Appendix VII: GHD Turner River Flood Study

LandCorp

Boodarie Strategic Industrial Area (BSIA)
Turner River Flood Study

24 March 2013

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Appendices

1. Executive Summary

This report summarises the hydrologic and hydraulic analysis of the Turner River catchment, to the west of the Boodarie Strategic Industrial Area (BSIA), and its implications for the BSIA concept plan. This study conducted hydraulic modelling using Mike Flood of the Turner River using methods recommended by Australian Rainfall and Runoff 1987, to estimate the peak 100-year water levels along the Turner River.

The model was configured using information obtained from previous modelling studies of the Turner River, and modelling results were compared against the results from the Port Headland Coastal Vulnerability Study (PHCVS) (Cardno, 2011). This report presents the modelled peak 100-year water levels at key locations along the Turner River.

The key objectives of this study and the location within the report where these objectives were addressed are given below.

1. Assess the potential impact to the current hydrology of LandCorp's development as a result of Great Northern Hwy overpass of proposed rail corridor. This is addressed within Section 4.2.7: Drainage strategy for AECOM upstream catchments, and Appendix D of this report. This letter report summarises the drainage strategy options to deal with the large catchment (around 8,100 ha) upstream of the BSIA, south-east of the Great Northern Highway (GNH). These options include transferring runoff from this catchment through the BSIA drainage system or diverting drainage along the side of the GNH before crossing it.
2. Assess the flood risk to LandCorp's development as a result of cuttings, embankments or drainage structures along the proposed railway alignment. This is addressed within Section 4.2.6: Proposed rail corridor in AECOM study of this report. The modelling results indicate that the 100-year peak water level in the Turner River in-line with the proposed rail corridor crossing is approximately 21.5 mAHD, and the Turner River east bank is approximately 34.5 mAHD. Information from AECOM in regards to the current plans for excavation within the rail corridor was not available during this study.
3. Recommend the current level of flood protection that the sand ridge along the waterway offers and assess the impact of sand mining on LandCorp's development. This is addressed within Section 4: Hydraulic Modelling. Based on the modelling results, three options have been proposed for future sand mining:
    i. Use of Turner River east bank for flood protection;
    ii. Construct a levee bank to minimise backwater effects; and
    iii. Excavate sand ridge leaving a bund.

2. Introduction

2.1 Background and context

GHD have been engaged by LandCorp to undertake a Waterways Assessment for the Boodarie Strategic Industrial Area (BSIA). This report outlines hydrologic and hydraulic analysis of the Turner River catchment, to the west of the BSIA, and its implications for the BSIA concept plan.

The Boodarie Strategic Industrial Area (BSIA) is located approximately 12 km south of the Port Hedland townsite and 4 km west of the South Hedland townsite. The 3600 ha area is adjacent to the Great Northern Highway and South West Creek on the east. The development will provide strategic and general / noxious industrial land in the form of large un-serviced lots.

The majority of the BSIA is protected from the Turner River floodway by a sand ridge running north to south within the western boundary of the site. The Turner River is a major floodway with a total catchment area of around 500,000 ha. The sand ridge reaches 31.5 mAHD at Great Northern Highway, south of the BSIA, and drops to a minimum of 10.5 mAHD at the north of the study area.

2.1.1 Previous studies

This waterways assessment was based on a number of previous investigations, including:

- Boodarie Drainage and Flood Management (Jim Davies and Associates, 1995);
- Greater Port Headland Storm Surge Study (Global Environmental Modelling Systems, 2000); and
- Port Hedland Coastal Vulnerability Study (Cardno, 2011).

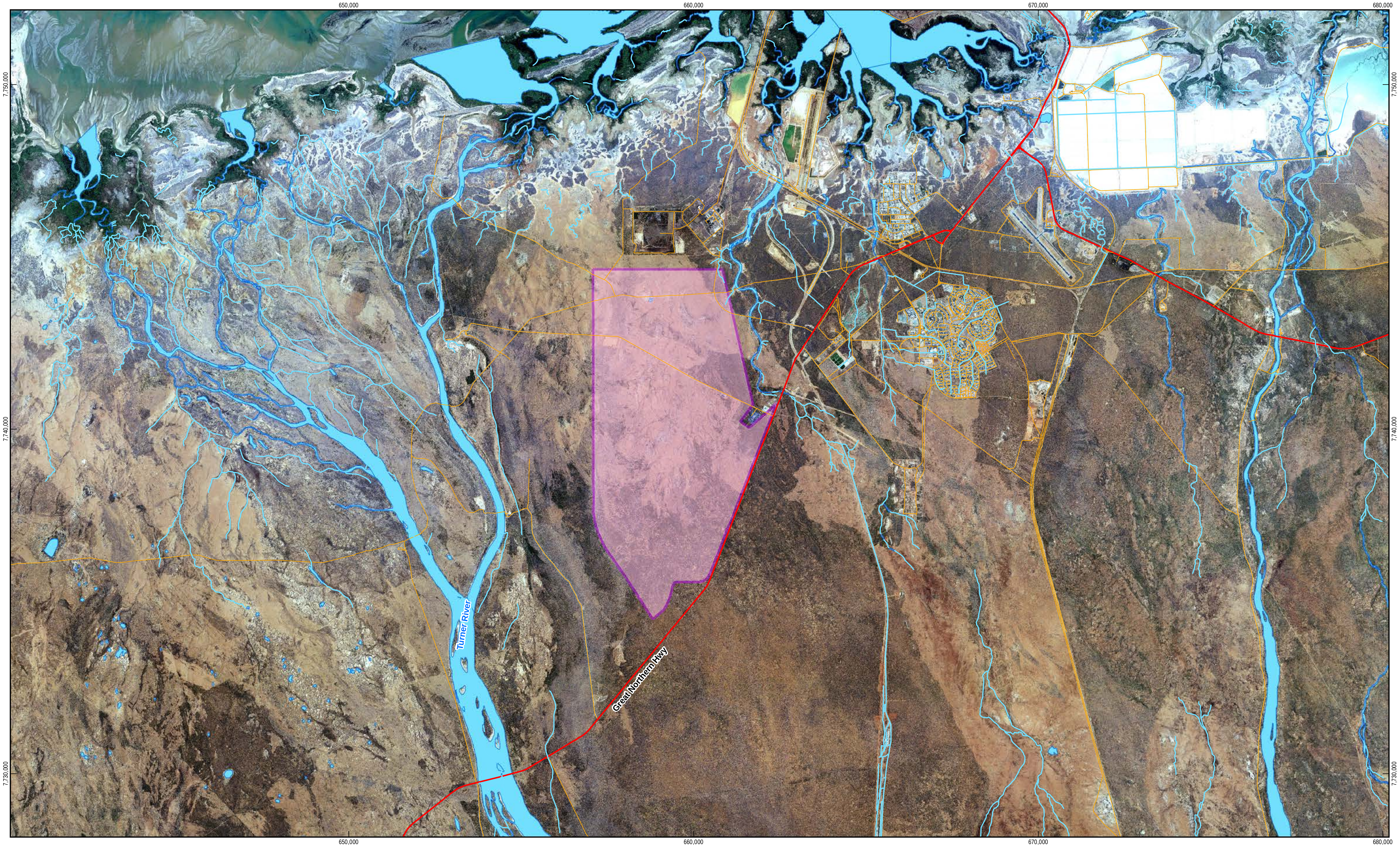
2.2 Scope and purpose

The scope of this study included:

- Identify and map the drainage catchments for the waterways assessment using available topographic maps and existing hydrology data;
- Estimate 100-year Average Recurrence Interval peak flow rates using methods recommended by Australian Rainfall and Runoff 1987.

The purpose of this hydrology study is to:

- Assess potential impact to the current hydrology of LandCorp's development as a result of Great Northern Hwy overpass of proposed rail corridor.
- Assess the flood risk to LandCorp's development as a result of cuttings, embankments or drainage structures along the proposed railway alignment.
- Recommend the current level of flood protection that the sand ridge along the waterway offers and assess the impact of sand mining on LandCorp's development.



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Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

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LEGEND

Roads

- Highway
- LocalRoad
- Hydrology
- BSIA DWMS Study Area

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Location of Study Area

Figure 1

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Data source: Landgate: Hydrology - 20120831, Roads - 20120831, PHTownNov2009 - 20120808; GHD: BSIA DWMS Study Area: 20121206. Created by: cnicol, erice

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3. Site Hydrology

3.1 Previous studies

3.1.1 Boodarie Drainage and Flood Management (Jim Davies and Associates, 1995)

Jim Davies & Associates (JDA) conducted a drainage and flood management study for the proposed Boodarie Resource Processing Estate (referred to in this document as the Boodarie Strategic Industrial Area (BSIA)) in 1995. A component of this study assessed the flooding potential of the Turner River with respect to the BSIA development. The study conducted hydraulic modelling of the Turner River for various ARI events using HEC-2 backwater model. The model was calibrated at the Great Northern Highway Turner River Bridge crossing against the historic flood water levels recorded by Main Roads. JDA (1995) performed a flood frequency analysis on the flood events, and extrapolated the data to estimate the 100-year ARI peak flood level at the crossing (Table 1). The study estimated that the 100-year ARI peak water level at the Great Northern Highway Turner River bridge crossing was within the range of 26.3 to 28.0 mAHD upstream of the crossing, and 25.0 to 6.7 mAHD downstream of the crossing.

Peak flow rate for the Turner River catchment upstream of the Great Northern Highway Turner River bridge crossing was estimated using RORB modelling package. The estimated 100-year ARI peak flow rate is 20,200 m^3/s. However, the study noted that the 100-year ARI peak flow estimate is subject to uncertainty, and the confidence interval could well be in excess of ± 50%.

Table 1 Flood frequency analysis for the Turner River Bridge crossing (JDA, 1995)

Year	Estimated flood frequency (Years)	Turner River – upstream of the bridge	Turner River – downstream of the bridge
1973	4	23.36	23.02
1975	6	24.40	24.03
1980	9	26.02	24.84
1988	25	26.17	24.84
Extrapolated 100-year ARI event	100	26.3 to 28.0	25.0 to 26.7

3.1.2 Greater Port Headland Storm Surge Study (Global Environmental Modelling Systems, 2000)

Global Environmental Modelling Systems (GEMS) conducted a storm surge study for the greater Port Headland region in 2000. As part of this study, hydraulic modelling was conducted for the Turner River catchment (upstream of the Great Northern Highway bridge crossing), and the peak flow rate for various ARI's were estimated using the revised index flood method, summarised below in Table 2.

Table 2 Greater Port Headland Storm Surge Summary - Design flood estimates (m^3/s) (GEMS, 2000)

ARIs	2	5	10	20	50	100
Turner River catchment	630	1329	2146	2289	6160	9732

3.1.3 Port Headland Coastal Vulnerability Study (Cardno, 2011)

Cardno conducted a coastal vulnerability study for Port Headland in 2011, to evaluate the combined effects of coastal inundation (flooding and storm surge). The study area includes the east branch of the Turner River, downstream on the river divergence (approximately 5 km downstream of the bridge crossing) and extends to the Port Headland coast line. The study conducted hydrologic assessment of the extreme rainfall events to determine the design flows for rivers for the nominated return periods, and hydraulic modelling of the combined effects of storm surge inundation from the sea and flooding from the land through a coupled hydrodynamic and coastal model system.

Table 3 Design storm events for the Turner River boundary condition (5km downstream of the bridge crossing) (Cardon, 2011)

ARI storm event	2 year	10 year	100 year
Critical storm duration (hour)	36	36	12
Peak flow (m^3/s)	263	2,793	9,485
Discharge volume (GL)	31.2	314.6	655.9

The study estimated that peak total still water level (TSWL) at Shellborough for various ARI events at the current (2010) levels based on Published Tidal Constituents (AHO, 2009). Peak TSWL exclude additional factors such as non-cyclonic residual water level and shoreline wave setup. The study also estimated the peak water level based on the future 2110 climate scenario, which includes an increase in the mean sea level of +0.9 m.

The study noted that there is no discernible relationship between rainfall and water level joint occurrence, where large ocean storm surge events tended not to be associated with peak catchment responses. However, the study recommends a conservative modelling approach, using a joint occurrence model for the design event simulation where the 20-year ARI ocean water level should be simulated in-conjunction with the 100-year ARI catchment flows (Cardno, 2011).

Table 4 Design Peak Total Still Water Level (TSWL) for Shellborough for the 2110 climate scenario (Cardno, 2011)

ARI (years)	Peak TSWL at 2010 (mAHD)	Peak TSWL at 2110 (mAHD)
2	3.9	4.8
10	4.7	5.6
20	5.1	6.0
50	5.3	6.2
100	5.9	6.8

The 100-year ARI peak flood level contours for the future climate conditions (at 2110) generated in this study were sourced from the Department of Water (2012) and displayed in Appendix A.

3.2 Design flood hydrographs

3.2.1 Catchment

The Department of Water hydrographic sub-catchments was used to define drainage catchment for the Turner River, upstream of the Great Northern Highway. The total catchment area for the Turner River is 3097 km^2, the main stream path length is 116 km, with an average slope of 2.05 m/km.

Table 5 Catchment properties

Catchment description	Area (km^2)	Stream length (km)	Average slope (m/km)
Turner River (upstream of Great Northern Highway)	3097	116	2.05

3.2.2 Design rainfall

The Turner River catchment is located near Port Headland in the Pilbara region of Western Australia. The region experiences an arid to semi-arid climate with hot, humid summers and warm dry winters. Rainfall is low throughout the year and is quite variable; annual totals vary from 250 mm to 450 mm, with the average annual rainfall of 328.1 mm at the Indee gauging station (004016), located within the Turner River catchment, approximately 30 km upstream of the Great Northern Highway (Bureau of Meteorology, 2012). Summer rains are a result of scattered thunderstorms and occasional tropical cyclones. Winter rains may be caused by tropical could bands.

The intensity frequency duration (IFD) rainfall data used to generate rainfall hydrographs for the design storm events was sourced from the Bureau of Meteorology IFD program, in accordance with AR&R (1987), at the Turner River Great Northern Highway bridge crossing (coordinates: 20.525 latitude, 118.475 longitude).

3.2.3 Design flood events

Peak flows for the Turner River catchment were estimated for various average recurrence interval (ARI) design events (10-, 20-, 50- and 100-years) using the rational method and the index flood method for the north-west Pilbara region for loamy soils, as recommended by AR&R

(1987). The estimated peak flows (m^3/s) for various ARIs are summarised in Table 6. AR&R (1987) provides an index flood method relationship up to the 50-year ARI event; therefore the 100-year peak flow rate was not estimated using this method. The peak flow rate for the various return periods are within the typical range estimated in the previous studies (discussed in Section 3.1).

Table 6 Peak flows (m^3/s) for the Turner River catchment (upstream of Great Northern highway) for various ARIs

ARI (years)	2	5	10	20	50	100
Turner River - rational method	525	1269	2479	5164	9899	11907
Turner River - index flood method	591	1244	2454	4763	10408	N/A

4. Hydraulic modelling

4.1 Model configuration

A two-dimensional hydraulic model of the Turner River catchment was configured using the Mike Flood modelling package. The Mike 21 model coupled with a one-dimensional hydraulic model of the Turner River Mike 11 Hydrodynamic (HD) modelling package using Mike Flood. The Mike 21 model simulates the two-dimensional overland flow pathways, while the Mike 11 simulates the one-dimension flow along the river centreline through the use of representative cross-sections.

Cross-sections in the Mike 11 model were generated along the Turner River using the digital elevation model, built from two data sources:

- SRTM 30m grid data – Geoscience Australia (October 2011); and
- 5 m LiDAR grid data – LandCorp.

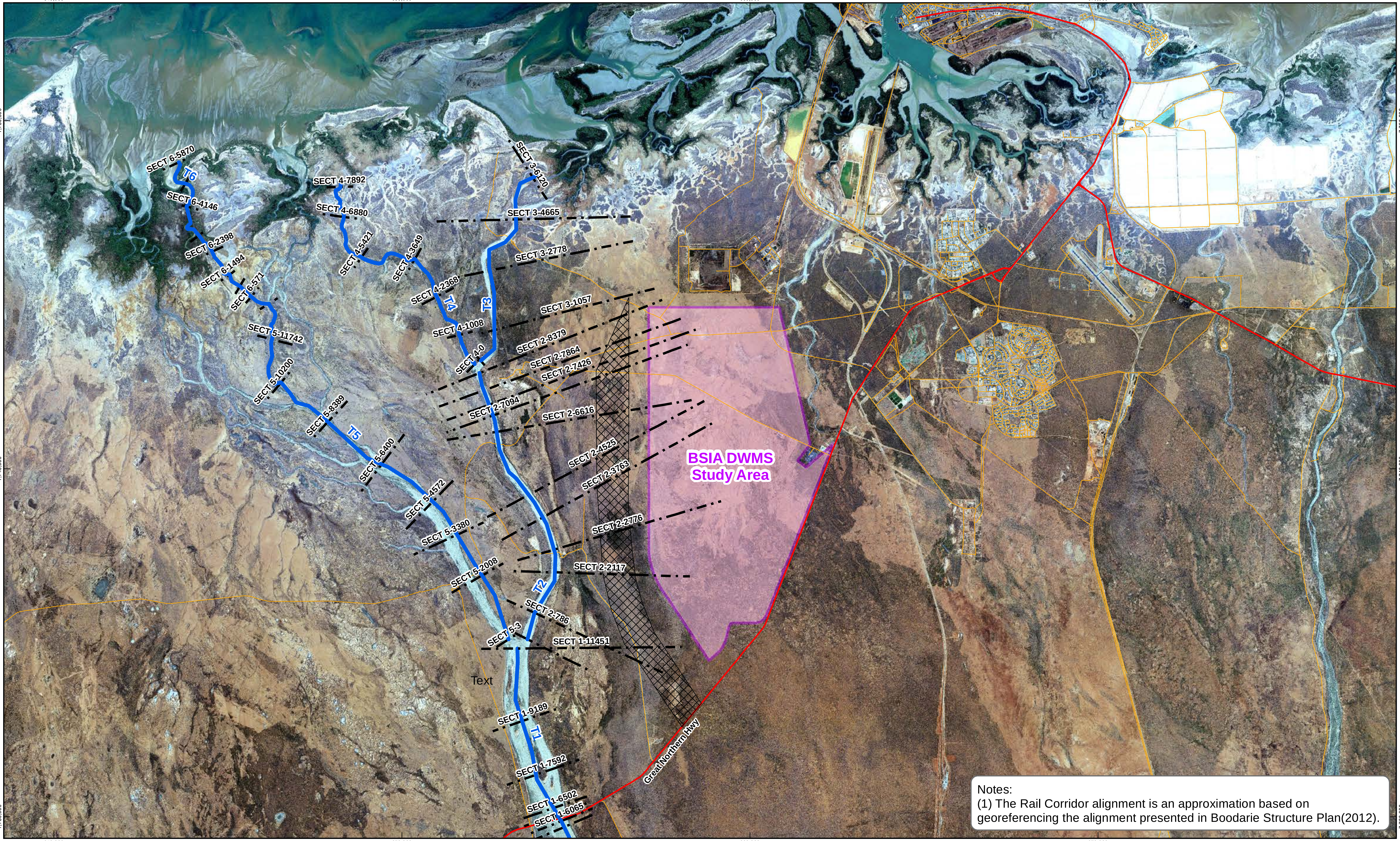
Cross-sections were spaced to capture the major changes in the channel shape and the hydraulic gradient, and were also located at key points of interest along the Turner River including the BJ Young proposed sand mining location, and the proposed BHP railway line. A uniform channel roughness coefficient of 0.0616 (Mannings ‘n’) was applied along the channel, which represents a moderately vegetated channel, consistent with the roughness coefficient used in the Port Headland Coastal Vulnerability Study (Cardno, 2011). The Great Northern Highway Turner River bridge crossing was included in the Mike 11 model as a bridge structure.

The Mike 21 model grid was generated for the Turner River catchment using the digital elevation model, with a 20 m model grid.

The model was configured to ensure that suitable boundary conditions could be generated, and extends 5 km upstream of the Great Northern Highway Turner River bridge crossing, and extends to the coast. The Mike11 network is displayed in Figure 2.

The peak flow rate calculated for the Turner River catchment (upstream of the Great Northern Highway) for the various return periods (discussed in Section 3.2.3) was used as the upstream boundary condition.

The downstream boundary is controlled by the peak tide water level. The design water level for the 20-year ARI event from the Port Headland Coastal Vulnerability Study (Cardno, 2011) accounting for climate change (presented as the 2110 peak water level) was used as the downstream boundary condition (6 mAHD). As discussed in Section 3.1.3, the study recommended that the 20-year ARI peak ocean water level be used as the downstream boundary condition when modelling the 100-year ARI hydraulic catchment, based upon a joint probability approach (Cardno, 2011). The Mike Flood model was simulated in the steady-state.



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LEGEND

Roads

- Highway
- LocalRoad
- Mike 11 Rivers
- Mike 11 Cross-sections
- Rail Corridor
- BSIA DWMS Study Area

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Flood Study

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Model Configuration

Figure 2

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Data source: Data source: Landgate: Roads - 20120831, PHTownNov2009 - 20120808; GHD: BSIA DWMS Study Area: 20121206, Mike 11 Rivers - 2012012, Mike 11 Cross-sections - 201201, Rail Corridor - 2013 (based on georeferencing rail corridor in the Boodarie Structure Plan (2012)). Created by: adrummond, erice

4.2 Results

4.2.1 Estimated 100 year flood levels

The hydraulic model was used to estimate the peak water levels that can be expected for a 100-year ARI to evaluate the sand-mining profile adjacent to the Boodarie Strategic Industrial Area to maintain or improve the current level of flood protection.

The 100-year peak water level at Turner River was extracted for eight cross-sections (SECT 1 - 11451, SECT 2 - 2117, SECT 2 -2776, SECT 2 -3763, SECT 2 - 4525, SECT 2 - 6616, SECT 2 -7094 and SECT 2 -7426) which are in-line with the potential sand resource (cross-section locations shown in Figure 2 and Figure 4). It is noted that cross-section SECT 2 - 6616 is in-line with the area identified as being a potential area for new B.J Young mining lease. The B.J Young mining lease application letter is provided in Appendix C.

Table 7 summarises the modelling results for the 100-year ARI peak water level along the Turner River at the key cross-sections, as well as the levels estimated along the Turner River and adjacent to the sand ridge from the Port Headland Coastal Vulnerability Study (PHCVS) (Cardno, 2011) which are shown in Appendix A. Key cross-sections are provided in Appendix B, which indicate the 100-year peak water level, and the Turner River banks.

Table 7 100-year ARI preliminary peak water level at proposed sand mining location

Mike 11 Cross Section	Mike 11 – at the Turner River (mAHD)	PHCVS – at the Turner River (mAHD)	PHCVS peak water – adjacent to the sand ridge (mAHD)	Mined Sand ridge elevation (mAHD)
SECT 1 – 11451	21.5	N/A(2)	-	24.0 - 27.3
SECT 2 - 2117	19.9	19.75	-	22.7 – 24.1
SECT 2 - 2776	19.0	19.00	-	19.1 – 23.0
SECT 2 – 3763	17.8	18.0	13.25	15.3 – 20.9
SECT 2 - 4525	16.7	16.75	13.0	15.5 – 18.7
SECT 2 - 6616	13.3	13.5	12.75	13.0 – 16.0
SECT 2 – 7094	12.7	13.0	9.75	12.9 – 16.3
SECT 2 – 7426	12.3	12.5	9.5	11.9 – 15.8

Notes – (1) Flood water is due to back water effects, and is located between the east Turner River flood plain bank and the sand ridge. - No flooding at these locations. (2) Outside the PHCVS study area

Figure 4 presents the 100-year peak flood level within the Turner River estimated from the Mike11 model for key cross-sections, in-line with the BSIA DWMS western boundary. The modelling results indicate that the 100-year peak water levels along the Turner River at all cross sections are contained within the Turner River banks, and are also within the corresponding sand ridge elevation ranges. Figure 4 provides an indication of the Turner River east bank, based on the PHCVS 100-year flood extent (Appendix A). The peak water levels ranged from 21.5 mAHD at the upstream cross-section SECT 1 - 11451, to 12.3 mAHD at downstream cross-section SECT 2 - 7426, and these results are consistent with the PHCVS estimates along the Turner River (Cardno, 2011).

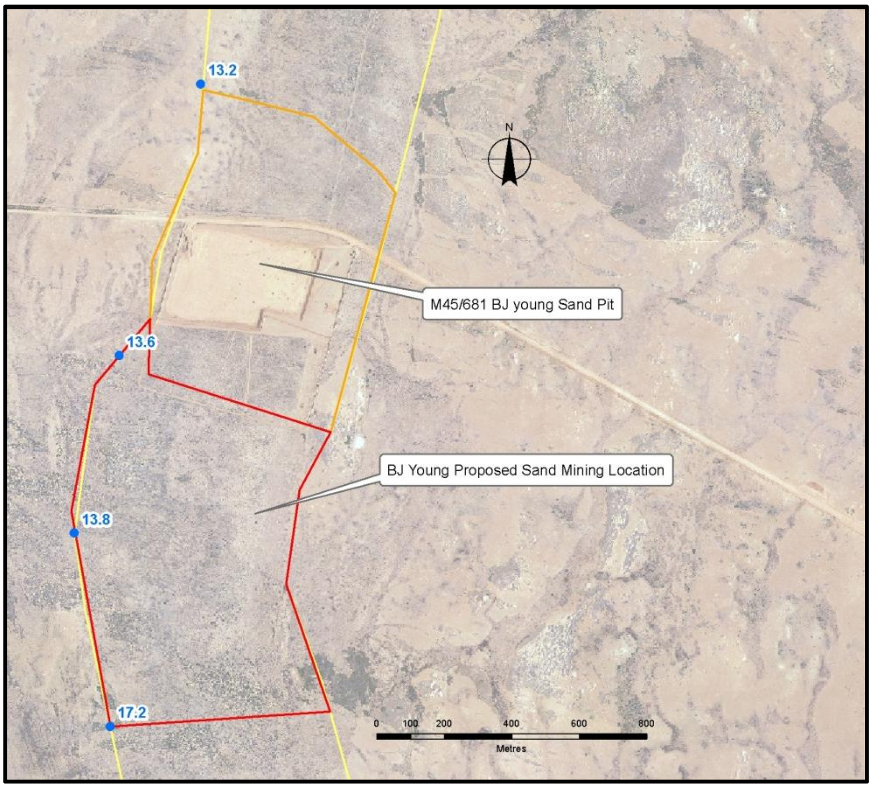
Appendix A shows the extent of predicted flooding simulated by the PHCVS adjacent to the mined sand ridge, provided by to GHD by the Department of Water (2012). A second figure is provided in Appendix A showing the PHCVS flood map overlain with the Mike11 cross-sections, river alignment, rail corridor and proposed sand mining areas to allow for easy visual interpretation of model results between the two studies. The two-dimensionally modelling results from the PHCVS (Cardno, 2011) indicate in the event of a 100-year flood, flood waters will inundate the low-lying valley between the Turner River east bank flood and the mined sand ridge, at locations downstream of cross section SECT 2- 3763. Modelled results of the 100-year peak water levels adjacent to the sand ridge are contained within the sand ridge elevations.

4.2.2 Flood levels at BJ Young proposed sand mining locations

Figure 4 presents the 100-year peak flood level within the Turner River estimated from the Mike11 model for key cross-sections, at the boundary of the 100-year flood plain (marked up from the PHCVS). The modelling results indicated that the 100-year ARI peak water level within the Turner River ranges from 16.7 mAHD (SECT 2 – 4525) on the south corner of the proposed sand mining area to 13.30 mAHD (SECT 2 – 6616) in the middle of the proposed sand mining area . This is consistent with the Port Headland Coastal Vulnerability Study (PHCVS) (Cardno, 2011) estimates of 16.75 mAHD and 13.5 mAHD (respectively) within the Turner River at these locations.

It should be noted that while the east bank of the Turner River contains the 100-year ARI flood waters at these locations, backwater effect results in the downstream flood waters inundating the low-lying valley between the Turner River flood plain east bank and the sand ridge (shown in Figure 4). While the PHCVS indicates that the 100-year peak water level adjacent to the proposed sand mining location area is 12.75 mAHD (Appendix A), it is recommended that the peak water levels within the Turner River of 16.7 mAHD (in the south), 13.3 mAHD (in the middle), and interpolated value of 13.1 mAHD (in the north) are adopted, providing a conservative approach. Therefore, it is advised that the western side of the sand ridge maintain a height of at least the values (100 year flood level and 500 mm free board) shown in Figure 3. It is advised that the eastern side of the sand ridge maintain the same heights as western side at this stage.

Figure 3 BJ Young proposed sand mining site 100 year flood levels with 500 mm free board



4.2.3 Use of Turner River east bank for flood protection

The 100-year flood extent (presented in Figure 4), indicates that there is no flood risk between the Turner River east bank and the sand ridge upstream of cross section SECT 2 – 3763. The existing elevation upstream of the SECT 2 – 3763 of Turner River east bank is above the 100 year flood level. Therefore, there is potential to mine the sand ridge upstream of SECT 2 – 3763 ensuring that the Turner River east bank and elevation between two ridges at SECT 2 – 3763 maintains at least 500 mm freeboard above the peak 100-year flood levels (shown on Figure 4). However, from a drainage point of view it is advisable to use elevation 18.3 mAHD, which is the 100-year flood level and 500 mm freeboard at SECT 2 – 3763, crossing the sand ridge and grade the sand ridge in upstream direction to a reasonable slope.

If Turner River east bank is reduced below the 100-year flood level, it is advisable to leave a bund as discussed in Section 4.2.5.

4.2.4 Construct a levee bank (See Figure 4) to minimise backwater effects

Another option to allow for mining of the sand ridge is to construct a levee, creating a barrier, and eliminating the flood backwaters which would otherwise have inundated the low lying valley between the sand ridge and Turner River east bank (second ridge). Constructing a levee between the two ridges in line with cross section SECT 2 - 7426 could allow for the sand ridge to be mined subjected to internal BSIA drainage hydraulic levels without increasing the potential flood risk to the BSIA from Turner River. The minimum height for the downstream levee barrier is 12.8 mAHD, which based on is the peak water level in the Turner River at the proposed location (12.3 mAHD) and at least a 500mm freeboard). This option would require further study on diverting local drainage, possibly to South West Creek, but will also require access through BHP's lease area which could be problematic.

4.2.5 Excavation of sand ridge leaving a bund

As discussed in Section 3.3.1, despite options for dropping the potential excavation level, it is advised that the mined sand ridge excavation level not exceed the Mike 11 peak flood level and 500 mm freeboard. In order to maintain the current level of flood protection to the BSIA, the sand ridge can be construction into a bund, enabling some excavation and sand mining. It is advised that the sand ridge bund be constructed to a height consistent with previously advised Mike 11 peak flood level and 500mm freeboard. This would vary from 21.9 mAHD at the corresponding upstream cross-section SECT 1 - 11451 to 12.8 mAHD at corresponding cross section SECT 2 - 7426. Given that the lease area is approximately 600 m to 800 m wide (east to west), a notional bund width of between 30 – 50 m should be left on the western side, leaving the eastern portion to be excavated. However, it is advised that a geotechnical assessment be conducted to consider the structural design, including width of bund. A geotechnical assessment will also consider the geotechnical aspects of the bund, including accounting for potential post flood seepage issues.

A bund is not required upstream of section SECT 2 – 3763 if the Turner River east bank maintains at least 500 mm freeboard above the peak 100-year flood levels (indicated on Figure 4).

4.2.6 Proposed rail corridor in AECOM study

Figure 2 and Figure 4 indicate the location of proposed rail corridor in the vicinity of the BSIA study area. It is noted that the exact rail alignment was not provided to GHD during this study. The rail alignment presented in Figure 2 and Figure 4 is an approximation based on spatially referencing the rail corridor presented in the Boodarie Structure Plan (Dec. 2012).

The rail corridor crosses the sand ridge and the Turner River east bank just downstream of the Great Northern Highway, approximately in-line with cross-sections SECT 1 - 11451.. The modelling results indicate that the 100-year ARI peak flood level at this location in the Turner River is approximately 21.5 mAHD, and the Turner River east bank is approximately 34.5 mAHD. Information from AECOM in regards to the current plans for excavation within the rail corridor was not available during this study. At the present time it can only be indicated from the modelling results that if the rail corridor does not excavate the Turner River east bank below 22.0 mAHD (peak flood level and 500 mm freeboard), then the rail crossing should not increase the current risk of flooding to the BSIA at this location.

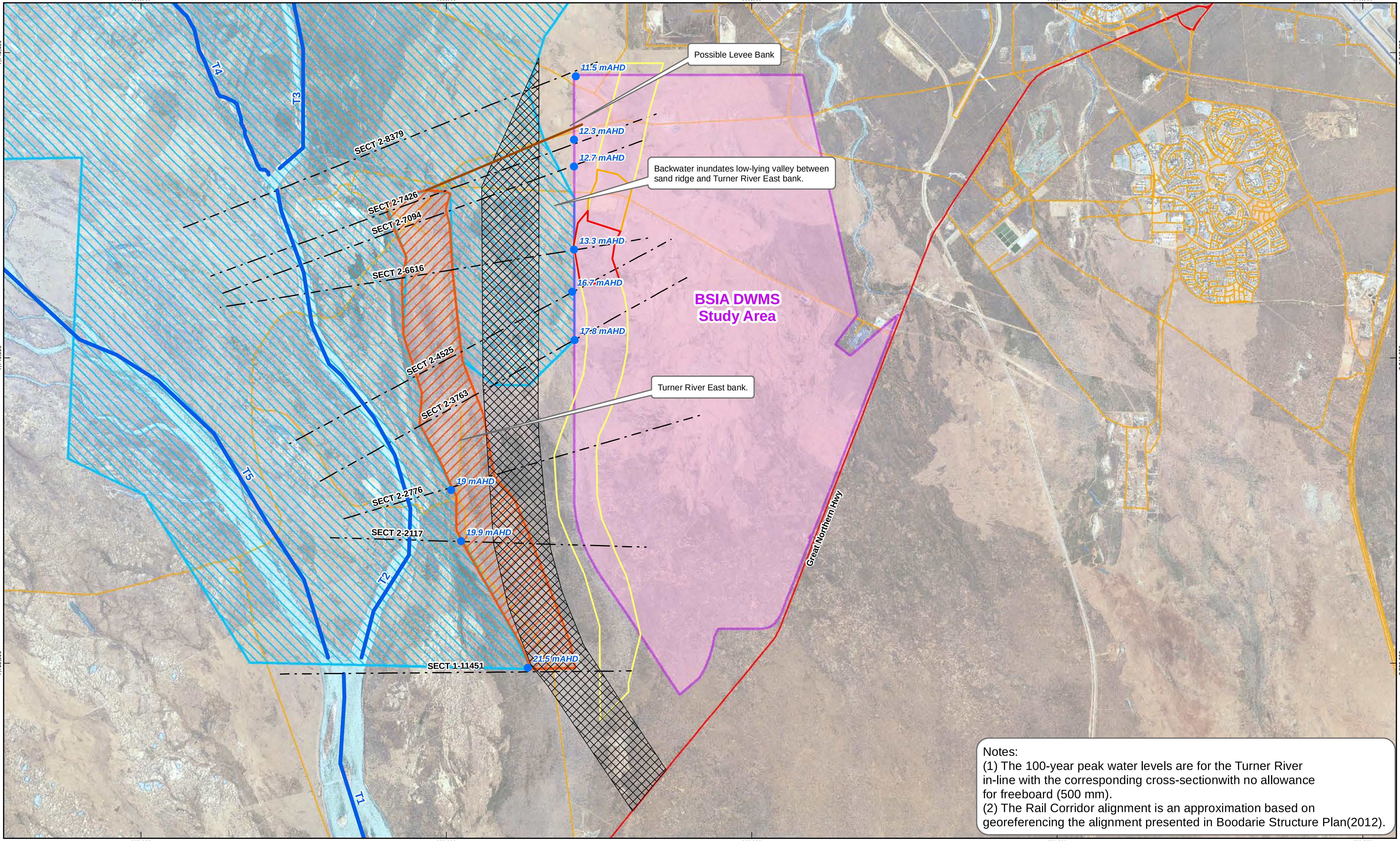
It is noted that the proposed rail corridor is located within the Turner River 100-year flood plain. Therefore, it is anticipated that the construction of the rail corridor will require an embankment, which would provide additional protection the BSIA DWMS area, and could potentially allow for additional sand mining to be conducted.

4.2.7 Drainage strategy for AECOM upstream catchments

Appendix D provides a letter (dated 19th February 2013) assessing the potential impact to the current hydrology of LandCorp's development as a result of Great Northern Highway overpass of the proposed rail corridor. The letter report summarises the drainage strategy options to deal with the large catchment (around 8,100 ha) upstream of the BSIA, south-east of the Great Northern Highway (GNH). Runoff from this catchment can be transferred through the BSIA and accommodated within the BSIA drainage system or it can be cut off before crossing GNH and diverted along the side of the highway. Four options have been proposed:

1. Option 1 – open drain along eastern side of Great Northern Highway (design proposed in the DWMS);
2. Option 2 – Open drain along BSIA services corridor and smaller open drain along Great Northern highway;
3. Option 3 – Open drain along BSIA services corridor only; and
4. Option 4 – Culverts return upstream flows to eastern side of Great Northern Highway

Refer to Appendix D for full details.



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Grid: GDA 1994 MGA Zone 50

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LEGEND

- Mike 11 Peak 100-year water level
- Mike 11 Rivers
- Mike 11 Cross-sections
- Possible Levee Bank

Roads
- Highway
- Local Road

BJ Young Sand Mining
- Potential Sand Resource
- M45/681 BJ Young Sand Pit
- Potential Area for new mining lease

- BSIA DWMS Study Area
- PHCVS 100-year Flood Extent
- Rail Corridor
- Turner River East Bank

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Flood Study

Job Number	61-2617100
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Peak 100-year Flood Levels in Turner River

Figure 4

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Data source: Data source: Landgate: Hydrology - 20120831, Roads - 20120831, PHTownNov2009 - 20120808; BJ Young Sand Mining - 20120220; GHD: BSIA DWMS Study Area: 20121206, Possible Levee Bank - 20130322, Mike 11 Rivers - 201201, Mike 11 Cross-sections - 201201, Rail Corridor - 2013 (based on georeferencing rail corridor in the Boodarie Structure Plan (2012)) Created by: ngamage, erice

5. Conclusions and recommendations

A two-dimensional Mike 21 flood model coupled with a one-dimensional Mike 11 hydrodynamic model was generated for the Turner River catchment to simulate the peak flood levels for the 100-year ARI event. The model was configured using information obtained from previous modelling studies of the Turner River, and modelling results were compared against the results from the Port Headland Coastal Vulnerability Study (PHCVS) (Cardno, 2011).

The modelling results were used in conjunction with results presented in the PHCVS to evaluate the potential for additional sand mining along the sand ridge adjacent to the Boodarie Strategic Industrial Area (BSIA), whilst maintaining the current level of flood protection. The 100-year ARI peak water levels were extracted from the model for eight cross-section locations in-line with the proposed sand ridge mining area.

The modelling results indicated that the 100-year peak water level is contained within the banks of the Turner River upstream of SECT 2 – 3763. It is advised that the mined sand ridge excavation level not exceed the Modelled peak flood level and 500mm freeboard in order to maintain the BSIA study area flood risk. Backwater effect results in the downstream flood waters inundating the low-lying valley between the Turner River flood plain east bank and the sand ridge.

The modelling results indicated that in the event of a 100-year flood, a backwater effect results in the downstream flood waters inundating the low-lying valley between the Turner River flood plain east bank and the sand ridge, downstream of cross section SECT 2 – 3763. Based on the modelling results, three options have been proposed for future sand mining:

1. **Use of Turner River east bank for future flood protection –** There is potential to use the Turner River east bank for flood protection upstream of SECT 2 – 3763. Therefore, the sand ridge can be mined subject to internal BSIA drainage hydraulic levels, as long as the Turner River east bank remains above the 100-year peak flood level (plus 500 mm freeboard).
2. **Construct a levee bank to minimise backwater effects** – Construct a levee between the two ridges in line with cross-section SECT 2 - 7426 eliminating the flood backwaters which would otherwise have inundated the low lying valley between the sand ridges. This would allow for the sand ridge to be mined subject to internal BSIA drainage hydraulic levels, without increasing the potential flood risk to the BSIA from Turner River.
3. **Excavate sand ridge leaving a bund -** In order to maintain the current level of flood protection to the BSIA, the sand ridge can be construction into a bund, enabling some excavation and sand mining. It is advised that the sand ridge bund be constructed to a height consistent with previously advised Mike 11 peak flood level and 500mm freeboard. It is recommended that a geotechnical assessment be conducted to consider the structural design, including width of bund and accounting for potential post flood seepage issues.

The modelling study also investigated the potential flood impact of the proposed rail corridor in the vicinity of the BSIA study area. The modelling results indicate that the 100-year peak water level in the Turner River in-line with the proposed rail corridor crossing is approximately 21.5 mAHD, and the Turner River east bank is approximately 34.5 mAHD. Information from AECOM in regards to the current plans for excavation within the rail corridor was not available during this study. At the present time it can only be indicated from the modelling results that if the rail corridor does not excavate the Turner River east bank below 22.0 mAHD (peak flood level and 500 mm freeboard), then the rail crossing should not increase the current risk of flooding to the BSIA at this location.

6. References

Cardno (2011) *Port Headland Coastal Vulnerability Study final Report,* Prepared for: LandCorp. Report number: Rep1022p.

Jim Davies & Associates (JDA) (1995) *Boodarie Resource Processing Estate Drinage and Flood Management,* Prepared for: Department of Resource Development and LandCorp. Reference number: J244L.

Global Environmental modelling Systems (GEMS) (2000) *Greater Port Headland Storm-surge Study,* Prepared for: WA ministry for Planning and Port Headland Town Council.

AECOM (2012) *Great Northern Highway Over Haul Road at Boodarie – Preliminary (15%) Road Design Report,* Prepared for: Atlas Iron Ltd. Reference number: 60190692-RD-021B.

The Institute of Engineers, Australia (1987) *Australian Rainfall and runoff – A Guide to Flood Estimation Volume 1.*

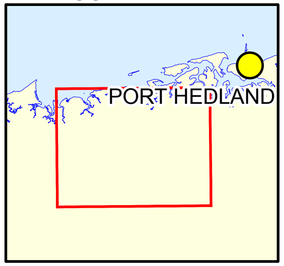
Appendices

Appendix A Port Headland Coastal Vulnerability Study 100-year ARI flood levels (provided by Department of Water, 2012)

Turner River

Port Hedland area

LOCALITY MAP



LEGEND

- Focus area
- Boodarie Industrial Estate
- 100 yr ARI flood levels (m AHD)
- 100 yr ARI floodplain
- Cadastre
- Road Centrelines, DLI

N

0 0.5 1 2 3
Kilometres

Datum and Projection Information
Vertical Datum: Australian Height Datum (AHD71)
Horizontal Datum: GDA94 MGAz50
Projection: Universal Traverse Mercator (UTM)
Spheroid: Geodetic Reference System (GRS80)

Project Information
Client:
Map Author: Toni Smythe
Task ID: B1305
Compilation date: 14/09/2012
Edition: Version 1

SOURCES

The Department of Water acknowledges the following datasets and their custodians in the production of this map:

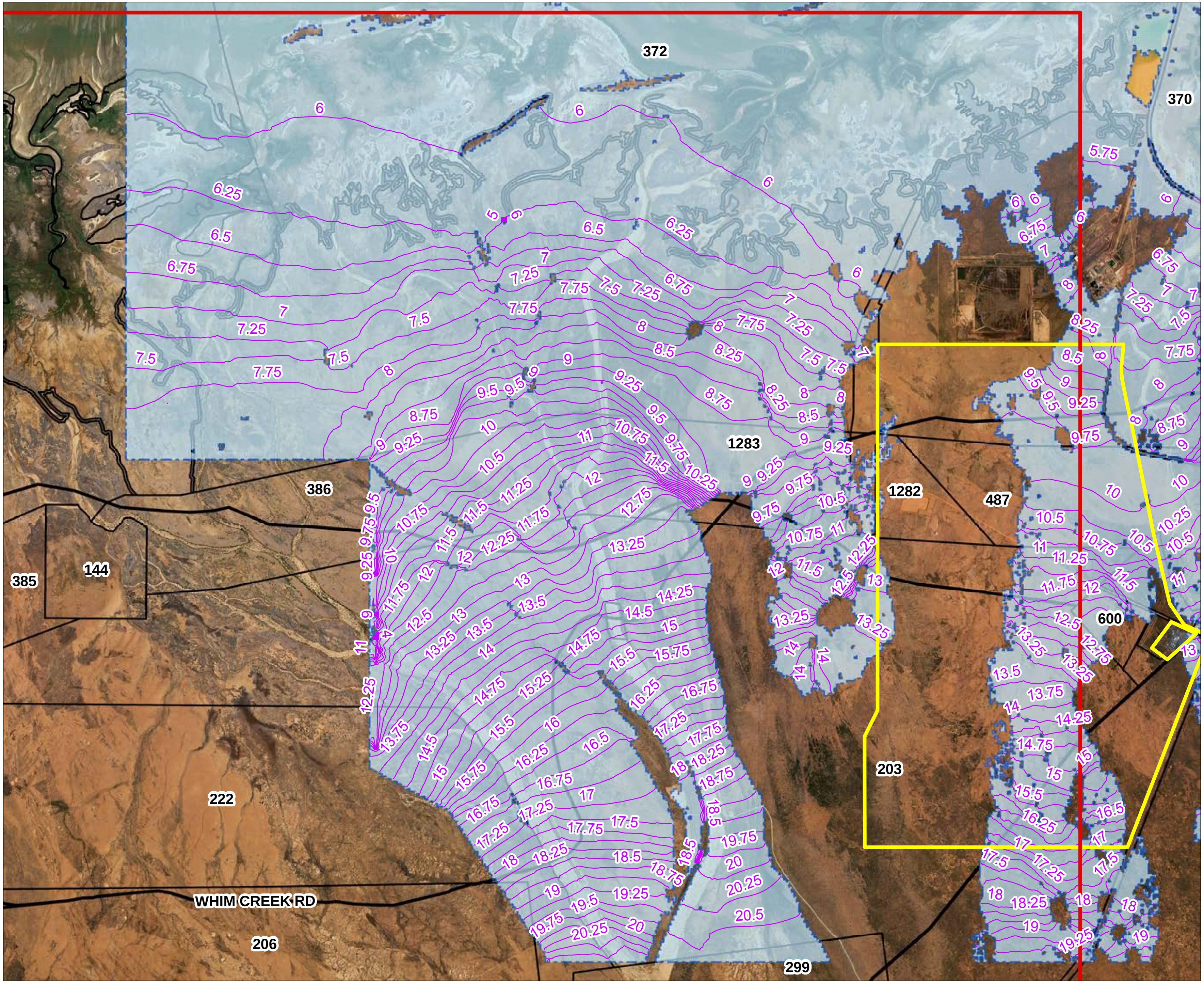
Spatial Cadastral Database - Landgate – 30/04/2012
Road Centrelines, DLI - Landgate - 13/01/2010
Western Australian Towns - Landgate - 12/07/2001

Government of Western Australia
Department of Water

This map is a product of the Department of Water, Assessment & Allocation and was printed on 14/09/2012.

This map was produced with the intent that it be used for display purposes.

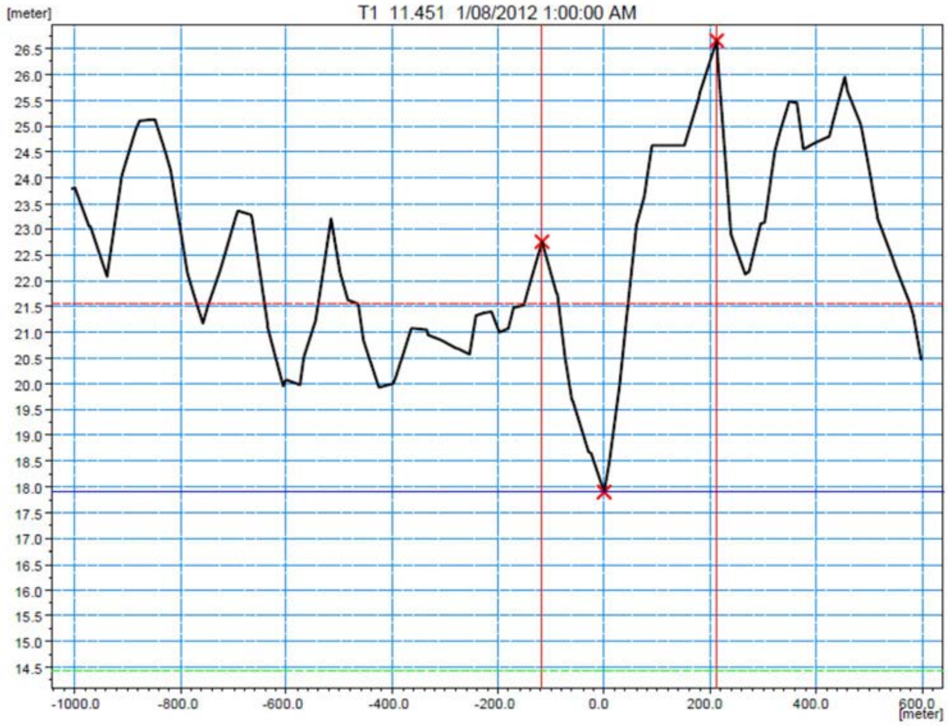
While the Department of Water has made all reasonable efforts to ensure the accuracy of this data, the department accepts no responsibility for any inaccuracies and persons relying on this data do so at their own risk.



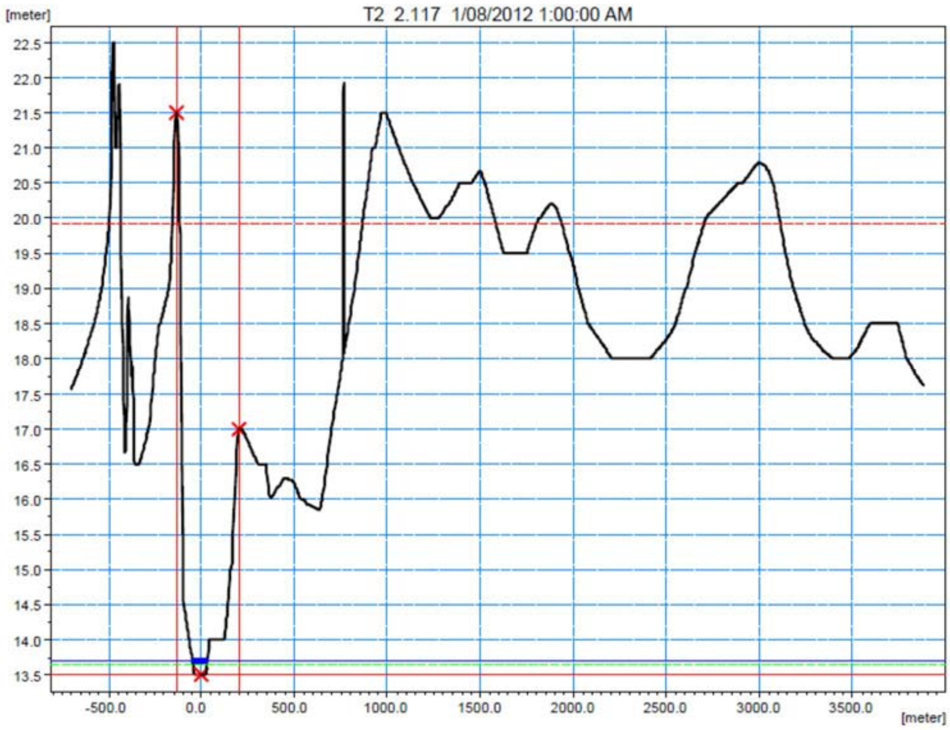
Path: J:\gisprojects\Project\B_Series\B1305\0001_FPM_Enquires\mxd\Port Hedland\FPM Boodarie SIA DWMS South Hedland eng v2.mxd

Appendix B Mike11 Cross-sections

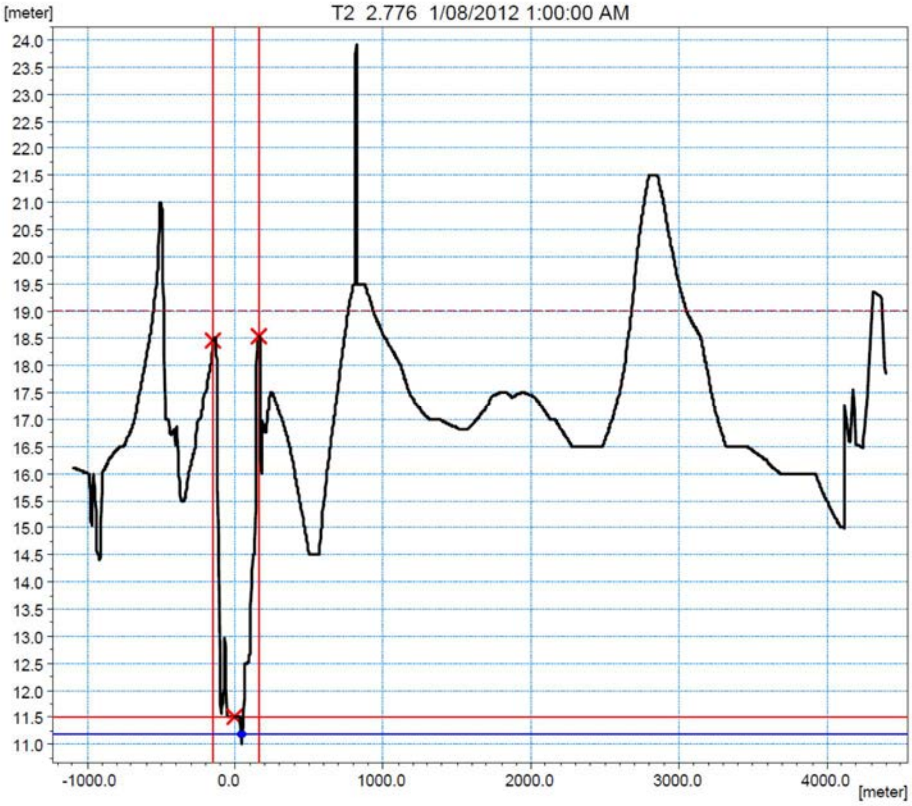
Cross-section SECT1-11451 100-year ARI peak water level 21.5 mAHD



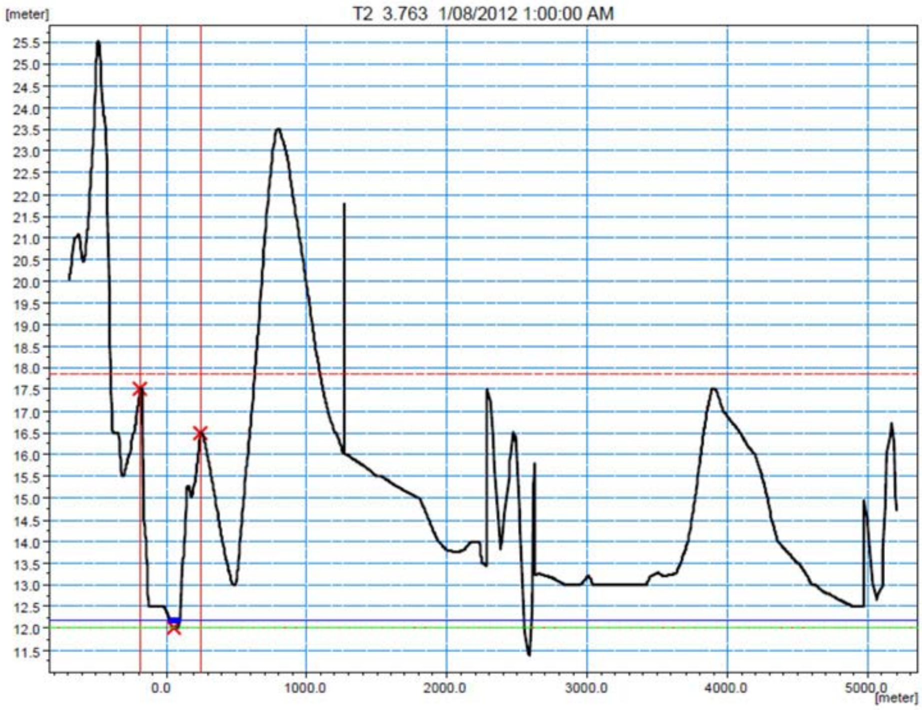
Cross-section SECT2-2117 100-year ARI peak water level 19.9 mAHD



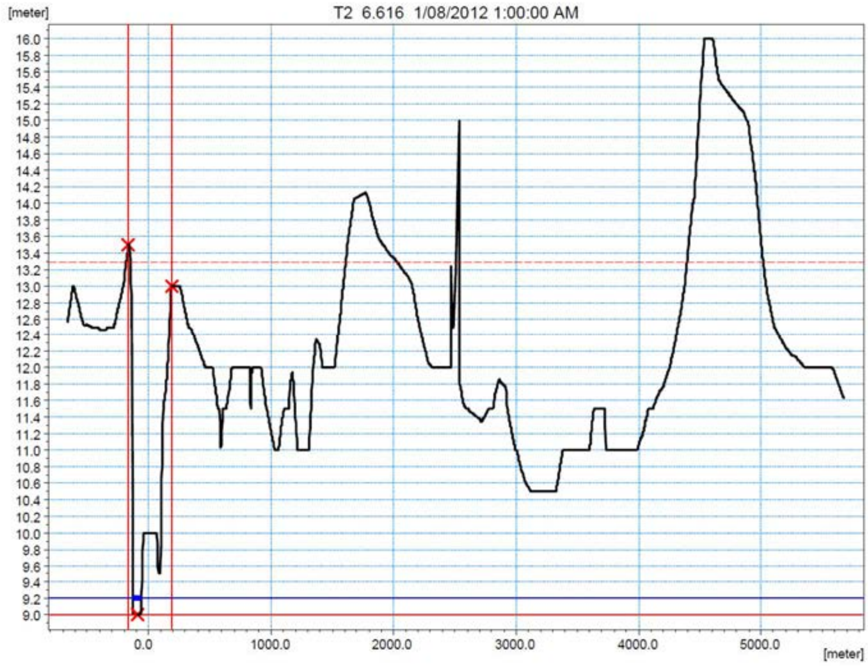
Cross-section SECT2-2776 100-year ARI peak water level 19.0 mAHD



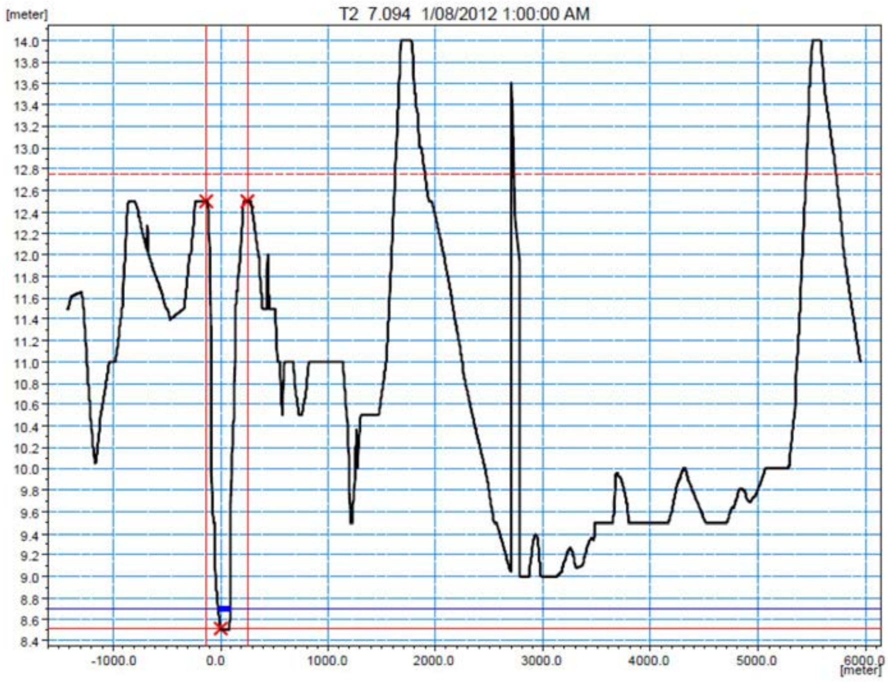
Cross-section SECT2-3763 100-year ARI peak water level 17.8 mAHD



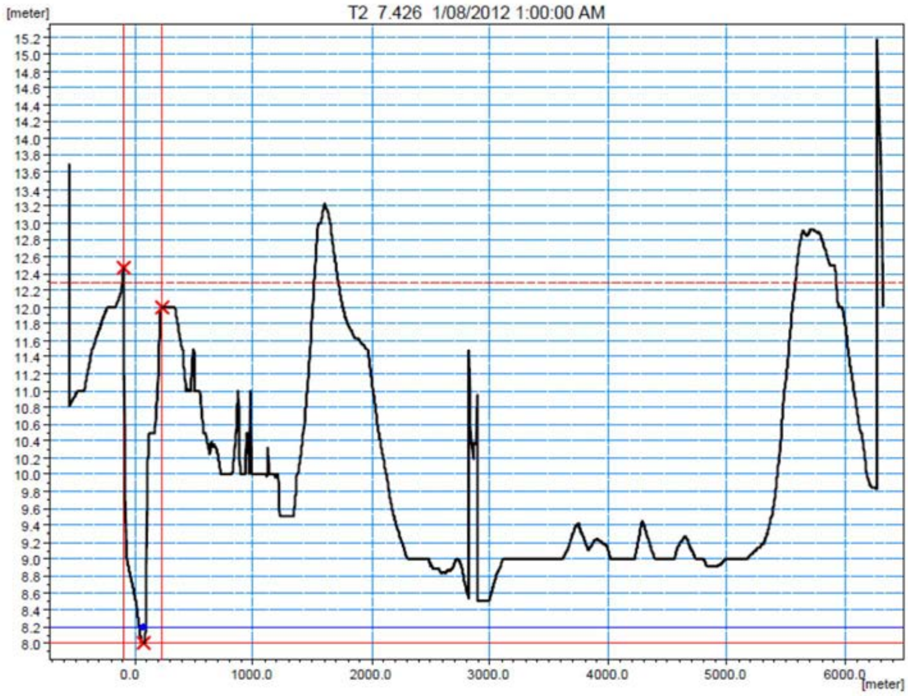
Cross-section SECT2-6616 100-year ARI peak water level 13.3 mAHD



Cross-section SECT2-7094 100-year ARI peak water level 12.8 mAHD



Cross-section SECT2-7426 100-year ARI peak water level 12.3 mAHD



Appendix C BJ Young Lease Application

BJ YOUNG EARTHMOVING

BJ Young Earthmoving Pty Ltd
ACN: 060 550 067
ABN: 37 117 511 891
PO Box 288
Port Hedland WA 6721
Telephone: 0419 847 988
Facsimile: 08 9173 4227
bjy@bjyoung.com.au
www.bjyoung.com.au

08 March 2012

Lucy Dunne
Acting Senior Project Officer
State Initiatives
Department of State Development
Level 6, 1 Adelaide Terrace
East Perth WA 6004

Dear Lucy

APPLICATION FOR A MINING LEASE WITHIN SECTION 19 AREA AT THE BOODARIE INDUSTRIAL ESTATE AT PORT HEDLAND

BJ Young Earthmoving Pty Ltd ('BJY') operates a sand quarry at M45/681 which is located at Boodarie near Port Hedland (Figure 1). The lessee of M45/681 is Brad Young who is also the co-owner, with his wife Julie, of BJY. As surveyed, M45/681 occupies 44.245ha. General views of the sand pit on M45/681 are provided in Plates 1 and 2.

BJY has undertaken two major sand mining contracts in early 2009 and mid 2011 in which approximately 800,000m^3 of material has been mined from M45/681. These mining campaigns were for the BHP Billiton Iron Ore ('BHPBIO') and Roy Hill developments at Finucane Island and have consumed approximately 50% of the available sand resource at M45/681.

BHPBIO and other major resource companies have been in discussions with BJY over the past year in regards to the provision of significant volumes of sand for further developments in the Boodarie area. The volume of sand remaining in M45/681 is totally insufficient to meet the likely demand.

BJY has other sand leases near Pippingarra at South Hedland (M45/531, M45/689 and M45/800) that could be utilised to provide large volumes of material for Boodarie and Finucane developments. The sand from the BJY Pippingarra Pit has been used as foundation pads for most of the residential and commercial developments in South Hedland and Port Hedland over the past 20 years. This material is considered to be of strategic importance for future housing developments. The volumes of material required for the Boodarie and Finucane developments would deplete the sand resources at the Pippingarra leases. There are no other sand leases in close proximity to Port Hedland or South Hedland.

For larger sand haulage campaigns such as would be required for a major development (possibly in excess of 400,000m^3 of sand) a fleet of >50 double or triple trailer road train combinations would be required over an extended period (possibly up to 6 months or longer). BJY is currently tendering on 4 major sand contracts with another 2 potential contracts. Total sand tenders and enquiries have now reached in excess of 3,000,000m^3. In order to provide the sand requirements to meet the needs of these major developments, BJY is seeking additional sand mining areas at Boodarie. A potential area has been identified south of the current lease M45/681 (Figure 3).

Current and proposed sand haulage routes are displayed in Figure 3. At present, material for Finucane is carted from M45/681 via Boodarie Station Road, Great Northern Highway and Boodarie Drive. This is a convoluted route that adds considerably to the cartage cost (an additional \$10/m^3 for material landed at Finucane). The route also necessitates the use of public roads by a fleet of semi-trailers and triples with associated public safety and road maintenance issues.

If material is carted from the Pippingarra Pit to Finucane (Figure 3), public roads are again utilised with the associated public safety and road maintenance issues. The cartage cost is likely to exceed \$17/m^3 for material landed at Boodarie.

If material is carted directly from M45/681 via the Whim Creek road (Figure 3), then cartage costs could be reduced to possibly \$5/m^3 for material landed at Finucane. For a larger haulage campaign, the costs savings by carting directly through Boodarie could be in the order of tens of millions of dollars. This option is not currently available due to the presence of a Section 19 area::

- S19/323 – Boodarie Strategic Industrial Estate.

Areas of potential sand resource have been identified by BJY to the north and south of M45/681 (Figure 2). This dune material is a significant sand resource, consisting of a linear dune rising approximately 5m above the surrounding plains (the same resource being mined from M45/681). Photos of the sand dune and surrounding plain are provided in Plates 4 to 6. The initial application of BJY to extend north was found by Landcorp as being not acceptable. Hence, this revised application to develop another sand lease south of M45/681.

In order to provide a cost effective sand resource in response to likely demand for the development of major projects at Boodarie and Finucane, BJY requests that DSD and Landcorp considers a request for BJY to apply for an additional mining lease at Boodarie to the south of M45/681 within S19/323.

Plate 1: General view of current pit at M45/681

Plate 2: View of pit edge at M45/681

Plate 3: Typical raise dune south of M45/681

Plate 4: Edge of raised dune south of M45/681 showing dune LHS (east) and flat country RHS (west)

Plate 5: Typical raised dune from Photo 4

Plate 6: Typical flat county west of the raised dune in Photo 4

The following points are raised for your consideration as possible benefits of the proposed additional mining lease at Boodarie:

- **Provision of basic raw materials:** Providing a high quality sand resource in close proximity to the Boodarie Industrial Estate and Finucane port facilities to meet the sand requirements of future mining and industrial developments.
- **Reduced delivery costs:** Significant cost savings for the provision of sand at Boodarie and Finucane though greatly reduced transportation distances. The cost savings by developing access via the Whim Creek Road from the proposed lease would be massive. For example, for a 5,000,000m^3 sand contract, a cost saving from reduced transport costs could be in the order of $25,000,000 as against using the current haulage route from M45/681 or in the order of $60,000,000 as against haulage from the Pippingarra Pit.
- **Facilitating industrial development:** Mining operations would be undertaken to facilitate a final landform suitable for industrial development. The dune is approximately 5m above the surrounding plains. Mining could occur to achieve a specific relative level (as specified by Landcorp or DSD), to facilitate future developments. Currently, the dune would most likely have to be removed of flattened to achieve an industrial foundation.
- **Logistics and efficiency:** Direct access to sand delivery areas through overland routes without public road traffic management issues and much shorter distances will greatly increase operational and logistical efficiencies.
- **Public safety:** Road trains kept off public roads. Larger campaign will require 40 to 50 road trains doubles for maybe 6 to 8 months. The risk to road safety will be greatly reduced by carting directly from the proposed lease overland to delivery area and relieving the congestion currently existing on the Hedland roads and rail crossings. Using the direct route will eliminate the risk of road trains interacting with rail transport.
- **Reduced wear on public roads:** The proposed lease with the overland route will enable the public road system to be bypassed, thus reducing the significant road maintenance costs from heavy haulage on public roads.
- **Diesel and greenhouse gas emissions:** – significant savings in greenhouse gas emission by reducing diesel usage. There will be a massive saving in diesel usage.

BJY is available to meet with Landcorp, DSD, DMP, Town of Port Hedland or any other stakeholder at anytime to discuss land planning issues in relation to this proposal.

If the event that Government decides to allow BJY access to ground at Boodarie, the Minister for Mines would invite BJY to mark out and apply for a mining lease over a specified section of ground. Under the *Mining Act 1978*, a mining proposal is required for lodgment along with the mining lease application.

The mining proposal is a statutory mechanism whereby detailed information is specified; on where mining can occur, excavation depths, final landforms, hand-back of mined-out areas, mining timeframes and other control mechanisms. The mining proposal is then imposed as a condition of lease. If the lessee fails to meet these specified obligations and commitments then the Minister is at liberty to forfeit the lease for breach of conditions. Additionally, further conditions can also be imposed as tenement conditions at any time. These two mechanisms (mining proposal obligations and tenement conditions) would give DMP and the Minister for Mines the ability to direct and regulate any mining activities occurring on the proposed lease.

BJY would also make a written commitment, contractual or otherwise, to undertake mining activities in designated areas to specific depths and to surrender mine-out land back to Government in accordance with scheduled timeframes.

Using the above described mechanisms, the Government is thus considered to have strong regulatory capacity to ensure that BJY undertakes mining operations and surrenders rehabilitated land to facilitate the orderly development of the Boodarie Industrial Estate.

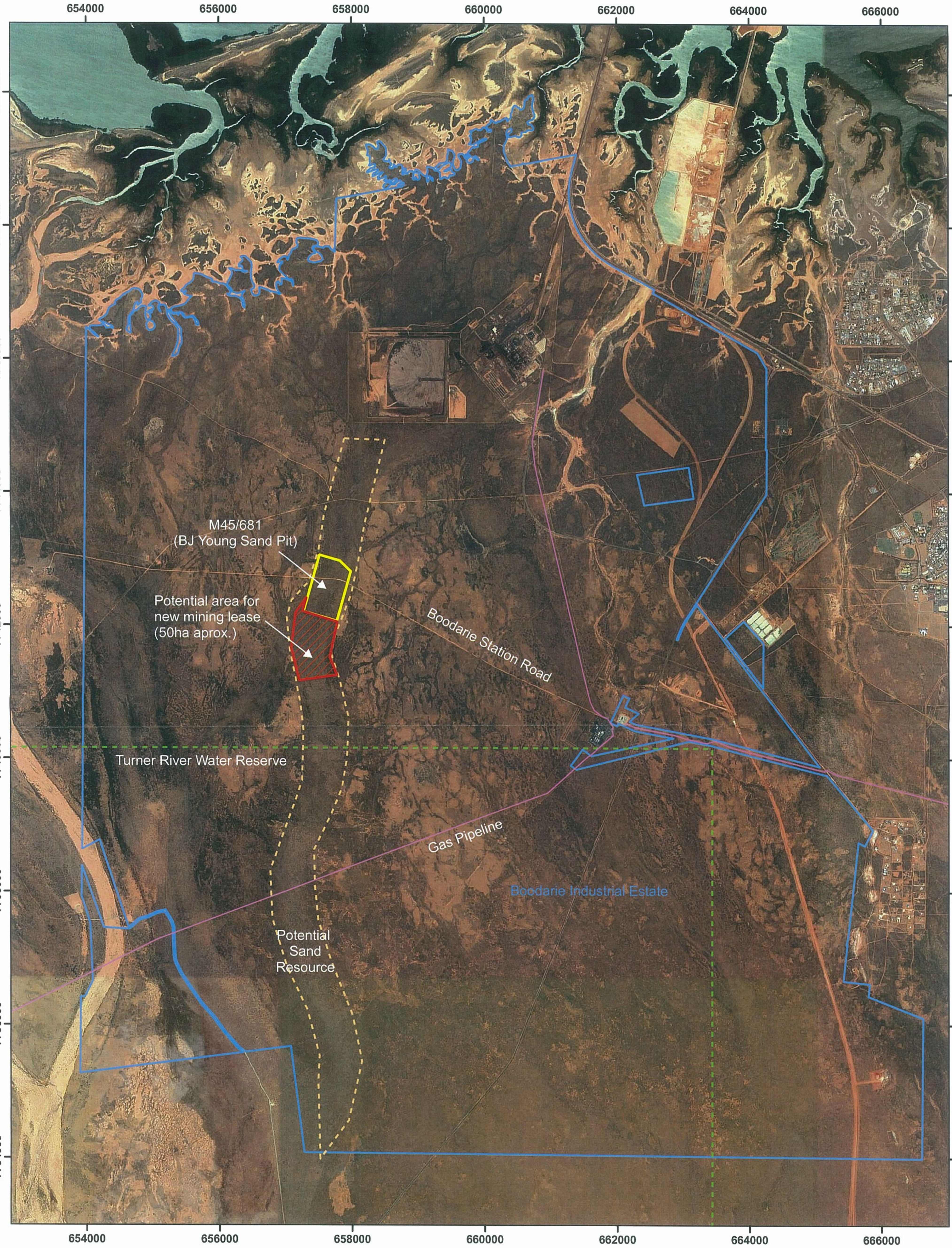
BJY has been involved with quarrying operations, mining developments, civil engineering earthworks and minesite rehabilitation in the Pilbara for the past 30 years. All endeavors have been undertaken to the highest possible standards of professionalism in all aspects of the BJY operations. BJY is committed to undertaking any development at Boodarie in an orderly and responsible manner in accordance with any conditions or requirements from Government.

Due to the likely timelines of gaining tenement grant and environmental approval, it would be greatly appreciated if a decision in regards to the two options presented herein could be reached as quickly as possible. This is to allow for sufficient lead-in time, in the event of a favorable outcome, to undertake the requisite Native Title negotiations and environmental approvals.

Please contact Charles Newland (0408 099 891 or Charles.newland@iinet.net.au) for any further information on the above.

Yours faithfully

Brad Young
Director
BJ Young Earthmoving Pty Ltd



BJY BJ YOUNG EARTHMOVING

Boodarie Sand Project February 2012

Authoured: B Young	Date: 08 February 2012
Drawn: C Newland	Print Size: A3
Base Map: Google Earth image georeferenced into ArcView	
Map Name: Figure 1 Regional Location S19-323 Boodarie.mxd	

Figure 1: Regional Location of BJ Young Lease and S19/323 at Boodarie

Legend

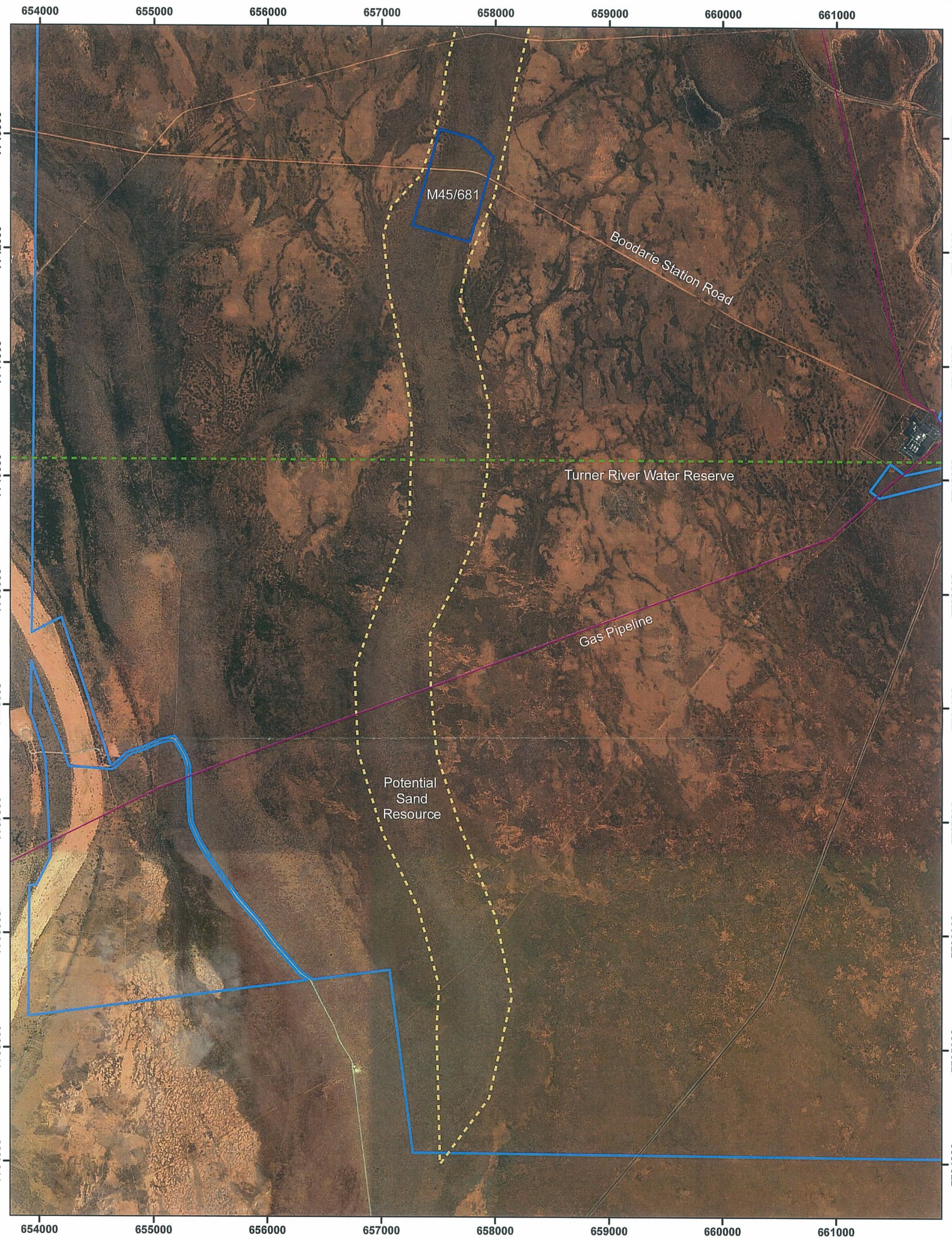
- M45/681
- S19/323
- Potential Sand Resource
- Turner River Water Reserve
- Gas Pipeline

N

0 1,000 2,000 3,000

Metres

GDA 1994 MGA Zone 50



BJ YOUNG EARTHMOVING	
Boodarie Sand Project June 2011	
Authoured: B Young	Date: 28 June 2011
Drawn: C Newland	Print Size: A3
Base Map: Google Earth image georeferenced into ArcView	
Map Name: Figure 2 Potential Resource Outline Boodarie.mxd	

Figure 2: Potential Sand Resource at Boodarie

Legend

- M45/681
- S19/323
- Potential Dune Resource
- Turner River Water Reserve
- Gas Pipeline

N

0 500 1,000 1,500 2,000
Metres
GDA 1994 MGA Zone 50

Figure 2: Potential Sand Resources at Boodarie

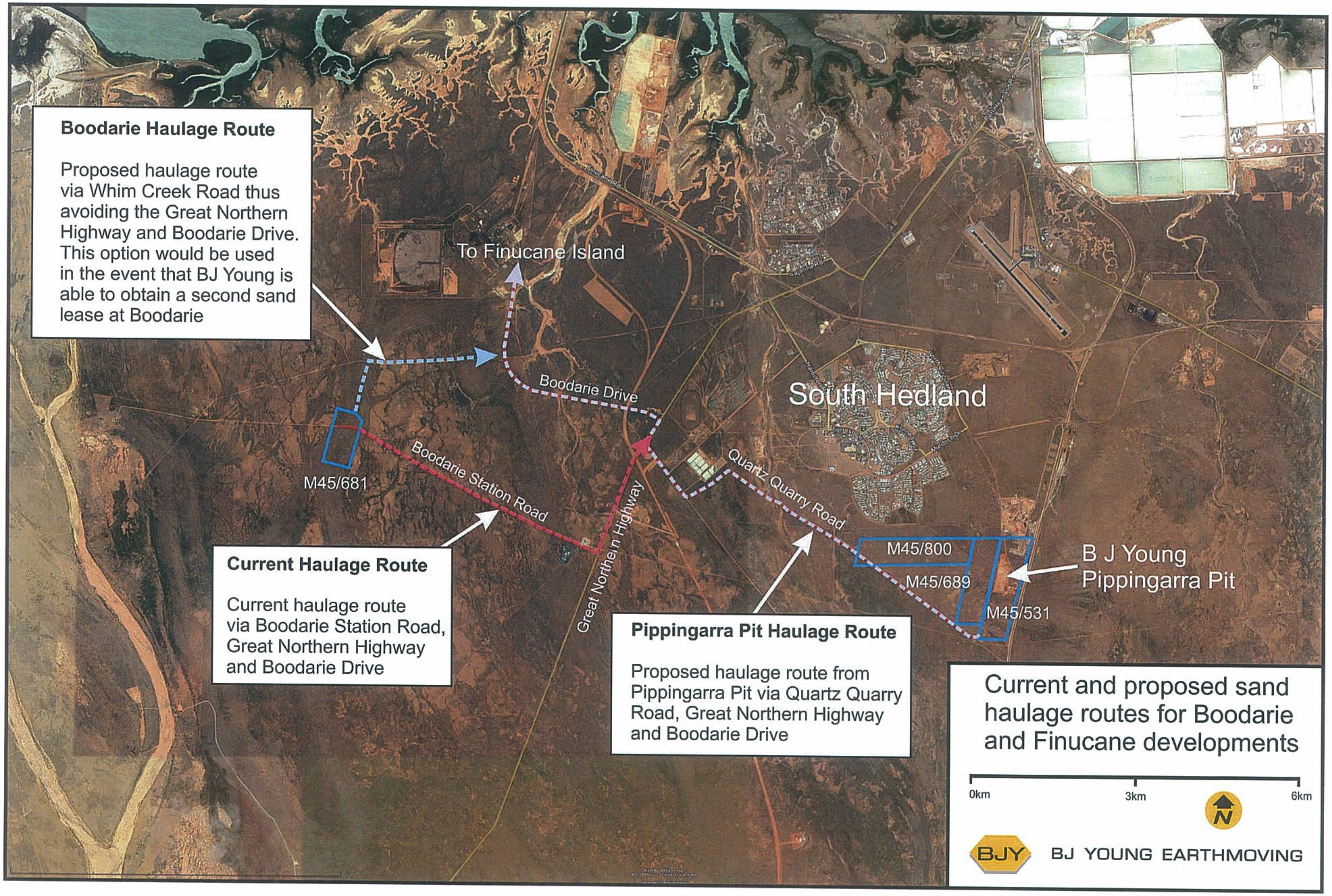


Figure 3: Current and proposed sand cartage routes to Boodarie and Finucane developments

Appendix D BSIA Drainage Strategy for AECOM upstream catchments

19 February 2013

David Cooper
LandCorp
Level 3 Wesfarmers House 40 The Esplanade
PERTH WA 6000

Our ref: 61/26171/00
130164
Your ref:

Dear David

Boodarie Strategic Industrial Area
Drainage Strategy for the AECOM upstream catchments

The following letter sets out drainage options to deal with the large catchment (around 8,100 ha) upstream of the Boodarie Strategic Industrial Area (BSIA) south east of Great Northern Highway (GHN). Runoff from this catchment can be transferred through the BSIA and accommodated within the BSIA drainage system or it can be cut off before crossing GNH and diverted along the side of the highway. This letter provides explanation of the preliminary study details of the various options.

1 Option 1 – Open drain along eastern side of Great Northern Highway (Design proposed in DWMS)

Runoff from the 8,100 ha upstream catchment is intercepted by an open drain on the eastern side of GNH. This option diverts the AECOM 15% drainage design flows into the open drain along GNH before crossing GNH (Figure 1).

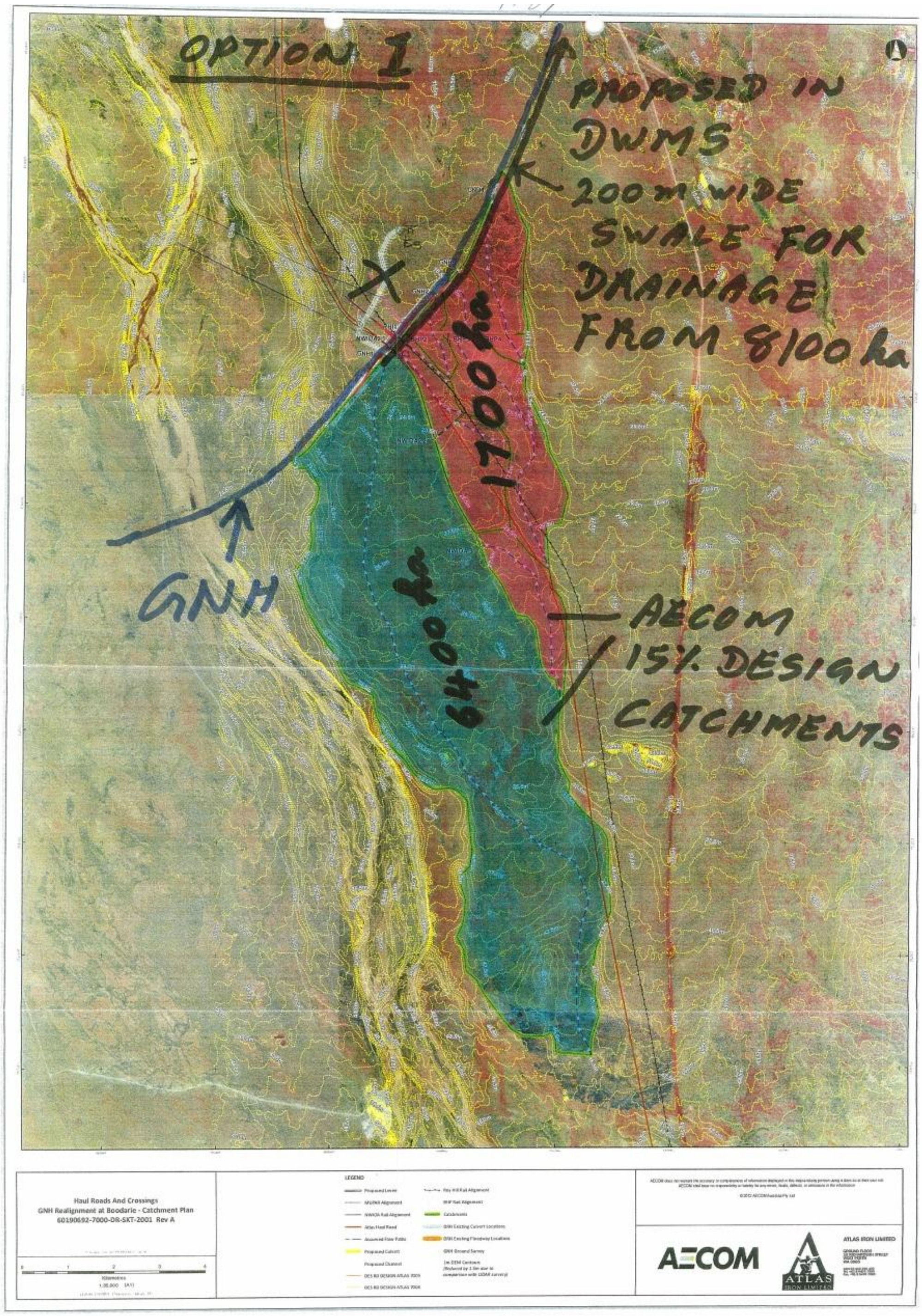
- GNH open drain: 200 m base width, 1.5 m deep, side slopes 1:3, 8 km long;
- No runoff will flow across GNH;
- No runoff from upstream catchment needs to be dealt with within BSIA;
- The drain will need to cross the Telfer gas pipeline just south of South West Creek, the pipeline has around 1 m of cover.

The open drain along GNH could be located on either side of the highway, however locating the open drain on the eastern side of the highway is recommended for the following reasons:

- On the western side of the highway the 200 m wide open drain would encroach on land desired for BSIA and other industries
- On the western side of the highway the 1.5 m deep open drain would have to cross an additional underground service (WaterCorp pipeline, in addition to Telfer gas pipeline)
- If the drain were located on the western side of the highway runoff from the upstream catchment that is not accommodated by the AECOM 15% drainage design would still have to cross the highway either via overland flow (as is currently the case) or culverts

- If the open drain were located on the western side, it would have to cross the three proposed access road roads into the BSIA, requiring large expensive culverts

Figure 1 Option 1- Proposed in DWMS (Base map – AECOM 15% Design report)



2 Alternative options

The following options make use of all or part of the AECOM 15% drainage design for the proposed GNH overpass, which has the following features:

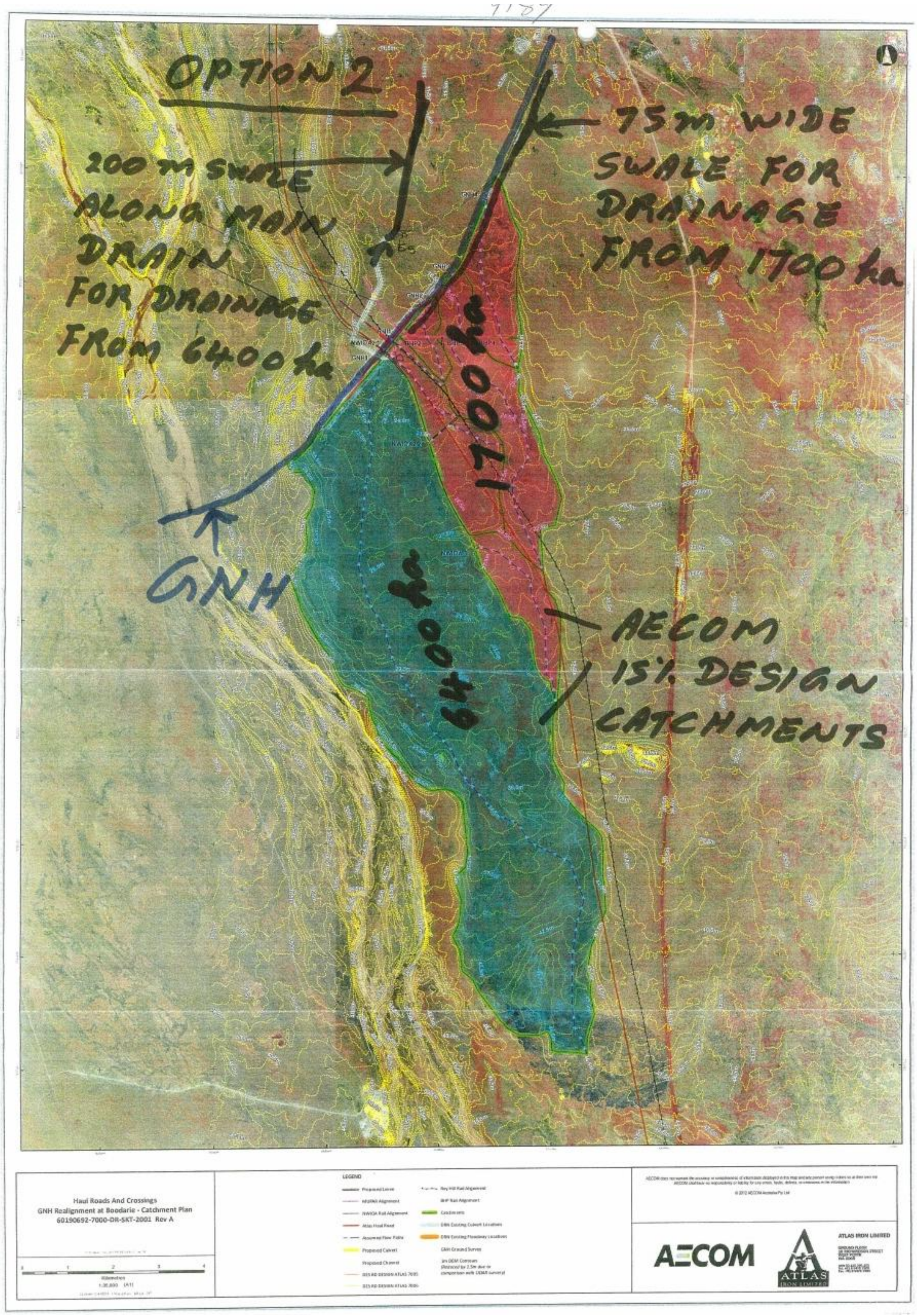
- The drainage design manages a catchment of around 6,400 ha (part of 8100 ha catchment eastern side of GNH);
- Runoff is directed through a floodway under the proposed GNH overpass;
- Runoff is directed into a channel that ultimately dumps the flow around 2.5 km north of the overpass (directly upstream of the BSIA).

2.1 Option 2 – Open drain along BSIA services corridor and smaller open drain along Great Northern Highway

Runoff from part of the upstream catchment flows under proposed GNH overpass as per AECOM 15% drainage design. The proposed channel is extended north and connected to an open drain running along the BSIA services corridor which will transfer flows through the BSIA and discharge into South West Creek north of the BSIA. Remaining upstream catchment flows will still require an open drain on the eastern side of GNH to transfer flows north east and discharge into South West Creek east of the BSIA (Figure 2).

- Services corridor open drain: 200 m base width, 2 m deep, side slopes 1:3
- Services corridor drain will need to cross
    - o Water Corporation pipeline once (in southern part of BSIA)
    - o Petroleum pipeline twice (in southern part and at north eastern border of BSIA)
    - o Five internal roads, requiring expensively large culverts
- GNH open drain: 75 m base width, 1.5 m deep, side slopes 1:3. This open drain is designed to take flows from 1700 ha catchment eastern side of GNH.
- GNH drain will need to cross the Telfer gas pipeline just south of South West Creek, the pipeline has around 1 m of cover.

Figure 2 Option 2- Open drain along BSIA services corridor and smaller open drain along Great Northern Highway (Base map – AECOM 15% Design report)

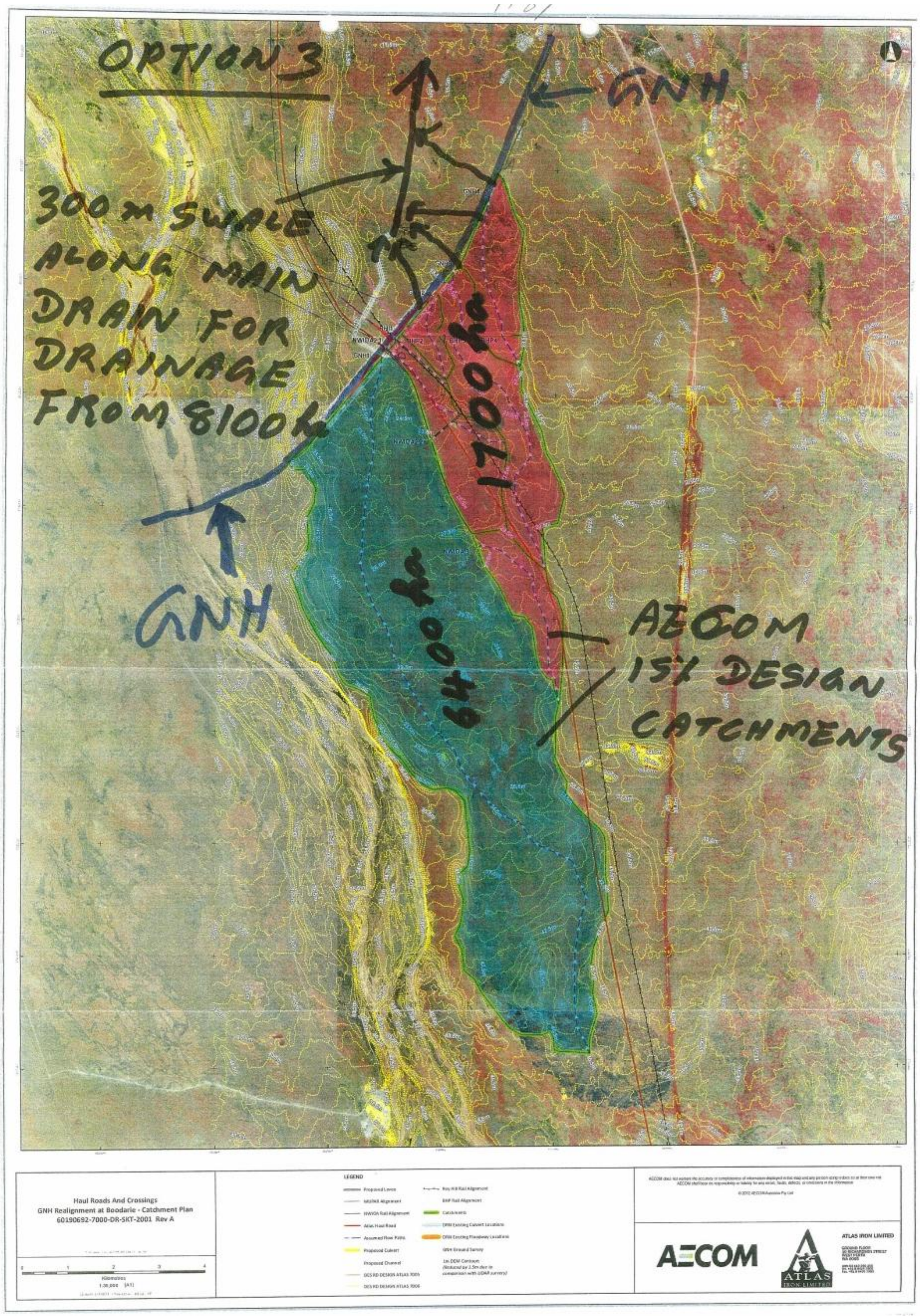


2.2 Option 3 – Open drain along BSIA services corridor only

Runoff from part of the upstream catchment flows under proposed GNH overpass as per AECOM 15% drainage design. The proposed channel is extended north and connected to an open drain running along the BSIA services corridor which will transfer flows through the BSIA and discharge into South West Creek north of the BSIA (as in option 2). Remaining upstream catchment flows will be transferred across GNH (via culverts or overland flow as is the current situation) and directed into the services corridor open drain (Figure 3).

- Services corridor open drain: 300 m base width, 2 m deep, side slopes 1:3
- Services corridor drain will need to cross
  - Water Corporation pipeline once (in southern part of BSIA)
  - Petroleum pipeline twice (in southern part and at north eastern border of BSIA)
  - Five internal roads, requiring expensively large culverts

Figure 3 Option 3- Open drain along BSIA services corridor only (Base map – AECOM 15% Design report)

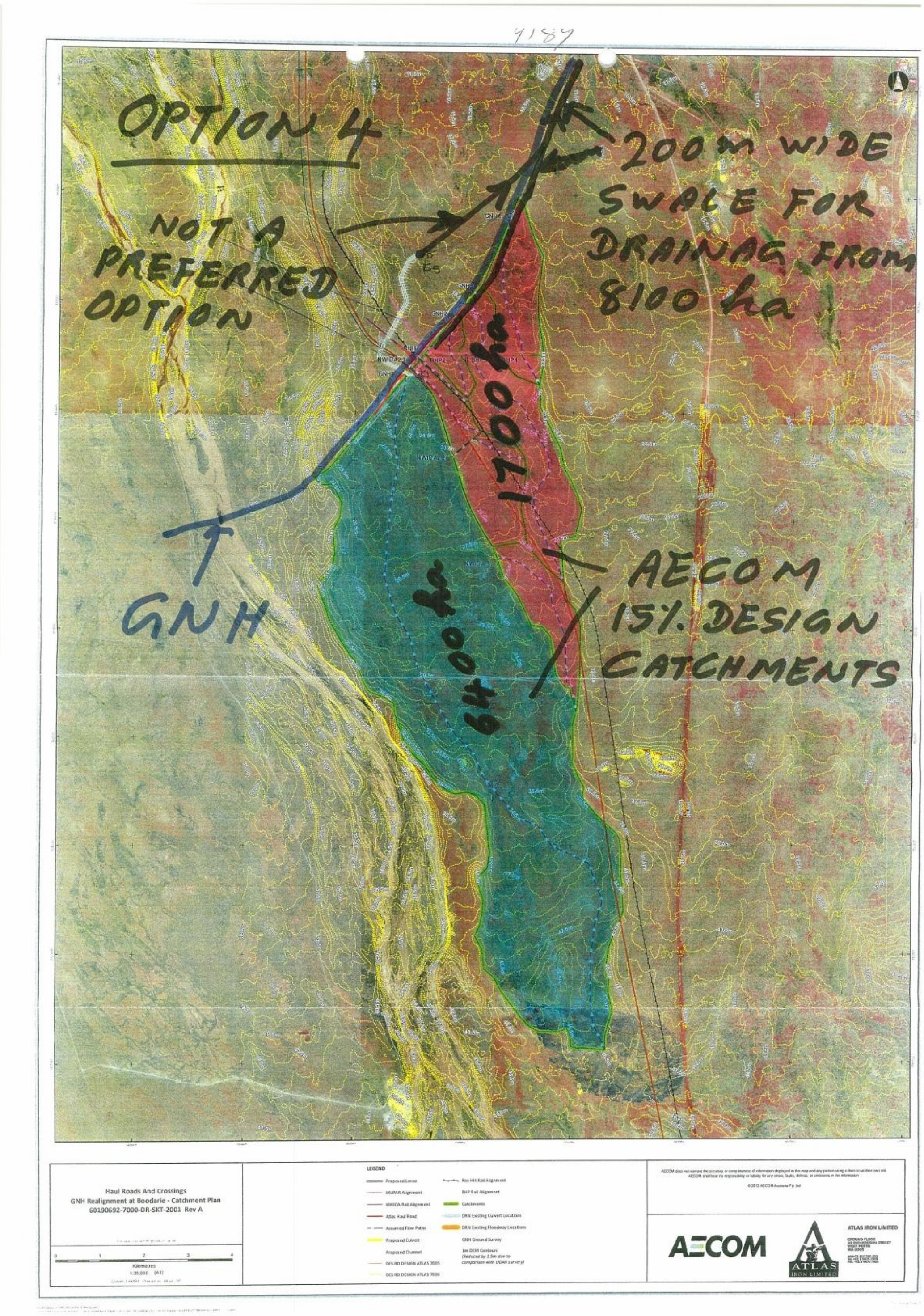


2.3 Option 4 - Culverts return upstream flows to eastern side of Great Northern Highway

Runoff from part of the upstream catchment flows under proposed GNH overpass as per AECOM 15% drainage design. The channel is extended east and directs flows back under GNH via culverts, into an open drain on the eastern side of GNH. Remaining upstream catchment flows will be intercepted by the open drain (Figure 4).

- GNH open drain: 200 m base width, 1.5 m deep, side slopes 1:3;
- The drain will need to cross the Telfer gas pipeline just south of South West Creek, the pipeline has around 1 m of cover.
- There is little grade available for the channel extension back to GNH (less than 0.04%), which will make the drain much deeper and more expensive as it approaches GNH, and then northwards along GNH till it can be graded out to meet existing ground levels;
- The size / number of culverts required to transfer flows back under GNH without causing any build-up of water on the North West side of the highway (and potential flooding) will be prohibitive.
- This diversion drain will still require a large culvert crossing at GNH, before then turning northwards.

Figure 4 Option 4 - Culverts return upstream flows to eastern side of Great Northern Highway (Base map – AECOM 15% Design report)



3 Conclusion

Whilst this is only a very high level description of the options considered and conceptual investigation carried out for the BSIA, based on the analysis as carried out for the DWMS, Option 1 is the recommended option to intercept stormwater from the AECOM 15% Drain Catchment.

This option has therefore been incorporated into the DWMS.

If this is not possible, one of the alternatives, namely Options 2 to 4 would need to be adopted; however there is no clear standout here, in terms of which would be the next best option, without undertaking a more rigorous detailed engineering assessment.

Regards,

John Kotula

Principal Civil Engineer

08 6222 8446

GHD

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Document Status

Rev No.	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
1	N Gamage	Nimal Gamage	D.G. Him	John Kotula	[signature]	22-3-13

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