GEORGES RIVER MARINA, MOOREBANK

AQUATIC ECOLOGY ASPECTS &
ENVIRONMENTAL ASSESSMENT
OF MARINA CONCEPT DESIGN

Frontis: Portion of existing quarry, proposed to be adaptively re-used as a marina basin

REPORT PREPARED FOR
BENEDICT INDUSTRIES PTY LTD

MARINE POLLUTION RESEARCH PTY LTD
MARCH 2010

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1 INTRODUCTION

Benedict Industries Pty Ltd own and operate a sand and gravel quarry at Moorebank, south of Newbridge Road and immediately adjacent to the Georges River. The use of the site for this purpose is nearing completion and the company now propose to redevelop the site to incorporate a marina, using the remaining quarry excavation as the basis for a marina basin. The remainder of the site would be developed for residential and commercial purposes and the foreshore would be remediated as riparian public parkland.

Marine Pollution Research Pty Ltd (MPR) has been commissioned to provide an aquatic ecology assessment report for the marina proposal. For this purpose MPR has been supplied with a copy of the Michael Fountain Preliminary Marina Concept Design and an Environmental Assessment by WorleyParsons (2010) which provide design details of the marina proposal and evaluates the impacts of the adopted design on river processes, flooding and water quality.

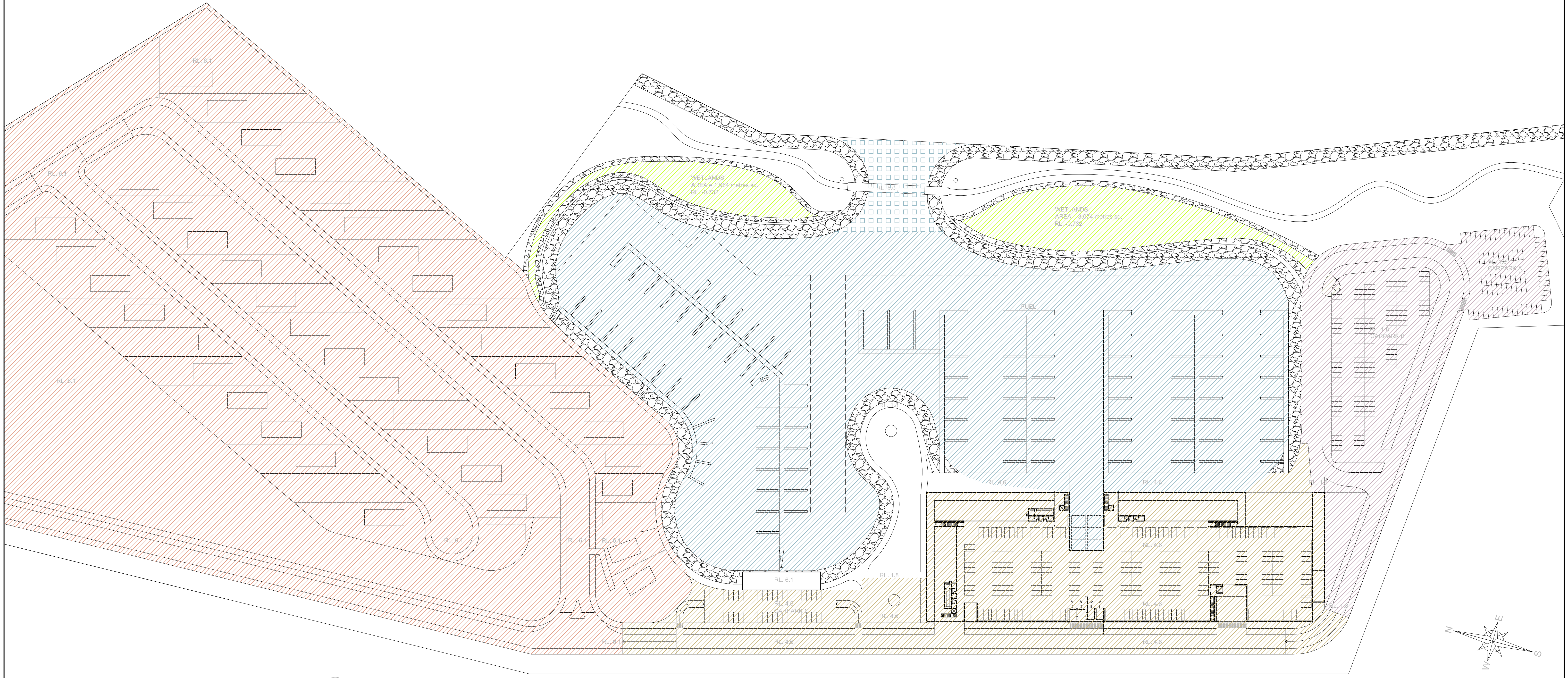
1.1 Site Overview

Figure 1 provides an aerial view of the Benedict Sands site in its locality:

- The site is located along the western bank of the Georges River downstream of the Milperra Bridge.
- There are residential and commercial developments existing, under construction or under consideration to the west of the site at Moorebank, to the north at Chipping Norton and distantly across the river to the east.
- There is a strip of riparian land along the site bank that runs north to the Davy Robinson Park public boat ramp and south down to Harris Creek, almost 2 km downstream.
- There is an unnamed creek draining to Georges River located alongside the site southern boundary and there is a constructed earthen stormwater channel along the western boundary that discharges to the unnamed creek.

Figure 2 provides the Micheal Fountain Architects Site Plan for the marina and adjacent housing development proposed for the Benedict Site. Comparison of the current state of the existing site in Figure 1 with the proposal in Figure 2 indicates that the formation of the proposed marina basin and the hardstand areas for the marina infrastructure will require considerable earthmoving activities, all wholly contained within the existing disturbed site. Construction of the outer part of the entrance channel and Georges River foreshore rock protection will occur in the riparian zone of the Georges River.

FIGURE 1
BENEDICT SANDS SITE SHOWING EXISTING QUARRY EXCAVATION



01 Site Plan - Ground Level
1: 2000

Legend

		Level	Area
	Northern Carpark & Surrounds	RL. 4.6	4,157 m sq
	Dry Store & Surrounds	RL. 4.6	17,714 m sq
	Southern Carpark & Roads	RL. 1.8	12,282 m sq
	Wetlands	RL. -0.732	5,038 m sq
	Marina Basin	RL. -2.932	45,079 m sq
	Entrance to Basin	RL. -2.932	1,853 m sq
	Residential Development	RL. 6.1	

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ISSUE	REV	AMENDMENTS	DATE
A		Issue to Client	23.02.10
B		Issue to Client	10.03.10

ISSUE	REV	AMENDMENTS	DATE

CLIENT
Benedict Industries Pty. Ltd.

PROJECT
Moorebank Marina
Newbridge Road
Moorebank NSW 2170

PRINTED: Mar 10, 2010 - 9:14am
P:\MOOREBANK MARINA\Cadwork\Drawings\SK-001- Site Plan- CURRENT.dwg

DRAWING
Site Plan - Diagram
Flood Area Calculations

DRAWN	CHKD	APPROVED
MF		
SCALE: 1 : 2000 @ A3	DATE: 27- 11- 09	CAD FILE No

JOB NO: 0914
DRAWING NO: SK- 100
ISSUE: B

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2 ASSESSMENT METHODS

In order to assess the possible impact on aquatic ecology of the proposal, the following tasks were undertaken:

- A review of literature regarding the aquatic ecology of the locality including a consideration of the potential for threatened and protected species to utilise the site. The results are incorporated into the aquatic ecology assessment.
- A review of water quality monitoring conducted at the Benedict Sands site and in the Georges River within the locality.
- Field studies of the aquatic ecological attributes of the site and surrounds.

Aquatic ecology field investigations have been undertaken by MPR staff over the following periods:

- A preliminary survey to ascertain the aquatic ecology of the Georges River boundary intertidal zone for a Constraints and Opportunities study was carried out on 11 August 2004.
- Following initial concept design production in early 2007 a further, more detailed survey of the site aquatic ecology habitats was undertaken on 30 April 2007. This survey was undertaken in the company of Surveyor Robert Ward from Matthew Freeburn Surveyors who provided a plan plus bank profiles for the site that indicated the location of intertidal vegetation (mangroves) plus the location of riparian trees (see Appendix A for full survey plans). Figure 3 indicates the locations of mangroves and seagrass patches at the site.
- A follow up aquatic ecology survey of the internal pond at the Benedict Site was undertaken on 30 May 2007. This survey included physical water quality profiles of the pond at various locations. Figure 3 shows the locations of sites where water quality profiles were made and also shows spot depths in the pools.

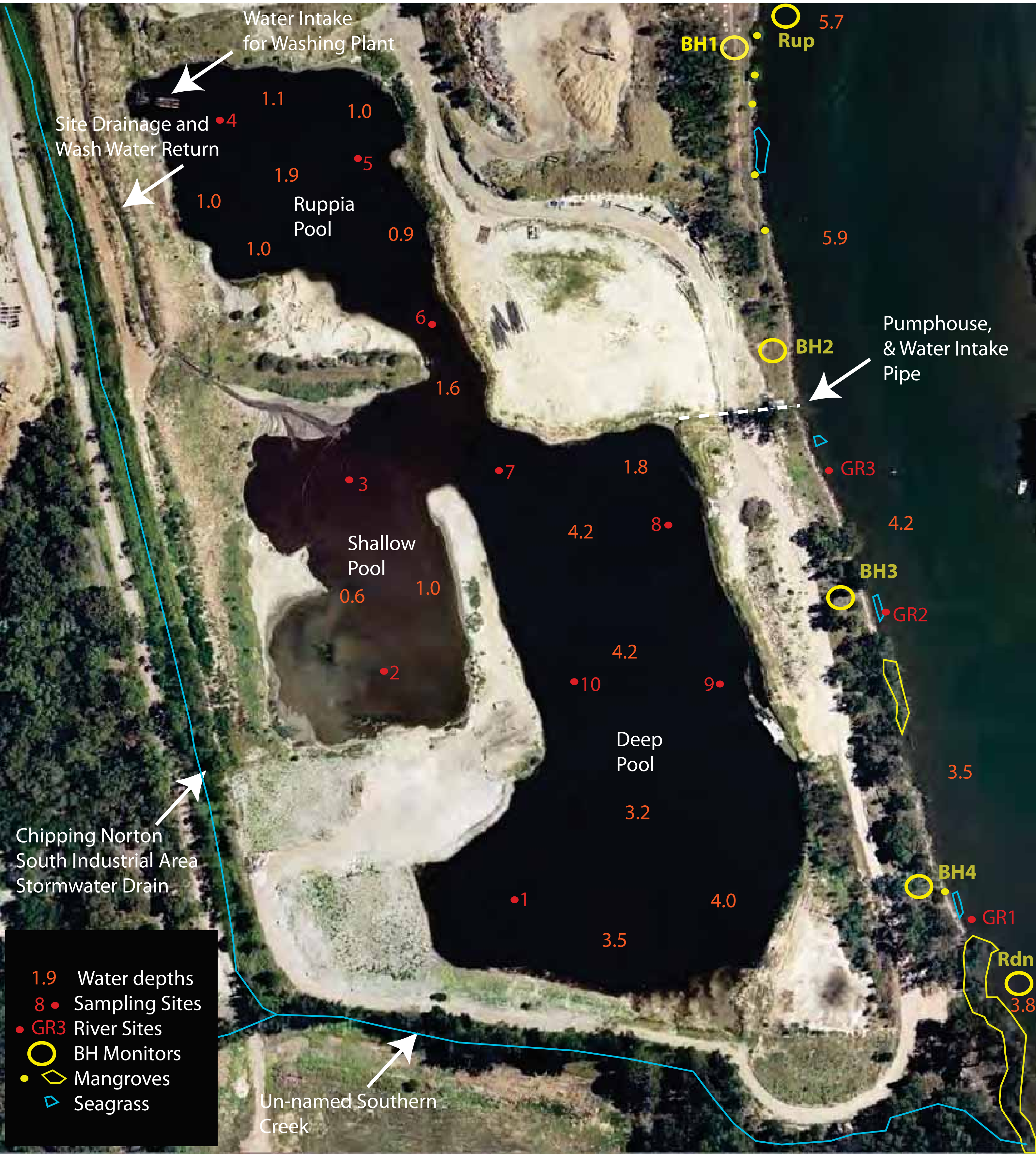

FIGURE 3 GEORGES RIVER MARINA SITE AQUATIC HABITATS & SAMPLING SITES

3 MARINA SITE AQUATIC ECOLOGY

Figure 3 provides an aerial view of the existing proposed marina site and shows details of aquatic habitats/quarry pool features plus the location of sampling sites for water quality profiles.

The aquatic habitats of the site can be separated into three distinct systems:

- The internal quarry pond system that is connected to the Georges River via an overflow pipe.
- The stormwater drain plus un-named southern creek system that drains to Georges River at the south end of the property and has no hydraulic connection to the quarry.
- The Georges River.

The hydrodynamic and water quality features of these systems are presented in Section 3.1 below followed by a consideration of the existing water quality interrelation of the quarry pond and Georges River (Section 3.2). Section 3.3 then provides a description of the resultant aquatic ecology of the system.

3.1 Existing Quarry Pond Hydrodynamics

The existing quarry comprises three pool sections and Figure 3 shows the relative pond depths for each of the pools. The aquatic ecology of the existing quarry is a function of the water volume and quality of the ponds and the water volume and quality are determined to a large degree by the hydraulic relationship between the three ponds and the surface plus groundwater relationships of the quarry to the Georges River.

With regard to groundwater connection between the quarry and the Georges River, Dames and Moore (1994) described the riparian bank of the Georges River at the quarry and between the quarry and the river as “a sequence of silty and sandy alluvial sediments with thin gravels, overlaying shale bedrock. The thickness of the sediments ranged from 11 to 17 m thinning towards the north and west” (p 1).

Dames and Moore (1994) installed six monitoring wells in August 1994, four along the riparian buffer land between the quarry and the river (BH1 to BH4 in Figure 3), one well on the western side of the quarry and one well at the northern end of the quarry 15 m from the tidal channel of a ‘northern creek’ that now no longer exists at the site. The riparian buffer sites (Bores BH1 to BH4) are all located within 10 m of the river. Medium and coarse sands predominate and measured permeability ranged from 12 to 47 m/day averaging 30 m/day. Groundwater levels in the wells were closely correlated with, and slightly above, the river tidal levels. Dames and Moore (1994) inferred that there was an overall flow of groundwater in a south-easterly direction towards the Georges River and the un-named Southern Creek.   They concluded that groundwater flows in the zone adjacent to the river were likely to be influenced by intrusion of brackish/saline river water at depth in the aquifer with fresh water flows towards the river concentrated in the shallow zone above approximately 5 to 6 m depth (p5).

Hydraulic relationships are described as follows:

- There is a water uptake pump located in the north-west corner of the ‘Ruppia’ Pool that extracts water from the quarry ponds, to be used for the Benedict sand wash plant (see Figures 1 and 3).
- Site runoff water and return water from the sand/gravel washing plant is drained into the north-west corner of the “Shallow Pool” (see Figure 3). Floating material in the return water is constrained to some degree by a surface boom across the shallow pool, whilst the remaining return water flows under the boom and drains/mixes into the other two pools. The ‘Deep Pool’ acts as a stilling basin and vertical mixing would be facilitated by local wind action.
- There is a pump-house on the riparian shore near the northeast corner of the Deep Pool that extracts water from the Georges River to ‘top up’ the water in the quarry ponds (See Figure 3).

The requirement for top up water from the river varies, depending on a number of factors including:

- Evaporative losses from on-site water usage (for dust suppression and in the washing plant).
- Climate variation, which balances natural evaporative losses against rainwater gains.
- Water loss via infiltration from the pools to the sandy sediments of the surrounding land, with a net groundwater drainage to Georges River (as described above).

As a result of the dynamic mixing of runoff, direct rainfall and Georges River waters, the quarry waters are brackish and the level of the waters in the ponds is variable but not in any regular way.

3.2 Water Quality Relationships Georges River and Quarry Ponds

As noted in Section 3.1 above, there are no direct hydraulic connections between the Chipping Norton stormwater drain to the west of the Benedict Sands site and the quarry and the only connection between the quarry and the Georges River is the makeup water pump for pumping Georges River water into the quarry when the quarry water level is low.

3.2.1 Georges River

The Benedict site is located towards the top of the estuarine portion of the Georges River and the river at this location carries stormwater runoff from highly urbanised sub-catchments upstream including wet weather sewage discharges from three Sewage Treatment Plants (STPs) ; Glenfield, Liverpool and Fairfield STPs.

Sydney Water (2007) provided a summary of sewage overflow volumes to the Georges River from key sewage overflow points between 1996 and 2005 (Table 1):

Table 1 Sewage Discharge Volumes to the Georges River from key overflow points above Milperra between 1996 and 2005

Year	Sewage Discharge Volume (ML/yr)			
Discharge Site	Glenfield	Fairfield	Chipping Norton	Total Discharge
96–97	214	486	714	1414
97–98	38	348	362	748
98–99	595	933	1,428	2956
99–00	68	411	902	1381
00–01	24	411	1,924	2359
01–02	230	706	3,051	3987
02–03	70	460	1,699	2229
03–04	0	72	1,001	1073
04–05	92	284	693	1069
Minimum	0	72	362	748
Maximum	595	933	3051	3987
Mean	148	457	1308	1913
Median	70	411	1001	1414

- The lowest total sewage discharges over the period occurred in 1997-1998 and 2003-2004, both dry years, and thus with fewer wet weather sewage overflows.
- Individual discharge volumes at Glenfield and Fairfield were lowest in 2003-2004 and 1997 to 1998 for Chipping Norton.

Sydney Water (1998) stormwater overflow EIS assessed the water and sediment quality of Georges River immediately downstream of the Chipping Norton Effluent Diversion Scheme overflow. This overflow discharges treated effluent from the NGRS. The river downstream of overflow is tidal and approximately 3-4 m deep. Sediments are predominantly composed of mud and muddy sand. Low dissolved oxygen concentrations during storm events have been observed downstream of this site. During large storm events, this reach of the river changes from saline to freshwater, but this is more likely attributable to stormwater flows, not overflows.

Ecological Risk Assessment for the estuarine section of the Georges River downstream of Chipping Norton sewerage overflow showed that there was potential risk to aquatic life from exposure to chemicals in sewer overflow and stormwater. Twenty-five chemicals were identified as COPCs following chronic exposures and 5 COPCs were identified for acute exposures. Detailed risk evaluation indicated that processes such as degradation and the settling of particle bound chemicals reduced the number of chemicals of potential concern. However risks were still predicted from 3 acute COPCs and 9 chronic COPCs.

Comparing potential risks from all sources (i.e., sewer overflows and stormwater) to potential risks from stormwater only, indicated that the potential risk to aquatic life at this site appeared to come from stormwater. In summary, the Risk Assessment made the following conclusions:

- Ammonia, the only chemical associated with sewerage overflows, posed only negligible risk because it exceeded toxicity thresholds for only a few days of the 10 years modelled.
- The risk evaluation also showed some potential risk to aquatic life from suspended particles, largely brought in by stormwater.
- Potential risks from low dissolved oxygen may occur, although both stormwater and sewer overflows contribute to these risks.
- Localised scouring of benthic habitat from overflows was possible at the overflow site, but this scour was assessed to be minor in comparison to general benthic habitat scour caused by stormwater flows.
- Some loss of intertidal organisms from stormwater inputs is expected since estuaries are dynamic systems that typically experience fluctuations due to salinity changes.

In practice, Sydney Water (1998) found that whilst preliminary sampling of sediments undertaken in 1996 identified arsenic, cadmium, chromium, copper, iron, nickel, lead, zinc, a & b-BHC, endosulphan, DDT, Chlordane, chloropyrifos as chemicals of potential concern, no toxicity was found in a sediment bioassay taken downstream of the overflow.

Table 2 Water Quality data at Chipping Norton Lakes (In River - Channel and in Lakes - Grand Flaneur Beach)

Site/Date	Time	Field Notes	Cond mS/cm	Turb NTU	Tot Phos ppm	DO % sat
		River Channel				
10/03/03	1400		21.0			87.9
21/03/03	0930		13.9			77.6
14/05/03	1130	Heavy rain for 3 previous days	0.5	57	0.03	77.4
13/10/03	1016	100% cloud, recent rain, SE breeze	14.7	8	0.02	90.9
17/12/03	1500	low tide, onshore breeze, choppy water	8.4			87.3
29/04/04	1425	low tide, recent rain, film on water, weed and rubbish present	4.8	23	0.12	82.5
13/05/04	1340	low tide, clear, dry weather, S breeze. No rain recently, slightly oily film	10.0	10	0.08	95.2
3/06/04	0955	high tide, recent light rain, samll amounts of foam & film on water. 90% overcast, little or no wind	17.8	6	0.05	77.3
10/08/04	1430	med/high tide, recent dry waether, fine and clear. Fresh SE breeze, very slight film	26.4	8	0.06	91.3
Minimum			0.5	6	0.02	77.3
Maximum			26.4	57	0.12	95.2
Mean			13.06	18.67	0.06	85.27
Standard Error of Mean			2.70	8.07	0.01	2.27
		Grand Flaneur Beach				
10/03/03	1415		20.7			88.3
21/03/03	0945		13.6			89.8
14/05/03	1140	heavy rain for 3 days previously	0.0	56	0.08	96.4
13/10/03	1039	100% cloud, recent rain, SE breeze	14.5	11	0.02	95.2
17/12/03	1500	low tide, onshore breeze, choppy water	8.3			110.0
29/04/04	1500	low tide, recent rain, weed and rubbish present	4.1	29	0.07	98.1
13/05/04	1400	low tide, clear, dry weather, S breeze. No rain recently, no film	9.5	10	0.06	92.4
3/06/04	1020	high tide, recent light rain, samll amounts of foam & film on water. 90% overcast. Little or no wind	15.9	14	0.02	86.3
10/08/04	1445	med/high tide, recent dry weather, fine and clear, fresh SE breezes	26.1	9	0.04	91.0
Minimum			0.0	9	0.02	86.3
Maximum			26.1	56	0.08	110.0
Mean			12.52	21.50	0.05	94.17
Standard Error of Mean			2.69	7.53	0.01	2.36

Note* Data from Georges River Environmental Education Centre via http://www.georgesriv-e.schools.nsw.edu.au/index.htm

Further, a survey of benthic organisms showed no difference between the aquatic communities upstream and downstream of the overflow discharge (although both communities appeared stressed), which suggested that overflows were not having a significant impact on sediments.

The Georges River Environmental Education Centre had river water quality data available for 2003 to 2004, from the river upstream of Milperra Bridge (in the vicinity of the key sewage discharge overflow point at Chipping Norton (see above). These data are shown in Table 2 above, and the results are summarised as follows:

- Water conductivity was very low during rainfall periods indicating large volumes of freshwater flow. Mean values for the two data sets were around 12 to 13 mS/cm indicating generally brackish waters at other times.
- Total Phosphorus was elevated and variable, with mean values around 0.05 to 0.06 ppm. There was no real correlation with rainfall but there was some correlation with tide (at least during dry weather); concentrations during medium to high tides were lower than concentrations during low tides.
- Dissolved oxygen values (expressed as % saturation) were generally reasonable, meeting the ANZECC (2000) guideline criteria (80 to during dry weather and just under the low criteria during wet weather.
- Turbidity was around 56 NTU during wet weather events. Mean turbidity was around 18 to 21 NTU. These values are generally close to the ANZECC (2000) upper range criteria of 6 to 50 NTU for low-land rivers but well above the criteria for estuaries and marine waters (0.5 to 10 NTU).

With regard to other turbidity criteria for the river in the immediate vicinity of the proposed marina, the SPCC Botany Bay project (SPCC 1979) collected water turbidity data from 0.5 m depth at two sites upper estuary sites over two extended periods, 2 May to 3 June 1977 (21 days) and 30 Nov 77 to Jan 78 (18 samples). The range of results (expressed as NTU) was as follows:

- First period Milperra 1.8 to 42 NTU, East Hills 1.4 to 26 NTU.
- Second period Milperra 1.8 to 13 NTU, East Hills 1.5 to 15 NTU

ANZECC (2000) notes that turbidity expressed as NTU is generally lineally correlated with suspended solids expressed as NFR (or TSS), at least on a local scale, and the relationship can be established by regression (see also SPCC 1979).

Figure 4 shows the regression relationship of NFR to NTU for available Georges River data. The correlation coefficient r^2 value is 0.9, which indicates a good fit.

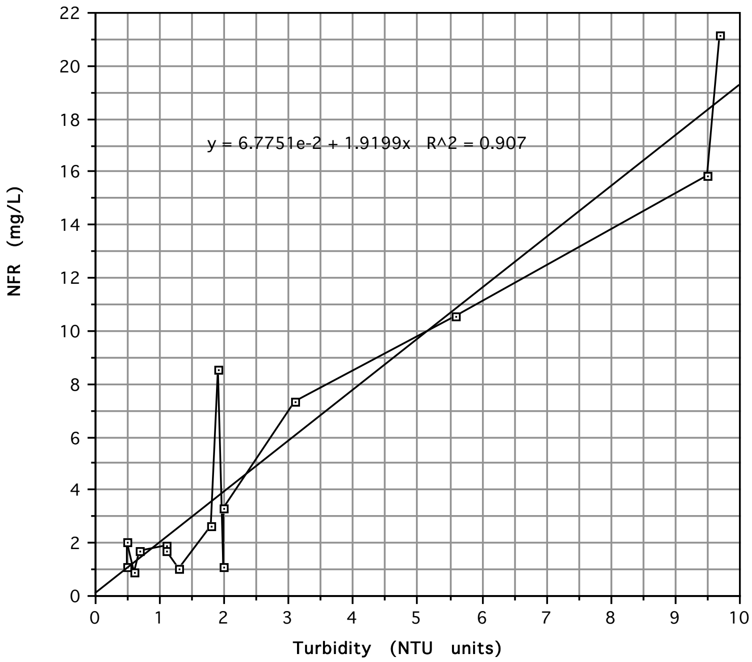

Figure 4 Relationship between Turbidity (NTU) and Suspended Solids Concentrations (TFR) for Georges River data at Milperra (data from SPCC 1979).

Using this correlation, and applying it to the 2003-2004 Milperra data, the turbidity of around 56 NTU during wet weather events would correlate with more than 100 mg/L Total Suspended Solids TSS (or Non Filterable Residue NFR). Mean turbidity around 18 to 21 NTU, relates to around 40 mg/L TSS.

3.2.2 Site Water Quality Data

As described in Section 3.1, Dames and Moore (1994) installed four monitoring wells along the riparian buffer land between the quarry and the river (BH1 to BH4 in Figure 3), all located within 10 m of the river. These sites plus two sites in the Georges River (sites Rup and Rdn in Figure 3) and a site in the Deep Pool (site 8 in Figure 3) were monitored at around monthly intervals for the time that the quarry was active. Table 3 provides summary statistics for the available data collected over the 2006 sampling period. The results are interpreted as follows:

- Acidity, expressed as pH units met ANZECC guideline values for the pond and river samples but was low for the groundwater bore samples possibly indicating some Acid Sulphate Soil activity in the buffer sands.

Table 3 Summary Statistics for Water Quality Results from 2006 Sampling Program*

Analyte**	Units	Detect Limit	ANZECC Limit***	Site	N	Min	Max	Mean	SE
pH	pH units		7 - 8.5	Pond	12	6.8	8.7	7.9	0.16
pH				Bank	48	3.2	6.3	5.0	0.14
pH				River	24	6.5	7.6	7.3	0.06
Cond	μS/cm			Pond	4	7200	14800	11250	1571
Cond				Bank	16	5400	14600	10038	695
Cond				River	8	8700	21000	16488	1771
TDS	mg/L			Pond	4	7300	9600	8450	608.96
TDS				Bank	16	4700	10000	7438	441.10
TDS				River	8	9600	14000	11950	562.84
Alkalinity	mg/L	< 0.1		Pond	4	110	140	122.5	7.50
Alkalinity				Bank	16	0.05	150	32.6	11.86
Alkalinity				River	8	65	95	75.1	3.41
TOC	mg/L			Pond	4	16	30	24.3	2.95
TOC				Bank	16	4	29	13.1	1.42
TOC				River	8	2	7	3.8	0.56
NH4-N	mg/L	<0.1	0.015	Pond	4	0.042	0.2	0.086	0.04
NH4-N				Bank	16	0.64	3.8	1.475	0.23
NH4-N				River	8	0.044	0.05	0.049	0.00
NOx	mg/L	<0.005	0.015	Pond	4	0.0025	0.43	0.133	0.10
NOx				Bank	22	0.0025	0.22	0.057	0.01
NOx				River	8	0.031	0.62	0.244	0.07
Al	mg/L	< 0.1	0.055	Pond	2	0.05	0.2	0.13	0.08
Al				Bank	8	0.05	65	17.67	9.84
Al				River	4	0.05	0.05	0.05	0.00
Cu	mg/L	<0.01	0.0014	Pond	3	0.005	0.005	0.005	0.00
Cu				Bank	12	0.005	0.1	0.023	0.01
Cu				River	6	0.005	0.005	0.005	0.00
Fe	mg/L	<0.02		Pond	2	0.05	0.22	0.14	0.09
Fe				Bank	8	22	230	87.38	26.22
Fe				River	4	0.01	0.36	0.12	0.08
Mn	mg/L		1.9	Pond	4	0.04	0.15	0.09	0.02
Mn				Bank	16	0.7	4.4	1.78	0.25
Mn				River	8	0.02	0.06	0.04	0.01
Pb	mg/L	<0.01	0.0044	Pond	3	0.005	0.015	0.012	0.00
Pb				Bank	12	0.005	0.07	0.019	0.00
Pb				River	6	0.005	0.015	0.012	0.00
Zn	mg/L	<0.02	0.015	Pond	0	0	0	0.000	0.00
Zn				Bank	10	0.03	0.3	0.119	0.03
Zn				River	2	0.01	0.01	0.010	0.00

Notes:
* Pond = single dredge pond site, Bank = 4 bore sites on riverbank,
and River = two river edge sites
** All other analytes (As, Ba, Cd, Cr, Hg, Se, TPH, OC pesticides, PAH & Phenols) were below
detection or non-significant at all sites and at all times (30 Mar, 4 May, 13 Jul and 25 Oct).
*** ANZECC (2000) limits for protection of 95% aquatic biota.

This conclusion is strengthened when the aluminium results are considered, as the river concentrations are below the ANZECC (2000) criteria of 0.08 mg/L for protection of 90% of aquatic species, the pond values are just above the ANZECC values and the bore-waters values are well in excess of the criteria (mean 17.67 mg/L) possibly indicating residual potential acid sulfate soils (PASS) within the land between the river and the quarry. The same trends are shown for the iron data with similar mean values for river and pond waters and highly elevated values for the bore waters.

- The conductivity data indicate that the waters are brackish, with the Georges River marginally more saline than the pond waters and the bore-waters marginally more fresh than the pond waters.
- Whilst there are no TSS or turbidity data there are Total Dissolved Solids (TDS) data. These data indicate that the pond and bore waters are marginally less turbid than the river waters.
- Total organic carbon (TOC) shows a six-fold decrease from pond waters (mean 24.3 mg/L) to river waters (mean 3.8 mg/L). The bore water mean was 13.1 mg/L.
- Mean concentrations of nitrogenous compounds (Nntrogen oxides NOx and ammonia NH4-N) were all elevated with regard to ANZECC (2000) criteria for lowland river and estuarine waters. For both compounds the bore waters had the highest concentrations, with the pond waters just under double the river concentrations.
- For most metal comparisons the bore-waters were elevated with respect to river and pond values and the pond values were generally similar to or marginally higher than the river values. It should also be noted that for most of the metal results the detection limits for analytsis are higher than the ANZECC (2000) criteria for protection of aquatic life:
- Lead, Copper and Zinc concentrations were below or near detection in river and pond waters, with elevated mean values in bore waters; 0.019 mg/L, 0.023 mg/L, 0.119 mg/L respectively.

The pond results from the Benedict Sands monitoring program were based on samples taken from a single depth (generally around 0.5 m depth) and a question remained as to whether the results would be representative of the total pond waters. That is, are the waters of the ponds sufficiently well mixed? Given the size of the pond system and its exposure to wind mixing, the initiative answer was that the waters would be well mixed, and this was tested by undertaking a series of water quality profile measurements throughout the three ponds and in the adjacent river shallows on 28 May 2007. Results are shown in Table 4 below.

Table 4 Benedict Sands Water Quality Profiles 28 May 2007											
Site	Pool Location	Time	Depth m	Bottom Depth	Temp C	Cond us/cm	Sal ppt	DO %sat	DO mg/l	pH pH	Turb NTU
4	NW Ruppia	12:45:39	0.1		16.33	7252	7.63	66.7	6.3	7.89	0.1
4		12:46:07	0.5		15.68	7359	7.58	64.5	6.1	7.84	0.5
4		12:46:27	1.0		15.16	7448	7.57	64.0	6.1	7.85	1.5
4		12:46:45	1.6	1.8	15.09	7459	7.58	63.5	6.1	7.85	1.5
5	E Ruppia	12:50:11	0.1		17.02	7139	7.57	47.6	4.4	7.60	3.2
5		12:50:47	0.6	1.3	15.11	7451	7.57	55.7	5.4	7.89	3.2
6	S Ruppia	13:01:53	0.1		16.78	7181	7.59	37.2	3.5	7.49	6.7
6		13:02:28	0.5		15.71	7360	7.57	21.2	2.0	7.35	16.6
6		13:03:07	1.0		15.58	7383	7.56	13.9	1.3	7.32	20.3
6		13:05:16	1.5	1.9	15.57	7388	7.56	15.3	1.5	7.33	151.0
3	N Shallow	12:34:16	0.1		16.59	7208	7.61	26.1	2.4	7.40	15.0
3		12:34:41	0.5		16.07	7296	7.57	22.0	2.1	7.35	87.9
3		12:35:05	1.0		15.67	7363	7.54	21.8	2.1	7.37	286.2
3		12:36:04	1.8	2	15.71	7360	7.54	22.6	2.1	7.37	519.5
2	S Shallow	12:19:36	0.1		15.83	7336	7.49	46.5	4.4	7.57	10.2
2		12:19:52	0.4	0.6	15.61	7370	7.49	47.3	4.5	7.60	17.6
7	N Deep	13:08:52	0.1		16.49	7229	7.57	26.9	2.5	7.44	6.5
7		13:09:21	0.5		15.97	7315	7.57	25.9	2.4	7.45	8.5
7		13:09:55	1.0		15.76	7349	7.56	25.4	2.4	7.46	8.5
7		13:10:17	1.5		15.69	7363	7.56	25.1	2.4	7.44	12.3
7		13:10:49	2.0	2.2	15.67	7367	7.55	24.0	2.3	7.43	10.1
8	NE Deep	13:22:09	0.1		16.69	7191	7.57	29.0	2.7	7.45	6.8
8		13:22:56	1.0		16.18	7279	7.56	27.1	2.5	7.45	9.2
8		13:24:10	2.0		15.67	7369	7.55	22.5	2.1	7.42	12.6
8		13:25:05	2.5	2.8	15.64	7371	7.56	21.6	2.1	7.41	13.0
9	E Deep	13:29:33	0.1		17.04	7140	7.56	29.4	2.7	7.46	4.4
9		13:30:02	1.0		16.44	7235	7.55	27.3	2.5	7.45	4.3
9		13:30:41	2.0		15.67	7363	7.55	22.1	2.1	7.42	5.6
9		13:31:17	3.0		15.61	7374	7.55	22.8	2.2	7.44	8.2
9		13:31:56	3.8	4.1	15.59	7378	7.56	23.4	2.2	7.45	7.5
10	W Deep	13:48:59	0.1		17.05	7135	7.56	31.6	2.9	7.48	4.3
10		13:49:22	1.0		16.12	7284	7.56	29.8	2.8	7.48	6.7
10		13:49:46	2.0		15.66	7363	7.55	26.7	2.5	7.45	9.7
10		13:50:06	3.0		15.60	7375	7.55	25.4	2.4	7.46	10.1
10		13:50:17	3.5	3.8	15.57	7379	7.55	25.3	2.4	7.45	13.8
1	SW Deep	12:04:13	0.1		16.05	7302	7.67	28.6	2.7	7.45	10.1
1		12:05:02	0.5		15.79	7347	7.59	27.7	2.6	7.46	7.8
1		12:05:36	1.0		15.76	7351	7.58	27.5	2.6	7.46	7.8
1		12:06:20	2.0		15.70	7363	7.57	26.6	2.5	7.46	6.5
1		12:06:43	2.5	2.8	15.67	7369	7.56	26.4	2.5	7.45	7.7
GR3	N end	14:28:03	0.1		17.37	7090	5.23	54.8	5.1	7.33	3.1
GR3		14:28:32	0.3		17.30	7104	5.19	54.5	5.1	7.34	5.1
GR1	S end	14:15:20	0.1		17.25	7107	5.25	54.7	5.1	7.17	5.8
GR1		14:16:50	0.3		17.20	7124	5.23	54.2	5.1	7.34	5.1
Minimum					15.09	7090	5.19	13.9	1.3	7.17	0.1
Maximum					17.37	7459	7.67	66.7	6.3	7.89	519.5
Median					15.74	7355	7.56	27.0	2.5	7.45	7.8
Mean					16.04	7304	7.35	33.7	3.2	7.48	31.0
SE of Mean					0.0939	15	0.10	2.2	0.2	0.0239	13.5

Ten Benedict Sands pool sites were profiled (sites 1 to 10 in Figure 3) as well as two adjacent river sites (GR1 and GR3 on Figure 3). At the time of sampling the weather was dry and sunny, the washing plant was operational and therefore the inlet pump at the NW corner of the Ruppia Pool was operational and there was a return wash water stream discharging into the NW corner of the Shallow Pool (see Figure 3 for these locations).

The results of the survey shown in Table 4 have been ordered from north to south, i.e., from Site 4 closest to the wash water intake, to Site 1 in the SW corner of the Deep Pool. Results are summarised as follows:

- Adjacent Georges River waters were less brackish (5.23 ppt salinity) compared to quarry pond waters (median 7.6 ppt). Dissolved oxygen levels were higher than the pond waters (54.5 % saturation compared to Pond median of 27 % sat). Other parameter values (pH, turbidity and temperature) were similar to the quarry water values.
- There were very slight temperature and conductivity gradients for most deeper quarry pool sites but the differences were not sufficiently high to conclude that the quarry waters were uniformly (or deeply) stratified. That is, there would appear to be sufficient mixing available to ensure that no significant stratification takes place.
- The salinity of the three ponds was relatively uniform, both with depth and between pools. The pool waters were brackish (mean 7.56 ppt) and more saline than the corresponding river waters (mean 5.23 ppt).
- Dissolved oxygen (DO) concentrations was generally higher in the surface waters for most sites, corresponding to the observations of algae and debris floating on the surface of the Ruppia and Deep Pools (see Figures 5 and 6). The dissolved oxygen levels in the remaining water column decreased gradually with depth. At Site 6 there was a much larger decrease in DO with depth (surface 37 %sat, bottom 15% sat).
- The Ruppia pond sites had increasingly higher DO concentrations to the north reflecting the proliferation of a submerged aquatic plant (*Ruppia sp.)* growing in this pond (see Figure 7).
- The pH values were relatively uniform (range 7.2 to 7.9 pH units) with generally higher pH values in the surface waters and a very slight depth gradient.
- Turbidity (expressed as NTU) varied from very low (± 1.5 NTU) at site 4 to very high (519 NTU and 151 NTU in bottom waters at sites 3 and 6 respectively). For the remaining sites turbidity generally ranged between 7 and 13 NTU. All sites (bar Site 10) had increasing turbidity with depth.

Figure 5 View of Deep Pool looking north from Dredge showing flocculants and algae floating on surface (Photo 27 April 2007).

Figure 6 Same view of Deep Pool, looking south from Site 7 towards dredge and showing denser floating flocculants plus algae on pool surface (Photo 28 May 2007).

Figure 7 *Ruppia sp*. growing in Ruppia Pool (Photo May 2007).

A pattern of water movement and behaviour through the existing pond system can be inferred from the above data is as follows:

- Wash water intake (Site 4) had reasonable dissolved oxygen (DO) concentrations and low turbidity reflecting the proliferation of *Ruppia* in the pond that both generates oxygen and aids sediment settlement.
- Return waste wash water with very high turbidity and low DO is captured by the floating boom between the shore discharge and Site 3 and the ‘dirty’ water is forced to the bottom to flow under the boom. Consequently Site 3 profile shows very high turbidity and low DO in the bottom waters.
- Some of the waste water stream is directed to deeper waters east and little is retaining in the Shallow pond. Consequently Site 2 has relatively high DO and relatively low turbidity.
- The sub-surface wastewater stream that is directed into the deep pool, becomes buoyant and generally flows clockwise along the eastern bank of the pool, gradually mixing with the remaining waters (sites 7 to 8 to 9 to 1 to 10). The buoyant scum from the wastewater aid algae growth and there is a gradual increase in DO

concentrations around the pool. This mechanism is also probably mediated by prevailing winds with scum and algae forced towards the southern shore on the sampling day resulting in an inverted turbidity profile at site 1 compared to all other sites.

- Some of the sub-surface waste-water flow is pushed north into the Ruppia pool and the circulation is most probably constrained by both shallow depth and the Ruppia growth. Consequently there is an area of dead water at the mouth of the Ruppia Pool (at Site 6) which has the only distinct DO stratification (73 % surface, 15 % bottom).
- Most probably there is further mixing of the Deep Pool clockwise flowing waters with the wastewaters and a resultant mixed flow into the Ruppia poll, at least when the washing plant is operational and drawing water from the Ruppia Pool.

In summary, the combination of wash water intake and discharge sets up circulatory water currents that mediate water mixing throughout the quarry ponds. Overall quarry water is similar to adjacent river waters in terms of salinity; both are brackish, most probably due to the pumping in of make-up river water. With regard to supporting aquatic life, the quarry waters have relatively low dissolved oxygen concentrations but as the waters are fairly well mixed there are very few areas of 'dead water'. Consequently the quarry could be expected to support a reasonable diverse assemblage of aquatic biota – and generally the assemblage would be more marine than freshwater.

3.3 Aquatic Ecology of the Site

In the following sections the basic aquatic habitats of the study site are described. The site has been considered as three more or less distinct systems; (i) the quarry pond system, (ii) the stormwater drain plus un-named southern creek system bounding the quarry to the west and south, and (iii) the adjacent river and river bank bounding the quarry ponds to the east.

Additional information on the riparian habitats of the Benedict site are available in a flora and fauna report (Total Earth Care 2006).

3.3.1 Existing Quarry Pond Habitats

The three quarry pond habitats comprise the benthic sediment habitat of each of the ponds, the pond water bodies and the pond riparian edges. Figures 8 and 9 provide panoramic views across the Deep Pool and the Shallow Pool, and Figures 10 to 14 provide various views of the quarry pool aquatic habitats (discussed below).

Figure 8 Panorama view of Deep Pool from the bank just north of the Dredge, looking north (along right edge) and south (along edge of dredge). Most of the pool edges are steep. Figure 10 (below) shows the remainder of the deep pond to the south-west (obscured by the dredge).

Figure 9 Panorama view of Shallow Pool in foreground and Deep Pool in background from the west looking south (along right edge) and north (along left edge). The return wash -water drain can be seen in the left hand corner of the Shallow Pool with the floating boom located off-shore from the discharge.

Figure 10 South-west corner of Deep Pool looking west from Dredge, and showing various emergent and bank plants.

Figure 11 Sand spit on west side of Deep pool looking south-west.

Figure 12 Bittou Bush and *Phragmites australis* growing on Deep Pool bank.

At the time of survey, active dredging in the ponds had ceased some 2 years previously (in 2005) and pumping for make up water for evaporative losses only occurs once every 2 to 3 months during prolonged droughts.

Whilst the ponds are brackish, they are not tidal, and the water levels in the ponds vary inconsistently, as a result of the interaction of a variety of climatic mechanisms, (rainfall, air pressure, wind pressure, evaporation due sunshine) and as a result of quarry washing plant operations (wash water draw down and wash water return plus river make up water).

The southern Deep Pool has depths varying from 1.8 m inshore to 4.2 in the centre of the pond. The bottom is firm and is generally sandy to silty sand. Presumably owing to the depth, there was no submerged aquatic vegetation found in the deep pond, but at the time of field studies there was a film of floating flocculants and algae over the surface of the deep pond (see Figures 5 and 6). The edges of the Deep Pool are generally steep (see Figures 8 and 10) and there is minimal slumping. The cleared and disturbed riparian edge vegetation comprises various grass and weed species, with scattered Sydney Green Wattle saplings and, where there is sufficient shallow slumped sediment, there are patches of emergent reeds (*Phragmites australis*).

Figure 13 View of Shallow pond looking north-west from sand spit with quarry wash water runoff in background (behind floating boom). Sand spit supports a variety of saltmarsh species.

Figure 14 Sand spit on east side of Shallow pool looking towards *Ruppia* Pond.

Other than *Phragmites*, there are scattered saltmarsh plants amongst the riparian grasses, mainly New Zealand Spinach. There are also isolated stands of Bittou Bush (see Figure 12).

The Deep pool is separated from the Shallow Pool by a constructed sand spit (see plan view in Figure 3 and various ground views in Figures 11, 13 and 14. The upper half of the sand spit comprises loose coarse sand and supports scattered terrestrial weed species (see Figure 11). The outer portion of the sand spit is much lower to the water and consequently it would be inundated from time to time. As a consequence the lower sand spit supports small and isolated clumps of saltmarsh species (Figures 13 and 14). Plants observed included several species of Atriplex, some Sarcocornia, Austral Seablight and Club Rush. These plants are commonly found on the edges of brackish water ponds and the intermittency of the inundation was evident in that there were also areas of dead saltmarsh plants observed.

The shallow pool (Figure 13) has depths generally less than 1 m. it has a hard sandy bottom with no observable epibenthic fauna, and there were no burrows of benthic organisms observed. It is concluded that the brackish nature of the waters probably preclude many estuarine benthic species. However, a large adult Dusky Flathead was observed in this pond, indicating that the waters are sufficiently brackish to support an adult flathead and that there must be some benthic fauna for the flathead to feed upon.

The Ruppia pool is so called as it supports a vigorous growth of a brackish water submerged plant *Ruppia sp.,* growing to between 1.5 and 2 m height (see Figure 7). The pond has gently sloping sides with 1 m depths around the edges and an open basin to about 2 m depth. Much of the riparian edge supports swathes of *Phragmites*. There were schools of small fish observed amongst the reeds, generally Mosquito Fish, an introduced pest species generally known from freshwaters but also found in brackish water ponds.

Other fish reported anecdotally from the ponds are Mullet and the introduced Carp. No fish have been directly placed into the ponds and the main mechanism for fish to enter the ponds is via the top-up water that is pumped in from time to time from the Georges River.

The ponds support a variety of aquatic bird life including ducks (Black Duck, Wood Duck and Chestnut Teal), Swans, Swamphens and Mooorhens, White faced Heron and White Ibis. There are a variety of fishing birds, Pelicans, Black and Pied Cormorants and the Australian Darter. Silver gulls also visit the site. Some of the ducks and Swans are known to breed in the ponds.

Figure 15 Chipping Norton Stormwater drain at Milperra Road (looking west).

Figure 16 Stormwater drain adjacent Study Site (looking upstream – north) from levee bank. Drain is filled with Cumbungi.

Figure 17 Stormwater Drain upstream of Un-named Creek confluence. Drain supports Alligator weed and Frogs Mouth.

Figure 18 Un-named Creek just downstream of Stormwater Drain confluence (looking east). Alligator Weed is main emergent aquatic plant.

Figure 19. Eastern Long-necked Turtle in Un-named Creek pool.

Figure 20. Un-named Creek just upstream of Georges River confluence (looking west). Grey Mangrove on right, *Phragmites* along north bank and Alligator weed in background.

Figure 21. Georges River bank at the Un-named Creek confluence (site south-east boundary) looking north. Grey and River mangroves with She-oaks on bank.

3.3.2 Stormwater Drain and Creek Habitats

The stormwater drain that runs along the western boundary of the site is separated from the site by a levee running from Milperra Road to the confluence with the un-named southern creek (Figures 1 and 3, and see also Sections 13 to 15 on the survey plan in Appendix A). This is a freshwater system draining stormwater from the Chipping Norton industrial area to the north of Milperra Road. Figures 15 to 17 show parts of the stormwater drain from the culvert pool below Milperra Road to just above the confluence with the un-named southern creek. The upper culvert pool did not appear to support any fish and the shallows lower down the drain supported Mosquito Fish. Much of the drain is filled with Cumbungi and Alligator Weed, a noxious aquatic weed.

The unnamed creek has a more or less intact native riparian cover along the creek from the confluence with the stormwater drain to its confluence with Georges River. The creek is freshwater for most of its length then becomes brackish and estuarine as it approaches the Georges River (Figures 18 to 21). The upper pools have grassy banks and patches of Duck weed, Alligator Weed and Persicaria and there were Mosquito Fish observed, as well as an Eastern Long-Necked Turtle (Figure 19). Another noxious aquatic weed *Ludwigia* is also reported from the site (Total Earth Care 2006). At the estuarine end of the creek there is a canopy of Swamp She-oak with *Phragmites* and *Juncus krausii* along the creek edge. There are two mangrove species in the lower creek confluence, the Grey Mangrove Avicennia marina, and the River Mangrove Aegicerus corniculatum. There are some mature Grey mangroves with canopy heights between 4 and 6 m at the confluence.

3.3.3 Georges River Habitats

The strip of riparian land between the quarry and the Georges River supports a variety of disturbed and partially intact sections of woodland – see Figures 1 and 3 for plan views and see the survey plan in Appendix A for the location of wooded areas. The vegetation of this riparian strip is described in Total Earth Care (2006).

The rivers' edge between the southern creek confluence and the northern end of the study site has been eroding over time and there have been a number of partially controlled and probably uncontrolled measures taken to check the erosion, ranging from engineered bank works to dumping of masonry. This would appear to have been undertaken over many years as there are mangroves growing out of the dumped materials scattered along the bank.

The survey plan in Appendix A provides location details of bank treatments plus the locations of mangrove stands and of individual mangroves. Grey Mangroves are identified as such and River mangroves are noted as 'mangrove'. Figures 22 to 36 show aquatic habitat aspects of the river bank, (from downstream - south to north):

- There is an engineered treatment along the bank immediately upstream of the mangrove stand at the property southern boundary (the Creek confluence mangrove stand) see Figures 22 to 26. This treatment has failed in several places with slumping of the rocks and exposure of the underlying silt cloth plus active bank erosion behind the treatment resulting in terrestrial trees (mainly She-oaks) falling into the river (Figure 24 and 25).
- Where the silt cloth is exposed in the intertidal it has been covered in a silt/algae matrix that provides food for grazing molluscs (Figure 26).
- Upstream of the rubble and siltcloth bank treatment there is a section where the bank is protected by larger piece of masonry, mainly concrete slab pieces (Figures 23 and 27). There are also dead trees amongst this rubble indicating earlier active bank erosion.
- The mixed masonary bank treatment continues to (and beyond) the northern boundary. This fill has been in place for many years and there are mangroves that have colonised the fill (Figures 31 and 33).

Figure 22 Georges River bank at north end of mangrove stand upstream of un-named creek confluence (looking south). Note engineered rubble bank treatment.

Figure 23 Engineered Rock Rubble embankment looking north of mangrove band with failed and slumped bank in foreground.

Figure 24 showing bank erosion and toppled she-oaks (looking south from Figure 23).

Figure 25. Detail of active bank erosion including exposure of silt-cloth plus slumped rubble fill treatment (looking south from Figure 23).

Figure 26. Littorinid snails grazing silt/algae matrix on exposed silt cloth.

- Although these mangroves are relatively small (up to 1.5 m) they are not young – as indicated by the thick trunks and multi-branching. That is, these are dwarfed forms of mangroves, most likely dwarfed owing to the limited space for lateral peg root development in the intertidal due to the masonry treatment.
- The variety of materials used for the fill ranges from road-base through reinforced concrete to brick masonry (Figures 27, 29, 30, 32).
- Where there has been significant slumping, there are shallow inshore areas along the banks and several of these have been colonised by seagrass patches (*Zostera capricorni*). The location of these patches is indicated on Figure 3, and Figure 36 provides a view of the southern patch, located just upstream of site GR1 in Figure 3.

In summary, the aquatic habitats of the Georges River edge of the property comprise:

- A mixture of earth bank and masonry intertidal bank that supports small stands of Grey and River mangroves and scattered individual mangrove trees, all mature and ranging from 1.5 m dwarf specimens to 4 m tall Grey mangroves at the unrestricted un-named creek confluence immediately downstream of the southern property boundary. There were a few crab holes in the exposed sdiments and littorinid snails on the rock.

- There are a few areas of intermittent shallow sub-tidal bank along the toe of the intertidal bank, generally where there has been active erosion, and several of these support small patches of seagrass, *Zostera capricorni*.

Figure 27. Next upstream bank treatment from engineered rock rubble treatment (Figure 23). This treatment continues up to the site boundary (see following photos).

Figure 28 Continuation of bank treatment looking upstream from Figure 27. Note individual mangroves in background (see Figure 74 below).

Figure 29. Diversity of masonry and road base fill material.

Figure 30. Masonry and concrete fill material.

Figure 31. River mangroves growing between masonry rubble (looking upstream). See Figures 33 and 34 for remaining views beyond the she-oak.

Figure 32. Trapped floating rubbish amongst masonry rubble.

Figure 33. Bank treatment around individual Grey mangroves at north-east end of study site looking downstream (i.e., back south towards Figure 31).

Figure 34. Bank treatment south of mangrove in Figure 33, looking downstream. Note pump-house on bank in middle distance.

Figure 35 Pump House and Inlet pipe for pumping ‘make up’ river water to Quarry (August 2004 photo).

Figure 36 Seagrass Patch upstream of Un-named Creek Confluence - see Figure 3 for location.

- Beyond these inshore habitats, the river bed comprises generally mobile sediments comprising coarse to finer river sands mixed with silts. There were no burrows or mounds of benthic crustaceans or polychaete worms noted during diving inspections near the bank, and no surface invertebrates (molluscs and prawns) were seen, indicating generally mobile sediments.

With regard to general aquatic ecological attributes of the Georges River in this locality the following are relevant:

- Since 2002 there has been a commercial fishing closure placed on the entire Georges River – Botany Bay estuary.
- Whilst Georges River once supported a thriving oyster farming industry there is now no aquaculture activities in Georges River and the closest aquaculture operations are located in Botany Bay; native Sydney Rock and triploid Pacific oyster farming in Woolooware Bay and Mulloway farming off Silver Beach, Botany Bay.
- Marine vegetation (mangroves, saltmarsh and seagrass) are all recognised as significant nursery habitats for estuarine fish (NSW Fisheries 1999) and there have been a number of studies to map the distribution of these fisheries resources in the Georges River catchment. The descriptions of these resources as presented above is consistent with the descriptions provided in West et al (1985) and in the more recent mapping in Williams et al (2004). This confirms that there is a patchy distribution of mangroves fringing the river along the upper river shores below Milperra Bridge with a very scattered distribution of Zostera seagrass, generally occurring in small patches. The report also indicates that there are no significant saltmarsh areas in the locality.

With regard to the possibility of listed threatened aquatic species or communities within the project area, no species as listed under the NSW Fisheries Management Act or under the Commonwealth EPBC Act were noted or observed during the field studies undertaken for this study and, given the aquatic habitats available at the site, none are expected. With regard to fish species, this conclusion is supported by the Williams et al (2004) study, which also reported no threatened fish species.

Whilst individual saltmarsh plants were found scattered or grouped along the margins of the internal waterways, these were not considered to form viable saltmarsh communities (which are listed as threatened under the TSC Act), as they are subjected to inconsistently varying water levels and exhibit dieback due to inundation.

4 IMPACT ASSESSMENT

WorleyParsons (2010) provides a description of the construction and operational aspects of the proposed marina and the following sections provide an assessment of the impacts that could potentially be associated with these aspects.

The proposal includes a marina basin of approximate dimensions of 150 m by 350 m. The depth of the basin will be higher than that of the adjacent river depth to minimise sediment deposition in the marina basin.

The marina would open to the Georges River with a short entrance channel, about 50 m long and 40-50 m wide. The opening has been located so as to avoid existing seagrass patches and mangroves. There would be a high pedestrian bridge over the marina river entrance to allow public pedestrian access along the river foreshore.

Bank edge treatments proposed for the internal marina basin have been selected to meet the combined functions of bank stability and environmental enhancement. There will thus be rock revetment treatments that incorporate complex crevice habitat for intertidal rocky shore species plus a combination of rock revetments and integrated vegetation zones. This latter treatment would incorporate a berm of saltmarsh (or other suitable aquatic habitat treatment).

This rock revetment and integrated vegetation zones treatment will also be used for the Georges River foreshore bank, to replace the existing actively eroding and inappropriate masonry rubble-based bank treatment.

The proposal also includes two constructed freshwater wetlands along the east side of the marina basin to treat runoff from carpark and residential areas (see Figure 2). The wetlands would be vegetated with suitable macrophytes and would enhance the riparian zone by increasing aquatic vegetation and habitat complexity. The riparian bank between the marina and the river would then be planted out with appropriate littoral species.

4.1 Construction Aspects

In order to limit the impact of construction on adjacent river and riverbank aquatic habitats, the marina basin will be formed by filling the existing quarry and shaping it into the final landform using a dredge and land-based earth moving machinery. The dredge would operate as at present, in the water-filled basin. The excavated sand will be used for forming the associated land areas required for the marina. This work would commence at the landward end forming the basin and land base prior to breakthrough of the banks to the river. In this way, these works would not impact on the river water quality or aquatic habitats.

The breakthrough to the river would be undertaken as the last activity after the water quality in the basin had stabilised and is suitable to discharge to the river once the banks are excavated. Stockpiled excavated sand from forming the marina basin would be used to line the vessel access channel. Connection to the river would be delayed for as long as practicable and would be completed during favourable water level conditions (i.e. at or around slack water) to enable management of the breakthrough with the deployment of an appropriate turbidity curtain.

4.1.1 Possible Impacts on Aquatic Ecology and Habitats

The internal quarry excavation and land forming works will result in the loss of the existing aquatic ecological attributes of the present quarry, including *Ruppia* aquatic vegetation (used by fish and edge saltmarsh plants and emergent reed areas (used by aquatic birds for nesting and roosting). The waters of the internal quarry would be disturbed to an extent that remaining fish would probably not be able to survive the high turbidity arising from the works. Fishing and foraging birds are likely to take advantage of the feeding opportunities arising from this activity over the short-term. Whilst there would not be any threatened species or communities affected by the works there would be a temporary diminution in the available aquatic habitats of the locality.

The formation of an entrance channel through the riparian land between the site and the river would result in the permanent loss of some foreshore riparian land but would provide a small amount of additional water habitat area.

The proposed river bank stabilisation works will potentially impact on individual mangroves currently scattered along the bank and, depending on the detailed engineering design, may require active removal of some or all of these trees to allow for the bank stabilisation works to be completed. Similarly, the small patches of seagrass growing on submerged areas of slumped shallow river-bank could be partially or wholly lost to bank stabilisation works.

From the broad perspective, if the site is not used for the proposed marina it will likely be used for some other land-use requiring filling of the existing quarry. That is, loss of the aquatic ecological attributes of the existing quarry is likely to occur regardless of the proposed end-use of the site. From this perspective, the marina proposal would result in an overall increase in Georges River aquatic habitat area and diversity and the resultant floating marina plus revetment treatments would provide suitable wetted habitat for a diverse assemblage of aquatic biota. Also, regardless of end-use for the site, riverbank stabilisation works are likely to be required, and thus the potential impacts on existing edge aquatic vegetation (mangroves and seagrass) remains the same. Even under the do-nothing option it is likely that the masonry fill currently used for shore protection would need to be removed, which would still put the adjacent marine vegetation at risk, either from direct loss to rubble removal or indirect loss to natural river bank movement.

From a more focused perspective, the individual impacts described above can be mitigated to some degree by timing the works to avoid or ameliorate particular aspects of the impact. For instance, initial site works could remove the edge vegetation at a time when the possibility of nesting birds is at a minimum. Then, as the vegetation is being removed any resident roosting aquatic birds (e.g., Swamphens and Moorhens) can re-locate to alternate aquatic habitats in the adjacent stormwater/un-named creek, and aquatic birds later seeking suitable nesting sites will by-pass the site for lack of suitable habitat.

There is also scope to harvest saltmarsh soil (with intact seed) from the sand-spit for eventual use in the revetment berms, in order to accelerate the colonisation of the berms, once built. Even individual dwarfed mangroves that are potentially to be lost to river bank works can be harvested for replanting into river revetment berms, if desired. Similar works have been undertaken successfully at Harrington, Manning River.

Creation of the channel connection between the marina and the river will require the removal of the existing soils between the quarry and the river. These soils are likely to be Acid Sulfate and if so, removal without associated remediation works poses a risk of acid discharges to the river. Remediation, if required would entail over-excavation and treatment or replacement of soils immediately adjacent to the proposed channel, to prevent long-term drainage of acid from the adjacent soils.

The final connection of the formed marina basin to the river has the potential to drain turbid water from the basin to the river and could scour the new channel if the levels of the marina and river are not similar. As noted in WorleyParsons (2010), these impacts can be mitigated to insignificance by matching the river and marina waters in level and quality prior to the final entrance connection and by placing a turbidity curtain around the final breakthrough point. This matching of waters could be achieved by use of the existing quarry make-up water pump (or similar).

Finally, the project incorporates a number of habitat enhancement proposals that are designed to achieve an overall diverse and integrated riparian and aquatic ecology for the site to the benefit of the whole river environment.

4.2 Operational Impacts

The main operational impacts of the use of the marina from the aquatic ecological perspective relate to overall water quality within the marina basin, water quality resulting from vessel movements in and out of the basin and resultant water quality in the river:

- Water quality related to direct exchange and mixing with the river waters.
- Stormwater quality and quantity draining to the marina basin.
- Behaviour of vessel antifouling leachate in relation to the above.
- Accidental spillages of fuels and other liquids into the marina waters from fuelling and workshop activities.
- Bilge and sewage discharge control from vessels within the marina.
- Potential for bottom scouring from propeller wash by vessels using the marina.

These matters have been considered in detail in WorleyParsons (2010) and Section 5 provides a summary of avoidance and mitigation measures that have been incorporated into the design of the facility to mitigate or minimise impacts on marina water quality.

4.2.1 ANZECC Water Quality Criteria

ANZECC/ARMCANZ (2000) provides water quality criteria for the protection of aquatic ecosystems and the WorleyParsons (2010) report has assessed the proposal against these criteria. The main pollutant inputs to the river associated with the proposal were determined to be suspended solids and nutrients (from stormwater) and copper, that would be derived from both stormwater and from anti-fouling paint ablation off boats stored in the marina.

Of these, the WorleyParsons (2010) modelling results determined that incorporation of water sensitive urban design including stormwater treatment elements would be sufficient to reduce suspended solids and nutrient loads to acceptable levels. Modelling for copper inputs indicated that the greatest copper load to the marina waters would be from the anti-fouling paints, which cannot be controlled by stormwater treatment. Accordingly, the measures taken to achieve satisfactory copper concentrations in the marina waters have been to design the marina to facilitate sufficient mixing and exchange with river waters plus adjust the mix of vessels to meet the modelled target criteria.

For modelling purposes WorleyParsons (2010) used the ANZECC/ARMCANZ (2000) default copper trigger levels for the protection of 90 % and 95% of estuarine aquatic organisms within the marina waters; being 3 μg/L and 1.3 μg/L respectively. However, the ANZECC guidelines suggest that the default trigger levels (as stated above) should only be used if there are no available water quality data from which a background value can be determined. In this case, Benedict Industries collected additional water samples from Georges River under various tidal and weather conditions that were analysed by CSIRO laboratories - see Section 6.1.4 and Table 6.2 of WorleyParsons (2010) for sampling and analysis details and results. These results have been used to establish a site background level for copper concentrations with the following statistics derived from the river sampling results:

- Mean ± Standard Deviation of the Mean for Dry Weather labile (i.e., bioavailable) copper concentrations in the Georges River is 1.5 ± 0.40 μg/L.
- When both wet weather and dry weather data are combined, the mean ± standard deviation copper concentration is 1.4 ± 0.41 μg/L.

As noted in the WorleyParsons (2010) report, the critical modelling conditions for copper concentrations in the marina are for dry weather. Accordingly, and as per the ANZECC/ARMCANZ (2000) guidelines, the appropriate background river concentration to be adopted for comparison of modelling results is the background dry weather river concentration. The measured background data provide a range (via the standard deviation calculations shown above) of 1.3 to 1.7 μg/L. The adopted design provided a predicted dry weather concentration of 1.46 μg/L, which is below the background mean value and within the range of the adopted dry weather background river copper concentrations for Georges River at this location.

Note also that this modelled value is considered conservative, as the assumption for occupancy rate (95 %) is considered more than would probably be achieved in practice. If a lower occupancy rate of 90 % is adopted, the modelled dry weather concentration reduces to 1.4 μg/L – see Section 6.5.5 in WorleyParsons (2010) for details of their sensitivity analysis.

In conclusion, the conservative modeling undertaken for this project indicates that the proposed development will not have any adverse impact on the levels of labile copper in the river, and the operation of the proposed marina would meet the required thresholds set by the ANZECC/ARMCANZ (2000) guidelines for the protection of aquatic ecosystems.

4.2.2 Operational Impacts – Conclusions

It is concluded that the proposed marina can be constructed and operated without any significant impact on river water quality, and can achieve a suitable water quality within the marina to support a representative assemblage of aquatic biota for this river reach.

With regard to potential water quality impacts on the aquatic biota of the river it should also be noted that the marina is situated in the upper portion of the estuary and is therefore subjected to periodic floods that cause the river waters (and by extension the waters of the marina) to become fresh. Depending on the magnitude of the flood, low salinity conditions can persist for sufficient time to adversely affect the estuarine biota in this portion of the river.

As a consequence, the composition of the aquatic biota community in this part of the river and in the proposed marina can be expected to be dynamic, changing in relation to the frequency and persistence of floods. Under these circumstances, potential impacts arising from copper concentrations - as measured and as modelled above - would also be insignificant (i.e., could not be measured) compared to adverse impacts due to freshwater inundation.

There are other potential off-site operational impacts that relate to the possible increased volume of vessel traffic within the river and the possible effect on river aquatic habitats, principally shallow water and bank habitats, that could be impacted by the increased frequency of vessel wash. As wash impacts are already being experienced along the length of the Georges River as a result of existing vessel traffic in the river, it is considered that any potential increase in river traffic volume that may arise from the use of the marina is unlikely to produce any measurable additional impact over the present wash impact.

Whilst mitigation of existing wash impacts on the Georges River is outside the scope of this project, the commitment by Benedict Industries Pty Ltd to remediate their present wash-impacted shoreline will provide an improvement for river water quality for this section of the river.

5 MITIGATION OF POTENTIAL IMPACTS

The description of the project plus the assessment of potential impacts provides a number of proposed and possible impact mitigation measures that have or can be applied to avoid or off-set significant impacts to the aquatic ecology of the locality. These have been brought together here.

5.1 Avoidance Measures

There are several direct avoidance measures incorporated into the marina design that provide protection for aquatic biota:

- Modelling has been used to design the shape, capacity and use of the marina so that adverse water quality and river hydraulic impacts can be avoided. This includes the incorporation of a significant dry boat storage component in the design.
- The design has incorporated freshwater wetlands to treat stormwater from the site and the wetlands have been sited to form a part of an ecotone grading from sub-tidal to intertidal rock revetment incorporating a reed or saltmarsh berm with enhanced planting out of the adjacent riparian land with suitable native littoral plant species.
- The design has incorporated a depth differential between the basin and the river to ensure that there will be no deep 'dead water' areas in the basin and ensure that there will be no significant accumulation of sediments within the basin.
- The entrance channel has been located to avoid direct loss of existing seagrass patches or of individual mangroves.
- Building the marina basin and marina infrastructure within the confines of the existing quarry site has avoided the possibility of construction water loss to the river.

5.2 Mitigation and Offset Measures

Construction mitigation measures include the following:

- Stage initial quarry construction activities to minimise impacts on the existing biota that currently use the quarry aquatic ecological resources.
- Harvest aquatic plant resources where appropriate for later use in riparian or aquatic remediation or enhancement works.
- Early testing for and remediation where required of possible Acid sulfate soil content to prevent possible discharge to the river from the proposed channel formation and connection works.

- Incorporation of strict vessel management controls within the confines of the marina to minimise the risk of deliberate discharges and of accidental spills related to vessel use.
- Delay and control entrance connection to the river until the basin and river water quality and levels are matched. Use a turbidity curtain to minimise the extent of turbidity arising from the final entrance breakout.
- Incorporate aquatic biota friendly construction methods into the basin and river breakwater designs, by the use of rock revetments and revetments with berms that will be planted with intertidal marine vegetation such as reeds, saltmarsh or mangroves.

Offset measures include the following:

- Provision of additional habitat for marine intertidal vegetation in the form of constructed berms as part of the rock revetment works for the basin and the river, to offset the potential loss of some of the river intertidal seagrass and mangroves that may be necessary as a result of the need to removal masonry fill materials currently placed along the river bank.
- Rehabilitation and enhancement of the existing riparian land between the river foreshore and the proposed marina by the planting of suitable local native littoral species.
- Rehabilitation of the creek bank vegetation between the marina and the un-named southern creek to provide a native vegetated barrier between the marina and creek.
- Rehabilitation of the levee bank vegetation between the marina and western stormwater drain to provide a native vegetated barrier between the marina and drain.

The intent of the these combined mitigation measures with regard to aquatic ecological function is to provide a diversity of natural or near-natural intertidal to riparian zone habitats that support local native terrestrial and marine trees and other vegetation, and link these combined habitats vertically as ecotones, from the water to the land and horizontally as habitat corridors for connecting the up stream and down-stream river corridor habitats to the southern creek habitats and to each other.

With regard to avoidance and mitigation of operational impacts on the aquatic ecology of the locality, the proposal will incorporate a series of measures to avoid and minimise the chances of fuel and other spills (from fuelling and workshop practices) entering the waterway, and will provide proper systems in place to deal with any spills should they occur.

Potential impacts from workshop activities will be minimised by a mix of direct avoidance and mitigation measures. Benedict Industries have advised that there will be no traditional "slipway" activities (which have a much higher potential for wastes and residues to enter the marine environment). All environmentally sensitive maintenance works will be undertaken on a dedicated hardstand area fully under cover and within the marina building. It is intended that all craft will be lifted from the water via an elevator or forklift system and placed within the adjoining maintenance facility, within the enclosed building in cradles for maintenance works. The maintenance facilities will be constructed and operated to comply with industry standards for the Marina workshop management, specifically for the management of all liquid wastes generated from the facility and for management of all potential liquid spills that may be associated with the facility.

With regard to fuelling activities, Benedict Industries have advised that bulk fuel storage will be above the 1:100 flood level. Standard industry practice mandates isolation valves and fail-safes. This means fuel supply from the bulk store can be turned off remotely from suitable points on the marina deck and surrounds. In addition, bunding will be constructed to contain fuel spills in the event of a rupture of the bulk fuel store. Further, AS 3962-2001 notes the need for particular precautions when supplying fuel over water such as the use of double containment lines. All of these precautions will be considered and where necessary integrated in the design, installation and operation of the facilities.

A number of operational features would also be incorporated into the system as required, to reduce and deal with potential hazards associated with the refuelling facilities. These include:

- Drip trays under and around the bowsers. Trays would be of sufficient size to hold any jerry cans being filled;
- A holding tray on site to collect and retain collected wastes from the drip trays;
- Provision would be made for regular emptying and disposal of the holding tray to an approved waste collection system or site;
- Oil/fuel boom kits located at a suitable point for quick deployment to contain any accidental fuel spillage; and
- Oil absorbent kits located at the fuelling point to be used in the event of a spill to absorb petroleum products spilt on the deck or on the water surface.

These mitigation requirements are only useful if undertaken by trained staff. Thus all fuel systems will be secured and operated only by marina staff who have been provided with the appropriate level of training.

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APPENDIX A

SHORELINE SURVEY

OF

BENEDICT INDUSTRIES PTY LTD

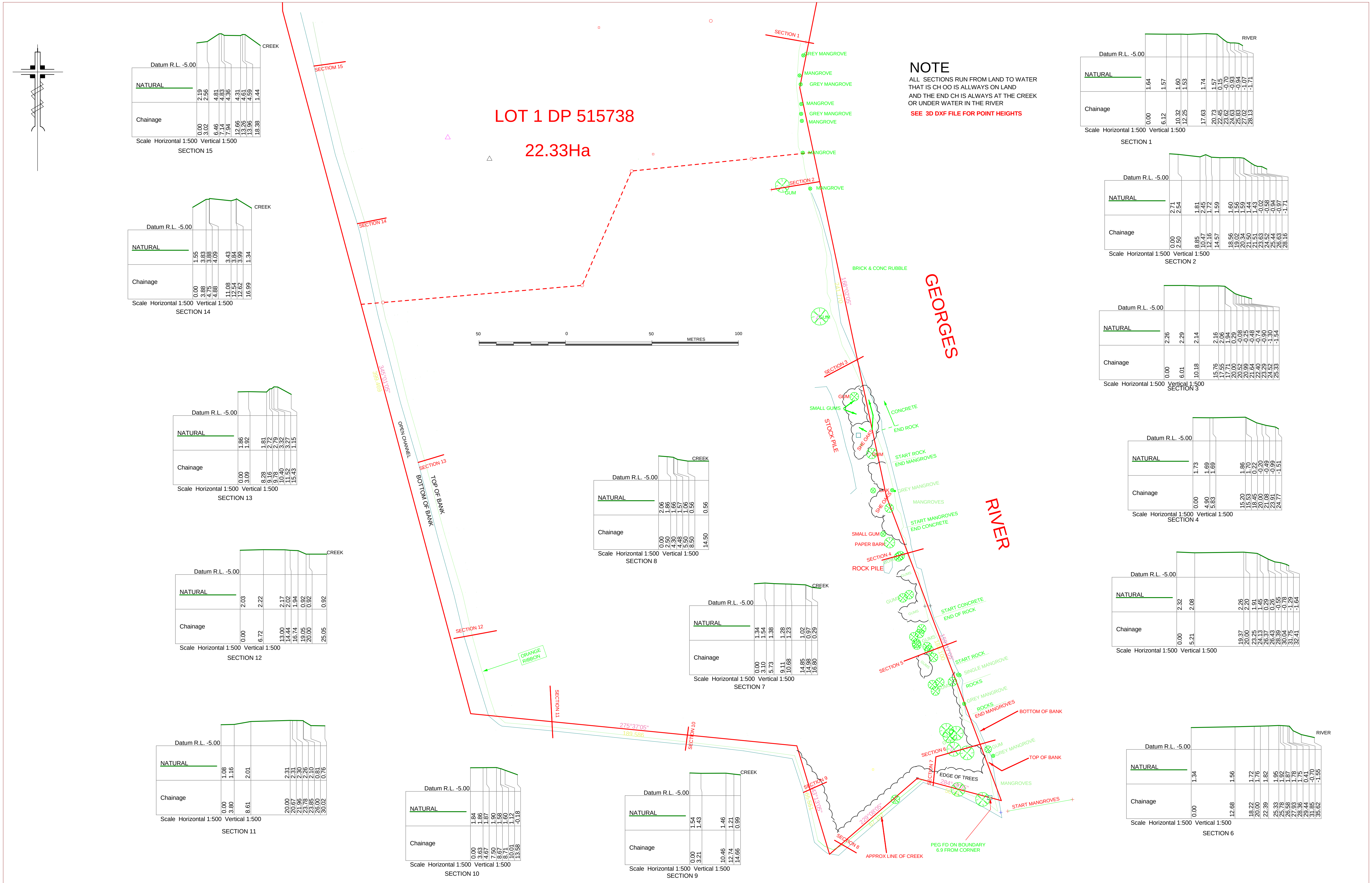
PROPOSE MARINA SITE

UNDERTAKEN BY

MATHEW FREEBURN SURVEYORS

ON

3 MAY 2007



PLAN SHOWING RIVER & CREEK DETAILS
OVER PART LOT 1 DP 515738
NEWBRIDGE RD MOOREBANK

CIVILCAD SOFTWARE

SCALE PLAN 1: 1000 - SECTIONS AS SHOWN

DATUM: AHD

DRAWN BY R.WARD

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SEE RW CC6

REFERENCE No:23848-30-04-07-DWG RIVER & CREEK