Riverside at Tea Gardens

Integrated Water Management

CRIGHTON PROPERTIES

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Riverside at Tea Gardens
Integrated Water Management

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BACKGROUND

As an extension of it's earlier involvement with the Myall Quays Project, in 2003 Cardno Willing was engaged by Crighton Properties Pty Ltd. to formulate a sustainable water management strategy for future (mixed use) development of the then Myall Quays site in Tea Gardens.

The site, which was rezoned for urban purposes in 2000 adjoined another residentially zoned parcel which by 2003, had been fully developed into 240 existing residential lots with an existing constructed extended detention lake around 6.0 ha in size This extended detention lake was constructed prior to the enactment of SEPP 50.

With the enactment of SEPP 71 a new masterplan was required to be developed and approved to permit further residential development within the site. A major component of the masterplan is an Integrated Water Cycle Management (IWCM) strategy for the site.

Cardno Willing has, over the last four years formulated an the IWCM strategy based on water Sensitive Urban Design (WSUD) principles for the Riverside at Tea Gardens site (formerly Myall Quays). The strategy has been based upon;

- Intensive analysis of existing site conditions;
- A significant assembly of base data regarding performance of the existing surface and groundwater systems and in particular the existing detention lake;
- Detailed computer modelling and assessment of a range of development options against performance criteria and legislative requirements;
- Refinement of the selected management strategy;
- Modelling of likely future performance and impacts of the selected management strategy; and
- Considerable consultation with specialized consultants and designers, the community at large, Council and other Authorities.

SITE CONDITIONS

The Riverside at Tea Gardens site consists of a sand plain adjoining the shoreline of the Myall River. The site is fringed for a major part of its frontage to the Myall River by SEPP 14 wetlands. A buffer zone was established at the time of rezoning to protect the SEPP 14 wetlands.

The surface water catchment extends well beyond the boundaries of the Riverside at Tea Gardens site and requires the consideration of how best to manage the significant runoff from adjacent Rural Residential development and its likely quality.

The site is virtually flat in profile and the ground level rises only a couple of metres over more than a kilometre. The shallow grades across the site, combined with a high water table and sandy soils pose challenges for traditional drainage and WSUD techniques particularly if the stormwater conveyance systems are forced to be connected to the existing detention lake in the southern boundary of the site. This approach would require the importation of massive quantities of fill material to establish even minimal grades on swales and floodways and to fill residential lots to the required level above 100 yr ARI flood levels.

The site presents only three real opportunities for stormwater runoff to discharge from the site. From the south to north these opportunities are;

(i) The existing outlet at the southern end of the lake outlet that discharges into an area adjoining the Myall River (under existing conditions the 100 yr ARI peak outflow is around 14.7 m^3/s)

(ii) Dispersed flows across the existing Conservation Zone the abuts the SEPP 14 wetland (under existing conditions the 100 yr ARI peak outflow is around 10.9 m^3/s)

(iii) To the Myall River via an existing watercourse in the north of the site (under existing conditions the 100 yr ARI peak outflow from the site is around 1.25 m^3/s)

A significant determining factor with regard to water movement across the site and detention requirements relates to the gradient available to drain water to each of these outlets and the peak flow limitations at each outlet.

OPTIONS

A detailed assessment of existing and future catchment runoff and pollutant exports and water management options to maintain as far as possible the existing lake water quality and its ancillary role as a fish was undertaken in September 2004.

A Do Nothing option and six schemes to mitigate the impact of planned future development on lake water quality were assessed. These schemes were:

1. Do nothing – keep the current water body as it is without increasing the size (but with BASIX implemented).
2. Existing lake (6 ha) with increased tidal flushing (x4);
3. **Extended lake (13.5 ha) with increased tidal flushing (x2);**
4. Existing lake with increased tidal flushing (x1.6) and a new freshwater lake (12 ha);
5. **Partially extended lake (8 ha) with increased tidal flushing (x1.8) and new freshwater lake (6.5 ha);**
6. Existing lake (6 ha) with increased tidal flushing (x1.6) and new wetlands (16 ha); and
7. Existing lake (6 ha) and dry swales.

Possible stormwater quantity (retardation) management strategies were also assessed. Retardation modelling was undertaken for Schemes 2 – 6.

A multi-criteria assessment of water quality performance, environmental impacts and viability was undertaken. The assessment criteria included:

- Water Quality
  - Salinity
  - Dissolved Oxygen
  - Algae
  - Total Nitrogen
  - Total Phosphorous

- Environmental Impacts
  - Impact on existing water body
  - Impact on SEPP 14 wetlands
  - Impact on Myall River
  - Impact on Groundwater

- Viability
  - Loss of potential lots
  - Aesthetic/Health
  - Landtake for Basins
  - Landtake for Ponds / Wetlands
  - Filling

The ranking of the seven schemes in order of performance and benefit was:

Rank	**Scheme**
1	Scheme 3
2	Scheme 5
3	Scheme 4
4	Scheme 6
5	Scheme 2
6	Scheme 7
7	Scheme 1

What won't work?

It was concluded from the multi-criteria assessment that attempting to implement a water management scheme without extending the existing detention lake is not viable and would deliver sub-optimal water quality and environmental outcomes. In particular a scheme based on swales that discharging into the existing detention lake (Scheme 7) would require the importation of massive quantities of fill material to establish even minimal grades on the swales and floodways and to fill residential lots to the required level above 100 yr ARI flood levels.

Likewise the changes in water quality in the existing detention lake (in particular salinity and TN) that result from retaining the existing outlet only has the potential to adversely impact on the existing aquatic ecology and may even change the mix of fish species.

What will work?

While it was concluded from the multi-criteria assessment that extending the tidally flushed lake to a 13.5 ha water body in combination with ancillary local ponds and local wetlands (Scheme 3) is the most viable approach and delivers the best overall outcomes for water quality and the environment it was also concluded that the partial extension of the existing detention lake in combination with a freshwater lake(s) and ponds and wetlands (Scheme 5) could deliver similar water quality and environmental outcomes.

Since September 2004 the development concept has evolved considerably including the removal of the nine hole golf course, an increase in the number of dwellings upon the site and wholesale changes to the site planning and layout in keeping with planning best practice. Despite these substantial changes to the proposed layout since September 2004, the principal conclusions of the comparative assessment presented in the 2004 report remain valid today and supported the detailed assessment of Schemes 3 and 5. The assessments of hydrology, hydraulics, stormwater quality and lake water quality described in this study follow the assessment approaches adopted in 2004. In relation to the stormwater quality assessment the previous **xpaqualm** modelling has been updated and undertaken using MUSIC.

It was concluded from the assessments described herein that the flooding, drainage and water quality objectives for the development could be met by either:

(i) Extending the existing detention lake (with increased tidal flushing) and constructing additional ponds and/or wetlands, swales and a biofilter as appropriate (Scheme 3); or

(ii) Partially extending the existing detention lake ((with increased tidal flushing) and constructing additional freshwater lakes, ponds and/or wetlands, swales and a biofilter as appropriate (Scheme 5).

Discussions held with the NSW Department of Planning highlighted a number of concerns held by NSW Government stakeholder with concept Scheme 3. Consequently the preferred approach to integrated water management is based on Scheme 5.

The proposed outlet configuration is to retain the existing outlet channel unchanged while a second channel of equal width is constructed approximately 70 m north of the existing outlet channel with invert levels that are uniformly 0.10 m lower than the existing channel. The second outlet channel would be constructed without disturbing the SEPP 14 wetland. It would connect to a second existing drain located within the SEPP 14 wetland zone.

LEGISLATIVE REQUIREMENTS

The Director-General's Environmental Assessment Requirements for water cycle and aquaculture management are in part as follows:

> "Address potential impacts on the water quality of surface and groundwater having regard to the relevant State Groundwater, River, Wetlands and Estuary Policies. Consideration must be made for water impacts to the Myall River and identified SEPP 14 Wetlands.
>
> …. Stormwater management should be designed to ensure ongoing protection of the groundwater aquifer in accordance with the principles of ANZECC & ARMCANZ: Guidelines for Groundwater Protection in Australia, National Water Quality Management Strategy, Commonwealth of Australia, 1995."

The compliance of any extension of the existing detention in the context of State Environmental Planning Policy 50 – Canal Estate Development has been reviewed previously.

Under SEPP50, canal estate development in part means development that:

> '… .incorporates wholly or in part a constructed canal, or other waterway or waterbody, that is inundated by or drains to a natural waterway or natural waterbody by surface water or groundwater movement (not being works of drainage, or for the supply or treatment of water, that are constructed by or with the authority of a person or body responsible for those functions and that are limited to the minimal reasonable size and capacity to meet a demonstrated need for the works)……………..'

The proposed partial extension of the lake is not the only measure proposed to mitigate the impacts of planned development and to protect the receiving waters. The water management scheme includes a series of freshwater lakes, swales, local ponds and wetlands and basins in addition to the partially extended detention lake. This approach is similar to the successful implementation of a number of measures at varying scales within the development completed to date.

The review concluded that the partial lake extension was the minimum reasonable size and capacity to meet statutory requirements and the management objectives of the LEP and DCP and would be in accordance with the provisions of SEPP50.

MITIGATING THE IMPACTS OF THE DEVELOPMENT

Mitigating Surface Water and Groundwater Impacts

The planned development will increase the rate of local runoff and peak flows. A number of basins have been sized to ensure that the post development peak flows in the 100yr ARI event is no greater than under existing conditions.

Groundwater modelling of the planned development with an extended lake indicates that groundwater levels in the northern, eastern and southern parts of the site will be similar to those under existing conditions. Groundwater levels to the north of the existing lake will be lowered by up to about 1 m due to the extension of the lake with groundwater to the west and north of the extended lake tending to flow towards the extended lake. As a result, general groundwater flow directions in the area will change slightly and a higher volume of groundwater will be discharged into the lake.

Groundwater levels along the SEPP 14 wetlands are assessed to be similar to the existing levels, with a marginal decrease in groundwater levels (less than 0.1 m drawdown) on the western edge of the SEPP 14 wetland area. It is considered that the minimal extent of groundwater changes associated with the proposed development is unlikely to affect SEPP 14 wetland vegetation.

The planned development will also increase the average annual export of pollutants from the site. Catchment water quality assessments of the planned development demonstrate that the preferred water management scheme (that utilises reclaimed water instead of rainwater harvesting):

- Reduces the average annual export of TSS, TP and TN from the catchment by greater than 80%, 45% and 45% respectively; and
- Reduces the export of TSS and TP under Developed Conditions to the wetland zone by 78%, 33% than the TSS and TP exports under Existing Conditions;
- Slightly increases the export of TN under Developed Conditions to the wetland zone by 3% than the TN export under Existing Conditions.

It was concluded from lake modelling that under developed conditions the freshwater lakes and the partially extended detention lake will continue to deliver water quality comparable to existing lake water quality. The installation of ancillary local ponds or local wetlands (without any change in the tidal flushing regime) is necessary to manage the water quality in the freshwater lakes and would further improve the water quality in the extended lake.

Practical Consideration of Climate Change

The planned development is subject to flooding from both the Myall River and from runoff from the local catchment. Sensitivity assessments of climate change were undertaken for the scenarios given in the 2007 DECC Guideline titled “Practical Consideration of Climate Change”. These scenarios include +0.18m, +0.55 m and +0.91 rises in sea level as well as 10%, 20% and 30% increase in rainfall intensities.

To mitigate the impacts of climate change, the planned development has adopted an additional freeboard of 0.3 m for mimimum floor levels over and above Council's adopted minimum floor level of 2.6 m AHD in areas subject to inundation from the Myall River to avoid over floor flooding in a 100 yr ARI event under all climate change scenarios. The adoption of a minimum floor level of 2.9 m AHD will provide all homes in the development with a far greater level of protection against climate change than a large number of existing properties in Tea Gardens.

Elsewhere in the planned development the adoption of a minimum floor level of 0.5 m above the local 100 yr ARI flood level (under no climate change) would provide a minimum 0.22 m freeboard above the local 100 yr ARI flood level under a high climate change scenario.

While under a high climate change scenario there would be increased inundation of a number of planned roads by up to 0.8 m (which would be still Low Hazard due to the expected very low velocity of flow on the fringes of the river flooding through the development) but would comply with the requirements for safe wading. Even under a high climate change scenario, planned roads would provide flood free egress via a number of roads for residents evacuating from threatened properties to higher ground on the northern and north western boundaries of the development.

Flood Warning

It was also noted from the 1980 Myall River flood study that the estimated 100 yr ARI outflow from the Myall Lakes peaked after 7 days. Consequently it is expected that the flood warning system in place to warn existing residents of Tea Gardens of major flooding in the Myall River would provide ample warning time for residents of properties that would be threatened under a high climate change scenario to safely evacuate their properties well before the Myall River would reach its peak.

MANAGEMENT, MAINTENANCE AND MONITORING

The management responsibilities of various stakeholders including the landowner, contractors/builders Myall Quays Community Association (Residents), Great Lakes Council and the Department of Environment and Climate Change are identified.

In view of the potential presence of acid sulphate soils a generic plan has been prepared for management of ASS in future earthworks that occur within the Riverside Estate that include the laying of sewer and drainage lines and the excavation of stormwater treatment basins. A concise version of this plan will be provided as a reference to all lot purchasers and contractors required to work on any home within the site. This plan has been formatted in a way to assist individual land owners obtaining DA approvals by outlining methods to control and manage ASS during the development of each lot. The plan will also guide the management of any future excavation to extend the detention lake.

Maintenance activities for constructed ponds and wetlands and the extended detention lake are outlined. The management of aquatic weeds in constructed pond and wetland systems and the extended detention lake will be based on the practices already implemented for existing ponds and wetlands located within developed areas of Riverside estate and the Myall River Downs estate and for the existing detention lake.

A monitoring program is proposed for the SEPP 14 wetlands, constructed ponds and wetlands and the extended detention lake. The management actions proposed to rectify any failures to meet the water quality objectives are also identified.

RECLAIMED WATER

Many water needs can be satisfied using reclaimed water as long as it is adequately treated to ensure water quality is appropriate for the proposed use (NSW DEC, 2004).

Based on the signature of key chemical constituents, three alternative approaches to the use of reclaimed water for the purposes of irrigation are identified as follows:

1. Treatment of the reclaimed water to meet health standards including pathogens. The reclaimed water may be used for irrigation if 10% of the reclaimed water is mixed with 90% of fresh water.
2. Treatment of the reclaimed water to limit P to an average concentration of 1.5 mg/L and NO_3 to an average concentration of 1.4 mg/L. If this level of treatment is obtained then a mixture of 50% of reclaimed water and 50% of fresh water may be used for irrigation.
3. Treatment of the reclaimed water to limit P to an average concentration of 0.4 mg/L and NO_3 to an average concentration of 0.7 mg/L. If this level of treatment is obtained then 100% of the reclaimed water may be used for irrigation purposes, assuming partial uptake of nutrients by vegetation.

The potential for reclaimed water applied for irrigation and garden watering to contaminate the groundwater was assessed. It is considered that irrigation of parks and open spaces within the development is unlikely to adversely impact groundwater or the water in the lake if one of the above reclaimed water use options is adopted.

There are a number of approaches to meeting the BASIX Water target for new development including the adoption of water efficient appliances and the installation of rainwater tanks to supply water for external and a number of internal household uses. An alternative to rainwater tanks is to install a reclaimed water supply system to meet external and a number of internal household demands. The decision to reticulate reclaimed water to the site as a non-potable water supply rather than to install rainwater tanks on all residential lots was influenced by a number of key considerations including:

(i) A reclaimed water supply is a more reliable source of water than rainwater tanks that are dependant on rainfall and the maintenance regime implemented by each individual lot owner,

(ii) A reclaimed water system can be integrated into all lots during the development phase;

(iii) Reclaiming water at the local Wastewater Treatment Plant can delay the need to expand an existing plant capacity and allow a plant to continue to meet effluent disposal limits and at the same time creating capacity to treat effluent from additional local development;

(iv) The adoption of a reclaimed water supply system for the Riverside estate is critical to the feasibility of implementing a reclaimed water system by the local water authority and would enable reclaimed water connections to be offered to other local users.

ARCHITECTURAL AND LANDSCAPE TREATMENT

In addition to the environmental performance of the proposed system, a number of opportunities are presented with regard to visual and physical interaction with the system that intelligent architectural and landscape design can capitalise upon, such as foreshore parks, walkways, cycleways, placement of public buildings etc.

The internalisation of the water management system and the unfettered public access which is proposed to be provided to all new waterbodies and detention basins will ensure ongoing adoption of maintenance regimes due to the surveillance and public amenity that the system provides.

This maintenance discipline has been proven to date, even though the existing lake does not enjoy the same level of public visibility (due to site layout) as the design currently proposed.

ONGOING PERFORMANCE

Demonstrated Performance

Detailed water quality data collected since 1996 has demonstrated the effective performance of the existing water management system, which is similar to that proposed for the planned development. It gives confidence of the likely future success of the proposal – it is rare to have this level of technical support.

Community Ownership and Maintenance

The Community Title ownership of the lake ensures a body exists in perpetuity as well as providing a funding mechanism to ensure the ongoing maintenance and monitoring of the system.

Fish Habitat

In addition to it's primary function of water management the existing lake functions as an evolving biological asset with its fish stocks and marine biodiversity - the proposed water management scheme is expected to augment this marine system whereby the benefits will likely exceed the mere extension of a greater area of lake.

It also offers an opportunity to increase the extent, complexity and quality of near-shore habitats for fish, invertebrates and birds.

Asset and Amenity

Above and beyond the expected performance of the proposed system and its benefits to the environment, the resulting design will likely become a proud community asset by providing a level of recreational and visual amenity that will help to ensure its ongoing sustainability and proper management. There exists a distinct opportunity whereby careful design and embellishment of the extended lake itself (particularly in the vicinity of the Town Centre) to take on the characteristics of the Tea Gardens waterfront and could assist in the continued attraction of tourists to the Tea Gardens area.

CONCLUSIONS

In summary, the integrated water management system proposed for the Riverside site is based on a strategy which collects, detains and treats stormwater runoff in an integrated train of local, neighbourhood and regional facilities.

It is also proposed to reticulate reclaimed water to the site as a non-potable water supply rather than to install rainwater tanks on all residential lots. This has the added advantage of delaying the need to expand the capacity of the local Wastewater Treatment Plant and will allow the plant to continue to meet effluent disposal limits while at the same time creating capacity to treat effluent from additional local development.

It is concluded that a water management scheme comprising the a number of local ponds, local wetlands, swales, basins, freshwater lakes and the partial extension of the existing detention lake we believe will meet the water quality, and quantity objectives for the site set down by the various relevant authorities.

The elements of the treatment train are summarised below.

It is our opinion that the proposed water management scheme delivers the best overall outcomes for water quality and the environment whilst meeting the performance requirements set down by the relevant authorities.

It is also our opinion, that this scheme is the most likely to succeed in the long term and, if properly managed in accordance with the plan provided in this report is likely to continue to perform at or near the already demonstrated performance levels.

The proposed scheme also offers an opportunity to increase the extent, complexity and quality of near-shore habitats for fish, invertebrates and birds that is rarely available in new developments.

Element	Description	Usage / Role
1	Swales and a Retarding Basin located in the northern open space corridor	To direct runoff from the upper catchment along the northern corridor to a swale that distributes runoff along the boundary of the Conservation Zone prior to its distributed discharge into the Conservation Zone.
2	Swales located within open space corridors in the development	To direct convey local urban runoff (at minimum grades) to local constructed ponds or wetlands and/or to convey runoff to the extended detention lake.
3	Constructed local ponds and wetlands (4.7 ha)	To pre-treat urban runoff prior to its discharge to the freshwater lakes and the partially extended detention lake. Constructed ponds and wetlands can also assist the conveyance of runoff in areas where there is insufficient grade for swales. The active storage above constructed ponds and wetlands also assist in managing peak flows in major storms.
3	Constructed freshwater lakes (6.5 ha)	To further treat urban runoff prior to its discharge to the extended detention lake. Freshwater lakes can also assist the conveyance of runoff in areas where there is insufficient grade for swales. The active storage above the freshwater lakes will also assist in managing peak flows in major storms.
4	Extension of existing brackish detention lake (2 ha)	To further treat urban stormwater runoff to meet water quality requirements prior to discharge to the Myall River while maintaining the existing water quality regime of the existing lake.

1. INTRODUCTION

As outlined previously by ERM (2006), Crighton Properties or its affiliated companies are the owner of two substantial development sites at Tea Gardens on the Mid North Coast. The location of these development sites is illustrated in **Figure 1**.

In 1991 Crighton Properties bought the 230 hectare site currently known as ‘Riverside at Tea Gardens’ (formerly ‘Myall Quays’) which lies immediately to the west of the Myall River and to the east of Myall Road (the main road linking Tea Gardens / Hawks Nest with the Pacific Highway). The location of the Riverside at Tea Gardens site is shown as **Figure 2**.

The second development site owned by Crighton Properties is known as the ‘Myall River Downs’ site and comprises approximately 320 hectares of land located to the west of the Riverside at Tea Gardens site and on the western side of Myall Road. An aerial photograph of the sites is provided at **Figure 3**.

The following overviews of the history of the Riverside at Tea Gardens site and project description are drawn from ERM, 2006.

1.1 SITE HISTORY

The Riverside at Tea Gardens Estate is currently being developed and comprises a range of residential, retail/commercial, recreation and tourist development including over 240 completed residential lots. The part of the site remaining to be developed and covered by the concept plan comprises Lot 34 and Lot 10 DP 270100.

In 1989, Crighton Properties predecessor in title lodged a rezoning request with Great Lakes Council for a multi-stage residential/resort type development on the site. The Council resolved to prepare a draft Local Environmental Plan (LEP) subject to the findings of a formal local environmental study (LES). The LES was prepared in 1991 and the site was finally rezoned to 2(f) mixed commercial residential in 2000.

In 2002 Crighton Properties began the process of seeking approval to develop a substantial portion of this site for residential purposes and for a nine hole golf course and tourist facilities. Following the introduction of State Environmental Planning Policy No 71 – Coastal Protection (SEPP 71) in November 2002, a master plan was required to be adopted by the Minister for Planning before any further residential subdivisions could be approved.

A Planning Focus Meeting was held on site on 28 December 2003 to discuss the master plan and the various development proposals. The Director- General’s requirements for the EIS were subsequently issued by the Department of Infrastructure, Planning and Natural Resources in January 2004 (Ref: N91/00721) for the artificial water detention body and the residential/tourist/recreational components. The Department also provided requirements regarding the preparation of a master plan for the development under SEPP 71 (Ref: S03/03010).

1.2 SITE DESCRIPTION

The Riverside at Tea Gardens site is bounded by Myall River to the east and Myall Road to the west. The Shearwater Residential Estate lies to the north of the site and residential development of Tea Gardens is to the south. The site has approximately a one kilometre frontage to Myall Road and two kilometre frontage to the Myall River. State Environmental Planning Policy No. 14 – Coastal Wetlands (SEPP 14) applies to wetlands within a portion of the eastern boundary of the site adjacent to the Myall River. These wetlands have been clearly identified along with a buffer to the wetlands and zoned accordingly when the site was rezoned in 2000. The remainder of the site is available for urban development and zoned accordingly.

The site is flat with generally sandy soils. There is a slight fall to the south. The site ranges in height from 0.6m Australian Height Datum (AHD) (along the foreshore of the Myall River) to 20m AHD (at the northern end of the side adjacent to the Shearwater Estate). However most of the site varies in height from between 1.6m AHD to 5.0m AHD.

The majority of the site was previously used for a pine plantation and has been substantially cleared of native vegetation. Some scattered isolated occurrences of both pines and natives currently exist on the site.

1.3 PROJECT DESCRIPTION

The Riverside at Tea Gardens site is already zoned 2(f) – Mixed Residential – Commercial for urban development (refer **Figure 4**). The concept plan for the development of the Riverside at Tea Gardens site consists of a residential / mixed use precinct proposed for the majority of the site and a tourist and larger lot component located in the NE corner of the site. Substantial areas of the 2(f) zoned land are proposed to be protected and enhanced as open space / wildlife movement corridors, over and above those already protected within the 7(a) and 7(b) zones.

The proposed development concept plan is provided in **Figure 6**.

1.4 PLANNING CONTEXT

ERM, 2006 discuss in detail the planning provisions that apply to the site and whether the project is permitted under the prevailing instruments, plans, policies and strategies.

It was concluded that the proposed development is consistent with the following instruments/plans/policies/strategies.

- Great Lakes LEP 1996
- DCP 30 – Residential – Urban Areas
- DCP 31 – Subdivision
- Stormwater Quality DCP
- Tea Gardens Hawks Nest Conservation & Development Strategy
- Draft Tea Gardens Hawks Nest Housing Strategy (2nd Draft)

- Recovery Plan for the Hawks Nest & Tea Gardens Endangered Koala Population
- Hunter REP 1989
- Hunter's Coast – Hunter Coastal Urban Settlement Strategy
- SEPP (Major Projects)
- SEPP 11 – Traffic Generating Developments
- SEPP 14 – Coastal Wetlands
- SEPP 44 – Koala Habitat Protection
- SEPP 50 – Canal Estate Development
- SEPP 71 – Coastal Protection
- NSW Coastal Policy 1997
- Coastal Design Guidelines for NSW

The proposed development is partly consistent with DCP 22 – Myall Quays Estate. As discussed by ERM (2006) DCP 22 is outdated as it was prepared prior to recent environmental studies and investigations into the capabilities and suitability of the site. While many of the management principles actions outlined in the DCP remain relevant, some of the specific controls are no longer appropriate as they are based on a previous master plan that has little resemblance to the current (and proposed) development of the site, nor in any event, can this masterplan be realised, given the current planning legislation. It is anticipated that the DCP will be repealed and replaced by a concept plan for the Riverside at Tea Gardens and Myall River Downs Estates.

1.5 CONSULTATION

Crighton Properties has been continually liaising with Great Lakes Council regarding the development of both sites over many years.

During the site's long history many government agencies have been consulted regarding other residential/recreation uses of the site and are aware of the site and its opportunities and constraints (ERM, 2006). The agencies that have been consulted include but were not limited to the following:

- Department of Planning
- NSW Fisheries
- Department of Environment and Climate Change including
    - NSW EPA in the former DEC
    - the former DNR

1.6 PREVIOUS STUDIES

A number of studies of surface water and groundwater issues for the Riverside at Tea Gardens site have been undertaken previously. These studies are overviewed in chronological order as follows:

Coffey Partners International Pty Ltd (1996a) *"Myall Quays Development - Groundwater and Surface Water Study", Report No. G39811-AJ*, prepared for Paterson Britton & Partners, February.

This study reported on existing site groundwater conditions. The report included:

- review of existing conditions,
- assessment of the need for further field studies,
- additional field testing,
- modelling of groundwater and surface flows, and
- assessment of the effects of proposed development.

Field monitoring of 10 bores was also undertaken in the Myall Quays area during 1994 -1995 including high rainfall events in May and June 1995. In most cases the peak groundwater level associated with a rainfall event followed within about a week of the rainfall. It was reported that a high level of groundwater response occurred under existing conditions, suggesting that little rainfall runs off and most reports to the groundwater system.

Water quality tests were performed on the bore water by Hunter Water Laboratories and the results are reported in CPI, 1996a. Bores close to the Myall River showed concentrations similar to seawater, while other bores were less saline. Lead levels exceeded guidelines for human consumption in many of the samples. It was considered that the lower salinity groundwater could be used for golf course irrigation provided that sodium levels were monitored.

Coffey Partners International Pty Ltd (1996b) "Myall Quays Development - Groundwater and Surface Water Study, Estuarine Lake Option*", Report No. G39811-AS*, prepared for Paterson Britton & Partners, June.

This study examined the groundwater and freshwater impacts of an Estuarine Lake option.

Cardno Willing (2003a) "Myall Quays Drainage and Water Quality Management Plan", *Draft Report*, prepared for Crighton Properties, April.

This report was prepared to provide background information on water quality solutions to address the potential impacts of proposed future stages of the Myall Quays development at Tea Gardens, NSW.

It was concluded that the existing detention lake on the site would need to be enlarged in order to maintain the existing water quality and its ancillary role as a fish habitat. Preliminary calculations and computer modelling showed that an increase in size to about 18 hectares may be needed in order to prevent more rapid and extreme changes in salinity and dissolved oxygen (DO), levels which would adversely affect the aquatic habitat. An increase in tidal flushing would be also necessary in order to maintain the mean salinity at the present value of about 12,000 ppm. Draft ecological principles for the extension of the existing detention lake were also formulated.

Cardno Willing (2003b) "Myall Quays Precincts 7 and 8, Water Management Plan", *Final Report*, prepared for Crighton Properties, September.

A Water Management Plan for Precincts 7 and 8 (that is now constructed) was prepared to address Great Lakes Council Deferred Commencement Conditions No. 2 and No. 4 as detailed in the Minutes of the Planning & Development Committee of the Great Lakes Council held on 25th March 2003.

The Plan identifies the water quality performance criteria to be achieved within the water quality treatment system for the site and the procedures for ensuring that the specified water quality performance criteria are met.

The Plan also outlines a monitoring program to ensure the long term viability of the water quality treatment system, including details of the monitoring procedure for ensuring the performance of the pollutant control function, with regard to nutrient stripping.

The Plan identifies the persons responsible for the monitoring and maintenance, including responsibility for costs for maintaining scenic and water quality of the water treatment system, and further identifies those persons responsible for any remediation actions or costs required to Improve scenic, recreation and water quality of the water quality treatment system.

Cardno Willing (2003c) "Myall Quays Development", *Options Paper*, prepared for Crighton Properties, July.

This paper discusses water management options to protect the aquatic environment that has been already established in the first stage of the detention lake by maintaining existing water quality under the ultimate developed condition.

Based on an assessment of water quality impacts and the advantages and disadvantages of each option it was concluded that the option that is best able to protect the aquatic environment that has been already established in the existing detention lake is to extend the lake to an 18 ha detention lake in combination with existing practices of implementing OSR on lots draining directly to the lake and construction of mini ponds and wetlands in strategic locations within the future developed areas.

Cardno Willing (2003d) "Myall Quays Water Quality Detention Lake, Applicability of SEPP50", Position paper, prepared for Crighton Properties, July.

As part of the planned development of the Myall Quays site it was proposed to extend the detention lake to mitigate the impacts of the development of the remaining area of the southern catchment while maintaining the aquatic environment that has been already established in the first stage of the detention lake. This paper reviewed the proposed detention lake extension in the context of State Environmental Planning Policy 50 – Canal Estate Development.

It was concluded that the lake extension was the minimum reasonable size and capacity to meet statutory requirements and the management objectives of the LEP and DCP and would be in accordance with the provisions of SEPP50.

Cardno (2004) "Myall Quays Development, Tea Gardens, Assessment of Water Management Options", Final Report, prepared for Crighton Properties, September.

This report provides background information on the proposed Myall Quays development at Tea Gardens, NSW. It overviews the LEP, DCP gazetted in 2000, zoning constraints, environmental constraints, development constraints and community constraints.

A detailed assessment of existing and future catchment runoff and pollutant exports and water management options to maintain as far as possible to maintain the existing lake water quality and its ancillary role as a fish habitat is outlined.

A Do Nothing option and six schemes to mitigate the impact of planned future development on lake water quality were assessed. These schemes were:

0. Existing conditions ie. a 6 ha lake;
1. Do nothing – keep the current water body as it is without increasing the size (but with BASIX implemented).
2. Existing lake (6 ha) with increased tidal flushing (x4);
3. **Extended lake (13.5 ha) with increased tidal flushing (x2);**
4. Existing lake with increased tidal flushing (x1.6) and a new freshwater lake (12 ha);
5. **Partially extended lake (8 ha) with increased tidal flushing (x1.8) and new freshwater lake (6.5 ha);**
6. Existing lake (6 ha) with increased tidal flushing (x1.6) and new wetlands (16 ha); and
7. Existing lake (6 ha) and dry swales.

Possible stormwater quantity (retardation) management strategies were also assessed and outlined. Retardation modelling was undertaken for Schemes 2 – 6.

The modelling of the various Schemes has been conducted to maintain, as close as possible, the existing (estimated) 100 year outflow to Myall River. The total volume of retardation required and other possible engineering interventions were considered for each of the Schemes and are outlined.

A multi-criteria assessment of water quality performance, environmental impacts and viability was undertaken. The assessment criteria included:

- Water Quality
  - Salinity
  - Dissolved Oxygen
  - Algae
  - Total Nitrogen
  - Total Phosphorous

- Environmental Impacts
  - Impact on existing water body
  - Impact on SEPP 14 wetlands
  - Impact on Myall River
  - Impact on Groundwater

- Viability
  - Loss of potential lots
  - Aesthetic/Health
  - Landtake for Basins
  - Landtake for Ponds / Wetlands
  - Filling

The three highest ranked schemes in order of performance and benefit were:

Rank	**Scheme**
1	Scheme 3
2	Scheme 5
3	Scheme 4

Cardno (2004) "Myall Quays Development EIS", partially prepared for Crighton Properties.

An EIS report was partially completed in response to the previous Director General requirements. This partially completed report is unpublished.

Coffey Geosciences Pty Ltd (2004) *"Groundwater Assessment, Myall Quays Development, Tea Gardens",* Report No. E12752/3-AF, prepared for Crighton Properties, December.

This report presents the results of a groundwater study and modelling program undertaken to assess the impact of a proposed development in Tea Gardens on local groundwater movements. The purpose of the assessment was to provide information to address specific issues raised by the Department of Infrastructure, Planning and Natural Resources (DIPNR) (Ref: N91/00721, 5 January 2004) for the Myall Quays development, in particular:

- Analysis of groundwater quality of the site;
- Interception and use of groundwater;
- Potential for groundwater contamination associated with the detention basin and resulting from the residential development and the proposed open space recreational areas;
- Beneficial uses of groundwater; and
- Contingency and remediation plans for the detention basin and aquifer in the event of detention basin pollution and/or eutrophication.

Coffey Geotechnics (2007a) "Proposed Subdivision – Riverside Estate Stage 9, Tea Gardens*", Report No. GEOTSGTE20248AA-AC*, prepared for Tattersalls Surveyors Pty Ltd, May.

The purpose of the assessment was to provide comments and recommendations on acid sulfate soils within the proposed development area. A generic Acid Sulfate Soils (ASS) Management Plan has been provided for Riverside Estate Stage 9 and subsequent stages.

The assessment also provides preliminary geotechnical information for the design and construction of road pavements and residential footings. On site soils have been assessed and preliminary site classifications in accordance with AS2870-1996 are provided.

Coffey Geotechnics (2007b) "Groundwater Assessment*", Draft Report No. GEOTLCOV23225AA-AC*, prepared for Crighton Properties, May.

This report presents the results of a groundwater study and modelling program undertaken to assess the Scheme 3 concept layout for the proposed Riverside development at Tea Gardens on local groundwater movements. The purpose of the study was to address the issues noted in the amended Director-General's Environmental Assessment Requirements (Ref.: MP 06_0010, dated 29 December 2006) for the site, in particular:

- Analysis of groundwater quality of the site;
- Interception and use of groundwater;
- Potential for impact on existing groundwater with respect to the latest concept layout for the development;
- Beneficial uses of groundwater; and
- The potential impact of reuse of reclaimed water and the quality required to minimise impact on
- groundwater.

Coffey Geotechnics (2007c) "Myall Quays Detention Lake Sediment Sampling and Analysis*", Letter Report*, prepared for Crighton Properties, 24 October.

The objectives of this investigation were to assess the lake sediments with regards to the potential for the lake to become a 'pollutant sink' resulting in the build up of nutrients and persistent chemical pollutants. The scope of work included:

- Fieldwork including sediment sampling at selected locations on the lake floor;
- Laboratory analysis of a selected number of samples for heavy metals (Sb, As, Cd, Cr, Cu, Pb, Ni, Ag, Sn, Zn, Hg), total petroleum hydrocarbons (TPH), benzene, toluene, ethylbenzene and xylenes (BTEX), Polynuclear aromatic hydrocarbons (PAH), organochlorine pesticides (OCP), polychlorinated biphenyls (PCB), total phosphorous, total oxidised nitrogen (NOx) and total Kjeldahl nitrogen (TKN);
- Data assessment and reporting.

The assessment concluded that:

- The sediment samples analysed from Myall Quay's Detention Lake show low heavy metals (Cr, Cu, Pb, Hg, Ni and Zn) concentrations which are below the adopted warning levels and may possibly be at background levels.
- OCP and PCB were not detected above the laboratory reporting limits. PAH were detected in sample D1 (duplicate of S1) at concentrations below the warning levels for this investigation.
- Nutrient concentrations (total nitrogen and total phosphorous) indicate they have not accumulated to levels typical of urban ponds and lakes.

Coffey Geotechnics (2007d) "Geotechnical and Acid Sulphate Assessment for Riverside Estate Project Application and Master Plan Area, Tea Gardens*", Report GEOTSGTE20248AA-AE*, prepared for Crighton Properties, 24 October.

This report presents the results of geotechnical and acid sulphate assessments of the Riverside Estate Master Plan area. The scope of work for the geotechnical assessment included providing recommendations on:

- Site preparation;
- Excavation conditions;
- The suitability of the site soils for use as fill and on fill construction procedures;
- Acid sulfate soil conditions and requirements for an acid sulfate soils management plan;
- Preliminary site classification to AS2870–1996;
- Preliminary pavement design and construction;
- Special requirements for construction procedures and or site drainage.

A generic plan for management of ASS in future earthworks that occur within the Riverside Estate was also prepared. It is understood that the plan will be provided as a reference to all lot purchasers and contractors required to work on the site. It has been formatted in a way that will be useable to individual land owners to assist in obtaining DA approvals and in controlling and managing ASS during the development of each lot.

Coffey Geotechnics (2007e) "Groundwater Assessment*", Report No. GEOTLCOV23225AA-AD*, prepared for Crighton Properties, 26 October.

This report presents the results of a groundwater study and modelling program undertaken to assess the Scheme 5 concept layout for the proposed Riverside development at Tea Gardens on local groundwater movements. The purpose of the study was to address the issues noted in the amended Director-General's Environmental Assessment Requirements (Ref.: MP 06_0010, dated 29 December 2006) for the site, in particular:

- Analysis of groundwater quality of the site;
- Interception and use of groundwater;
- Potential for impact on existing groundwater with respect to the latest concept layout for the development;

- Beneficial uses of groundwater; and
- The potential impact of reuse of reclaimed water and the quality required to minimise impact on
- groundwater.

This assessment of groundwater issues is summarised in Section 3 and is attached in **Appendix G**.

Harris Research (2007) Fish Community Survey of the Riverside Lake, Summary Report, prepared for Crighton Properties, May, 5 pp + Apps.

The fish community of the Riverside lake (previously Myall Quays) was surveyed in April 2007 as part of a series of biological studies to record the aquatic ecological development of the lake. Seine netting and gill netting captured numbers of both individual fish and fish species that were well in excess of previous surveys. Substantially larger-bodied fish and some fisheries species were caught including yellow-fin bream, striped mullet, sand mullet and silver biddies. The distribution patterns and occurrence of aquatic plants in the lake were similar to those recorded in 2002.

Increased biological diversity and abundance of the fish community show that the Riverside lake is continuing its development towards the ecological condition of the surrounding Myall River estuary and supports casual observations of recreational fishing in the lake. Habitat conditions, water quality and the food web are continuing to develop, supporting fish recruitment and productivity. Fish recruitment and growth in the lake are contributing to biological values in the estuary as a whole and this should increase as ecological processes mature further.

It is recommended that previous recommendations for enhancing the amount and quality of aquatic habitats remain relevant and should be pursued in the design of any extension of the existing lake system, particularly with respect to increasing the extent, complexity and quality of near-shore habitats for fish, invertebrates and birds.

This fish survey is attached in **Appendix H**.

1.7 THIS STUDY

As discussed above, a detailed assessment of existing and future catchment runoff and pollutant exports and water management options to maintain as far as possible the existing lake water quality and its current ancillary role as a fish habitat was reported in 2004 (Cardno, 2004).

Since September 2004 the development concept has evolved considerably including the removal of the nine hole golf course, an increase in the number of dwellings upon the site and wholesale changes to the site planning and layout in keeping with planning best practice.

Despite these substantial changes to the proposed layout over the period to date from September 2004, the principal conclusions of the comparative assessment presented in the Cardno, 2004 report remain valid today and support the adoption of either of the two highest ranked water management options (Scheme 3 or Scheme 5). Both these schemes were further developed (refer **Figures 5** and **6**). In the interests of completeness the Cardno, 2004 report is included in **Appendix F**. The assessments of hydrology, hydraulics, stormwater quality and lake water quality described in Appendices **B, C, D** and **E** follow the assessment approaches adopted in 2004. In relation to the stormwater quality assessment the previous **xpaqualm** modelling has been updated and undertaken using MUSIC.

The aims of the current study were to update the previous hydrological, hydraulic, groundwater and water quality assessments of the two highest ranked water management schemes (Scheme 3 and Scheme 5) to reflect the current concept development and to refine and develop each scheme and any other measures that may be required to mitigate the impacts of the planned development. This report has been specifically prepared to accompany a Part 3A Concept Plan and Project Application to be submitted to the NSW Department of Planning and to address the Director General Requirements for Environmental Assessment dated 6 March 2007 (Ref.: MP 06_0010, dated 29 December 2006).

2. FLOODING AND DRAINAGE

2.1 Hydrology

The aims of the hydrological analyses were to

- Assemble an **xprafts** rainfall/runoff model of the Riverside at Tea Gardens catchment;
- Estimate catchment runoff under existing catchment conditions as a benchmark for comparison with proposed development conditions for the 5 yr ARI, 20 yr ARI and 100 yr ARI event;
- Estimate catchment runoff under proposed development conditions; and
- If needed, size detention structure(s) to reduce the 100y ARI peak flow downstream of the proposed development areas to no greater than the 100 yr ARI peak flow under existing conditions.

Estimates of runoff from the Riverside at Tea Gardens catchment during design storms were obtained using the **xprafts** rainfall/runoff model.

The hydrological analyses of the Riverside at Tea Gardens catchment are described in **Appendix B**.

2.1.1 Existing Conditions

The catchment of Riverside at Tea Gardens is bounded to the north by the ridge line of the ridge outcrop, and to the south-west by Myall Road. Riverside at Teagardens represents a major portion of the catchment. With the exception of the portion at the south of the site that has already been developed, there is little natural development of surface drainage features and as the surface soils are generally sandy such that a high level of rainfall infiltration to the groundwater system takes place. As a result, significant surface runoff is unlikely except during periods of high rainfall.

The site contains several low natural sand ridges which tend to channel runoff in the western half of the site from north to south. However a number of shallow drains have been previously constructed to convey runoff from the western areas of the site to the east to join with runoff from the eastern area of the site that flows east towards the SEPP 14 wetlands and the Myall River.

During wet periods, water ponds in low lying areas in the western and northern areas of the site.

The Riverside at Tea Gardens catchment layout is presented in **Figure 7**

The estimated peak 100 yr ARI outflows from the Riverside at Tea Gardens site are summarised in **Table B.4**.

Table 1
Estimated Peak Flows (m^3/s) at Key Locations in Riverside at Tea Gardens under Existing Conditions

5 yr ARI	20 yr ARI	100 yr ARI	Comment
5.3 *(9)*	9.8 *(9)*	17.1 *(2)*	Total inflow to the existing detention lake
3.3 *(9)*	8.6 *(9)*	14.7 *(2)*	Outflow from the existing detention lake
6.9 *(9)*	8.7 *(9)*	10.9 *(9)*	Aggregated flow to the Conservation Zoned
0.58 *(9)*	0.88 *(9)*	1.25 *(9)*	Outflow to an existing drainage line that discharges directly into the Myall River

Note: The Critical Storm Burst Duration (hrs) is reported in brackets

2.1.2 Developed Conditions – Scheme 3

In concept it is proposed to direct runoff in events up to the 100 yr ARI event from the upper catchment areas east along the proposed open space corridor located on the northern boundary of the development and then south east to a swale located on the eastern boundary of the site. This swale is intended to distribute runoff along the western boundary of the buffer zone to reduce the concentration of runoff into the buffer zone and the SEPP14 wetland. With the exception of limited areas of planned development on the eastern boundary of the site that will drain to the buffer zone, the planned development located south of the open space corridor will drain southwards towards the proposed extended detention lake.

The developed catchment layout is presented in **Figure 8.**

The estimated peak 100 yr ARI outflows under developed conditions (without ancillary retarding basins) are summarised in **Table 2.**

2.1.3 Scheme 3 Developed Conditions with Basins

The impact of integrating a major retarding basin into the open space corridor was assessed as was the performance of a separate basin to reduce peak flows from the area of planned development that discharges directly to the Myall River (subcatchment N42). A concept retarding basin was also sized to manage runoff from an area of planned development that could discharge directly to the conservation zone (subcatchment N43).

Table 2
Estimated Peak Flows (m^3/s) at Key Locations in Riverside at Tea Gardens under Scheme 3 Developed Conditions

5 yr ARI	20 yr ARI	100 yr ARI	Comment
24.5 *(1.5)*	33.0 *(1.5)*	42.0 *(1.5)*	Total inflow to the extended detention lake
5.9 *(9)*	9.5 *(9)*	14.4 *(9)*	Outflow from the extended detention lake
9.1 *(1.5)*	13.2 *(1.5)*	18.1 *(1.5)*	Aggregated flow to the Conservation Zone
1.5 *(1.5)*	2.1 *(1.5)*	2.6 *(1.5)*	Outflow to an existing drainage line that discharges directly into the Myall River

Note: The Critical Storm Burst Duration (hrs) is reported in brackets

Basin Properties

Concept basin sizes and outlet configuration were sized iteratively. In the case of Basin EW the aim was to either:

(i) limit the 100 yr ARI peak discharge to the Conservation Zone under developed conditions to no greater than the existing peak 100 yr ARI discharge to the Conservation Zone, or to
(ii) limit basin outflows to around 6 m^3/s based on the feasibility of constructing a waterway through rising ground to the east of the concept basin wall.

It was found that the latter aim controlled the basin size.

In the case of Basins N42 and N43 the aim of the basins was to limit 100 yr ARI peak flows to no greater than the 100 yr ARI peak flow under existing conditions.

The adopted basin properties are detailed in **Appendix B.4.**

The estimated peak basin water levels for 20 yr ARI, 50 yr ARI and 100 yr ARI events are summarised in **Table 3**. The peak basin outflows and resulting peak discharges to the Conservation Zone under developed conditions are summarised in **Tables 4** and **5**.

Table 3
Estimated Peak Basin Water Depths

Basin	5 yr ARI	20 yr ARI	100 yr ARI
EW	0.97	1.22	1.58
N42	0.55	0.79	0.92
N43	0.53	0.78	0.87

Table 4
Estimated Peak Flows (m^3/s) at Key Locations in Riverside at Tea Gardens under Scheme 3 Developed Conditions with Basins EW and N42

5 yr ARI	20 yr ARI	100 yr ARI	Comment
24.5 *(1.5)*	33.0 *(1.5)*	42.0 *(1.5)*	Total inflow to the extended detention lake
5.9 *(9)*	9.5 *(9)*	14.4 *(9)*	Outflow from the extended detention lake
3.3 *(9)*	8.6 *(9)*	14.7 *(2)*	Existing outflow from the existing detention lake
9.1 *(1.5)*	13.2 *(1.5)*	18.1 *(1.5)*	Inflow to Basin EW
1.5 *(1.5)*	2.1 *(1.5)*	2.6 *(1.5)*	Outflow from Basin EW
5.5 *(9)*	7.1 *(9)*	9.0 *(2)*	Aggregated flow to the Conservation Zone with Basin EW
6.9 *(9)*	8.7*(9)*	10.9 *(9)*	Aggregated flow to the Conservation Zone under existing conditions
1.5 *(1.5)*	2.1 *(1.5)*	2.6 *(1.5)*	Inflow to Basin N42
0.55 *(9)*	0.83 *(9)*	1.25 *(9)*	Outflow from Basin N42
0.58 *(9)*	0.88 *(9)*	1.25 *(9)*	Existing outflow to an existing drainage line that discharges directly into the Myall River

Note: The Critical Storm Burst Duration (hrs) is reported in brackets

Table 5
Estimated Peak Flows (m^3/s) at Key Locations in Riverside at Tea Gardens under Scheme 3 Developed Conditions with Basin N43

5 yr ARI	20 yr ARI	100 yr ARI	Comment
1.4 *(1.5)*	1.9 *(1.5)*	2.4 *(1.5)*	Inflow to Basin EW
0.53 *(9)*	0.77 *(9)*	1.2 *(9)*	Outflow from Basin EW
0.51 *(9)*	0.77 *9)*	1.2 *(9)*	Peak runoff under existing conditions
5.4 *(9)*	6.8 *(9)*	8.8 *(2)*	Aggregated flow to the Conservation Zone with Basin EW
6.9 *(9)*	10.9 *(9)*	10.9 *(9)*	Aggregated flow to the Conservation Zone under existing conditions

Note: The Critical Storm Burst Duration (hrs) is reported in brackets

2.1.4 Scheme 5 Developed Conditions with Basins

The model of future developed Scheme 3 conditions with retarding basins was modified based on an amended detailed concept layout of planned future stages of the development under Scheme 5. Under the Scheme 5 concept it is also proposed to direct runoff in events up to the 100 yr ARI event from the upper catchment areas east along the proposed open space corridor located on the northern boundary to a major retarding basin with outflows from the basin discharging south east to a swale located on the eastern boundary of the site. This swale is intended to distribute runoff along the western boundary of the buffer zone to reduce the concentration of runoff into the buffer zone and the SEPP14 wetland. With the exception of limited areas of planned development on the eastern boundary of the site that will drain to the buffer zone, the planned development located south of the open space corridor will drain southwards towards the a series of ponds and freshwater lakes that will discharge into the proposed extended detention lake.

The 5 yr ARI, 20 yr ARI and 100 yr ARI hydrographs under Scheme 5 developed conditions were estimated and input into the hydraulic model of the Scheme 5 development to estimate peak outflows from the detention lake as well as the 5 yr ARI, 20 yr ARI and 100 yr ARI flood levels.

2.2 Hydraulics

The aims of the hydraulic analyses were to

- Assemble an **xpswmm** hydraulic model of the main drainage lines under proposed developed conditions with concept waterways and basins in place; and
- Estimate peak flows and peak flood levels under developed conditions for the 5 yr ARI, 20 yr ARI and 100 yr ARI events.

2.2.1 Concept Sizing of Waterways

Prior to assembling an hydraulic model of the main drainage lines, the concept grading and concept sizing of each of the main drainage lines was undertaken. Four main drainage lines were identified. The East Branch, West Branch, North Branch and EastWest Branch drainage lines are identified in **Figure C.1**.

Hydraulic assessments of the sensitivity of maximum channel depth, channel top width and maximum flow velocity were undertaken using spreadsheet models of a single trapezoidal channel.

The adopted properties of the single trapezoidal channel are given in **Figure C.2**.

The channel capacity and maximum flow velocity for each assumed overall channel top width. The assumed bed slopes for each reach were guided by the concept grading bed. The assumed Manning roughness value was an average of 0.065 across all sections ie. some sections of a channel may be lightly vegetated while other sections of the channel may be more heavily vegetated.

Waterways were assessed for the 100 yr ARI event with basins in place.

The concept waterway dimensions for the East Branch, West Branch, North Branch and EastWest Branch are given in **Tables D.1, D.2, D.3** and **D.4** respectively. The highlighted cells are the channel widths that were selected for inclusion in the **xpswmm** model. These tables disclose the "trade-off" between channel width v flow depth v velocity for other channel dimensions.

An **xpswmm** hydraulic model was assembled for Riverside at Tea Gardens under the proposed Developed Conditions. The model includes the four main drains and a concept retarding basin located on the EastWest Branch.

2.2.2 Flood Levels under Scheme 3 Developed Conditions

The layout of the **xpswmm** model of the Scheme 3 developed condition is shown in **Figure C.1**.

The **xpswmm** model was run to estimate the 5 yr ARI, 20 yr ARI and 100 yr ARI peak flows and basin water levels. Based on the outcomes of the hydrological analysis the **xpswmm** model was run for both the 1.5 hour and 9 hour storm durations.

The estimated peak outflows from the extended detention lake and the flood level in the 5 yr ARI, 20 yr ARI and 100 yr ARI events are summarised in **Table 6**. The estimated peak discharges to the Conservation Zone without and with the major basin on the EastWest Branch (Basin EW) in the 5 yr ARI, 20 yr ARI and 100 yr ARI events are summarised in **Table 7**. This table also summarise the estimated peak basin water levels.

Table 6
Estimated Peak Outflows (m^3/s) from the Extended Detention Lake under Scheme 3 Developed Conditions

5 yr ARI	20 yr ARI	100 yr ARI	Comment
4.23 *(0.867)*	7.12 *(0.960)*	11.8 *(1.028)*	Outflow from the extended detention lake

Note: The estimated peak basin water level (in m AHD) is reported in brackets

Table 7
Estimated Peak Outflows (m^3/s) from Basin EW under Developed Conditions

5 yr ARI	20 yr ARI	100 yr ARI	Comment
3.73 *(0.86)*	4.65 *(1.07)*	5.48 *(1.30)*	Outflow from Basin EW
6.07	8.16	11.77	Aggregated flow to the Conservation Zoned (without Basin EW)
4.59*)*	5.93	7.45	Aggregated flow to the Conservation Zone (with Basin EW)

Note: The estimated peak basin water level (in m) is reported in brackets

The estimated 100 yr ARI peak flows, flood levels and flood depths within the hydraulic study area for storm bursts of 1.5 hours and 9 hours are presented in **Figures 9** and **10** respectively.

2.2.3 Flood Levels under Scheme 5 Developed Conditions

The **xpswmm** hydraulic model that was assembled for Riverside at Tea Gardens under the proposed Scheme 3 Developed Conditions was modified based on an amended detailed concept layout of planned future stages of the development under Scheme 5.

The concept Scheme 5 layout of waterways, ponds and lakes is given in **Figure C.5.**

The Scheme 5 hydraulic model includes a number of small ponds, three large ponds, three freshwater lakes and a partial extension of the detention lake. It also includes the four main drains and a concept retarding basin located on the EastWest Branch. The active storage available above the extended detention lake, freshwater lakes and ponds was represented as flood storage at selected nodes.

The Scheme 5 **xpswmm** model was run to estimate the 5 yr ARI, 20 yr ARI and 100 yr ARI peak flows and basin water levels under the proposed Scheme 5 development. Based on the outcomes of the hydrological analysis the **xpswmm** model was run for both the 1.5 hour and 9 hour storm durations.

The estimated peak outflows from the extended detention lake in the 5 yr ARI, 20 yr ARI and 100 yr ARI events are summarised in **Table 8.**

Table 8
Estimated Peak Outflows from the Extended Detention Lake under Scheme 5 Developed Conditions

5 yr ARI	20 yr ARI	100 yr ARI	Comment
3.47 *(0.83)*	7.17 *(0.96)*	12.57 *(1.09)*	Outflow from the extended detention lake

Note: The estimated peak basin water level (in m AHD) is reported in brackets

The estimated 100 yr ARI peak flows, flood levels and flood depths within the hydraulic study area for storm bursts of 1.5 hours and 9 hours are presented in **Figures 11** and **12** respectively.

The estimated 5 yr ARI and 20 yr ARI flood levels under 1.5 hour and 9 hour storm bursts are presented spatially in **Figures C.7** to **C.10**.

2.3 Practical Consideration of Climate Change

The planned development is subject to flooding from both the Myall River and from runoff from the local catchment. Sensitivity assessments of climate change were undertaken for the scenarios given in the 2007 DECC Guideline titled "Practical Consideration of Climate Change". These scenarios include +0.18m, +0.55 m and +0.91 rises in sea level as well as 10%, 20% and 30% increase in rainfall intensities.

It was concluded from the results of the sensitivity runs for the Myall River that:

- The current adopted 100 yr ARI level of 2.1 m AHD could accommodate up to a 30% increase in rainfall under conditions where there is no increase in sea level;
- The increase in 100 yr ARI levels in the Myall River in the vicinity of Riverside due to increases in rainfall reduce as the sea level rise increases ie. a 30% increase in rainfall increases 100 yr ARI levels in the Myall River by

- 0.06 m to 0.07 m under a sea level rise of 0.18 m
  - 0.04 m to 0.06 m under a sea level rise of 0.55 m
  - 0.03 m to 0.04 m under a sea level rise of 0.91 m

- Under the +0.18 m sea level rise scenario the freeboard in Council's adopted minimum Flood Planning Level of 2.6 m AHD is around 0.43 to 0.25 m depending on the adopted increase in rainfall intensity;
- Under the +0.55 m sea level rise scenario the freeboard in Council's adopted minimum Flood Planning Level of 2.6 m AHD is only around 0.02 to 0.07 m depending on the adopted increase in rainfall intensity;
- Under the +0.91 m sea level rise scenario Council's Flood Planning Level of 2.6 m AHD is exceeded by 0.26 m to 0.3 m depending on the adopted increase in rainfall intensity; and
- It is noted that the Riverside proposal has an additional freeboard of 0.3 m over and above Council's adopted minimum floor level of 2.6 m AHD in areas subject to inundation from the Myall River to avoid over floor flooding in a 100 yr ARI event under all climate change scenarios.

It was concluded from the river flooding inundation plots that:

- River flooding under either a low or a medium climate change scenario would not inundate any unimproved lots;
- River flooding under a high climate change scenario would partially inundate around 180-220 unimproved lots (but not over floors) to a maximum depth of 0.3 m;
- Under a low climate change scenario there would be minimal inundation of planned roads;
- Under a medium climate change scenario there would be inundation of a number of planned roads by up to 0.5 m (which would be Low Hazard due to the expected very low velocity of the fringes of the river flooding through the development); and
- Under a high climate change scenario there would be increased inundation of a number of planned roads by up to 0.8 m (which would be still Low Hazard due to the expected very low velocity of flow on the fringes of the river flooding through the development) but would comply with the requirements for safe wading.

It was concluded from the results of the sensitivity runs for the local catchment that:

- In areas where the estimated 100 yr ARI flood level is greater than 2.1 m AHD the 1.5 hour storm burst gives higher local 100 yr ARI flood levels than the 9 hour storm burst;
- The East Branch and North Branch Flood Planning Levels are controlled by the Myall River under a +0.18 m or greater sea level rise;
- The Flood Planning Levels adjacent to the West Branch are controlled progressively by the Myall River as the sea level rise increases;

- The Flood Planning Levels adjacent to the lower reaches of the East West Branch are controlled progressively by the Myall River as the sea level rise increases; and
- The greatest increase in the 100 yr ARI flood level in the East West Branch in the reach unaffected by sea level rise is 0.28 m.

It is noted that an additional freeboard of 0.3 m for mimimum floor levels over and above Council's adopted minimum floor level of 2.6 m AHD has been adopted fro planned development in areas subject to inundation from the Myall River to avoid over floor flooding in a 100 yr ARI event under all climate change scenarios. The adoption of a minimum floor level of 2.9 m AHD for all homes in the planned development will provide all homes in the development with a far greater level of protection against climate change than a large number of existing properties in Tea Gardens.

Elsewhere in the planned development consideration a minimum floor level of 0.5 m above the local 100 yr ARI flood level (under no climate change) would provide a minimum 0.22 m freeboard above the local 100 yr ARI flood level under a high climate change scenario.

While under a high climate change scenario there would be increased inundation of a number of planned roads by up to 0.8 m (which would be still Low Hazard due to the expected very low velocity of flow on the fringes of the river flooding through the development) but would comply with the requirements for safe wading. Even under a high climate change scenario, planned roads would provide flood free egress via a number of roads for residents evacuating from threatened properties to higher ground on the northern and north western boundaries of the development.

It was also noted from the 1980 flood study that the estimated 100 yr ARI outflow from the Myall Lakes peaked after 7 days. Consequently it is expected that the flood warning system in place to warn existing residents of Tea Gardens of major flooding in the Myall River would provide ample warning time for residents of properties that would be threatened under a high climate change scenario to safely evacuate their properties well before the Myall River would reach its peak.

The climate change assessment is attached in **Appendix I**.

3. GROUNDWATER

The following assessment of groundwater issues is drawn directly from the groundwater assessment undertaken by Coffey Geotechnics in October 2007. A copy of this assessment is attached in **Appendix G**.

3.1 Topography and Geology

Within the study area the ground surface generally slopes gently south-east towards the Myall River with ground levels below 3 m AHD. A series of sand ridges trending roughly north-south are present across the site. An elevated bedrock outcrop, rising to about 25 m AHD, is present at the northern end of the site. Elevated bedrock levels are also present at the north-western limit of the site.

Soils in low lying areas are generally silty sand and topsoil overlying fine to medium grained sand containing cemented layers (coffee rock) and peaty bands. Basement rock occurs at a depth of 10 m to 20 m over much of the site, rising steeply at the northern end of the site forming an outcrop. A surface clay layer of 1m to 2.5 m thickness exists at the north-west of the site accompanied by an underlying layer of peat.

The sand aquifer is underlain by basement sandstone at a depth of up to approximately 20 m. Sand thickness varies from 0m in the elevated areas in the north of the site to about 20 m at the southern limit of the proposed development.

3.2 Groundwater Conditions

The subsurface sands form an aquifer characterised by moderate to high transmissivity, previously estimated at $200m^2$/day, which is present over much of the development site and over the SEPP 14 wetland area. Previous groundwater levels indicated shallow water tables are present over the site. generally within 1m of the surface and at the western limit of the SEPP 14 wetlands and Myall River, groundwater levels are within 0.5m of the ground surface. Groundwater flow is south-east toward the Myall River and groundwater is relatively fresh in the main body of the sand aquifer. There is a secure town water supply well to the north of the area and currently groundwater is not used except for minor home irrigation.

The shallow rock levels to the north of the site provide a barrier to groundwater inflow from that direction. The sand aquifer is expected to extend to the south and west of the site and be in hydraulic contact with the waters of the Myall River to the south, Wobbegong Bay and Pindimar Bay (Port Stephens) to the south-west and Kore Kore Creek to the west.

During periods of low rainfall, losses from the groundwater system will occur due to seepage to the Myall River and evapotranspiration from areas of shallow water table. Evapotranspiration losses from the water table reduce with increasing depth of the water table in a non-linear fashion (CPI, 1996).

Rainfall infiltration forms the main groundwater recharge mechanism. Previous monitoring results from the bores over the site show marked groundwater level response to rainfall events.

The aquifer is in contact with saline water in the Myall River and also in contact with the brackish water in the lake in the south of the site. This results in the development of an interface between high quality fresh groundwater and saline water. The depth of the fresh/salt water interface is a function of the density difference between fresh and salt water and the height of the groundwater surface.

The proposed development (Scheme 5) involves the extension of the existing lakes on the western side and a series of stepped freshwater lakes on the eastern side. Evaporation from these lake extensions would be greater than evapotranspiration losses from the water table over a similar area. These increased evaporative losses are expected to be balanced in part by the reduced evapotranspiration losses that would accompany covering part of the ground surface for residential development.

3.3 Existing Groundwater Levels

A network of twelve groundwater monitoring bores (Bore 1 to Bore 12) was installed by DJ Douglas & Partners in 1994 and four monitoring bores (Bore 21 to Bore 24) were installed by Coffey in 2006. Four of the bores (Bore 1, Bore 2, Bore 3 and Bore 7) have been destroyed or lost between the March 2007 and previous monitoring rounds in April and May 2004. The remaining available bores formed a network for Coffey's 2007 monitoring program.

One round of groundwater level monitoring was undertaken from the existing monitoring network using a dip meter. Table 1 in **Appendix G** presents a summary of groundwater monitoring data from the previous and recent monitoring rounds.

The depth to groundwater at the site has decreased since April 2004 at all locations with the exception of Bore 21. Groundwater level ranges from 0.5m to 1.7m below ground surface and tends to be shallower in the vicinity of the Myall River and the lake (Bores 4, 10, 21, 22, 23 and 24) and deeper further from the river (Bores 5, 8, 9, 11 and 12). The shallow groundwater conditions at the site will limit the capacity of the groundwater system to accept rainfall recharge.

Previous groundwater level data collected by automatic loggers indicates that the measured groundwater levels respond to rainfall events. Groundwater levels measured in March 2007 are typically 0.3 m lower than corresponding levels measured in April 2004. The largest reductions were recorded for Bore 11 (reduction of 0.87 m) and Bore 12 (reductions of 1.1 m). These monitoring bores are in elevated ground and are the two bores most distant from the existing lake of the bores for which comparisons could be made.

As groundwater levels respond to prevailing climatic conditions that a decrease in groundwater levels would be experienced during periods of lower than average rainfall. Lower than average rainfall has been experienced on the mid central coast of NSW in recent years. It is most likely that this is the cause of groundwater level decreases observed.

3.4 Acid Sulphate Soils

An assessment of potential acid sulfate soils was undertaken at the site (Coffey 2007d). The laboratory results indicated elevated levels of total potential sulfidic acidity and peroxide oxidisable sulfur were present in the samples tested. It was considered that the potential acid sulfate soils were likely to be present in the area.

Groundwater modelling indicates that the lake extension will cause groundwater level reductions by approximately up to 0.75 m. To date there is no indication of the potential for sulfate production in the area but a number of bores were drilled within close proximity of the lake extension. Several test holes were drilled and the soils tested for the potential to produce acid sulfate soils. BH37 is located in the area where the maximum drawdown has been predicted and the results of SPOCAS analysis indicate that from 2 m below surface, samples tested exceed the Acid Sulfate Soil Management Advisory Committee (ASSMAC) action criteria. The potential to produce acid soils increased with depth with the interval 2.0 – 2.5 m just exceeding the criteria.

Groundwater levels in this area are approximately 1.5 m below surface and a 0.75 m groundwater level decline will lower groundwater levels into this zone however, the area affected would be restricted to the 0.75 m drawdown contour indicated in Figure 14 of the geotechnical report attached in **Appendix G**.

A comparison of pH from previous investigations conducted in April 2004 with recent results collected in March 2007 indicates that there has been no discernable change in groundwater pH. This suggests that even with the groundwater level reductions assessed to be affected by lower than average rainfalls in the last few years, there has been no additional increase in acid production resulting from the drying of acid producing soils..

In view of the potential presence of acid sulphate soils, Coffey Geotechnics, 2007d has prepared a generic plan for management of ASS in future earthworks that occur within the Riverside Estate that include the laying of sewer and drainage lines and the excavation of stormwater treatment basins. A concise version of this plan will be provided as a reference to all lot purchasers and contractors required to work on any home within the site. This plan has been formatted in a way to assist individual land owners obtaining DA approvals by outlining methods to control and manage ASS during the development of each lot. The plan will also guide the management of any future excavation to extend the detention lake.

3.5 Groundwater Quality

Laboratory results from the groundwater bores selected for analysis indicate that groundwater quality has not changed significantly since the last monitoring round in 2004. The 2004 report indicated that groundwater chemistry had not changed significantly since the groundwater quality monitoring undertaken in 1994/1995.

The results are generally below the key criteria for protection of species in marine water (90% protection) presented in the ANZECC (2000) guidelines, with the exception of some metal concentrations.

Evidence of significant heavy metal contamination in the groundwater samples was not observed however the concentrations of zinc, chromium and copper slightly exceed the guidelines in some samples.

Groundwater from monitoring bores closer to the Myall River tend to be characterised by higher EC and a similar anion to cation ratio as seawater, suggesting the dilution of seawater is occurring as a result of rainfall recharge from the catchment.

Groundwater quality was compared to the Australian Drinking Water Guidelines (NHMRC, 2004) and is not potable due to concentrations of a range of analytes exceeding the drinking water guidelines. Groundwater in all bores and the surface water in the lake are acidic to slightly acidic and below the criteria for drinking water of pH 6.5. Groundwater near the Myall River (including Bores 21, 22, 24) has elevated levels of EC, anions and cations (due to the interaction of groundwater with seawater in this area) that do not meet the criteria for drinking water. Groundwater in Bores 9, 21, 22 and 24 are not potable due to the concentration of ammonia exceeding the ANZECC guidelines.

Groundwater away from the Myall River may be considered for irrigation purposes, however high concentrations of phosphorus have the potential to result in bioclogging of irrigation equipment (ANZECC 2000).

Groundwater quality is such that treatment would be required to allow potable use given the limited extent of the aquifer and the constraints on usage rates which would need to be imposed to avoid saltwater intrusion and the impacts on wetland areas. Consequently, Coffey consider the groundwater resource unsuitable for development as a significant potable supply.

3.6 Potential Impacts of Development on Groundwater Levels

The results from the current monitoring round indicate groundwater levels have decreased across the majority of the site since 2004, when development at the site commenced. The decrease in groundwater levels has been in the order of 0.1mAHD to 0.2mAHD in the majority of wells and a maximum of 0.47mAHD. Groundwater levels respond to prevailing climatic conditions and the decrease in groundwater levels experienced are likely to be the result of lower than average rainfall which has occurred on the mid central coast of NSW in recent years.

Groundwater modelling indicates that groundwater level contours are altered in the vicinity of the lake extension with the greatest impact at the north-western most point of the proposed lake extension. This will induce groundwater flow towards the lake within the vicinity of the lake which will act to prevent the intrusion of saline water into the aquifer from Myall River and brackish water from the lake.

The enclosed nature of the groundwater system within the localised Riverside area limits the potential impacts on other groundwater users further afield.

It is considered the proposed development is unlikely to affect the groundwater in the vicinity of the SEPP 14 wetland vegetation.

3.7 Potential for Groundwater Contamination resulting from the Development

Potential Impact on Adjacent Ecosystems

Groundwater quality results are generally below the key criteria for protection of species in marine water (90% protection) presented in the ANZECC (2000) guidelines, with the exception of some metal concentrations. Groundwater quality modelling indicates that the salt water interface would not be significantly affected by the development and groundwater level modelling indicates that there will be little impact within the wetland area. Groundwater level changes resulting from the proposed development are assessed to be below 0.25 m beyond 300 m from the development and 0.1 m within the wetland area. Changes of this magnitude would be within the existing groundwater level variability and are therefore considered unlikely to adversely affect adjacent ecosystems.

Impact on Potential Future Use of Groundwater as a Potable water Source

Groundwater quality is not considered to be potable due to concentrations of a range of analytes exceeding the drinking water guidelines (ANZECC 2000). Groundwater in all bores and the surface water in the lake are acidic to slightly acidic and below the criteria for drinking water of pH 6.5. Groundwater near the Myall River (including Bores 21, 22, 24) has elevated levels of EC, anions and cations (due to the interaction of groundwater with seawater in this area) above the criteria for drinking water. Groundwater in Bores 9, 21, 22 and 24 are not potable due to the concentration of ammonia exceeding the ANZECC (2000) guidelines.

The groundwater results indicate that it is generally select parameters, namely pH, ammonia and salinity (or TDS) that are limiting the potential use of the groundwater rather than a wide range of parameters. Consequently, some treatment of groundwater with respect to these parameters is likely to increase the potential uses of the groundwater across the Site. It is also noted that groundwater away from the Myall River tends to have greater potential usability, primarily due to lower salinity (or TDS) and lower concentrations of sodium and chloride.

Groundwater quality is such that treatment would be required to allow potable use given the limited extent of the aquifer and the constraints on usage rates which would need to be imposed to avoid saltwater intrusion and the impacts on wetland areas. Consequently, Coffey consider the groundwater resource unsuitable for development as a significant potable supply.

Re-use of reclaimed water

A laboratory developed a water sample with similar concentrations of nitrate, phosphorus and pH to th reclaimed water data supplied by Mid Coast Water. This water was used as a leaching agent for three soil samples collected from the site.

The concentration of nitrate in the leachate water was similar or greater than the concentration of nitrate in the lab-produced reclaimed water. This indicates that the potential for nitrate adsorption on the soil is low and the travel time of nitrate through the soil is likely to be similar to the rate of water through the soil.

The concentration of phosphorus in the leachate water was consistently significantly below the concentration of phosphorus in the lab-produced reclaimed water. These results indicate the soil at the site has the capacity to adsorb the phosphorus present in the reclaimed water and that the travel time of phosphorus through the soil is very slow.

These initial results show that with respect to phosphorus, the reclaimed water may be used for irrigation purposes. However, Coffey recommend further testing when a sample of reclaimed water from Mid-Coast Water is available. The following provides groundwater quality and indicative concentration parameters for key chemical constituents.

Parameter	Average Concentration in Groundwater (mg/L)	ANZECC Guidelines (mg/L)	Indicative Concentration of STP Effluent (mg/L)
NO_3	0.02	0.7	5
NH_4	0.53	1200	1
P	0.79	0.05	2.2

The groundwater results from the current monitoring round suggest that the reclaimed water may be suitable for irrigation of open spaces and gardens within the development area subject to a small reduction in total nitrogen concentrations. This reduction may be achieved through a combination of treatment and dilution of the reclaimed water with water of higher quality.

Based on the signature of key chemical constituents present above, three re-use options are presented as possible scenarios for the use of reclaimed water for the purposes of irrigation:

1. Treatment of the reclaimed water to meet health standards including pathogens. The reclaimed water may be used for irrigation if 10% of the reclaimed water is mixed with 90% of fresh water.
2. Treatment of the reclaimed water to limit NO_3 to an average concentration of 0.7 mg/L. If this level of treatment is obtained on an average basis, 100% of the reclaimed water may be used for irrigation purposes, assuming partial uptake of nutrients by vegetation.
3. Treatment of the reclaimed water to limit NO_3 to an average concentration of 1.4 mg/L. If this level of treatment is obtained on an average basis, a mixture of 50% of reclaimed water and 50% of fresh water may be used for irrigation.

Calculations of the average time required for the groundwater to migrate from the development area to the lake or river indicated that the groundwater moves at a rate of approximately 10 m/year. This is based on an assumed hydraulic conductivity of 8 m/day, a porosity of 35 % and a groundwater gradient of 0.12 %. The leaching tests indicate that nitrate will move at a similar rate to the groundwater and that phosphorus will move at a significantly slower rate.

Given this low rate of groundwater movement, Coffey consider that the irrigation impacts can be considered on a time averaged basis. With respect to use of reclaimed water for irrigation purposes, it is considered that irrigation of parks and open spaces within the development is unlikely to adversely impact groundwater or the water in the lake if one of the above treatment options is employed. It is concluded that appropriate monitoring of irrigated areas should however be employed to ensure key indicators remain within relevant guidelines.

4. WATER QUALITY

4.1 Existing Lake Water Quality

A water quality monitoring programme for the existing detention lake was established in 1996 firstly by the developer, and more recently taken over by the Myall Quays Community Association. Hunter Water Laboratories collects and analyses samples at 5 lake locations approximately every 3 months. Sampling locations are shown on **Figure A.1**.

Initial testing involved the following parameters:

- pH
- Salinity
- Turbidity
- Suspended solids
- Kjeldahl nitrogen
- Oxidised nitrogen
- Ammonia#
- Nitrates#
- Nitrites#
- Phosphate
- Chlorophyll#
- Dissolved oxygen
- Faecal coliforms

(# denotes testing commenced in November 1997)

The results are reported in Hunter Water Laboratories, 2002 and summarised together with subsequent sampling results for Sites 1 to 5 in **Tables A.5** to **A.9.**

4.1.1 Salinity

The sampling indicates that the lake water is brackish having a 50th percentile value of salinity of 12.9 g/L, which is approximately one third of the salinity of seawater. There is variability in the salinity concentration due to both catchment (freshwater) runoff as well as the influence of tides and varying salinity in the Myall River. The observed salinity varied from 4.4 g/L to 25.9 g/L (between the 10th percentile and 90th percentile values).

4.1.2 Dissolved Oxygen

The 50th percentile of all Dissolved Oxygen (DO) values (120 readings) in the lake for the sampling period is 6.7 mg/L, with a 10th percentile level of 4.9 mg/L. The 4.9 mg/L level is just below the recommended ANZECC trigger value of 5.0 mg/L for freshwater fish. A comparison of the DO levels measured within the existing lake and the Myall River disclosed that the ANZECC guidelines for DO are not currently met at all times, in either the lake or river (at Copeland Ave Wharf). As indicated in **Figure 13**, DO levels in the existing lake are often better than in the Myall River.

4.1.3 Suspended Solids

The sampling indicates that the 50th percentile value of suspended solids for the lake is 24.5 mg/L. In comparison the 50th percentile value of suspended solids for the Myall River (at Site 5) was 44 mg/L. As indicated in **Figure 14**, the TSS levels in the existing lake are often better than in the Myall River.

4.1.4 Nutrients

The adopted ANZECC, 2000 trigger value for Phosphorus (TP) is 0.03 mg/L for estuarine systems. Most of the samples have been below the recommended value with a 50th percentile (120 readings) of 0.005 mg/L. Higher P levels occurred soon after the lake was constructed, possibly due residual P released from exposed soil. The TP levels in the existing lake are compared with the TP levels in the Myall River in **Figure 15**

The ANZECC, 2000 trigger value for Nitrogen (TN) is 0.3 mg/L, NO_x is 0.015 mg/L and Ammonia is 0.015 mg/L for estuarine systems. TN values could not be calculated from the available data. The 50th percentile of all NO_x values (44 readings) in the lake for the sampling period was 0.0105 mg/L. The 50th percentile of all Ammonia values (104 readings) in the lake for the sampling period is 0.03 mg/L. The Ammonia levels in the existing lake are compared with the Ammonia levels in the Myall River in **Figure 16**

The nutrient levels measured in the lake have generally been low, contributing to the overall good water quality in the existing lake. The nutrient levels in the existing lake are often better than in the Myall River.

4.2 Water Quality Objectives

4.2.1 Water Quality Objective identified in the Environmental Assessment Requirements

The Director-General's Environmental Assessment Requirements for water cycle and aquaculture management are in part as follows:

> "Address potential impacts on the water quality of surface and groundwater having regard to the relevant State Groundwater, River, Wetlands and Estuary Policies. Consideration must be made for water impacts to the Myall River and identified SEPP 14 Wetlands.
>
> …. Stormwater management should be designed to ensure ongoing protection of the groundwater aquifer in accordance with the principles of ANZECC & ARMCANZ: Guidelines for Groundwater Protection in Australia, National Water Quality Management Strategy, Commonwealth of Australia, 1995."

4.2.2 Water Quality Objective for DCP No. 22

As identified in Myall Quays Estate DCP No. 22, Section 2.4.1 the stated objective was that:

> "the standard of water from the site to the Myall River is to meet primary contact recreation requirements".

In Section 2.4.1, subparagraph (iii) it is further stated that the performance criteria for the water quality treatment system are specified in the Australian Water Quality Guidelines for Fresh and Marine Waters (ANZECC, 1992).

The ANZECC, 1992 water quality guidelines for primary contact recreational waters are summarised in **Table 9**.

Table 9
ANZECC Guidelines for Primary Contact Recreational Waters

Parameter	Guideline
Microbiological	The median bacterial content in samples of water should not exceed: • 150 faecal coliform organisms per 100ml (minimum of 5 samples taken at regular intervals not exceeding one month, with 4 out of 5 samples containing less than 600 organisms per 100ml); • 35 enterococci organisms per 100ml (maximum number in any one sample = 60-100 organisms per 100ml) Pathogenic free-living protozoans should be absent (to be sampled only when water temperature is greater than 24˚C.
Nuisance organisms	Macrophytes, phytoplankton scums, filamentous algal mats, sewage fungus, leeches, etc. should not be present in excessive amounts. Large numbers of midges & aquatic worms should be avoided.
Visual clarity & colour	To protect the aesthetic quality of a water body: • the natural visual clarity should not be reduced by more than 20%; • the natural hue of the water should not be changed by more than 10 points on the Munsell Scale; • the natural reflectance of the water should not be changed by more than 50%.
pH	The pH of the water should be within the range 5.0-9.0, assuming that the buffering capacity of the water is low.
Temperature	For prolonged exposure, temperature should be in the range 15-35˚C.

Toxic chemicals	Water containing chemicals that are either toxic or irritating to the skin or mucous membranes are unsuitable for recreation. Toxic substances should not exceed levels given for untreated drinking water.
Surface films	Oil and petrochemicals should not be noticeable as a visible film on the water nor should they be detectable by odour.

As discussed by HWR, 2001 these guidelines relate to water bodies used for primary recreational purposes rather than water flowing into such water bodies. For example, the guidelines for visual clarity and colour are only relevant to the Myall River itself and are difficult to interpret for water flowing into the Myall River.

As discussed by HWR, 2001 algal mats, phytoplankton blooms, midge outbreaks, etc. occur in eutrophic or high nutrient waters. Accordingly, it is desirable to adopt an objective for nutrient status of the discharge water at a level that would not encourage algal blooms, etc.

4.2.1 Lake Water Quality Objectives

The existing lake meets multiple objectives for flood detention, water quality, aquatic habitat and amenity.

In 1998 Australian Museum Business Services (AMBS) undertook a baseline survey of the lake (AMBS, 1998) (refer **Appendix H**). In September 2002, AMBS carried out a further ecological survey of the existing lake to assess the aquatic habitats present and determine changes to the assemblages since the baseline survey in 1998. An evaluation of the health of the lake was carried out by comparing historical water quality parameters with those recommended in the ANZECC Guidelines with relevance to the seagrass, macroalgae, fish and macroinvertebrates present. It was concluded by AMBS that the variable salinity regime is more favourable to those species that are able to withstand fluctuations in salinity levels.

During this study seven species of fish were collected. The lake was found to be supporting a number of resident fishes that are probably present year round and breed within the lake. These fishes include the flathead gudgeon, dwarf flathead gudgeon, blue-spot goby and southern blue-eye.

Harris Research, 2007 reports that seine netting and gill netting undertaken in April 2007 captured numbers of both individual fish and fish species that were well in excess of previous surveys. Substantially larger-bodied fish and some fisheries species were caught including yellow-fin bream, striped mullet, sand mullet and silver biddies. The distribution patterns and occurrence of aquatic plants in the lake were similar to those recorded in 2002.

Increased biological diversity and abundance of the fish community show that the Riverside lake is continuing its development towards the ecological condition of the surrounding Myall River estuary and supports casual observations of recreational fishing in the lake. Habitat conditions, water quality and the food web are continuing to develop, supporting fish recruitment and productivity. Fish recruitment and growth in the lake are contributing to biological values in the estuary as a whole and this should increase as ecological processes mature further.

Consultation that has occurred at several stages during the planning process has highlighted also the value that the community places on the existing lake and the aquatic habitat and species it supports.

The proposed water quality objective for the development is to maintain as far as possible in an extended detention lake the water quality regime that exists within the existing lake. The measures of water quality that have been adopted include salinity, DO, TN, TP and algal concentrations (chlorophyll 'a').

As is demonstrated in **Figures 13** to **16** the water quality in the existing lake is often better than the water quality in the Myall River. It is concluded that the achievement of the adopted lake water quality objective will therefore protect the Myall River.

4.2.1 Treatment Objectives for Stormwater Discharges

The adopted treatment objectives for runoff from development that flows directly into the Myall River or into the Conservation Zone are the stormwater treatment objectives established by the NSW EPA in the 1997 Draft Managing Urban Stormwater: Council Handbook. These objectives include:

- 85% retention of the average annual load of TSS
- 45% retention of the average annual load of TN
- 45% retention of the average annual load of TP

4.3 Catchment Water Quality

The aims of the catchment based water quality modelling were to

- Create MUSIC models of the Pre-existing and Existing conditions based on the approaches adopted in 2004 catchment based water quality (**xpaqualm**) assessments;
- "Calibrate" the MUSIC model parameters against the unit area results previously calculated using the **xpaqualm** model(s);
- Estimate catchment exports under the Pre-existing and Existing conditions for input into models of the Pre-existing detention lake and Existing detention lake;
- Create MUSIC models of the proposed concept development with and without rainwater tanks and run the generate for inputs into the Scheme 3 Pond model; and
- If needed, size ancillary pond(s) and/or wetland(s) to achieve the receiving water quality objectives for the receiving waters.

4.3.1 Catchment Water Quality Models

MUSIC water quality models were assembled for the Existing and Scheme 3 and Scheme 5 Developed Conditions.

The approach to MUSIC modelling is described in **Appendix D**.

The various assumptions and model parameters that were adopted for the water quality modelling are also outlined in **Appendix D**. Model parameters for MUSIC were "calibrated" to match as far as possible to match the runoff and pollutant export rates previously estimated using **xpaqualm** in 2004. The MUSIC parameters adopted by Patterson Britton and Partners in 2006 for the adjacent Myall River Downs development were also considered.

The adopted period of modelling was 1/01/1982 – 31/05/2004 in which 22 calendar years (1/01/1982 – 31/12/2003) were selected for generating statistics.

4.3.2 Pre-Existing and Existing Conditions

The Pre-existing Condition was defined as the conditions that existing in the early 1990s with a lake area of around 5 ha, subcatchments R1 & R2 were fully developed and there were a limited number of dwellings in subcatchments L1L, L2R, WQB1 and Nat3 (refer **Figure D.1** for location).

The Existing Condition was defined as the conditions at around 2004 with the lake area extended to 6 ha, and more dwellings constructed in subcatchments L1L, L2R, WQB1, and Nat3.

The layout of the model of Pre-existing and Existing Conditions is shown in **Figure D.3**.

The estimated average annual runoff and TSS, TN and TP exports to the Myall River, Conservation Zone and SEPP14 wetlands are summarised in **Table 10**.

The average annual runoff and TSS, TN and TP exports that would be estimated if the existing diversion drains were not in place were also estimated and are summarised in **Table 10**.

4.3.3 Developed Conditions

A number of MUSIC models of Developed Conditions were created based on Scheme 3 and Scheme 5 from the 2004 assessment and concept development plans. These models were of the following scenarios:

(i) Developed with the Scheme 3 extended detention lake only;
(ii) Developed with the Scheme 3 extended detention lake plus rainwater tanks;

Table 10
Estimated Runoff and Pollutant Exports under Existing Conditions

ID	Area (ha)	Rainfall (ML/yr)	Runoff and Pollutant Loads				Remark
			Runoff (ML/yr)	TSS (kg/yr)	TP (kg/yr)	TN (kg/yr)	
Existing Catchment + Drains + Existing Lake (Current Conditions)							
N42	15.8	220	28	4330	9	68	Discharges direct to Myall River
N43	13.5	189	20	2810	6	47	Discharge to Conservation Zone
Myall-2	206.0	2882	684	116000	234	1710	Discharge to Conservation Zone
	219.5	3071	704	118810	240	1757	Total Discharge to Conservation Zone
Lake Inflow	74.4	1040	318	28700	55	459	
Lake Outflow			229	4190	22	263	
				85%	*59%*	*43%*	*Reduction*
			933	123000	262	2020	Discharge to Wetland Zone
Existing Catchment + No Drains + Existing Lake (Theoretical Condition)							
N42	15.8	220	28	4330	9	68	Discharges direct to Myall River
N43	13.5	189	20	2810	6	47	Discharges to Conservation Zone
Myall-2	70.7	988	128	20600	41	322	Discharges to Conservation Zone
	84.1	1177	148	23410	47	369	Total Discharge to Conservation Zone
Lake Inflow	209.7	2934	874	124000	247	1850	
Lake Outflow			785	21190	92	1131	
				83%	*63%*	*39%*	*Reduction*
			933	44600	139	1500	Discharge to Wetland Zone

Subcatchment N42 discharges direct to the Myall River
Total Discharge to Conservation Zone = Myall-2 + N43
Discharge to Wetland Zone = Lake Outflow + Myall-2 + N43

(iii) Scenario (ii) plus a series of proposed major ponds and wetlands to treat runoff from residential development discharging to the Myall River (subcatchment N42) or to the Conservation Zone (subcatchment N43) plus a 770m swale along the eastern edge of the development (to distribute flow to the Conservation Zone) – the wetlands were sized to achieve target reductions of 80%, 45% and 45% in the average annual export of TSS, TP and TN respectively);

(iv) Scenario (iii) but with rainwater tanks removed

(v) Scenario (iii) but reconfigured to include four small ponds, three large ponds, three freshwater lakes and an extension of detention lake in accordance with Scheme 5; and

(vi) Scenario (v) but with rainwater tanks removed.

The layouts of the developed conditions model with and without rainwater tanks are shown in **Figure D.4, D.5** and **D.6** (Scenarios (iii), (iv) and (v)) respectively.

Scheme 3

The estimated average annual runoff and TSS, TN and TP exports to the Myall River, Conservation Zone and SEPP14 wetlands under the four Scheme 3 scenarios are summarised in **Table 11**. The adopted properties of the lake, ponds, wetlands and swale and rainwater tanks are summarised in **Tables D.11** and **D.12** respectively.

In the case of ponds and the swale the size of ponds and swale remained unchanged for scenarios with or without rainwater tanks. In the case of wetlands these were re-sized if possible to account for differences in runoff from developed areas with or without rainwater tanks eg. Wetland N42 (with rainwater tanks in place) and Wetland N42 nrwt (no rainwater tanks) (refer **Table D.11**). Under Scenario (iv) it was necessary to include a bio-filter upstream of Wetland N44 to meet the treatment objectives.

It was concluded from the results that under Scheme 3 Developed Conditions:

(i) The extended detention lake in combination with rainwater tanks, ponds, wetlands and a swale:
- Delivers greater than 80%, 45% and 45% reductions in the average annual export of TSS, TP and TN respectively from the proposed development;
- Reduces the export of TSS, TP and TN under Developed Conditions to the wetland zone by 80%, 39% and 5% less than the TSS, TP and TN exports under Existing Conditions;

(ii) The extended detention lake in combination with, ponds, wetlands and a swale but without rainwater tanks:
- Delivers greater than 80% and 45% reductions in TSS and TP respectively and close to a 45% TN reduction from the proposed development;
- Reduces the export of TSS and TP under Developed Conditions to the wetland zone by 78%, 33% than the TSS and TP exports under Existing Conditions;
- Slightly increases the export of TN under Developed Conditions to the wetland zone by 3% than the TN export under Existing Conditions;

(iii) Additional ponds/wetlands beyond those already proposed may not be needed if rainwater tanks are deleted in preference to a reclaimed water supply.

Scheme 5

The estimated average annual runoff and TSS, TN and TP exports to the Myall River, Conservation Zone and SEPP14 wetlands under the two Scheme 5 scenarios are summarised in **Table 12**. The adopted properties of the lakes, ponds, wetlands and swale are summarised in **Tables D.14.** The rainwater tank properties are as given in **Table D.15** respectively.

In the case of ponds and the swale the size of ponds and swale remained unchanged for scenarios with or without rainwater tanks.

It was concluded from the results that under Scheme 5 Developed Conditions:

(i) The partially extended detention lake in combination with freshwater lakes, rainwater tanks, ponds, wetlands and a swale:
- Delivers greater than 80%, 45% and 45% reductions in the average annual export of TSS, TP and TN respectively from the proposed development;
- Reduces the export of TSS, TP and TN under Developed Conditions to the wetland zone by 80%, 41% and 8% less than the TSS, TP and TN exports under Existing Conditions;

(ii) The extended detention lake in combination with freshwater lakes, ponds, wetlands and a swale but without rainwater tanks:
- Delivers greater than 80%, 45% and 45% reductions in the average annual export of TSS, TP and TN respectively from the proposed development;
- Reduces the export of TSS and TP under Developed Conditions to the wetland zone by 78%, 33% than the TSS and TP exports under Existing Conditions;
- Slightly increases the export of TN under Developed Conditions to the wetland zone by 3% than the TN export under Existing Conditions;

(iii) Additional ponds/wetlands beyond those already proposed may not be needed if rainwater tanks are deleted in preference to a reclaimed water supply.

Table 11
Estimated Runoff and Pollutant Exports under Scheme 3 Developed Conditions

ID	Area (ha)	Rainfall (ML/yr)	Runoff and Pollutant Loads				Remark
			Runoff (ML/yr)	TSS (kg/yr)	TP (kg/yr)	TN (kg/yr)	
Developed + No RWT + Extended Lake							
N42	15.8	220	78	9180	20	157	Discharges direct to Myall River
N43	14.8	207	68	7370	16	132	Discharges to Conservation Zone
Myall-2	87.9	1230	418	65430	134	988	Discharges to Conservation Zone
	102.7	1437	486	72800	150	1120	Total Discharge to Conservation Zone
				39%	*37%*	*36%*	*Reduction to Current Conditions*
Lake Inflow	187.2	2619	1320	129000	277	2170	Southern lake inflow
Lake Outflow			1154	20800	116	1370	
				84%	*58%*	*37%*	*Reduction to Developed Conditions*
			1640	93600	266	2490	Discharge to Wetland Zone
			N	Y	N	N	Less than Current Conditions?
Developed + RWTs + Extended Lake							
N42	15.8	220	68	8610	18	142	Discharges direct to Myall River
N43	14.8	207	59	6840	14	117	Discharges to Conservation Zone
Myall-2	87.9	1230	409	4760	55	711	Discharges to Conservation Zone
	102.7	1437	468	11600	69	828	Total Discharge to Conservation Zone
				90%	*71%*	*53%*	*Reduction to Current Conditions*
Lake Inflow	187.2	2619	1190	121000	249	1960	Southern lake inflow
Lake Outflow			1022	17800	102	1222	
				86%	*63%*	*44%*	*Reduction to Developed Conditions*
			1490	29400	171	2050	Discharge to Wetland Zone
			N	Y	Y	N	Less than Current Conditions?

Developed + RWTs + Extended Lake + Ponds + Swale							
N42	15.8	220	63	1160	5	86	Downstream of constructed wetland
N43	14.8	207	59	6840	14	117	Discharges to Conservation Zone
Myall-2	87.9	1230	406	3660	53	700	Discharges to Conservation Zone
	102.7	1437	465	10500	67	817	Total Discharge to Conservation Zone
				91%	*72%*	*54%*	*Reduction to Current Conditions*
Lake Inflow	187.2	2619	1140	50600	144	1520	Southern lake inflow
Lake Outflow			975	14400	93	1103	
				89%	*66%*	*49%*	*Reduction to Developed Conditions*
			1440	24900	160	1920	Discharge to Wetland Zone
			N	Y	Y	Y	Less than Current Conditions?
Developed + No RWTs + Extended Lake + Ponds + Swale							
N42	15.8	220	68	994	5.3	87	Downstream of constructed wetland
				89%	*74%*	*45%*	*Reduction to Developed Conditions*
N43	14.8	207	68	7370	16	132	Discharges to Conservation Zone
Myall-2	87.9	1230	416	3430	53	713	Discharges to Conservation Zone
	102.7	1437	484	10800	69	845	Total Discharge to Conservation Zone
				91%	*71%*	*52%*	*Reduction to Current Conditions*
Lake Inflow	187.2	2619	1260	54000	161	1700	Southern lake inflow
Lake Outflow			1096	16100	106	1245	
				88%	*62%*	*43%*	*Reduction to Developed Conditions*
			1580	26900	175	2090	Discharge to Wetland Zone
			N	Y	Y	N	Less than Current Conditions?

Subcatchment N42 discharges direct to the Myall River
Total Discharge to Conservation Zone = Myall-2 + N43
Discharge to Wetland Zone = Lake Outflow + Myall-2 + N43

Table 12
Estimated Runoff and Pollutant Exports under Scheme 5 Developed Conditions

ID	Area (ha)	Rainfall (ML/yr)	Flow and Pollutant Loads				Remark
			Runoff (ML/yr)	TSS (kg/yr)	TP (kg/yr)	TN (kg/yr)	
Existing Catchment + Drains + Existing Lake (Current Conditions)							
N42	15.8	220	28	4330	9	68	Discharges direct to Myall River
N43	13.5	189	20	2810	6	47	Discharge to Conservation Zone
Myall-2	206.0	2882	684	116000	234	1710	Discharge to Conservation Zone
	219.5	3071	704	118810	240	1757	Total Discharge to Conservation Zone
	74.4	1040	318	28700	55	459	Existing Lake Inflow
			229	4190	22	263	Existing Lake Outflow
				85%	*59%*	*43%*	*Reduction*
			933	123000	262	2020	Discharge to Wetland Zone
Existing Catchment + No Drains + Existing Lake (Theoretical Condition)							
N42	15.8	220	28	4330	9	68	Discharges direct to Myall River
N43	13.5	189	20	2810	6	47	Discharges to Conservation Zone
Myall-2	70.7	988	128	20600	41	322	Discharges to Conservation Zone
	84.1	1177	148	23410	47	369	Total Discharge to Conservation Zone
	209.7	2934	874	124000	247	1850	Existing Lake Inflow
			785	21190	92	1131	Existing Lake Outflow
				83%	*63%*	*39%*	*Reduction*
			933	44600	139	1500	Discharge to Wetland Zone
Developed + No RWT + Fresh Lakes + Extended Lake							
N42	15.8	220	78	9180	20	157	Discharges direct to Myall River
N43	14.8	207	68	7370	16	132	Discharges to Conservation Zone
Myall-2	87.9	1230	418	65430	134	988	Discharges to Conservation Zone
	102.7	1437	486	72800	150	1120	Total Discharge to Conservation Zone
				39%	*37%*	*36%*	*Reduction to Current Conditions*

			813	86400	185	1410	Fresh Lake Inflow
			724	13400	74	904	Fresh Lake Outflow
			502	41900	90	727	Local Inflows
			1226	55300	164	1631	Saline Lake Inflow
			1120	17200	107	1280	Saline Lake Outflow
				87%	*61%*	*40%*	*Reduction to Developed Conditions*
			1606	90000	257	2400	Discharge to Wetland Zone
			N	Y	Y	N	Less than Current Conditions?
Developed + RWTs + Fresh Lakes + Extended Lake							
N42	15.8	220	68	8610	18	142	Discharges direct to Myall River
N43	14.8	207	59	6840	14	117	Discharges to Conservation Zone
Myall-2	87.9	1230	409	4760	55	711	Discharges to Conservation Zone
	102.7	1437	468	11600	69	828	Total Discharge to Conservation Zone
				90%	*71%*	*53%*	*Reduction to Current Conditions*
			729	81700	167	1280	Fresh Lake Inflow
			641	12300	66	803	Fresh Lake Outflow
			462	39700	81	662	Local Inflows
			1103	52000	147	1465	Saline Lake Inflow
			995	15500	96	1140	Saline Lake Outflow
				88%	*65%*	*47%*	*Reduction to Developed Conditions*
			1463	27100	165	1968	Discharge to Wetland Zone
			N	Y	Y	Y	Less than Current Conditions?
Developed + RWTs + Fresh Lakes + Extended Lake + Ponds + Swale							
N42	15.8	220	63	1160	5	86	Downstream of constructed wetland
N43	14.8	207	59	6840	14	117	Discharges to Conservation Zone
Myall-2	87.9	1230	406	3660	53	700	Discharges to Conservation Zone
	102.7	1437	465	10500	67	817	Total Discharge to Conservation Zone
				91%	*72%*	*54%*	*Reduction to Current Conditions*
			675	22500	77	845	Fresh Lake Inflow
			587	8470	56	663	Fresh Lake Outflow
			457	29600	67	609	Local Inflows
			1044	38070	122	1272	Saline Lake Inflow
			936	13700	88	1030	Saline Lake Outflow
				89%	*68%*	*52%*	*Reduction to Developed Conditions*

			1401	24200	155	1847	Discharge to Wetland Zone
			N	Y	Y	Y	Less than Current Conditions?
Developed + No RWTs + Fresh Lakes + Extended Lake + Ponds + Swale							
N42	15.8	220	68	994	5.3	87	Downstream of constructed wetland
				89%	*74%*	*45%*	*Reduction to Developed Conditions*
N43	14.8	207	68	7370	16	132	Discharges to Conservation Zone
Myall-2	87.9	1230	416	3430	53	713	Discharges to Conservation Zone
	102.7	1437	484	10800	69	845	Total Discharge to Conservation Zone
				91%	*71%*	*52%*	*Reduction to Current Conditions*
			758	24500	87	955	Fresh Lake Inflow
			670	9520	63	755	Fresh Lake Outflow
			497	30900	73	668	Local Inflows
			1167	40420	136	1423	Saline Lake Inflow
			1060	15300	100	1160	Saline Lake Outflow
				88%	*64%*	*46%*	*Reduction to Developed Conditions*
			1580	26900	175	2090	Discharge to Wetland Zone
			N	Y	Y	N	Less than Current Conditions?

Subcatchment N42 discharges direct to the Myall River

Total Discharge to Conservation Zone = Myall-2 + N43

Discharge to Wetland Zone = Saline Lake Outflow + Myall-2 + N43

4.4 Lake Water Quality

The aims of the lake modelling were to

- Re-run the Pond models of the Pre-existing and Existing detention lakes using catchment inputs calculated using the MUSIC model and to confirm that similar results to previous runs were obtained;
- Re-run the Scheme 3 Pond model and Scheme 5 Pond models for catchment inputs under developed conditions and compare with the 2004 results; and
- If needed, size pond(s) and/or wetland(s) to achieve the receiving water quality objectives for receiving waters.

The approach to lake modelling is described in **Appendix E**.

The various assumptions and 2004 model calibration of the lake water quality model are outlined in **Appendix E**.

4.4.1 Pre-Existing and Existing Conditions

The Pond models of the Pre-existing detention lake and the Existing detention were re-run using inputs calculated using the MUSIC model to compare with the previous results reported in 2004. The results are compared in **Table 13**.

It was concluded that the calculated lake water quality using inputs generated by MUSIC are very similar to the lake water quality previously calculated using inputs generated by **xpaqualm**.

Table 13
Comparison of Lake Water Quality under Pre-existing and Existing Conditions

Percentile	Pre-existing Condition		Existing Condition	
	2004 Study	This Study	2004 Study	This Study
DO Bottom				
5%	1.0	0.7	1.5	1.6
20%	4.5	4.3	4.6	4.4
50%	5.9	5.8	5.9	5.8
80%	7.2	7.1	7.2	7.1
95%	8.2	8.1	8.1	8.1
DO % Saturation				
5%	12%	8%	21%	20%
20%	59%	57%	61%	59%
50%	78%	76%	78%	77%
80%	88%	88%	89%	88%
95%	95%	94%	95%	95%
TP				
5%	0.0014	0.0014	0.0011	0.0010
20%	0.0028	0.0026	0.0019	0.0019
50%	0.0055	0.0055	0.0040	0.0040
80%	0.0124	0.0135	0.0094	0.0106
95%	0.0283	0.0371	0.0221	0.0278
TN				
5%	0.29	0.27	0.31	0.29
20%	0.34	0.31	0.36	0.33
50%	0.41	0.39	0.42	0.40
80%	0.50	0.51	0.50	0.51
95%	0.68	0.77	0.64	0.72
Algal Biomass				
50%	0.0010	0.0010	0.0010	0.0010
70%	0.0011	0.0011	0.0010	0.0010
90%	0.0016	0.0021	0.0012	0.0014
95%	0.0034	0.0048	0.0022	0.0026
100%	0.0374	0.0323	0.0268	0.0265

4.4.2 Developed Conditions

Scheme 3

The Pond model of Developed Conditions with the extended detention lake was run with inputs calculated using the MUSIC model. Three scenarios were assessed as follows:

(i) Developed Conditions with rainwater tanks and the extended detention lake;

(ii) Developed Conditions with rainwater tanks and the extended detention lake and ancillary ponds or wetlands; and

(iii) Developed Conditions without rainwater tanks and with the extended detention lake and ancillary ponds or wetlands.

The results of this assessment are compared with the previous results reported in 2004 in **Table 14**.

It was concluded from the results of this assessment that:

(i) Under Scheme 3 Developed Conditions with rainwater tanks and the extended detention lake it is estimated that the:
- median salinity, DO levels, TN concentrations and algal levels were close to the results reported in 2004;
- median TP concentration is higher than estimated in 2004; and
- the maximum algal concentration is also higher than estimated in 2004 (and was similar to the maximum algal concentration estimated under Pre-existing and Existing Conditions).

(ii) The installation of ancillary ponds or wetlands (without any change in the tidal flushing regime) is estimated to:
- slightly increase the median salinity and DO levels;
- slightly decrease the median TP and TN concentrations to levels lower than the median concentration estimated in 2004;
- have no effect on the estimated median algal concentration; and
- slightly decrease the maximum algal concentration.

(iii) Constructing the extended detention lake and ancillary ponds and/or wetlands but not installing rainwater tanks (due to the possible installation of a reclaimed water system) is estimated to:

- Further reduce the median salinity;
- Provide DO levels the same as estimated in 2004;
- Slightly increase TP and TN concentrations above the estimated levels with rainwater tanks but still achieve levels lower than estimated in 2004;
- have no effect on the estimated median algal concentration; and
- slightly decrease the maximum algal concentration.

Table 14
Estimated Lake Water Quality under Scheme 3 Developed Conditions

	Scheme 3				
Percentile	2004 Study	This Study RWT + Lake	This Study RWT + Lake + Ponds	This Study No RWT + Lake + Ponds	ANZECC, 2000 Trigger Value / Ranges
Salinity (g/L)					
5%	3.4	3.8	3.8	3.7	3-20 g/L
20%	8.2	7.9	8.0	7.7	
50%	13.7	14.0	14.4	13.7	
80%	21.6	22.6	23.3	22.0	
95%	26.7	28.1	28.8	27.7	
DO Bottom (mg/L)					
5%	2.8	2.0	3.0	2.6	
20%	5.8	5.7	6.1	5.9	
50%	7.1	6.9	7.2	7.1	
80%	8.2	7.9	8.2	8.1	
95%	9.1	8.8	9.0	9.0	
DO Saturation (%)					
5%	32%	22%	33%	30%	80%-100%
20%	69%	66%	73%	70%	
50%	86%	84%	87%	86%	
80%	94%	93%	95%	94%	
95%	99.3%	98.1%	99.6%	99.2%	
TP (mg/L)					
5%	0.0023	0.0028	0.0019	0.0020	0.03
20%	0.0051	0.0057	0.0038	0.0043	
50%	0.0103	0.0130	0.0077	0.0085	
80%	0.0240	0.0310	0.0175	0.0179	
95%	0.0527	0.0579	0.0362	0.0373	
TN (mg/L)					
5%	0.27	0.23	0.18	0.21	0.3
20%	0.34	0.30	0.24	0.27	
50%	0.45	0.41	0.33	0.36	
80%	0.59	0.63	0.50	0.52	
95%	0.91	0.91	0.76	0.78	
Algal Biomass (mg/L)					
50%	0.0011	0.0011	0.0011	0.0011	0.004
70%	0.0012	0.0012	0.0012	0.0012	
90%	0.0016	0.0018	0.0018	0.0019	
95%	0.0023	0.0035	0.0031	0.0034	
100%	0.0191	0.0305	0.0282	0.0253	

Scheme 5

Scheme 5 comprises a partial extended saline lake (8 ha) with increased tidal flushing and new freshwater lakes (6.5 ha in total); supported by additional ponds or wetlands as needed (total area of pons draining to the lakes is 4.7 ha). The Developed Conditions Pond models of the freshwater Lakes and a separate linked model of the partially extended saline lake were run with inputs calculated using the MUSIC model.

Four scenarios were assessed as follows:

(i) Developed Conditions with rainwater tanks and freshwater lakes and a partially extended detention lake;

(ii) Developed Conditions with rainwater tanks and freshwater lakes and a partially extended detention lake and ancillary ponds or wetlands;

(iii) Developed Conditions without rainwater tanks and with freshwater lakes and a partially extended detention lake; and

(iv) Developed Conditions without rainwater tanks and with freshwater lakes and a partially extended detention lake and ancillary ponds or wetlands.

The results of the assessment of the original Scheme 5 are compared with the previous results reported in 2004 in **Table 15**. The original Scheme 5 was based on widening the existing outlet channel by 80% and lowering the outlet channel uniformly by 0.09 m.

It was concluded from the results of this assessment that:

(i) Under Scheme 5 Developed Conditions with rainwater tanks and the partially extended detention lake and freshwater lakes it is estimated that the:

- median salinity and DO levels are slightly lower in the saline lake and freshwater lakes;
- median TN and TP concentrations are slightly higher in the saline ;
- median algal levels were close to the results reported in 2004;and
- maximum algal concentration is also higher than estimated in 2004 (particularly in the freshwater lakes).

(ii) The installation of ancillary ponds or wetlands (without any change in the tidal flushing regime) is estimated to:

- slightly increase the median salinity and DO levels;
- slightly decrease the median TP and TN concentrations to levels lower than the median concentration estimated in 2004;
- have minimal effect on the estimated median algal concentration; and
- significantly decrease the maximum algal concentration.

Table 15
Estimated Lake Water Quality under Scheme 5 Developed Conditions

Percentile	Scheme 5										ANZECC, 2000 Trigger Value / Ranges
	2004 Study		This Study								
			RWTs only		RWTs + Ponds		No RWTs		No RWT + Ponds		
	Saline Lake	Fresh Lake(s)	Saline Lake	Fresh Lake	Saline Lake	Fresh Lake	Saline Lake	Fresh Lake	Saline Lake	Fresh Lake	
Salinity (g/L)											
5%	3.3		1.4		3.5		1.4		3.4		3-20 g/L
20%	8.2		5.9		7.9		5.6		7.6		
50%	14.1		12.5		15.2		11.5		14.3		
80%	22.8		22.1		25.1		20.2		23.7		
95%	28.9		30.4		32.2		27.9		30.4		
DO Bottom (mg/L)											
5%	2.7	5.9	1.5	3.1	3.6	4.8	1.4	2.7	3.6	4.4	
20%	4.6	7.9	4.4	6.9	4.7	7.6	4.3	6.6	4.8	7.4	
50%	6.0	8.6	5.9	8.1	6.2	8.6	5.9	7.9	6.2	8.5	
80%	7.4	9.4	7.2	8.8	7.5	9.2	7.1	8.8	7.6	9.1	
95%	8.4	10.1	8.2	9.4	8.5	9.8	8.1	9.4	8.5	9.8	
DO Saturation (%)											
5%	35%	62%	19%	33%	51%	52%	15%	29%	50%	46%	80%-100%
20%	65%	85%	61%	71%	72%	80%	57%	69%	71%	78%	
50%	80%	94%	79%	86%	82%	93%	77%	84%	82%	92%	
80%	88%	100%	87%	99%	89%	100%	86%	98%	89%	100%	
95%	93.0%	100.0%	92.8%	100.0%	93.8%	100.0%	92.5%	100.0%	93.5%	100.0%	
TP (mg/L)											
5%	0.0041	0.0007	0.0037	0.0007	0.0028	0.0007	0.0039	0.0007	0.0029	0.0007	0.03
20%	0.0065	0.0015	0.0066	0.0011	0.0049	0.0007	0.0073	0.0012	0.0052	0.0007	
50%	0.0098	0.0055	0.0126	0.0097	0.0081	0.0019	0.0140	0.0115	0.0086	0.0024	
80%	0.0174	0.0206	0.0247	0.0467	0.0142	0.0150	0.0261	0.0486	0.0147	0.0164	
95%	0.0332	0.0572	0.0490	0.0821	0.0251	0.0332	0.0506	0.0849	0.0258	0.0354	
TN (mg/L)											
5%	0.24	0.87	0.22	0.75	0.18	0.53	0.25	0.76	0.20	0.56	0.3
20%	0.30	0.92	0.29	0.81	0.23	0.56	0.32	0.81	0.24	0.58	
50%	0.39	0.98	0.42	0.92	0.30	0.62	0.45	0.92	0.32	0.63	
80%	0.52	1.08	0.64	1.19	0.43	0.75	0.66	1.19	0.45	0.77	
95%	0.77	1.30	0.94	1.39	0.63	0.97	0.96	1.40	0.65	0.99	
Algal Biomass (mg/L)											
50%	0.0012	0.0010	0.0012	0.0010	0.0011	0.0010	0.0013	0.0010	0.0012	0.0010	0.004
70%	0.0013	0.0010	0.0014	0.0010	0.0013	0.0010	0.0015	0.0011	0.0013	0.0010	
90%	0.0017	0.0013	0.0020	0.0016	0.0016	0.0014	0.0021	0.0016	0.0017	0.0015	
95%	0.0021	0.0017	0.0027	0.0026	0.0019	0.0018	0.0028	0.0027	0.0019	0.0022	
100%	0.0105	0.0304	0.0323	0.1397	0.0052	0.0592	0.0344	0.1860	0.0065	0.0912	

(iii) Partially extending the detention lake and constructing the freshwater lakes and ancillary ponds and/or wetlands but not installing rainwater tanks (due to the possible installation of a reclaimed water system) is estimated to:

- further reduce the median salinity;
- provide DO levels similar to the levels estimated in 2004;
- slightly increase TP and TN concentrations above the estimated levels with rainwater tanks but still achieve levels lower than estimated in 2004;
- have no effect on the estimated median algal concentration; and
- slightly decrease the maximum algal concentrations in the lakes.

Final Scheme 5

Concerns expressed by several stakeholders regarding any modification of the existing outlet channel within the SEPP 14 wetland zone meant that consideration was given to a different outlet arrangement. Under this outlet configuration the existing outlet channel remains unchanged while a second channel of equal width is constructed approximately 70 m north of the existing outlet channel with invert levels that are uniformly 0.10 m lower than the existing channel. The second outlet channel would connect to a second existing drain located within the SEPP 14 wetland zone.

These two channels were represented as the existing channel width increased by 100% and the channel invert levels uniformly lowered by 0.05 m.

For comparison the impact on water quality in the saline lake of retaining the existing outlet channel unchanged without a second outlet channel was also assessed.

The results of the assessment of the retaining the existing outlet channel unchanged with and without a second outlet channel are compared with the original Scheme 5 results in **Table 16**.

It was concluded that the impacts of retaining the existing outlet channel unchanged would:

(i) significantly reduce the median salinity from around 14.0 mg/L under existing conditions to around 6.3 – 6.9 mg/L ie. the extended detention lake would become “fresher” and would experience a lower range of salinities;

(ii) increase the median DO from around 5.8 mg/L under existing conditions to around 7.1 mg/L

(iii) increase the median TP from around 0.004 mg/L under existing conditions to around 0.0047 – 0.0050 mg/L

(iv) increase the median TN from around 0.4 mg/L under existing conditions to around 0.42 – 0.43 mg/L

(v) slightly decrease the 95th percentile algal biomass from 0.0026 under existing conditions to around 0.018 mg/L

It was concluded that the impacts of retaining the existing outlet channel unchanged and constructing a second channel of equal width is constructed with invert levels that are uniformly 0.09 m lower than the existing channel would:

(i) achieve a median salinity of around 12.5 – 13.4 mg/L which is only slightly lower than the median salinity of around 14.0 mg/L under existing ie. the existing salinity regime in the extended detention lake would preserved;

(ii) increase slightly the median DO from around 5.8 mg/L under existing conditions to around 6.4 mg/L

(iii) increase the median TP from around 0.004 mg/L under existing conditions to around 0.0073 – 0.0077 mg/L (which is lower than estimated for the existing Scheme 5);

(iv) lower the median TN from around 0.4 mg/L under existing conditions to around 0.32 -0.34 mg/L

(v) slightly decrease the 95th percentile algal biomass from 0.0026 under existing conditions to around 0.0018 mg/L

It is concluded that on balance constructing a second outlet is preferable to retaining the existing channel (unmodified) only because the changes in water quality in the lake (in particular salinity and TN) that result from retaining the existing outlet only has the potential to adversely impact on the existing aquatic ecology and may even change the mix of fish species.

The proposed outlet configuration is to retain the existing outlet channel unchanged while a second channel of equal width is constructed approximately 70 m north of the existing outlet channel with invert levels that are uniformly 0.10 m lower than the existing channel.

Table 16
Estimated Lake Water Quality under Final Scheme 5 Developed Conditions

	Original Scheme 5		Existing Outlet Only		Final Scheme 5	
Channel Widening Factor	1.8		1.0		2.0	
Ave Lowering of Channel (m)	0.09		0.0		0.05	
Percentile						
Salinity	WSUD 1	WSUD 2	WSUD 1	WSUD 2	WSUD 1	WSUD 2
5%	3.5	3.4	1.3	1.2	3.0	2.9
20%	7.9	7.6	3.1	2.8	6.9	6.6
50%	15.2	14.3	6.9	6.3	13.7	12.8
80%	25.1	23.7	12.2	10.8	23.1	21.6
95%	32.2	30.4	16.7	15.2	30.2	28.2
DO Bottom	WSUD 1	WSUD 2	WSUD 1	WSUD 2	WSUD 1	WSUD 2
5%	3.6	3.6	4.4	4.4	3.7	3.8
20%	4.7	4.8	6.1	6.1	5.0	5.0
50%	6.2	6.2	7.1	7.1	6.3	6.4
80%	7.5	7.6	8.3	8.3	7.7	7.7
95%	8.5	8.5	9.0	9.0	8.6	8.6
DO % Saturation	WSUD 1	WSUD 2	WSUD 1	WSUD 2	WSUD 1	WSUD 2
5%	51%	50%	54%	53%	52%	51%
20%	72%	71%	75%	74%	73%	71%
50%	82%	82%	85%	84%	83%	82%
80%	89%	89%	92%	92%	90%	89%
95%	94%	94%	97%	96%	95%	94%
TP	WSUD 1	WSUD 2	WSUD 1	WSUD 2	WSUD 1	WSUD 2
5%	0.0028	0.0029	0.0009	0.0010	0.0022	0.0023
20%	0.0049	0.0052	0.0017	0.0019	0.0039	0.0043
50%	0.0081	0.0086	0.0047	0.0050	0.0074	0.0078
80%	0.0142	0.0147	0.0127	0.0134	0.0139	0.0148
95%	0.0251	0.0258	0.0252	0.0258	0.0256	0.0265
TN	WSUD 1	WSUD 2	WSUD 1	WSUD 2	WSUD 1	WSUD 2
5%	0.18	0.20	0.31	0.33	0.20	0.21
20%	0.23	0.24	0.35	0.37	0.25	0.26
50%	0.30	0.32	0.42	0.44	0.32	0.34
80%	0.43	0.45	0.55	0.56	0.45	0.47
95%	0.63	0.65	0.73	0.75	0.66	0.67
Algal Biomass	WSUD 1	WSUD 2	WSUD 1	WSUD 2	WSUD 1	WSUD 2
50%	0.0011	0.0012	0.0010	0.0010	0.0011	0.0011
70%	0.0013	0.0013	0.0011	0.0011	0.0012	0.0013
90%	0.0016	0.0017	0.0014	0.0014	0.0016	0.0016
95%	0.0019	0.0019	0.0017	0.0018	0.0018	0.0019
100%	0.0052	0.0065	0.0049	0.0060	0.0053	0.0066

WSUD 1 Scheme with RWTs + Ponds
WSUD 2 Scheme without RWTs + Ponds

5. INTEGRATED WATER MANAGEMENT PLAN

The concept plan for the development of the Riverside at Tea Gardens site consists of a residential / mixed use precinct proposed for the majority of the site and a tourist and larger lot component located in the NE corner of the site. Substantial areas of the land are proposed to be protected and enhanced as open space / wildlife movement corridors, over and above those already protected in the Conservation Zone and the Wetland Zone.

The flooding, drainage and water quality objectives for the development could be met by either:

(i) Extending the existing detention lake (with increased tidal flushing) and constructing additional ponds and/or wetlands, swales and a biofilter as appropriate (Scheme 3); or

(ii) Partially extending the existing detention lake ((with increased tidal flushing) and constructing additional freshwater lakes, ponds and/or wetlands, swales and a biofilter as appropriate (Scheme 5).

Discussions held with the NSW Department of Planning highlighted a number of concerns held by NSW Government stakeholder with concept Scheme 3. Consequently the preferred approach to integrated water management is based on Scheme 5.

The preferred development concept plan is provided in **Figure 6**.

5.1 Flooding & Drainage

It is proposed to direct runoff in events up to the 100 yr ARI event from the upper catchment areas east along the proposed open space corridor located on the northern boundary of the development and then south east to a swale located on the eastern boundary of the site. This swale is intended to distribute runoff along the western boundary of the buffer zone to reduce the concentration of runoff into the buffer zone and the SEPP14 wetland. With the exception of limited areas of planned development on the eastern boundary of the site that will drain to the buffer zone, the planned development located south of the open space corridor will drain southwards towards the proposed extended detention lake.

Four main drainage lines have been identified within the development. One of these drainage lines lies within the proposed open space corridor located on the northern boundary of the development. It is proposed to convey floodwaters down these drainage lines in wide, shallow swales.

It is proposed to integrate a major retarding basin into the open space corridor as well as to construct a local basin to reduce 100 yr ARI peak flows from the area of planned development that discharges directly to the Myall River (subcatchment N42) and to the Conservation Zone.

Under the preferred scheme the partial extension of the existing lake in combination with additional freshwater lakes and ponds will create additional active storage that will mitigate the increases in peak runoff up to the 100 yr ARI event due to the planned development.

A concept retarding basin has been also sized to manage runoff from an area of planned development that could discharge directly to the conservation zone (subcatchment N43) if required.

5.2 Water Quality

5.2.1 Temporary Controls

Sediment and erosion control measures will be implemented in the construction phases in accordance with the requirements of the current edition of the Managing Urban Stormwater – Soils and Construction (Blue Book) released by the NSW Department of Housing.

5.2.2 Permanent Controls

The stormwater treatment objectives and lake water quality objectives will be met by:

(i) Partially extending the existing detention lake to create a to a water body with a 8.0 ha water surface;
(ii) Constructing three cascading freshwater lakes upstream of the saline lake with a combined surface area of 6.55 ha;
(iii) Constructing a number of ancillary ponds (with a combined surface area of around 4.7 ha) to pre-treat runoff discharged to the freshwater lakes and the partially extended detention lake;
(iv) Constructing local wetlands to treat runoff from residential development discharging to the Myall River (subcatchment N42) or to the Conservation Zone (subcatchment N43), as well as
(v) Constructing a 440m swale along the eastern edge of the development (to distribute flow to the Conservation Zone).

It should be noted that experience to date in Tea Gardens has shown that there is little need to install GPTs as even sediment is highly controlled from the individual lots as part of a comprehensive Community Title arrangement that imposes strict controls on individual builders during construction

5.3 Maintenance Activities

5.3.1 Pond and Wetland Maintenance

The maintenance activities for the pond and wetland systems will be based on the practices already implemented for existing ponds and wetlands located within developed areas of Riverside at Tea Gardens and the Myall River Downs estate. The following maintenance activities are expected to be undertaken but may not be required at all times:

- Routine inspection of inlet and outlet points to identify any area of scour, litter build up and blockages;
- Inspection and removal of accumulated litter and debris from inlet and outlet structures (every 3 months);
- Periodic draining and desilting of the ponds (every 5 -10 years);
- Inspection and removal of noxious and invasive weeds from within the macrophyte zone (every 1-3 months during establishment phase);
- Replacement of plants that have died with plants of equivalent size and species (as needed);
- A macrophyte zone will need to be 'reset' every 20 to 50 years depending on the pollutant loading rate on the system.

Design attributes that will facilitate maintenance activities include:

- Inlet zone for the removal of coarse particulates;
- Provision of an access and entry point to the macrophyte zone for the periodic removal of accumulated material; and
- Access to outlet structure for routine inspections.

5.3.2 Lake Maintenance

The maintenance activities for the extended lake will be based on the practices already implemented for existing detention lake by contractors experienced in this type of work acting under instructions from the Community Association Manager. The maintenance activities generally include:

Maintenance activities for the lakes would involve:

- Inspection and removal of accumulated debris and litter from inlets and outlet structures;
- Inspection and removal of noxious weeds from within the water body;

- Inspection and removal of any vegetation that may invade the outlet channel to maintain the outlet capacity;
- Inspection and removal of accumulated sediment from inlet zones as needed.

Design attributes that will facilitate maintenance activities include:

- Provision of access to inlets and to the perimeter of the extended detention lake; and
- Provision of access to the outlet channel for routine inspections and removal of accumulated debris and/or invasive vegetation.

5.4 Management of Aquatic Weeds

The management of aquatic weeds in constructed pond and wetland systems and the extended detention lake will be based on the practices already implemented for existing ponds and wetlands located within developed areas of Riverside at Tea Gardens and the Myall River Downs estate and for the existing detention lake. Aquatic plants are inspected periodically to control pest species and to promote the desired mix of plants for conservation and landscape purposes.

The constructed Wetlands Manual defines an aquatic weed as a plant ‘out of place’ or a plant that interfere with the objectives of the wetland or its desired function.

Weed management in constructed wetlands is important to ensure that weeds do not out compete the species planted for the particular design requirements. This may also include some native species like Phragmites that naturally can appear in constructed wetlands and out-compete other more important planted species.

It is possible to minimise and control weeds by incorporating the following:

- Buying seed that is either known to be free of weeds or certified free of weed seeds, preventing weeds from being introduced;
- Timing activities to minimise weed germination;
- Applying pre-emergent herbicides;
- Manual removal; and
- Competition with a dense, health crop to crowd out potential weeds.

5.5 Management of Aquatic Species and Birdlife

Wetlands and lakes usually provide a sanctuary for waterbirds and other animals.

During the early stages of wetland establishment, water birds can be a major nuisance due to their habit of pulling out recently planted species. Interlocking planting systems (i.e. where the maintenance activities for the pond and wetland systems will be based on the practices already implemented for existing ponds and wetlands located within developed areas of Riverside at Tea Gardens and the Myall River Downs estate several plants are grown together in a single container such as 'floral edges') can be used, as water birds find it difficult to lift the interlocking plants out of the substrate unlike single plants grown in tubes.

Harris Research, 2007 also recommend that the 2002 recommendations for enhancing the amount and quality of aquatic habitats remain relevant and should be pursued, particularly with respect to increasing the extent, complexity and quality of near-shore habitats for fish, invertebrates and birds (refer **Appendix H**, Report Appendix 3). These recommendations for optimising the quality of aquatic habitats, which are incorporated in current proposals to extend the lake area, include:

- Influencing the water-quality regime to increase habitat diversity and stability.
- Continuing effective management of the series of runoff-treatment ponds.
- Increasing variability of depth profiles by introducing physical structures such as submerged logs, rockwork or other artificial reefs
- Experimentally introducing indigenous submerged and emergent aquatic plants and planting littoral trees, shrubs and grasses and
- Introducing shoreline complexity in newly created waterway areas.

5.6 Monitoring Program

The proposed monitoring program is based on the monitoring program previously adopted in late 2003 for Precincts 7 and 8 of Riverside at Tea Gardens as follows.

5.6.1 SEPP 14 Wetland

The monitoring program for the SEPP 14 wetland is based on:

- The establishment of 3 transects in the vicinity of Precincts 7 and 8, perpendicular to the environmental gradient;
- Hand-auguring, small bore piezometers at intervals along the transects;
- Collecting further data on groundwater depth and salinity at each piezometer at regular intervals to supplement the data previously collected from Bores 3 and 6 (refer CPI, 1996a); and

- Undertake a quantitative plot based vegetation monitoring program to determine species composition, relative abundance and plant condition.

The timetable that was proposed was three monthly monitoring:

- immediately after construction (for 36 months),
- 5 years after the initial 3 years of monitoring (for 12 months), and
- 10 years after the initial 3 years of monitoring (for 12 months).

Comparison of post-construction data with the baseline dataset would generally be undertaken using non-parametric multivariate techniques, such as analysis of similarities (ANOSIM), which would provide a statistical assessment of whether changes had occurred.

Technical detail on methods would be provided in a methods statement in a baseline survey report to be submitted to Council within 3 months of the date of commencement.

Reports on the groundwater observations and vegetation monitoring would be provided after every 12 month period of monitoring.

5.6.2 Constructed freshwater Lakes, Ponds and Wetlands

The proposed monitoring program of both basin inflow and outflow is detailed in **Table 17**. It is proposed that the key stakeholders including the landowner, the Myall Quays Community Association, Great Lakes Council and DECC officers meet to review the outcomes of the monitoring program after three (3) years and to agree on the scope of any ongoing monitoring program and the timing of any subsequent review.

Table 17
Monitoring Program for Constructed Ponds and Wetlands (after HWR, 2001)

Parameter	Frequency	Test
Microbiological	Two (2) event monitoring periods per year with a minimum of 4 samples during each storm event. Storm event to be at least 15 mm with first flush to be targeted	Water samples for laboratory analysis
Nuisance organisms	Two (2) event monitoring periods per year with a minimum of 4 samples during each storm event. Storm event to be at least 15 mm with first flush to be targeted	Visual during storm events and water samples for laboratory analysis
Visual clarity & colour	Two (2) event monitoring periods per year. Storm event to be at least 15 mm with first flush to be targeted	In-situ analysis at time of sampling during storm events

pH	Two (2) event monitoring periods per year. Storm event to be at least 15 mm with first flush to be targeted	In-situ analysis at time of sampling during storm events
Toxic chemicals	In response to actual or potential toxic spills in Precincts 7 or 8.	Water samples for laboratory analysis
Surface films	Two (2) event monitoring periods per year. Storm event to be at least 15 mm with first flush to be targeted	Visual & smell at time of sampling during storm events
Phosphorus	Two (2) event monitoring periods per year with a minimum of 4 samples during each storm event. Storm event to be at least 15 mm with first flush to be targeted	Water samples for laboratory analysis
Nitrogen	Two (2) event monitoring periods per year with a minimum of 4 samples during each storm event. Storm event to be at least 15 mm with first flush to be targeted	Water samples for laboratory analysis

The frequency of monitoring would be increased in the event of a potential pollution incident within a basin's catchment.

5.6.3 Extended Detention Lake

It is proposed to continue the current monitoring program of the existing detention lake for at least a further three years. This current program comprises sampling and testing of lake water at five sites (refer **Figure A.1**) at three monthly intervals. The parameters that are monitored include:

- pH
- Salinity
- Dissolved oxygen,
- Turbidity, Suspended Solids
- Oxidised nitrogen, ammonia, nitrates, nitrites, phosphate
- Chlorophyll 'a'

It is proposed that the key stakeholders including the landowner, the Myall Quays Community Association, Great Lakes Council and DECC officers meet to review the outcomes of the monitoring of the detention lake after three (3) years and to agree on the scope of any ongoing lake monitoring program and the timing of any subsequent review.

It is further proposed to:

- undertake 6-monthly algae testing/analysis including one (1) summer assessment;

- Undertake additional sampling and testing of lake water if more than 50 mm of rain falls in a two day period or less. Council requires no more than two (2) such sampling events per year.

5.7 Management Responsibilities and Actions

The responsibilities of various stakeholders are summarised in **Table 18**.

Table 18
Responsibilities of Stakeholders

Parameter	Management Action
Landowner	Responsible for preparing and submitting management plans in accordance with Council requirements. Responsible for implementing the approved Soil and Water Management Plan and for maintaining the effectiveness of all measures during the construction and building phases. Responsible for undertaking remedial actions to reinstate the effective operation of measures during the construction/building phase as may be directed by the Superintendent, Great Lakes Council and/or DECC (NSW EPA).
Contractors/ Builders	Responsible for implementing the approved Soil and Water Management Plan and for maintaining the effectiveness of all measures during the construction and building phases. Responsible for undertaking remedial actions to reinstate the effective operation of measures during the construction/building phase as may be directed by the Superintendent, Great Lakes Council and/or DECC (NSW EPA).
Myall Quays Community Association (Residents)	Responsible for the operations and maintenance of permanent stormwater management measures and the detention lake and undertaking any remedial actions to reinstate the effective operation of measures as may be directed by Great Lakes Council and/or DECC (NSW EPA).. Responsible for commissioning the SEPP 14 wetland monitoring program detailed above and submitting reports on the monitoring undertaken and the conclusions drawn at the end of each 12 month period. Responsible for commissioning a qualified agent to undertake post-construction monitoring of water bodies as detailed above. Reports are to be provided to Great Lakes Council at 3 monthly intervals. Each report is to provide details on the testing undertaken, including full results and will include an overview of water quality performance during the relevant period.

Great Lakes Council	Responsible for periodic review of soil and water management measures during the construction/building phase and the post-construction phase and issuing of directions to the appropriate stakeholder(s) to rectify any significant defects in the measures. Responsible for reviewing submitted reports on water quality and discussing any concerns regarding water quality trends with the Myall Quays Community Association and/or NSW EPA as appropriate.
DECC (NSW EPA).	Responsible for providing advice to Great Lakes Council on water quality issues that may be of concern to Council. Responsible for undertaking any site inspections that may be requested by Great Lakes Council in relation to water quality issues of concern.

As stated above it is proposed that the key stakeholders including the landowner, the Myall Quays Community Association, Great Lakes Council and DECC officers meet to review the outcomes of the monitoring of the constructed ponds and wetlands and the detention lake after three (3) years and to agree on the scope of any ongoing pond, wetland and lake monitoring programs and the timing of any subsequent review.

The management actions proposed to rectify any failures to meet the water quality objectives are set out in **Table 19**. These proposed actions have been adapted from HWR, 2001. In addition to these actions, if a potential pollution event (e.g. oil spill or chemical spill) occurs within the development, this event would trigger immediate sampling of the water bodies that may be affected for all water quality parameters, and the frequency of monitoring will be increased above that listed in **Table 17** until it is certain that any effect of the event has either been prevented from reaching the water body or has passed through the water body.

These measures should ensure that water discharged from the development does not impact upon the primary contact recreational condition of the Myall River.

Table 19
Management Actions to Address Failure to Meet Water Quality Objectives
(after HWR, 2001)

Parameter	Management Action
Microbiological	Search for and rectify potential human sources of bacteria such as sewerage overflows. If source of bacteria is found to be non human eg birds or animals then consult with Great Lakes Council and other stakeholders as appropriate regarding appropriate management actions.
Nuisance organisms	Check correlation between nuisance organisms and nutrient levels. If nutrient levels excessive, follow actions under 'Nutrients' below. If nutrient levels are not excessive, consider other actions that may include aeration and/or increased flushing.
Visual clarity & colour	Search for and rectify potential sources of turbidity and/or colour.
pH	Search for and rectify potential sources of acidity or basicity as appropriate.
Toxic chemicals	Implement measures to prevent future contamination from spill, etc.
Surface films	Search for and rectify potential sources of oils. Implement measures to prevent future contamination.
Phosphorus	Assess water body loadings by comparing input levels with output levels. If input levels are excessive, search for and rectify potential sources of phosphorus. If water body performance is unsatisfactory, enhance water body performance by redesign and/or other actions that may include aeration and/or increased flushing.
Nitrogen	Assess water body loading by comparing input levels with output levels. If input levels are excessive, search for and rectify potential sources of nitrogen. If water body performance is unsatisfactory, enhance water body performance by redesign and/or other actions that may include aeration and/or increased flushing.

6. QUALIFICATION

It is important to recognise that any modelling studies provide only an estimate of the predicted flood levels, flows, pollutant loads and/or treatment efficiencies. Although these estimates are based on the best data available at the time of writing, new data obtained in the future may lead to a revision of the estimates.

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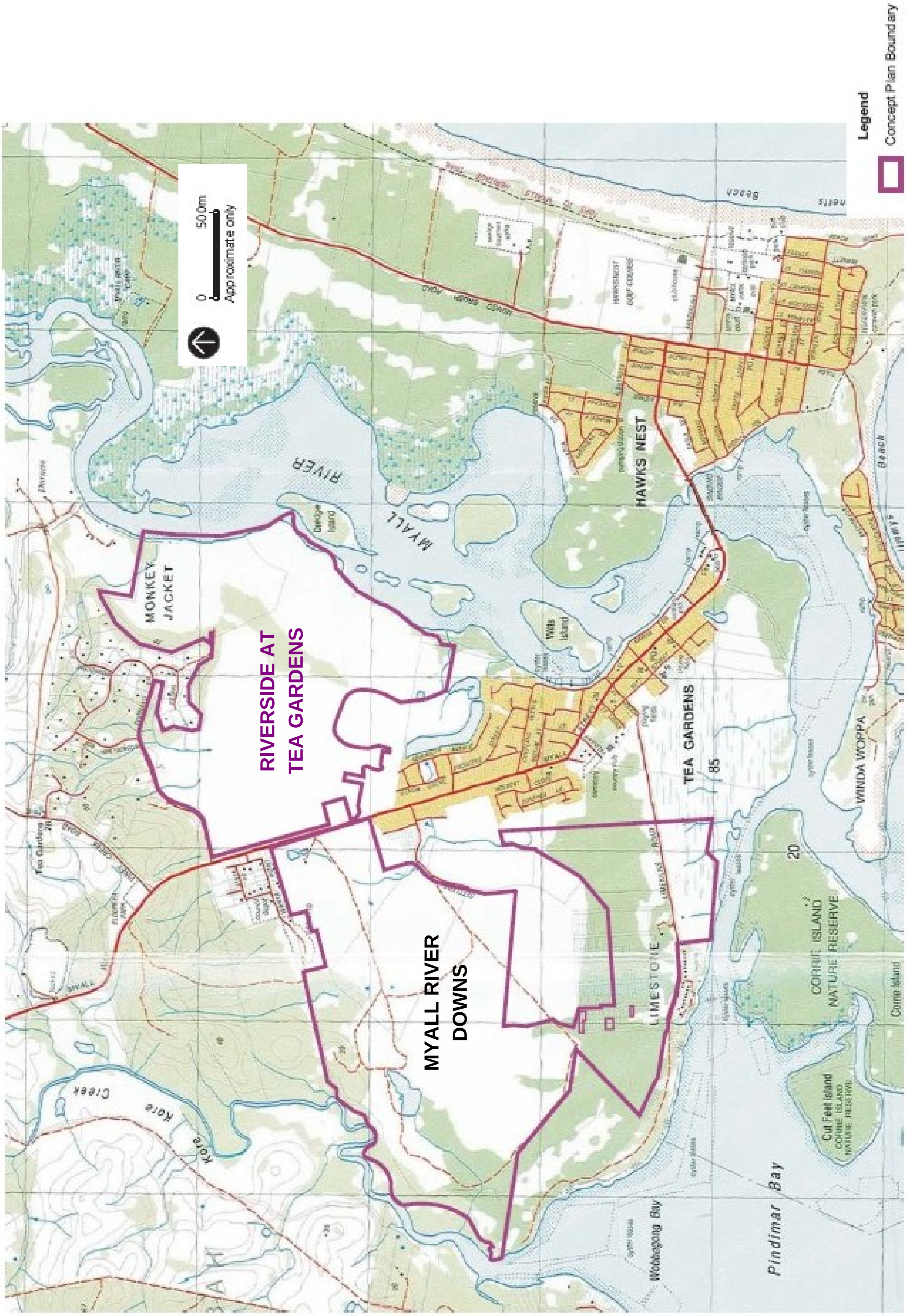


Figure 1
Locality Plan (after ERM, 2006)

Cardno Willing

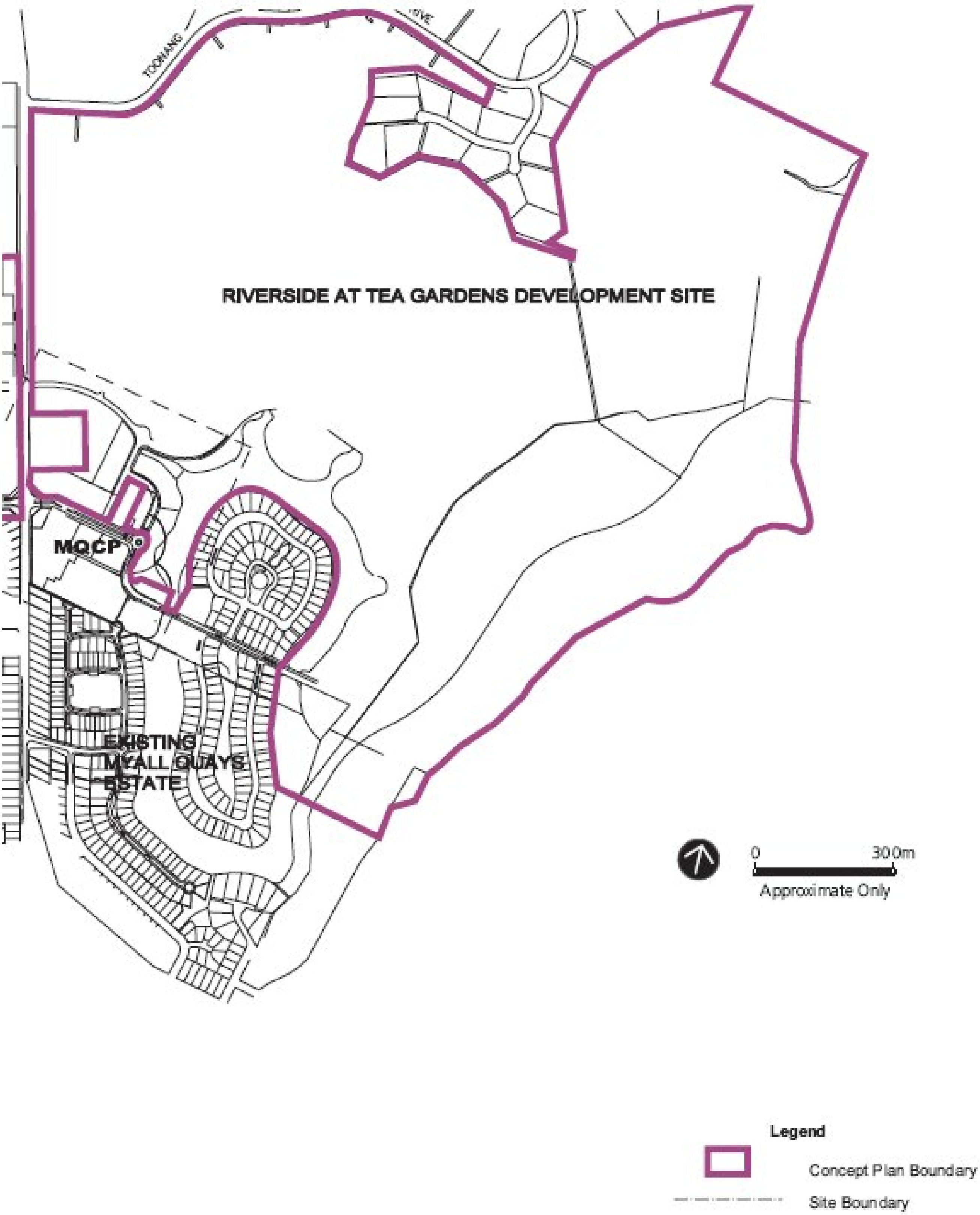


Figure 2
Riverside at Tea Gardens Site Plan (after ERM, 2006)

Cardno Willing

Figure 3
Aerial Photograph (after ERM, 2006)

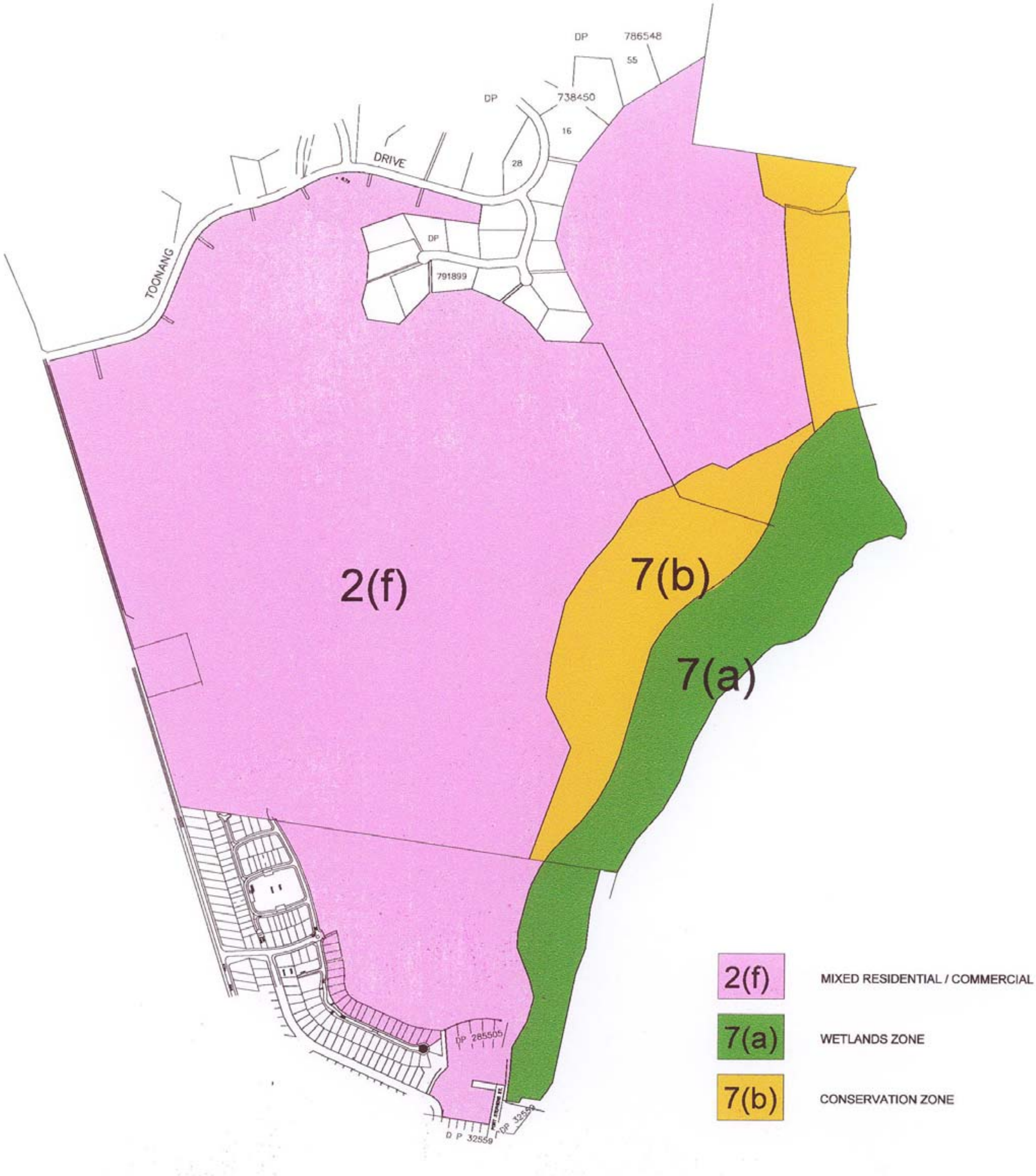
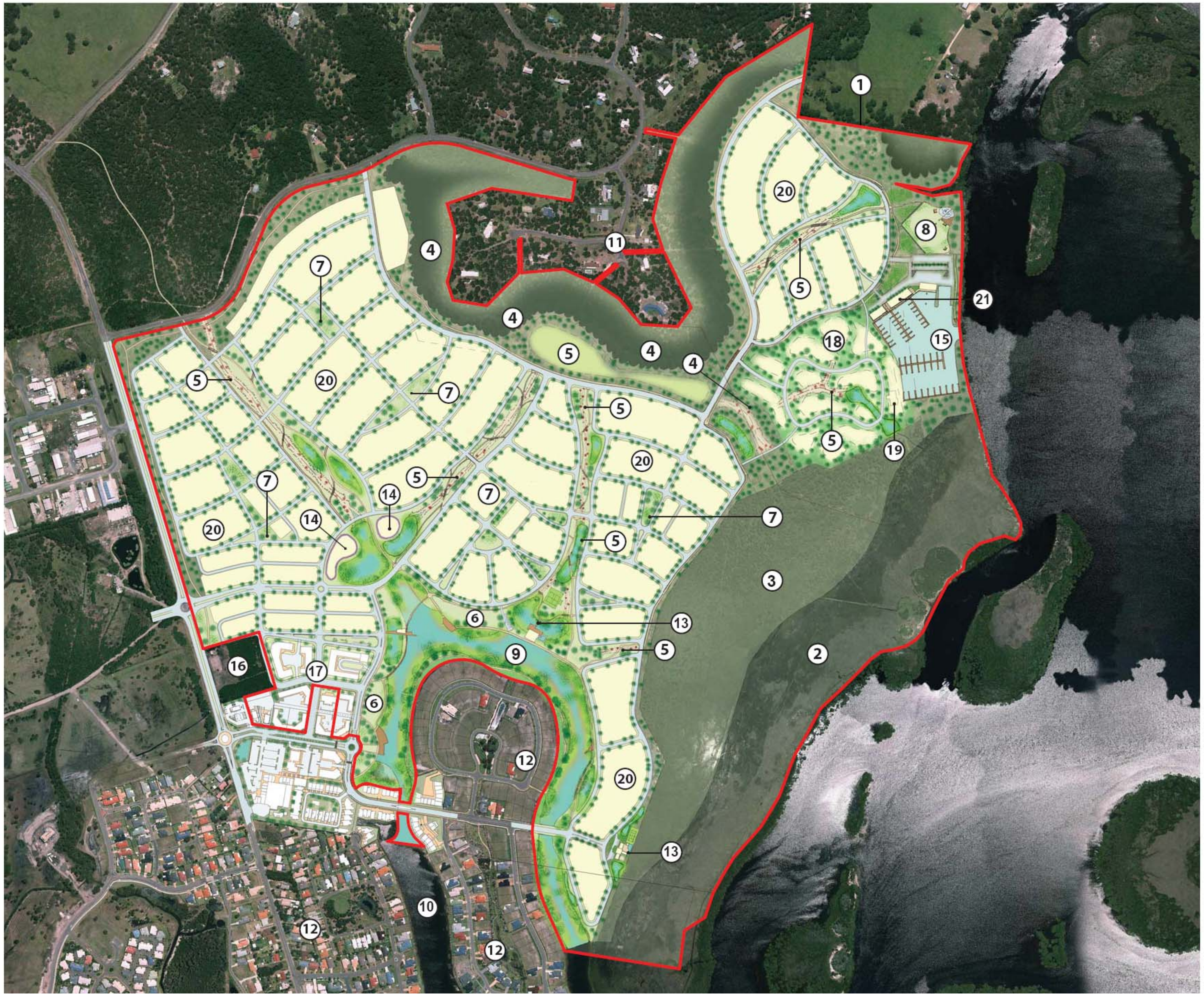


Figure 4
Riverside at Tea Gardens Zoning Plan

Cardno Willing

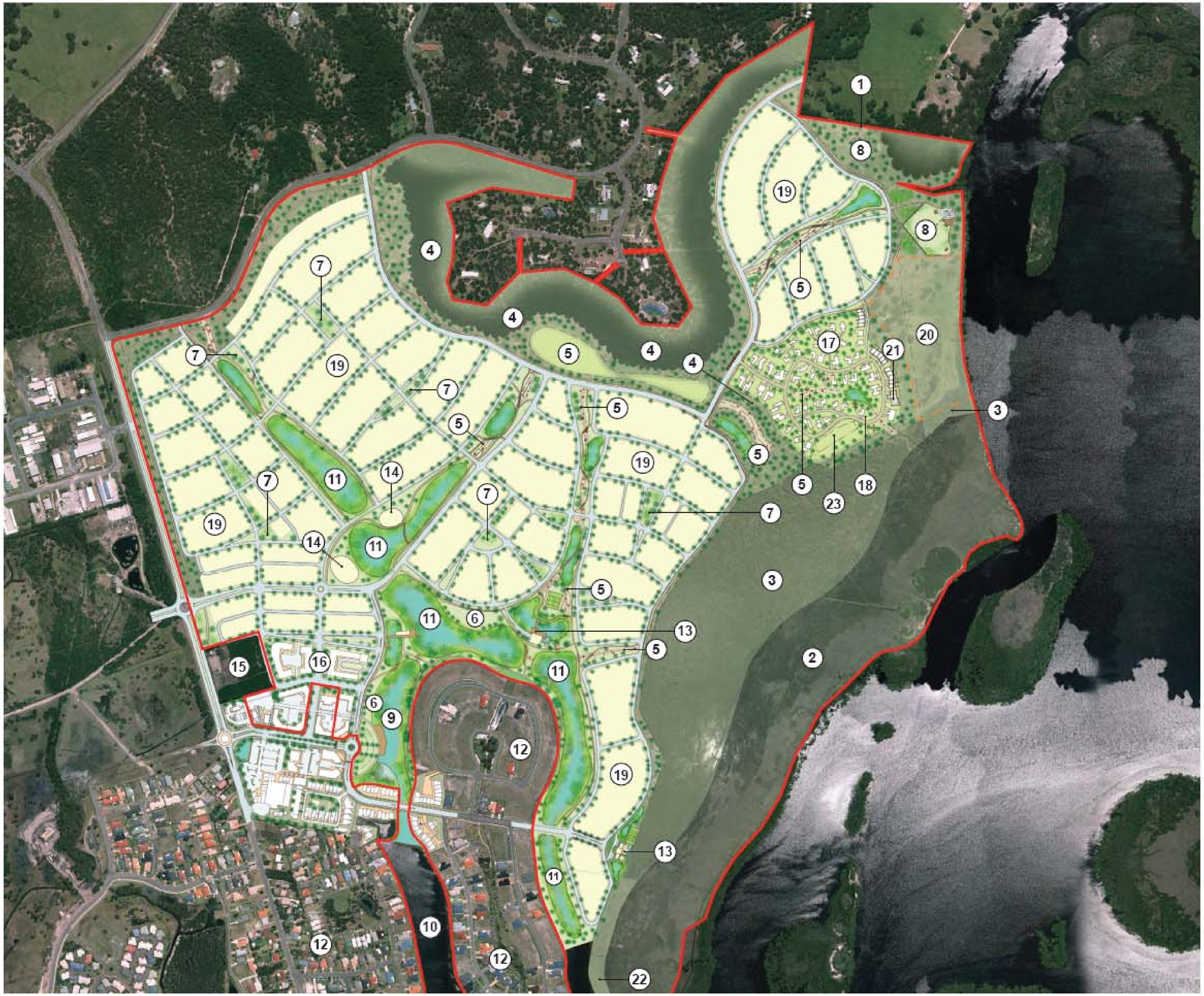


Item	Description
1	Extent of site holding 'Riverside' at Tea Gardens.
2	Existing 7(a) wetland zone.
3	Existing 7(b) buffer zone.
4	Wildlife movement corridor.
5	Water management & open space corridors.
6	Community parks incorporating walking/cycle ways, BBQ's, children's play area equipment.
7	Community pocket parks.
8	Myall foreshore park.
9	Extended lake area for water detention & water quality management (6.5 Ha).
10	Existing detention and water quality lake.
11	Existing rural residential estate 'Shearwater'.
12	Existing residential development.
13	Precinct community facilities.
14	Future precinct community facilities.
15	100 berth marina - including boat ramp.
16	Site area currently owned by Great Lakes Council
17	Extension of existing commercial precinct. Waiver received (Dept. of Planning).
18	Low density 'tourist lodgings'.
19	Conference & community facilities, associated low rise town house accommodation
20	Proposed residential lot development to be developed under community title.
21	Marina facilities buildings including office, chandlery, slip way, etc.

Land Use Legend

Total Site	Ha	%
Open Space		
- Wetlands (zoned 7a)	24.4	11.2
- Wetland Buffer Zones (zoned 7b)	21.1	9.7
- Wildlife Corridors	27.3	12.6
- Myall Foreshore Park (incl parking)	7.6	3.5
- Drainage Corridors, Lake & Large Parks	35.1	16.1
- Pocket Parks	2.6	1.2
Total	118.1	54.3
Built Upon Area		
- Residential (including roads & community facilities)	83.6	38.4
- Tourist/Residential (Lodgings)	8.4	3.9
- Marina Basin and facilities	3.0	1.4
- Commercial Total	4.3	2.0
Total	99.3	45.7
Total	**217.4**	**100%**

Figure 5
Riverside at Tea Gardens Scheme 3 Concept Development Plan



Item	Description
1	Extent of concept plan area 'Riverside' at Tea Gardens.
2	Existing 7(a) wetland zone.
3	Existing 7(b) buffer zone.
4	Wildlife movement corridor.
5	Water management & open space corridors.
6	Community parks incorporating walking/cycle ways, BBQs, children's play area equipment.
7	Community pocket parks.
8	Myall foreshore park.
9	Extended lake area for water detention & water quality management (2.0 Ha).
10	Existing detention and water quality lake.
11	New fresh water water quality management & detention ponds.
12	Existing residential development.
13	Precinct community facilities.
14	Future precinct community facilities.
15	Site area currently owned by Great Lakes Council.
16	Extension of existing commercial precinct. Waiver received (Dept. of Planning).
17	Low density tourist residential lodgings.
18	Conference & community facilities, associated low rise town house accommodation
19	Proposed residential lot development to be developed under community title.
20	Future development site
21	Existing house
22	DCP buffer
23	Location of known midden & buffer

Land Use Legend

Total Site	Ha	%
Open Space		
- Wetlands (zoned 7a)	28.4	12.4
- Buffer Zones (zoned 7b)	20.6	9.0
- Additional Conservation Buffer	1.4	0.6
- Wildlife Corridors	27.3	11.9
- Myall Foreshore Park	5.6	2.4
- Drainage Corridors, Ponds & Large Parks	35.1	15.4
- Pocket Parks	2.6	1.1
- Existing detention & water quality lake	6.7	2.9
Total	127.7 Ha	55.7%
Built Upon Area		
- Residential (including roads & community facilities)	83.6	36.5
- Tourist/Residential (Lodgings)	8.4	3.7
- Future Development Site	5.0	2.2
- Commercial/Retail	4.3	1.9
Total	101.3 Ha	44.3%
Total	229.0 Ha	100%

Figure 6
Riverside at Tea Gardens Scheme 5 Concept Development Plan

Cardno Willing

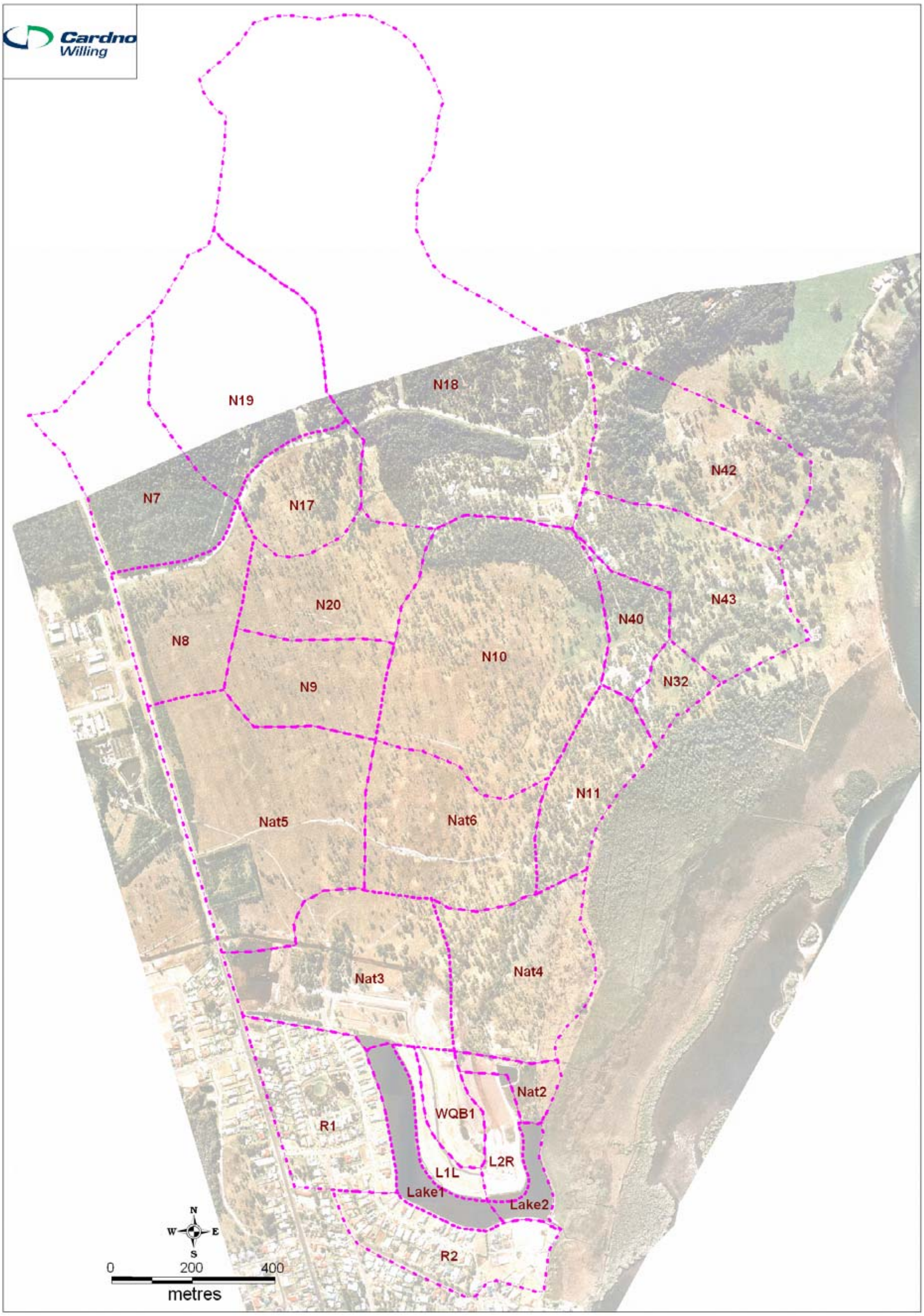


Figure 7
Catchment Layout - Existing Conditions

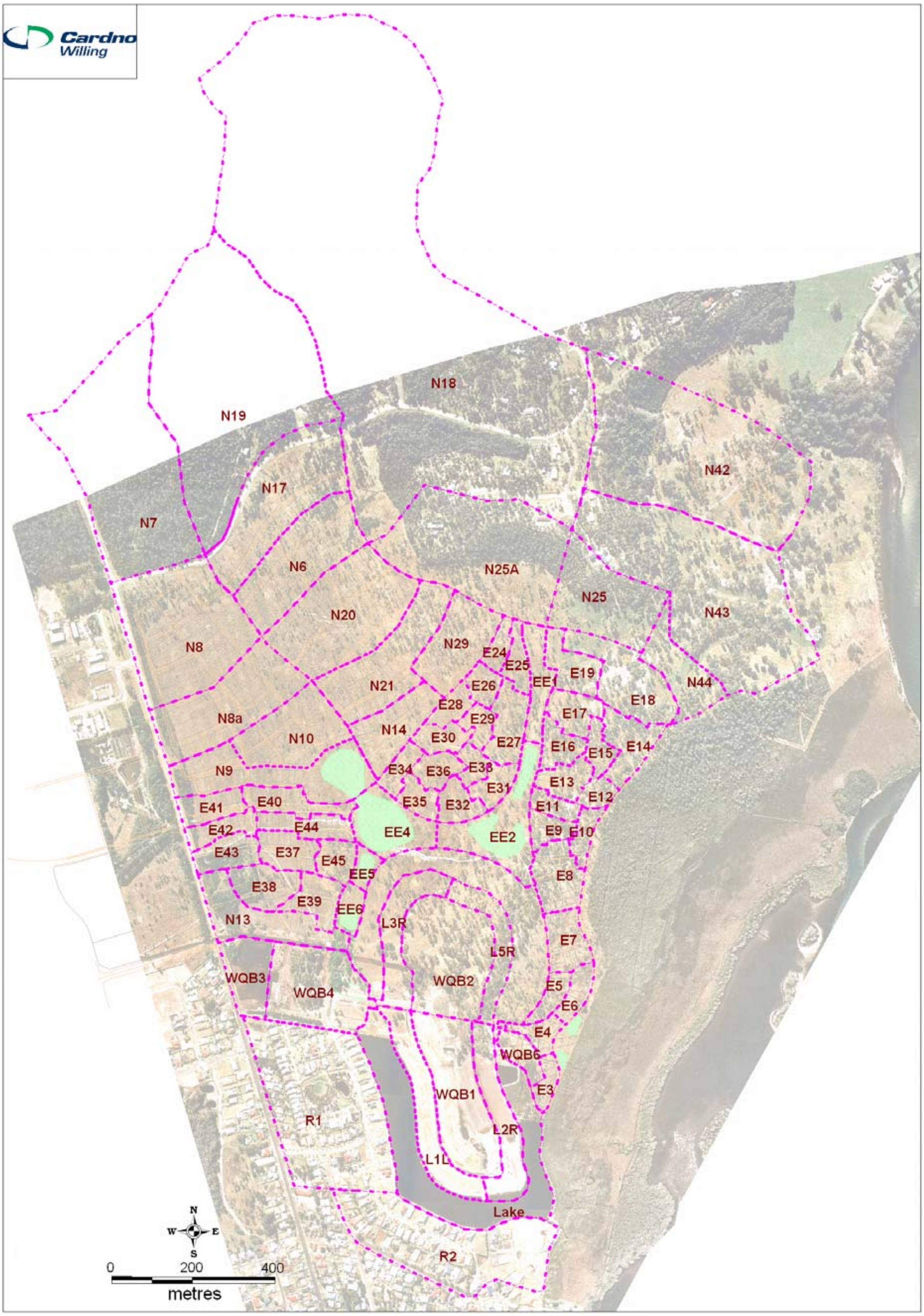


Figure 8
Catchment Layout - Developed Conditions

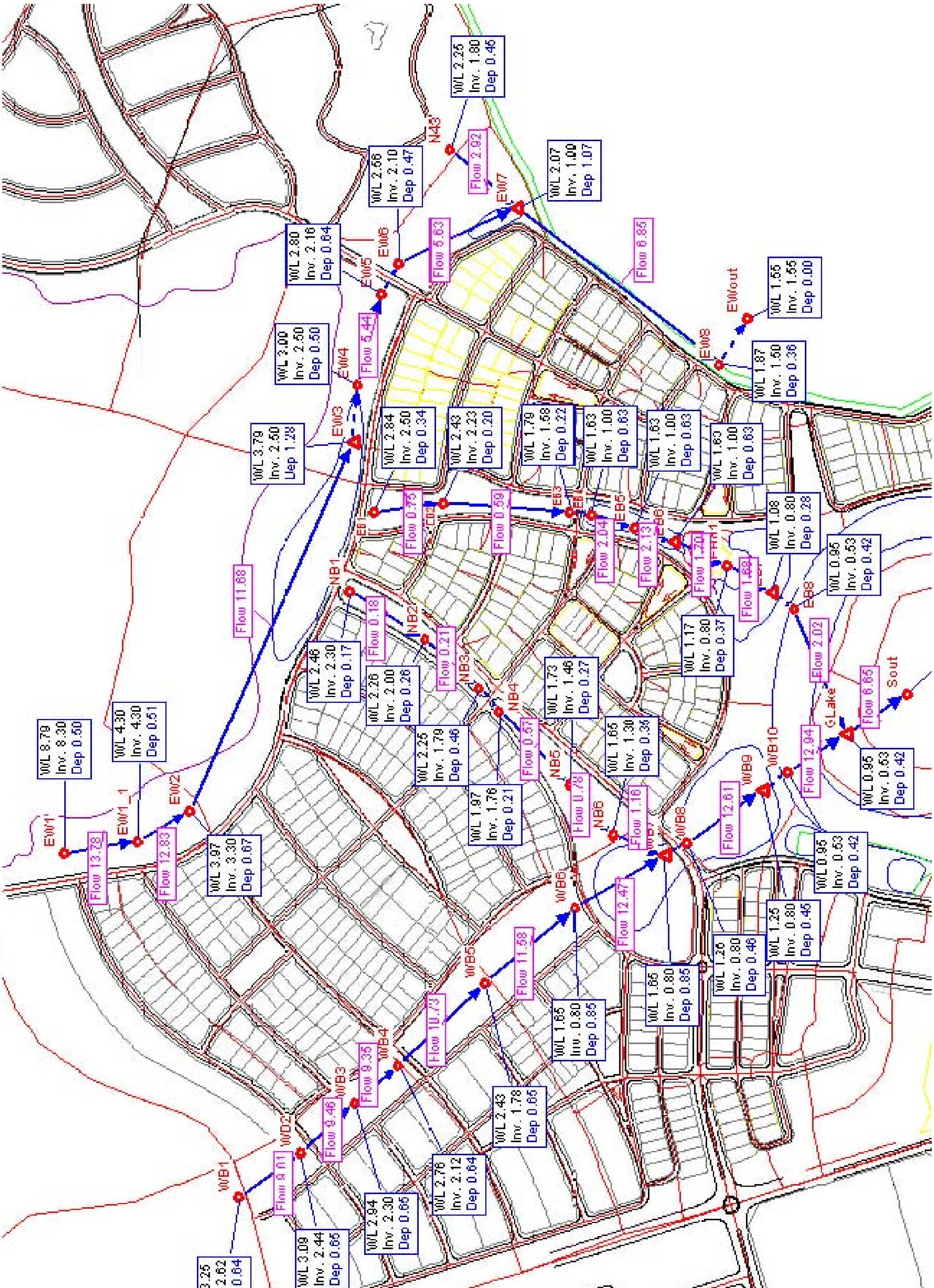


Figure 9

100 yr ARI Peak Flows, Flood Levels and Flood Depths for 1.5 hour Storm Burst – Scheme 3

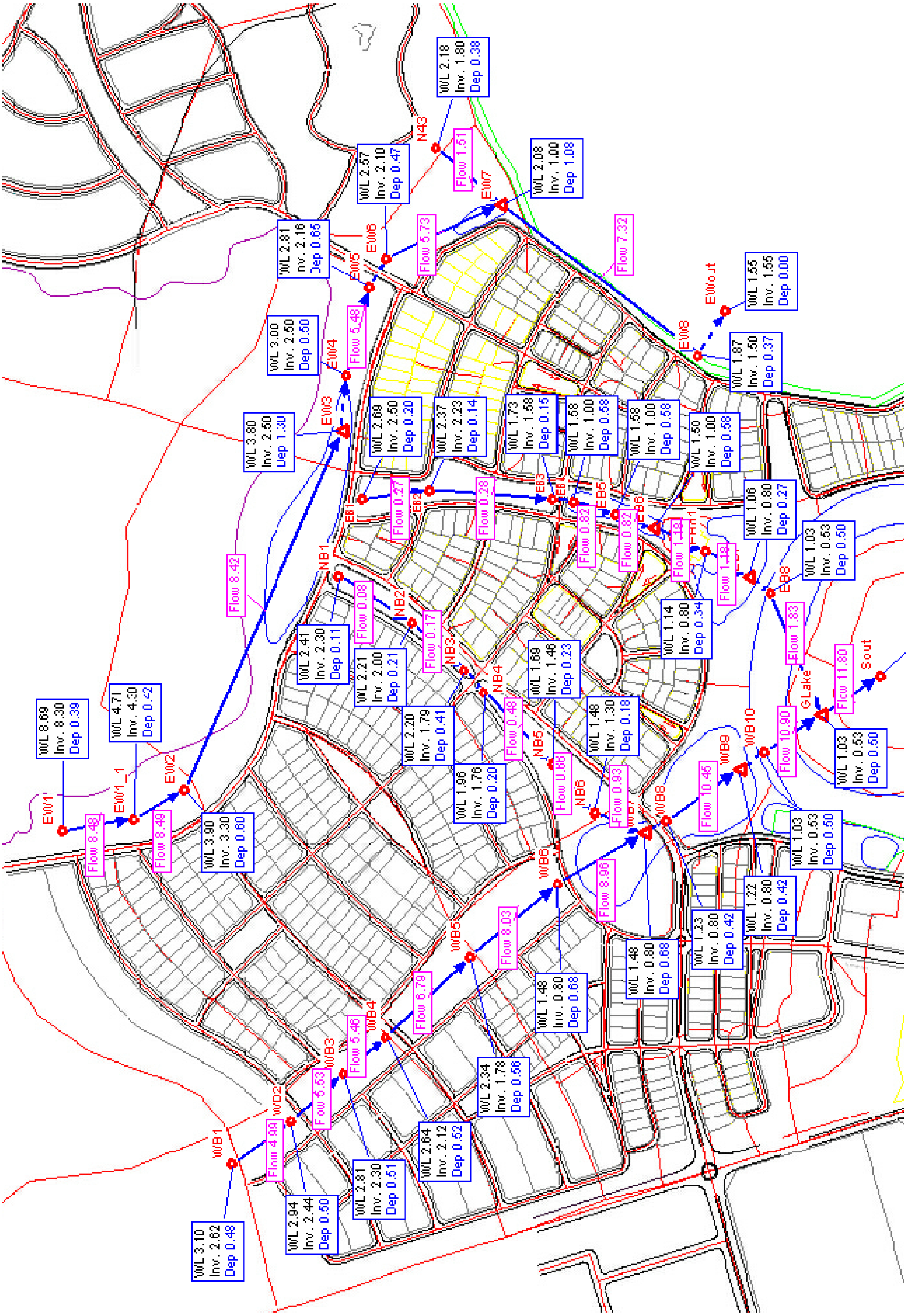


Figure 10

100 yr ARI Peak Flows, Flood Levels and Flood Depths for 9 hour Storm Burst – Scheme 3

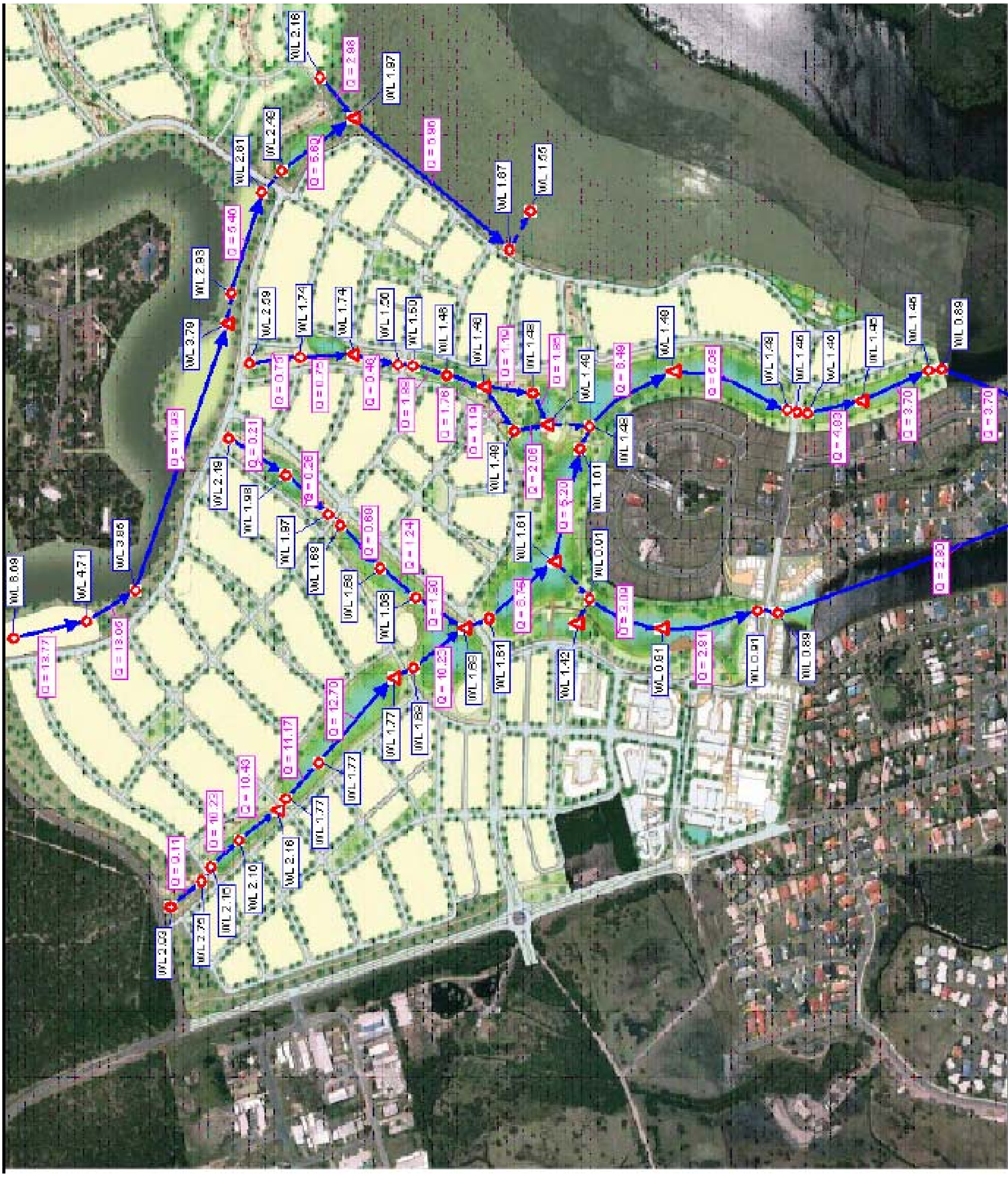


Figure 11
100 yr ARI Peak Flows and Flood Levels for 1.5 hour Storm Burst – Scheme 5

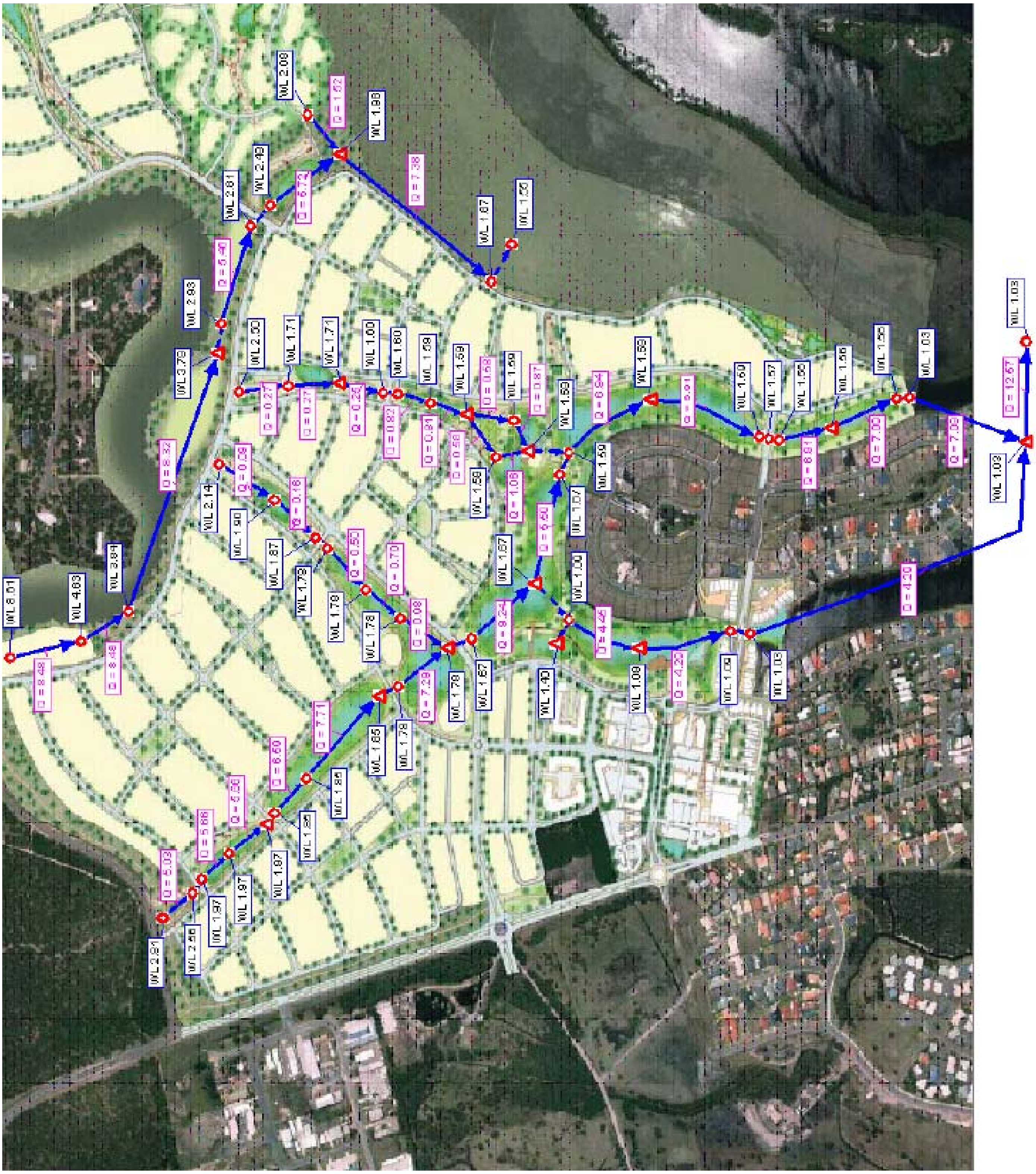


Figure 12
100 yr ARI Peak Flows and Flood Levels for 9 hour Storm Burst – Scheme 5

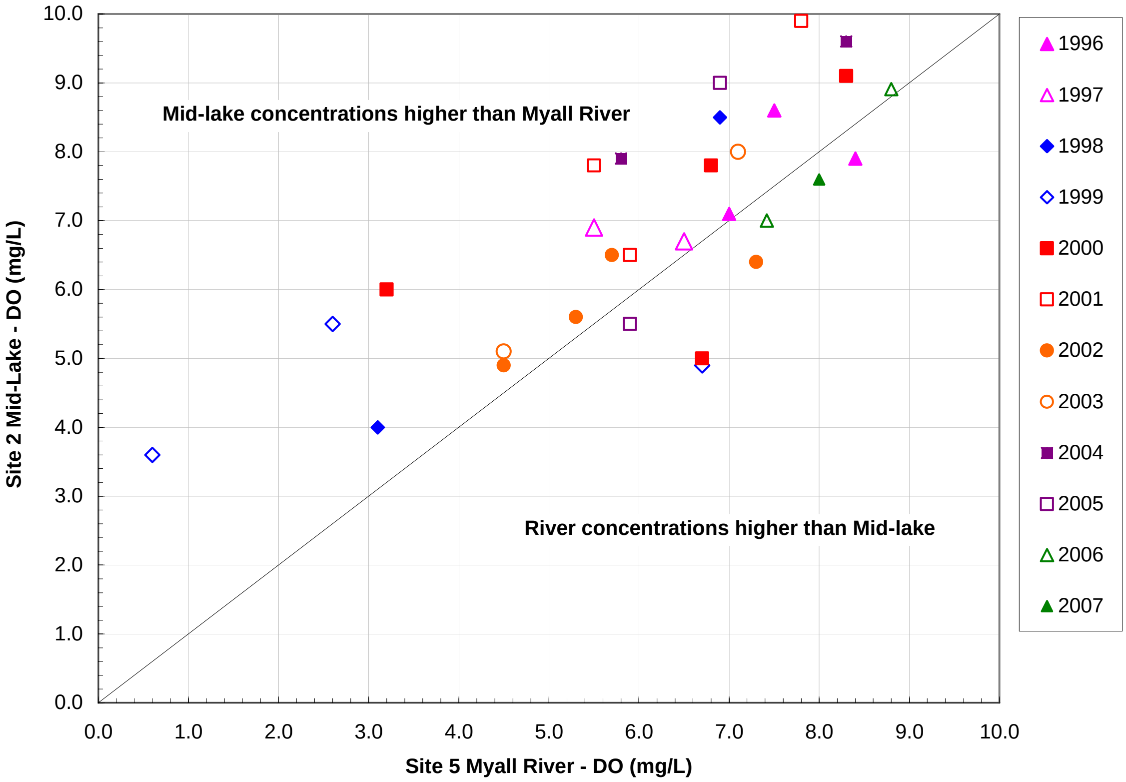


Figure 13
Comparison of DO Levels in the Existing Lake and the Myall River

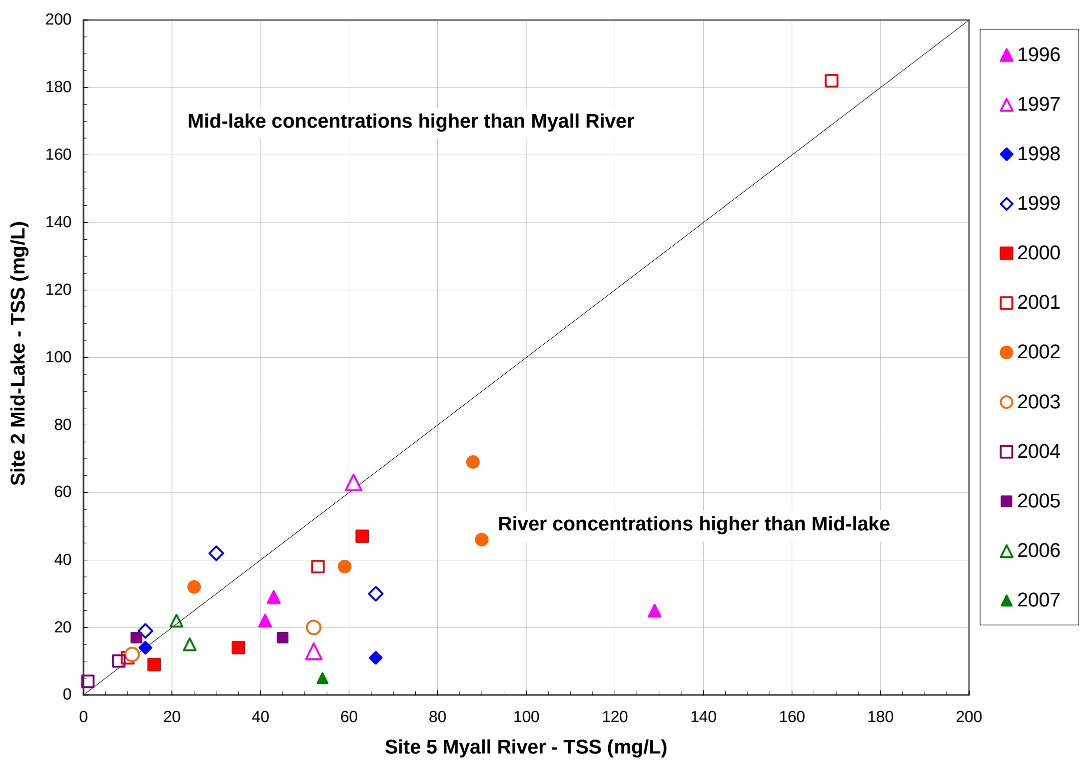


Figure 14
Comparison of TSS Levels in the Existing Lake and the Myall River

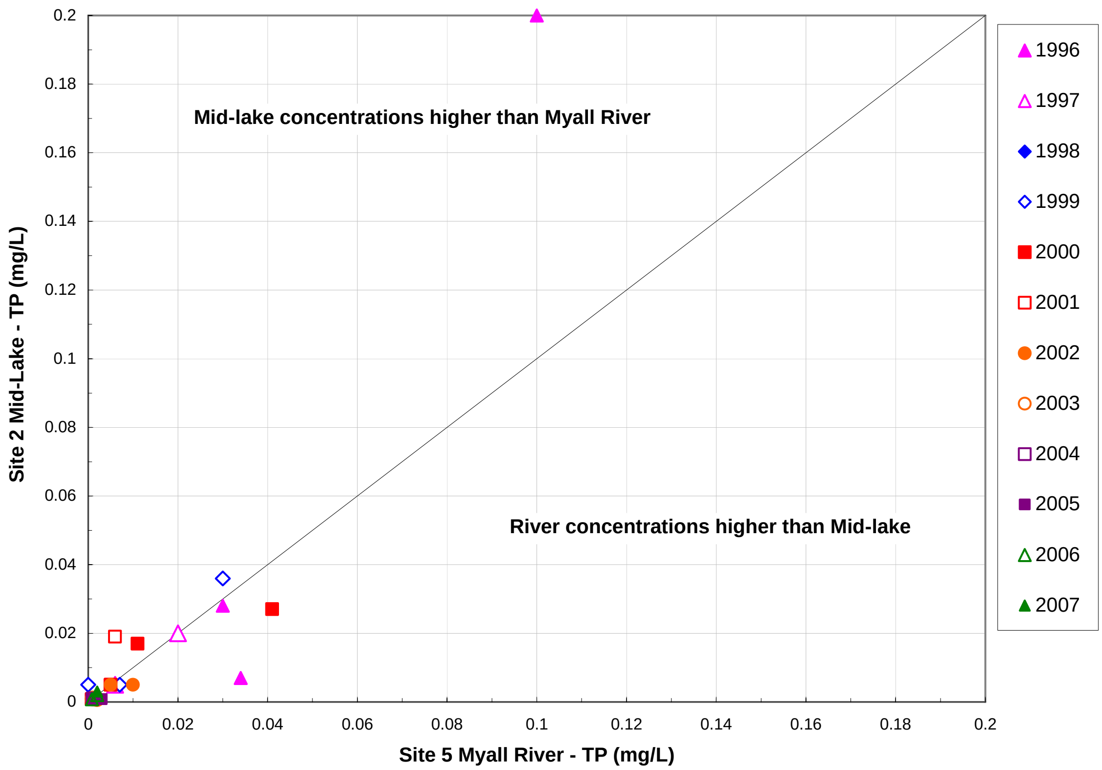


Figure 15
Comparison of TP Levels in the Existing Lake and the Myall River

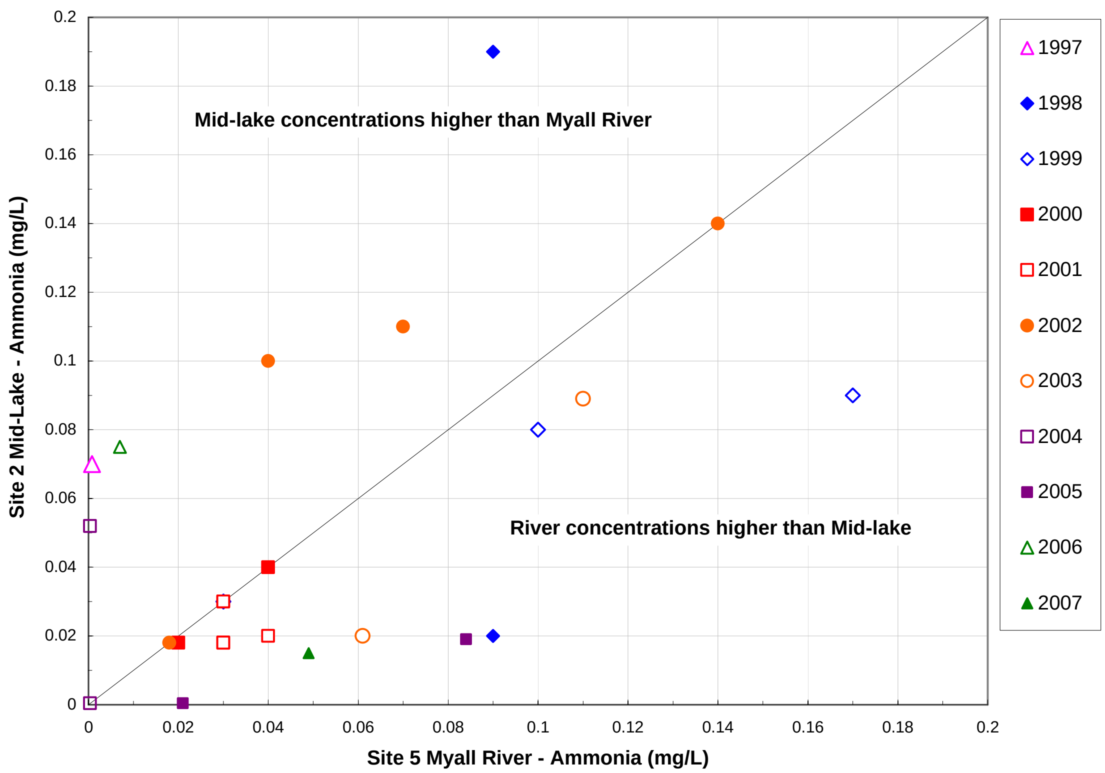


Figure 16
Comparison of Ammonia Levels in the Existing Lake and the Myall River