activity. During construction, regular monitoring should occur and include locations at outlets from the stormwater system and two locations in the receiving stream. Parameters to be measured include:

- flow rate;
- suspended solids;
- turbidity;
- total phosphorus;
- total nitrogen;
- oil and grease;
- pH;
- conductivity;
- dissolved oxygen;
- total hydrocarbons;
- metals (copper, zinc, lead, cadmium, aluminium, iron); and
- volatile organic compounds (including benzene, toluene, ethyl benzene and xylene from explosives).

Sampling should be undertaken once per month during dry weather and during rain events, to capture peak flow from the site. A rainfall event is classified as over 10 millimetres of rainfall in the preceding 24 hours. The program should aim to capture about 12 events per year.

Monitoring should also include inspection and regular reporting of the integrity of structures such diversion drains, sediment ponds or filter fences.

9.2.2 GROUNDWATER MONITORING

Pre-construction

A thorough understanding of the hydrogeological environment at the sites is required in order to identify the risks to groundwater from the airport construction and operation. To this end, a groundwater monitoring network should be installed, ideally 12 months prior to the onset of construction activities. The monitoring bores would be constructed to accepted international standards and surveyed to determine elevation and location.

The required number and locations of groundwater monitoring bores is site specific. Bores would be placed so as to confirm the regional groundwater flow direction, and provide strategically located monitoring sites. Areas which will ultimately have potential to act as contamination sources would have a sufficient density of groundwater monitoring sites to ensure reasonable understanding of hydraulic properties.

The monitoring network would provide data on the baseline conditions and indicate the natural variations of the groundwater system prior to development. Hydraulic properties of the aquifers would be determined by test pumping, and a monitoring program instigated to record water levels and chemical parameters on a quarterly basis. Parameters to be measured would include:

- pH;
- electrical conductivity;
- dissolved oxygen;
- redox potential;
- major cations (calcium, magnesium, sodium, potassium);
- major anions (chloride, sulphate, carbonate, bicarbonate, nitrate);
- metals (lead, copper, zinc, cadmium, aluminium, iron);
- total phosphorus;
- total nitrogen;
- total petroleum hydrocarbons;
- volatile organic compounds (including benzene, toluene, ethyl benzene and xylene); and
- polycyclic aromatic hydrocarbons.

Construction Phase

Groundwater contamination may result from infiltration of contaminants from the surface. If surface water mitigation measures are adequately implemented during the construction phase, the potential for groundwater contamination would be minimised. Procedures should however be put in place to promptly deal with any fuel or chemical spillage's occurring away from suitably engineered locations.

Water infiltrating fill is likely to leach salts into the groundwater and ultimately the creeks. Measures to reduce the amount of salt leaching depend upon reducing the amount of infiltration. This may be achieved by ensuring rapid runoff of surface waters to suitably engineered drains, and/or application of a suitable cover material to physically act as a barrier to infiltration.

Infiltration of water from detention dams into the groundwater could be minimised by sealing the base of the dams.

Monitoring would include a report on the integrity of the monitoring boreholes.

Groundwater monitoring would utilise the bores installed prior to the commencement of construction. Parameters to be measured would be the same as for the pre-construction phase (see above).

9.3 MITIGATION OF OPERATIONAL IMPACTS

9.3.1 STORMWATER MANAGEMENT

The potential for stormwater pollution from the operation of an airport and ancillary services has been recognised in the proposed airport design. This section examines the efficacy of storm water quality measures.

The following measures are proposed to control stormwater quality or discharge volumes once the airport is operational:

- bunding of storage facilities;
- flame/fuel traps;
- gross pollutant traps;
- extended detention ponds;
- gravel filter beds; and
- flocculent dosing.

Pollutants such as suspended solids, heavy metals, oils and greases, detergents and gross pollutants such as litter should be adequately controlled through the processes operating in flame/fuel traps, gross pollutant traps, stormwater settling basins and reed gravel filters.

As discussed in *Section 7*, the nutrient removal processes in the settling basins and wetland reed filters would not completely remove nitrogen and phosphorus in the stormwater. It is proposed to provide additional dosing of flocculants to enhance sediment and nutrient removal. This would occur in the detention basins when monitoring detects excessive nutrients escaping from the system. Although flocculants would assist phosphorus removal by adsorption processes, they are unlikely to fully remove phosphorus and would have minimal effect on dissolved nitrogen.

Adequate management and maintenance programs are essential for the continued efficacy of these measures. This includes regular cleaning of traps and desilting of sediment basins. The reed beds need to be monitored for clogging and short-circuiting and replacement of reed plants as required.

The discharges from the system should be measured (rate of flow and cumulative discharge) and monitored for the following parameters:

- suspended solids;
- total phosphorus;
- total nitrogen;
- faecal coliforms;
- oils and grease;
- polycyclic aromatic hydrocarbons;
- total petroleum hydrocarbons; and
- metals (copper, zinc, lead, cadmium, aluminium, iron).

Monitoring should be undertaken at the same frequencies as recommended for the construction monitoring.

9.3.2 WASTEWATER MANAGEMENT

The proposed wastewater treatment system for the airport incorporates tertiary processes, including disinfection and a high level of nutrient removal. To achieve a higher effluent quality would require processes such as reverse osmosis filtration with a substantially higher cost and generation of side streams such as brine.

To ensure maximum efficiency from the treatment plant, it would be necessary to optimise and monitor plant operation, provide sufficient redundancy for essential plant components and to develop an appropriate contingency response plans.

9.3.3 AIRCRAFT CRASHES

This section outlines the emergency responses to aircraft crashes into reservoirs or sewage system infrastructure. It should be remembered, however, that the probability of such emergencies is not high (refer *Technical Paper No. 10 - Hazards and Risks*).

Emergencies within the airport would be dealt with under the standard emergency response procedures. In terms of water quality this would involve containment and clean-up of spills.

An aircraft crash into water supply or sewerage system infrastructure would be responded to by emergency services and invoke the relevant Sydney Water emergency procedure.

In the case of a crash into a water supply reservoir most contaminants would either settle or float. Booms would be introduced to limit the spread of surface contaminants. The level of water offtake could also be adjusted to avoid these contaminants. Filtration plants provide treatment for some contaminants but would not remove fuel or dissolved chemicals.

Damage to dam walls, supply pipelines, service reservoirs or filtration plants would require the arrangement of alternative water supplies where possible. Water restrictions may need to be applied if large volumes of water are lost or if repairs are lengthy.

If sewerage systems were severely damaged there would be a need for rapid response to prevent environmental or human health impacts. Where possible, discharges would be contained within receiving streams and warnings issued. There would also need to be rapid repairs to the infrastructure to minimise overflows.

9.3.4 FIRE TRAINING

It is proposed to provide fire fighting training, twice a week at the Second Sydney Airport. For Holsworthy this facility would be located beside Punchbowl Creek. For Option A it would be just upstream of the storm water detention ponds and for Option B it would be between the upper arms of Punchbowl Creek.

It is estimated that approximately 400 litres of kerosene and between 20 to 40 litres of petrol would be used in each training session. These fires would be extinguished using a biodegradable aqueous film forming foam and potassium bicarbonate. Under the Draft Airports Environment Protection Regulations, Schedule 2, such chemicals are collected and partially treated on site before discharging to sewer. Although these regulations are in draft form, advice from the Federal Airports Corporation is that the water quality limits, Schedule 2, would be adopted for future fire fighting operations. The resultant drainage works and fuel interceptors should prevent runoff from the fire fighting entering the local waterways (pers com. T. McGuiness, Federal Airports Corporation).

In addition to the routine fire drills, a "Hot Fire" and LPG training area may also be incorporated into the new airport. Sydney Airport does not have this facility due to the proximity of surrounding dwellings and factories. Again the operation of this training area would be in accordance with the Draft Airports Environment Protection Regulations, Schedule 2 (pers com. T. McGuiness, Federal Airports Corporation). The possibility of sparks igniting nearby bushland in water supply catchments may need to be considered before the decision to include the "Hot Fire" and LPG facility is finalised.

9.3.5 FLIGHT PATH IMPACT MANAGEMENT

The recommended flight paths for Holsworthy Option A show a high concentration of air movements over Lake Woronora and the Woronora and O'Hares Creek catchment areas. Lake Cataract would also be frequently overflown. Holsworthy Options B has some flight paths traversing the catchment areas for Lake Woronora but no flight paths near the dam wall. For this option, however, Cataract Reservoir is affected.

For minimising the risk of aircraft crash or accidental fuel release it is recommended that flight paths avoid the regions of the lake close to the dam wall. This would also reduce any potential water quality impacts.

9.4 MONITORING OF OPERATIONAL IMPACTS

9.4.1 SURFACE WATER MONITORING

A licence for discharge to receiving waters would need to be issued by the Environment Protection Authority. This would specify effluent quality requirements and a monitoring regime. It is recommended that the monitoring program incorporate biological assessment of the Georges River to provide a direct measurement of any ecosystem impacts as well as additional water quality information.

9.4.2 GROUNDWATER MONITORING

In principle, groundwater contamination will be dependant upon infiltration of contaminants from the surface. If surface water contamination mitigation measures are adequately implemented during airport operations, contamination of groundwater from point sources will be minimised.

The permanent fuel storage facilities will incorporate bunding and impervious basins within confining walls. Monitoring bores should however be installed around fuel storage facilities to ensure that the integrity of containment measures is maintained. These bores should be added to the ongoing groundwater monitoring program, and sampled on a quarterly basis, along with the monitoring bores installed prior to the commencement of the construction phase. The parameters to be measured would be the same as for the construction phase (refer *Section 9.2.2*).

The monitoring results should be reviewed after 12 months, at which time the range of chemical parameters sampled may be reduced if no changes in groundwater chemistry are identified. If at any time contamination were detected, the full monitoring program would be reinstated.

Part E

Summary of Impacts

10 SUMMARY OF WATER QUALITY IMPACTS - BADGERYS CREEK

Tables 10.1 to *10.4* summarise the issues which are relevant to water quality for the three options at Badgerys Creek, considering criteria for human health, ecological health, commercial and recreational considerations. There are no substantial differences between the water quality impacts of the three Badgerys Creek options, except that Option A would involve least infilling of streams.

The data in the Potential Influence and Potential Risk columns refers to the impacts prior to any control or mitigative measures. The magnitude of these parameters gives an indication of the importance of mitigation. Residual Impact describes the remaining effects after mitigation and the net aquatic environmental impact of the proposal.

Predicted water body and stream areas impacted by the Badgerys Creek airport options are shown in *Figures 6.1* and *6.2*, for local and regional impacts.

10.1 HUMAN HEALTH RELATED IMPACTS

Human health related issues include potable water consumption, recreational water use such as swimming or boating and water quality effects on fish, shellfish and agricultural produce.

TABLE 10.1 SUMMARY OF HUMAN HEALTH RELATED IMPACTS

Issue	Cause	Potential Influence (without mitigation)	Probability	Mitigation Measures	Residual Impact	Significance of Residual Impact
Sydney Drinking Water Quality	Fuel Discharges	contamination	low	offtake level below surface	none	low
	Aircraft Crashes	contamination structural damage	low	flight path avoidance emergency response procedures, alternative water supplies	potentially high	unlikely but serious consequences
	Aerial Pollution	negligible	moderate	-	possible cumulative impact	not able to be quantified

Issue	Cause	Potential Influence (without mitigation)	Probability	Mitigation Measures	Residual Impact	Significance of Residual Impact
Potable Water from Rainwater Tanks	Aerial Pollution	potential for human health impacts	(concern with existing quality)	Water treatment or first flush diversion	possible cumulative impact	not able to be quantified
Primary Contact Recreation	Effluent Discharge from Airport	pathogens, contaminants	low	treatment, disinfection, minimise discharge	residual pathogens	low (minimal use)
Food Consumption	Aerial pollution, effluent discharges	pathogens, containments	not able to be quantified	treatment, disinfection, minimise discharge	not able to be quantified	not able to be quantified

10.2 ECOLOGICAL HEALTH

TABLE 10.2 ECOLOGICAL HEALTH CRITERIA - SUMMARY OF IMPACTS

Issue	Cause	Potential Influence (without mitigation)	Probability	Mitigation Measures	Residual Impact	Significance of Residual Impact
Habitat destruction	Infilling of creeks by earthworks	total for infill areas	certain	replacement habitat	loss of permanent water habitats in infill areas	moderate but local
Flow regime	Continuous sewage effluent discharge	change to permanent flow	certain	none	downstream ecosystem change to more lotic (flowing) biota	major but relatively local
Sediment Impacts	Soil erosion during construction	major (but system adapted to periodic high turbidity)	high	sediment erosion control	loss of habitat, smothering, impairment of gill function and feeding , light reduction.	low to moderate but could have regional effects
Toxicants & Contaminants	Runoff contaminated by spills; aerial pollutants	major	high	stormwater management, containment, emergency response procedures	occasional pulses may lead to acute and chronic toxicity, potential for bioaccumulation	local impact but potential residual regional impacts
Salinity	Disturbance of saline soils	exacerbate an existing problem	certain	drainage of leachate from disturbed areas	low, given current high salinity	cumulative on a regional level
Nutrients	Sewage effluent and stormwater runoff from developed areas	major	high	nutrient removal for wastewater and stormwater, source minimisation	increased eutrophication, changed ecology	low local, cumulative impacts more regional

The ecological survey for the headwaters of these streams showed that although the streams were eutrophied with high levels of aquatic plants and algae, they also supported a diversity of invertebrates. The faunal and habitat survey for the Draft EIS (as reported in *Technical Paper No. 8 - Flora and Fauna*) determined a conservation status index for the Badgerys Creek sites. This index takes into account the presence of significant species or natural areas of high conservation value, habitat diversity and riparian zone disturbance. For the Badgerys Creek area and downstream, the index was found to be less than 1. This places the streams in the lower end of a sample of over 1000 streams in south-eastern Australia, where indices ranged from 0.25 to 3 and indicates a relatively low conservation value.

10.3 COMMERCIAL USES OF WATER

TABLE 10.3 COMMERCIAL USES - SUMMARY OF IMPACTS

Issue	Cause	Potential Influence (without mitigation)	Probability	Mitigation Measures	Residual Impact	Significance of Residual Impact
Crop Irrigation		moderate	low	stormwater management, sediment control containment, emergency response procedures	low	may be significant in extreme events
Animal Watering		high	moderate			
Fishing / Shellfish		not applicable	none	-	-	-

10.4 RECREATION AND AMENITY

TABLE 10.4 WATER QUALITY ISSUES AND ASSESSMENT OF MANAGEMENT: RECREATION & AMENITY

Issue	Cause	Potential Influence (without mitigation)	Probability	Mitigation Measures	Residual Impact	Significance of Residual Impact
Primary Contact / Secondary Contact		local streams	Not applicable	-	-	
		Hawkesbury River	low	stormwater & effluent management	contribution to cumulative nutrient impacts	
Fishing		encourage exotic species such as carp	high	sediment control, stormwater & effluent management	exotic species remain, possible regional cumulative influences	
Passive Recreation / Amenity		major	high	stormwater & effluent management	changed local flow regime, turbidity, possible regional cumulative influences	

Conclusions

The major water quality impacts predicted for Badgerys Creek options are:

- removal of stream habitat;
- potential regional impacts from sediment releases;
- local ecological impacts from reduced stream variability;
- regional impacts from effluent discharges, particularly from nutrient addition;
- potential human health impacts from effluent discharges, aerial fall-out into rainwater tanks;
- potential regional impacts from increased salinity; and
- potential regional impacts for recreation, fishing and agricultural uses.

The analysis of aerial pollutants does not indicate contamination of Sydney's water supply or ecological impacts. Although the probability of a plane crash into water supply and other Sydney Water infrastructure is considered low, the serious consequences from such an event recommend flight path avoidance of dam walls and water extraction offtakes.

11 SUMMARY OF WATER QUALITY IMPACTS - HOLSWORTHY

Tables 11.1 to *11.4* summarise the issues which are relevant to water quality for the two options at Holsworthy, considering criteria for human health, ecological health, commercial and recreational considerations. The data in the Potential Influence and Potential Risk columns refer to the impacts prior to any control or mitigative measures. The magnitude of these parameters gives an indication of the importance of mitigation. Residual Impact describes the remaining effects after mitigation and the net aquatic environmental impact of the proposal.

Predicted water body and stream areas impacted by the Holsworthy airport options are shown in *Figures 6.3* and *6.4* for local and regional impacts.

11.1 HUMAN HEALTH RELATED IMPACTS

Human health related issues include potable water consumption, recreational water use such as swimming or boating and water quality effects on fish, shellfish and agricultural produce.

TABLE 11.1 SUMMARY OF HUMAN HEALTH RELATED IMPACTS

Issue	Cause	Potential Influence (without mitigation)	Probability	Mitigation Measures	Residual Impact	Significance of Residual Impact
Sydney Drinking Water Quality	Fuel discharges	contamination	low	offtake level below surface	none	low
	Aircraft Crashes	contamination structural damage	low	flight path avoidance emergency response procedures, alternative water supplies	*water restrictions, repair costs etc.*	unlikely but serious consequences
	Aerial Pollution	negligible	low	-	cumulative impact	low
Potable Water from Rainwater Tanks	Aerial Pollution	potential for human health impacts	(concern with existing quality)	Water treatment or first flush diversion	cumulative impact	not able to be quantified
Primary Contact Recreation	Effluent Discharge from Airport	pathogens, contaminants	depends on treatment and instream processes	treatment, disinfection, minimise discharge	residual pathogens	could be high (locally)

Issue	Cause	Potential Influence (without mitigation)	Probability	Mitigation Measures	Residual Impact	Significance of Residual Impact
Food Consumption	Aerial pollution, discharges	pathogens, contaminants	not able to be quantified	treatment, disinfection, minimise discharge		

11.2 ECOLOGICAL HEALTH

TABLE 11.2 ECOLOGICAL HEALTH CRITERIA - SUMMARY OF IMPACTS

Issue	Cause	Potential Influence (without mitigation)	Probability	Mitigation Measures	Residual Impact	Significance of Residual Impact
Habitat destruction	Infilling of creeks by earthworks	total for infill areas	certain	none	loss of habitats in infill areas	major
Flow regime	Gradual release of storm flows from detention basins	extended flow duration after storms	certain	none	downstream ecosystem change to less variable flow regime	moderate and regional
	Continuous discharge of sewage effluent	moderate increase in Georges R. base flow	certain	none	negligible	none
Sediment Impacts	Soil erosion during construction	serious sedimentation of streams, change of habitat, smothering of biota	high	sediment erosion control	loss of habitat, smothering, impairment of gill function and feeding , light reduction.	high and regional
Toxicants & Contaminants	Runoff contaminated by spills; aerial pollutants	major	high	stormwater management, containment, emergency response procedures	occasional pulses may lead to acute and chronic toxicity, potential for bioaccumulation	local impact but potential residual regional impacts
Salinity (dissolved salts)	Stormwater runoff and leaching of fill material	potential impact on sensitive organisms	certain	drainage of leachate from disturbed areas	loss of species, shift to salt-tolerant forms	moderate, mostly local
Nutrients	Stormwater runoff from developed areas	major change in trophic status and ecosystems of creeks	high	nutrient removal for stormwater, source minimisation	increased eutrophication, changed ecology	high local, cumulative regional impacts

Issue	Cause	Potential Influence (without mitigation)	Probability	Mitigation Measures	Residual Impact	Significance of Residual Impact
	Sewage effluent discharge	major change in trophic status and ecosystem of Georges River	high	nutrient removal in sewage treatment	increased eutrophication, changed ecology	moderate local, cumulative regional impacts

The significance of the streams surrounding Holsworthy were analysed in *Technical Paper No. 8 - Flora and Fauna* using a conservation index. This index takes into account the presence of significant species, natural areas of high conservation value, habitat diversity and riparian zone disturbance. For the Holsworthy area and downstream the index was 1.75 to 5.25. This would rank these streams as of higher conservation value than any other stream in a sample of over 1000 streams in south-eastern Australia, where indices ranged from 0.25 to 3.

In addition, the flora and fauna study found that there was a high proportion of stream length where there were no exotic fish, which is becoming increasingly rare with the spread of introduced species. The fauna included a number of fish and crayfish of high conservation or recreational value.

The impacts of sediments on aquatic ecosystems would extend far beyond the immediate vicinity of the airport. Because of the high conservation status of these streams, the adverse impacts are likely to continue, virtually unabated for their full length until the confluence with the Georges River.

11.3 COMMERCIAL USES OF WATER

There appear to be no commercial uses of water that could be affected by water draining from the sites of the Holsworthy airport options. It is understood that there is no known extraction of water for either crop irrigation or animal watering, nor is there any commercial fishing in the Georges River.

11.4 RECREATION AND AMENITY

TABLE 11.4 WATER QUALITY ISSUES AND ASSESSMENT OF MANAGEMENT: RECREATION & AMENITY

Issue	Cause	Potential Influence (without mitigation)	Probability	Mitigation Measures	Residual Impact	Significance of Residual Impact
Primary Contact/ Secondary Contact	Pathogens from stormwater (local streams)	risk of infection	low	stormwater treatment	very low	low
	Pathogens from effluent (Georges River)	risk of infection	high	effluent management (disinfection)	low (assuming viruses controlled)	low (assuming viruses controlled)
Fishing	Nutrients and contaminants from stormwater and sewage effluent	encourage exotic species such as carp	major	sediment control, stormwater & effluent management	possible regional cumulative influences	minor (recreational fishing currently discouraged above Georges Hall)
Passive Recreation/ Amenity	Sediment runoff, nutrient influx	Turbidity, algal growth	high	stormwater & effluent management	residual turbidity and algal growth, possible regional cumulative influences	high for local streams and Woronora River

Conclusions

The major water quality impacts predicted for the two Holsworthy options are:

- removal of long lengths of stream habitat;
- local and regional impacts to streams and rivers from sediment releases;
- local and regional impacts from stormwater nutrient discharges;
- stream ecological impacts from reduced flow variability;
- local impacts from increased stream salinity;
- local and regional impacts from effluent discharges, particularly from nutrient additions;

- potential human health impacts from effluent discharges, aerial fall-out into rainwater tanks; and
- reduced recreational opportunities in Georges and Woronora Rivers.

The analysis of aerial pollutants does not indicate contamination of Sydney's water supply or ecological impacts. Although the probability of a plane crash into water supply and other Sydney Water infrastructure is considered low, the serious consequences from such an event recommend flight path avoidance of dam walls and water extraction offtakes.

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Appendices

Appendix A

Description of Water Quality Parameters

Appendix A
Description of Water Quality Parameters

Suspended Solids and Turbidity

Suspended solids reflect the amount of particles within the water column, which may include wastewater treatment plant discharge contributions, but the major contributor in Australian systems comes from diffuse sources such as soil and stream bank erosion (Australia and New Zealand Environment Conservation Council, 1992). Algal growth can also substantially increase suspended solids concentrations. Turbidity is a measure of light penetration through the water column. Suspended solids and turbidity affect aquatic plant growth and hence ecosystem health by restricting the penetration of light and, as sediments settle, by smothering. Particulates may also be detrimental to fish by clogging gills. Highly turbid waters impair aesthetic and recreational quality.

Conductivity

The concentration of dissolved salts in an aquatic system is determined by electrical conductivity (measured in microsiemans per centimetre) or salinity (milligram per litre). Increased conductivity can affect aquatic organisms (and irrigated crops or watered stock) by impairing cell function. In fresh waters the upper limit for ecosystem protection is 1,500 microsiemans per centimetre, however, for saline intolerant crop irrigation, a limit of 800 microsiemans per centimetre is suggested (Australia and New Zealand Environment Conservation Council, 1992). The Environment Protection Authority recommend a criteria of 800 microsiemans per centimetre for the Hawkesbury-Nepean River.

Phosphorus

Phosphorus is a major nutrient needed for plant growth and has been implicated in encouraging algal blooms in the non-estuarine sections of the Hawkesbury-Nepean River (Environment Protection Authority, 1994). Phosphorus analysis provides an indication of the potential for algal and higher plant growth and possible eutrophication (excessive aquatic plants or macrophytes and/or algae). Total phosphorus provides a measure of all phosphorus forms; soluble, colloidal or particulate. Phosphorus can change forms due to the influence of pH or redox potential (generally oxygen availability) as well as various biological processes.

Sources of phosphorus include wastewater treatment plant discharges and diffuse urban and agricultural runoff. Sewage overflows are high in phosphorus from sources such as household soaps and detergents. Sewage and treated effluent phosphorus tends to be predominantly soluble (Sainty and Jacobs, 1981). Phosphorus is readily adsorbed onto the surface of clays. These fine soils are rapidly transported into waterways during periods of wet weather.

Eutrophication can result in impaired ecological health through elimination of species, reduction in habitat quality, reduction in light penetration, and, in the case of macrophytes, physical obstruction to fish migration. Eutrophication impacts on human activities in reducing aesthetic and recreational amenity, obstructing boating and in imparting taste and odour to drinking water. Cyanobacteria or blue-green algae are a specific nuisance group which have the potential to produce toxins with implications for human and animal health. Some cyanobacteria can grow under low nitrogen concentrations by fixing atmospheric nitrogen.

Nitrogen

Nitrogen, another plant nutrient, is present in a number of forms including ammonia, nitrate, nitrite or organic nitrogen. Total nitrogen is a sum of all forms, and TKN (Total Kjeldahl Nitrogen) the sum of organic nitrogen and ammonia. Nitrogen is important in sustaining algal and macrophyte growth, although it is not considered to be the major limiting factor for algal growth in the non-estuarine Hawkesbury-Nepean system (Environment Protection Authority, 1993). The most bioavailable forms of nitrogen are ammonia and nitrate. Ammonia is also important as an acute (short term effect) toxin to aquatic organisms, depending on the specific pH and temperature. Major sources of nitrogen to the Hawkesbury-Nepean system include Sewage treatment plant discharges, fertilisers applied to agricultural crops and gardens and animal droppings.

Dissolved Oxygen

Dissolved oxygen levels are required for aerobic organisms such as fish and invertebrate animals. As dissolved oxygen concentrations depend on water temperature, levels are often expressed as a percentage saturation rather than milligram per litre. Oxygen can be reduced through additions of organic material or indirectly through excessive plant growth. The parameter, BOD_5 (biochemical oxygen demand) provides an indicator of aquatic materials which consume oxygen. Dissolved oxygen concentrations can fluctuate during the day, with maxima associated with photosynthesis during daylight hours and minima occurring in the early morning from oxygen removal often through night-time plant respiration. The decomposition of macrophytes or algae can also create an oxygen demand. Australia and New Zealand Environment Conservation Council state a level of 6 milligram per litre or 80 percent oxygen saturation for the protection of aquatic ecosystems.

pH

The parameter pH measures the acidity or alkalinity of a water (ranging from acidic to alkaline, 1 to 14), with most fresh waters having a pH near 7 (neutrality). Extremes of pH (below 6 and over 9) can have chronic or acute effects on biota, including fish spawning failure and diminished egg hatching (Australia and New Zealand Environment Conservation Council, 1992). Elevated pH also increases the toxicity of ammonia, whereas increased acidity can release toxic levels of aluminum. Changes in pH can occur with additions of some industrial wastes, influx of acid sulphate soils or from algal growth activity. Australia and New Zealand Environment Conservation Council recommends two ranges for pH: 6.5 to 9.0 for the protection of aquatic ecosystems and 5.0 to 9.0 for primary contact such as swimming and bathing.

Oil and Grease (Total Grease)

Oils are simply greases which are liquid at room temperature. They may be categorised into two types; material derived from fatty tissue from animals and plants or from petroleum based products. This analysis may also detect other chemical such as chlorophyll (plant pigments), sulphur and certain organic compounds (often synthetic materials), consequently results should be interpreted with caution. Oils and greases may form films, inhibiting the passage of gases such as oxygen and carbon dioxide between the water and air interface. They may also contain toxic chemicals derived from petroleum.

Total Petroleum Hydrocarbons (TPH)

This analysis assists in qualifying any oils and greases, as it specifically detects chemicals arising from petroleum. Crude petroleum may consist of thousands of different chemicals. Many of these chemicals are toxic and persistent and are therefore an environmental concern. As this procedure does not identify specific chemicals, it is more difficult to set environmental guidelines. There are no Australia and New Zealand Environment Conservation Council guidelines for this parameter

Polynuclear Aromatic Hydrocarbons (PAH's)

This group of chemicals are by products of combustion and are often associated with industry and vehicle emissions. Bushfires are also a source. Atmospheric settling of PAHs is understood to be a major source of these chemicals entering waterways, however runoff from roads is also believed to contribute significant levels. Many of the individual PAH'S are toxic and are persistent. In addition, combinations of certain PAH's have been found to be deleterious to fish. Australia and New Zealand Environment Conservation Council recommends that the concentration of PAH's should not exceed three micrograms per litre (Australia and New Zealand Environment Conservation Council 1992).

Methylene Blue Active Substances (MBAS)

These are substances such as certain detergents which can cause a number of environmental effects. Most Methylene Blue Active Substances type detergents may be divided into two categories, depending upon their persistence in the environment. Generally, the more persistent substances are less toxic whilst the more toxic substances are more biodegradable. Some detergents have been attributed to lowering the dissolved oxygen of running waters. Many of these chemicals are toxic and change the surface tension of water, as well as having their own intrinsic toxicity. Such changes may have implications for surface dwelling organisms and may also effect surface chemistry (Australia and New Zealand Environment Conservation Council 1992).

Total Organic Carbon

Carbon is a ubiquitous element, essential for life and is a vital component of nearly all synthetic or manufactured products. It may exist in the environment in both living and decaying organisms, as naturally occurring substances, such as carbon dioxide or from anthropogenic sources. Differentiating the organic carbon (biological and often synthetic sources) from the inorganic carbon (for example carbon dioxide) can assist in understanding the productivity of a waterbody. Usually low Total Organic Carbon levels correspond to a pristine or unproductive system whereas higher concentrations can indicate human influences.

Volatile Halogenated Compounds

This group consists of synthetic chemicals to which one or more of the halogens, chlorine, fluorine or bromine has been added, such as chloroform, vinyl chloride and carbon tetrachloride. The addition halogens may increase the toxicity of a chemical or may also render the compound less vulnerable to degradation in the environment. Some of the volatile halogenated compounds can dissolve readily into water whilst others are more likely to be found attached to sediments of organic matter. The toxicity these chemicals is complex and in many instances is quite organism specific. Consequently there are no Australia and New Zealand Environment Conservation Council guidelines for Volatile Halogenated Compounds. They have a wide variety of uses as solvents, dry cleaning fluids, anaesthetics, soil fumigants, degreasing agents and as chemical intermediates and may enter the environment through volatisation during production or use, discharge of industrial waste and runoff from agricultural of municipal lands.

Volatile Aromatic Compounds

Volatile aromatic compounds are a diverse group of chemicals which include substances such as Benzene, Toluene and chlorinated benzenes. The structure of aromatic compounds generally makes them less resistant to breakdown in the environment and more toxic than some other synthetic chemicals. The chlorinated aromatic compounds are particularly persistent and more readily bioaccumulated than the more simple aromatics. This group of substances is used extensively in industry as intermediate chemicals and as components of deodorants, petrol, paints, inks, explosives, detergents and pesticides. Entry into the environment may be through industrial air and wastewater emissions and through their use. Australia and New Zealand Environment Conservation Council have recommended some limits for some of the chemicals such as benzene, at 300 micrograms per litre, whilst there is insufficient data to set levels for other volatile aromatic compounds (Australia and New Zealand Environment Conservation Council 1992).

Total Phenols

This group of chemicals is used widely in industry as an intermediate substance in the manufacture of other chemicals and as a by product of coal and oil refining. They are also used as disinfectants, dyes, pesticides and preservatives. Emissions during manufacture or refining are a major route of entry for phenols into the environment. Phenol itself may be broken down quite quickly in the environment through the action of microorganisms. It does not easily bioaccumulate and is eliminated from an organism fairly quickly once exposure has stopped. Australia and New Zealand Environment Conservation Council set a limit of 50 micrograms per litre in fresh waters. Chlorinated phenols are generally more persistent and toxic chemicals and some have been shown to bioaccumulate. The behaviour of chlorinated phenols in the environment is complex and no single figure has been provided as a guideline value by Australia and New Zealand Environment Conservation Council.

Metals

The toxicity and fate of metals in the environment is specific to the particular metal and may depend upon a wide variety of factors including levels of dissolved oxygen, pH, the presence of other metals or compounds, temperature and water hardness. In addition, metals may exist in several forms, some of which may be quite innocuous whilst others may be highly toxic. Consequently Australia and New Zealand Environment Conservation Council have often set maximum ranges for certain metals to accommodate this factor. Bioaccumulation is a problem with specific metals, especially mercury (Australia and New Zealand Environment Conservation Council 1992) Metals are used in a great number of applications, however air pollution and road runoff are major routes of entry into the environment for some metals such as lead, iron and copper (Hogan 1996).

Appendix B

Stream Survey Chemical Analyses

Badgerys Creek Streams
Chemical Results

	Badgerys Ck (B1)	Badgerys Ck (B2)	Badgerys Ck (B3)	Cosgrove Ck (C1)	Cosgrove Ck (C3)	Thompsons Ck (T1)	Duncans Ck (D1)	Detection Limit
Dissolved Oxygen (% saturation)	63	150	24	34	25	23	15	
Dissolved Oxygen (mg/L)	4.5	12.2	2.2	3.1	2.2	2.2	1.3	
pH	6.9	7.3	6.7	7.4	6.7	6.4	6.7	
Conductivity (µS/cm)	1170	2900	1080	10100	1500	4960	1750	
Suspended Solids (mg/L)	**2**	**33**	**14**	**2**	**5**	**5**	**13**	2
Turbidity (NTU)	**1.1**	**7**	**5.1**	**0.7**	**2.9**	**4.9**	**5.2**	0.1
Soxhlet Grease (mg/L)	<5	<5	<5	<5	<5	<5	<5	5
Total Phosphorus (mg/L)	<0.02	**1.2**	**0.26**	<0.02	<0.02	<0.02	<0.02	0.02
Nitrate as N (mg/L)	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.02
Nitrite as N (mg/L)	<0.02	<0.02	<0.02	<0.02	<0.02	0.026	<0.02	0.02
Ammonia as N (mg/L)	**0.054**	**0.38**	**0.21**	**0.064**	**0.12**	**0.13**	**0.025**	0.02
Total Kjeldahl Nitrogen (mg/L)	**0.5**	**2.9**	**0.7**	**0.4**	**0.9**	**0.5**	**0.2**	0.2
MBAS (mg/L)	<0.02	**0.22**	**0.12**	**0.2**	<0.02	<0.02	<0.02	0.02
Total Organic Carbon (mg/L)	**10**	**25**	**14**	**10**	**16**	**16**	**12**	1
Phenolics as Phenols (mg/L)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01
Iron	**0.22**	**1.8**	**1.1**	<0.05	<0.05	**4.9**	**0.53**	0.05
Nickel	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.005
Copper	**0.005**	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.005
Chromium	<0.005	**0.01**	**0.005**	**0.05**	<0.005	**0.005**	<0.005	0.005
Zinc	**0.013**	<0.01	<0.01	<0.01	**0.018**	**0.018**	0.01	0.01
Lead	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.005
Cadmium	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.005
Mercury	<0.001	<0.001	<0.001	<0.001	<0.001	0.01	<0.001	0.001
TPH C6-C9	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.02
TPH C10-C14	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	0.04
TPH C15-C28	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	0.2
TPH C29-C36	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	0.2
VAC - benzene	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001
VAC - toluene	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001
VAC - xylene	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.003
Ethyl Benzene	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001
VAC - others	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001-most analytes
PAH's	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001- most analytes
VHC's - 1,2, dichlorbenzene	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001
VHC's - others	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001 per analyte

Holsworthy Streams
Chemical Results

	Harris Ck	Punchbowl Ck (PO)	Punchbowl Ck (P1)	Punchbowl Ck (P2)	Wappa Ck	O'Hares Ck (OH1)	O'Hares Ck (OH2)	Detection Limit
Dissolved Oxygen (% saturation)	24	100	95	100	122	100	77	
Dissolved Oxygen (mg/L)	2.2	9.3	8.2	8.4	11.7	8.6	6.7	
pH	5.7	7.4	6.3	6.5	7.2	6.5	6.6	
Conductivity (µS/cm)	300	210	210	190	220	150	140	
Suspended Solids (mg/L)	<2	<2	<2	<2	<2	<2	<2	2
Turbidity (NTU)	2.3	0.8	0.3	<0.1	0.1	0.4	<0.1	0.1
Soxhlet Grease (mg/L)	<5	<5	<5	<5	<5	<5	<5	5
Total Phosphorus (mg/L)	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.02
Nitrate as N (mg/L)	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.02
Nitrite as N (mg/L)	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.02
Ammonia as N (mg/L)	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.02
Total Kjeldahl Nitrogen (mg/L)	0.1	0.1	0.09	0.1	<0.02	0.08	0.11	0.02
MBAS (mg/L)	0.08	0.04	<0.02	<0.02	<0.02	<0.02	<0.02	0.02
Total Organic Carbon (mg/L)	4	3	2	2	1	2	2	1
Phenolics as Phenols (mg/L)	<0.01	<0.01	<0.01	0.011	<0.01	<0.01	<0.01	0.01
Iron	2.3	0.31	0.17	0.26	0.08	0.24	0.24	0.05
Nickel	<0.005	<0.005	<0.005	<0.005	0.006	<0.005	<0.005	0.005
Copper	0.005	0.019	<0.005	<0.005	0.014	<0.005	<0.005	0.005
Chromium	0.005	0.006	<0.005	<0.005	<0.005	<0.005	<0.005	0.005
Zinc	<0.01	0.014	<0.01	<0.01	0.022	<0.01	<0.01	0.01
Lead	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.005
Cadmium	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.005
Mercury	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001
TPH C6-C9	0.02	0.02	0.5	<0.02	<0.02	<0.02	<0.02	0.02
TPH C10-C14	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	
TPH C15-C28	<0.2	<0.2	0.3	<0.2	<0.2	<0.2	<0.2	0.2
TPH C29-C36	<0.2	<0.2	0.2	<0.2	<0.2	<0.2	<0.2	0.2
VAC - benzene	0.001	<0.001	0.001	<0.001	<0.001	0.001	<0.001	0.001
VAC - toluene	0.006	0.006	0.001	<0.001	0.002	0.001	<0.001	0.001
VAC - xylene	<0.003	<0.003	<0.003	0.006	0.003	<0.003	<0.003	0.003
Ethyl Benzene	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	0.001
VAC - others	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001- most analytes
PAH's	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001- most analytes
VHC's - 1,2, dichlorobenzene	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001
VHC's - others	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	0.001 per analyte

Holsworthy Streams
Chemical Results

	Gunyah Ck	Deadmans Ck	Deadmans Ck	Williams Ck	Williams Ck	Georges R	Detection Limit
		(D2)	(D3)	(W2)	(W3)	(Ge1)	
Dissolved Oxygen (% saturation)	90	78	73	91	86	112	
Dissolved Oxygen (mg/L)	7.6	7.6	6.8	8.3	8	9.2	
pH	6.4	5.6	6.5	5.6	5.6	6.8	
Conductivity (µS/cm)	210	260	240	220	220	240	
Suspended Solids (mg/L)	<2	12	4	<2	4	<2	2
Turbidity (NTU)	0.3	0.2	0.2	0.2	0.2	<0.1	0.1
Soxhlet Grease (mg/L)	<5	<5	<5	<5	<5	<5	5
Total Phosphorus (mg/L)	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.02
Nitrate as N (mg/L)	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.02
Nitrite as N (mg/L)	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.02
Ammonia as N (mg/L)	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.02
Total Kjeldahl Nitrogen (mg/L)	0.08	0.14	0.14	0.24	0.06	0.24	<0.02
MBAS (mg/L)	<0.02	<0.02	<0.02	0.14	<0.02	<0.02	0.02
Total Organic Carbon (mg/L)	1	2	2	3	2	3	1
Phenolics as Phenols (mg/L)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01
Iron	0.13	0.38	0.33	0.21	0.15	0.3	0.05
Nickel	<0.005	<0.005	<0.005	<0.005	<0.005	0.006	0.005
Copper	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.005
Chromium	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.005
Zinc	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01
Lead	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.005
Cadmium	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.005
Mercury	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001
TPH C6-C9	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.02
TPH C10-C14	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	0.04
TPH C15-C28	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	0.2
TPH C29-C36	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	0.2
VAC - benzene	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001
VAC - toluene	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001
VAC - xylene	<0.003	<0.003	<0.003	<0.003	<0.003	0.004	0.003
Ethyl Benzene	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001
VAC - others	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001-most analytes
PAH's	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001-most analytes
VHC's - 1,2, dichlorobenzene	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001
VHC's - others	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001 per analyte

Appendix C

Stream Survey Biological Analyses

Site	Date	Class	Order	Family	Common name	Grade	Abundance	Number of taxa	Score
Badgerys Creek - B1	4/12/96	Arachnida			spider	0	1	1	0
			Acarina		Mite	5	3	3	15
		Crustacea			copepod	0	4	1	0
					ostracod	0	2	1	0
			Cladocera	Daphniidae	water flea	0	3	1	0
		Gastropoda		Lymnaeidae	water snail	3	1	1	3
				Physidae	snail	3	2	1	6
		Hirudinea			leech	3	1	1	3
		Insecta	Coleoptera	Dytiscidae	beetle	5	2	1	10
				Haliplidae	beetle	0	2	2	0
			Diptera	Chironomidae	gnat/midge	1	3	7	3
			Hemiptera	Corixidae	lesser water-boatmen	5	2	1	10
				Hebridae	velvet water bugs	6	1	1	6
				Naucoridae	bug	5	1	1	5
				Notonectidae	water-boatmen	4	2	1	8
				Veliidae	bug	4	2	1	8
			Odonata	Aeschnidae	dragonfly	6	2	2	12
				Cordulidae	dragonfly	7	2	1	14
				Gomphidae	dragonfly	7	3	2	21
				Lestidae	damselfly	7	3	4	21
				Megapodagrionidae	damselfly	7	2	1	14
			Trichoptera	Leptoceridae	caddis fly	7	2	1	14
		Osteichthyes		Poeciliidae	mosquito fish (intro	0	3	1	0
							49	**37**	**173**

Site	Date	Class	Order	Family	Common name	Grade	Abundance	Number of taxa	Score
Badgerys Creek - B2	4/12/96	Crustacea			ostracod	0	4	1	0
					copepod	0	4	1	0
			Cladocera			0	4	1	0
			Decapoda	Atyidae	shrimp	7	2	1	14
		Insecta	Coleoptera	Dytiscidae	beetle	5	3	3	15
				Hydraenidae	beetle	7	2	1	14
				Hydrochidae	beetle	7	3	1	21
				Staphylinidae	beetle	5	1	1	5
			Diptera	Chironomidae	gnat/midge	1	3	4	3
				Culicidae	mosquito	2	1	1	2
				Stratiomyidae	soldier-flies	2	1	1	2
			Ephemeroptera	Leptophlebiidae	mayfly	10	1	1	10
			Hemiptera	Corixidae	lesser water-boatmen	5	4	1	20
				Notonectidae	water-boatmen	4	4	1	16
				Veliidae	bug	4	1	1	4
			Odonata	Coenagrionidae		7	1	1	7
				Cordulidae	dragonfly	7	1	1	7
				Lestidae	damselfly	7	1	1	7
			Trichoptera	Leptoceridae	caddis fly	7	2	1	14
		Oligochaeta			"earthworm"	1	1	1	1
		Osteichthyes		Poeciliidae	mosquito fish (intro	0	3	1	0
							47	**26**	**162**

Site	Date	Class	Order	Family	Common name	Grade	Abundance	Number of taxa	Score
Badgerys Creek - B3	4/12/96	-	Hydrozoa	Hydridae	Hydra	0	1	1	0
		Arachnida	Acarina		Mite	5	1	1	5
		Crustacea			ostracod	0	4	1	0
					copepod	0	4	1	0
			Amphipoda	Gammeridae		6	1	1	6
			Decapoda	Atyidae	shrimp	7	1	1	7
		Gastropoda		Physidae	snail	3	2	1	6
		Insecta	Coleoptera	Dytiscidae	beetle	5	2	2	10
			Diptera	Chironomidae	gnat/midge	1	4	1	4
				Stratiomyidae	soldier-flies	2	1	1	2
			Hemiptera	Corixidae	lesser water-boatmen	5	3	2	15
				Naucoridae	bug	5	3	1	15
				Notonectidae	water-boatmen	4	3	1	12
			Odonata	Coenagrionidae		7	1	1	7
				Gomphidae	dragonfly	7	1	1	7
				Lestidae	damselfly	7	1	1	7
				Megapodagrionidae	damselfly	7	1	1	7
			Trichoptera	Leptoceridae	caddis fly	7	2	1	14
		Oligochaeta			"earthworm"	1	1	1	1
		Osteichthyes		Poeciliidae	mosquito fish (intro	0	2	1	0
		Turbellaria	Tricladida	Dugesidae	Flatworm	3	1	1	3
							40	**23**	**129**

Site	Date	Class	Order	Family	Common name	Grade	Abundance	Number of taxa	Score
Cosgrove Creek - C1	4/12/96	Arachnida	Acarina		Mite	5	3	2	15
		Crustacea	Decapoda	Atyidae	shrimp	7	4	1	28
		Gastropoda		Physidae	snail	3	2	1	6
		Insecta	Coleoptera	Dytiscidae	beetle	5	3	1	15
				Haliplidae	beetle	0	1	1	0
				Hydrochidae	beetle	7	2	1	14
				Hydrophilidae	beetle	5	1	1	5
			Diptera	Chironomidae	gnat/midge	1	3	2	3
				Culicidae	mosquito	2	1	1	2
				Stratiomyidae	soldier-flies	2	1	1	2
			Ephemeroptera	Baetidae	mayfly	5	2	1	10
			Hemiptera	Corixidae	lesser water-boatmen	5	3	1	15
				Gerridae	water-strider	5	3	1	15
				Notonectidae	water-boatmen	4	4	1	16
			Odonata	Coenagrionidae		7	2	1	14
				Cordulidae	dragonfly	7	2	1	14
				Isostictidae	damselfly	7	2	1	14
				Lestidae	damselfly	7	3	1	21
			Trichoptera	Calamoceratidae	caddis fly	8	3	1	24
		Osteichthyes		Poeciliidae	mosquito fish (intro	0	2	1	0
		Pisces		Cyprinidae	carp	0	3	1	0
							50	**23**	**233**

Site	Date	Class	Order	Family	Common name	Grade	Abundance	Number of taxa	Score
Cosgrove Creek - C3	10/12/96	Arachnida	Acarina		Mite	5	4	2	20
		Crustacea	Cladocera			0	1	1	0
		Gastropoda		Viviparidae		0	1	1	0
		Hirudinea			leech	3	2	1	6
		Insecta	Coleoptera	Hydrophilidae	beetle	5	1	1	5
			Diptera	Chironomidae	gnat/midge	1	4	1	4
			Hemiptera	Hydrometridae	water measurer	5	1	1	5
				Mesoveliidae	surface bugs	4	4	1	16
				Veliidae	bug	4	1	1	4
			Odonata	Coenagrionidae		7	4	1	28
				Cordulidae	dragonfly	7	2	1	14
			Trichoptera	Calamoceratidae	caddis fly	8	4	1	32
		Turbellaria	Tricladida	Dugesidae	Flatworm	3	2	1	6
							31	**14**	**140**

Site	Date	Class	Order	Family	Common name	Grade	Abundance	Number of taxa	Score
Duncans Creek - D1	10/12/96	Amphibia			tadpole	0	3	1	0
		Arachnida	Acarina		Mite	5	2	1	10
		Bivalvia	Veneroida	Sphaeridae	bivalve	6	1	1	6
		Crustacea			copepod	0	4	1	0
			Decapoda	Atyidae	shrimp	7	1	1	7
		Gastropoda		Physidae	snail	3	2	1	6
		Insecta	Coleoptera	Dytiscidae	beetle	5	4	2	20
				Hydraenidae	beetle	7	1	1	7
				Hydrophilidae	beetle	5	1	1	5
			Diptera	Chironomidae	gnat/midge	1	3	2	3
			Ephemeroptera	Baetidae	mayfly	5	2	1	10
			Hemiptera	Notonectidae	water-boatmen	4	2	2	8
			Odonata	Coenagrionidae		7	3	1	21
			Trichoptera	Calamoceratidae	caddis fly	8	3	1	24
		Osteichthyes		Mordaciidae/Geotriid	eel larvae	0	1	1	0
				Poeciliidae	mosquito fish (intro	0	2	1	0
		Pisces		Cyprinidae	carp	0	1	1	0
		Turbellaria	Tricladida	Dugesidae	Flatworm	3	2	1	6
							38	21	133

Site	Date	Class	Order	Family	Common name	Grade	Abundance	Number of taxa	Score
Thompsons Creek - T1	10/12/96	Arachnida	Acarina		Mite	5	4	2	20
		Crustacea	Amphipoda	Gammeridae		6	1	1	6
			Cladocera			0	2	1	0
			Decapoda	Atyidae	shrimp	7	4	1	28
		Gastropoda		Physidae	snail	3	3	1	9
		Hirudinea			leech	3	1	1	3
		Insecta	Coleoptera	Dytiscidae	beetle	5	4	1	20
				Gyrinidae	beetle	5	2	1	10
				Haliplidae	beetle	0	1	1	0
				Helminthidae(Elmidae	beetle	7	1	1	7
				Hydrophilidae	beetle	5	2	2	10
			Diptera	Chironomidae	gnat/midge	1	4	2	4
				Culicidae	mosquito	2	1	1	2
			Ephemeroptera	Baetidae	mayfly	5	1	1	5
				Caenidae	mayfly	5	2	1	10
			Hemiptera	Corixidae	lesser water-boatmen	5	1	1	5
				Notonectidae	water-boatmen	4	2	1	8
			Odonata	Coenagrionidae		7	2	1	14
				Cordulidae	dragonfly	7	2	1	14
				Megapodagrionidae	damselfly	7	1	1	7
			Trichoptera	Calamoceratidae	caddis fly	8	4	1	32
		Osteichthyes		Poeciliidae	mosquito fish (intro	0	1	1	0
							46	**25**	**214**

Site	Date	Class	Order	Family	Common name	Grade	Abundance	Number of taxa	Score
Georges River - GE1	13/11/96	Arachnida	Acarina		Mite	5	4	4	20
		Crustacea	Decapoda	Atyidae	shrimp	7	2	1	14
		Insecta	Coleoptera	Dytiscidae	beetle	5	4	4	20
				Gyrinidae	beetle	5	2	1	10
				Haliplidae	beetle	0	1	1	0
				Hydrophilidae	beetle	5	1	1	5
			Diptera	Chironomidae	gnat/midge	1	3	7	3
			Ephemeroptera	Leptophlebiidae	mayfly	10	3	4	30
			Hemiptera	Gerridae	water-strider	5	2	2	10
				Notonectidae	water-boatmen	4	2	2	8
			Odonata	Cordulidae	dragonfly	7	2	2	14
				Gomphidae	dragonfly	7	1	1	7
			Trichoptera	Ecnomidae	caddis fly	4	1	1	4
				Odontoceridae	caddis fly	8	1	1	8
		Insects	Trichoptera	Hydroptilidae	caddis fly	6	1	1	6
							30	**33**	**159**

Site	Date	Class	Order	Family	Common name	Grade	Abundance	Number of taxa	Score
Gunyah Creek - G1	14/11/96	Arachnida	Acarina		Mite	5	4	1	20
		Crustacea	Decapoda	Atyidae	shrimp	7	3	1	21
				Parastacidae	yabbie	7	2	1	14
		Insecta	Coleoptera	Dytiscidae	beetle	5	3	1	15
				Gyrinidae	beetle	5	2	1	10
				Helminthidae(Elmidae	beetle	7	1	1	7
				Hydrophilidae	beetle	5	1	1	5
			Diptera	Culicidae	mosquito	2	1	1	2
			Ephemeroptera	Leptophlebiidae	mayfly	10	2	3	20
			Hemiptera	Gerridae	water-strider	5	2	1	10
				Mesoveliidae	surface bugs	4	2	1	8
				Notonectidae	water-boatmen	4	1	1	4
			Odonata	Aeschnidae	dragonfly	6	1	1	6
				Megapodagrionidae	damselfly	7	2	1	14
			Trichoptera	Leptoceridae	caddis fly	7	4	1	28
				Odontoceridae	caddis fly	8	1	1	8
		Temnocephalidea				0	3	1	0
							35	**19**	**192**

Site	Date	Class	Order	Family	Common name	Grade	Abundance	Number of taxa	Score
O'Hares Creek - OH1	14/11/96	Arachnida	Acarina		Mite	5	1	1	5
		Crustacea	Decapoda	Atyidae	shrimp	7	3	1	21
		Insecta	Coleoptera	Dytiscidae	beetle	5	2	1	10
				Hydrophilidae	beetle	5	1	1	5
			Diptera	Chironomidae	gnat/midge	1	2	2	2
				Culicidae	mosquito	2	2	1	4
			Ephemeroptera	Leptophlebiidae	mayfly	10	4	6	40
			Hemiptera	Notonectidae	water-boatmen	4	1	1	4
			Odonata	Aeschnidae	dragonfly	6	2	1	12
				Gomphidae	dragonfly	7	2	2	14
			Trichoptera	Atriplectidae	Caddis fly	0	1	1	0
				Leptoceridae	caddis fly	7	4	1	28
				Odontoceridae	caddis fly	8	1	1	8
		Oligochaeta			"earthworm"	1	1	1	1
							27	**21**	**154**

Site	Date	Class	Order	Family	Common name	Grade	Abundance	Number of taxa	Score
O'Hares Creek - OH 2	13/11/96	Arachnida	Acarina		Mite	5	3	1	15
		Crustacea	Decapoda	Atyidae	shrimp	7	3	2	14
		Insecta	Coleoptera	Dytiscidae	beetle	5	4	3	20
				Hydrophilidae	beetle	5	1	1	5
			Diptera	Ceratopogonidae	biting midge	6	3	1	18
			Ephemeroptera	Caenidae	mayfly	5	2	1	10
				Leptophlebiidae	mayfly	10	4	2	40
			Hemiptera	Gerridae	water-strider	5	2	1	10
				Veliidae	bug	4	2	1	8
			Odonata	Gomphidae	dragonfly	7	1	2	7
			Trichoptera	Hydrobiosidae	caddisfly	7	1	1	7
				Leptoceridae	caddis fly	7	3	3	21
							29	**19**	**175**

Site	Date	Class	Order	Family	Common name	Grade	Abundance	Number of taxa	Score
Williams Creek - W2	4/11/96	Amphibia			tadpole	0	1	1	0
		Crustacea	Decapoda	Atyidae	shrimp	7	4	1	28
		Insecta	Coleoptera	Haliplidae	beetle	0	1	1	0
				Helminthidae(Elmidae	beetle	7	1	1	7
				Hydrophilidae	beetle	5	1	1	5
			Diptera	Chironomidae	gnat/midge	1	4	5	4
				Culicidae	mosquito	2	1	1	2
			Ephemeroptera	Leptophlebiidae	mayfly	10	2	2	20
			Hemiptera	Notonectidae	water-boatmen	4	1	1	4
			Odonata	Cordulidae	dragonfly	7	1	1	7
				Gomphidae	dragonfly	7	1	1	7
				Megapodagrionidae	damselfly	7	1	1	7
			Trichoptera	Leptoceridae	caddis fly	7	3	5	21
				Polycentropodidae	caddis fly	8	1	2	8
							23	**24**	**120**

Site	Date	Class	Order	Family	Common name	Grade	Abundance	Number of taxa	Score
Williams Creek - W3	4/11/96	Crustacea	Decapoda	Atyidae	shrimp	7	4	1	28
					shrimp	7	4	1	28
		Insecta	Coleoptera	Pesphenidae	beetle larvae	5	1	1	5
			Diptera	Chironomidae	gnat/midge	1	2	3	2
				Tanyderidae	Fly larvae	0	1	1	0
			Ephemeroptera	Leptophlebiidae	mayfly	10	2	2	20
			Odonata	Cordulidae	dragonfly	7	1	2	7
				Gomphidae	dragonfly	7	1	1	7
							16	**12**	**97**

Site	Date	Class	Order	Family	Common name	Grade	Abundance	Number of taxa	Score
Punchbowl Creek - P0	19/11/96	Arachnida	Acarina		Mite	5	3	1	15
		Crustacea	Decapoda	Atyidae	shrimp	7	3	1	21
		Insecta	Coleoptera	Dytiscidae	beetle	5	3	1	15
				Helminthidae(Elmidae	beetle	7	1	1	7
				Hydrophilidae	beetle	5	3	1	15
			Diptera	Chironomidae	gnat/midge	1	3	1	3
			Ephemeroptera	Leptophlebiidae	mayfly	10	4	3	40
			Hemiptera	Gerridae	water-strider	5	3	2	15
				Veliidae	bug	4	1	1	4
			Odonata	Chlorolestidae	damselfly	7	1	1	7
				Gomphidae	dragonfly	7	3	2	21
				Libellulidae	dragonfly	8	2	2	16
				Megapodagrionidae	damselfly	7	2	1	14
			Plecoptera	Gripopterygidae	stonefly	7	1	1	7
			Trichoptera	Ecnomidae	caddis fly	4	1	1	4
				Leptoceridae	caddis fly	7	4	1	28
				Odontoceridae	caddis fly	8	1	1	8
				Polycentropodidae	caddis fly	8	2	1	16
							41	23	256

Site	Date	Class	Order	Family	Common name	Grade	Abundance	Number of taxa	Score
Punchbowl Creek - P1	14/11/96	Arachnida			spider	0	1	1	0
			Acarina		Mite	5	4	2	20
		Bivalva		Hyriidae		6	1	1	6
		Crustacea			copepod	0	3	1	0
			Decapoda	Atyidae	shrimp	7	4	1	28
		Insecta	Coleoptera	Dytiscidae	beetle	5	3	2	15
				Haliplidae	beetle	0	2	1	0
			Diptera	Ceratopogonidae	biting midge	6	1	1	6
				Chironomidae	gnat/midge	1	1	1	1
				Culicidae	mosquito	2	1	1	2
			Ephemeroptera	Leptophlebiidae	mayfly	10	3	3	30
			Hemiptera	Notonectidae	water-boatmen	4	1	1	4
			Odonata	Aeschnidae	dragonfly	6	2	1	12
			Plecoptera	Gripopterygidae	stonefly	7	1	1	7
			Trichoptera	Helicopsychidae	caddis fly	10	3	1	30
				Leptoceridae	caddis fly	7	4	1	28
				Odontoceridae	caddis fly	8	1	1	8
				Polycentropodidae	caddis fly	8	1	1	8
		Oligochaeta			"earthworm"	1	1	1	1
							38	**23**	**206**

Site	Date	Class	Order	Family	Common name	Grade	Abundance	Number of taxa	Score
Punchbowl Creek - P2	13/11/96	Arachnida	Acarina		Mite	5	3	2	15
		Crustacea	Decapoda	Atyidae	shrimp	7	2	1	14
		Insecta	Coleoptera	Dytiscidae	beetle	5	3	1	15
				Gyrinidae	beetle	5	2	1	10
				Hydrophilidae	beetle	5	2	1	10
			Diptera	Chironomidae	gnat/midge	1	3	3	3
			Ephemeroptera	Leptophlebiidae	mayfly	10	3	2	30
			Hemiptera	Gerridae	water-strider	5	3	1	15
			Odonata	Cordulidae	dragonfly	7	2	3	14
				Gomphidae	dragonfly	7	2	2	14
			Trichoptera	Atriplectidae	Caddis fly	0	2	1	0
				Leptoceridae	caddis fly	7	2	1	14
		Insects	Trichoptera	Hydroptilidae	caddis fly	6	2	1	12
							31	**20**	**166**

Site	Date	Class	Order	Family	Common name	Grade	Abundance	Number of taxa	Score
Harris Creek - H2	19/11/96	Arachnida	Acarina		Mite	5	4	5	20
		Crustacea	Decapoda	Atyidae	shrimp	7	1	1	7
		Insecta	Coleoptera	Dytiscidae	beetle	5	1	1	5
				Hydrochidae	beetle	7	4	1	28
				Hydrophilidae	beetle	5	1	1	5
			Diptera	Chironomidae	gnat/midge	1	2	4	2
			Ephemeroptera	Leptophlebiidae	mayfly	10	4	2	40
			Hemiptera	Gerridae	water-strider	5	3	1	15
			Odonata	Cordulidae	dragonfly	7	3	4	21
				Lestidae	damselfly	7	1	1	7
				Megapodagrionidae	damselfly	7	1	1	7
			Trichoptera	Leptoceridae	caddis fly	7	3	2	21
		Oligochaeta			"earthworm"	1	1	1	1
							29	**25**	**179**

Site	Date	Class	Order	Family	Common name	Grade	Abundance	Number of taxa	Score
Wappa Creek - Wa1	19/11/96	Arachnida	Acarina		Mite	5	1	1	5
		Crustacea	Amphipoda	Gammeridae		6	1	1	6
			Decapoda	Atyidae	shrimp	7	4	1	28
				Parastacidae	yabbie	7	1	1	7
		Insecta	Coleoptera	Dytiscidae	beetle	5	1	1	5
			Diptera	Chironomidae	gnat/midge	1	3	3	3
				Tipulidae	crane-flies	5	1	2	5
			Ephemeroptera	Leptophlebiidae	mayfly	10	3	3	30
			Odonata	Cordulidae	dragonfly	7	1	1	7
				Gomphidae	dragonfly	7	1	1	7
			Trichoptera	Ecnomidae	caddis fly	4	1	1	4
				Leptoceridae	caddis fly	7	2	3	14
				Psychomiidae	caddis fly	0	2	2	0
							22	**21**	**121**

Site	Date	Class	Order	Family	Common name	Grade	Abundance	Number of taxa	Score
Deadmans Creek - D2	4/11/96	Crustacea	Cladocera			0	2	1	0
			Decapoda	Atyidae	shrimp	7	4	1	28
		Insecta	Coleoptera	Dytiscidae	beetle	5	1	1	5
				Helminthidae(Elmidae	beetle	7	2	2	14
			Diptera	Chironomidae	gnat/midge	1	2	5	2
				Tipulidae	crane-flies	5	1	1	5
			Ephemeroptera	Leptophlebiidae	mayfly	10	2	2	20
			Hemiptera	Notonectidae	water-boatmen	4	3	1	12
			Odonata	Aeschnidae	dragonfly	6	2	3	12
				Gomphidae	dragonfly	7	1	1	7
				Megapodagrionidae	damselfly	7	1	1	7
			Plecoptera	Gripopterygidae	stonefly	7	1	1	7
			Trichoptera	Leptoceridae	caddis fly	7	1	1	7
							23	**21**	**126**

Site	Date	Class	Order	Family	Common name	Grade	Abundance	Number of taxa	Score
Deadmans Creek - D3	4/11/96	Amphibia			tadpole	0	1	1	0
		Arachnida	Acarina		Mite	5	1	1	5
		Crustacea			copepod	0	2	1	0
			Decapoda	Atyidae	shrimp	7	3	1	21
		Insecta	Coleoptera	Curculionidae	"weevel"	0	1	1	0
				Gyrinidae	beetle	5	1	1	5
				Helminthidae(Elmidae	beetle	7	1	1	7
				Hydrochidae	beetle	7	1	1	7
			Diptera	Chironomidae	gnat/midge	1	2	5	2
				Culicidae	mosquito	2	2	1	4
				Tipulidae	crane-flies	5	1	2	5
			Ephemeroptera	Leptophlebiidae	mayfly	10	2	2	20
			Hemiptera	Notonectidae	water-boatmen	4	2	2	8
			Odonata	Aeschnidae	dragonfly	6	1	1	6
				Cordulidae	dragonfly	7	1	1	7
				Gomphidae	dragonfly	7	1	1	7
				Megapodagrionidae	damselfly	7	1	1	7
			Plecoptera	Gripopterygidae	stonefly	7	1	1	7
			Trichoptera	Leptoceridae	caddis fly	7	2	2	14
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Second Airport EIS Phytoplankton

Site	Date	Phylum	Group	Genus	Lentic	Taste or Odour	Filamentous	Colonial	Potentially Tox
Badgerys Ck at Elizabeth Dr	4/12/96	Chlorophyta	Chlorococcales	Ankistrodesmus		False	False	False	False
	4/12/96		Desmidiaceae	Arthrodesmus		False	False	False	False
	4/12/96		uni cell flagellate	Chlamydomonas		True	False	False	False
	4/12/96		Chlorococcales	Golenkinia	nearly always	False	False	False	False
	4/12/96		colonial flagellate	Gonium	usually	True	False	True	False
	4/12/96		Chlorococcales	Nephrocytium		False	False	True	False
	4/12/96		Chlorococcales	Scenedesmus		True	False	True	False
	4/12/96	Chrysophyta	uni cell flagellate	Mallomonas		True	False	False	False
	4/12/96	Cryptophyta	uni cell flagellate	Chroomonas		False	False	False	False
	4/12/96		uni cell flagellate	Cryptomonas		True	False	False	False
	4/12/96		uni cell flagellate	Rhodomonas		False	False	False	False
	4/12/96	Cyanobacteria	Cyanophyta	Dactylococcopsis		False	False	False	False
	4/12/96		Cyanophyta	Merismopedia		False	False	True	False
	4/12/96	Euglenaphyta	uni cell flagellate	Euglena		True	False	False	False
	4/12/96		uni cell flagellate	Trachelomonas		False	False	False	False
	4/12/96		uni cell flagellate			False	False	False	False
Badgerys Ck at Mersey St	4/12/96	Chloromonadophyta	uni cell flagellate	Merotrichia	bogs, swamps	False	False	False	False
	4/12/96	Chlorophyta	Chlorococcales	Ankistrodesmus		False	False	False	False
	4/12/96		uni cell flagellate	Chlamydomonas		True	False	False	False
	4/12/96		Chlorococcales	Nephrocytium		False	False	True	False
	4/12/96		Chlorococcales	Scenedesmus		True	False	True	False
	4/12/96		filamentous green	Zygnemopsis	no	False	True	False	False
	4/12/96	Chrysophyta	Bacillariophyceae	Cyclotella		True	False	False	False
	4/12/96		Bacillariophyceae	Cymbella		False	False	False	False
	4/12/96		Bacillariophyceae	Gyrosigma		False	False	False	False
	4/12/96		uni cell flagellate	Mallomonas		True	False	False	False
	4/12/96		Bacillariophyceae	Navicula		False	False	False	False
	4/12/96		Bacillariophyceae	Synedra		True	False	False	False
	4/12/96	Cryptophyta	uni cell flagellate	Chroomonas		False	False	False	False
	4/12/96		uni cell flagellate	Cryptomonas		True	False	False	False
	4/12/96		uni cell flagellate	Rhodomonas		False	False	False	False
	4/12/96	Cyanobacteria	Cyanophyta	Anabaena	sometimes	True	True	False	True
	4/12/96		Cyanophyta	Dactylococcopsis		False	False	False	False
	4/12/96		Cyanophyta	Oscillatoria	sometimes	True	True	False	True
	4/12/96	Euglenaphyta	uni cell flagellate	Euglena		True	False	False	False

Second Airport EIS Phytoplankton

Site	Date	Phylum	Group	Genus	Lentic	Taste or Odour	Filamentous	Colonial	Potentially Tox
Badgerys Ck at Mersey St	4/12/96	Euglenaphyta	uni cell flagellate	Trachelomonas		False	False	False	False
	4/12/96	Pyrrhophyta	Dinophyceae	Peridinium		True	False	False	False
Badgerys Ck nr Badgerys Ck Rd	4/12/96	Chlorophyta	uni cell flagellate	Chloromonas		False	False	False	False
	4/12/96		Chlorococcales	Scenedesmus		True	False	True	False
	4/12/96	Euglenaphyta	uni cell flagellate	Euglena		True	False	False	False
	4/12/96		uni cell flagellate	Phacus		False	False	False	False
	4/12/96		uni cell flagellate	Trachelomonas		False	False	False	False
Cosgroves Ck at Elizabeth Dr	4/12/96	Chlorophyta	uni cell flagellate	Chlamydomonas		True	False	False	False
	4/12/96	Chrysophyta	Bacillariophyceae	Cyclotella		True	False	False	False
	4/12/96		Bacillariophyceae	Gyrosigma		False	False	False	False
	4/12/96		Bacillariophyceae	Melosira		True	True	False	False
	4/12/96	Cryptophyta	uni cell flagellate	Chroomonas		False	False	False	False
	4/12/96	Euglenaphyta	uni cell flagellate	Euglena		True	False	False	False
	4/12/96		uni cell flagellate	Phacus		False	False	False	False
	4/12/96		uni cell flagellate	Trachelomonas		False	False	False	False
	4/12/96	Pyrrhophyta	Dinophyceae	Peridinium		True	False	False	False
Cosgroves Ck, nr Research stat	10/12/96	Chlorophyta	Chlorococcales	Ankistrodesmus		False	False	False	False
	10/12/96		uni cell flagellate	Chlamydomonas		True	False	False	False
	10/12/96		colonial flagellate	Gonium	usually	True	False	True	False
	10/12/96		Chlorococcales	Nephrocytium		False	False	True	False
	10/12/96		Chlorococcales	Scenedesmus		True	False	True	False
	10/12/96	Chrysophyta	Bacillariophyceae	Navicula		False	False	False	False
	10/12/96	Cyanobacteria	Cyanophyta	Dactylococcopsis		False	False	False	False
	10/12/96		Cyanophyta	Oscillatoria	sometimes	True	True	False	True
	10/12/96	Euglenaphyta	uni cell flagellate	Euglena		True	False	False	False
	10/12/96		uni cell flagellate	Trachelomonas		False	False	False	False
Duncans Ck, nr Vickery Rd	10/12/96	Chlorophyta	Chlorococcales	Ankistrodesmus		False	False	False	False
	10/12/96		uni cell flagellate	Chlamydomonas		True	False	False	False
	10/12/96		colonial flagellate	Gonium	usually	True	False	True	False
	10/12/96		Chlorococcales	Scenedesmus		True	False	True	False
	10/12/96	Chrysophyta	Bacillariophyceae	Cocconeis		False	False	False	False
	10/12/96		Bacillariophyceae	Diatomella		False	False	False	False
	10/12/96		Bacillariophyceae	Eunotia		False	False	False	False
	10/12/96		Bacillariophyceae	Navicula		False	False	False	False

Second Airport EIS Phytoplankton

Site	Date	Phylum	Group	Genus	Lentic	Taste or Odour	Filamentous	Colonial	Potentially Tox
Duncans Ck, nr Vickery Rd	10/12/96	Chrysophyta	Bacillariophyceae	Pinnularia		False	False	False	False
	10/12/96		Bacillariophyceae	Synedra		True	False	False	False
	10/12/96	Cryptophyta	uni cell flagellate	Cryptomonas		True	False	False	False
	10/12/96		uni cell flagellate	Rhodomonas		False	False	False	False
	10/12/96	Cyanobacteria	Cyanophyta	Dactylococcopsis		False	False	False	False
	10/12/96		Cyanophyta	Oscillatoria	sometimes	True	True	False	True
	10/12/96	Euglenaphyta	uni cell flagellate	Euglena		True	False	False	False
	10/12/96		uni cell flagellate	Trachelomonas		False	False	False	False
Thompsons Ck, nr the Retreat	10/12/96	Chloromonadophyta	uni cell flagellate	Vacuolaria	ditches, swamps	False	False	False	False
	10/12/96	Chlorophyta	Chlorococcales	Ankistrodesmus		False	False	False	False
	10/12/96		uni cell flagellate	Chlamydomonas		True	False	False	False
	10/12/96		Chlorococcales	Scenedesmus		True	False	True	False
	10/12/96		filamentous green	Zygnemopsis	no	False	True	False	False
	10/12/96	Chrysophyta	Bacillariophyceae	Cocconeis		False	False	False	False
	10/12/96		Bacillariophyceae	Diatomella		False	False	False	False
	10/12/96		Bacillariophyceae	Eunotia		False	False	False	False
	10/12/96		Bacillariophyceae	Gomphonema		False	False	False	False
	10/12/96		Bacillariophyceae	Navicula		False	False	False	False
	10/12/96		Bacillariophyceae	Pinnularia		False	False	False	False
	10/12/96		Bacillariophyceae	Synedra		True	False	False	False
	10/12/96	Cryptophyta	uni cell flagellate	Chroomonas		False	False	False	False
	10/12/96		uni cell flagellate	Cryptomonas		True	False	False	False
	10/12/96		uni cell flagellate	Rhodomonas		False	False	False	False
	10/12/96	Cyanobacteria	Cyanophyta	Dactylococcopsis		False	False	False	False
	10/12/96	Euglenaphyta	uni cell flagellate	Euglena		True	False	False	False
	10/12/96		uni cell flagellate	Trachelomonas		False	False	False	False

Site	Date	Phylum	Group	Genus	Abundance	Lentic	Filamentous	Colonial	Potentially Tox
Badgerys at Badgerys Ck Rd	4/12/96	Chlorophyta	Desmidiaceae	Closterium	5		False	False	False
	4/12/96		Chlorococcales	Ankistrodesmus	4		False	False	False
	4/12/96		Chlorococcales	Scenedesmus	4		False	True	False
	4/12/96		Chlorococcales	Chlorella	5		False	False	False
	4/12/96		filamentous green	Spirogyra	5	no	True	False	False
	4/12/96	Chrysophyta	Bacillariophyceae	Cymbella	5		False	False	False
	4/12/96		Bacillariophyceae	Gomphonema	5		False	False	False
	4/12/96		Bacillariophyceae	Navicula	3		False	False	False
	4/12/96	Cyanobacteria	Cyanophyta	Oscillatoria	5	sometimes	True	False	True
	4/12/96		Cyanophyta	Anabaena	4	sometimes	True	False	True
	4/12/96	Euglenaphyta	uni cell flagellate	Euglena	4		False	False	False
	4/12/96		uni cell flagellate	Phacus	5		False	False	False
	4/12/96		uni cell flagellate	Trachelomonas	1		False	False	False
Badgerys Ck at Elizabeth Drive	4/12/96	Chloromonadophyta	uni cell flagellate	Vacuolaria	3	ditches, swamps	False	False	False
	4/12/96	Chlorophyta	Desmidiaceae	Closterium	5		False	False	False
	4/12/96	Chrysophyta	Bacillariophyceae	Cocconeis	5		False	False	False
	4/12/96		Bacillariophyceae	Eunotia	5		False	False	False
	4/12/96		Bacillariophyceae	Fragilaria	5		True	False	False
	4/12/96		Bacillariophyceae	Gomphonema	5		False	False	False
	4/12/96		Bacillariophyceae	Amphora	5		False	False	False
	4/12/96		Bacillariophyceae	Synedra	5		False	False	False
	4/12/96		Bacillariophyceae	Navicula	4		False	False	False
	4/12/96	Euglenaphyta	uni cell flagellate	Euglena	5		False	False	False
	4/12/96		uni cell flagellate	Phacus	5		False	False	False
	4/12/96		uni cell flagellate	Trachelomonas	1		False	False	False
Badgerys Ck at Mersey St	4/12/96	Chloromonadophyta	uni cell flagellate	Vacuolaria	1	ditches, swamps	False	False	False
	4/12/96	Chlorophyta	uni cell flagellate	Chlamydomonas	1		False	False	False
	4/12/96		Chlorococcales	Oocystis	5	usually	False	True	False
	4/12/96		Chlorococcales	Nephrocytium	3		False	True	False
	4/12/96		Chlorococcales	Elakatothrix	3		False	True	False
	4/12/96		Chlorococcales	Pediastrum	5		False	True	False
	4/12/96		Desmidiaceae	Closterium	5		False	False	False
	4/12/96		Chlorococcales	Scenedesmus	4		False	True	False
	4/12/96		Chlorococcales	Ankistrodesmus	4		False	False	False
	4/12/96		filamentous green	Zygnemopsis	5	no	True	False	False
	4/12/96		filamentous green	Spirogyra	1	no	True	False	False
	4/12/96	Chrysophyta	Bacillariophyceae	Pinnularia	5		False	False	False
	4/12/96		Bacillariophyceae	Synedra	5		False	False	False
	4/12/96		Bacillariophyceae	Gyrosigma	4		False	False	False
	4/12/96		Bacillariophyceae	Eunotia	4		False	False	False

Site	Date	Phylum	Group	Genus	Abundance	Lentic	Filamentous	Colonial	Potentially Tox
Badgerys Ck at Mersey St	4/12/96	Chrysophyta	Bacillariophyceae	Fragilaria	5		True	False	False
	4/12/96		Bacillariophyceae	Cymbella	4		False	False	False
	4/12/96		Bacillariophyceae	Navicula	3		False	False	False
	4/12/96	Cyanobacteria	Cyanophyta	Oscillatoria	5	sometimes	True	False	True
	4/12/96		Cyanophyta	Dactylococcopsis	5		False	False	False
	4/12/96		Cyanophyta	Anabaena	1	sometimes	True	False	True
	4/12/96	Euglenaphyta	uni cell flagellate	Phacus	2		False	False	False
	4/12/96		uni cell flagellate	Euglena	1		False	False	False
	4/12/96		uni cell flagellate	Trachelomonas	2		False	False	False
Cosgroves Ck at Elizabeth Dr	4/12/96	Chlorophyta	filamentous green	Spirogyra	5	no	True	False	False
	4/12/96		filamentous green	Zygnemopsis	5	no	True	False	False
	4/12/96		filamentous green	Cladophora	5	no	False	False	False
	4/12/96	Chrysophyta	Bacillariophyceae	Navicula	4		False	False	False
	4/12/96		Bacillariophyceae	Synedra	5		False	False	False
	4/12/96		Bacillariophyceae	Gyrosigma	2		False	False	False
	4/12/96		Bacillariophyceae	Gomphonema	2		False	False	False
	4/12/96		Bacillariophyceae	Cocconeis	5		False	False	False
	4/12/96		Bacillariophyceae	Eunotia	5		False	False	False
	4/12/96	Cyanobacteria	Cyanophyta	Oscillatoria	5	sometimes	True	False	True
	4/12/96		Cyanophyta	Spirulina	5	usually	True	False	True
	4/12/96		Cyanophyta	Merismopedia	5		False	True	False
	4/12/96	Euglenaphyta	uni cell flagellate	Trachelomonas	2		False	False	False
	4/12/96		uni cell flagellate	Euglena	4		False	False	False
	4/12/96	Pyrrhophyta	Dinophyceae	Peridinium	3		False	False	False
Cosgroves Ck, nr Research stat	10/12/96	Chloromonadophyta	uni cell flagellate	Vacuolaria	5	ditches, swamps	False	False	False
	10/12/96	Chlorophyta	Charophyceae	Chara	2		False	True	False
	10/12/96		Chlorococcales	Scenedesmus	5		False	True	False
	10/12/96		Desmidiaceae	Closterium	5		False	False	False
	10/12/96	Chrysophyta	uni cell flagellate	Mallomonas	4		False	False	False
	10/12/96		Bacillariophyceae	Gyrosigma	5		False	False	False
	10/12/96		Bacillariophyceae	Cymbella	5		False	False	False
	10/12/96		Bacillariophyceae	Navicula	4		False	False	False
	10/12/96	Cyanobacteria	Cyanophyta	Oscillatoria	1	sometimes	True	False	True
	10/12/96	Euglenaphyta	uni cell flagellate	Eutrepia	5		False	False	False
	10/12/96		uni cell flagellate	Trachelomonas	4		False	False	False
	10/12/96		uni cell flagellate	Phacus	5		False	False	False
Deadmans Ck lower, nr ford	4/12/96	Chlorophyta	filamentous green	Zygnemopsis	5	no	True	False	False
	4/12/96	Chrysophyta	Bacillariophyceae	Navicula	5		False	False	False
Duncans Ck, nr Vickery Rd	10/12/96	Chloromonadophyta	uni cell flagellate	Vacuolaria	5	ditches, swamps	False	False	False

Site	Date	Phylum	Group	Genus	Abundance	Lentic	Filamentous	Colonial	Potentially Tox
Duncans Ck, nr Vickery Rd	10/12/96	Chlorophyta	Charophyceae	Chara	3		False	True	False
	10/12/96		Desmidiaceae	Closterium	5		False	False	False
	10/12/96		filamentous green	Zygnemopsis	5	no	True	False	False
	10/12/96		filamentous green	Spirogyra	1	no	True	False	False
	10/12/96	Chrysophyta	uni cell flagellate	Mallomonas	5		False	False	False
	10/12/96		Bacillariophyceae	Eunotia	5		False	False	False
	10/12/96		Bacillariophyceae	Amphora	5		False	False	False
	10/12/96		Bacillariophyceae	Fragilaria	5		True	False	False
	10/12/96		Bacillariophyceae	Gomphonema	5		False	False	False
	10/12/96		Bacillariophyceae	Cymbella	5		False	False	False
	10/12/96		Bacillariophyceae	Pinnularia	5		False	False	False
	10/12/96		Bacillariophyceae	Navicula	4		False	False	False
	10/12/96		Bacillariophyceae	Gyrosigma	2		False	False	False
	10/12/96	Cryptophyta	uni cell flagellate	Chroomonas	5		False	False	False
	10/12/96	Cyanobacteria	Cyanophyta	Spirulina	5	usually	True	False	True
	10/12/96		Cyanophyta	Dactylococcopsis	5		False	False	False
	10/12/96		Cyanophyta	Anabaena	5	sometimes	True	False	True
	10/12/96		Cyanophyta	Cylindrospermum	5		True	False	True
	10/12/96		Cyanophyta	Oscillatoria	3	sometimes	True	False	True
	10/12/96	Euglenaphyta	uni cell flagellate	Phacus	5		False	False	False
	10/12/96		uni cell flagellate	Euglena	5		False	False	False
	10/12/96		uni cell flagellate	Trachelomonas	4		False	False	False
Georges Rr nr ford	13/11/96	Chlorophyta	Desmidiaceae	Hyalotheca	3	no	True	False	False
	13/11/96		filamentous green	Spirogyra	3	no	True	False	False
	13/11/96		"pseudo" desmid	Genicularia	4		True	False	False
	13/11/96		filamentous green	Microspora	2	no	True	False	False
	13/11/96		filamentous green	Zygnemopsis	2	no	True	False	False
	13/11/96	Chrysophyta	Bacillariophyceae	Diatoma	5		True	False	False
	13/11/96		Bacillariophyceae	Gyrosigma	5		False	False	False
	13/11/96		Bacillariophyceae	Navicula	2		False	False	False
	13/11/96	Euglenaphyta	uni cell flagellate	Trachelomonas	5		False	False	False
Harris CK at firing range	19/11/96	Chlorophyta	Desmidiaceae	Closterium	5		False	False	False
	19/11/96		filamentous green	Zygnema	5	no	True	False	False
	19/11/96	Chrysophyta	Bacillariophyceae	Navicula	4		False	False	False
	19/11/96	Cyanobacteria	Cyanophyta	Oscillatoria	5	sometimes	True	False	True
O'Hares Ck lower nr quarry	14/11/96	Chlorophyta	Desmidiaceae	Cosmarium	5		False	False	False
	14/11/96		Desmidiaceae	Staurastrum	5		False	False	False
	14/11/96		filamentous green	Zygnemopsis	2	no	True	False	False
	14/11/96		filamentous green	Microspora	3	no	True	False	False
	14/11/96		filamentous green	Zygnema	2	no	True	False	False

Site	Date	Phylum	Group	Genus	Abundance	Lentic	Filamentous	Colonial	Potentially Tox
O'Hares Ck lower nr quarry	14/11/96	Chrysophyta	Bacillariophyceae	Navicula	5		False	False	False
	14/11/96		Bacillariophyceae	Diatoma	0		True	False	False
O'Hares Ck upper nr auto gauge	13/11/96	Chlorophyta	Chlorophyta	Green Flagellate	4		False	False	False
	13/11/96		Desmidiaceae	Staurastrum	3		False	False	False
	13/11/96		Desmidiaceae	Cosmarium	5		False	False	False
	13/11/96		filamentous green	Zygnema	0	no	True	False	False
	13/11/96		filamentous green	Spirogyra	3	no	True	False	False
	13/11/96	Chrysophyta	Bacillariophyceae	Gyrosigma	5		False	False	False
	13/11/96		Bacillariophyceae	Cymbella	5		False	False	False
	13/11/96		Bacillariophyceae	Navicula	4		False	False	False
	13/11/96	Cyanobacteria	Cyanophyta	Oscillatoria	5	sometimes	True	False	True
	13/11/96	Euglenaphyta	uni cell flagellate	Trachelomonas	5		False	False	False
Punchbowl Ck d/s of tributary	19/11/96	Chlorophyta	Chlorophyta	Green Flagellate	3		False	False	False
	19/11/96		Desmidiaceae	Staurodesmus	5		False	False	False
	19/11/96		filamentous green	Zygnemopsis	4	no	True	False	False
	19/11/96		filamentous green	Zygnema	2	no	True	False	False
	19/11/96	Chrysophyta	Chrysophyceae	Dinobryon	5		False	False	False
	19/11/96		uni cell flagellate	Mallomonas	5		False	False	False
	19/11/96		Bacillariophyceae	Gyrosigma	5		False	False	False
	19/11/96		Bacillariophyceae	Cymbella	5		False	False	False
	19/11/96		Bacillariophyceae	Navicula	2		False	False	False
	19/11/96	Cryptophyta	uni cell flagellate	Cryptomonas	5		False	False	False
Punchbowl CK nr G1	14/11/96	Chlorophyta	Chlorophyta	Green Flagellate	5		False	False	False
	14/11/96		Desmidiaceae	Staurastrum	5		False	False	False
	14/11/96		filamentous green	Zygnema	5	no	True	False	False
	14/11/96		filamentous green	Zygnemopsis	5	no	True	False	False
	14/11/96	Chrysophyta	Bacillariophyceae	Achnanthes	5		False	False	False
	14/11/96		Bacillariophyceae	Cymbella	5		False	False	False
	14/11/96		Bacillariophyceae	Navicula	4		False	False	False
	14/11/96	Cyanobacteria	Cyanophyta	Oscillatoria	5	sometimes	True	False	True
Punchbowl Ck upper	13/11/96	Chlorophyta	Charophyceae	Chara	2		False	True	False
	13/11/96		Chlorophyta	Green Flagellate	5		False	False	False
	13/11/96		filamentous green	Zygnema	5	no	True	False	False
	13/11/96	Chrysophyta	Bacillariophyceae	Fragilaria	5		True	False	False
	13/11/96		Bacillariophyceae	Gomphonema	5		False	False	False
	13/11/96		Bacillariophyceae	Pinnularia	5		False	False	False
	13/11/96		Bacillariophyceae	Navicula	3		False	False	False
Thompsons Ck, nr the Retreat	10/12/96	Chlorophyta	uni cell flagellate	Chlamydomonas	5		False	False	False
	10/12/96		filamentous green	Cladophora	5	no	False	False	False

Second Airport EIS Periphyton

Site	Date	Phylum	Group	Genus	Abundance	Lentic	Filamentous	Colonial	Potentially Tox
Thompsons Ck, nr the Retreat	10/12/96	Chlorophyta	filamentous green	Spirogyra	5	no	True	False	False
	10/12/96	Chrysophyta	uni cell flagellate	Mallomonas	5		False	False	False
	10/12/96		Bacillariophyceae	Fragilaria	5		True	False	False
	10/12/96		Bacillariophyceae	Gomphonema	5		False	False	False
	10/12/96		Bacillariophyceae	Navicula	4		False	False	False
	10/12/96		Bacillariophyceae	Amphiprora	5	usually marine	False	False	False
	10/12/96		Bacillariophyceae	Eunotia	4		False	False	False
	10/12/96	Cyanobacteria	Cyanophyta	Dactylococcopsis	5		False	False	False
	10/12/96		Cyanophyta	Oscillatoria	5	sometimes	True	False	True
	10/12/96		Cyanophyta	Anabaena	5	sometimes	True	False	True
	10/12/96	Euglenaphyta	uni cell flagellate	Euglena	5		False	False	False
	10/12/96		uni cell flagellate	Trachelomonas	5		False	False	False
Wappa Ck d/s gravel pit	19/11/96	Chlorophyta	filamentous green	Zygnemopsis	5	no	True	False	False
	19/11/96	Chrysophyta	Bacillariophyceae	Meridion	5		False	True	False
	19/11/96		Bacillariophyceae	Navicula	4		False	False	False
Williams Ck upper	4/11/96	Chlorophyta	filamentous green	Zygnemopsis	2	no	True	False	False
	4/11/96	Chrysophyta	Bacillariophyceae	Meridion	5		False	True	False
	4/11/96		Bacillariophyceae	Fragilaria	5		True	False	False
Willliams Ck lower	4/11/96	Chlorophyta	Desmidiaceae	Closterium	5		False	False	False
	4/11/96		Desmidiaceae	Cosmarium	5		False	False	False
	4/11/96		filamentous green	Zygnemopsis	5	no	True	False	False
	4/11/96	Chrysophyta	Bacillariophyceae	Fragilaria	5		True	False	False
	4/11/96		Bacillariophyceae	Navicula	5		False	False	False

Appendix D

Licenced Bore Records

DEPARTMENT OF LAND AND WATER CONSERVATION
Centre for Natural Resources

WATER DATA DISCLAIMER

Warning to Clients:

Water data have been supplied to the Department of Land and Water Conservation (DLWC) by various sources. In some cases, analyses, plots and other data presentations make use of information on the DLWC archive. Because of the historical nature of the archive, there may well be errors and omissions in the data, or the quality of the information may make it unsuitable for the intended purpose.

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Date/Time: 07-Feb-1997 1:47 PM
User: JHARLOW
Report: RMGW001D.QRP
System: Groundwater

DEPARTMENT OF LAND & WATER CONSERVATION
Work Summary

LAND & WAT[illegible] CONSERVAT[illegible]

GW032310

Converted From HY[illegible]YS

License :

		Authorised Purpose(s)	Intended Purpose(s)
Work Type :	Bore open thru rock		DOMESTIC
Work Status:	(Unknown)		STOCK
Construct. Method:	Rotary		
Owner Type :	Private		

Commenced Date :
Completion Date : 01-Jan-1969
FinalDepth : 152.40 m
Drilled Depth : 152.40 m

Contractor Name :
Driller :

Property :
GWMA :
GW Zone :

Standing Water Level : m
Salinity : mg/L invalid code
Yield : L/s

Site Details

Site Chosen By		County	Parish	Portion/Lot DP
	Form A:	CUMBERLAND	WEDDERBURN	[illegible]
	Licensed:			

Region: 10 - SYDNEY SOUTH COAST
River Basin : 213 - SYDNEY COAST - GEORGES RIVER
Area / District:

CMA Map : 9029-1S APPIN
Grid Zone : 56 1 Scale : 1 25,000

Elevation : m (A.H.D.)
Elevation Source: (Unknown)

Northing : 6218420
Easting : 299050

Latitude (S) : 34° 9' 21"
Longitude (E) : 150° 49' 13"

GS Map : 0075D1 AMG Zone: 56
Coordinate Source : GD.,ACC.MAP

Construction

Negative depths indicate Above Ground Level H-Hole P-Pipe OD-Outside Diameter ID-Inside Diameter C-Cemented SL-Slot Length A-Aperture GS-Grain Size Q-Quantit[illegible]

H	P	Component	Type	From (m)	To (m)	OD (mm)	ID (mm)	Interval	Details
		Casing	Threaded Steel	[illegible]	[illegible]	152			Suspended in Clamps

Water Bearing Zones

From (m)	To (m)	Thickness (m)	WBZ Type	S.W.L. (m)	D.D.L. (m)	Yield (L/s)	Hole Depth (m)	Duration (hr)	Salinity (mg/L)
[illegible].80	29.90	0.10	Consolidated			0.01			(Unknown)
60.90	61.00	0.10	(Unknown)	35.90		0.11			(Unknown)

Drillers Log

From (m)	To (m)	Thickness (m)	Drillers Description	Geological Material	Comments
0.00	0.91	0.91	Soil	Soil	
0.91	6.10	5.19	Sandstone Yellow Soft	Sandstone	
6.10	10.67	4.57	Sandstone Yellow	Sandstone	
10.67	13.72	3.05	Sandstone Grey Shale Seams	Sandstone	
13.72	18.29	4.57	Sandstone Yellow	Sandstone	
18.29	24.69	6.40	Sandstone Cream	Sandstone	
24.69	25.91	1.22	Shale Grey Sandy Soft	Shale	
25.91	27.43	1.52	Sandstone Grey Hard	Sandstone	
27.43	60.96	33.53	Sandstone Hard Fine Water Supply	Sandstone	
60.96	103.63	42.67	Sandstone Grey Hard Fine Water Supply	Sandstone	
60.96	103.63	42.67	Shale Seams	Shale	
103.63	105.16	1.53	Conglomerate Dark Grey Sandstone	Conglomerate	
105.16	111.25	6.09	Sandstone Grey	Sandstone	
111.25	112.17	0.92	Shale Dark Grey	Shale	
112.17	120.09	7.92	Sandstone Grey	Sandstone	
120.09	129.54	9.45	Sandstone Coarse	Sandstone	
129.54	135.33	5.79	Shale Grey	Shale	
135.33	142.04	6.71	Sandstone Cream	Sandstone	
142.04	143.26	1.22	Sandstone Hard	Sandstone	
142.04	143.26	1.22	Shale Bands	Shale	
143.26	152.40	9.14	Sandstone Grey Hard	Sandstone	

*** End of GW032310 ***

DEPARTMENT OF LAND & WATER CONSERVATION
Work Summary

GW038159 *Converted From HYDSYS*

License :

Work Type : Bore open thru rock
Work Status: (Unknown)
Construct. Method: Cable Tool
Owner Type : Other Govt

Authorised Purpose(s)	Intended Purpose(s)
	DOMESTIC STOCK

Commenced Date :
Completion Date : 01-Nov-1974

FinalDepth : 121.90 m
Drilled Depth : 121.90 m

Contractor Name :
Driller :

Property :
GWMA :
GW Zone :

Standing Water Level : m
Salinity : mg/L (Unknown)
Yield : L/s

Site Details

Site Chosen By	County	Parish	Portion/Lot DP
Form A:	CUMBERLAND	WEDDERBURN	41
Licensed:			

Region: 10 - SYDNEY SOUTH COAST
River Basin : 213 - SYDNEY COAST - GEORGES RIVER
Area / District:

CMA Map : 9029-1S APPIN
Grid Zone : 56 1 **Scale :** 1:25,000

Elevation : m (A.H.D.)
Elevation Source: (Unknown)

Northing : 6220950 **Latitude (S) :** 34° 7' 58"
Easting : 298420 **Longitude (E) :** 150° 48' 50"

GS Map : 0075D1 **AMG Zone:** 56 **Coordinate Source :** GD.,ACC.MAP

Construction

Negative depths indicate Above Ground Level H-Hole P-Pipe OD-Outside Diameter ID-Inside Diameter C-Cemented SL-Slot Length A-Aperture GS-Grain Size Q-Quantity

H	P	Component	Type	From (m)	To (m)	OD (mm)	ID (mm)	Interval	Details

(No Construction Details Found)

Water Bearing Zones

From (m)	To (m)	Thickness (m)	WBZ Type	S.W.L. (m)	D.D.L. (m)	Yield (L/s)	Hole Depth (m)	Duration (hr)	Salinity (mg/L)
12.30	12.60	0.30	Consolidated	42.30		0.01			(Unknown)

Drillers Log

From (m)	To (m)	Thickness (m)	Drillers Description	Geological Material	Comments
0.00	0.60	0.60	Clay Sandy	Clay	
0.60	14.93	14.33	Sandstone Yellow Hard	Sandstone	
14.93	16.45	1.52	Sandstone Grey Silty	Sandstone	
16.45	34.13	17.68	Sandstone Yellow Hard	Sandstone	
34.13	42.36	8.23	Sandstone	Sandstone	
42.36	69.49	27.13	Sandstone Grey	Sandstone	
69.49	121.92	52.43	Sandstone Grey Silty	Sandstone	

***** End of GW038159 *****

DEPARTMENT OF LAND & WATER CONSERVATION
Work Summary

GW063062

Converted From HYDSYS

License : 10BL126198 NASSO, M A

Work Type: Bore
Work Status: (Unknown)
Construct. Method: Rotary
Owner Type : Private

Authorised Purpose(s)	Intended Purpose(s)
DOMESTIC	IRRIGATION
INDUSTRIAL	
STOCK	

Commenced Date : FinalDepth : 151.00 m
Completion Date : 01-Jan-1989 Drilled Depth : 0.00

Contractor Name :
Driller :

Property : Standing Water Level : m
GWMA : - Salinity : mg/L (Unknown)
GW Zone : - Yield : L/s

Site Details

Site Chosen By

	County	Parish	Portion Lot DP
Form A:	CUMBERLAND	BRINGELLY	L7 (20)
Licensed:	CUMBERLAND	BRINGELLY	LOT6 DP126824

Region: 10 - SYDNEY SOUTH COAST CMA Map : 9030-3S WARRAGAMBA
River Basin : 212 - HAWKESBURY RIVER Grid Zone : 56 1 Scale : 1:25,000
Area / District:

Elevation : m (A.H.D.) Northing : 6243010 Latitude (S) : 33° 55' 56"
Elevation Source: (Unknown) Easting : 289570 Longitude (E) : 150° 43' 24"

GS Map : 0056C4 AMG Zone: 56 Coordinate Source : GD.,ACC.MAP

Construction

Negative depths indicate Above Ground Level H-Hole P-Pipe OD-Outside Diameter ID-Inside Diameter C-Cemented SL-Slot Length A-Aperture GS-Grain Size Q-Quan

H	P	Component	Type	From (m)	To (m)	OD (mm)	ID (mm)	Interval	Details
1	1	Casing	Steel	0.00	0.00	159			(Unknown)

Water Bearing Zones

From (m)	To (m)	Thickness (m)	WBZ Type	S.W.L. (m)	D.D.L. (m)	Yield (L/s)	Hole Depth (m)	Duration (hr)	Salinity (mg/L)

(No Water Bearing Zone Details Found)

Drillers Log

From (m)	To (m)	Thickness (m)	Drillers Description	Geological Material	Comments

(No Drillers Log Details Found)

***** End of GW063062 *****

DEPARTMENT OF LAND & WATER CONSERVATION
Work Summary

GW072454 *Converted From HYDSYS*

License :

Work Type : Bore
Work Status:
Construct. Method: Rotary Air
Owner Type : Private

Authorised Purpose(s)	Intended Purpose(s)
	DOMESTIC
	IRRIGATION

Commenced Date :
Completion Date : 16-Dec-1994

FinalDepth : 162.00 m
Drilled Depth : 162.00 m

Contractor Name :
Driller :

Property :
GWMA :
GW Zone :

Standing Water Level : m
Salinity : mg/L Good
Yield : L/s

Site Details

Site Chosen By		County	Parish	Portion/Lot DP
	Form A:	CUMBERLAND	WEDDERBURN	L10 DP3221
	Licensed:			

Region: 10 - SYDNEY SOUTH COAST
River Basin : 213 - SYDNEY COAST - GEORGES RIVER
Area / District:

CMA Map : 9029-1S APPIN
Grid Zone : 56 1 **Scale :** 1:25,000

Elevation : 0.00
Elevation Source:

Northing : 6217872.6
Easting : 297605.3

Latitude (S) : 34° 9' 37"
Longitude (E) : 150° 48' 16"

GS Map : **AMG Zone:** 56 **Coordinate Source :**

Construction

Negative depths indicate Above Ground Level H-Hole P-Pipe OD-Outside Diameter ID-Inside Diameter C-Cemented SL-Slot Length A-Aperture GS-Grain Size Q-Quantity

H	P	Component	Type	From (m)	To (m)	OD (mm)	ID (mm)	Interval	Details
1	1	Casing	P.V.C.	0.00	162.00	125			Driven into Hole

Water Bearing Zones

From (m)	To (m)	Thickness (m)	WBZ Type	S.W.L. (m)	D.D.L. (m)	Yield (L/s)	Hole Depth (m)	Duration (hr)	Salinity (mg/L)
60.00	90.00	30.00	Consolidated	24.00		0.30			Good

Drillers Log

From (m)	To (m)	Thickness (m)	Drillers Description	Geological Material	Comments
0.00	1.00	1.00		Soil	
1.00	6.00	5.00		Clay	
6.00	162.00	156.00		Sandstone	

*** End of GW072454 ***

DEPARTMENT OF LAND & WATER CONSERVATION
Work Summary

GW072774

Converted From HYDSYS

License :

Authorised Purpose(s)

Intended Purpose(s)
G/WATER XPLORE

Work Type : Bore
Work Status :
Construct. Method : Rotary
Owner Type : Private

Commenced Date :
Completion Date : 26-Oct-1994
FinalDepth : 30.00 m
Drilled Depth : 19.00 m

Contractor Name :
Driller :

Property :
GWMA :
GW Zone :

Standing Water Level : m
Salinity : mg/L
Yield : L/s

Site Details

Site Chosen By	County	Parish	Portion/Lot DP
Form A:	CUMBERLAND	CLAREMONT	L1 DP542395
Licensed:			

Region: 10 - SYDNEY SOUTH COAST
River Basin : 212 - HAWKESBURY RIVER
Area / District:

CMA Map :
Grid Zone :
Scale :

Elevation : 0 00
Elevation Source:

Northing : 6249933 9
Easting : 292549 4

Latitude (S) : 33° 52' 14"
Longitude (E) : 150° 45' 26"

GS Map :
AMG Zone: 56
Coordinate Source : GD..ACC.GIS

Construction

Negative depths indicate Above Ground Level H-Hole P-Pipe OD-Outside Diameter ID-Inside Diameter C-Cemented SL-Slot Length A-Aperture GS-Grain Size Q-Quantity

H	P	Component	Type	From (m)	To (m)	OD (mm)	ID (mm)	Interval	Details
1	1	Casing	P V C	-0 50	17 00	50			
1	1	Casing	P V C	29 00	30 00	50			
1	1	Opening	(Unknown)	17 00	29 00	50		1	Plastic. SL 3mm A 0mm
1	1	Annulus	(Unknown)	17 00	29 00	0			GS -2mm

Water Bearing Zones

From (m)	To (m)	Thickness (m)	WBZ Type	S.W.L. (m)	D.D.L. (m)	Yield (L/s)	Hole Depth (m)	Duration (hr)	Salinity (mg/L)

(No Water Bearing Zone Details Found)

Drillers Log

From (m)	To (m)	Thickness (m)	Drillers Description	Geological Material	Comments
0 00	0 50	0 50	Hard Yellow Brown. Mottled. Dry Clay	Clay	
0 50	1 40	0 90	Stiff. Red-brown. Mottled. Moist. Plastic Clay	Clay	
1 40	2 00	0 60	Stiff. Grey. Moist. Plastic Clay	Clay	
2 00	3 50	1 50	Stiff. Red Brown To Grey. Mottled. Slightly Mo	Clay	
3 50	4 50	1 00	Hard To Stiff. Red-brown. Mottled. Dry Clay	Clay	
4 50	5 00	0 50	Hard To Stiff. Grey To Brown. Mottled Dry Cla	Clay	
5 00	6 00	1 00	Weak. Grey. Fissile. Dry Shale	Shale	
6 00	8 50	2 50	Med Strength. Grey. Fissile. Dry Shale. Minor C	Shale	
8 50	9 00	0 50	Siltstone/sandstone Hard. Grey. Massive. Silt To	Siltstone	
9 00	10 50	1 50	Carbonaceous Shale Medium Strenght. Dark Gr	Shale	
10 50	11 00	0 50	Weak. Dark Grey To Black. Fissile Dry Carb Sh	Shale	
11 00	18 00	7 00	Med Strength. Dark Grey. Fissile. Dry Carb Shl	Shale	
18 00	19 00	1 00	Hard Grey. Massive Silt To Very Fine Grained	Siltstone	
19 00	21 50	2 50	Carbonaceous Shle. Med Strength. Dark Grey.	Shale	
21 50	22.50	1 00	Slsn And Sdsn. Hard. Grey. Massive. Silt To Ve	Siltstone	
22 50	24 00	1.50	Carb Shale. Med Strength. Dark Grey Fissile. D	Shale	
24 00	26 00	2 00	Slsn/sdsn And Carb Shale interbeded	Siltstone	
26 00	30 00	4 00	Carbonaceous. Med Strength. Dark Grey. Fissil	Shale	

***** End of GW072774 *****

DEPARTMENT OF LAND & WATER CONSERVATION
Work Summary

GW100136

License : 10BL144703 PULO. CHARLES

Authorised Purpose(s)	Intended Purpose(s)
STOCK	

Work Type : Bore
Work Status:
Construct. Method: Rotary
Owner Type :

Commenced Date : FinalDepth : 110.70 m
Completion Date : 27-Nov-1991 Drilled Depth : 110.70 m

Contractor Name : WATERMIN DRILLERS
Driller : 1530 JONES. Clive Francis

Property : Standing Water Level : m
GWMA : - Salinity : mg/L
GW Zone : Yield : L/s

Site Details

Site Chosen By		County	Parish	Portion/Lot DP
	Form A:	CUMBERLAND	CLAREMONT	LT10 DP32026
	Licensed:	CUMBERLAND	CLAREMONT	LT10 DP32026

Region: 10 - SYDNEY SOUTH COAST CMA Map :
River Basin : Grid Zone : Scale :
Area / District:

Elevation : m (A.H.D.) Northing : Latitude (S) :
Elevation Source: Easting : Longitude (E) :

GS Map : AMG Zone: Coordinate Source :

Construction

Negative depths indicate Above Ground Level;H-Hole P-Pipe OD-Outside Diameter ID-Inside Diameter C-Cemented SL-Slot Length A-Aperture GS-Grain Size Q-Quantity

H	P	Component	Type	From (m)	To (m)	OD (mm)	ID (mm)	Interval	Details
1		Hole	Hole	0.00	0.00				
1		Hole	Hole	0.00	39.60	165			Rotary Air
1		Hole	Hole	39.60	110.70	165			Rotary Air

NO [illegible]

Water Bearing Zones

From (m)	To (m)	Thickness (m)	WBZ Type	S.W.L. (m)	D.D.L. (m)	Yield (L/s)	Hole Depth (m)	Duration (hr)	Salinity (mg/L)
39.60	39.90	0.30		23.80		0.60	39.90		Salty

Drillers Log

From (m)	To (m)	Thickness (m)	Drillers Description	Geological Material	Comments
0.00	0.30	0.30	TOPSOIL		
0.30	1.50	1.20	BROWN CLAY		
1.50	11.60	10.10	RED CLAY		
11.60	39.60	28.00	YELLOW SANDSTONE		
39.60	80.20	40.60	GREY SHALE		
80.20	110.70	30.50	BLACK SHALE		

*** End of GW100136 ***

*** End of Report ***

S

Land & Water Conservation

Water Quality Archive Samples & Results Report

Variable	Sample No.	Bot	Time	Date	Value	Flag	Qual	Acc.
** Station = GB032310								
2010.12 Electrical Conductivity @ 25C (Microsiem	1969001628		0	01/01/1969	297.0000000		40	4
2100.12 pH (pH units)	1969001628		0	01/01/1969	6.5000000		40	4
2125.12 Bicarbonate as HCO3 (Milligrams/Litre)	1969001628		0	01/01/1969	114.7120000		40	4
2301.12 Calcium as Ca - total (Milligrams/Litre)	1969001628		0	01/01/1969	20.0200000		40	4
2681.12 Iron as Fe - total (Milligrams/Litre)	1969001628		0	01/01/1969	0.0000000	ND	40	4
** Subtotal **							200	20
*** Total ***							200	20

Date/Time: 07-Mar-1997 3:39 PM
User: JBRODERI
Report: RMGW001D.QRP
Executable: S:\G5\PROD\GROUND.EXE
Exe Date: 20-Feb-1997
System: Groundwater
Database: S_coast

LAND & WATER CONSERVATION

DEPARTMENT OF LAND & WATER CONSERVATION
Work Summary

GW073533

Converted From HYDSYS

License :

Work Type : Bore
Work Status:
Construct. Method:
Owner Type : Private

Authorised Purpose(s)	Intended Purpose(s)
	DOMESTIC

Commenced Date :
Completion Date : 01-Jan-1990

FinalDepth : 330.00 m
Drilled Depth : 0.00

actor Name :
Driller :

Property :
GWMA :
GW Zone :

Standing Water Level :
Salinity :
Yield :

Site Details

Site Chosen By

	County	Parish	Portion/Lot DP
Form A:	CUMBERLAND	BRINGELLY	L7 DP2650
Licensed:			

Region: 10 - SYDNEY SOUTH COAST
River Basin : 212 - HAWKESBURY RIVER
Area / District:

CMA Map :
Grid Zone :
Scale :

Elevation : 0.00
Elevation Source:

Northing : 6242949.3
Easting : 289513.8

Latitude (S) : 33° 55' 58"
Longitude (E) : 150° 43' 22"

GS Map :
AMG Zone: 56
Coordinate Source : GD.,ACC.GIS

Construction

Negative depths indicate Above Ground Level; H-Hole; P-Pipe; OD-Outside Diameter; ID-Inside Diameter; C-Cemented; SL-Slot Length; A-Aperture; GS-Grain Size; Q-Quantity

H	Component	Type	From (m)	To (m)	OD (mm)	ID (mm)	Interval	Details
	Casing	P.V.C.	0.00	0.00	50			

Water Bearing Zones

From (m)	To (m)	Thickness (m)	WBZ Type	S.W.L. (m)	D.D.L. (m)	Yield (L/s)	Hole Depth (m)	Duration (hr)	Salinity (mg/L)

(No Water Bearing Zone Details Found)

Drillers Log

From (m)	To (m)	Thickness (m)	[illegible]	Geological Material	Comments

(No Drillers Log Details Found)

Chemical Treatment

Treatment	Method	Duration	[illegible]

(No Chemical Treatment Details Found)

Development

Method	Time Taken	Other [illegible]

(No Development Details Found)

Warning To Clients: This raw data has been supplied to the Department of Land and Water Conservation (DLWC) by [illegible] and other sources. The DLWC does not verify the accuracy of this data. The data is [illegible] for use by you at your own risk. You should consider verifying this data [illegible]. [illegible] should be sought [illegible] and using this data.

Appendix E

Calculations

APPENDIX

CALCULATIONS

CALCULATION OF POTENTIAL SOIL LOSS

The following analyses are derived from the Department of Housing (1993) to estimate the propensity of sediment to be eroded, dispersed and transported.

Several factors contribute to erosion and sediment movement:

- rainfall erosivity
- soil erodibility
- slope length/gradient
- ground cover

Badgerys Creek Options

Rainfall erosivity is a measure of the ability of rainfall to cause erosion. The erosivity factor for the Badgerys Creek site is 2500 (in the vicinity of Sydney factors range from 2500 in western Sydney to 6000 near Wollongong)

The soil erodibility is the susceptibility of soil particles to detach. It is generally determined from detailed soil analyses. Such analysis was performed for the Luddenham soil landscape and showed the soil to be moderately expansive. Sediment control with artificial flocculation is recommended. The average gradient over the site is 5%.

The risk of sediment movement can be computed using the Universal Soil Loss Equation (USLE):

A = RKLSPC

where:
R = erosivity (2500 for Badgerys Creek)
K = soil erodibility (0.038 - assuming Luddenham soil landscape)
LS = slope length-gradient factor (assuming 50m of disturbed slope)
P = Erosion Control Practice Factor (assume 1)
C = Cover Factor (assume 1)

For average slope: LS = 0.68

A = 2,500 x 0.038 x 0.68 x 1 x 1
= 655 tonnes /hectare / year

Holsworthy Options

Rainfall erosivity is a measure of the ability of rainfall to cause erosion. The erosivity factor for the Holsworthy site is 3500 (in the vicinity of Sydney factors range from 2500 in western Sydney to 6000 near Wollongong)

The soil erodibility is the susceptibility of soil particles to detach. It is generally determined from detailed soil analyses. Such analysis was performed for Lucas Heights soil landscape and showed the soil to be stony and of low fertility. Sediment control with artificial flocculation is recommended.

The slope/gradient for Holsworthy is highly dependent on the area of working. Where land disturbance extends onto the slopes of creeks the gradient varies from 2:1 to 3:1. On ridge tops the gradient ranges from 20:1 to 100:1.

The risk of sediment movement can be computed using the Universal Soil Loss Equation (USLE):

A = RKLSPC

where:
- R = erosivity (3500 for Holsworthy)
- K = soil erodibility (0.042 - assuming Lucas Heights soil landscape)
- LS = slope length-gradient factor (assuming 50m of disturbed slope)
- P = Erosion Control Practice Factor (assume 1)
- C = Cover Factor (assume 1)

For creek slopes: LS = 15.6

A = 3,500 x 0.042 x 15.6 x 1 x 1
= 2295 tonnes /hectare / year

For ridge tops: LS = 0.3

A = 3,500 x 0.042 x 0.3 x 1 x 1
= 44 tonnes / hectare / year

STORMWATER RUNOFF LOAD CALCULATIONS

Residual Pollutants after stormwater mitigation

Given drainage area and expected export rate of nutrients and stormwater treatment efficiency, what residual N & P concentrations remain.

An estimate was also made given the detention times and performance of pond and wetlant systems (Lawrence 1996). For the nutrient phosphorus there would be some removal of particulate forms in settling of solids in the detention basins. It is estimated that this type of system would provide 35% removal for an average 10 day retention time . For reed bed systems a further removal of approximately 45% phosphorus is estimated. The system thus gives a total phosphorus removal of 70% for storms less than the 1 in 1 year ARI, 2 hour duration. This equates to approximately 95% of storm events, reducing the overall capture of phosphorus to 60%. Nitrogen removal not as efficient due to reduced nitrification rates in winter.

Thus expect average removal of 60% TP and 50% TN from detention ponds and gravel filters

Export rates from landuse (CMSS modelling in Hawkesbury-Nepean Catchment, Marston 1993):

Commercial / Industrial Landuse

TP exports of 1.8 kg/ha/yr
TN exports of 6 kg/ha/yr

Badgerys Creek

CMSS modelling (Cuddy et al, 1994) estimates loads from the existing Badgerys Creek catchment (catchment area 2770 ha)

TP = 1857 +/- 516 kg/yr
TN = 11506 +/- 4598 kg/yr

TP = 0.67 kg/ha/yr
TN = 4.15 kg/ha/yr

i Option A (1136 ha drains to Badgerys Creek)

TP load = (1136 x 1.8) 0.4 + (1634 x 0.67) = 1913 kg/yr
TN load = (1136 x 6) 0.5 + (1634 x 4.15) = 10189 kg/ha/yr

ii Option B (1743 ha drains to Badgerys Creek)

TP load = (1743 x 1.8) 0.4 + (1027 x 0.67) = 1943 kg/yr
TN load = (1743 x 6) 0.5 + (1027 x 4.15) = 9491 kg/ha/yr

ii Option C (2357 ha drains to Badgerys Creek)

TP load = (2357 x 1.8) 0.4 + (413 x 0.67) = 1947 kg/yr
TN load = (2357 x 6) 0.5 + (413 x 4.15) = 8785 kg/ha/yr

Holsworthy

Existing load from bushland (Marston 1993)

TP exports of 0.1 kg/ha/yr
TN exports of 1.5 kg/ha/yr

i Option A (4250 ha)

Existing

TP = 4250 x 0.1 = 425 kg/yr
TN = 4250 x 1.5 = 6375 kg/yr

Post development

TP = (4250 x 1.8) 0.4 = 3060 kg/yr
TN = (4250 x 6)0.5 = 12750 kg/yr

ii Option B (2805 ha)

Existing

TP = 2805 x 0.1 = 280 kg/yr
TN =2805 x 1.5 = 4207 kg/yr

Post development

TP = (2805 x 1.8) 0.4 = 2020 kg/yr
TN = (2805 x 6)0.5 = 8415 kg/yr

Calculations for Partioning of Benzene between Air and Water

$$\text{Concentration} = \frac{P_{Benzene}}{H}$$

where: $P_{Benzene}$ = partial pressure of benzene

H = Henrys Law Constant (for benzene = $0.0055 \frac{atm\ m^3}{mole}$) [Lyall 1990]

1. Holsworthy A and B Options

Partial pressure benzene = ppb x 10^{-9} atm

ppb for benzene = 2.0×10^{-2} (from air contour map) [Coffey 1997]

∴ Partial pressure benzene = 2.0×10^{-11}

∴ Concentration benzene in water = $\frac{2.0 \times 10^{-11} atm}{0.0055\ atm\ m^3/mole}$

= 0.000 000 003 moles/m^3

To convert moles/m^3 to micrograms/L:

1 mole benzene x concentration mole/m^3 = grams/m^3 (divide by 1000 to obtain micrograms/litre)

1 gram mole benzene = 78.11 grams

∴ 78.11 grams x 0.000 000 003 moles/m^3 = 0.000 000 284 grams/m^3

= 0.000 000 284 milligrams/litre

= 0.000 284 micrograms/ litre

NH&MRC (1996) Drinking Water Guideline for benzene = 1microgram/litre

ANZECC (1992) Protection of Aquatic Ecosystems Guideline = 300 micrograms/litre

2. Badgerys Creek All Options

Partial pressure benzene = ppb x 10^{-9} atm

ppb for benzene = 5.0 x 10^{-3} (from air contour map) [Coffey 1997]

∴ Partial pressure benzene = 5.0 x 10^{-12}

∴ Concentration benzene in water = $\frac{5.0 \times 10^{-12} \text{atm}}{0.0055 \text{ atm m}^3/\text{mole}}$ [Lyall 1990]

= 9.09 x 10^{-10} moles/m^3

To convert moles/m^3 to micrograms/L:

1 mole benzene x concentration mole/m^3 = grams/m^3 (divide by 1000 to obtain micrograms/litre)

1gram mole benzene = 78.11 grams

∴ 78.11 grams x 9.09 x 10^{-10} moles/m^3 = 0.000 000 071 grams/m^3

= 0.000 000 071 milligrams/litre

= 0.000 071 micrograms/ litre

NH&MRC (1996) Drinking Water Guideline for benzene = 1microgram/litre

ANZECC (1992) Protection of Aquatic Ecosystems Guideline = 300 micrograms/litre