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Southern Seawater Desalination Projects
Project Management Branch
Water Corporation
604 Newcastle Street
LEEDERVILLE WA 6007

Attention: Mrs Sung Joo-lee

Dear Sirs

**PROPOSED SOUTHERN DESALINATION PLANT – BINNINGUP
OVERVIEW OF GEOLOGICAL AND GEOTECHNICAL CONDITIONS**

INTRODUCTION

This letter provides an overview of the geological and geotechnical conditions both offshore and onshore at the location of the proposed Southern Desalination Plant.

This letter has been prepared to provide a combined “executive summary” of three separate studies concerning the ground and seabed conditions from a geological and geotechnical perspective. Environmental considerations are not included in this overview. At the time of preparing this summary, none of the reports were complete. The reports on which this summary is based are indicated below:

- Report on Marine Investigations for the Southern Seawater Desalination Plant by Fugro Survey Pty Ltd Draft Final Report (2 November 2007).
- Draft Report on Jet Probing and Drilling Program, Desalination Plant 2, Binningup by Douglas Partners (16 January 2008).
- Draft Report on Southern Seawater Desalination Plant –Preliminary Geotechnical Investigation by GHD Geotechnics (December 2007).

This letter is not intended to provide review comments. Plans and sections need to also be prepared to illustrate the description in the text provided herein. At this stage, these figures are omitted as Golder Associates is awaiting completion of the final reports by the various consultants before preparing composite cross sections and figures. Figures may be taken directly from the GHD report for inclusion in the Public Environmental Review (PER) document.

LOCATION AND GEOMORPHOLOGICAL SETTING

The proposed site of the southern desalination plant is on the coast approximately 150 km south of Perth. The land based infrastructure is located within and landward of the coastal dune system and comprises part of Lot 8 Binningup Road and Lots 32 and 33 Taranto Road, Binningup.

Associated with the desalination plant are pipelines from the shore, intake and diffuser structures and offshore pipelines. The intake and diffuser structures are to be located approximately 400 and 800 m offshore on a generally sandy seabed.

The site lies on the western edge of the Swan Coastal Plain. The coastal plain is characterised by a broad, level alluvial belt with lines of sand dunes and limestone ridges on its seaward side.

Interdune Lagoons

Former nearshore, inter-dune lagoons, occur parallel to the present coastline and dunelines, and are most notably represented by Lake Preston some kilometres north of the desalination site and the Leschenault Inlet to the south. The two are however joined by a string of seasonal marshes, wetlands and former wetlands.

Little surface exposure remains of these wetlands at the desalination plant site as they have in the recent geological past been substantially overridden by the landward migration of the coastal dune system. Wetlands were however present in historical times at the north-eastern and south-eastern corners of the desalination site. The wetland in the north-eastern corner has been removed through former quarrying on this part of the site, but in the southern-eastern corner the former wetland remains as pastoral farm land with isolated wetland vegetation.

Coastal Dune System

The most dominant geomorphological feature of the site is the dune system. These dunes are part of a relatively recent dune system known as the Quindalup Dunes. They comprise Safety Bay Sand and form a series of naturally stable and mobile parabolic dunes up to 40 m in height, that can extend 1 km inland.

The open end of the parabolic dunes face the coastline, the limbs of the parabolic dune tend to result in east-west trending parallel ridges whilst the curved closed end of the parabolic dunes tends to be forms a prominent face where it has advanced over the former lagoons along the eastern side of the site.

Small recent dune activity tends to form a north to south trending fore-dune immediately landward of the highwater mark.

Whilst not a prominent geomorphological feature, another older dune system is also present. This is the Spearwood Dune system. Unlike the parabolic dunes of the Quindalup Dune system, the Spearwood Dune system forms north-south trending dunes. These dunes are however masked beneath the more recent dunes and only have surface expression in the extreme eastern part of the site and further east between the site and the Old Coast Road.

Sand and limestone associated with the Spearwood Dune system is present beneath the whole site, including offshore components. These materials were formerly quarried in the eastern part of the site, where exposures of limestone can be observed.

Infrastructure Location within the Dune System

It is proposed that most of the desalination plant infrastructure will be located landward of the dune system. However, it is still necessary to bring intake and outfall pipework through the dunes and locate some facilities within the dunes.

The route through the dunes strategically utilises the dune geometry. The shore crossing coincides with an existing “low-point” in the foredune, and the pipeline route has been selected to follow a linear depression between two east-west trending dune ridges.

Former Quarry

Tamala Limestone and sand were formerly quarried from the north-eastern and extreme eastern part of the site. Quarrying continues on adjacent lots to the north. Much of the land that has previously been quarried has been rehabilitated and a shallow backfill of sand and limestone is noted in the geotechnical investigations. It is proposed to utilise these quarried and backfilled areas for locating components of the desalination plant.

Coastline

The coast forms a relatively narrow beach trending north to south and is uninterrupted by headland or promontory for many kilometres in each direction. The dune system backs directly onto the beach and there is an absence of any rocky cliff similar to those seen in similar geological settings further north in the Swan Coastal Plain. At certain stages of the tide, isolated ledges of rock, assumed to be a weakly indurated unit of the Tamala Limestone, can be noted, suggesting generally shallow rock may exist in the nearshore environment. The beach itself is gently shelving. Offshore bathymetry indicate water depths of 8 m below chart datum about 400 m offshore increasing to 10 m below chart datum about 600 m offshore. Beyond about 800-1000 m offshore the seabed is relatively level between 11 and 12 m deep.

The normal tidal range (MHHW to MLLW) is 0.5 m.

GEOLOGY AND CONSTRUCTION CONSIDERATIONS

Offshore

Offshore the geology comprises sandy seabed sediments ranging from thicknesses greater than 4 m to zero (where surface rock is exposed). The sediments overlie limestone of variable strength. Although not encountered in any of the offshore investigations, the limestone is assumed to overlie an older and more rock formation, the Leederville Formation. Based on extrapolating onshore data, the Leederville Formation is likely to be present offshore at a level of about -20 m AHD.

Surface Features

Marine investigations by Fugro indicate seabed features. Much of the nearshore area in which the inlet and outfall structures will be located has been interpreted to comprise unconsolidated fine to coarse sand. Fugro noted a series of sub parallel east-west orientated features in the nearshore shore zone (up to about 600 m) and these were interpreted to be gravelly sand and shells. Areas of “seagrass and shallow sediment over rock of low relief rock outcrop” generally occur more than 600 m offshore, although they are closer to the shore south of the pipeline centreline.

Surface Sediments

A series of jet probes was carried out along the proposed intake and diffuser pipeline centreline and 100 m either side to characterise the shallow seabed conditions.

The jet probing generally confirmed the geophysical interpretation by Fugro and indicated an absence of surface or very shallow rock along the pipeline route, although it is present offshore of the proposed route. In the first two to three hundred metres, there were several locations where the unconsolidated sediment are thicker than 4 m. At the approximate location of the intake structure, approximately 400 m offshore, the sediments are in the region of 1.5 to 3.5 m thick.

Along the pipeline centreline some 600 to 800 m offshore and in the vicinity of the proposed diffuser, the seabed sediments thin to approximately 0.5 to 2.5 m. Further offshore still, the sediments thin further, and surface outcrop may occur about 1 km offshore. Accounting for the gradient of the seabed, it appears that the top surface of the limestone is at a level of approximately -10 m AHD 500 m offshore, and is from about -2 m to deeper than -6 m AHD at the beach.

Testing of seabed sediments indicates a range of particle sizes from gravelly medium to coarse sand to silty fine sand. Medium to coarse sand is the dominant seabed material.

Underlying Rock

A series of five boreholes was drilled along the centreline of the proposed pipeline out to approximately 600 m offshore.

The borehole closest to shore (approximately 100 m offshore) was drilled in 1.8 m of water and encountered sand with shell fragments throughout its full depth to 6.5 m.

In all the other offshore boreholes located between 200 and 600 m offshore, Tamala Limestone was encountered beneath surficial sands that varied between about 1 m and 3.3 m in thickness.

The Tamala Limestone is variable in nature comprising calcarenite (limestone comprising sand sized particles), bioclastic limestone (limestone comprising shell and marine detritus cemented together), and calcisiltite (limestone comprising silt sized grains). Zones of core loss indicate variable cementation and uncemented sediments. These materials displayed a wide range of strength from very low to very high strength.

Although not encountered by investigations, the Leederville Formation is conjectured to underlie the offshore part of the project at a depth of about -20 m AHD. The Leederville Formation is an interbedded sequence of sandstone, shale, siltstone, claystone and minor conglomerate.

Construction Issues

It will be necessary to dredge a trench into which the various pipelines can be laid. The superficial materials are principally sand and can be easily dredged. Generally, the sediments are medium to coarse sand and are not expected to yield significant amounts of suspended sediments to the water column. Some silty sands are locally present and more suspended sediment should be expected at these locations.

Although high strength and very high strength limestone are present that need to be dredged, it is expected that the limestone will be generally dredgable using an appropriate size cutter suction dredger or large dredge backhoe. The stronger limestone is considered to be dredgable because of its variability and the absence of any massive or thick layers of high or very high strength material. The core was generally fragmented, of low rock mass quality, and it is interbedded with no cemented zones or areas of core loss interpreted to be either very weak limestone or uncemented sand or gravel. It is possible that locally higher strength, and massive material may be encountered that may require blasting.

Construction options for the shore crossing include a temporary cofferdam through the surf zone and beach and/or a temporary jetty. Both options would necessitate the use of driven steel tubular

or sheet piles. The limestone is considered to be sufficiently fragmented, and the higher strength layers of limited extent to allow driving of the piles.

Onshore

Figure 1 shows a west to east long section along the pipeline route across the dunes and best illustrates the onshore geology.

Overview

The figure illustrates shows the dune system comprising Safety Bay sands, overlying a thin band of lagoonal sediments. These sediments are generally about 1 m in thickness and are present slightly above AHD in the eastern part of the site and slightly below (approximately -1 m AHD) beneath the foredune in the west.

The lagoon sediments have been covered by the Safety Bay sands as the dune system advanced towards the east in recent geological times. A small section of lagoonal sediments still remains, close to the surface at the farm pasture in the east part of the site.

The lagoonal sediments form a marker horizon between the overlying Safety Bay Sands and the underlying sediments associated with the Spearwood Dune system. The Spearwood dune sediments have been cemented to form a calcarenite, known as the Tamala Limestone. The Tamala Limestone has then leached to form an uncemented sand described as Tamala Sand on the long section. The lower part of the Tamala Limestone, at the site appears to be marine in origin and contains abundant shells fragments.

Beneath the Tamala Limestone the Leederville Formation. This formation comprises sandstone, siltstone and shale lithologies of considerably older geological age and was encountered in the four land-based boreholes. The Leederville Formation is inferred to slope gently towards the coast between about -17 m AHD and -20 m AHD.

Safety Bay Sands

The Safety Bay Sands are typically white to pale brown, fine to medium grained and sub-angular to subrounded, comprising quartz and calcareous grains.

The thickness of the safety bay sand varies with the dune topography. It has a minimum thickness of about 5 m and a maximum thickness of about 20 m below dune ridges. It is generally medium dense, with occasional loose bands. Some weakly cemented material may be present close to the groundwater table. Bands of weak limestone within the Safety Bay sand can also be seen in the eastern scarp of the dune next to the former quarry in the north eastern part of the site.

The bulk excavation associated with the pipeline route from the pumping station through to the water treatment plant is located in this unit.

Lagoonal Sediments

A layer of clay and silty clay was intersected beneath the Safety Bay Sands. CPT testing carried out as part of the investigations indicate this material to be relatively thin, between 0.2 and 0.9 m in thickness. Beneath the western part of the site, the lagoonal sediments are up to 3 m thick, but here, the unit is more sandy, described as sandy silt, dark grey to black with sand sized shell fragments

The lagoonal sediments are not envisaged to present significant construction issues although they are potentially acid sulfate generating. It is possible that the materials may need to be removed beneath items on plant in the eastern part of the site to limit settlement.

Acid Sulfate Soils

The DEC maps of Acid Sulfate Soil (ASS) risk areas classify parts of the southern boundary of Lot 8 as having high to medium risk of ASS.

This risk appears to be associated with the lagoonal sediments. During the investigation, 29 samples were tested for ASS. Only four samples were found to be acid sulfate generating. The 4 non-compliant samples all related to the lagoonal materials.

Further ASS tests will be required and an acid sulfate management plan will be required to facilitate excavation of the lagoonal materials and possibly other materials.

Tamala Limestone and Tamala Sand

Geologically, the Tamala Limestone and Tamala Sand are the same formation. The latter is the leached derivative of the former.

Tamala Limestone is a highly variable material and consisting of aeolianites (cemented dune sands), beachrocks (cemented nearshore detritus), shallow marine beds, coral reef and marl.

The extremely variability is a function not only of its depositional history, but also subsequent leaching and sometimes re-cementation.

The upper part of the Tamala Limestone and Sand sequence encountered at the desalination plant comprises the aeolianite, and the limestone typically comprises quartz and calcareous grains.

A borehole located close to the proposed location of the deep excavation that will be necessary for the pumping station encountered some of the weaker Tamala Limestone beneath the site. Much of this Tamala Limestone has been logged as a gravelly sand, but close examination of the core suggests this material has broken down to a gravelly sand through the drilling process and is likely to be present *in situ* as a weakly cemented calcarenite.

Further inland, where deep excavation into the limestone is not required for the plant, the upper part of the limestone is highly leached and relatively weak, but becomes more competent below about -6 to -10 m AHD.

The Tamala Sand is generally in a medium dense to dense condition beneath the site and is primarily a medium grained quartz sand.

Karst

Karst features including sink holes, surface depressions and cave systems, are known to occur in Tamala Limestone. Cave systems tend to be associated with existing or former groundwater levels and are most developed where the surface cover is relatively small.

A minor cavity of 0.3 m thickness was noted in the core of borehole BH 03/07, towards the landward side of the dunes. A further 1.3 m sized cavity was encountered in the same borehole in sandstone attributed to the Leederville Formation. However, no cavities were noted in the limestone in any of the other boreholes, including the borehole at the location of the pumping station where dewatering will be required.

The existing groundwater table is well above the level of the Tamala Limestone and there is no current mechanism for creating major karst features in the limestone.

Although the limestone is not regarded as cavernous, nonetheless it is expected to have a significantly greater permeability than the residual sands. Further studies are required for dewatering design.

Leederville Formation

The Leederville Formation is an interbedded sequence of sandstone, shale, siltstone, claystone and minor conglomerate.

Boreholes at the site encountered gravelly and shelly sandstone of medium strength. In borehole BH 04/07 at the location of the proposed pumping station, the assumed boundary between the overlying Tamala Limestone and the underlying Leederville Formation is at about -19 m AHD. Below this level, grey to orange brown low strength sandstone was encountered. The upper 6 m appear to be highly weathered with significant zones of core loss or uncemented sand. Below the 6 m weathered zone, more massive grey fine to coarse grained high strength sandstone up to 2 m thick was encountered. These competent rock materials had further zones of core loss for the rest of the borehole, which terminated at -47 m AHD.

No part of the permanent works will be located in the Leederville Formation. However, it may be necessary to extend diaphragm walls to the Leederville Formation to form a cut-off for dewatering to enable deep excavation for the pump station.

Groundwater

Groundwater flow in the Swan Coastal plain is generally from east to west, with local variations around interdune lakes. Groundwater discharges locally to watercourses and swamps, and downwards to the Leederville Formation and in to the Indian Ocean.

The Leederville Formation is a multi-layered aquifer recharged by downward leakage from the superficial formations (Tamala Limestone, Safety Bay Sand, etc), particularly in the area between the Wellesley River and Myalup Swamp east of the site.

Groundwater flow in the Leederville Formation is towards the west, with discharge occurring offshore. Discharge from the Leederville Formation may also occur into the superficial formations between Myalup Swamp and the saline interface. In low lying areas west of Myalup Swamp, artesian flows may occur from the Leederville Formation.

A wedge of saline and hypersaline water extends for a significant distance, in the order of 2 km inland, within the superficial formations in the Binningup area. A layer of fresh water is often found overlying the saline and hypersaline groundwater.

Groundwater levels noted on-site during the investigations vary from around 1.3 m AHD beneath the eastern part of the site to sea level at the beach. Minor groundwater mounding of between about 0.3 and 0.8 m occurs beneath the eastern and western dune ridges respectively.

Groundwater sampled from site reported compliance with DEC EIL criteria for heavy metals and metalloids.

The site has a relatively complex hydrogeological setting. Given the potential need to dewater a deep excavation for construction of the pumping station, further detailed investigations will be required, including pump testing and groundwater modelling.

An acid sulfate management plan will be necessary if shallow dewatering is required to facilitate removal of lagoonal sediments in the eastern part of the site.

Construction Issues

Pump Station Excavation

The main onshore construction issues relate to deep excavation in the foredune. Excavation will be required through Safety Bay sand, a minor thickness of lagoonal sediments, Tamala Sand and the highly leached, weak Tamala Limestone. The latter two units will be saturated and highly permeable. The principal construction issue with the excavation is considered to be dewatering. A cut-off wall into the Leederville Formation is an option to control groundwater flow into the excavation. There will be construction challenges with forming a deep cut-off, especially as very high strength rock is present in the Leederville Formation interbedded with highly weathered layers that are mainly uncemented. As artesian conditions can occur in the Leederville Formation a careful understanding of the hydrogeological regime will be necessary for the dewatering design. Further investigations are required in the area of the pump station for this purpose.

It will be necessary to carefully model groundwater drawdown, and identify possible mitigation measures, such as groundwater recharge, to limit drawdown.

Pipe Jacking

Mixed face conditions (variable strength materials, or sand and limestone) are also likely to be encountered in pipe jack excavations and need to be taken into account by contractors in selecting suitable equipment.

Bulk Excavation (cut to fill through the dunes)

Bulk excavations in the Safety Bay Sands are not expected to present any major construction issues. Cut and slope angles must be geotechnically stable, and also take account of erosion potential and the potential need for vegetation to become re-established and maintained.

Treatment Plant

Details of the plant have not been finalised. The following strata are considered sound founding materials:

- Safety Bay Sand,
- Tamala Sand;
- Tamala Limestone; and
- Granular Fill materials in the former quarries (subject to ground improvement).

The lagoonal deposits are not expected to adversely affect foundation conditions where they underlie a significant thickness of Safety Bay Sand. However, analyses must however be carried out to assess the likely short and long term settlement associated with this weak stratum.

Parts of the desalination plant may be located over shallow lagoonal materials, for instance in the degraded wetland area (farm pasture) near the south-eastern boundary of the site. It may be necessary to remove these lagoonal sediments and replace them with granular materials. As these materials are potentially acid sulfate generating, a management plan would need to be put in place. It may be possible to fill directly over these materials, raise site levels and create a granular pad for foundation without first removing the potentially compressible layer. This is an option that would require careful analysis of the potential short and long term settlement associated with the compressibility of the lagoonal sediment layer.

Construction in Former Quarry Areas

Test pits in rehabilitated quarry areas generally indicate a relatively thin granular fill over natural materials (sand, calcarenite or lagoonal deposits). Detailed investigations are needed to characterise the nature and thickness of the fill materials and the presence of any remaining lagoonal materials.

The backfill is an uncontrolled fill. However, investigations to date indicate it is generally less than 2 m thick and comprises inert granular materials). Assuming the fill can be shown to be free of deleterious materials, the fill can be improved to form a suitable foundation material. The backfill may be excavated, re-used and compacted using conventional compaction plant. Other alternatives may include dynamic compaction or the use of an impact roller without first excavating the fill materials.

CLOSURE

We trust we have provided the right level of simplification and overview of the geology and related construction considerations for inclusion the Public Environmental Review (PER) document. Please contact the undersigned to discuss illustrations for inclusion. We believe that the long section produced by GHD and a generic location/site plan showing the site boundary, principal infrastructure and geographic/geomorphology features are required. The latter may be one of GHD's figures or a Water Corporation figure, on which we can annotate some geomorphological features as required.

Yours faithfully

GOLDER ASSOCIATES PTY LTD



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