AQUIS RESORT AT THE GREAT BARRIER REEF PTY LTD

ENVIRONMENTAL IMPACT STATEMENT

VOLUME 2

CHAPTER 15

GEOLOGY AND SOILS

15. GEOLOGY AND SOILS

15.1 GEOLOGY

15.1.1 Existing Situation

The site is located within the Barron River floodplain and formed of unconsolidated Holocene age alluvial deposits of sands, gravels, silts and clays. Published geological information from *Queensland Digital Geological Map Data 1:100,000 Cairns 8064 series Department of Natural Resources and Mines* indicates that the site is dominated by Holocene sediments. The surficial geology is dominated by three major geological units as shown on **Figure 15-1**. This shows that the majority of the development area is underlain by younger creek alluvium with the outer parts of the property bordering coastal flats and mangrove flats.

Interpreted stratigraphic information available from Queensland Government Registered Groundwater Bores and selected soil log profiles published in the Department of Natural Resources and Mines (Qld) 'Acid Sulfate Soil Package: Yorkeys Knob', 2013 (see Appendix A of **Appendix Q**) situated on or adjacent to the development site indicates the following:

- the younger (Holocene age) alluvial deposits are generally present to depths of about 7 m to 10 m below the ground surface. Much deeper deposits (up to 25 m) are apparent on the eastern and southern margins of the site
- the younger alluvial deposits are underlain by older (Pleistocene age), consolidated alluvial deposits
- bedrock (Barron River Metamorphics) underlies the alluvial deposits at depths of between 68 m and 94 m (approximately -66 m to -92 m AHD).

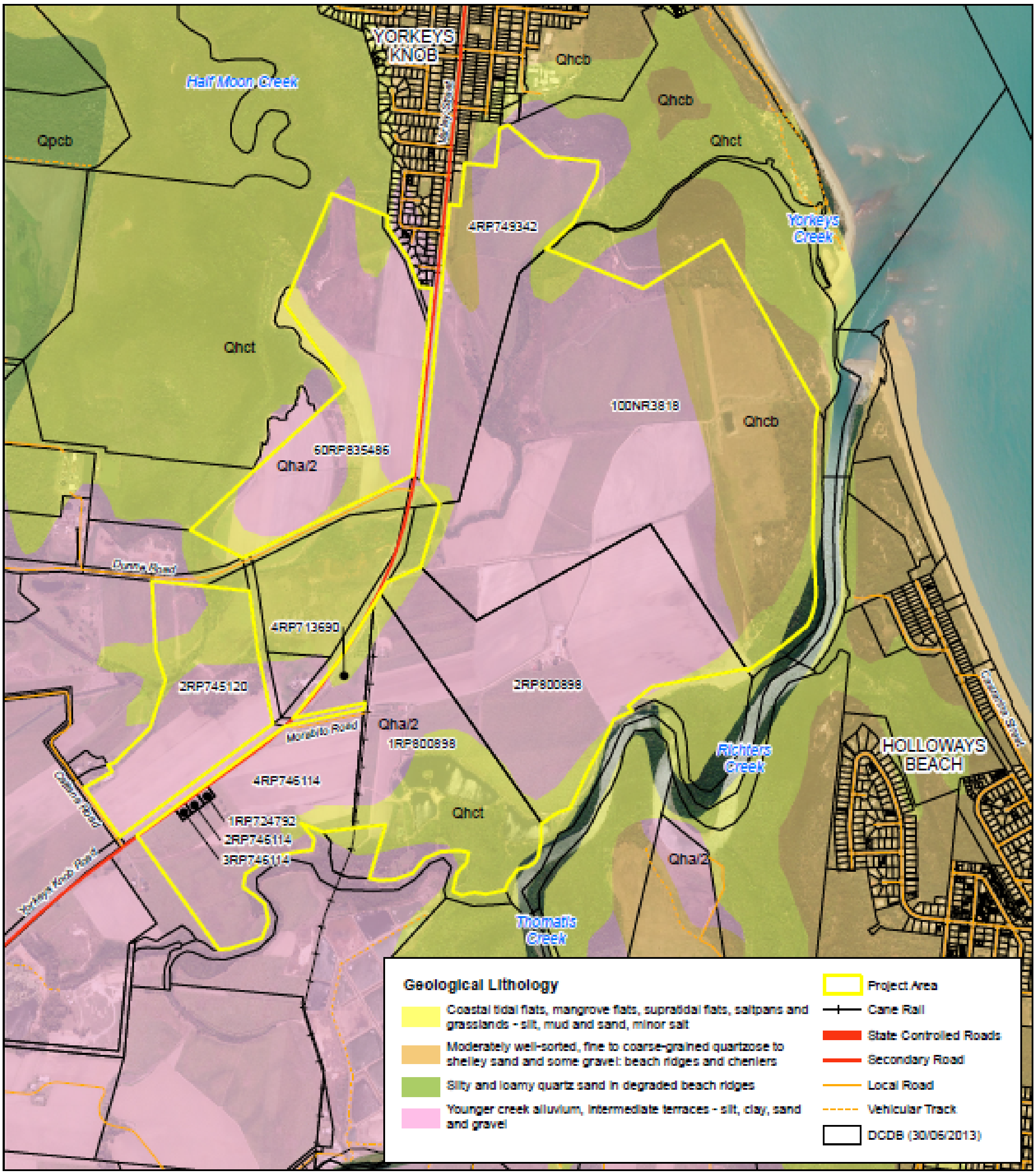

Figure 15-1 Surficial geology and landform.

Source: Based on **Appendix Q** (Figure 2). See end of text for a larger version of this figure.

15.1.2 Impacts

The proposal will have no impacts on the geology of the site.

15.2 SOILS

15.2.1 Existing Situation

The soil survey undertaken for the project involved a review of existing information including data from Queensland registered groundwater bores and supplemented by fieldwork including drilling 23 boreholes to depths of generally between 4 and 6 m. The results of the survey confirmed that the surface soils are alluvial deposits that are present to depths of between 7 to 25 m. These are underlain by older consolidated alluvial deposits with bedrock occurring at depths of between 68 and 94 m. The five major soil units found on-site are summarised in **Table 15-1** and shown on **Figure 15-2**.

TABLE 15-1 SITE SOILS

UNIT NAME	% SITE COVER	TYPICAL ORIGIN	DESCRIPTION
Hull	11%	Beach Dune	Deep sandy soils – Tenosols.
Holloway	40%	Alluvium	Peaty soils - Organosols: Mottled grey and yellow duplex or uniform textured soils. Formed on poorly drained alluvium and usually abutting the littoral zone.
Mangrove	7%	Swamps and Intertidal Zone	Not typically assessed in detail.
Liverpool	39%	Alluvium	Deep sandy soils – Tenosols and Rudosols: Uniform fine sandy loam or loam soils on low alluvial flood plains and levees.
Disturbed Land	3%	Fill material	Anthroposol: Fill material of various sources. Not typically assessed in detail.

Source: **Appendix Q** (Table 1).

The survey found that the soil conditions within the site are broadly consistent with published geology and soil units. Generally, the surface layer of soil is firm to stiff clay to around 2 m below ground level and is underlain by looser sands and gravels typically between 7 to 10 m (but as much as 13 m) below ground level. At greater depths the soils vary depending on proximity to watercourses, with soft clays located along the eastern and southern margins near Richters Creek (shown as the *Mangrove* mapping unit in the above figure) and sandy material in the central development area (*Holloway* and *Liverpool* mapping units in the above figure). Generally, there is a layer of stiff to hard clays interspersed with medium dense to dense sands plus gravels below the younger soils.

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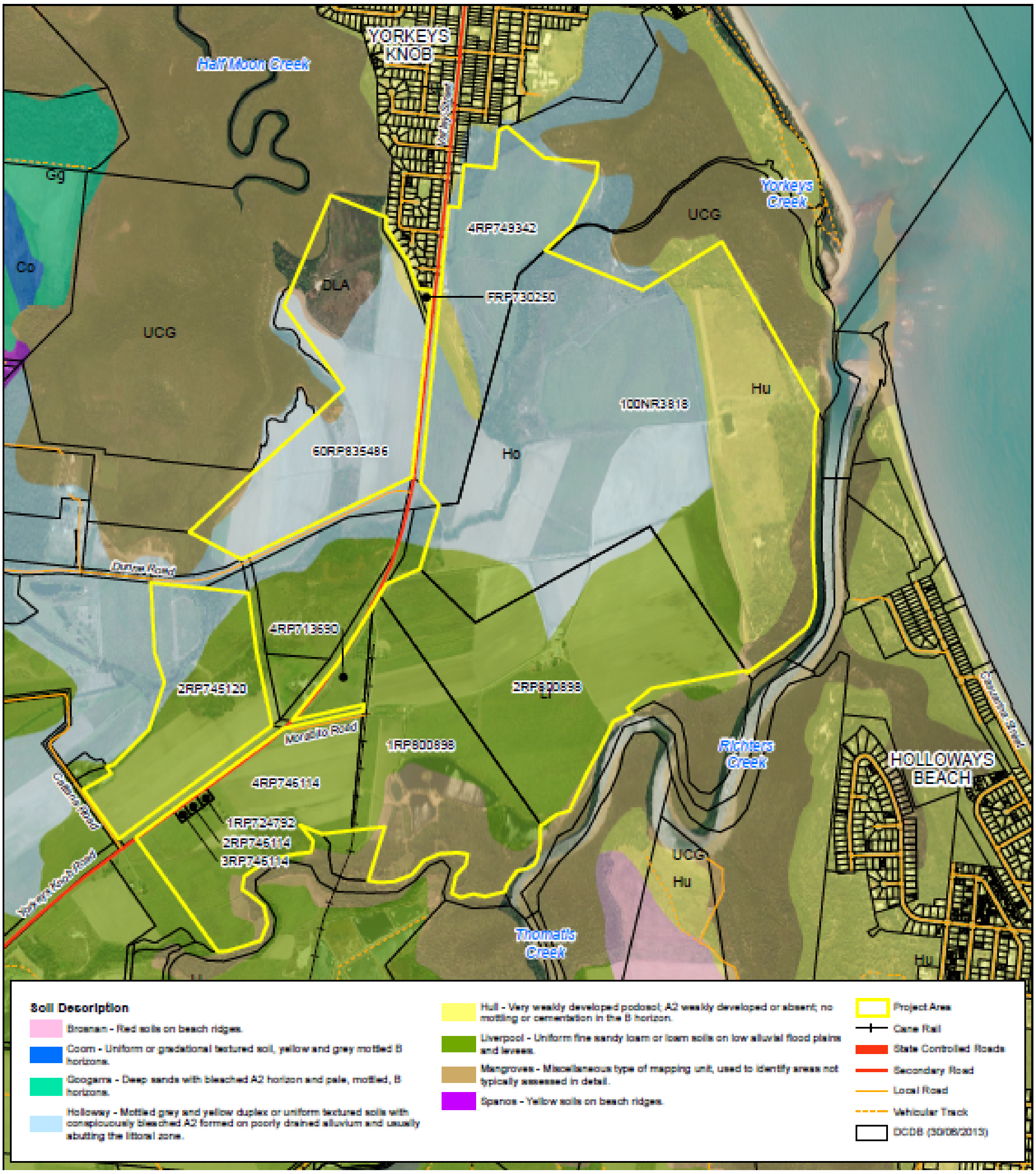

Figure 15-2 Soils.

Source: Based on **Appendix Q** (Figure 3). See end of text for a larger version of this figure.

The survey noted that the main profile variations occur in low lying areas associated with adjacent creeks and mangrove areas. The following (**Figure 15-3**) provides a generalised profile of soils on the site.

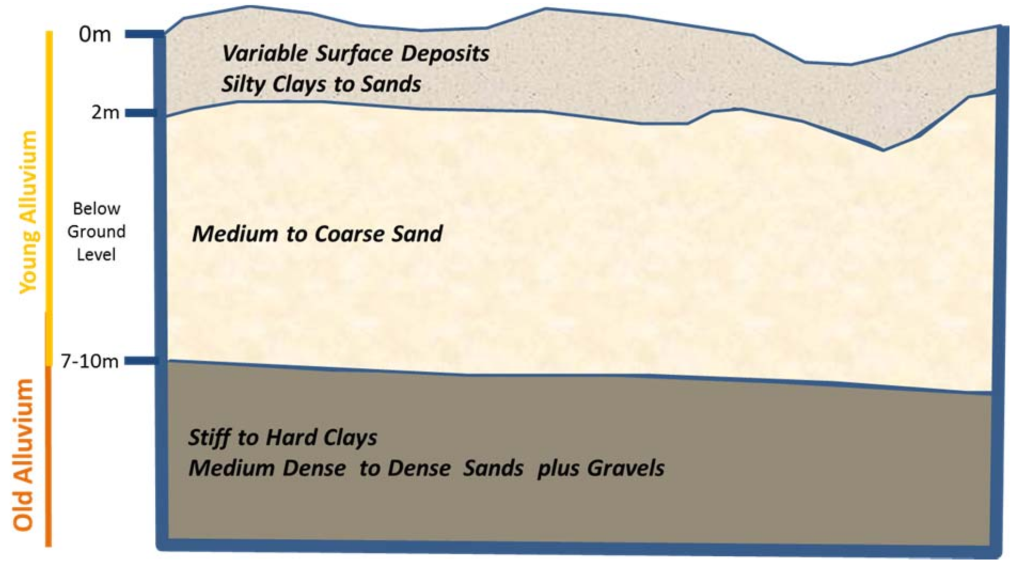

Figure 15-3 Generalised soil profile.

Source: Golder Associates (2013).

The survey found that, with the exception of parts of the bank of Richters Creek, no significant active erosion areas were evident. In addition, other than small areas of contaminated land and acid sulfate soils that are dispersed throughout the site (see **Section 15.4**), the soils likely to be encountered do not have any particular management needs arising from wetness, erosivity, depth, salinity, or other features.

15.2.2 Impacts

The surface layer of soil on the site is firm-to-stiff clay to around 2 m below ground level and this is underlain by looser sands and gravels, typically between 7 m and 10 m (but as much as 13 m) below ground level. At greater depths, the soils vary depending on proximity to watercourses. Within the main disturbance footprint (i.e. the lake), there is a layer of stiff-to-hard clays, interspersed with medium-dense to dense sands, as well as gravels below the younger soils. This layer is sufficiently deep to be not affected by lake construction.

With the exception of contaminated soils and ASS / PASS (**Section 15.3** and **Section 15.4**), the site's soils do not present any particular design constraint, nor require a specific construction management response.

The impact on soils cannot be avoided or minimised as there are no prudent and feasible alternatives to the lake in particular and the overall site development in general. However, management of the earthmoving and general construction process is proposed.

With the exception of contaminated soils and ASS / PASS (**Section 15.3** and **Section 15.4**), the site's soils will not involve any particular impacts. However, without appropriate management, earthworks during construction have the potential to result in erosion and subsequent sedimentation and thereby threaten water quality.

In particular, construction activities have the potential to contribute sediment to the waters of Half Moon, Yorkeys, and Richters Creeks and the downstream coastal environment. This risk is highest during the wet season. Any increase in the sediment load entering the system would be expected to directly increase the levels of turbidity and suspended sediments in the water column, and may lead to enhanced sediment deposition and the smothering of benthic communities.

The potential impacts of increased turbidity, sediment suspension and smothering on local aquatic communities are:

- reduced growth of marine plants by limiting light for photosynthesis
- reduced respiration and feeding of benthic invertebrate communities leading to a reduction in abundance and biodiversity
- traumatization of fish gill tissues affecting growth and survival
- burying of aquatic plants (including roots and mangrove pneumatophores) and invertebrate communities (burrowing polychaetes and crustaceans)
- reduced algal and coral diversity and reductions in epifaunal densities in coral communities (however, note that the nearest coral community is >10 km from the mouth of Richters Creek).

The effect of increased suspended solid concentrations and sediment deposition on marine vertebrate communities is likely to be minimal, primarily because mobile organisms tend to avoid unfavourable environments. Further, the likely absence of seagrass in the area makes it unlikely habitat for listed threatened, migratory or marine species such as dugongs (*Dugong dugon)*, green turtles (*Chelonia mydas*) and syngnathids (seahorses and sea dragons). While some marine vertebrates will avoid areas of high turbidity, these waters may attract a range of fishes, particularly juveniles, as it confers a greater degree of protection from predators.

The effects of increased suspended solids and sedimentation resulting from excavation and spoil handling are highly variable and will depend on both the techniques used and the season. The likelihood of increases in suspended sediments and of smothering are closely related to the characteristics of the sediment. Coarse sediments settle from the water column quickly and are less likely to move away from the excavation site. Fine sediments remain suspended longer and may be carried further before settling, and consequently are more likely to smother marine organisms.

15.2.3 Mitigation and management

Standard soil and water management and other site controls (e.g. dust control) will be required under the site's EMP (Construction) to reduce normal construction impacts. The net impacts are likely to be very minor.

Management of soils (and in particular the development of a detailed Erosion and Sedimentation Control Plan) is an element of the proposed EMP (Construction) described in Section [23.4.4]. The net impacts are likely to be very minor.

15.2.4 Residual Impacts

Management of soils (and in particular the development of a detailed Erosion and Sedimentation Control Plan) is an element of the proposed EMP (Construction) described in Section [23.4.4]. The net impacts are likely to be very minor.

15.3 CONTAMINATED LAND

15.3.1 Existing Situation

The site history and field inspection do not identify volumes of chemical storage on any allotment that would constitute a Notifiable Activity under Section 374 of the *Environmental Protection Act 1994*. The results of a search of the Queensland Government Environmental Management Register (EMR) and Contaminated Land Register (CLR) regarding the site are provided in **Table 15-2** along with the status of listing on the EMR and the CLR. While these potential contamination sources are typically surficial, they may have the potential to impact the shallow unconfined aquifer.

TABLE 15-2 POTENTIAL SOURCES OF CONTAMINATION

LOT PLAN	EMR / CLR STATUS	POTENTIAL ISSUES	FURTHER DETAILS
Lot 100 on NR3818	Not listed	Hydrocarbon spill / dumping (Report by Burns 1995) –reported use of oil on farm roads for dust suppression (Appendix D of **Appendix Q**)	Figure 2 of **Appendix Q**
Lot 1 on RP800898	Not listed	Possible storage of farm chemicals, oils and lubricants.	-
Lot 2 on RP800898	EMR Listed: Petroleum Product Or Oil Storage	Petroleum or oil storage; leakage or spills from tanks. Storage of farm chemicals, oils and lubricants. Workshop identified with above ground diesel tanks, 220 L oil drums, 20 L containers of poisons / pesticides / herbicides. Minor staining identified around workshops and fill tanks. Reported use of oil on farm roads for dust suppression.	Plate 1-3 Appendix I of **Appendix Q**
Lot 2 on RP745120	Not listed	Possible storage of farm chemicals, oils and lubricants.	
Lot 60 on RP835486	Not listed	Possible storage of farm chemicals, oils and lubricants.	
Lot 4 on RP713690	Not listed	Possible storage of farm chemicals, oils and lubricants.	
Lot 1 on RP724792	Not listed	Possible storage of farm chemicals, oils and lubricants.	
Lot 2 on RP746114	Not listed	Possible storage of farm chemicals, oils and lubricants.	
Lot 3 on RP746114	Not listed	Possible storage of farm chemicals, oils and lubricants.	
Lot 4 on RP746114	Not listed	Petroleum or oil storage; leakage or spills from tanks. Storage of farm chemicals, oils and lubricants. Workshop / shed identified with 4 disused above ground diesel tanks, 220 L oil drums, 20 L containers of poisons / pesticides / herbicides.	Plate 3-6 **Appendix 8** of **Appendix Q**
Lot 4 on RP749342	Not listed	Possible storage of farm chemicals, oils and lubricants.	

Source: **Appendix Q** (Table 4).

No parcels of land in the site are listed on the CLR and only Lot 2 on RP800898 is listed on the EMR (for the prescribed activity 'Petroleum product or oil storage'). Fuel and oil storage is being undertaken on this lot and minor staining is present. It is expected that other areas of minor contamination may occur around farm buildings where fuel and chemical mixing may have occurred.

It is known that a hydrocarbon spill / dumping event occurred in January 1994 and affected part of Lot 100 on NR3818. However, a report by Kathryn Burns from the Australian Institute of Marine Sciences (see **Appendix Q**) concluded that only limited areas were still moderately-to-slightly contaminated by July 1994, with very sensitive biota already colonising the area.

Advice on historic use of agrichemicals was obtained from Salmec Harvesting (M Savina pers. comm. 23 August 2013) as shown in **Table 15-3** below.

TABLE 15-3 AGRICHEMICAL USE

TYPE	CONSTITUENTS / COMPONENTS	APPLICATION RATE
Fertiliser		
Ratoon 2005 to 2008		
Urea	184 N	400 kg/ha
Murate Potash	100 K	200 kg/ha
Plant 2005 to 2008		
66S	48N 39P 56K 18S	375 kg/ha
Nitra King	59N 35K	180 kg/ha
Ratoon 2009 to2013		
CB44678	140N 10.5P 95K 16S	562 kg/ha
Plant 2009 to 2013		
CB83350	52N 9.8P 43K 52S	350 kg/ha
Nitra King	59N 35K	180 kg/ha
Herbicides		
Round up	470 g/L Glyphosate	2 to 6 L/ha
StompXtra	455 g/L Pendimethalin	3 L/ha
Shirquat	250 g/L Paraquat	0.75 L/ha
Soccer	700 g/L Metribuzin	1.5 L/ha
Barrage	468 g / kg Diuron, 132 g / kg Hexazinone	2.2 kg/ha
Agroxone	750 g/L MCPA	1 to 0.4 L/ha
Strane	33 g/L 24D	0.4 L/ha
Tordon 75D	75 g/L Picloram	0.4 L/ha
Fungicides		
Throtel	426 g/L Hydrocarbon	0.12 L/ha
Insecticides		
Telstar	250 g/L Bifenthrin	0.15 L/ha

Source: Salmec Harvesting (M Savina pers. comm. 23 August 2013).

The majority of the herbicides and pesticides listed above are all common chemicals used in association with sugar cane farming. Typically, these strongly adsorb to soil particles, have low water solubility and are relatively immobile. These herbicides and pesticides typically have half-lives that range from less than two days to eight months and are readily degraded depending on soil and climatic conditions.

The exceptions to these general conditions are:

- Paraquat is rapidly and strongly adsorbed onto clay surfaces and is not significantly mobile in most soils but has a half-life of greater than 1000 days.
- Metribuzin is poorly bound to most soils and soluble in water, giving it a potential for leaching in many soil types. The half-life of Metribuzin varies according to soil type and climatic conditions. Soil half-lives of 30 to 120 days have been reported.

- Hexazinone is very poorly adsorbed to soil particles, very soluble in water. Soil half-lives of 30 to 180 days have been reported. Hexazinone is slightly toxic to fish and other freshwater organisms.
- MCPA leaches in most soils, but its mobility increases as organic matter decreases. The half-life is five to six days in slightly acidic to slightly alkaline soils.
- Picloram is poorly bound to soils, although it is bound better by soils with higher proportions of soil organic matter. Picloram half-lives from 20 to 300 days have been reported.

Previous experience has also identified residual concentrations of pesticides, herbicides, arsenic and mercury within cultivation areas that do not represent a risk to human health under more sensitive land use scenarios (e.g. residential land use). However, residual herbicide / pesticide concentrations in soils may impact upon some aquatic ecosystems.

The majority of the herbicides and pesticides listed are all common chemicals used in association with sugar cane farming. An assessment of agrichemical used on the site and surrounds (including what is now the Ponderosa Prawn Farm) include fertilisers, fungicides, herbicides and insecticides and a combined list is included in **Table 15-4** below.

TABLE 15-4 CHEMICALS PREVIOUSLY USED ON AND NEAR THE SITE

PRODUCT NAME	CHEMICAL CONSTITUENTS	USE
CB44678	–	unknown
CB83350	–	unknown
66S	–	unknown
Agroxone	MPCA	herbicide
Barrage	diuron and hexazinone	herbicide
Glyphosate 360	glyphosate	herbicide
Round up	glyphosate	herbicide
Murate potash	potassium chloride	fertiliser
Nitra King	nitrogen, phosphate, potash, iron, calcium and sulphur	fertiliser
Shirquat	paraquat	herbicide
Shirtan 120	methoxy ethyl mercury chloride	liquid fungicide
Shirweed 500	2,4–dichloro–phenoxy–acetic acid	herbicide
Strane	2,4–dichloro–phenoxy–acetic acid	herbicide
StompXtra	pendimethalin	herbicide
Suscon Blue	chloropyrifos	insecticide
Soccer	metribuzin	herbicide
Telstar	bifenthrin	insecticide
Throtel	hydrocarbons	fungicide
Tordon 75D	picloram	herbicide
Urea	carbamide	fertiliser

Source: **Appendix F** (Table 4.3).

Sediment samples from all adjacent watercourses and on the site were tested for the presence of herbicides, insecticides and fungicides (see **Chapter 7**). All were below detectable limits, with the exception of paraquat in one of the cane drains on-site. The concentrations of all other parameters (e.g. BTEX and TPH) were below laboratory limits of reporting. The concentrations of all herbicides and pesticides, known to be used in the region, were also below laboratory limits of reporting, except for paraquat that had a concentration of 1.3 mg / kg. While detectable, the concentration of paraquat in the sediment was low. As it strongly adsorbs to sediment and is biologically unavailable in that form, it is unlikely to be significantly negatively impacting aquatic ecosystems on the site. Paraquat degrades quickly and does not bio-accumulate, further decreasing any likely risk.

15.3.2 Impacts

No parcels of land in the site are listed on the CLR and only Lot 2 on RP800898 is listed on the EMR (for the prescribed activity 'Petroleum product or oil storage') (see **Table 15-2**). Fuel and oil storage is being undertaken on this lot and minor staining is evident. It is expected that other areas of minor contamination may occur around farm building where fuel and chemical mixing may have occurred.

Possible impacts arising from the disturbance of areas of contaminated land or other land that may have been contaminated by agrichemicals cannot be practically mitigated by design.

Existing Contaminants – Agrichemicals

The chemicals listed in **Table 15-4** are all common chemicals used in association with sugar cane farming. In a detailed assessment of agrichemical usage associated with planning for the nearby Ponderosa Prawn Farm undertaken by Fisheries Research Consultants (now frc environmental) (1995), it was found that at high concentrations all then-used chemicals associated with cane farming can impact aquatic flora and fauna. However, a survey of potential contaminants found that residual concentrations of organophosphate pesticides and metals and metalloids were unlikely to result in an adverse effect on crustaceans and fish (Fisheries Research Consultants 1995). Although these findings should be confirmed based on-site-specific testing, it is instructive to note that even direct contact with soils containing chemicals by prawns in ponds excavated into such soils, has not been found to be an issue for Ponderosa.

As discussed in **Section 15.3.1**, the toxicity and bioaccumulation of several of the listed chemicals is known to affect aquatic organisms. However, site samples were tested for the presence of herbicides, insecticides, and fungicides and all results were below detectable limits, with the exception of paraquat for a sample found in one of the cane drains on-site. While detectable, the concentration of paraquat in the sediment was low.

As this chemical strongly adsorbs to sediment and is biologically unavailable once bound to soil, it is unlikely to be negatively impacting aquatic ecosystems on the site to any significant degree. Paraquat degrades quickly and does not bioaccumulate, further decreasing any likely risk.

Existing Contaminants – Hydrocarbons and Other Chemicals

Small areas of land around farm buildings where fuel and chemical mixing may have occurred, and the part of Lot 100 on NR3818 where a fuel spill occurred nearly 20 years ago, can all be expected to contain minor remnant soil pollution. In the absence of management, the disturbance of this soil (which is unavoidable) could release small amounts of minor pollution.

However, this impact is easily managed by removal and remediation and feasible techniques exists for this type of work.

Possible Future Contaminants

It is likely that hydrocarbons and chemicals will be stored on the site both during construction and operation of the Aquis Resort. However, in order to comply with the General Environmental Duty according to the EP Act, requirements documented in Australian Standards relating to the storage of relevant quantities of hydrocarbons (e.g. AS 1940) and chemicals (e.g. AS 2507) will need to be met.

The impacts of contamination can be reduced through use of standard remediation techniques. Alternatively, the contamination could be managed on-site to control and mitigate risks to human health and the environment.

15.3.3 Mitigation and Management

More detailed investigations and possible remediation of contaminated areas will need to occur to enable a suitability statement to be issued under the EP Act for the proposed development. This can be a development approval condition.

The remediation / management of contamination associated with historical cane farming activities is not a complex task. A large number of former cane farming properties in the Cairns region have been successfully remediated and redeveloped for residential and other sensitive land uses. In addition, a detailed investigation undertaken in 1995 for the nearby Ponderosa Prawn Farm (Fisheries Research Consultants 1995) concluded that even direct contact with soils containing cane farming-related chemicals by prawns in ponds excavated into such soils was not likely to be a concern and this has proved to be the case.

Management of soils is an element of the proposed EMP (Construction) described in **Section 23.4.4**. The net impacts are likely to be very minor.

15.3.4 Residual Impacts

Management of contaminated soils is an element of the proposed EMP (Construction) described in **Section 23.4.4**. The net impacts are likely to be very minor.

15.4 ACID SULFATE SOIL / POTENTIAL ACID SULFATE SOIL

15.4.1 Existing Situation

a) Terminology

There are several terms that are relevant to the consideration of acid sulfate soil issues. A summary from the NRM website (http://www.nrm.qld.gov.au/land/ass/what_are_ass.html) is provided in **Table 15-5** below.

TABLE 15-5 TERMINOLOGY FOR ASS / PASS

ACRONYM	TERM	DESCRIPTION
ASS	Acid sulfate soil	Acid sulfate soil (ASS) is the common name given to soils and sediments containing iron sulfides, the most common being pyrite. When exposed to air due to drainage or disturbance, these soils produce sulfuric acid, often releasing toxic quantities of iron, aluminium, and heavy metals. The term acid sulfate soils generally includes both actual and potential acid sulfate soils (AASS and PASS), which often occur in the same soil profile. AASS usually overlie PASS.
PASS	Potential acid sulfate soil	ASS are not always a problem. Under the anaerobic reducing conditions maintained by permanent groundwater, the iron sulfides are stable and the surrounding soil pH is often weakly acid to weakly alkaline. Such soils are called potential acid sulfate soils (PASS) as they have potential to produce sulfuric acid when disturbed or exposed to air. Potential acid sulfate soils: • often have a pH close to neutral (6.5–7.5) • contain unoxidised iron sulfides • are usually soft, sticky and saturated with water • are usually gel-like muds but can include wet sands and gravels • have the potential to produce acid if exposed to oxygen.

ACRONYM	TERM	DESCRIPTION
AASS	Actual acid sulfate soil	When PASS are disturbed or exposed to oxygen, the iron sulfides are oxidised to sulfuric acid and the soil becomes strongly acidic (usually below pH 4). These soils are then called actual acid sulfate soils (AASS) (that is, they are already acidic). Actual acid sulfate soils: • have a pH of less than 4 (i.e. they are already acid) • contain oxidised iron sulfides • vary in texture • often contain jarosite (a yellow mottle produced as a by-product of the oxidation process).

Source: Study team compilation based on http://www.nrm.qld.gov.au/land/ass/what_are_ass.html.

b) Site Survey

ASS mapping published by the Department of Science, Information Technology, Innovation and the Arts (DSITIA) indicates that areas on the site that are associated with mangroves and intertidal areas will contain ASS in the top 0.5 m of the soil profile. Over the remainder of the site, the mapping indicates that ASS is expected between 0.5 m and > 3 m below the existing ground surface. **Figure 15-4** below shows the variability of the anticipated ASS depth and distribution.

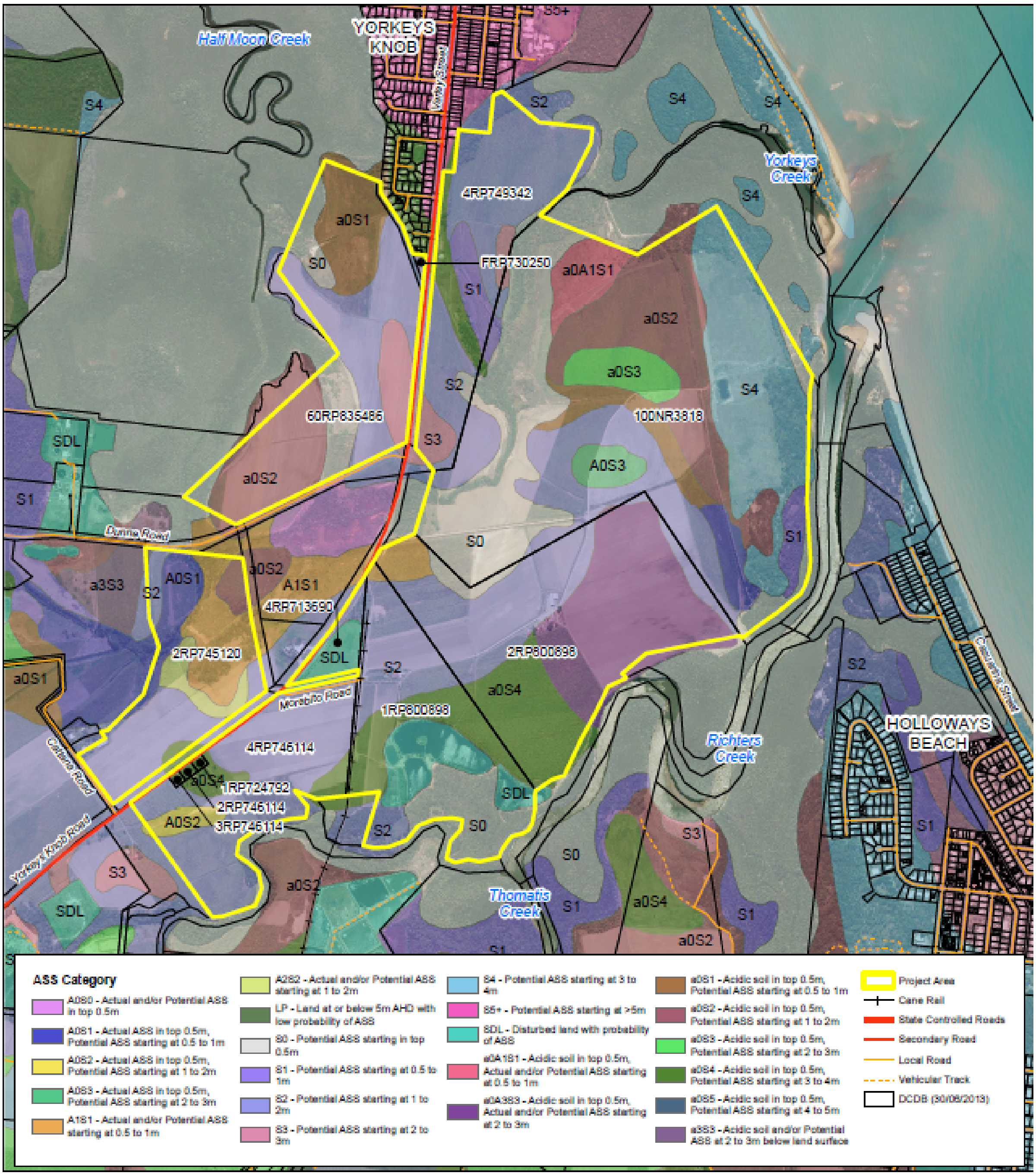

Figure 15-4 Published ASS risk map.

Source: Based on **Appendix Q** (Figure 4). See end of text for a larger version of this figure.

The soil survey included a preliminary assessment of the presence of ASS including both AASS and PASS. At each borehole location samples were collected at 0.25 m intervals and field tested for indicators of ASS. Based on the results of the field tests, 30 samples were then analysed for Chromium Suite Testing. It was found that the top 1 to 2 m of the soil profile within the cultivated area on the site is not AASS or PASS. However, PASS underlies the entire site below this layer, with AASS material occurring in lenses with thicknesses of between 1 m and 4 m. PASS material was strongly associated with soft grey-dark grey silty clays and loose sands. This is demonstrated in cross section D-D which runs south-west to north-east through the central part of the site and shown on **Figure 15-5** and **Figure 15-6**.

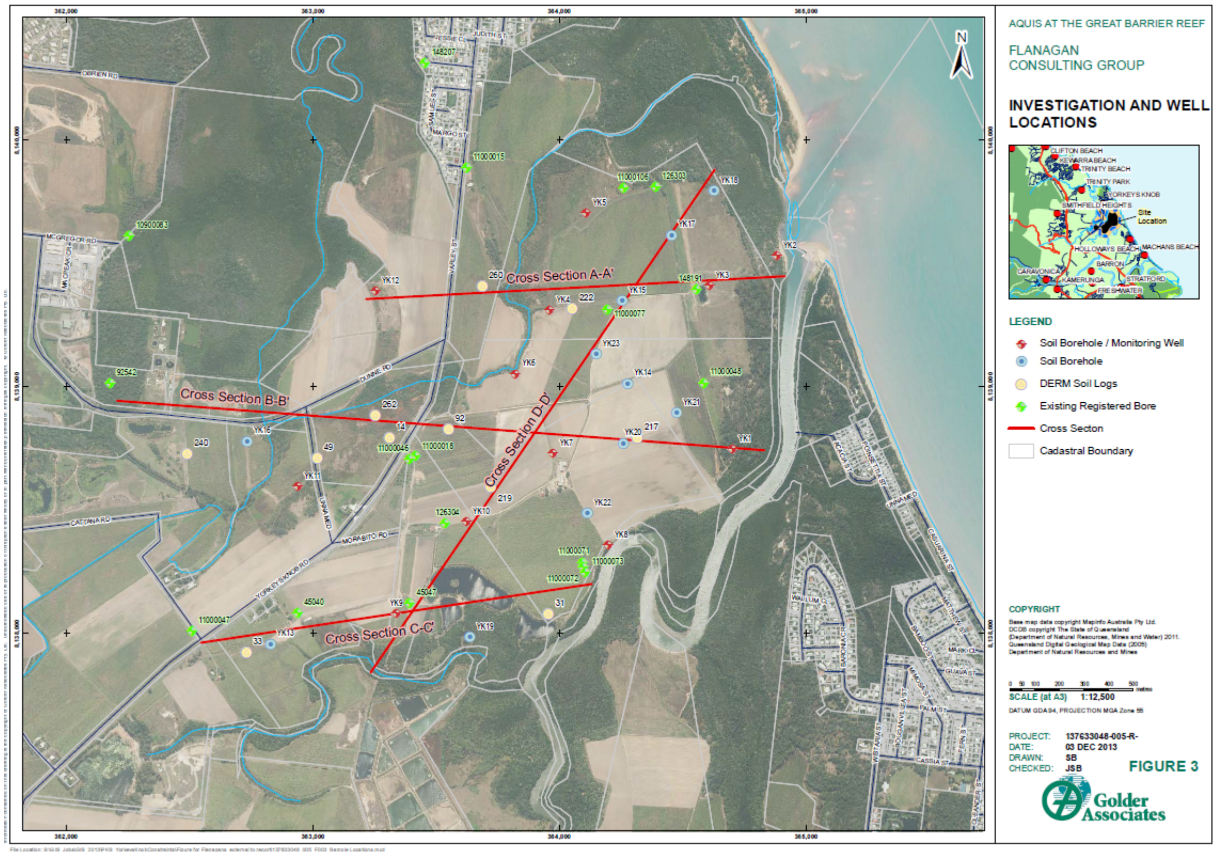

Figure 15-5 Map showing location of cross section D-D (south-west to north-east through cultivated area).

Source: Appendix Q (Figure 3).

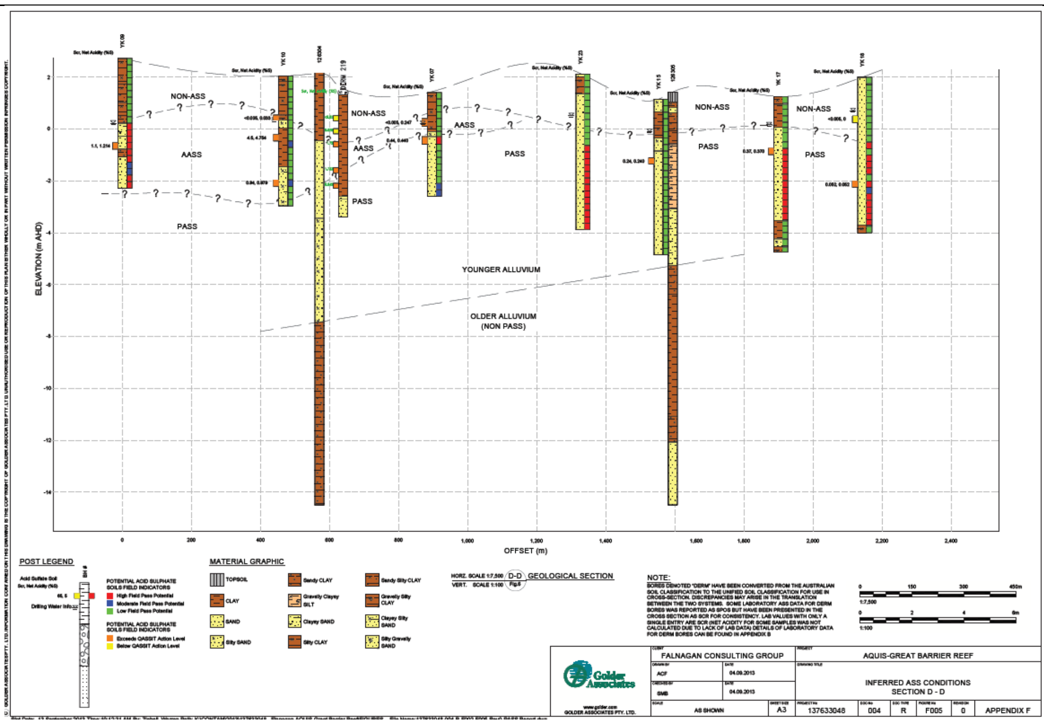

Figure 15-6 Cross section D-D interpretation of borehole data.

Source: **Appendix Q** (Appendix S p318).

Studies undertaken by the former Department of Environment and Resource Management (DERM) in 2009 (referenced in **Appendix Q**) stated that acid water is being released from a site on the corner of Dunne Road and Yorkeys Knob Road. The investigation found that the oxidation of PASS was the result of road construction, drainage and tidal control (tide gates). A working group was formed to undertake remediation including liming and amendments to the tidal gates and monitoring through the installation of a pH and electrical conductivity (EC) monitoring station in Yorkeys Creek.

Similarly, FHAs that lie downstream of the site on Half Moon Creek are known to be impacted by acid sulfate soil runoff on occasion. These two observations confirm that acid runoff is a common occurrence from the general study area.

c) Groundwater Indications of ASS

Groundwater can be affected by AASS, and chemical characteristics that may indicate that groundwater is being affected are described in the West Australian ASS Guideline Series 2001. These chemical characteristics are shown in **Table 15-6** below along with the results from site groundwater sampling (**Appendix Q**).

TABLE 15-6 GROUNDWATER INDICATION OF ASS

PARAMETER	INDICATOR OF ASS	SAMPLING RESULT
Alkalinity:sulfate ratio	Less than 5	Less than 5
Chloride:sulfate ratio	Less than 2 (this ratio has little relevance in a freshwater groundwater environment where the alkalinity: sulfate ratio is more relevant)	7.1 (averaged)
pH	Less than 5	4.7 to 6.6
Soluble aluminium concentration	Greater than 1 mg/L	Less than 1 mg/L

Source: Based on **Appendix Q**.

The results above indicate that some past oxidation of ASS may have occurred.

NRM has provided collated data from bore holes drilled on the site in the past. The information, prepared by NRM's in-house expert on acid sulfate soils (David Morrison) has been assessed. While the results differed somewhat from the current investigations (**Appendix Q**), they have resulted in no major change to the outcome of the investigation or the appreciation of the issue.

d) Summary

In summary, PASS materials were found to underlie the entire site, generally at depths greater than 1 m to 2 m below current ground level. PASS materials were strongly associated with soft grey-dark grey silty clays and loose sands.

15.4.2 Impacts

When ASS is exposed to oxygen as a result of direct disturbance (via excavation or displacement) or drainage (via dewatering or other means), pyrite can oxidise and form sulfuric acid. Sulfuric acid can dissolve metals from the soil profile (including iron, aluminium and heavy metals) as it leaches out of the affected soils. The resulting contaminated acidic water can then migrate into surface waters and groundwater. This could have unacceptable impacts and should be avoided.

The main design-related mitigation option to deal with ASS / PASS is to not disturb it, either directly, or by lowering the groundwater level. This option is not available given the decision to construct the lake as a flood mitigation solution (**Chapter 9** – Flooding). The construction of the lake requires excavation of approximately 2.8 million m^3 of material that will definitely contain considerable ASS/PASS. The following discussion first outlines the impacts that can arise when ASS / PASS is disturbed and then provides details of the proposed mitigation.

The release of acidic water can lead to degradation of terrestrial vegetation through:

- stunting of root growth
- increased toxicity from higher concentrations of aluminium, iron and manganese
- reduced plant minerals and nutrients
- reduced resistance to pathogen attack.

Longer term impacts may include species die off and changes to vegetation cover (i.e. domination by more acid-tolerant species).

The discharge of acidic water to aquatic (especially estuarine) environments may cause the following impacts:

- increased acidity, iron and aluminium concentrations which may be toxic to some aquatic organisms and cause fish death and disease (e.g. Red spot)
- creation of precipitates of iron and aluminium, thereby affecting water quality and coating streambanks, benthic (sediment-dwelling) organisms, and aquatic vegetation
- aquatic vegetation communities may change to become dominated by acid-tolerant species, thereby displacing desirable naturally occurring vegetation
- de-oxygenated water may also result from the secondary oxidation of the Fe2+ ion, thereby consuming oxygen and lowering the level of dissolved oxygen in surface waters.

Acidified waters can also weaken concrete and steel infrastructure such as culverts, pipes, and piles.

15.4.3 Mitigation and Management

<u>Overview</u>

The limited preliminary investigations conducted to date generally indicate the absence of ASS within the upper 1 m to 2 m of soil across the site with the majority of materials below this indicated to be ASS. Until more detailed ASS investigations are completed to enable a detailed Acid Sulfate Soil Management Plan (ASSMP) to be completed, it is considered prudent to assume that all materials to be excavated will be ASS and will therefore require management.

The method of excavation has not been finalised at this time. Potential ASS impacts have been identified for three possible excavation methodologies detailed in **Table 15-7**, namely:

- dry excavation
- wet excavation
- dredged excavation.

The excavation methodology adopted may comprise one or a combination of these, as explained in the following discussion.

The soil profile across the lake area typically comprises between 0.5 m and 2 m of stiff clays and sandy clays, overlying sand to depths of between 7 m and 11 m. Soft clay inclusions are present in some areas within the sand layer.

Excavation Volume

Current surface levels across the main portion of the site are about 2 m AHD. The lake covers an area of about 33 hectares and will be excavated to about -2.5 m AHD. The central island covers an area of about 40 hectares and will have basements extending below the lake bed level.

The volume of excavation associated with creating the above land forms (lake and building basement) is in the order of 2.8 million m^3. For a six day working week and a six month excavation program, approximately 21 000 m^3 of material will need to be excavated per day. This excavation rate is assumed in the following discussion.

Excavation Equipment Requirements

To meet a production rate of 21 000 m^3 per day, the excavation equipment requirements are likely to be:

- Dry excavation – excavators / loaders with equivalent to 840 'truck and dog' movements per day or 700 'moxy' (off-road dump truck) truck movements/day. Alternatively about 1100 scraper movements per day.
- Wet excavation – draglines, excavators/loaders with equivalent to 840 truck and dog movements per day or 700 moxy truck movements per day.
- Dredged excavation – two cutter suction dredges that can each achieve production rates of about 650 m^3/hr), and dozers.

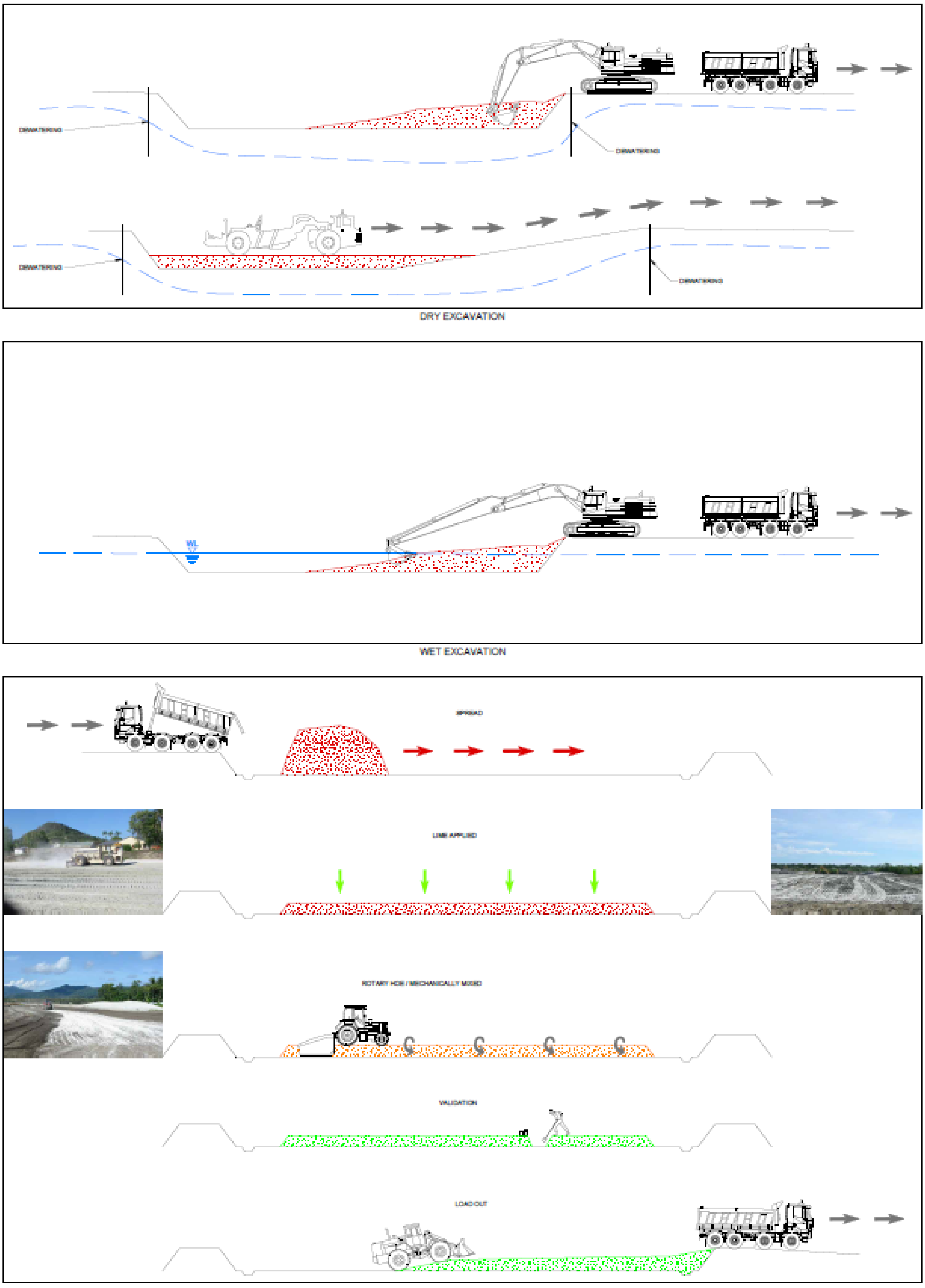

Figure 15-7 Details of dry and wet excavation.

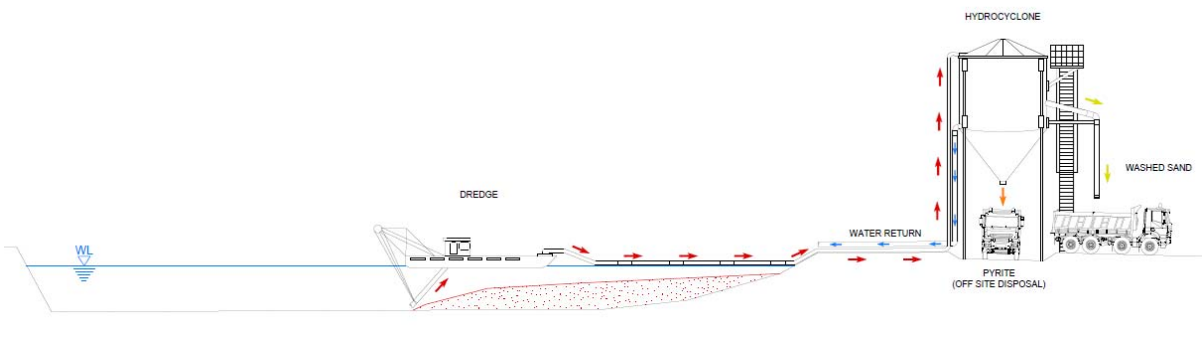

Figure 15-8 Details of dredge excavation.

<u>Treatment Facility Requirements and Operation</u>

Land Farming

To accommodate this daily volume of material, a treatment cell of about 6 ha to 10 ha in area (to accommodate a placed soil thickness of between 0.3 m and 0.5 m) will be required.

Proposed lime treatment process is as follows:

- Construction of a treatment facility complying with the requirements of the *Queensland Acid Sulfate Soils Technical – Soil Management Guidelines V3.8* (2008).
- In addition to the guidelines' requirements, an automatic pH dosing pump will be installed to treat water collected in the facility and direct this water back to the lake excavation. As a general principle, all land will be drained to the lake during the construction phase so it can collect any runoff and thereby prevent export of sediments and pollutants to the adjacent environment.
- Excavated material will be placed and spread to a thickness of approximately 0.3 m to 0.5 m.
- Where required, the spread soil will be tilled with a rotary hoe or similar to assist in drying prior to incorporation of lime.
- Lime will be spread at the required rate across the surface of the soil using conventional lime spreader trucks.
- Lime will be incorporated through the soil using a rotary hoe or other mechanical mixer.
- Validation samples will be collected at a rate agreed with the regulator to confirm neutralisation of each batch.
- Following validation, treated soils will be excavated and removed from the treatment facility for stockpiling, use or export, as determined by the detailed construction methodology.

It is expected that each treatment cell would contain 30 000 m^3 of soil. Each cell would require a three day cycle as follows:

- Day 1: Typically one cell would be filled and limed each day as a continuous process.
- Day 2: Validation samples would be collected on the next day.
- Day 3: Validation results would be available and removal of material can commence (local NATA registered laboratory has confirmed that it is feasible to complete about 120 Chromium Suite tests within 24 hours turn-around period).

On this basis, at least four cells would be required to accommodate this treatment regime. An additional contingency cell is considered prudent to allow for unforeseen events and delays.

An area of about 30 ha to 50 ha would be required for the entire treatment facility. This area of land is available clear of the proposed building footprint.

Pug Mill Treatment

Pug mills have production rates in the order of 150 m^3/hr. To accommodate a production rate of 21 000 m^3/day, about 14 pug mills would be required.

Pug mills are better suited to processing of finer grained soils and will have a limited capacity at this site due to the predominantly (coarse) sandy soils.

Storage and processing of ASS by the pug mill process should occur within a bunded facility with similar construction requirements to the land farming facility described above.

Lime Requirements

Given the limited investigation information available at present, the following has been assumed for current estimates of lime requirements:

- Three-quarters of the excavated material will be sands with a treatment requirement of 30 kg lime per cubic metre.
- One-quarter of the excavated materials will be clays with a treatment requirement of 120 kg lime per cubic metre.

On this basis, the total lime requirement would be in the order of 150 000 tonnes. In terms of handling:

- B-double trucks have a capacity of 84 m^3 and therefore this would require about 1700 of these truck movements during construction, or
- Semi- trailers can carry about 30 tonnes and therefore this would require about 5000 of these truck movements during construction.

Sourcing suitable limestone is not an issue as extensive limestone deposits are present on the Tablelands west of Cairns including:

- Mirriwinni Lime has leases at several locations and currently produces 100 000 tonnes of agricultural lime (aglime) per year. Mirriwinni Lime has confirmed it has the capacity to supply the tonnage required for this project.
- Phoenix Lime has leases across a 3.5 million tonne deposit at Ootann. Phoenix Lime is currently seeking approval to supply 350 000 tonnes of lime per annum to the NORNICO nickel project.
- Additional smaller operators supply lime from leases in the Mt Garnet, Almaden and Ootann regions.

Storage hoppers and/or a storage shed will be provided on-site to enable safe/dry storage of lime.

Hydraulic Separation

Hydraulic separation (hydrocyloning, or sluicing) of fine textured sulfides (pyrite) from coarse textured material is suited to sediments that contain less than 10%–20% clay and silt with a low organic matter content. These processes require intensive management and monitoring, and final management of the concentrated sulfidic fines. This method can result in significant savings on earthmoving and neutralising agents.

Both sluicing and hydrocyloning separation methods can be added to a dredging process stream, where the dredging activity directly supplies the feed slurry for the separation process, or as an addition to other processes.

Hydraulic separation activities would be best sited near the lake excavation to allow tailwater to flow back into the excavation. Sluicing operations would require two or three operational cells (similar in size to the land farming cells). Lesser area would be required for hydrocyloning, as treated materials may be stockpiled to greater heights. Again treatment areas would need to be bunded to contain fines and runoff. Sulfidic fines need to be either neutralised or collected for off-site disposal.

Options for Reuse of ASS

Possible options for the reuse of untreated and treated ASS are summarised below (subject to confirmation):

Untreated

- Used as backfill below the permanent water table at sand pits within the Barron River delta. Backfilling of these pits can assist in rehabilitating the land back to agriculture use. Alternatively the sand pits may choose to re-mine and process these materials (hydrocyloning to remove pyrite) to supply the local sand and concrete markets. Available sand pit volumes may constrain the amount of material that could be utilised.
- Dredged sand could be pumped directly to beaches for replenishment purposes. The volumes required and timing of such works may constrain this option.

Treated

- Treated and screened ASS sands may be suitable for concrete batching at the development site, or off-site as a source of sand for concrete production.
- Treated ASS materials have previously been utilised as engineered fill on residential subdivisions. Local examples include the Bluewater canal estate at Trinity Park and the Bluewater estate at Trinity Beach.
- Treated ASS may be used as a surcharge load and fill for major earthworks projects in the Cairns area. Examples include the Main Roads’ Smithfield Bypass and redevelopment of Cairns Airport.

TABLE 15-7 EXCAVATION METHODOLOGIES AND POTENTIAL IMPACTS

EXCAVATION SCENARIO	METHODOLOGY	POTENTIAL IMPACTS	MANAGEMENT STRATEGIES
Dry excavation (on-site treatment)	Under this scenario the excavations are dewatered to enable the use of conventional equipment such as excavators and trucks or scrapers.	Excavated ASS materials will generate acid. Runoff of acid from these materials may impact on terrestrial vegetation, surface water and groundwater quality, ecology, and the built environment.	Minimise the volume of untreated soil stockpiled on-site at any time. Stockpile and treat excavated soil in a bunded facility to collect and contain runoff. Treat the excavated soil with fine-ground agricultural lime to neutralise the potential acid generation. Treat collected runoff with neutralising agent.
		Prolonged dewatering of excavations may cause a lowering of the water table external to the excavation and allow in situ ASS materials to oxidise and generate acid. Potential impacts to surface water and groundwater quality.	Isolate the excavation from the surrounding area using sheet piles or other containment measure to reduce groundwater drawdown outside the excavation. Infiltration trenches may still be required to maintain groundwater levels external to the containment area. Some treatment of dewatered soils that are to remain in place within the containment area may be required. Alternatively, the acid flushed from the residual soils when dewatering ceases can be treated. This will require containment measures to remain in place while the water levels in the lake are cycled to promote flushing. Water within the lake excavation will be treated with neutralising agent.
		Existing groundwater is degraded and acidic, untreated dewatering discharges have the potential to impact on surface water quality.	Collect and treat water extracted from excavation.
Wet excavation (on-site treatment)	Under this scenario minimal dewatering is conducted and excavations below the water table are conducted using long arm excavators or draglines.	Excavated ASS materials will generate acid. Runoff of acid from these materials may impact on terrestrial vegetation, surface water and groundwater quality, ecology, and the built environment.	Minimise the volume of untreated soil stockpiled on-site at any time. Stockpile and treat excavated soil in a bunded facility to collect and contain runoff. Treat the excavated soil with fine ground agricultural lime to neutralise the potential acid generation. Treat collected runoff with neutralising agent.

EXCAVATION SCENARIO	METHODOLOGY	POTENTIAL IMPACTS	MANAGEMENT STRATEGIES
		Existing groundwater is degraded and acidic, untreated dewatering discharges have the potential to impact on surface water quality.	Collect and treat water extracted from excavation.
Dredged excavations (on-site treatment)	Under this scenario, conventional excavation is conducted to enable a dredge to be established. 'Top-up' water is pumped into the excavation to maintain dredging operations and prevent drawdowns in the surrounding area.	Dredged ASS materials will generate acid. Runoff of acid from these materials may impact on terrestrial vegetation, surface water and groundwater quality, ecology, and the built environment.	Minimise the volume of untreated soil stockpiled on-site at any time. Use hydrocyloning or sluicing to remove pyrite from the dredge materials and to dewater the sandy materials to improve handling. Collect pyritic fines and neutralise or dispose of at approved facility. Alternatively stockpile and treat dredged soil as discussed above for dry excavated materials.
		Suspended sediments in dredging tailwater may contain ASS and may settle in areas that may dry out in the future, leading to acid generation.	Direct tailwater back into the lake excavation.
Dredged excavations (off-site treatment)	Under this scenario, dredging as above is conducted with spoil pumped to an off-site location.	Dredged ASS materials will generate acid. Runoff of acid from these materials may impact on terrestrial vegetation, surface water and groundwater quality, and the built environment.	Minimise the volume of untreated soil stockpiled at off-site location at any time. Alternative 1 Place all ASS materials back below the permanent water table at off-site location. (This alternative would also apply to reuse of sand for beach replenishment). Alternative 2 Use hydrocyloning or sluicing to remove pyrite from the dredge materials and to dewater the sandy materials to improve handling. Collect pyritic fines and neutralise or dispose of at approved facility. Alternative 3 Stockpile and treat dredged soil as discussed above for dry excavated materials.
		Suspended sediments in dredging tailwaters may contain ASS and may settle in areas that may dry out in the future, leading to acid generation.	Ensure no discharges from the off-site location by pump tail waters and any excess water back to the lake excavation on-site.

Source: Study team compilation.

It should also be noted that the current fieldwork program and sampling intensity does not fully meet the Guidelines on Acid Sulfate Soils (State Interest—Emissions and hazardous activities) associated with SPP 2013. Further detailed investigations will be required subject to discussions with CRC and EHP prior to commencement of bulk earthworks. Given the size of the proposed development, management of ASS at this site would be classified as XH (extra high level) treatment according to the guidelines and so, requires a 'standalone' ASS Management Plan.


Photo 15-1 Example of lime treatment at Bluewater Canal Estate, Trinity Park.

15.4.4 Residual Impact

The management and treatment of ASS to mitigate potential environmental impacts is a mature process that has commonly been adopted for ground disturbance projects in the Cairns Region and for lake/water developments of a similar size elsewhere along the Queensland coastline.

With appropriate management there is not expected to be a significant residual environmental impact.