Gilbert & Sutherland
EMP and ASS

Appendix 5
Acid Sulphate Soil

Gilbert & Sutherland
Soil & Water Resource Consultants

Soil Survey, Acid Sulfate Assessment, Stormwater Management Plan, Surface Water Assessment and Environmental Management Plan Pacific Pines, Lennox Heads.

Prepared for

Ardill Payne & Partners Pty. Ltd.

March, 2004

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Soil & Water Science & Engineering in New South Wales & Queensland

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1. Introduction and purpose of report

1.1. Background

Gilbert and Sutherland Pty Ltd, was commissioned by Ardill Payne & Partners Pty Ltd to prepare a Soil Survey, Acid Sulfate Assessment, Stormwater Management Plan, Surface Water Assessment and Environmental Management Plan (EMP) in relation to the proposed water quality control pond at Pacific Pines Estate, Montwood Drive, Lennox Head (DP 259704). The site location is shown on Figure 1.

The report is divided into sections dealing with the proposal, a description of the physical characteristics of the site and the assessments as described above including an assessment of stormwater runoff, loading estimates and management of the potential impacts during the construction and operational phases. It is these management sections that form the EMP.

The report is based on a soil survey performed by qualified Gilbert and Sutherland staff, AQUALM-XP modelling of stormwater nutrient concentrations and detailed water balance modelling of the movement of surface water and groundwater.

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PROJECT

ARDILL PAYNE & PARTNERS

PACIFIC PINES ESTATE, LENNOX HDS.

SITE LOCATION

FIGURED DIMENSIONS TO BE READ IN PREFERENCE TO SCALING.	APPROVED	SCALE AS SHOWN	DRAWN A.G.G.	DRAWING No.
		DATE 05/02/01	CHECKED	Figure 1

2. The proposal

Figure 2 shows the proposed pond location with respect to the existing Pacific Pines Estate and the proposed extensions. The area of the proposed water quality control pond is 3.33 ha, and is shown as Figure 3. The water quality control pond is to be situated in the north west area of the site.

The site is situated east of North Creek, just north of its confluence with Deadmans Creek, and is entirely within the North Creek catchment. North Creek flows south through the Ballina region into Richmond River approximately 5.75km downstream of the site and 1km upstream of the river's outlet into the Pacific Ocean.

The southern portion of the site abuts the Ballina Nature Reserve, the width of which (between the subject land and North Creek) varies between approximately 50 to 300 metres.

Given that runoff from the site flows through The Ballina Nature Reserve and discharges into North Creek, care has been taken to ensure that the runoff quality will be such that it will have minimal impact on any aquatic ecosystems in the downstream environment and The Ballina Nature Reserve.

	STAGES 1 & 2 EXISTING	STAGE 3	BALANCE
No OF SINGLE RES. LOTS	158	33	429
No OF DUPLEX LOTS	13	7	81
MEDIUM DENSITY AREA	-	-	8.86 ha
MEDIUM DENSITY No OF UNITS	-	-	233
PASSIVE OPEN SPACE	2.87 ha	-	4.24 ha
ACTIVE OPEN SPACE	-	6.16 ha	-

(MEDIUM DENSITY 300m² / UNIT)

Base plan supplied by Ardill Payne & Partners

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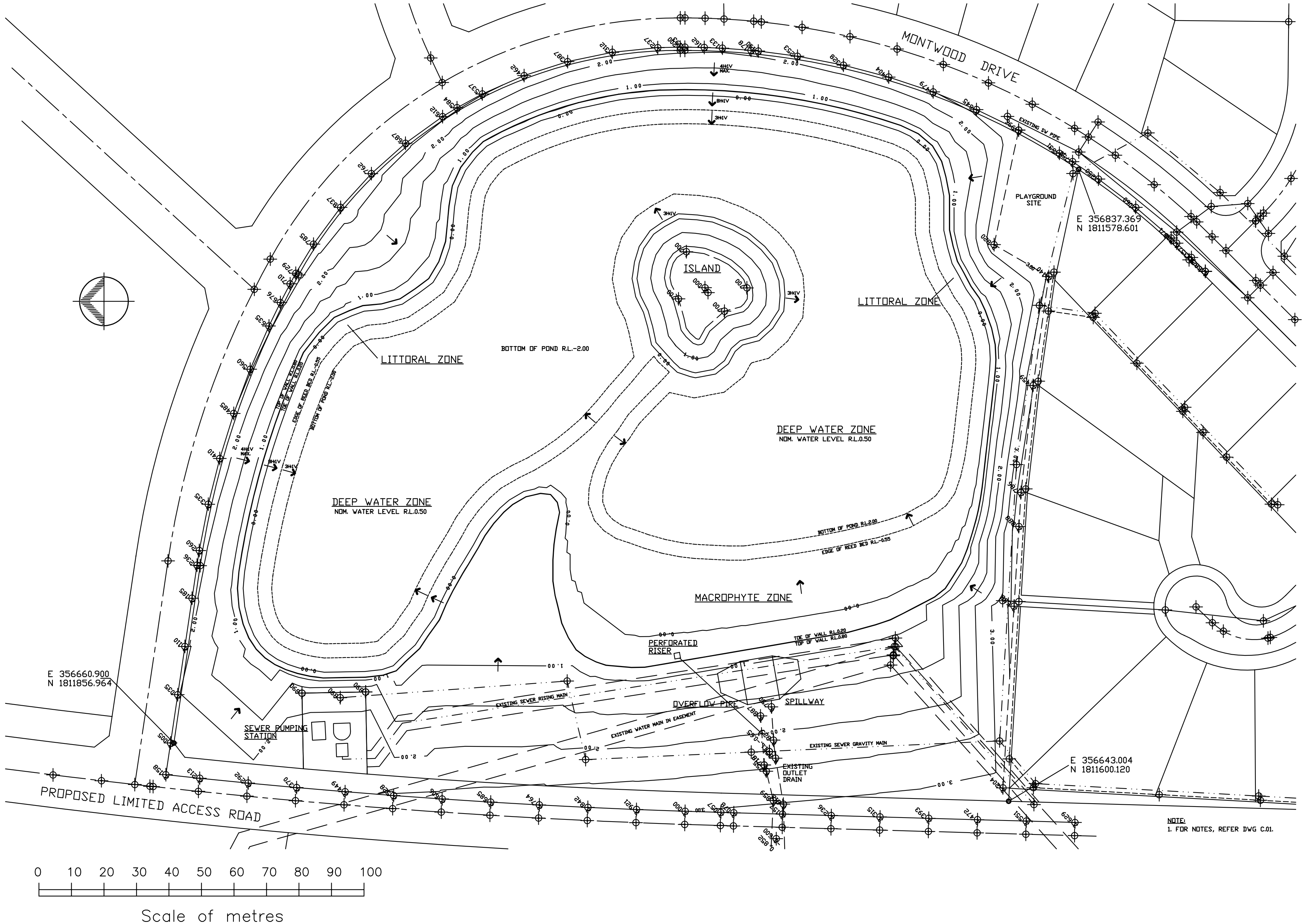
PROJECT
ARDILL PAYNE & PARTNERS
PACIFIC PINES ESTATE, LENNOX HDS.
PROPOSED DEVELOPMENT

FIGURED DIMENSIONS TO BE READ IN PREFERENCE TO SCALING.	APPROVED	SCALE AS SHOWN	DRAWN A.G.G.	DRAWING No.
		DATE 05/02/01	CHECKED	Figure 2



Detail Plan provided by Ardill Payne & Partners.

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PROJECT
ARDILL PAYNE & PARTNERS
PACIFIC PINES ESTATE, LENNOX HDS.
WATER QUALITY CONTROL POND
PROPOSED DETAILS

FIGURED DIMENSIONS TO BE READ IN PREFERENCE TO SCALING.	APPROVED	SCALE AS SHOWN	DRAWN A.G.G.	DRAWING No.
		DATE 05/02/01	CHECKED	Figure 3

3. Site description and physical characteristics

3.1 Site description

The area of the proposed water quality control pond site is approximately 3.33 hectares and is to be situated on the portion of land described as Lot 217 on DP 1017615. The development is bordered by Hendersons Lane to the north and North Creek Road to the east.

The area around the proposed water quality control pond site is gently sloped.

3.2 Catchment description

The development is situated to the east of North Creek, and entirely within its catchment. It ranges in elevation from below RL 10.0m AHD to above RL 70m AHD. The water quality control pond site is an end of line measure located in the lowest portion of the development, at below RL 10m AHD.

North Creek Road on the eastern boundary of the development runs along the ridge that forms the eastern boundary of the North Creek Catchment, rising from RL 40m AHD to above RL 70m AHD at the southern and northern extremities of the development respectively. To the east of North Creek Road, runoff flows eastward towards the Pacific Ocean.

North and south of the development are areas that are also within the North Creek catchment. At the northern boundary of the site, the elevation rises from below RL 10m AHD to above RL 60m AHD at the western and eastern extremities of the development respectively. At the southern side, the elevation rises from below RL 10M AHD closest to North Creek to above RL 40m AHD towards the east. It is expected that the development will not alter the flow pattern and that North Creek Catchment will remain the catchment for the entire site.

3.3 Vegetation

The majority of the site has been cleared of native tree and shrub vegetation and consists predominantly of open grassland.

3.4 Geology

A review of the 1:250,000 Geological Series SH56-3 (Tweed Heads) indicates that the site of the proposed water quality control pond is underlain by Cainozoic rocks dominated by basalt of the Tertiary Lamington Volcanics, and Quaternary Alluvium generally comprised of river gravels, sand and clay.

3.5 Soil classification

Gilbert and Sutherland conducted a soil survey and agricultural assessment of the site in November 2000. These assessments included 10 detailed boreholes to approximately 3.0m depth around the area of the proposed water quality control pond.

Soil sampling and profile description was undertaken according to the Australian Soil and Land Survey Field Handbook (McDonald *et al*, 1990) with the soils classified according to the Australian Soil Classification (Isbell, 1996). The soil borelogs are presented in Appendix 1 with the borehole locations shown on Figure 4.

Four main soil orders were identified within the area of the water quality control pond (WQCP). These were Ferrosols, Kandosols, Kurosols and Chromosols. A brief description of the characteristics of these soil orders is given below (Isbell, 1996).

3.5.1 Ferrosols

These are soils with B2 horizons which are high in free iron oxide and which lack strong texture contrast between A and B horizons.

These soils were generally of greyish brown to black colour and were therefore classified into the Brown/Grey/Black Suborder.

3.5.2 Kandosols

These are soils that lack strong texture contrast, have massive or weakly structured B horizons and are not calcareous throughout.

These soils were generally of grey to black colour and were therefore classified into the Grey/Black Suborder.

3.5.3 Kurosols

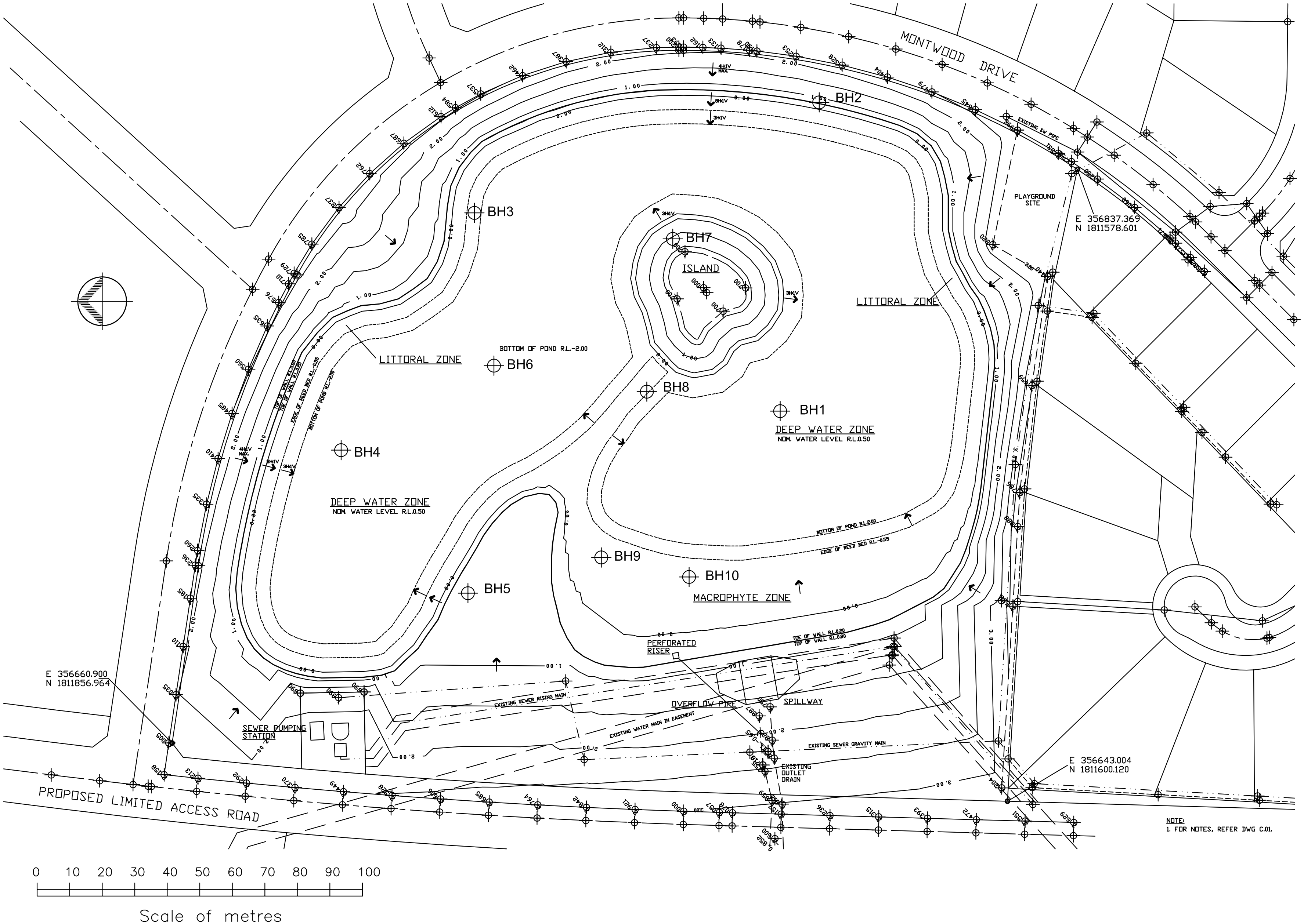
These are soils with strong textural contrast between A horizons and strongly acid B horizons.

These soils were generally of grey to black colour and were therefore classified into the Grey/Black Suborder.

3.5.4 Chromosols

These are soils with strong texture contrasts between A horizons and B horizons which are not strongly acid or sodic.

These soils were generally of yellow to grey colour and were therefore classified into the Grey/Yellow Suborder.



Detail Plan provided by Ardill Payne & Partners.

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PROJECT
ARDILL PAYNE & PARTNERS
PACIFIC PINES ESTATE, LENNOX HDS.
BOREHOLE LOCATIONS

FIGURED DIMENSIONS TO BE READ IN PREFERENCE TO SCALING.	APPROVED	SCALE AS SHOWN	DRAWN A.G.G.
		DATE 05/02/01	CHECKED

DRAWING No.
Figure 4

The soils encountered were in general accordance with those described by Morand (1996)[1], for the area.

3.6 Soil distribution

The distribution of the soils encountered at the site is shown in Figure 5. Soils from each of the four soil orders identified were found in the vicinity of the proposed pond. Such a distribution is not uncommon in this area, given the geological history of the region.

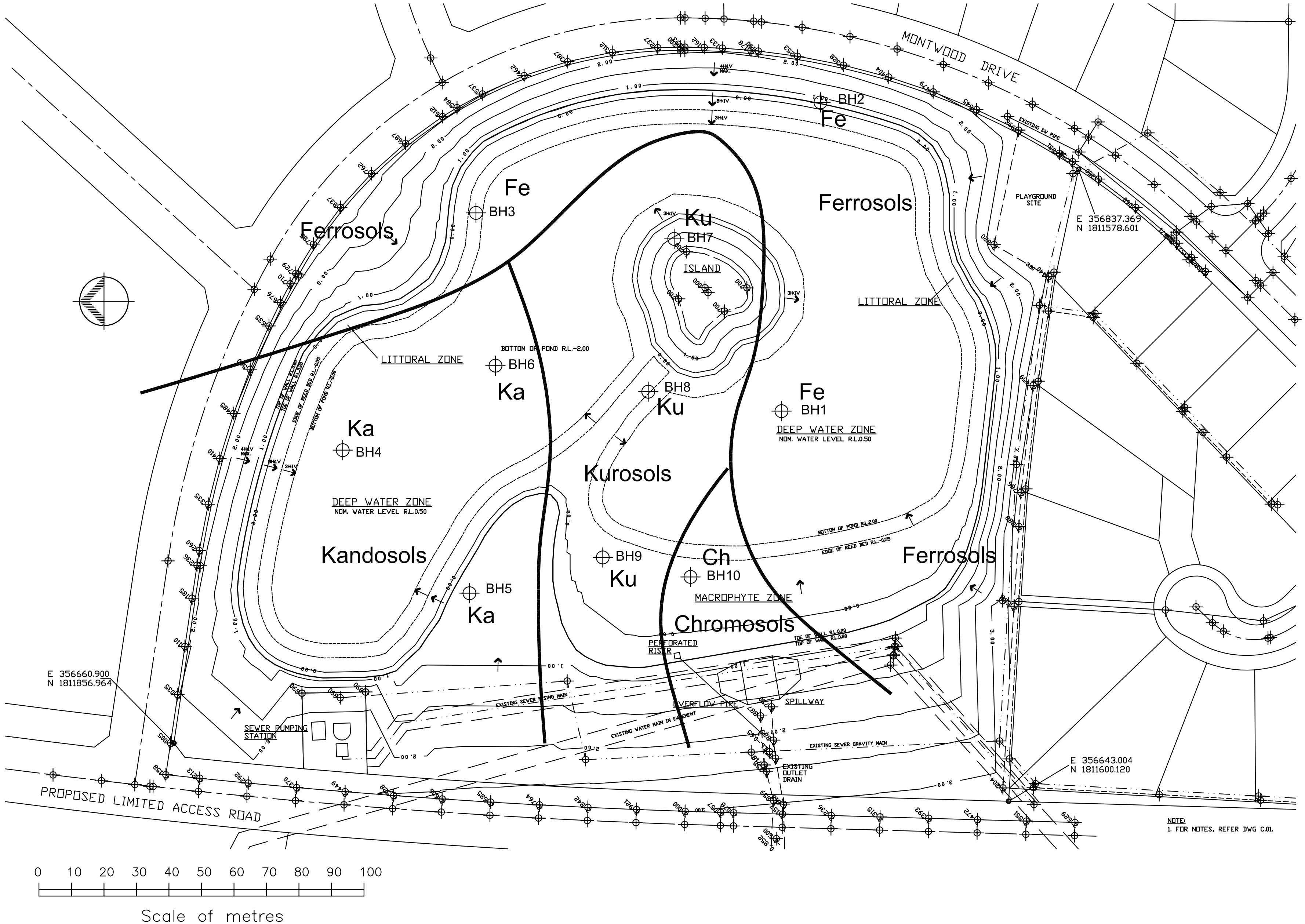
Soils classified as Ferrosols occurred on the gentle incline of the eastern part of the area of the proposed water quality control pond, in the vicinity of boreholes 1, 2, and 3. These ranged from coarse sand to medium clay, but were generally silty clay loams to silty clays. The colours ranged from dark reddish brown (5YR3/4) to black (2.5Y2/1), the majority being shades of grey or black.

Soils classified as Kandosols occurred in the vicinity of boreholes 4, 5 and 6, in the northern portion of the site and consisted of coarse sands to medium clay, being largely clayey sands and medium clays. The colours ranged from dark greyish yellow (2.5Y 5/1) to olive black (5Y3/1).

Soils classified as Kurosols occurred in the vicinity of boreholes 7, 8, and 9. These ranged from sand to medium clay, but were generally clayey sands, sandy silty clays and medium clays. The colours ranged from dark greyish yellow (2.5Y 5/1) to olive black (5Y3/1).

Soils classified as Chromosols occurred in the vicinity of borehole 10, and consisted of material ranging from coarse sand to medium clay. The colours ranged from dark greyish yellow (2.5Y 5/1) to brownish black (10YR 3/1). This Chromosol was similar in composition to the Kurosols in the vicinity of boreholes 7, 8 and 9, but had slightly different physico-chemical values.

[1] Morand, D.T. (1996) in Soil Landscapes of the Murwillumbah-Tweed Heads 1:100,000 Sheet, Report. Department of Land and Water Conservation, Sydney.



Detail Plan provided by Ardill Payne & Partners

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PROJECT
ARDILL PAYNE & PARTNERS
PACIFIC PINES ESTATE, LENNOX HDS.
SOILS DISTRIBUTION

FIGURED DIMENSIONS TO BE READ IN PREFERENCE TO SCALING.	APPROVED	SCALE AS SHOWN	DRAWN A.G.G.
		DATE 05/02/01	CHECKED

DRAWING No.
Figure 5

4. Acid sulfate soil assessment

4.1 Background

The site of the proposed water quality control pond has been classified as an alluvial plain. An acid sulphate soil assessment was therefore carried out to determine weather acid sulfate soils were present at the site and if so their extent and nature. A total of ten boreholes were constructed in the area of the proposed water quality control pond and from these, soil samples were recovered for analysis.

This Acid Sulfate Soil Assessment is written in accordance with the recommendations in the New South Wales Acid Sulfate Soil Advisory Committee (ASSMAC) Acid Sulfate Soil Manual, August 1998[2].

4.2 Objectives

The objectives of the assessment were as follows;

- to determine the extent and spatial variability of acid sulfate soils at the site and;
- to provide site specific options for managing and treating those soils in view of proposed disturbances.

4.3 Sampling protocol and procedure

Sampling was undertaken using a 4WD-mounted vibrocore sampler.

This method incorporates a 6m stainless steel tube which is inserted into the sediments under vacuum and vibration and allows the recovery of undisturbed samples which can be accurately logged and sampled. Upon recovery, the intact cores are ejected from the tube into PVC socks and stored in that sealed condition until sampling.

Ten boreholes were constructed in this manner, generally at spacings of 50m to 100m across the subject area, with each borehole location located with a hand held GPS unit. This was in general accordance with the 2 holes per hectare requirement for sites greater than 4ha stipulated in the ASSMAC Guidelines.

[2] New South Wales Acid Sulfate Soil Management Advisory Committee (1998) Acid Sulfate Soil Manual.

The boreholes were constructed to a depth of 3m from near surface level (NSL) to enable the collection of samples at a depth of 1.0m below the base of the proposed excavation for the proposed water quality control pond. The borelogs are presented in Appendix 1.

Because of the clear delineation of soil types within the undisturbed cores, samples were recovered on the basis of individual soil facies, not at predetermined depth intervals. However, samples were generally recovered from every 0.5m of the soil profile in accordance with the ASSMAC guidelines.

Logging of cores was undertaken according to the Australian Soil and Land Survey Field Handbook (McDonald et al, 1990).

A total of 59 samples were recovered from the 10 cores and screened for acid sulfate potential by Gilbert and Sutherland. Of the 59 samples screened, a total of 25 were subsequently sent for laboratory analysis to the Environmental Analysis Laboratory at the Centre for Coastal Management, Southern Cross University. The remaining 34 samples were dried and stored for further analysis if needed.

4.4 Screening procedures

The initial soil pH (pH_F) was determined for each sample from a 1:5 soil:water suspension.

All samples were analysed using van Beers field technique of rapid oxidation and petrographic analysis using brief microscopic examination.

The van Beers method involves the oxidation of a 5cm^3 subsample with 20cm^3 30% H_2O_2 in a 200ml glass jar placed in a 50°C water bath. The temperature of this reaction is noted, and when cool, the pH of the supernatant after oxidation is determined.

Brief microscopic examination was used to determine the presence or absence and the grade (or size) of pyrite and shell material. Small samples of the soil were smeared on the glass slides. On a separate portion of each slide, a drop of 30% H_2O_2 and a drop of 6N HCl were applied and the degree of reaction was noted. In this way, fine pyrite and shell material, invisible during examination, were noted by reaction.

Both methods complement each other and serve as a fairly accurate indication of the presence of pyrite within samples (Sutherland *et al*, 1996)[3].

All 59 samples were screened in this manner.

4.5 Analytical procedures

Twenty five (25) of the 59 samples recovered from the 10 boreholes were analysed using the POCAS method (Method 21) of Ahern et al (1997)[4], and the Chromium Reducible Sulfur (S_{CR} %) method (Method 22B)[5].

The POCAS method utilises the Total Potential Acidity (TPA) technique which follows the acidity trail as well as the Peroxide Oxidisable Sulfur (S_{POS}%) technique which follows the sulfur trail and is acknowledged as providing a comprehensive indicator of the acid sulfate risk.

The Chromium Reducible Sulfur method utilises chromium reduction to quantify the level of reduced inorganic sulfur compounds and unlike the POCAS method, is essentially unaffected by sulfur in an organic form or sulfate minerals.

4.6. Results and discussion

4.6.1 Screening results

The results for the screening analysis are presented in Appendix 2. In general, a soil exhibiting a pH after oxidation (pH_{FOX}) of less than 3 with a slight to violent reaction and high reaction temperature is considered a potential acid sulfate soil (PASS). Those soils exhibiting a pH_{FOX} of >3, with nil to slight peroxide reaction and low temperature of reaction (<50°C), are in most cases non-acid sulfate. A soil with an initial pH (pH_F) of <4 is generally considered to be an actual acid sulfate soil (AASS).

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[3] Sutherland, N.M., Westerberg, B,R., Joyce, A.S. Refining Qualitative Field Tests To Reduce Acid Sulfate Assessment Costs. "Proceedings 2nd National Conference of Acid Sulfate Soils" Robert J Smith and Associates and ASSMAC, Australia.

[4] Ahern, C.R., McElnea, A., Baker, D.E. and Hicks, W. (1997) Peroxide Oxidation – Combined Acidity & Sulfate (POCAS) Method. (ASS Method 21).

[5] The Chromium Reducible Sulfur (CRS) technique utilises the conversion of inorganic S to H_2S by a hot $CrCl_2$ solution. The H_2S generated is trapped in a zinc acetate solution and may be quantified by iodometric titration (Sullivan et al, 1998)[4]. CRS is an alternative to the Peroxide Oxidisable Sulfur (S_{POS} %) method of the POCAS technique and unlike S_{POS} % is not subject to significant interference from sulfur in either organic matter or sulfate minerals (Sullivan et al. 1998).

[4] Sullivan, L.A., Bush, R., McConchie, D., Lancaster, G., Clark, M., Norris, N., Southon, R. and Saenger, P. (1998) *Chromium Reducible Sulfur S_{CR} – Method 22B.* Miscellaneous Research Methods section 4.9 in NSW Acid Sulfate Soil Manual (1998).

Initial pH values (pH_F) ranged from 4.83 to 6.86 for the samples screened, all being above pH_F 4, indicating no appreciable Actual Acid Sulfate Soil present within the soil profile.

pH after oxidation (pH_{FOX}) ranged from 1.45 to 4.98 in the samples screened with 32 of the 59 samples exhibiting a pH_{FOX} of <3. Of these, 22 exhibited violent reactions with peroxide and high reaction temperatures (~80-90+°C) during van Beers analysis.

Violent reactions were observed only from samples that displayed a pH >3 after oxidation, which does not indicate the possible presence of a carbonate source.

The majority of the remaining samples exhibited only nil to medium reactions with peroxide and low reaction temperatures.

Those samples exhibiting a pH_{FOX} of <3, with violent reactions and high reaction temperatures were associated with soils at at least one metre depth, composed of significant proportions of silts, clays and sands.

Petrographic analysis revealed pyrite by reaction in 21 of the 22 samples which exhibited violent reactions during van Beers analysis, which could be expected from the content of fine material in the soils.

Four (4) of the 59 samples screened exhibited a slight to violent reaction with 6N HCl during screening with medium to coarse shell fragments noted, indicating a possible buffering source.

4.6.2 Laboratory results

The results of the laboratory analysis for the 25 samples tested are presented in table 4.1 below, with the laboratory certificates attached as appendix 3

The results in general show that the majority of samples below approximately 1m NSL had acid sulfate potential with %S concentrations ranging from 0.002 to 1.032%S and TPA values of 0 to 656 moles H+/t.

Table 4.1. Laboratory results

Borehole	Depth from NSL (m)	TPA (POCAS) mol H^+/t	%S (POCAS) (S_{POS}%)	CRS (S_{CR}%)
BH1	1.00 – 1.20	7	0.057	-
BH1	1.80 – 2.30	220	0.321	1.388
BH1	2.50 – 3.00	428	1.032	-
BH2	0.50 – 1.00	0	0.009	0.013
BH2	1.10 – 1.40	48	0.168	-
BH3	0.75 – 1.00	2	0.018	-
BH3	2.15 – 2.70	468	0.616	-
BH3	2.70 – 3.00	124	0.180	0.211
BH4	0.50 – 0.75	2	0.006	0.003

Borehole	Depth from NSL (m)	TPA (POCAS) mol H /t	%S (POCAS) (S_{POS}%)	CRS (S_{CR}%)
BH4	1.90 – 2.00	0	0.002	-
BH5	1.30 – 1.70	2	0.011	-
BH5	2.20 – 2.70	108	0.214	0.257
BH5	2.70 –3.00	144	0.256	-
BH6	0.00 – 0.50	8	0.009	-
BH6	1.70 – 2.20	0	0.002	0.009
BH7	1.00 – 1.50	4	0.009	0.009
BH7	1.50 – 1.70	0	0.005	-
BH7	2.20 – 2.60	468	0.696	-
BH8	1.50 – 2.00	4	0.004	0.005
BH8	2.40 – 3.00	456	0.612	-
BH9	1.00 – 1.60	20	0.004	-
BH9	2.00 – 2.50	84	0.573	-
BH9	3.00 – 3.50	656	0.781	1.121
BH10	0.75 – 1.50	48	0.083	-
BH10	2.20 – 2.80	76	0.161	0.185

The results show good agreement between TPA and S_{POS}% values for the samples analysed. This supports the theory that both TPA and S_{POS}% values are influenced by the presence of organics.

Generally, there was a good agreement between S_{POS}% and S_{CRS}%, with the exception of BH1 1.8 - 2.3 m, where the S_{CRS}% value was significantly higher than the S_{POS}%. For this instance, the screening results were referred to, where the samples displayed characteristics of potential acid sulphate soils, and therefore this soil must be classified as PASS material. The S_{CRS}% value was confirmed by a second analysis, which re-enforces the assumption that the sample was a PASS material.

Given the good agreement between TPA and S_{POS}%, these values were adopted for comparison to threshold values, except in the case of BH1 1.8 - 2.3 m, where the S_{CRS}% value was taken, as it was the more conservative, and a better reflection of the acid sulphate potential for that sample.

The %S action level thresholds for different soil textures given in the Acid Sulfate Soils Manual (ASSMAC, 1998)[6] are shown below in table 4.2.

[5] Stone, Y., Ahern, C.R. and Blunden, B (1998) Acid Sulfate Soils Manual 1998. Acid Sulfate Soil Management Advisory Committee, Wollongbar, NSW, Australia.

Table 4.2 %S action level thresholds for soil treatment.

Texture category	Texture Range	%S Action level
Coarse	Sands to loamy sands	0.03
Medium	Sandy loams to light clays	0.06
Fine	Light medium to heavy clays and silty clays	0.1

The ASSMAC guidelines further specify that for developments proposing to excavate more than 1000 tonnes of material, the %S action level of 0.03 should be applied. As the proposed works would involve excavating more than a thousand tonnes of sandy material, an action level threshold of 0.03 S_{POS}% was applied.

In most cases the materials exhibiting S_{POS}% above the threshold were associated with dark greyish yellow (2.5Y 5/1) to olive black (7.5Y 3/1) silty fine sands to silty clays.

The materials of highest acid producing potential (>0.5%S) were associated with boreholes 1, 3, 7, 8 and 9 at depth, generally below 2.0 m NSL, and were characterised predominantly as olive black (5Y 3/1) sandy silty clays and silty clays underlying the silty fine sands.

The materials of lowest acid producing potential (≤0.03%S) were associated predominantly with the surface strata of loamy sands and fine sands generally from 0 to approximately 1m NSL.

4.7 Discussion

The screening and laboratory results, together with the borelogs, show a clear delineation between PASS and non-PASS materials throughout the profile. All materials that had greater than 0.03 S_{POS}% had violent reactions in the screening process. The materials that exceeded the threshold ranged from coarse sand to medium clay. Those soils which far exceeded the threshold were generally clayey sands or sandy silty clays.

The materials exceeding the threshold were all found below 0.75m NSL, and the majority of materials exceeding the threshold were generally found between 1.75m and 3m. These materials would have been deposited in a low energy environment during the last sea level rise (approximately 10,000 years ago) where the accumulation of iron rich silts, sands and clays, and the presence of sulfate from seawater would have been ideal for the formation of pyrite.

Over time, these materials were capped by non-PASS materials, characterised in the borelogs as loams or clays, occurring from 0.0m - 0.75 m.

There was only fair agreement between the screening results and the laboratory analysis, with fourteen (14) of the twenty-five (25) samples sent for laboratory analysis after screening being above the threshold.

This supports the lower rate of laboratory analysis and the assumption that similar materials can be assigned a representative %S concentration based on the screening results and laboratory analysis undertaken.

There was good agreement between the POCAS and CRS laboratory methods for the samples tested. The CRS method in this case confirming the inorganic sulfur component in the predominantly sandy materials. Total Potential Acidity (TPA) was generally in agreement with the equivalent S_{POS}%. However, as many samples still had appreciable potential acidity (TPA > 18moles H+/t) in most cases, precautionary measures will need to be employed if excavations are to extend below approximately 0.75m NSL.

4.8 Conclusions

Potential acid sulfate soils have been identified at the site. These were generally of a moderate severity where coarse sands to fine silty sands were encountered, to high severity where silty clays were encountered.

Given the predominantly sandy to silty nature of the PASS materials, and as these are recognised as having little buffering capacity, it is recommended that all excavations for stormwater treatment measures and/or services proposed around the area of the proposed water quality control pond be undertaken according to the attached EMP. Although boreholes 4 and 6 did not display any PASS material, their location with respect to the rest of the PASS materials found in the other boreholes means that it would be inappropriate to draw boundaries between areas of PASS material and non PASS material.

Excavated material should be reinterred below the water table or treated with lime. This would involve sampling every 1,000m^3 of excavated material to determine appropriate liming rates.

5. Surface water assessment

5.1 Description of the proposed development

The physical characteristics of the site have been described in section 3 of this EMP.

The proposed development comprises the construction and/or installation of the following components;

- site earthworks and house-pad benching,
- roads,
- stormwater drains,
- sewer reticulation mains,
- water reticulation mains,
- underground electricity distribution cables,
- telecommunication cables,
- other ancillary services,
- landscaping.

The layout of the entire Pacific Pines Estate, with the proposed extensions and water quality control pond is shown on Figure 2. A more detailed layout of the proposed water quality control pond is shown on Figure 3.

The development aims to control the water quality of the water received from the Pacific Pines Estate, and when completed the site will be covered largely by water, which will protect soils from erosion and oxidation.

5.2 Assessment of receiving environment

5.2.1 Description and state of receiving environment

The proposed development is bordered on the western side by a narrow section of the Ballina Nature Reserve, which adjoins North Creek. North Creek shall be receiving the water discharged from the proposed WQCP, and is subject to tidal variation, due to its proximity to and connection with the Pacific Ocean, which is approximately 5.75 km as the crow flies downstream of the site.

The water from a tidally influenced drain (connecting the waters with North Creek) in the north-western corner of the proposed water quality control pond, was analysed on-site for the physico-chemical parameters of pH and electrical conductivity. Also, samples were taken and sent to a certified laboratory for the determination of the total suspended solids and the levels of nutrients nitrogen and phosphorus.

Two water samples were collected on each of three days, one at low tide and one at high tide. The water flow direction was also recorded at the time of each sampling. The test results for these samples are shown in table 5.2.1 below.

Table 5.2.1 Water Sampling Results

Sample	pH	EC (mS/cm)	TSS (mg/L)	TN (mg/L)	TP (mg/L)
27/10/00 Outgoing High tide	6.68	3.72	3	0.243	0.005
27/10/00 Outgoing Low tide	6.91	14.54	18.5	0.389	0.023
03/11/00 Outgoing Low tide	6.22	9.47	8.5	0.248	0.002
03/11/00 Incoming High tide	6.62	29.80	40.0	0.819	0.007
10/11/00 Outgoing High tide	6.82	11.80	20	0.424	<0.001
10/11/00 Outgoing Low tide	6.90	10.02	17	0.336	0.018

Copies of the laboratory certificates for the water sampling of North Creek are attached as appendix 4.

The results show that the saline water of North Creek has a fairly neutral pH. The TN and TP levels are in general accordance with ANZECC guideline levels for rivers and streams. These results provide three sets of baseline water quality results in what will ultimately be the discharge drain for the water quality control pond.

These results confirm generally good water quality in this vicinity. Consequently care should be taken to ensure that the proposed development does not have an adverse impact on the receiving environment.

5.3 Assessment of future surface water quality

An assessment of the potential impacts of the proposed development was undertaken using the AQUALM-XP computer model. AQUALM-XP is a water resources package with components for generating surface and subsurface runoff, non-point source and point source pollutant export and pollutant transporting and routing. It enables an analysis of the effects of planned land use changes.

The data requirements are as follows.

5.3.1 Climatic Data

The rainfall, evaporation and temperature data were obtained from records kept for Ballina, which is considered typical in terms of proximity and relief for the study undertaken. The records which date from 1893 to 1995 have been obtained from Queensland Department of Primary Industries (DPI) in the form of electronic data files designed for use with MEDLI effluent disposal software. This data has been analysed by DPI and compared with records from other nearby weather stations and adjusted if necessary to ensure that the records are complete. The data from these files has been converted by this office to a format compatible with AQUALM. An analysis of these records provides the following annual rainfall data;

Driest Year	714 mm
10th percentile year	1220 mm
Average year	1782 mm
Median Year	1702 mm
90th percentile	2380 mm
Wettest year	2848 mm

The model was run using the following rainfall sequences;

- wet year 90th percentile (1925 data) 2477 mm
- median year (1956 data) 1718 mm
- dry year 10th percentile (1951 data) 1215 mm

to assess the stormwater runoff and quality under a wide range of rainfall conditions.

5.3.2 Water Quality Parameters

The water quality parameters modelled were:

- Suspended Sediment
- Total Nitrogen
- Total Phosphorous

The sediment and pollutant export characteristics were taken from typical values in South East Queensland (BCC, October 2000[7]).

5.3.3 Catchment Description

A physical description of the catchment has been included in section 3 of this EMP. The land is presently used for grazing of cattle. The proposed land use is urban residential.

The catchment within which the site is situated is shown on Figure 6, while the boundaries of the catchments modelled in

[7] Brisbane City Council, Guidelines for Pollutant Export Modelling in Brisbane, Version 6, October 2000.

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PROJECT

ARDILL PAYNE & PARTNERS

PACIFIC PINES ESTATE, LENNOX HDS.

EXTERNAL CATCHMENT PLAN

FIGURED DIMENSIONS TO BE READ IN PREFERENCE TO SCALING.	APPROVED	SCALE AS SHOWN	DRAWN A.G.G.	DRAWING No.
		DATE 05/02/01	CHECKED	Figure 6

this report are shown on Figure 7. It has been assumed that runoff from the land in the catchment to the north of the development will be treated before it flows onto the site and will flow through the site to the point of release without further treatment. It has also been assumed that all runoff from catchment A will pass through the proposed water quality control pond (Pond A) and the runoff from catchment B will pass through and be treated prior to release in Pond B.

The land uses and their proportions are shown for each catchment in their undeveloped state and subsequent to completion of the proposed development table 5.3.3 below.

Table 5.3.3 Catchment Areas

Details	Rural Land Use Area ha	Urban Land Use Area ha
Undeveloped		
Catchment A	95.37	7.01
Catchment B	7.10	0
Developed		
Catchment A	2.78	99.60
Catchment B	0	7.10

The Urban area included in the table in the Undeveloped land uses is intended to include the existing developments near the north-eastern corner of the site. The Rural area remaining in the Developed catchment is to account for the land between the eastern boundary of the site and North Creek Road. This area may be developed in the future and would be expected to provide stormwater treatment and management measures to treat its runoff.

5.3.4 Modelling Undertaken

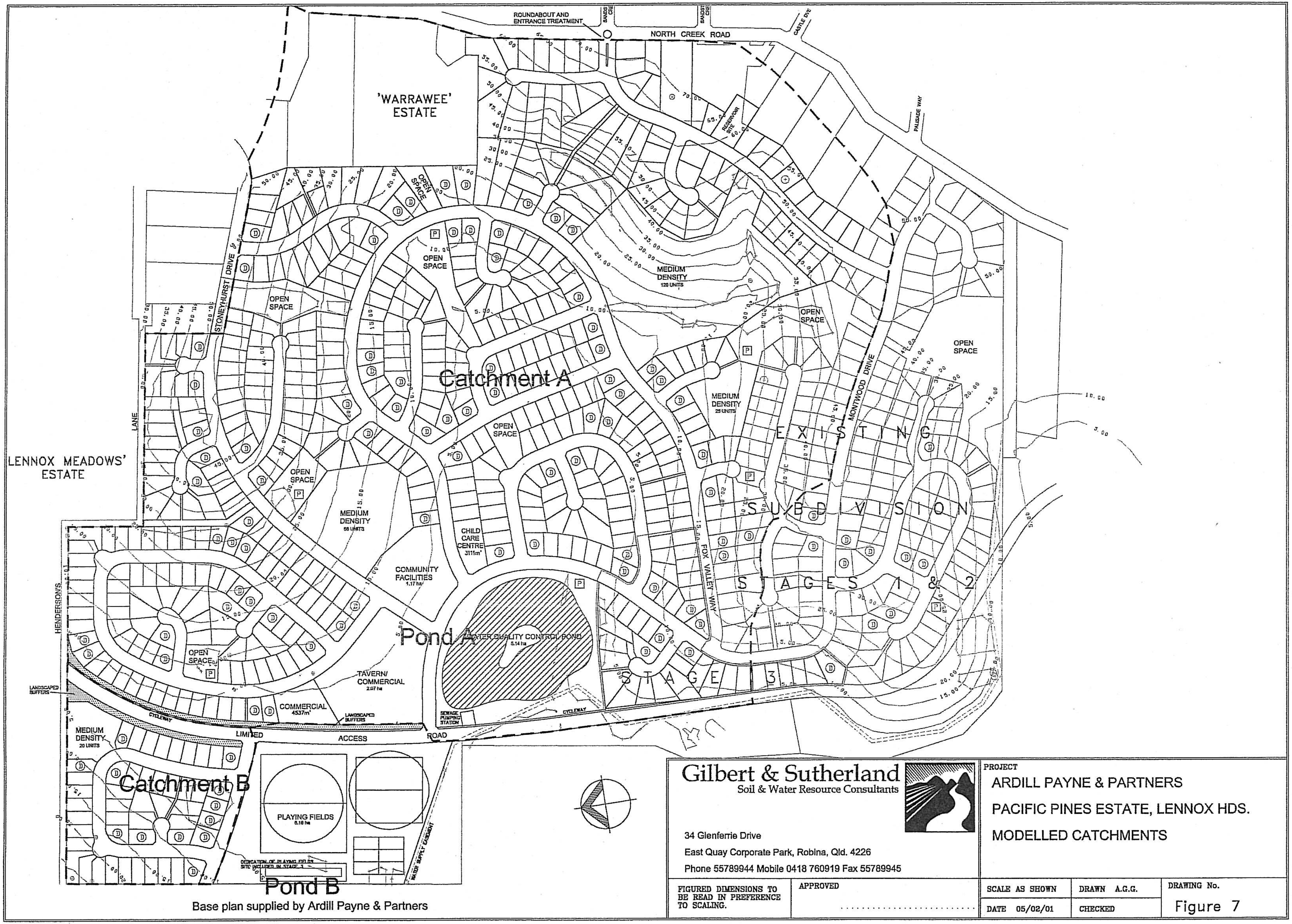
The AQUALM-XP model was used to form models for each drainage system simulating the existing environment (base case) to compare with models representing the anticipated environment subsequent to the change in land use (developed case).

A summary of scenarios modelled is as follows:-

- Base Case
- Developed Case **WITHOUT** treatment measures
- Developed Case **WITH** treatment measures

Pollutant export rates are generally a function of runoff, and as a result, the first step in setting up the AQUALM model is to establish a rainfall runoff relationship for the pervious and impervious surfaces.

Two land use types were represented in the model, these being rural and urban. The rural land use assumes no development and is used as the base case. Whilst this is a reflection of the current



Base plan supplied by Ardill Payne & Partners

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PROJECT
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PACIFIC PINES ESTATE, LENNOX HDS.
MODELLED CATCHMENTS

FIGURED DIMENSIONS TO BE READ IN PREFERENCE TO SCALING.	APPROVED	SCALE AS SHOWN	DRAWN A.G.G.	DRAWING No.
	....	DATE 05/02/01	CHECKED	Figure 7

land use, no additional loading has been added for the current fertiliser regime or animal inputs. The Urban land use comprises the developed areas within the site including roads, roofs, yards and landscaped gardens and parks.

Relevant model parameters for the land uses were sourced from previous extensive data collection by the Brisbane City Council (BCC October 2000) and are presented in Table 5.3.4.1 below.

Table 5.3.4.1. AQUALM Model Hydrologic Parameters

Parameter	Rural	Urban
Direct Runoff	0.15	0.25
Initial Loss	0.0	0.0
Evapotranspiration	0.75	0.75
Drainage Throughflow	0.5	0.25
Upper Soil Throughflow	0.04	0.02
Drainage Loss	0.0	0.05
Upper Soil Loss	0.2	0.1
Interception Store (mm)	15	10
Drainage Store (mm)	50	60
Upper Soil Store (mm)	80	50
Lawn Watering (mm/day)	0.5	0.1

The AQUALM model quality expressions required to simulate pollutant transport were also sourced from the data collection undertaken by Brisbane City Council (BCC October 2000). The expressions are depicted in Table 5.3.4.2 below.

Table 5.3.4.2. AQUALM Model Pollutant Export Expressions

Landuse	Suspended Solids	Total Nitrogen	Total Phosphorus
Rural	0.45SR+0.05TF	0.02SR+0.0073TF	0.0028SR+0.0009TF
Urban	1.4SR+0.09TF	0.02SR+0.015TF	0.0032SR+0.0012TF

NB – SR = Surface runoff (mm/day), TF = Throughflow (mm/day), pollutant export in kg/ha

5.3.5 Results and Interpretation

5.3.5.1 Base Case Scenario

The base case AQUALM-XP model assumes that the entire site land use is "rural". Given the AQUALM export equations available, this we consider that this provides the best representation for the current situation. Table 5.3.5.1 presents the annual runoff volumes and quantities of suspended sediment, nitrogen and phosphorus predicted to be exported from the rural catchment scenario under a range of rainfall conditions.

Table 5.3.5.1 Base Case (Undeveloped) AQUALM-XP Model Results

Year	Runoff (ML)	Suspended Sediment (kg)	Total Nitrogen (kg)	Total Phosphorus (kg)
Catchment A				
Dry	396	11,224	532.58	63.91
Median	644	18,657	880.28	106.49
Wet	1040	33,084	1500.80	186.61
Catchment B				
Dry	26.2	607.6	34.28	4.05
Median	42.7	1021.2	56.79	6.78
Wet	68.9	1818.4	97.07	11.92
Total				
Dry	422	11,832	566.86	67.96
Medium	686	19,678	937.07	113.27
Wet	1,110	34,902	1,597.87	198.53

5.3.5.2 Developed Case

The same areas as above were modelled under a range of rainfall conditions in a developed state. It has been assumed that a constructed wetland will be installed in each of the treatment areas to intercept and retain pollutants. The pond dimensions used in the modelling are shown in table 5.3.5.2.1 below.

Table 5.3.5.2.1 Water Quality Control Pond Characteristics

Depth (m)	Area (ha)	Outflow (m^3/sec)
Pond A		
0	1.755	0
1.45	2.3437	0
2.0	2.72	0
2.2	2.974	0
2.5*	3.001	0
2.8	3.028	0.02
3.0	3.38	0.04
3.5	3.84	Q100
Pond B		
0	0.1414	0
2.5*	0.355	0
2.7	0.38	Q100

* Indicates nominal water level

The conceptual treatment areas have been modelled with and without the treatment measures installed to demonstrate, by comparison with the base case scenario, the impacts of the proposed change in land use and the likely improvements in the water quality derived by installing the proposed treatment measures.

The results of the modelling are shown in the Table 5.3.5.2.2, with the developed and treated results in Table 5.3.5.2.3.

Table 5.3.5.2.2 Developed Case (No Treatment) AQUALM Model Results

Year	Runoff (ML)	Suspended Sediment (kg)	Total Nitrogen (kg)	Total Phosphorus (kg)
Catchment A				
Dry	442	39,422	792.3	107.47
Median	718	63,300	1,285.0	173.58
Wet	1,180	110,744	2,141.9	296.15
Catchment B				
Dry	29.8	2,770	54.2	7.39
Median	48.3	4,444	87.8	11.92
Wet	79.5	7,774	146.2	20.32
Totals				
Dry	472	42,191	846.5	114.8
Median	766	67,744	1,372.8	185.5
Wet	1,260	118,518	2,288.1	316.5

Table 5.3.5.2.3 Developed Case (With Treatment) AQUALM Model Results

Year	Runoff (ML)	Suspended Sediment (kg)	Total Nitrogen (kg)	Total Phosphorus (kg)
Catchment A				
Dry	398	5,403	387.8	28.05
Median	671	9,372	637.2	47.4
Wet	1,120	23,317	1218.0	109.4
Catchment B				
Dry	25.2	280	25.4	1.68
Median	42.7	452	40.3	2.68
Wet	73.7	1,345	80.0	6.87
Total				
Dry	423	5,683	413.2	29.73
Median	714	9,824	677.5	50.06
Wet	1,200	24,663	1,298.0	116.24

5.3.6 Summary of AQUALM modelling

A comparison of the tables above for the base case and the developed case with treatment show that the proposed treatment measures have the capacity to treat the runoff to a quality that achieves a no net increase in average annual pollutant loads. The average annual water quality of discharges is shown in table 5.3.6.1 below.

Table 5.3.6.1 Average water Quality

Parameter	Average Runoff Quality Before Development	Average Runoff Quality After Development
Suspended Solids (mg/L)	28.7	13.76
Total N (mg/L)	1.36	0.95
Total P (mg/L)	0.16	0.07

Based on these estimates it is considered that the quality of the stormwater runoff from the site during the operational phase will be acceptable provided the modelled permanent control measures are installed and properly maintained. However, careful management will be required to ensure that the projected quality levels are achieved and maintained. These details are considered in the following management plan. It is possible that the detailed design phase could result in a refinement of the treatment methodologies, depths and areas of the wetlands.

5.4 Constructed Wetland – Design Overview

The proposed constructed wetland for the subject site was proportioned in accordance with 'The Constructed Wetlands Manual' Department of Land and Water Conservation (DLWC) NSW (1998)[8]. The conceptual layout is in accordance with the DLWC manual and includes deep water and macrophyte zones with a total surface area of 3.0 hectares. The performance of the wetland was assessed and refined using AQUALM-XP software which is a daily time step modelling program. The AQUALM-XP modelling performed, under a wide range of flow regimes, indicated that the wetland will perform as required. The constructed wetland conceptual plan is shown on figure 3.

The following provisions have been included to improve wetland performance:

- Collection of all stormwater from the site in a network of stormwater drains
- discharge of stormwater to wetland via one inlet located in north western corner
- Installation of a trash rack at the inlet to remove rubbish and floating debris
- Creation of a high flow diversion to redirect flows >Q2 around the wetland
- Installation of a fibre reinforced cement (FRC) divider to prevent flow short circuiting through the wetland
- A variety of macrophyte species are to be planted in the macrophyte zone in strips normal to the flow direction, i.e. radiating outward from the island. A species list will be submitted as part of the detailed design of the wetland.

5.5 Blue-Green Algae

Blue-green algae are microscopic organisms which thrive in nutrient enriched waters. When the algae flourish to such an

[8]The Constructed Wetlands Manual: Volume 1 and 2. Department of Land and Water Conservation, 1998. DLWC, NSW, Australia.

extent that they colour the water they are said to be blooming. Factors such as pH, temperature, turbidity, nutrients and light are known to influence the growth and survival of algae, though the exact factors or combination of factors that trigger algal blooms is still poorly understood. The following sections outline the Vollenweider results performed by AQUALM-XP on predicting eutrophication and Blue-green algae blooms as well as design and management principles for the prevention and control of algal blooms.

5.5.1 Vollenweider Results

The time series analysis model 'AQUALM-XP' has a Vollenweider component in the constructed wetland module to assess the probability of eutrophication. While the Vollenweider Model was developed primarily in OECD countries, modifications have been made by the software authors to ensure the model is applicable to Australian conditions.

The results from the Vollenweider Model give a phosphorous load and associated chlorophyll-a concentration in the lake and an indication of the state of the lake. Three lake states are defined, Oligotrophic (Chlorophyll-a < 5mg/m^3), Mesotrophic (Chlorophyll-a < 5mg/m^3) and Eutrophic (Chlorophyll-a < 5mg/m^3). Blue-green algae blooms are associated with eutrophic water bodies.

The results indicated the lake to be oligotrophic for all three years modelled, wet, median and dry.

5.5.2 Management Principles

The most desirable method of controlling Blue-green algae blooms is to design the constructed wetland to prevent the environmental conditions needed for such algal blooms to occur. Factors that are known to enhance Blue-green algae growth in wetlands include nutrient enrichment, high pH, shallowness leading to high temperatures and low flow rate.

The proposed constructed wetland has a large portion devoted to providing habitat for emergent and submerged macrophytes that will both reduce the nutrients and light needed for algal blooms. The location of the constructed wetland on the North Coast of New South Wales means that the average number of rainy days will be amongst the highest for the state. The associated high flow rate and will promote displacement of algae and will prevent algal bloom development. The pH of the wetland should be monitored and measures used to maintain it in the range of 6.5-8.5. This is consistent with the discharge criteria for the lake and has been incorporated into the management plan.

5.6 Groundwater Issues

The interaction between a constructed wetland and the local groundwater depends on such things as the existing surface and groundwater systems, the quality of effluent entering the wetland, the ability of the wetland to remove and trap pollutants, the hydraulic loading to the wetland and the soil characteristics of the wetland substrate.

The water level in the proposed constructed wetland has been designed to be equal to the natural groundwater level. This should minimise the amount of recharge and discharge to and from the natural groundwater. The soil survey of the site indicated that the wetland will be constructed in medium clays to clayey sands. These types of soils have relatively low permeability and should minimise groundwater recharge. This indicates a low potential for groundwater contamination.

6. Environmental Management Plan– objectives and implementation

6.1 Objectives

The principle objective of this EMP is to provide mitigation measures to minimise the potential impacts of the development.

Additionally, the EMP provides information on specific site management issues relating to potential environmental impacts from the development during the construction and operational phases.

The control measures detailed in this EMP have been developed to minimise impacts on the environment and achieve the following objectives:

- appropriate stewardship of natural resources,
- protection of downstream flora and fauna habitats,
- confirmation of the success of impact control measures by the means of monitoring during the construction of each stage,
- compliance with statutory requirements and;
- preservation of water quality within the receiving environment.

6.2 Implementation

The EMP requires the Proponent to mitigate the potential environmental impacts associated with the construction of the subdivision works.

It is intended that the EMP will provide a set of performance criteria and guiding principles with which the engineering designs for the development will comply. The plans and specifications forming part of the construction contract for each stage should also include these performance criteria.

The estate should be developed in stages to minimise the potential for soil erosion and water pollution and this would enable the site to be progressively rehabilitated as the development proceeds. As soon as is practicable, after the completion of the earthworks in each stage, the lots will be topsoiled and reseeded to establish a fast growing cover crop which will minimise erosion and movement of sediment across and off the site. On steeper slopes, hydromulching may be required.

Where ever possible the site will remain grassed and otherwise undisturbed until construction of residences commences.

6.2.1 Construction phase control measures

Although no AQUALM-XP modelling has been completed for the construction phase, it is evident that temporary sedimentation ponds and other sediment control measures should be installed during this phase.

Prior to commencement of bulk earthworks, temporary sedimentation ponds should be installed. All runoff from disturbed areas is to be collected by means of surface drains and diverted to a sedimentation pond. Where practicable runoff from undisturbed areas should be diverted around disturbed areas and away from the sedimentation pond.

Other control measures such as (but not limited to) silt fences, contour drains, and straw bales should be installed and maintained in accordance with the recommendations contained in the "Managing Urban Stormwater" 3rd Edition, August 1998 by the Housing Production Division, Department of Housing, New South Wales.

The temporary sedimentation ponds may be removed when the site has been revegetated after completion of the bulk earthworks. However the other control measures mentioned above must be installed in disturbed areas during the building construction phase and maintained until landscaping has been completed and becomes established.

The soils identified on the site are described as low to moderate fertility soils (Morand 1996). Nevertheless, it is considered that nutrient transport from the site during the construction phase should be minimised by installing temporary sedimentation basins designed in accordance with the recommendations contained in the "Blue Book".

Any acid sulfate soils disturbed during the construction works should be identified, managed and treated in accordance with the enclosed EMP and the ASSMAC manual.

6.2.2 Operational phase control measures

It is noted that the site is to be sewered and that all wastewater will be transported off-site to be treated at Ballina Shire Council's Sewage Treatment Plant. Consequently disposal of treated effluent on-site by irrigation or other methods is not required.

It is recommended that the water quality of discharges from the site be managed by treating all runoff from the site in one of the constructed wetlands.

All open drains should be broad and shallow to minimise disturbance of acid sulfate soils on the site.

It should be noted that sediment, erosion and runoff control is pertinent to maintaining water quality across the development areas particularly in the vicinity of discharge points into the existing waterbodies and drainage systems.

The movement of dust and sediments across and off the site can be minimised by implementing the practices detailed in the attached tables.

As the site is progressively developed, the completed allotments and footpaths will be landscaped and grassed. This will necessitate planning and coordination of the development activities and arranging the availability of turf, plants and mulching materials.

Topsoil is important for revegetating exposed areas and should not be used for fill.