Gales-Kingscliff Pty Ltd

ABN: 75 093 540 080

Cudgen Lakes Sand Extraction Project

Flooding and Drainage Assessment

Prepared by

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April, 2008

Specialist Consultant Studies

Part 2

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Flooding and Drainage Assessment

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EXECUTIVE SUMMARY

The Project Site is located on the far southern flank of the Chinderah-Kingscliff-Cudgen floodplain. The Project Site is subject to inundation from both local catchment floods and major overbank floods in the Tweed River. These latter floods break out over the natural levee banks of the river and overtop the Pacific Highway near where the Pacific Highway turns away from the river and heads to the south. Overtopping occurs in floods that are in excess of 20 years average recurrence interval (ARI). In such floods, the Project Site is likely to be inundated by more than 1m of water and in the order of 2.5m in a 100 year ARI flood.

Despite this high degree of flood liability, the Project Site has a relatively benign flooding regime. Flow velocities at the 100 Year ARI flood peak are very low in this area (generally in the order of 0.1m/s). The floodplain which contains the Project Site is therefore very much a *Flood Storage* area rather than a *Floodway*.

For Tweed River floods, there is a long warning time (in the order of 6 to 12 hours) which would allow time for the safe evacuation of personnel and the removal of vulnerable equipment from the Project Site. However, the operation would be disrupted for some time; there would inevitably be some flood damage to fixtures and fittings; and some cleaning up would be required after the flood receded. For local catchment flooding, access would still be available to the Project Site although the road may be overtopped by 10cm of water in a 1 in 100 year ARI event prior to its realignment, and both the processing area and the extraction ponds would be flood free except in extreme events. Local catchment flooding may have a very short warning time, but because of the continued availability of access to the Project Site, there would be no risk to personnel and flood damages would be minimised by the proposed bunding, and the raising of the processing area.

The issues that may be of concern from a flooding and drainage perspective include the following.

- The operation is likely to be affected by flooding.
- The likelihood that the development of the Project Site would have an adverse affect on others.
- The likelihood that the extraction of fill material from the Project Site and its use for filling of the Proponent's land within the same floodplain would adversely affect the flooding regime.
- Any cumulative adverse effects on surrounding land users from the Project and other similar developments within the floodplain.

The Project Site is relatively large and the degree of flow obstruction within the Project Site has been minimised by keeping earthworks that may affect flow behaviour to a minimum. Hence, for local catchment floods, the relatively shallow depths of flooding mean that there would be little or no impact on surrounding land users. For large Tweed River floods, once flood depths exceed about 0.5m, floodwaters would be able to pass freely through the extraction ponds from west to east. The processing area would not allow through flow, but floodwaters would be able to pond within the area so there would be negligible impacts on flood storage.

As extraction proceeds, additional flood storage would become available in the southern extraction pond area above the water table. The net effect on flood storage in the long term would be an increase in flood storage available within the Project Site.

Fill material extracted from the Project Site would largely be placed within the same flood basin within the Proponent's lands that have been approved for development. Again, because of the benign flooding environment there is little potential for adverse effects. Local catchment floods produce a maximum 100 year ARI flood level in the order of 1.5m less than Tweed River floods, so as long as adequate flow paths (drainage reserves) are maintained, filling of the proposed fill areas would not have an adverse effect in local catchment floods. For Tweed River floods, the only fill area where there is potential for adverse effects is the land proposed for the District Town Centre south of the Ozone Industrial Area and east of Tweed Coast Road. Because of the much lower flows and velocities shown in the recently released Tweed Valley Flood Study when compared with earlier studies, it is expected that this area can, with appropriate design of flow paths, and minimisation of fill volumes, be developed without any adverse effects on surrounding land users.

Cumulative adverse impacts from the Project, and other known existing or proposed developments, would be negligible. The very low flow velocities again mean that the potential for adverse impacts is small. The maintenance of large flood storage areas, and minimisation of flow path obstructions, means that the developments could proceed without adverse impacts on existing development and surrounding land users.

1 INTRODUCTION

1.1 Background

The Project Site for the Cudgen Lakes Sand Extraction Project lies within the floodplain of the Lower Tweed River (**Figure 1**). As a consequence, it is necessary and prudent to evaluate flooding and drainage issues carefully when planning and carrying out development in this area. In particular, it is necessary to consider whether the Project itself is likely to be affected by flooding, and if so, provide appropriate remedial measures. It is also necessary to evaluate whether the Project would adversely affect surrounding landholders. In accordance with good practice, likely cumulative effects from similar developments in the same area are also an important consideration when evaluating new developments.

The Floodplain Development Manual (DIPNR, 2005), provides guidance on the carrying out of development in floodplain areas with a view to minimising future flood problems. The manual needs to be carefully considered when developing flood-liable land, particularly if there is significant risk to life and property.

As discussed later in this report, the flooding situation at the Project Site is relatively benign. The Project Site is located on the fringe of the floodplain near the base of the Cudgen Plateau. Both local catchment flooding and main river flooding from the Tweed River produce very low velocities in this area (of the order of 0.1m/s at the peak of the flood). Local catchment flooding, even in an extreme event, such as that which occurred in June 2005, produces benign flooding conditions with flood depths of the order of 0.6m or less, and very low velocities. For main river flooding from the Tweed River, there is likely to be a significant warning time (at least 6 hours and maybe 12), and evacuation from the area before the commencement of flooding would be relatively straightforward. Main river flooding also occurs relatively rarely, as floods of less than 20 years average recurrence interval (ARI) cannot breakout into this area.

Even though the nature of the Project itself means that it is not a high flood risk, i.e. it is relatively unlikely to suffer significant damages from floods and involves a relatively small number of personnel, it is still necessary to evaluate properly the consequences of major floods. It is also important that the possible impacts of the Project on other properties and land users be considered.

1.2 Description of the Study Area

This description is provided in the context of flooding and drainage issues. A description of the Project itself is provided in Section 2.

The Project Site lies within an overbank flood storage area of the Tweed River floodplain. It is therefore subject to inundation in large floods. These can be sourced either from the local catchment feeding directly onto the floodplain or from the Tweed River itself. The Tweed River overflows its banks and enters the area less than once every 20 years on average. This still means that there is a good chance that the Project Site would be flooded during the life of the operation (expected to be approximately 15 to 20 years).

Figures 9 and **10** provide information on the flood liability of the Project Site. **Figure 10** clearly shows the Project Site is within the 100 year ARI flood contour of 3.3m AHD which passes through the western corner of the Project Site. **Figure 10** also shows the extent of flooding in the same flood. Given that the natural ground levels at the Project Site are of the order of 0.8 to 1.0m AHD, flood depths in the order of 2.5m can be expected in a 100 year ARI flood.

Local catchment floods produce lower flood depths, but are likely to occur more often. In June 2005, a very large to extreme flood occurred over the local catchment. It was well in excess of a 100 year ARI flood event for the local catchment. It is therefore unlikely that such a flood would occur during the life of the Project. It produced flood depths of the order of 0.6m on the Project Site and velocities would have been extremely low (generally less than 0.1m/s). Such floods would be rated as a nuisance, but would only interrupt the operation for a short time and would produce no risk to life and little risk to equipment, providing that appropriate mitigation measures were taken prior to the flood.

Floods from the local catchment would tend to be generated from heavy rainfall over the floodplain, with additional surface runoff flowing onto the floodplain from the Cudgen Plateau hills to the south and east of the Project Site. Initially floodwaters would pond on the area until the Tweed River level reduced, and then the floodwaters would drain away by surface runoff and then through the network of agricultural drains criss-crossing the floodplain.

For Tweed River floods, there would be reasonable warning of imminent overbank flooding as discussed above. Floodwaters would initially breakout across the Pacific Highway and into the local floodplain. Flows would tend to come from the river to the northwest (see **Figure 9**) and flow on to the Project Site. Velocities would be low, but ponding depths would be high. Floodwaters would not recede until the Tweed River dropped back within its banks. Once the flood level dropped below about 2.3m AHD, floodwaters could only flow back into the Tweed River via the drains and floodgates, so drainage would be slow and could take several days.
The topography of the local area on and around the Project Site is very flat with natural ground levels ranging from about 0.8m AHD up to slightly in excess of 1m AHD. Computer modelling has shown that flow velocities are very low as a consequence. Because of the flat topography, man-made structures such as roads, bunds, fill areas and drains, potentially have impacts on the distribution of floodwaters and post-flood drainage flows.

Other potential constraints to flow in the immediate vicinity include the proposed 0.5 m bund around the Hanson Tweed Sand Quarry immediately to the west, the new WWTP site to the northwest which has elevated areas and bunding, and the approved (but not yet constructed) aquaculture facility further to the west, which has extensive areas of bunding.

1.3 Flooding & Drainage Issues

The flooding and drainage issues identified in the consultation process are set out in **Appendix 1** with cross-references to sub-sections within the text where the issues are addressed. In summary, the main issues to be addressed are as follows.

- Provide descriptions of the Project Site and surrounding land relevant to flooding and drainage. Identify water bodies including floodplains. Provide flow directions and flow depths.

- Describe the nature of the proposed works as far as they affect flooding and drainage behaviour.
- Determine any changes to the hydrology likely to be caused by the Project (including drainage patterns, flow regimes, etc).
- Assess the flooding and drainage impacts of the Project on its own and in conjunction with the adjoining sand quarry (Guinane/Bolster). In particular, take into account the impacts of any levees/banks whether temporary or permanent.
- Consider any cumulative impacts of these two sand quarry Projects with any other Projects in the area that also could affect flood behaviour.

This assessment has been prepared with reference to the *EIS Guidelines Extractive Industries – Dredging and other extraction in riparian and coastal areas* (DUAP, 1996) and the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC, 2000).

2 DESCRIPTION OF THE PROJECT

Gales-Kingscliff Pty Ltd (the "Proponent") proposes to develop and operate a sand extraction operation within part of the Project Site to supply fill sand to a number of nominated fill sites via two pipeline corridors and to produce a range of sand products for sale to the regional construction industry. The Project would also be appropriately licensed to accept virgin excavated natural material (VENM) which would either be used in production of saleable sand products or placed at or near the base of the extraction ponds. The Project would involve the removal of approximately 5 000 000m^3 of sand over a period of approximately 15 to 20 years.
The Project Site covers a total area of 67ha which includes: a 37ha extraction site south of Altona Drive (the 'southern extraction site'); a 9ha extraction site the north of Altona Drive (the 'northern extraction site') and a processing area north of Altona Drive covering an area of 3.7ha (see **Figure 2**). The two pipeline corridors extend north (the "northern pipeline corridor") and east (the "eastern pipeline corridor") for a distance of approximately 0.8km and 1.5km respectively.

The operation has been designed to optimise the recovery of sand whilst at the same time addressing and managing the environmental constraints within and surrounding the Project Site. As the Project proceeds, finalised sections of the edge of the southern extraction pond would be progressively rehabilitated in order to form a recreational lake and surrounding parklands whilst the northern extraction pond would be backfilled to form sporting fields and recreational facilities.

The extraction sequence would involve: stripping of topsoil; formation of bunds; and extraction of the sand resource. Extraction within the northern extraction site would be undertaken over four stages progressing east to west using an excavator and trucks. Within the southern extraction site the upper loamy sand material would be extracted using excavators with the remaining fine grained sand material recovered using a cutter-suction dredge. Extraction within the southern extraction site would be to the depth of the resource, typically 20m below current ground level, and a depth of approximately 5m within the northern extraction site.

The upper loamy sand material would be placed within the southern extraction site and treated using alkaline amendments, such as agricultural lime, prior to being transferred to the processing area for production of various construction materials, such as mortar sand. The fine grained sand would be transported to the processing area and washed to remove oversize and undersize materials, producing construction grade sand, or pumped to a nominated fill site for use as fill material.

Both non acid generating VENM - VENM(a) and acid producing VENM – VENM(b) would be received at the Project Site via road trucks, appropriate details recorded and the material classification verified. VENM(a) would either: be processed to produce saleable products; used to backfill the northern extraction site or as backfill along finalised edges of the southern extraction pond to create wetland areas. VENM(b) which is suitable for processing would be placed adjacent to the southern extraction pond for treatment, as for the loamy sand material, prior to processing. VENM(b) not suitable for processing would be interned within finalised sections of the southern extraction pond or use to backfill the lower sections of the northern extraction pond.

All VENM delivered to the Project Site and processed materials despatched from the processing area would occur via Altona Drive and Tweed Coast Road. Access to the Project Site would be provided via three entrances off Altona Drive, one to the processing area and northern extraction site and two to the southern extraction site.

The active extraction ponds and area of loamy sand extraction would be enclosed by a topsoil bund approximately 1m high containing spillways approximately 0.5m high at the eastern and western extents. The floor of the processing area would also be raised by approximately 0.75m to 1.0m using sand recovered from the northern extraction site. The processing area would then be surrounded by a further 3m high noise/amenity bund with a gap in the southeastern corner for vehicle access. The topsoil bunds would be stabilised using a pasture seed mix whilst the noise/amenity bund would be stabilised using a mixture of pasture and shrub species.

The Proponent would adopt a progressive approach to site landscaping and rehabilitation to ensure that, wherever possible, disturbed areas are either temporarily or permanently stabilised to limit erosion and adverse visual impacts. An important component of the rehabilitation of the Project Site would be the progressive backfilling of selected finalised sections of the shore of the southern extraction pond and introduction of native vegetation to create wetland areas and parklands. The northern extraction pond would also be progressively backfilled to the existing ground level. The construction of recreational facilities such as walking and equestrian tracks would occur following completion of sand extraction activities. The final lake within the southern extraction site would have a depth of up to 20m and cover an area of 37ha.

3 LITERATURE REVIEW

The Tweed River Valley has a long history of flooding. The largest flood in recent historical times was in 1954. It has been assessed as being a 100 year ARI flood in the vicinity of Chinderah and about a 20 year ARI event at Murwillumbah (WBM, 2005). This flood, together with other major floods in the late 1940's and early 1950's on the North Coast and in the Hunter Valley, triggered a response from the then Public Works Department (PWD). Major data collection exercises were carried out, including flood height data collection, installation of rain and river gauges, and collection of detailed topographical data. Flood mitigation works plans were drawn up accompanied by major spending programs over many years.

Initially studies were carried out by the PWD (PWD, 1956), but in later years consultants became involved, working with Councils and the PWD.

The studies that are the most relevant to the Project are discussed briefly below and referred to, where relevant, at various points herein. The key document for this Flooding & Drainage assessment is the Tweed Valley Flood Study published in 2005 (WBM, 2005). The Tweed Valley Flood Study is discussed first, and the remainder of the relevant documents are then discussed in turn from the oldest to the most recent.

Tweed Valley Flood Study (WBM, 2005)

This is a comprehensive flood study using a two-dimensional hydraulic computer model and an updated database, particularly with regard to topographical information. It provides very detailed information on flood levels and flood behaviour for the 5 year, 20 year, 100 year and 500 year ARI events and the 'Extreme' event. This information is available from upstream of Murwillumbah to the ocean, and includes detailed information across the whole floodplain within which lies the Project Site. The Proponent provided detailed topographical information for the West Kingscliff area for incorporation in the Digital Terrain Model (DTM) used as the basis for the 2D model. Stephen N Webb & Associates provided informal review comments on the draft flood study report.

Tweed River Flood Mitigation Report (PWD, 1956)

There were a number of very large floods in the late 1940's and early to mid 1950's from the Hunter River through to the North Coast of New South Wales. Kempsey on the Macleay River was the worst affected, having floods of similar magnitude and of the order of 100 year ARI floods in both 1949 and 1950. The Tweed River had its largest major flood in recent times in 1954. At Chinderah, which is the village on the Tweed River northeast of the Project Site, the flood level recorded was in the order of a 100 year ARI event. Upstream of Chinderah at Murwillumbah, the flood level was representative of a 20 year ARI event, and flood levels downstream of Chinderah do not reflect the magnitude we would expect from a 100 year ARI event.

During the 1954 flood, the Project Site would have been inundated by floodwaters to a similar, but probably slightly lower level, than in a 100 year ARI flood. The lower flood levels upstream would have meant that the gradient along the river would have been flatter, and there would have been less flow overbank into the floodplain in this flood than in a 100 year ARI flood.

The 1956 report by the PWD would have been initiated in response to the 1954 flood. Data for the 1954 flood was documented, and flood mitigation measures for the towns and rural areas examined in order to reduce damages from similar large floods in future.

Flood Investigation Dodds Island (WBM, 1974)

This was one of the first studies by consultants of major rivers on the North Coast of New South Wales. Previous studies had been largely undertaken by the PWD. This hydraulic study looked at flood behaviour in the vicinity of Dodds Island, which lies within the Tweed River northwest of the Project Site (see **Figure 9**).

WBM Oceanics have carried out a very large number of hydrologic and hydraulic modelling studies in the Tweed Valley for Council and the PWD (and its subsequent evolutions, being DLWC (Department of Land & Water Conservation), and its current form – DNR (Department of Natural Resources)). Only the reports that are directly relevant to the Project Site are described below. For a fuller description of previous hydraulic and hydrologic modelling studies in the Tweed Valley, see the Tweed Valley Flood Study (WBM, 2005).

River Management Plan, Lower Tweed Estuary (WBM, 1992)

This study involved the setting up of a quasi two-dimensional hydraulic ESTRY model of the Tweed River from upstream of Murwillumbah to the ocean based on new river surveys. Prior to this time, a number of studies by WBM had looked at short sections of the river, or had used a less refined model. The floodplain west of Kingscliff encompassing all of the floodplain to the south of the Tweed River, including the Project Site, was included in this modelling.

A number of flow paths were assumed across the area with interlinked branches allowing distribution of flows within and across the floodplain. Results from this model showed significant flows out of the Tweed River at the upstream (western) end, across the floodplain to Tweed Coast Road, and back into the Tweed River east of Chinderah.

Subsequent two-dimensional modelling (WBM, 2005) has shown a much more benign flooding situation in this area (lower flood levels, lower flows and much lower velocities). This is partly due to lower design flood levels in the Tweed River channel proper, and partly due to better account being taken of the barriers to flow for floodwaters leaving the Tweed River and entering the southern floodplain. The construction of the Pacific Highway bypass has also contributed to less flow entering the area.

Kingscliff Drainage Strategy Plan (WBM, 1994)

This study examined the Chinderah Drain catchment which extends from the Tweed River near Chinderah to Kingscliff in the south. It examined the area for local catchment flows only. Because of the very large amount of flood storage available in the area, and the very low elevation of the natural ground surface (around 0.8m AHD), local catchment runoff produces much lower flood levels than overbank flooding from the Tweed River determined in WBM, 2005. Peak 100 year ARI flood levels for local catchment flooding were found to be less than 2m AHD, whereas 100 year ARI flood levels from Tweed River flooding are closer to 3.3m AHD. The study used the EXTRAN-XP quasi two-dimensional hydraulic model.

This study is relevant to the present study as it was the first to formulate a trunk drainage strategy and determine design flood levels for local catchment flooding in the catchment immediately west of Kingscliff wherein lies most of the Proponent's land. Sand fill from the Project Site would be used to raise levels within this area to above the 100 year ARI flood level thus reducing the flood storage available for floods, including local catchment floods. Without appropriate drainage strategies in place, such filling could adversely affect flood levels and drainage times.

Kingscliff Catchment & Drainage Management Plan (WBM, 2000)

This study mainly considered water quality issues, but it did also revise flood levels along Chinderah Drain and the main east-west drainage lines in the southern part of the area. It did not propose a revised trunk drainage strategy for the area even though development since the WBM, 1994 study had already eliminated some of the trunk drainage options considered in that study. The study took into account the Chinderah Bypass of the Pacific Highway, and in particular, the elevated culverts placed under the new road. The study used MIKE11, also a quasi one-dimensional hydraulic model.

Outcomes from this model included 50m drainage reserves along the main drainage lines based on plans provided to WBM by Council. Outcomes from the study were included in the Section 94 Contributions Plan for the area and these still provide the basis for the Plan today.

Aquaculture Development – Cumulative Flood Impact Assessment – Tweed River Floodplain (WBM, 2004)

This study was carried out by WBM for Australian Bay Lobster Producers Pty Ltd using the draft flood study model (TUFLOW) being developed for Council, and later published in final form in WBM (2005). The draft flood study model was modified subsequent to this study, producing lower levels within the Tweed River and therefore lower levels in the overbank floodplain wherein the proposed aquaculture development lies.

The aquaculture development lies immediately to the east of the Yelgun Bypass of the Pacific Highway and between the new waste water Treatment Plant (WWTP), currently being built by Council, and the Bypass (see **Figure 1**).

The study assessed the impacts of the development on flood levels, and also the cumulative impact of the development and likely filling within the floodplain in the Chinderah/West Kingscliff area including the areas nominated by the Proponent for filling. The study demonstrated that the aquaculture development restricted flows entering the floodplain from the west, and thus had the effect of reducing flood levels near to and south of Chinderah. Similarly, the development would marginally reduce flood levels in the vicinity of the Project Site.

Environmental Impact Statement – Proposed Expansion of Sand Quarry at Crescent Street Cudgen (JGA, 2005)

The existing sand quarry lies immediately to the western boundary of the Project Site. The dredge pond can be clearly seen on **Figure 1**. WBM Oceanics carried out the flood study assessment for the Environmental Impact Statement (EIS) accompanying the development application and their letter format report is included as Appendix P of the EIS.

On the basis of WBM's assessment, the EIS concludes, *"In both the 100 year and 5 year ARI flood events flood velocities in the vicinity of the subject site are low, being less than 0.5 m/s, as the locality is essentially a backwater flood storage area".* It goes on to conclude, *"It is unlikely that the proposed works and activities would have any impact on local flooding behaviour"*.

These conclusions were predicated based on the dredge pond being protected by a 0.5m bund. The bund proposed for the Project Site is proposed to be 1m high, but it would have spillways at 0.5m above natural ground level to allow the through flow of floodwaters in large floods. Hence, on the basis of WBM's assessment of the adjoining site, the proposed design for the Project Site would have similar negligible effects.

Compendium of Data for the June 2005 Storm over the Lower Tweed Valley (SNW, 2007a)

A very large storm occurred over the coastal areas of northern New South Wales and southern Queensland, from just north of Byron Bay up to and including Coolangatta, in late June 2005. During the event, over 600mm of rain fell over the West Kingscliff area including over the Project Site. The storm had an average recurrence interval well in excess of 100 years. A data collection exercise was initiated by the Proponent throughout the West Kingscliff area during the storm. Extensive photographs were taken, peak flood levels were marked, and a follow-up survey recorded these levels to Australian Height Datum (AHD). Subsequently Stephen N. Webb & Associates (SNW) collected river height and rainfall data from the responsible authorities for the whole coastal area and assembled it into a database for use in subsequent studies by the Proponent and other interested parties.

The compendium consists of a database arranged in a logical order with a brief description of the sources and limitations of the data. A brief assessment of the likely recurrence interval of the storm is also provided.

Relocation of the Western Drainage Channel West of Tweed Coast Road, Cudgen (SNW, 2007b)

As noted in the *Environmental Assessment*, it is proposed to realign Altona Drive. This is to maximise utilisation of the resource and provide a contiguous water body for future recreational purposes after the sand has been removed. Altona Drive is currently a straight east-west road from Crescent Street. After realignment, it would follow a sweeping curve to the north before returning to the existing alignment in the vicinity of the new WWTP. The current road has a substantial drain on its southern side and a small table drain on its northern side.

Realignment of the road would require relocation of the drain as well, with it being retained on its southern side, at least initially. It is possible that the drain could be relocated to the northern side of Altona Drive late in the development of the southern extraction pond to maximise the recovery of the resource, and to provide better drainage for the land north of the road into the future.

The report describes the data collected, and the hydrologic and hydraulic modelling carried out to establish an appropriate drain size to ensure no adverse impacts on drainage times for the local area.

Re-assessment of Flood Behaviour for Local Catchment Floods Within the Chinderah Drain Catchment Following the June 2005 Storm (SNW, 2007c)

WBM, 1994 and WBM, 2000 above, describe the trunk drainage modelling that has been done in the West Kingscliff area on behalf of Council. Included in the outcomes of the latter study was a 50m drainage reserve along the existing major drainage lines. As noted above, the WBM, 2000 study was in turn used as the basis for developing a Section 94 Plan for the area.

SNW carried out a number of assessments of drainage behaviour in the area prior to the June 2005 storm, and it became readily apparent that even after extensive filling for development as proposed by the Proponent, there would still be a large volume of floodplain storage available to contain runoff in local catchment runoff events. It therefore seemed unlikely that wide drainage reserves would be required, especially since drainage constraints in the downstream section of Chinderah Drain (dog-leg around Noble Park Lake and relatively small culverts under the Pacific Highway and Chinderah Bay Drive) meant that only relatively small flows were capable of moving through the drainage system following a local catchment storm.

Once the June 2005 storm occurred, it was confirmed by the relatively low elevation of the peak flood levels, even with very large rainfall volumes and little or no outflow during the period of heavy rainfall, that storage effects dominated flood behaviour in this area, and this had not been fully accounted for in the previous studies discussed above.

Extensive survey data were collected to establish natural ground levels within the area and thus allow accurate assessment of flood behaviour using a combination of hydrologic and hydraulic models for both existing conditions and after development. The June 2005 storm was used as a calibration event.

The report documents revised design flood levels and re-assesses the necessary width of drainage reserves for future developed conditions.

Assessment of Flood Behaviour within the Gales Holdings' Land Adjoining Chinderah, (SNW, 2007d)

The Proponent is developing a Structure Plan for all of its and partner Company, Gales Holdings Pty Ltd land holdings, including the District Town Centre which is proposed on land east of Tweed Coast Road and adjoining and to the south of the existing Ozone Street Industrial area (see **Figure 4**). The proposed fill area is shown on **Figure 2**. The development would also include most of the old WWTP site.

Earlier studies by WBM culminating in the quasi two-dimensional hydraulic study described in WBM, 1992, found that there were significant flows out of and back into the floodplain area which encompasses the Project Site. The studies showed that the flows returning to the Tweed River passed through the Proponent's land near Chinderah. On the basis of these studies, Council's DCP5 subsequently restricted development of this area requiring that the filled proportion be no more than 50%. Theoretically, this was to minimise the displacement of floodplain storage, and allow flow paths for floodwaters in major Tweed River floods to return to the river.

SNW has been providing flooding advice to the Proponent in the preparation of the Structure Plan. Whilst providing advice on the basis of the earlier studies and the existing DCP5, SNW foreshadowed that a more benign flooding situation was likely than was shown in the earlier WBM studies.

WBM has completed a fully two-dimensional flood study of the Lower Tweed Valley (WBM, 2005), and this produced lower flood levels and much more benign flood behaviour in the area. Velocities at the peak flood level are in general only in the order of 0.2m/s, and flood flows would enter this area from both the northeast and the west. This means that through flow of floodwaters from west to east would be minimal, and therefore the effects of filling would be much less than previously expected.

This report describes the input provided to the Structure Plan development on the basis of the new flood study and the existing DCP5, and anticipates the likely future evolution of DCP5 when the Risk Management Study for this area considers the impacts on flood flows from the Project and filling of the proposed fill sites using the updated flood model.

4 FLOOD BEHAVIOUR

4.1 Background

The Project Site is located within the far southern part of the Chinderah-Kingscliff-Cudgen floodplain of the Tweed River. The Project Site is subject to inundation from both local catchment floods and major floods in the Tweed River.

Local catchment floods result from rain falling on the floodplain itself and on the hills bounding the southern edge of the floodplain. Tweed Coast Road forms a man-made boundary to the east for such floods. Floodwaters generated within the local catchment drain to the Tweed River via a system of agricultural drains. In June 2005, an extreme rainfall event occurred over the local catchment and the Proponent collected a considerable amount of data to enable a better understanding of the flood behaviour of this catchment under such conditions[1]. This database has proved invaluable in assessing local catchment flood behaviour.

Tweed River flooding has recently been reassessed in WBM, 2005. This study has provided a solid foundation for assessing flood behaviour in the vicinity of the Project Site, and in areas where fill material from the Project is likely to be placed.

The flood behaviour likely to be experienced on and around the Project Site in local catchment and Tweed River floods is discussed in the following sections.

4.2 Local Catchment Flooding

The local catchment (referred to as the "Western Drain Catchment") encompassing the Project Site is shown on **Figure 5**. The Project Site is centrally located within this catchment. Only a limited part of the catchment is high land and not subject to flooding. This land is to the south and includes the residential area of Cudgen and the adjoining plateau to its west. The rest of the catchment is low-lying floodplain at an elevation of around 0.8m AHD to 1.0m AHD.

The Western Drain is shown as a heavy blue line on **Figure 5**. There are also networks of smaller subsidiary drains connecting with this drain. The outflow from the Western Drain to the Tweed River is via culverts under the Pacific Highway and then under Chinderah Bay Drive, which lies on the bank of the Tweed River. There are floodgates on the river side of the culverts under Chinderah Bay Drive.

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[1] **(SNW, 2007a):** Gales Holdings Pty Ltd, "Compendium of Data for the June 2005 Storm over the Lower Tweed Valley", Stephen N Webb & Associates, in preparation, 2007.

The catchment boundary in the east is along Tweed Coast Road. There are some minor culverts which do allow some exchange of flow across the road but the flows are insignificant compared with the flows generated within the catchment. A ridgeline forms the boundary to the south. To the west, the catchment boundary has been located at the mid-point of two similar and roughly parallel drains. The more westerly drain provides drainage for the area up to the new Highway Bypass which can be seen on **Figure 5**. The short northern boundary is formed by the Pacific Highway.

A very large storm occurred over the costal areas of northern New South Wales and southern Queensland from just north of Byron Bay up to and including Coolangatta in late June 2005. The main part of the storm commenced in the early hours of 30 June and the rain essentially stopped at about 1300 hours. During this period, including lead-up rain, over 600 mm fell over a wide part of this area. The heavier rain did not extend in as far as Murwillumbah, but did extend across all of the local catchment shown on **Figure 5**.

Stephen N Webb & Associates is preparing a Compendium of Data for this storm (SNW, 2007a). The storm had an average recurrence interval well in excess of 100 years. A data collection exercise was initiated throughout the West Kingscliff area as the storm occurred. Extensive photographs were taken, peak flood levels were marked, and a follow-up survey recorded these levels relative to AHD. **Figure 6** shows the levels collected throughout the area. It is apparent from this figure that Tweed Coast Road provides an effective barrier to flow even in such a large storm. Levels to the east of the road are generally in the range 1.85m AHD to 1.90m AHD; levels to the west are generally in the range 1.55m AHD to 1.57m AHD.

Stephen N Webb & Associates (SNW, 2007b) has carried out a hydraulic analysis of the mean Western Drain described above and shown in **Figure 5**. Data from the June 2005 storm was used for calibration of the hydrologic and hydraulic models. The main purpose of the study was to determine the likely impacts on drainage of relocating Altona Drive and the Western Drain which flows westward through the Project Site.

Two of the figures from the report are reproduced at **Figures 7** and **8**. **Figure 7** shows in red the varying cross-sections along the existing drain from downstream of the Project Site to Tweed Coast Road. A somewhat surprising outcome from the survey of the existing drain was that the invert level was relatively higher as one moved down the drain towards the Tweed River. By replacing the existing drain with the assumed new drain section as shown on **Figure 7**, flood levels for in-bank flows were maintained. With replacement of several undersized culvert crossings, flood levels were reduced, and drainage improved using this drain section.

The purpose of this exercise was to determine a suitable drain section along the proposed re-aligned route of Altona Drive (see Section 2.9.2 of the *Environmental Assessment*). **Figure 5** shows the adjustment of the realigned drain which would be immediately south of and adjoining the realigned Altona Drive shown on **Figure 2**.

Figure 8 shows the drainage characteristics of the existing Western Drain for a flood that just fills the drain at the upstream end at Crescent Street ("bankfull flood") and drains to a river level of 0.4m AHD, approximately the peak level in the river for a neap tide with no significant flood flow in the river. The somewhat erratic invert level should be noted. It is also apparent from this figure that the culverts at the Pacific Highway and Chinderah Bay Drive are adequate (there is no significant afflux), but the culverts under the various property access crossings cause significant affluxes (increases in flood level).

It was determined in the analysis of drain behaviour through this local catchment (SNW, 2007b) that a uniform relatively smaller drain (such as that shown in **Figure 7**) would provide an adequate drainage system. This would require appropriate culverts under any drain crossings, and these would need to have invert levels consistent with the drain invert. Under these circumstances, a much smaller drain (approximately 6m wide at a natural ground level of 0.8m AHD) would be more effective than the present drain, which is up to 10m in width.

It is also apparent from the experience of the June 2005 flood, that during large local catchment floods there would normally be little or no outflow from the local catchment until the river level dropped, as local runoff and ocean surge effects are likely to raise the river level. This also means that drainage of local runoff ponded above natural ground level is largely dependent on the size of the culverts under the Pacific Highway and Chinderah Bay Drive, rather than the size of the drain itself.

Two dimensional modelling of the area (WBM, 2005) has shown that velocities are extremely low in major overbank floods sourced from the Tweed River (generally less than 0.1 m/s). For floods from the local catchment, overbank flood velocities would not be any greater. For local catchment floods, the 100 year ARI flood level would be less than the 1.57m AHD level recorded in June 2005, and being in the order of 1.2m AHD to 1.3m AHD.

4.3 Tweed River Flooding

The Project Site lies within an area which is subject to flooding from the Tweed River. The natural levee banks along the Tweed River, together with the embankment of the Pacific Highway, provide a barrier to most flows up to in excess of a 20 year ARI flood in the Tweed River. This means that in the proposed life of the Project (of up to 16 years) there is a reasonable chance that the Project Site would be flooded from the Tweed River. Flooding from the Tweed River could also theoretically happen more than once during the life of the Project, but this is much less likely.

Tweed River floods break out over the natural levee banks of the river and overtop the Pacific Highway, just to the east of where the Highway turns away from the river and heads to the south (see **Figure 1**). Velocities would be low, but ponding depths would be high. In such floods, the Project Site is likely to be inundated by more than 1m of water and in the order of 2.5m above natural surface level in a 100 year ARI flood. Floodwaters would recede once the Tweed River dropped back within its banks, once the flood levels drop below about 2.3m AHD, floodwaters would only flow back into the Tweed River via the agricultural drains and floodgates over a period of several days.

As noted in Section 3, the largest flood in recent historical times occurred in 1954, and this was of a similar order to a 100 year ARI flood at Chinderah, but was a more frequent event (smaller flood) further upstream. This means that it would have inundated the Project Site, but to a marginally lesser depth than a 100 year ARI flood, because overbank flows further upstream would have been less than in a 100 year ARI flood.

The recently completed Flood Study (WBM, 2005), which was initiated by Tweed Shire Council (Council) and the Department of Natural Resources (DNR), determined the various modes of flood behaviour in the whole of the Tweed Valley from upstream of Murwillumbah to the Pacific Ocean. Flood behaviour in a 100 year ARI flood, as determined in WBM, 2005, is presented on **Figures 9** and **10**. **Figure 9** (Figure 5-9 from the Flood Study) gives flood contours throughout the Lower Tweed Valley. It shows that the 100 year flood level at the Project Site is 3.3m AHD at the upstream (western) end (it would be marginally lower at the eastern end). The widely-spaced contours are indicative of the very low velocities experienced in this area at the peak of the 100 year ARI flood. The study found that velocities in the vicinity of the Project Site are of the order of 0.1 m/s at the peak of a 100 year ARI flood.

Figure 10, which is included in Council's Draft Version 2.3 of DCP5, and which in turn was sourced from WBM, 2005, shows all of the Project Site inundated in a 100 year ARI flood. The figure also shows, not surprisingly, that all of the Proponent's land proposed to be filled both east and west of Tweed Coast Road (see **Figure 2**) is also inundated. The 100 year ARI flood contours on **Figure 10** are understood to be the current flood levels adopted by Council in approving developments in the area.

Despite its high degree of flood liability (as evidenced by the information presented on **Figures 9** and **10**), the Project Site would have a relatively benign flooding regime, primarily because of the very low flow velocities. For this reason, the floodplain which contains the Project Site is therefore very much a *Flood Storage* area, rather than a *Floodway*, when evaluated in accordance with criteria in the Floodplain Development Manual (DIPNR, 2005).
For Tweed River floods, there is a long warning time (in the order of 6 to 12 hours) which would allow time for the safe evacuation of personnel, the removal of vulnerable equipment from the Project Site and blocking of the access to the processing area with sand prior to the Project Site becoming inundated.

5 DESIGN AND OPERATIONAL SAFEGUARDS

5.1 Background

As discussed in earlier sections, the Project Site is flood liable and can be inundated by up to 2.5m of floodwaters in a major Tweed River flood. However, the Project Site is located on the southern fringe of the floodplain adjoining the Cudgen Plateau. Floodwaters spilling over the banks of the Tweed River in floods greater than 20 years ARI, would move with very low velocities by the time they reach the Project Site. Providing there are reasonable provisions for flow paths during and post-development, the Project itself would not suffer any high velocity impacts, and there would be a reasonable warning time in which to move equipment to high ground and evacuate personnel. It also follows that as long as flow paths are reasonably maintained and embankments/bunds are kept to a minimum, or are allowed to overtop in a safe manner, any impacts on other properties are likely to be negligible.

With regard to placement of the fill sand acquired from the Project Site at other locations in the floodplain, each location has its own hydrologic characteristics which need to be considered when placing fill. These issues are detailed below.

The Project Site is subject to flooding by both local catchment flows and overbank flows from the Tweed River. In providing safeguards, the different characteristics of each type of flooding needs to be considered as set out below. The two different types of flooding also have potential implications for surface water quality within the Project Site. These are discussed briefly below.

5.2 Project Site - Local Catchment Flooding

The very rare flood of June 2005 provides conservative design criteria for local catchment flooding. As can be seen on **Figure 6**, this flood peaked at about 1.57m AHD in the vicinity of the Project Site. The existing Altona Drive has an elevation of approximately 1.2m AHD. The approved realignment will have an elevation of 1.4m AHD or greater and would intersect with Crescent Street and Tweed Coast Road at slightly higher elevations. This means that access would always be available to the Project Site by road during such a flood although the road may be overtopped by 10cm of water during a 1 in 100 year ARI event prior to the realignment of Altona Drive.

It is proposed that the processing area would be elevated to between 1.55m AHD and 1.8m AHD, which means that it would also be above flood level for even extreme local catchment floods. The bund around the extraction ponds would generally be at 1.8m AHD, but would need to have spillways at each end (western and eastern) at 1.3m AHD and positioned so as to be adjacent to the deepest part of the pond at that point in time. Again, this means that no local catchment floods are likely to enter the extraction ponds during the life of the Project (the 100 year ARI flood level from local catchment flooding is of the order of 1.2m AHD to 1.3m AHD – see Section 4.2).

The northern and southern extraction ponds would be expanded in stages as shown on **Figure 3**. The northern extraction pond would be entirely protected by bunding while the area protected by bunding in the southern extraction pond would initially only embrace Stages 1 and 2. Although the bunding around Stages 1 and 2 would not restrict local catchment flows in the area south of Altona Drive, it would still be necessary to have spillways on the eastern and western faces of the bund as indicated on **Figure 3**. When the southern extraction pond is expanded to embrace first Stage 3, and then Stage 4, the bund would restrict local catchment flows through the middle of the site, so flows would have to pass to the south in the drain adjoining the Cudgen Plateau, and to the north, in the drain south of and parallel to Altona Drive. The spillways within the bunding for the northern extraction pond would not need to be repositioned, however, the western spillway would need to be modified as the southern extraction pond is expanded from Stage 1 and 2 to Stage 4. Thereafter, the western bund would not need to be modified. The spillway on the eastern boundary of the southern extraction pond bunding would need to be included in each new alignment of the eastern side of the bund as it is progressively expanded up to and including Stage 10.

With regards to the balance of the Project Site which is not excluded from flooding in local catchment floods by filling or bunding, the only essential requirement would be to maintain drainage overflow paths within the Project Site that connect to the Western Drain adjoining and to the south of Altona Drive. This would allow floodwaters to drain away freely once the Tweed River dropped and the main drains were able to function again.

After completion of the Project, the land surrounding the lake would be developed, generally in accordance with **Figure 4**. In the future, development application(s) for the uses envisaged for this land, it is essential that provision be made for adequate flow paths through the area, together with minimal use of fill so as not to unnecessarily displace flood storage. This could be readily accomplished in the context of the landscaping treatment envisaged on **Figure 4**.

Local catchment floods are very unlikely to enter the extraction ponds or the processing area during the life of the Project. Floodwaters tend to contain large volumes of sediment, but because of the very low velocities, only very fine sediments are likely to be conveyed through the Project Site by floodwaters. There would be limited deposition of such sediments within the inundated areas but these are unlikely to cause any inconvenience. No special provisions need to be made within the Project Site to accommodate surface water quality impacts from local catchment flooding.

5.3 Project Site - Tweed River Flooding

Tweed River overbank flooding occurs in the vicinity of the Project Site on average less than once every 20 years. This still means that the Project Site is quite likely to be flooded from the Tweed River at least once, and possibly twice or more, during the life of the Project. Once the Tweed River overtops its banks, floodwaters are likely to rise steadily to a high elevation. In a 100 year ARI event, the flood level would reach 3.3m AHD giving flood depths of up to 2.5m.

Road access along Altona Drive would not be possible at the flood peak as it is likely to be covered by almost 2m of water. Even though flood depths would be substantial, the rate of rise would be relatively slow, and there would be time to remove vulnerable equipment and safely evacuate personnel (warning of potential overbank flooding should be at least 6 hours and possibly 12 hours). To ensure that personnel on the Project Site respond appropriately to a warning of an imminent Tweed River overbank flood, a Flood Evacuation Plan should be prepared prior to commencement of the sand extraction operation, and staff trained in its implementation. This would ensure that lives are not put at risk, and that economic damages from flooding are minimised.

Even though the processing area is to be raised to at least 1.8m AHD, and surrounded by a high bund, this bund would have a gap in it for road access and the processing area would still be inundated by of the order of 1.5m of floodwaters at the peak of a 100 year ARI Tweed River flood. If sand stockpiled within the processing area is used to block the entrance during the period of flooding the level of inundation may be reduced.

Floodwaters would enter the extraction ponds from the east and west over the spillways located within the eastern-most and western-most parts of the bunds surrounding the ponds (the locations of the bund and spillways are described in Section 5.2). This would allow the depth of water in the pond to equalise with outside flood levels, so that when the remainder of the bund at 1.8m AHD was overtopped, there would be no significant difference in water level. This would minimise any scour of the bunds as they are progressively overtopped. When the floodwaters within the Project Site start to recede as Tweed River level drops, it is proposed that gaps be cut to natural ground level within the spillways to allow floodwaters trapped behind the bund to spill down an unobstructed flow path to the Western Drain adjoining and to the south of Altona Drive.

For Tweed River flooding, similar comments would apply as those set out in Section 5.2 for design and operational safeguards for local catchment flooding with regard to future usages of the land surrounding the lake upon completion of the Project. In this regard, the greater depth of floodwaters during Tweed River flooding makes it even easier to maintain natural flow paths.

For Tweed River floods there would also be no need for any special provisions with regard to surface water quality impacts on or by the Project from such floods. Tweed River floods would differ from local catchment floods in that they would inundate the processing area and pass through the extraction ponds. As already noted, spillways at each end of the extraction ponds would enable controlled overtopping and equalisation of water levels, thus minimising any likely erosion and sediment mobilisation from overtopping waters when the main bunds are overtopped. Floodwaters passing through the extraction ponds would slow down to even lower velocities than those in the floodplain, so there could be some minor deposition of fine sediments. There would be no mobilisation of extraction pond sediments. Mixing of the floodwaters with the extraction pond waters as the flood passes through should increase the pH of the extraction pond waters closer to neutral.

5.4 Filling South of Noble Park Estate

Figure 2 shows the proposed fill areas 3, 4a, 4b, 5 and 6 south and east of Noble Lakeside Park Estate. This sub-section addresses filling east of Tweed Coast Road in an almost continuous band up to the existing village of Kingscliff.

The report SNW, (2007c), describes the setting up of hydrologic and hydraulic models to analyse the effects on local catchment flooding of filling in this area. The report is summarised in Section 3. The experience of the June 2005 flood (SNW, 2007a) showed that flood levels in this area under existing conditions were very much lower than the design 100 year ARI level for Tweed River flooding. Hence, even though it was an extreme event for local catchment flooding (much larger than a 100 year ARI event) flood levels were still more than a metre lower than the 100 year ARI flood level for Tweed River flooding (1.9m AHD versus 3.3m AHD). This meant that no property was adversely affected by the June 2005 flood.

The filling shown in this area on **Figure 2** still leaves a substantial portion of the existing floodplain unfilled. This is mainly because of ecological constraints, but also because of the need to provide drainage corridors and open space reserves. Future detailed design of this area would ensure that adequate drainage reserves are maintained along the main drains so that as flood levels in the Tweed River recede, floodwaters would be able to drain away along Chinderah Drain to the Tweed River. The combination of restricted filling and adequate drainage paths, would ensure that flooding from local catchment floods would not affect existing development into the future.

During major Tweed River floods, floodwaters would enter and leave the southern area south of Noble Park Estate through the network of drains and drainage reserves provided in the future development plans. Given the relatively slow rate of rise of such floods, and the size of the future drainage paths, floodwaters would be able to equalise throughout the area and reach similar levels to what they do now (3.2 to 3.3m AHD in a 100 year ARI flood).

5.5 Filling North of Noble Park Estate

Figure 2 shows an extensive area of filling east of Tweed Coast Road and just south of the Ozone Street industrial estate, fill areas 7 and 8. The area is bisected by Chinderah Drain. This fill area is the subject of this sub-section.

SNW has provided advice to consultants preparing a structure plan for this northern area. The advice is documented in SNW, (2007d). Filling of this area is subject to special provisions in Council's DCP5. From a flooding and drainage viewpoint, this essentially reduces to ensuring that no more than 50% of that portion of this area to the west of Chinderah Drain is filled above the general level of the surrounding roads (about 2.2m AHD). No such restriction applies to the east of Chinderah Drain. The 50% rule was developed based on flood advice contained in WBM, 1992, which as discussed in Section 3, showed considerable flows through this area from west to east. More recently, WBM, 2005, has updated the flood behaviour information and demonstrated a much more benign flooding situation with relatively little through flow. A Risk Management Study will examine this area in more detail in the near future using the 2005 study hydraulic model as the appropriate tool to identify impacts.

The Proponent's current Structure Plan (**Figure 4**), which is based on flooding and drainage advice contained in SNW, (2007d), complies with the 50% rule in DCP5 and provides for flow paths through the development for large floods. It is envisaged that when the area is looked at more closely in the Risk Management Study on the basis of current flood behaviour information, the 50% rule will be relaxed, but there could still be some requirement for flow paths to be provided.

The filling proposed for this area therefore provides adequate safeguards to meet current and likely future Council requirements.

Local catchment flooding in this northern area is not a major issue. Even in the extreme June 2005 flood, levels reached about 1.85m AHD, well below the 100 year ARI design flood level for Tweed River floods of about 3.2m AHD. Chinderah Drain passes through this area and has substantial capacity to drain local floodwaters once Tweed River levels recede. Providing that any development in this area has appropriate local drainage paths, there would be no adverse effect on the development itself or adjoining developments from the proposed filling.

5.6 Filling West of Tweed Coast Road

The remaining fill areas 1 and 2 (see **Figure 2)** lie west of Tweed Coast Road and within and immediately to the east of the Project Site. Referring to **Figure 4**, it can be seen that the majority of this area is flood compatible development such as playing fields and limited supporting infrastructure. That part of the fill area between Crescent Street and Tweed Coast Road and to the south of Altona Drive is already approved for residential development.

All of this area is again on the fringe of the floodplain and subject to very low flow velocities in both local catchment floods and Tweed River floods. The land that has not already been approved for development has low intensity development wherein the majority of the fill would only be to bring the ground level up to the general level of the surrounding roads (2.1m AHD to 2.2m AHD). This means that there is little or no potential for the development to have an adverse effect on local catchment or Tweed River floods.

Design of the development to allow flow paths and minimise fill volumes would be a straightforward task. Filling proposed for this area therefore provides adequate safeguards to meet current and likely future Council requirements.

6 IMPACT ASSESSMENT

6.1 Background

Section 5 describes the likely flood behaviour in each area, and under the different types of flooding, and provides details of the safeguards proposed to address flooding and drainage issues. In this section, the same areas are again examined to see whether impacts on flooding and drainage from the Project are acceptable, and whether the placement of the sand as fill would result in any unacceptable impacts.

Any likely implications for surface water quality from the Project in local catchment floods or Tweed River floods are also discussed.

In Section 6.7, the potential for cumulative impacts from the Cudgen Lakes Sand Extraction Project, together with other existing or proposed developments within this part of the Tweed River floodplain, is discussed.

6.2 Project Site - Local Catchment Floods

Local catchment flooding does not generate the peak flood levels in this area. It is flooding from the Tweed River that produces the peak design flood levels. This means that local catchment flooding is therefore less likely to be a problem from an impact assessment viewpoint.

The impacts on the Project itself from local catchment flooding would be minimal. The site access road, Altona Drive, would still be trafficable during flood events with ARI's well in excess of 100 years; the processing area would be dry; and, normal local drainage provisions would mean that the balance of the Project Site would drain freely once the rain stopped and the Tweed River levels dropped.

After the Project is completed and the Project Site developed in accordance with the Structure Plan, which largely envisages flood compatible development in this area, provision of suitable flow paths would again ensure the area is compatible with local catchment flooding conditions.

With regard to the potential impact of the Project on local catchment floods, small parts of the floodplain, being the active extraction pond areas and the processing area, would be excluded from the flood storage area, but this would have minimal impacts because of the relatively small size of the floods. Furthermore, the new drainage system along and south of the realigned Altona Drive would be more efficient than the present drain, and would allow faster drainage once the flood levels reduce to in-bank flows.

Overall, the Project Site would be minimally impacted by local catchment floods and it would have minimal impacts on such floods. Furthermore, there would be negligible or no increase in adverse impacts on other properties and land users.

Local catchment floods are highly unlikely to enter the processing area or extraction ponds during the life of the Project. The Project would therefore have no adverse effects on surface water quality during local catchment floods and there would be no adverse surface water quality impacts on the Project from such floods.

6.3 Project Site - Tweed River Floods

Tweed River overbank floods generate the peak design flood levels within the Project Site. They are relatively rare – at least 20 years ARI on average. Such floods have reasonably long warning times, enter the floodplain area at low velocities, and rise at a reasonably slow rate. However, such floods when they do occur would be disruptive to the operation of the Project.

The impacts on the Project Site would be minimised by raising key infrastructure above flood levels, removing vulnerable equipment before the flood arrives, and evacuating staff. Damage to the physical facilities would be minimised by allowing the extraction ponds to overtop in a safe manner that minimises erosion of the surrounding bund walls. Appropriate post-flood drainage infrastructure would ensure minimal down time for the operation once the peak of the flood has passed and the floodwaters have receded in bank, firstly in the Tweed River itself, and subsequently in the trunk drains.

The impacts of the works within the Project Site on surrounding properties would be minimal. All of the Project Site would be covered by floodwaters in a Tweed River flood. The small volumes of fill used for the processing area and for the bunds would be more than compensated for, from a flood storage viewpoint, by the excavation and removal of material above the water table, particularly within the southern extraction pond. The available volume of flood storage would increase as the pond was enlarged. The overall effect would be a net increase in flood storage capacity over time. Flow velocities are small so the minor effects of obstructions such as the bunds around the extraction ponds and the processing area would have minimal effect as floodwaters pass over and around them.

Overall, the Project Site would be minimally impacted by Tweed River catchment floods other than a short period of down time, and it would have minimal impacts on such floods. There would be negligible adverse impacts on other properties.

In Tweed River floods, the whole of the Project Site would be inundated. The floodwaters will only contain relatively minor amounts of sediments because the heavier sediments will be deposited nearer to the Tweed River where overtopping initially occurs. There would be deposition of fine sediments within the Project Site but the quantities would be small and would have no adverse impacts on the operation. Passage of the floodwaters through the extraction ponds would increase the pH from its normal level closer to neutral. This would therefore provide some short term benefit to water quality whilst also elevating the water table and recharging the aquifer. When the ponded water is drained off as the flood recedes, it would not have any adverse effects on other land uses as sediment levels would be reduced and the pH would be close to neutral.

6.4 Filling South of Noble Park Estate

The experience of the June 2005 flood (SNW, 2007a), and recent modelling using the data from this flood (SNW, 2007c), has demonstrated that local catchment flooding in this area after filling would not have adverse impacts on adjoining properties and the development itself would be free from the impacts of such floods. The large retained area of natural flood storage and drainage flow paths ensures this.

For Tweed River floods, ensuring that there are adequate drainage flow paths for floodwaters to safely enter the area on the rising stage of the flood, and safely leave the area as the flood levels drop back within the banks of the Tweed River, would ensure negligible impacts on the new backfilled development areas and existing development. Existing local main drains can convey the residual drainage waters safely away much the same as they do for local catchment flooding.

6.5 Filling North of Noble Park Estate

This is the most difficult area of the floodplain to fill in a safe manner to ensure that it is not impacted by floodwaters and to ensure that the proposed filling does not adversely affect others.

With regard to local flooding, this area is barely affected, and filling to the 2.2m AHD level permitted by Council's DCP5 would ensure that the development itself is not affected by local catchment flooding. Filling to this level would also not affect others as properties are already require to be filled to at least 3.3m AHD to provide a suitable platform to remain above the 100 year ARI Tweed River flood.

As noted in Section 5.5, the Proponent has adopted a conservative approach to planning the fill for this area. The current DCP5 is based on the much higher flood flows and levels determined in WBM, 1992. The more benign flooding behaviour demonstrated in WBM, 2005, when applied in the Risk Management Study currently being carried out by Council, is likely to lead to relaxation of the 50% fill rule. In the meantime, forward planning via a Structure Plan for this area is adopting a conservative approach in complying with the existing DCP5.

It is clear from the forward planning work already done that the proposed development of this land can proceed in a staged manner that would ensure that it is compatible with the existing Council requirements and can be adapted to revised requirements if and when they occur. Flow paths would be provided in excess of current requirements to ensure that there would be no adverse impact on other properties in Tweed River floods.

6.6 Filling West of Tweed Coast Road

Part of this area is approved for residential development already. This area immediately adjoins existing high ground on the fringe of the floodplain and filling and development of this area would have negligible impacts on other land users and the development would be readily accessible during Tweed River floods.

The remainder of the filled area for this part of the floodplain is essentially flood compatible development. The filling of this area would be very a straightforward exercise to maintain adequate flow paths for Tweed River floods. There would also be minimal loss of flood storage for Tweed River floods.

Access to the area would be available by Altona Drive and Tweed Coast Road which deliver traffic onto a rising road to the Cudgen Plateau allowing easy access to Kingscliff during a rising flood. Flood warning times for this area are also long enough to evacuate people who may be attending the sporting and other facilities proposed for this area.

The development in this area would be flood compatible and would only minimally interfere with local flood flows. The impact of flooding on the development would be minimal because of its flood compatible nature, and because of the limited fill and restrictions to flow paths. The development itself would have minimal impacts on floods and hence on other properties and land users.

6.7 Cumulative Impacts

A standard requirement for developments that potentially affect flood behaviour within a floodplain is to require assessment of cumulative impacts. This is also a specific consideration in the Floodplain Development Manual (DIPNR, 2005). Such an assessment has also been requested during the consultation process for this Project.

In relatively recent times, a number of developments have occurred (or have been proposed and approved) within and adjoining this floodplain, which have the potential to affect flood behaviour (see **Figure 1**). These include the:

- Chinderah Bypass of the Pacific Highway;
- Yelgun Bypass of the Pacific Highway;
- new waste water Treatment Plant opposite and to the west of the Project Site;
- proposed aquaculture development to the northwest of the Project Site and adjoining the Yelgun Bypass; and
- extension of the existing sand quarry immediately to the west of the Project Site - referred to as the Hanson Tweed Sand Quarry.

WBM in their assessment of the proposed aquaculture development (WBM, 2004) showed that this development would in fact reduce flood levels in the floodplain because it would have the effect of restricting flows through the culverts under the Yelgun Bypass. The recent Flood Study by WBM (WBM, 2005) has also shown that the Chinderah and Yelgun Bypasses have restricted flows entering the floodplain. WBM's flood impact assessment of the extension of the Hanson Tweed Sand Quarry (JGA, 2005) also concluded that there would be minimal effects from this development. A small increase in flood storage may in fact marginally reduce flood levels in Tweed River floods.

With regards to the Cudgen Lakes Sand Extraction Project, there would also be a marginal increase in flood storage capacity on the floodplain in major Tweed River floods after allowing for filling within the processing area and the bunding around the extraction ponds and processing area. In large Tweed River floods, this development would therefore contribute to a marginal decrease in flood impacts.

It would seem therefore that the cumulative impacts of all of the developments identified above would not have a significant adverse impact on flood behaviour in this particular floodplain. If anything, there should be a small reduction in overall flood impacts.

With regard to the use of fill from the Project Site on the areas identified on **Figure 2**, each of these areas has been assessed independently, and would be further assessed into the future as developments proceed. It has already been demonstrated that filling should be able to proceed without adverse effects on existing development. The fact that cumulative flood impacts within the area from recent existing developments identified above have marginally reduced the impacts of flooding in major Tweed River floods means that any future filling would take place in a relatively benign environment.

7 CONCLUSIONS/RECOMMENDATIONS

- The Project Site would be fully inundated in both local catchment and Tweed River floods because of its relatively low elevation.
- During local catchment floods, access would still be possible to the Project Site along Altona Drive. The processing area and the extraction ponds would remain flood free. Although the Project Site would be accessible, it is likely that activities on site would be disrupted, at least to some extent, for a day or two.
- The Tweed River breaks its banks and floods the floodplain containing the Project Site in floods greater than the 20 year ARI flood. The Project Site is therefore quite likely to be inundated by a Tweed River flood during its life, but is unlikely to be inundated more than twice by such floods. When such floods do occur, all of the Project Site would be inundated by up to 2.5 metres of low velocity floodwaters (in a 100 year ARI flood). There would be sufficient warning time to remove vulnerable equipment, safely evacuate staff and block the access to the processing plant. A large Tweed River flood would clearly make the Project Site inaccessible and inoperable for a number of days, although operations would be able to resume quickly after the floodwaters recedes.
- A Flood Evacuation Plan should be prepared prior to commencement of the sand extraction operation, and staff trained in its implementation. This would ensure that lives are not put at risk and economic damages from flooding are minimised.
- The flood storage volume within the Project Site in large Tweed River floods would be marginally increased by the development.
- In local catchment floods, the Project would have a negligible impact on local flood behaviour. The small volume of flood storage isolated from the floodplain by the bunds around the extraction ponds, and the fill within the processing area, would be minor in comparison with the total flood storage in the floodplain.

- In large Tweed River floods, the Project would have no significant impact on local flood behaviour. The minor increase in flood storage noted above (once the development reached an advanced stage) would not be sufficient to produce a noticeable change in flood behaviour.
- The cumulative impact of the Project, given other existing developments within this floodplain, and other foreshadowed developments, would be negligible. In large Tweed River floods, this development would have a minor positive impact, as more flood storage would be available when the development was completed.
- A large proportion of the sand extracted from the Project Site would be placed as fill sand within approved development sites in the same floodplain. Each of these sites is the subject of ongoing studies to ensure no significant adverse effects on existing development. Given that peak flood levels reached in local catchment floods are at least 1.5m lower than in a 100 year ARI Tweed River flood, there is little or no potential for filling to adversely affect other properties in such floods provided that adequate drainage reserves are provided. For large Tweed River floods, such as the 100 year ARI flood, the only area where flood behaviour could potentially be adversely affected by filling is in the development area north of Noble Park Estate. Careful attention would be paid to minimising fill volumes and maintaining flow paths to minimise the potential for any adverse effects from the development.

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Figures

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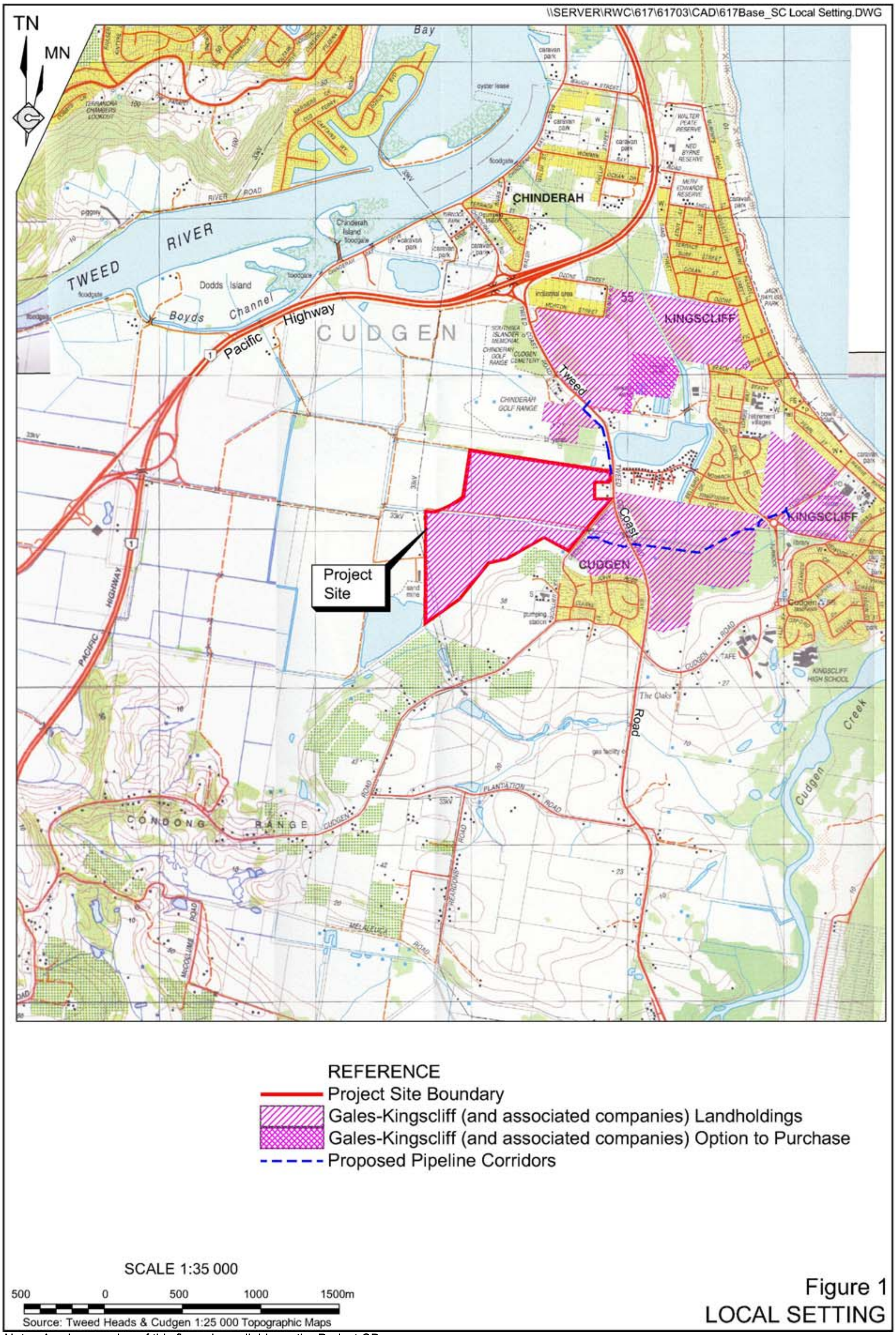


Figure 1
LOCAL SETTING

Note: A colour version of this figure is available on the Project CD.

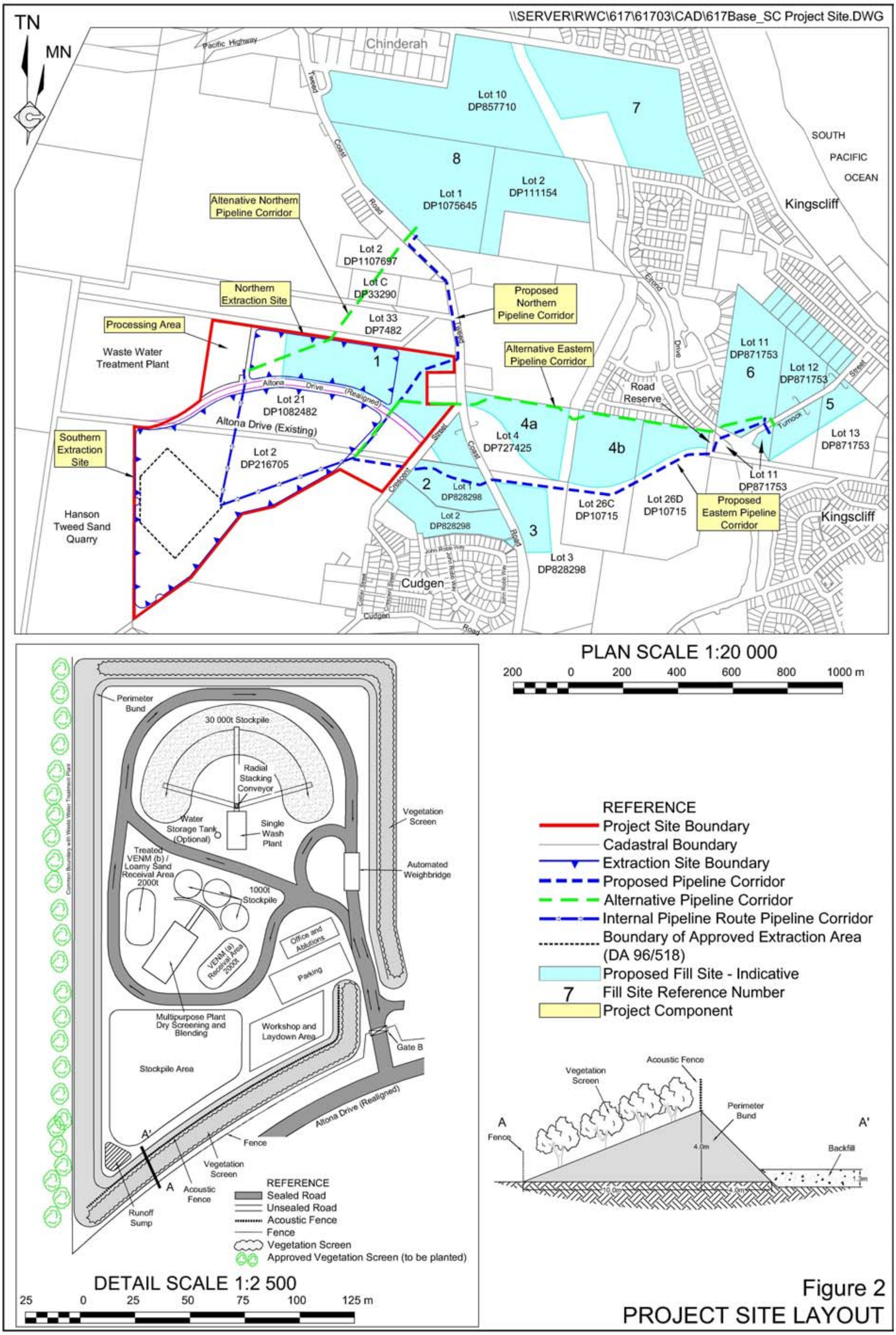
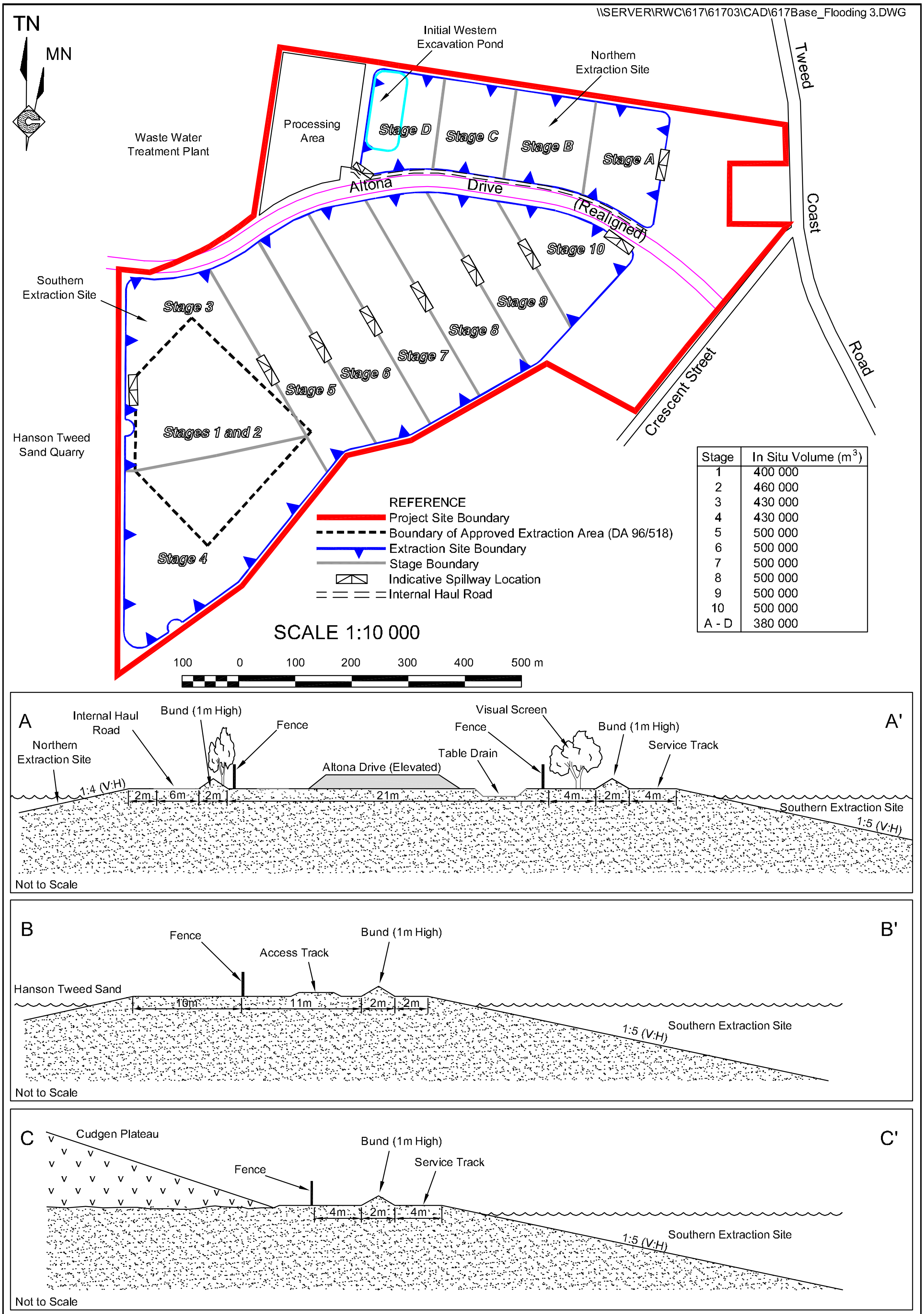


Figure 2
PROJECT SITE LAYOUT

Note: A colour version of this figure is available on the Project CD.



Stage	In Situ Volume (m^3)
1	400 000
2	460 000
3	430 000
4	430 000
5	500 000
6	500 000
7	500 000
8	500 000
9	500 000
10	500 000
A - D	380 000

Figure 3
EXTRACTION STAGES

Note: A colour version of this figure is available on the Project CD

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Figure 4
INDICATIVE FINAL LAND USE - GALE'S LANDHOLDINGS

TN MN

SCALE 1:20 000

200 0 200 400 600 800 1000 m

Source: Allen Jack + Cottier (15/11/2007)

Note: A colour version of this figure is available on the Project CD

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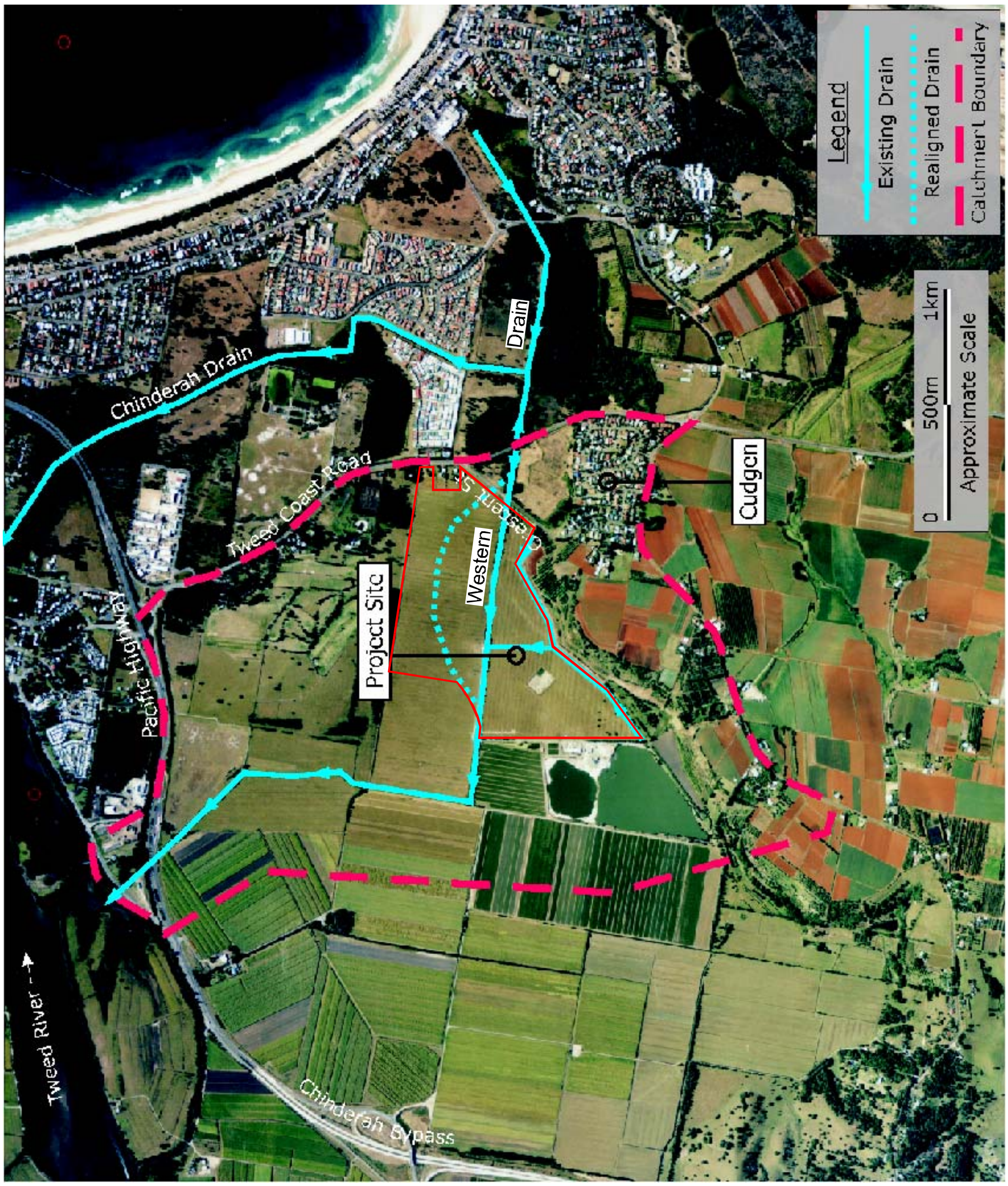

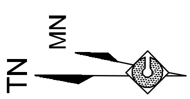

Figure 5
WESTERN DRAIN CATCHMENT BOUNDARY

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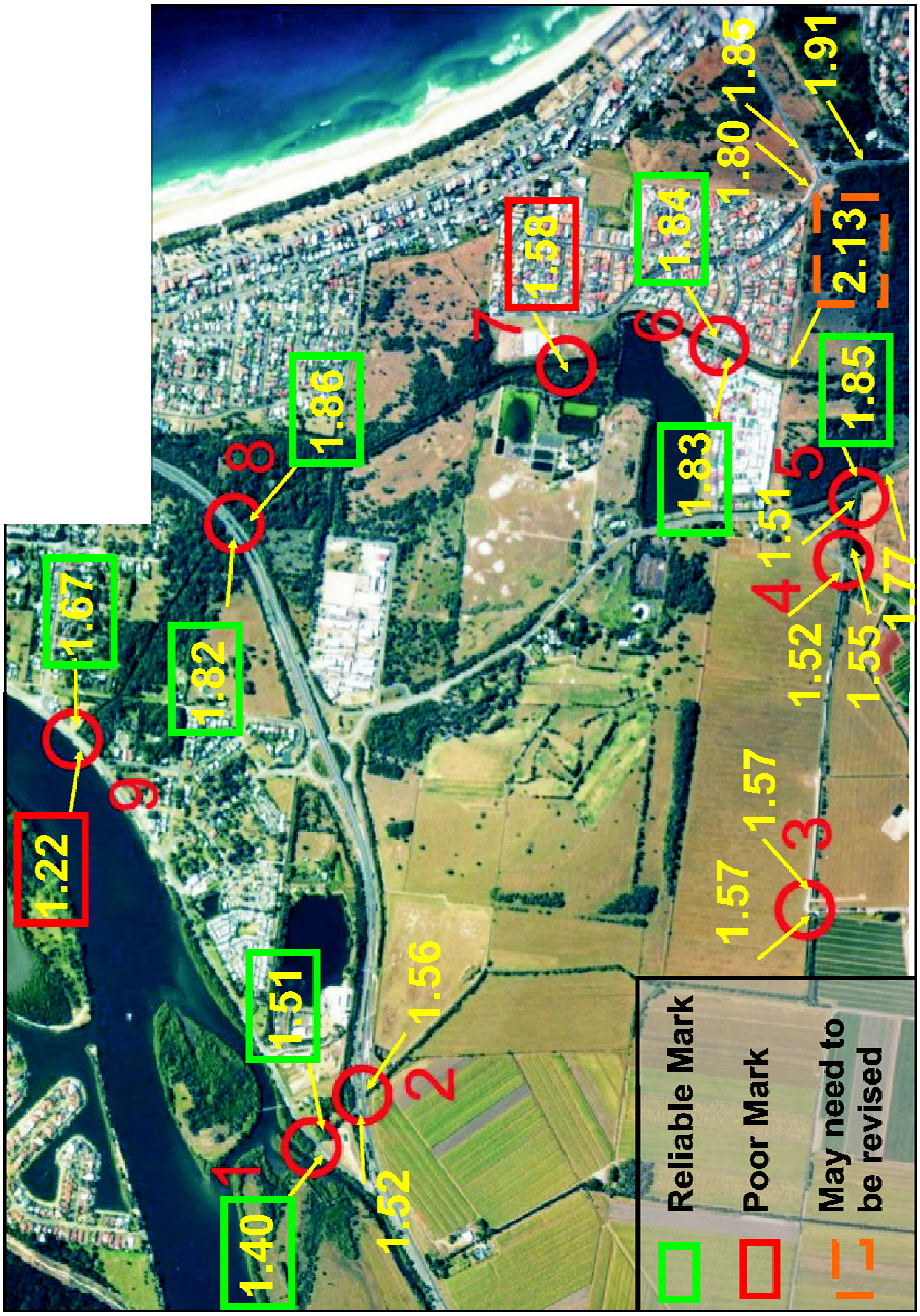

Note: All Levels in m AHD

Figure 6
JUNE 2005 FLOOD MARKS

TN MN

Source: B & P Surveys

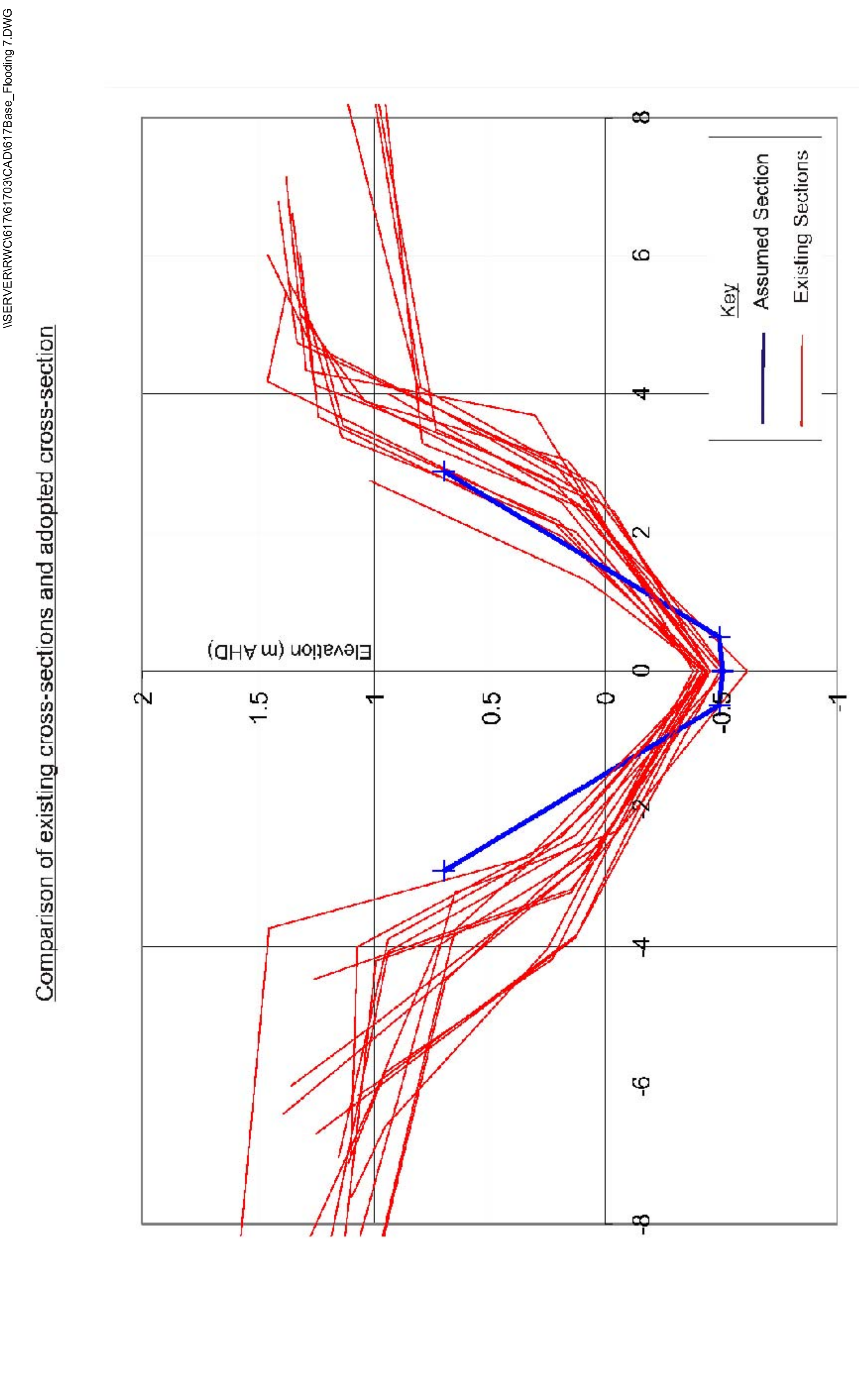

Figure 7
WESTERN DRAIN CROSS SECTIONS

Note: A colour version of this figure is available on the Project CD

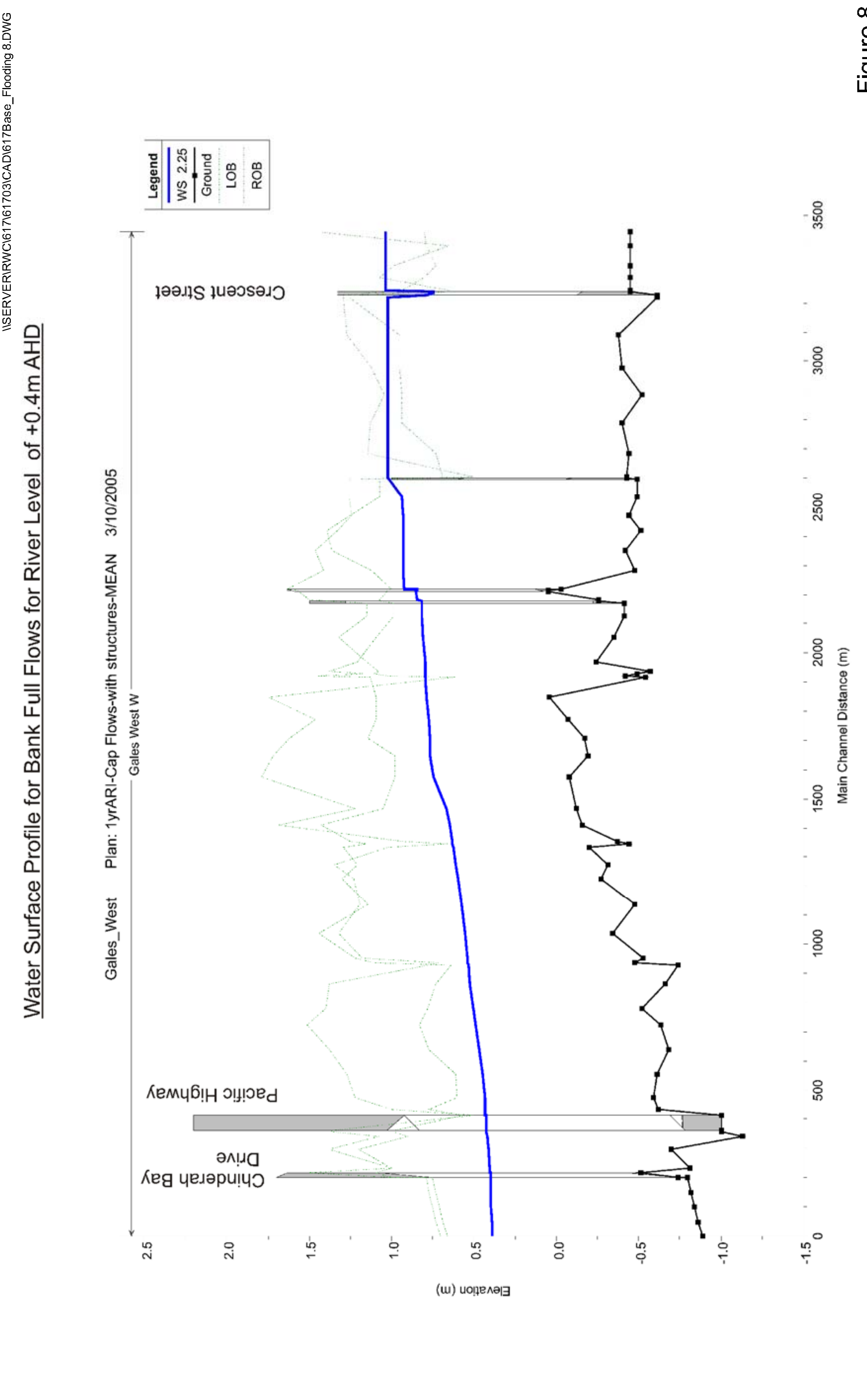

Figure 8
WESTERN DRAIN WATER SURFACE PROFILE EXISTING DRAIN

Note: A colour version of this figure is available on the Project CD

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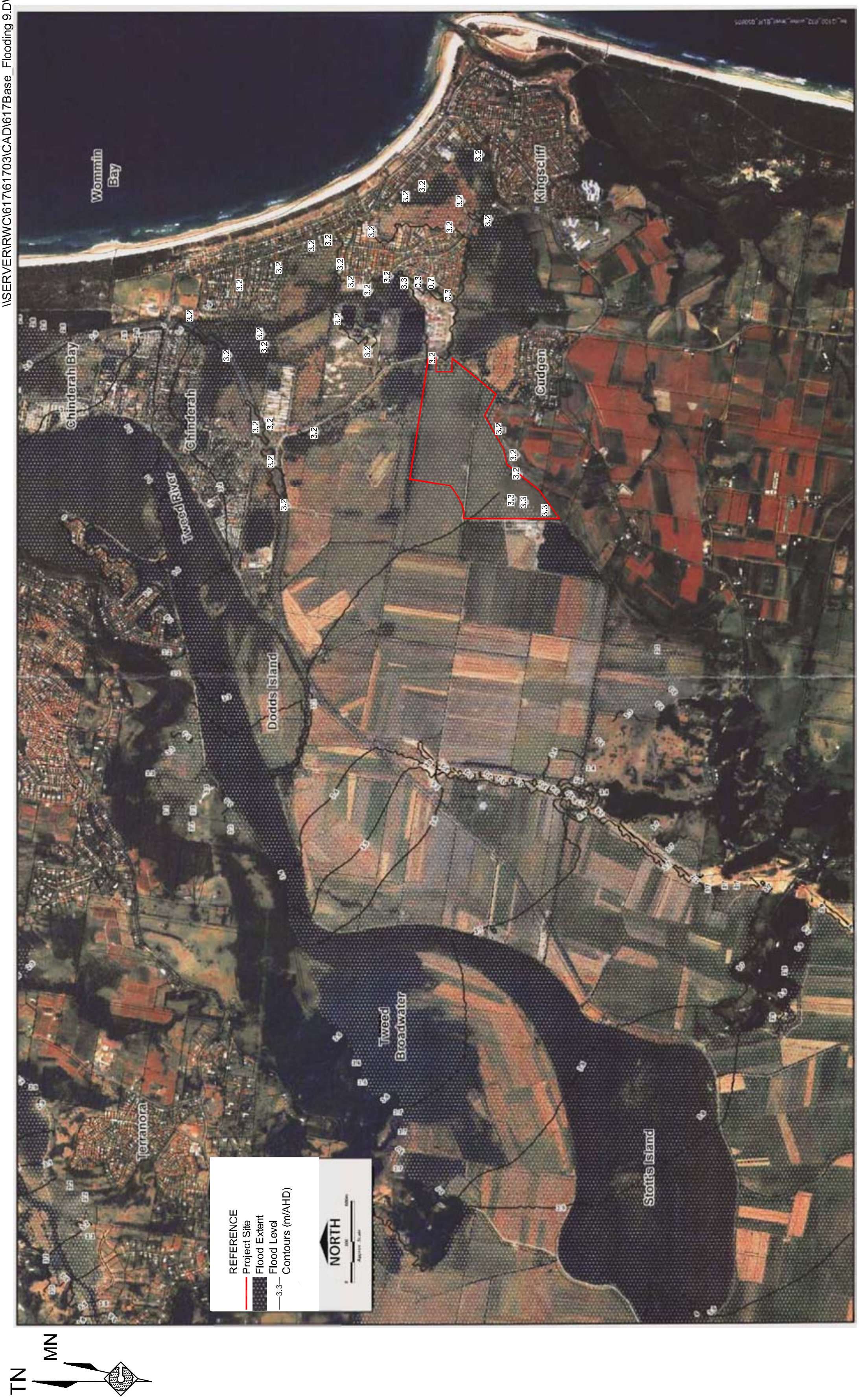

Figure 9
DESIGN FLOOD LEVELS 100 YEAR ARI FLOOD (WBM, 2005)

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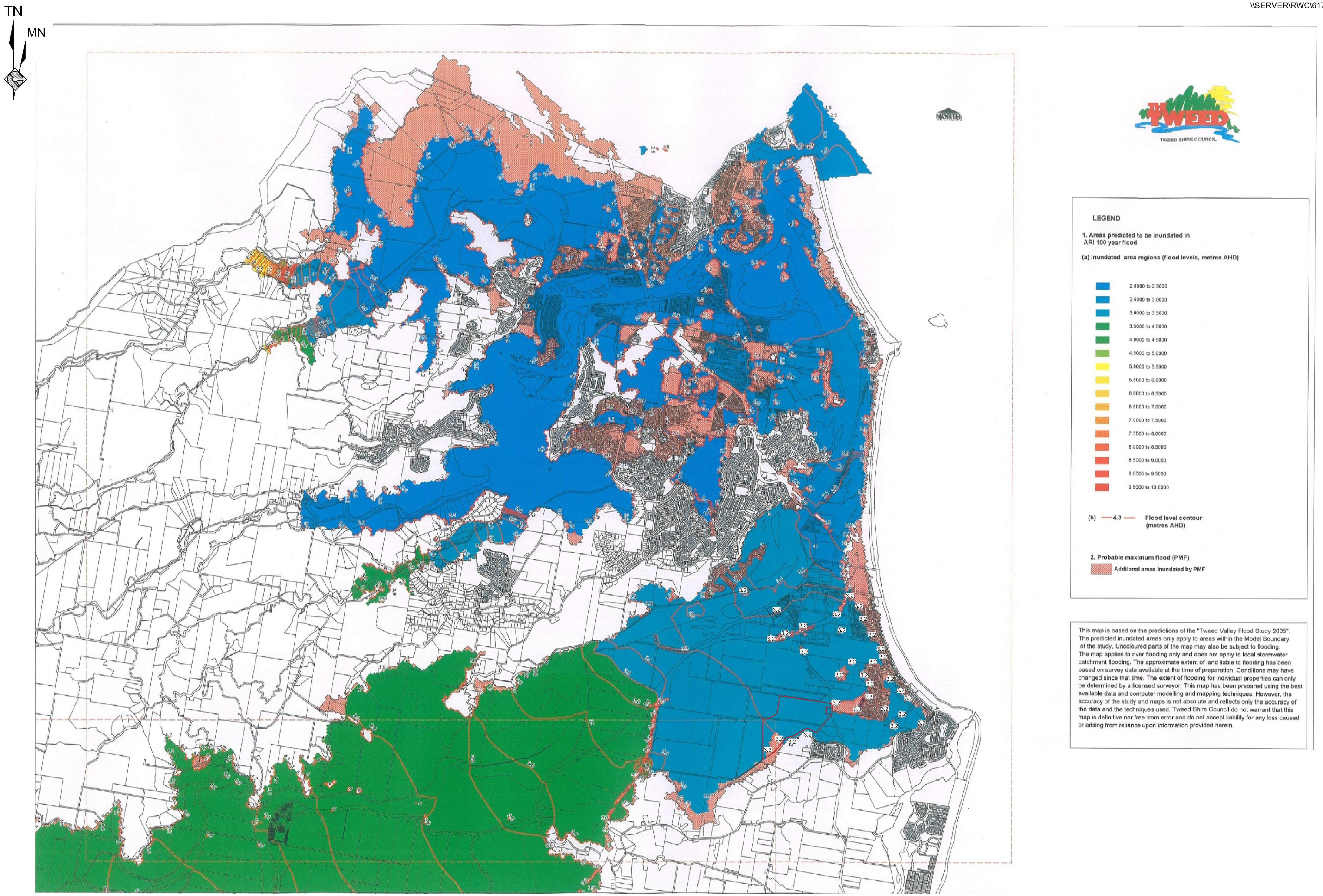

Figure 10
DESIGN FLOOD LEVELS 100 YEAR ARI
FLOOD (TSC, DRAFT DCP5, , 2005)

Appendix 1

Coverage of Environmental Assessment Requirements and Environmental Issues

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Table A1-1
Coverage of Environmental Assessment Requirements and Environmental Issues in the Flooding and Drainage Assessment

Page 1 of 2

<table>
<tr><th colspan="3">ENVIRONMENTAL REQUIREMENTS RAISED BY THE DIRECTOR-GENERAL
RELATING TO FLOODING AND DRAINAGE (06.01.06)</th></tr>
<tr><th colspan="2"></th><th>Relevant Section(s)</th></tr>
<tr><td colspan="2">Key Assessment Requirements, namely:
• Flooding and Drainage - Assess the potential impacts of the Project (including any potential cumulative impacts that may arise from the combined operation of the Project with the existing or approved operations at the Bolster Quarry), and describe what measures would be implemented to avoid, minimise, mitigate, offset, manage and/or monitor these impacts.
References
Refer to the:
• Guidelines for Fresh and Marine Water Quality (ANZECC);
• Managing Urban Stormwater: Soils & Construction (Landcom);
• the various State Groundwater Policy documents and Floodplain Development Manual (Department of Natural Resources); and</td><td>Sections 5 & 6</td></tr>
<tr><th colspan="3">ENVIRONMENTAL REQUIREMENTS RAISED BY GOVERNMENT AGENCIES
RELATING TO FLOODING AND DRAINAGE</th></tr>
<tr><th>Government Agency</th><th>Paraphrased Requirement</th><th>Relevant Section(s)</th></tr>
<tr><td rowspan="5">Department of Environment and Conservation
(15 October 2004)</td><td>Provide maps showing the locality of the proposed development in a regional and local context. Base local context maps on 1:25 000 topographic plans.</td><td>Figures 1 & 5</td></tr>
<tr><td>Provide a description of:
– the existing environment on the subject and surrounding land;
– the proposed development and ancillary works; and
– the manner in which the environment will be modified by the proposal.</td><td>Section 4
Section 2
Section 5 & 6</td></tr>
<tr><td>Clearly identify on an appropriately scaled plan the area subject to development.</td><td>Figures 1 & 2</td></tr>
<tr><td>Consult the general requirements from the EIS Guidelines Extractive Industries – Dredging and other extraction in riparian and coastal areas during the preparation of the EIS.</td><td>Sections 5 & 6</td></tr>
<tr><td>Document surveys and assessments that have been undertaken by suitably qualified persons and provide the qualifications and experience of the person(s) undertaking the work.</td><td>Section 4</td></tr>
</table>

Table A1-1 (Cont'd)
Coverage of Environmental Assessment Requirements and Environmental Issues in the Flooding and Drainage Assessment

Page 2 of 2

ENVIRONMENTAL REQUIREMENTS RAISED BY GOVERNMENT AGENCIES RELATING TO FLOODING AND DRAINAGE		
Government Agency	**Paraphrased Requirement**	**Relevant Section(s)**
Department of Environment and Conservation (Cont'd) (15 October 2004)	Substantiate conclusions drawn in surveys and assessments with evidence resulting from those surveys and assessments.	Section 4
	Provide details of the Project that are essential for predicting and assessing impacts to waters including drainage works and associated infrastructure; land-forming and excavations; working capacity of structures; and water resource requirements of the proposal.	Section 2 Figure 2
	Outline site layout, demonstrating efforts to avoid proximity to water resources and showing potential areas of modification of contours, drainage etc.	Figure 2 Sections 5.2 & 5.3
	Outline how total water cycle considerations are to be addressed showing total water balances for the development. Include water requirements and proposed storm and wastewater disposal, including type, volumes, proposed treatment and management methods and re-use options.	EA Section 2
	Provide site drainage details and surface runoff yield.	Section 4
	Determine changes to hydrology (including drainage patterns, surface runoff yield, flow regimes, wetland hydrologic regimes and groundwater).	Section 5
Department of Infrastructure and Natural Resources (North Coast Region) (6 December 2004)	Conduct a detailed study of the whole catchment taking into account the impact of any levees/banks whether temporary or permanent and any resultant environmental impact that may occur.	Section 4
	Outline the potential for damage from wave action in the excavation site/recreational lake.	EA Section 2
Department of Primary Industries (Agriculture) (7 October 2004)	Identify all water bodies including wetlands and floodplains.	EA Section 4
	Specify the direction of river flow and provide hydrological and stream morphological including depth contours and stream bed substrate information, water quality and if appropriate tidal characteristics.	Section 4 Figure 5