



April 2012

ROPER BAR IRON ORE PROJECT

Preliminary Assessment of Surface Water Conditions and the Implications to Proposed Mine Development

Submitted to:

Andy Bennett - Senior Supervising Geologist
Western Desert Resources Ltd
Level 1, 26 Greenhill Road
WAYVILLE SA 5034

REPORT

Report Number. 117666004-001-R-Rev0

Distribution:

1 Copy - Western Desert Resources Ltd
1 Copy - Golder Associates Pty Ltd





Table of Contents

1.0 INTRODUCTION	1
1.1 Project Description.....	1
1.2 Study Context	1
2.0 SCOPE OF SERVICES	1
3.0 PROJECT SETTING	2
3.1 Climate, Soils and Topography.....	2
3.2 Regional Hydrology	2
4.0 DATA REVIEW	4
4.1 Available Reports and Commentary	4
4.1.1 <i>Draft Environmental Impact Statement (EIS), McArthur River Mine Open Cut Project, URS, 2005</i>	4
4.1.2 <i>Environmental Impact Statement Supplement, McArthur River Mine Open Cut Project, URS, 2005</i>	4
4.1.3 <i>Recommended Improvements in the Design of the McArthur River and Barney Creek Diversion Channels for the McArthur River Mine Open Cut Project, Wayne D Erskine (University of Newcastle), Department of Natural Resources, Environment, the Arts and Sport</i>	4
4.1.4 <i>Preliminary Analysis of Streamflow Characteristics of the Tropical Rivers Region, DR Moliere, Department of the Environment and Water Resources, 2007</i>	5
4.1.5 <i>Land systems of the Roper River catchment, Northern Territory, JM Aldrick and PM Wilson, joint report by Soil and Land Appraisal Pty Ltd and the Conservation Commission of the Northern Territory, first published 1992</i>	5
4.1.6 <i>Gulf Water Study: Water Resources of the Roper River Region, U Zaar, co-funded by the Department of Natural Resources, Environment the Arts and Sport and the Water Smart Australia Program, 2009</i>	5
4.1.7 <i>Roper River Catchment: An Assessment of the Physical and Ecological Condition of the Roper River and its Major Tributaries, JJ Faulks, Department of Lands, Planning and Environment, 2001</i>	5
4.1.8 <i>Water Resources Investigation - Roper River Mission, Field Officer's Report, CF Forbes and D Kneebone, Water Resources Branch, Northern Territory Administration, 1960</i>	5
4.1.9 <i>Baseflow Water Quality Surveys in Rivers in the Northern Territory, Volume 11: Roper, Wilton and Hodgson Rivers, David F Field, Water Directorate, Power and Water Authority, 1988</i>	5
4.1.10 <i>Water Monitoring Strategy, Roper Bar Iron Ore Project, VDM Consulting, 2011</i>	6
4.1.11 <i>Additional Remarks</i>	6



5.0 SITE INSPECTION 6

5.1 River Geomorphology and Surrounds 6

5.2 River Bed Assessment 6

6.0 DATA INTERPRETATION AND ANALYSIS 6

6.1 Surface Water 6

6.1.1 Flood Estimation 6

6.1.2 Hydraulic Modelling 8

7.0 POTENTIAL SURFACE WATER IMPLICATIONS TO MINE DEVELOPMENT 13

8.0 CONCLUSIONS AND RECOMMENDATIONS 14

8.1 Conclusions 14

8.2 Recommendations 14

8.2.1 Regional Scale Flooding 14

8.2.2 Local Scale Flooding 16

8.2.3 Runoff from Pit, Stockpile and Infrastructure Areas 16

9.0 LIMITATIONS 16

REFERENCES 17



TABLES

Table 1: Areas of Drainage Catchments 7
Table 2: Runoff Coefficients for Northern Territory (AR&R) 7
Table 3: Estimated Rainfall Intensities 8
Table 4: Estimated Flood Peak Discharge 8
Table 5: Estimated Flood Depth and Peak Velocities 11

FIGURES

Figure 1: Monthly Rainfall Data of Ngukurr (Station Number 014609) 2
Figure 2: Impacting Catchments and Project Location 3
Figure 3: Adopted IFD for the Roper Bar Project 8
Figure 4: HECRAS - Hydraulic Modelling Cross-Sections and Model Domain 10
Figure 5: Flood Maps - 5, 10 and 100 Year ARI Flood Events 12
Figure 6: Flow Velocities during the 10 Year ARI Rainfall Event 13
Figure 7: Conceptual Plan 15

APPENDICES

APPENDIX A

Site Visit: Photographs and Approximate River Geometries

APPENDIX B

Hydraulic Analysis

APPENDIX C

Limitations



1.0 INTRODUCTION

1.1 Project Description

The Roper Bar Iron Ore Project (Project) lies within the Roper Bar Iron Ore Province (the Province), which covers an area of approximately 2500 km² and encompasses eight exploration licences. The Province comprises two project areas, namely Roper Bar and Mountain Creek, and is situated east of Mataranka and 50 km inland from the Gulf of Carpentaria, Northern Territory.

The Project is 100% owned by Western Desert Resources Ltd (WDR), with its tenement covering most of the outcropping areas of the Sherwin Ironstone Member (SIM). The SIM contains all known hematite mineralisation in the province, with the iron-rich outcrops covering an area of about 100 km². Drilling results, as at June 2011, indicate the presence of five distinct deposits with a total resource of 311 Mt @ 40% Iron (Fe) including 14.5 Mt @ 57.4% Fe direct shipping ore (DSO) and >295 Mt of beneficiable ore. The results of a scoping study in 2010 proposed a two stage project: Phase 1 DSO at 1.5 Mtpa and Phase 2 export of concentrate.

The Province is located within a large sedimentary basin (McArthur Basin). The key topographic features of the area include low sandstone escarpments and plains, with little sandstone outcrop comprising boulders, rubble and sands that are interpreted to be derived by the weathering of the underlying sandstones. The site topography varies from around 126 to 156 metres above mean sea level. The climate is wet-dry tropics, with average annual rainfall of around 700 mm occurring mainly in the wet season months of November to April.

1.2 Study Context

This study is designed to highlight the main surface water issues likely to affect the Project and to understand the potential implications of surface water on mining operations.

2.0 SCOPE OF SERVICES

Stage 1 - Desktop Review

Available data were collated and reviewed in order to gain an understanding of catchment conditions and likely hydrological behaviour. Particular focus was on:

- NT Govt information (e.g. soils, land systems and topographic maps, relevant hydrological reports)
- WDR information (e.g. aerial photography, topographic maps, site plans), and
- hydrological aspects of McArthur River Mine EIS, particularly creek diversion issues.

Stage 2 - Field Visit

Golder's Senior Surface Water Hydrologist (Matt Goode) visited the project area, in order to assess general site conditions and collect relevant site data (where available).

During the course of the visit, the immediate catchments were viewed and considered in the context of potential development of the Project. In addition, discussions were held with local staff who provided useful comments on recent flooding events.

Stage 3 - Data Analysis and Reporting

Following the site visit, the data were analysed and a map developed (using available topographic data as the base) identifying key hydrological issues and flood potential. Estimates of the approximate catchment areas of any likely creek crossings and associated flood discharges were made using analysis methods considered appropriate, as proposed in the Australian Rainfall and Runoff (Institution of Engineers Australia, 1998). Potential flood conditions and potential mitigation measures, at a conceptual level, are presented to WDR for consideration.

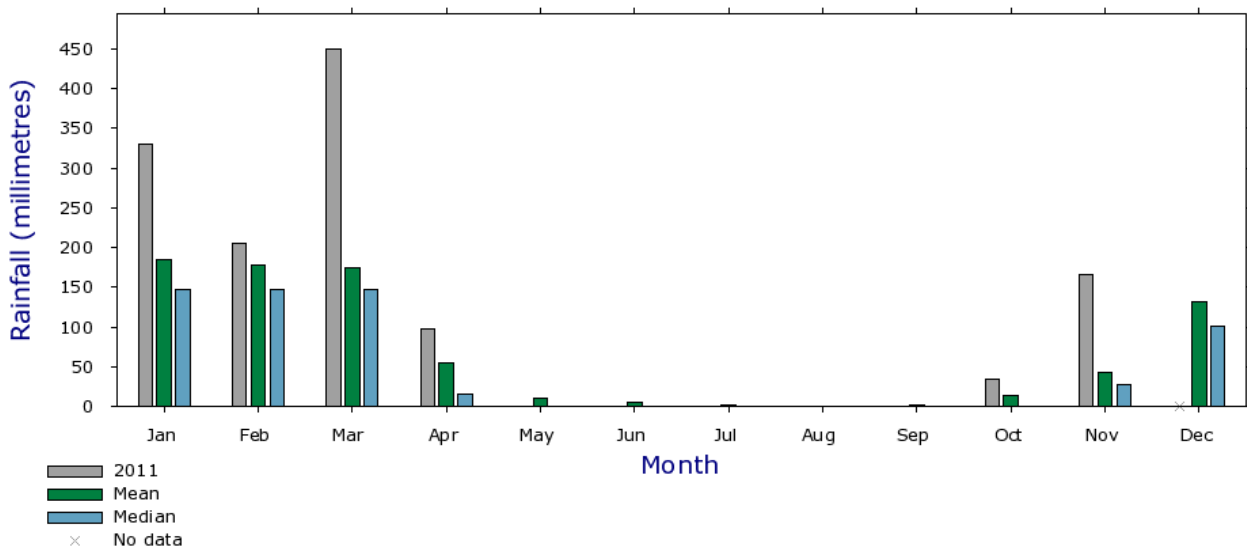


3.0 PROJECT SETTING

3.1 Climate, Soils and Topography

The Roper Bar Iron Ore Province is located about 550 km south-east of Darwin, Northern Territory. The nearest town is Ngukurr, which lies 21 km east of the Roper Bar Camp (located at 14.73° S and 134.73° E at an elevation of 34 m AMSL).

The Project site has a tropical wet-dry climate with the wet season from November to April and the dry season from May to October. Annual rainfall data for 2011 are compared with annual mean and median data.



Note: Mean and median are calculated for the years 1910-2010 (Bureau of Meteorology, 2011).

Figure 1: Monthly Rainfall Data of Ngukurr (Station Number 014609)

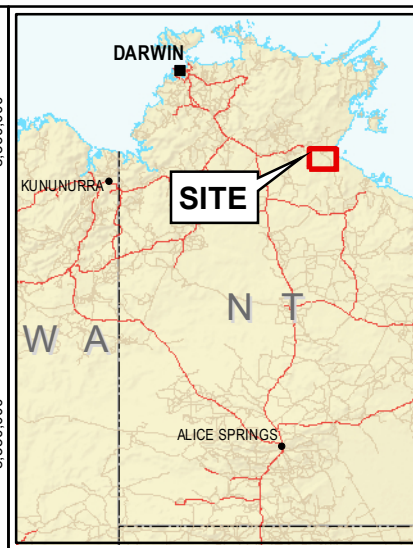
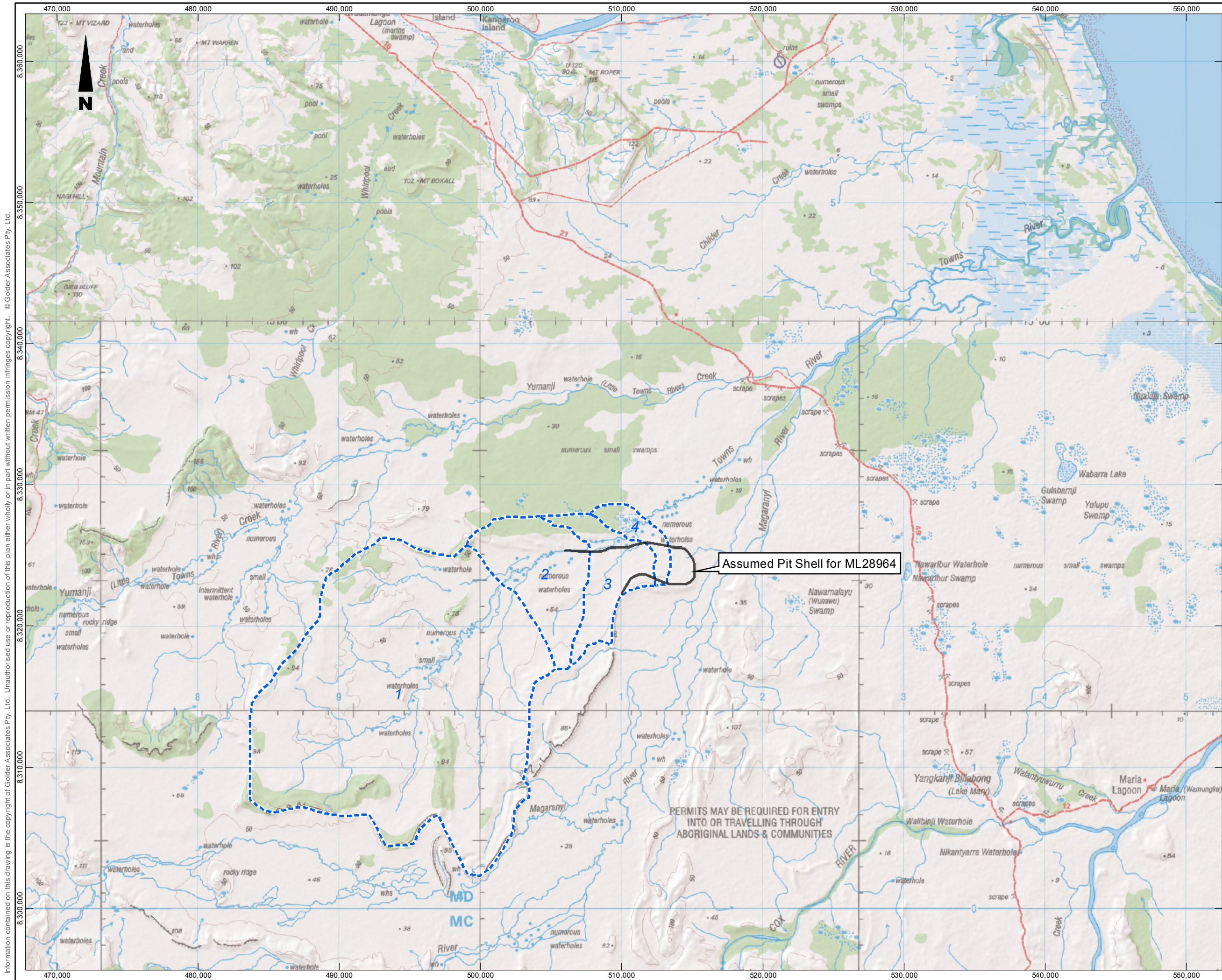
Mean monthly minimum temperature varies from 15-26°C and maximum from 30-39°C. Average annual Class A pan evaporation is about 2400 mm for the region, with evaporation exceeding rainfall even in the wettest months of the year. Mean monthly relative humidity (at 3 pm) varies from 24-56% (Zaar, 2009).

Cyclones, thunderstorms and monsoonal rainfall are typical for the Roper Bar Iron Ore Province and lead to highly variable stream flows in catchments located in the region (URS, 2005).

3.2 Regional Hydrology

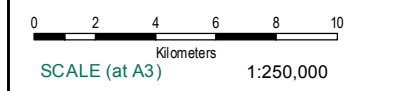
The upper reaches of the Towns River meander through the proposed mining area (Figure 2). The head of the catchment has an elevation of approximately 30.5 m (AMSL) and flows into the Arafura Sea; a part of the Indian Ocean. The Towns River is approximately 84 km long (Bonzle Digital Atlas of Australia, 2011). The river lies south of the Roper River and north of the Limmen Bright River and McArthur River. Yumanji Creek (Little Towns River) and Magaranyi River both flow into the Towns River.

The Towns River has similar characteristics to the larger Roper and McArthur rivers. The highest flows occur during the wet season, predominantly due to cyclones and monsoonal rainfall. However, in contrast to the larger rivers, the Towns River is ephemeral and usually runs dry during the dry season.



LEGEND
 --- Impacting Catchment Boundary

NOTES
 Coordinate System: GDA 1994 MGA Zone 53
COPYRIGHT
 Topographic base sourced from Geoscience Australia
 1:250,000 Topographic series.
 World shaded Relief © Esri (2009)



Golder Associates

CLIENT Western Desert Resources Ltd
 DOCUMENT 117666004-001-R-REV0
 DATE 03 Apr 2012
 COMPILED SR
 APPROVED MG

**Roper Bar
 Iron Ore Project**

**PROJECT
 LOCATION**

FIGURE 2

Information contained on this drawing is the copyright of Golder Associates Pty. Ltd. Unauthorised use or reproduction of this plan either wholly or in part without written permission infringes copyright. © Golder Associates Pty. Ltd.

PERMITS MAY BE REQUIRED FOR ENTRY
 INTO OR TRAVELLING THROUGH
 ABORIGINAL LANDS & COMMUNITIES

This page has been intentionally left blank.



4.0 DATA REVIEW

4.1 Available Reports and Commentary

WDR has provided Golder with digital copies of various reports which have been reviewed. A brief comment on each document and its applicability to this Project is provided in the following sections.

4.1.1 *Draft Environmental Impact Statement (EIS), McArthur River Mine Open Cut Project, URS, 2005*

The McArthur River Mine (MRM) is situated approximately 200-250 km south-east of the Project. Points of relevance from the surface water section of the draft environmental impact statement (EIS), relevant to the hydrology of the Project, are provided below:

1) Catchment context and regional hydrology

The McArthur River catchment, within which MRM is located, does not encompass the Project.

2) Hydrology (flood flows, typical wet season flows, etc).

Given that the Project is unlikely to be affected by the McArthur River (and vice versa); the hydrological characteristics of this watercourse do not need further examination.

3) Local surface water systems

These are applicable solely to MRM and its environment.

4) Hydraulic assessment of the McArthur River

While the hydraulic characteristics of the McArthur River are not applicable elsewhere, the structure of this assessment provides a suitable template for similar studies elsewhere in the Northern Territory.

5) Existing and proposed water management strategies

The water management strategy (WMS) for a particular mining operation could be appropriate for use in this Project.

6) Proposed river and creek realignment works

In general terms, realignment works must be appropriate to the watercourse in question. However, given that the preferences of local regulatory bodies vary throughout Australia, a review of the river/creek realignment undertaken at MRM may provide a framework for comparable works for the Roper Bar Project.

7) Impact of proposed realignment works

This section may provide guidance regarding the assessment of river/creek realignment works within the Northern Territory.

4.1.2 *Environmental Impact Statement Supplement, McArthur River Mine Open Cut Project, URS, 2005*

Further to comments from various regulatory bodies, this document seeks to expand upon certain items contained in the draft EIS.

4.1.3 *Recommended Improvements in the Design of the McArthur River and Barney Creek Diversion Channels for the McArthur River Mine Open Cut Project, Wayne D Erskine (University of Newcastle), Department of Natural Resources, Environment, the Arts and Sport*

This report was commissioned by the Department of Natural Resources, Environment, the Arts and Sport (DNREAS) following the submission of the draft EIS. It includes a review of the proposed river realignment works and recommendations regarding further work. In conjunction with the documents discussed above, this report will prove useful in identifying specific design requirements for realignment works within the Northern Territory.



4.1.4 *Preliminary Analysis of Streamflow Characteristics of the Tropical Rivers Region, DR Moliere, Department of the Environment and Water Resources, 2007*

This report seeks to establish the broad flow characteristics of rivers located in Australia's wet-dry tropical rivers region. A detailed assessment was carried out in respect of three specific rivers, none of which is likely to impact on the Project or its surrounding hydrology. This report may provide some useful climatic information regarding the region under discussion but is otherwise unlikely to be of significant use.

4.1.5 *Land systems of the Roper River catchment, Northern Territory, JM Aldrick and PM Wilson, joint report by Soil and Land Appraisal Pty Ltd and the Conservation Commission of the Northern Territory, first published 1992*

This report discusses the geology, soil, vegetation and other traits of the Roper River catchment. The catchment is considered in the context of 62 individual land systems, each of which contains a unique mix of the aforementioned attributes. Given that the Project is not located within the Roper River catchment, this report does not contain any site-specific data of potential relevance to future design work (e.g. rates of infiltration and/or sedimentation). However, in a broader sense, the report provides a useful overview of existing land characteristics within the region under discussion (Certain aspects of this information should be considered in the context of the current study, having been carried out almost 20 years ago).

4.1.6 *Gulf Water Study: Water Resources of the Roper River Region, U Zaar, co-funded by the Department of Natural Resources, Environment the Arts and Sport and the Water Smart Australia Program, 2009*

This report contains some useful data regarding flow and water quality in the Towns River (The Roper River region, as defined in the Gulf Water Study, includes a portion of the Towns River catchment).

4.1.7 *Roper River Catchment: An Assessment of the Physical and Ecological Condition of the Roper River and its Major Tributaries, JJ Faulks, Department of Lands, Planning and Environment, 2001*

This report describes the condition of the Roper River from the standpoint of various physical parameters (e.g. ecology, channel stability, sediment types, vegetation, etc). In terms of addressing surface water issues applicable to the Project, this information is unlikely to be of particular relevance.

4.1.8 *Water Resources Investigation - Roper River Mission, Field Officer's Report, CF Forbes and D Kneebone, Water Resources Branch, Northern Territory Administration, 1960*

The report assesses the physical and geological characteristics of the Roper River, the present and future water requirements with which it is associated, sources of water for the mining operation under discussion and the feasibility of alternative water sources. These studies are not considered relevant in the context of either the Project and/or the Towns River. Also (*Field Trip Report, Roper River Mission Water Resources Survey, CF Forbes and D Kneebone, Water Resources Branch, Northern Territory Administration, 1962 and Roper River Mission, Water Resources Survey, CF Forbes and D Kneebone, Water Resources Branch, Northern Territory Administration, ca. 1962*).

4.1.9 *Baseflow Water Quality Surveys in Rivers in the Northern Territory, Volume 11: Roper, Wilton and Hodgson Rivers, David F Field, Water Directorate, Power and Water Authority, 1988*

The water quality information contained in this report does not refer to the Towns River.



4.1.10 *Water Monitoring Strategy, Roper Bar Iron Ore Project, VDM Consulting, 2011*

This report addresses the issue of future surface and groundwater monitoring in respect of the Towns River. A general overview of existing conditions is also included; however, the lack of relevant existing data is noted.

4.1.11 *Additional Remarks*

Personal discussions with Simon Cruickshank (Department of Natural Resources, Environment, The Arts and Sport) have established that no historical stream flow data exists for the Towns River. Some instantaneous monitoring was undertaken at part of the Gulf Rivers Study but this is insufficient in terms of preparing a reliable estimate of the prevailing flow conditions within the river.

5.0 SITE INSPECTION

A site inspection was undertaken from 1 to 4 November 2011. The purpose was to provide an overview of the area, determine general river characteristics and collect available data.

5.1 River Geomorphology and Surrounds

Photographs and approximate river geometries (measured with a handheld tape measure) for selected sites around the proposed Project site are contained in Appendix A. Selection of the sites was made on the basis of ease of access of vehicles.

The River displays a highly sinuous and meandering form with often well defined active channel areas. The floodplain in the vicinity of the proposed mine is wide and flat but also contains many non-active channel features including ox-bow lakes, and abandoned pools. The exception is where the River abuts the ridgeline (Appendix A; Photo #10). The channel in this location is heavily armoured and straight. It is likely that this section of the river has remained stable for some time.

There are a number of smaller, local scale catchments that have small, often poorly defined, drainage lines associated with them (Appendix A; Photo #8).

The smaller catchments associated with the "horseshoe" shaped ridgeline at the east side of the Mining Lease act as a small sink for smaller runoff events.

5.2 River Bed Assessment

Critical parameters necessary for hydraulic modelling (Manning's n) were visually assessed. Based on observations made and hydrological judgment, it was concluded that an 'n' value of 0.030 (dimensionless) for the channel and 0.035 for the overbank regions should be adopted for hydraulic modelling purposes.

6.0 DATA INTERPRETATION AND ANALYSIS

6.1 Surface Water

6.1.1 Flood Estimation

The Australian Rainfall and Runoff (AR&R) (Institution of Engineers, Australia (1998)) has been prepared to provide Australian designers with the best available information on methods for design flood estimation. Recourse has been made to this document as the basis for flood estimation due to the lack of historical streamflow data for the Towns River.

Only limited design information is available in the Northern Territory. This translates to a greater uncertainty than for other regions in Australia. The Rational method has been adopted in this study as recommended in AR&R for studies of this type and provides useful order-of-magnitude design flood estimates.

The method was used to estimate flood peak discharges from the main catchments for the 5, 10 and 100 year average recurrence interval (ARI) rainfall events.



The Rational method is based on following formula:

$$Q_p = 0.278 \times C \times i \times A$$

- where
- Q_p = peak flow (m³/s)
 - C = coefficient of runoff
 - i = intensity of rainfall in time t_c (mm/hr)
 - A = area of catchment (km²)

Digital elevation data of the study site was provided by WDR and used together with SRTM data (freely available from NASA) to develop a topographic map, including surrounding catchments. ArcMap, the main component of the geospatial processing programme ArcGIS, was used to define the main impacting drainage catchments, based on the topographic map. For the purposes of this study, four drainage catchments were defined by digitising their spatial extent on the topographic map. These catchments are located sequentially within the Towns River watershed and have been delineated in a manner intended to provide peak discharge estimates at specific locations of interest.

The catchments are presented in Figure 2. The calculated catchment areas are outlined in Table 1.

Table 1: Areas of Drainage Catchments

	Catchment 1	Catchment 2	Catchment 3	Catchment 4
Area (km ²)	345	51	32	11

AR&R suggests the following runoff coefficients for the entire Northern Territory (Table 2):

Table 2: Runoff Coefficients for Northern Territory (AR&R)

ARI	Runoff coefficient
1:2 year	0.5-0.7
1:5 year	0.6-0.8
1:10 year	0.7-0.9

The higher runoff coefficient values in Table 2 are used for the steeper catchments, while the lower values are appropriate for very flat catchments. Since the areas of the impacting catchments in the region of the proposed mining area are relatively flat, the lower values from Table 2 were generally used in the Rational method calculations. For the 100 year ARI, a runoff coefficient value of 0.9 was adopted for this study.

The final step in the hydrological estimation is to determine the time of concentration (t_c). This is the time required for rain falling at the farthest point of the catchment to flow to the catchment outlet. After time t_c , the whole catchment area is contributing to the flow in the river (Shaw, 1994). The Bransby-Williams formula was adopted to estimate t_c (Institution of Engineers Australia, 1998):

$$t_c = \frac{58 \times L}{A^{0.1} \times S_e^{0.2}}$$

- where
- t_c = time of concentration (min)
 - L = mainstream length (km)
 - A = area of catchment (km²)
 - S_e = average slope of catchment (m/km)



The mainstream length and the average slope of the catchment were calculated within ArcMap using a contour data map of the region. Rainfall at t_c was determined using the online computer programme offered by the Bureau of Meteorology (2011b), which calculates IFD curves (Intensity-Frequency-Duration) for every region within Australia. For this study, rainfall intensity values were determined for the three rainfall events (5, 10 and 100 year ARIs) using the time of concentration as the rainfall duration.

The IFDs for the proposed project site are presented in Figure 3.

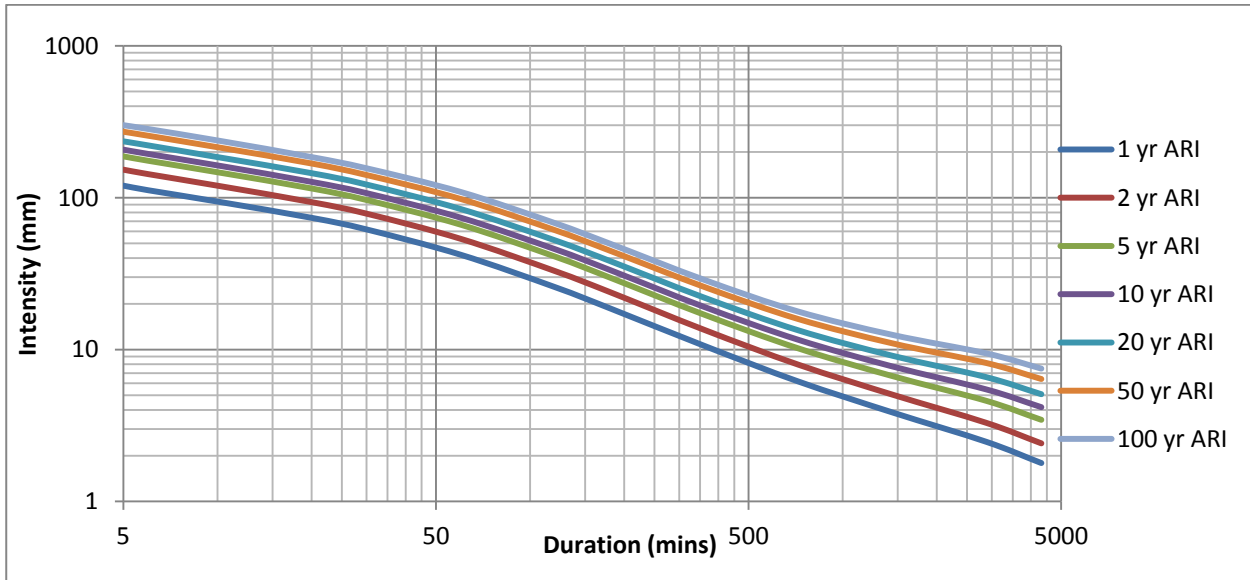


Figure 3: Adopted IFD for the Roper Bar Project

Estimated rainfall intensity values ‘i’ for the times of concentration for the various catchments and assumed ARI rainfall events are contained in Table 3.

Table 3: Estimated Rainfall Intensities

	Catchment 1			Catchment 2			Catchment 3			Catchment 4		
ARI	5	10	100	5	10	100	5	10	100	5	10	100
<i>i</i> (mm/h)	12.4	14.1	21.4	17.0	19.1	28.8	29.8	33.4	49.8	33.5	37.5	55.9

Estimated peak flood discharges for various ARI events are contained in Table 4.

Table 4: Estimated Flood Peak Discharge

	Catchment 1			Catchment 2			Catchment 3			Catchment 4		
ARI	5	10	100	5	10	100	5	10	100	5	10	100
Q (m ³ /s)	715	946	1847	145	189	367	159	208	398	61	80	154

6.1.2 Hydraulic Modelling

In order to gain an initial understanding of the areal extent of flooding in the vicinity of the proposed mine site, it was considered appropriate that preliminary hydraulic modelling and flood mapping should be undertaken. HEC-RAS (version 4) was used as the hydraulic modelling software to simulate flooding of the Towns River only as a result of different design rainfall events. The potential for flooding of adjacent catchments and water courses was not assessed.



HEC-RAS is a one-dimensional hydraulic programme which allows development of models to simulate both steady and unsteady, gradually varied flow. The model can be used to derive water surface profiles within a river network. The programme takes into consideration both the physical characteristics of the stream network such as river channel gradients, channel cross-sections and bed material composition, as well as existing or planned infrastructure such as storages, modifications to channel sections, and similar that impact on flow hydraulics. The programme solution is based on solving the one-dimensional energy equation. Energy losses between river sections are evaluated in terms of two components, friction losses within the channel and overbank area, based on the Manning's roughness parameter 'n', and channel contraction/expansion losses defined by a coefficient multiplied by the velocity head.

The required model geometry for river in the vicinity of the project was developed based on the available topographic information using the HEC-GeoRAS programme. This is an ArcGIS extension, specifically designed to process geospatial data for use with HEC-RAS. The HEC-GeoRAS programme creates a file of geometric data for input into HEC-RAS and subsequent hydraulic analysis. The main processes in HEC-GeoRAS comprise the following steps:

- Digitising the creek by creating stream centrelines, flow-path centrelines, banks and cross-section HEC-RAS layers. Cross-sections were defined over a channel length of approximately 22 km. Each section was of sufficient length to define the main channel and overbank areas through which the flow would be conveyed. Cross-sections were defined approximately every 50-100 m for meandering stretches and approximately every 200-500 m for river stretches that are uniform, to ensure any changes in river channel and overbank geometries were adequately defined.
- Geo-referencing HEC-RAS layers with required attributes including cross-sectional widths, elevations and distances between cross-sections.
- Exporting the GIS data into the HEC-RAS platform for processing and hydraulic modelling.

The main input data in the HEC-RAS model include:

- Channel and overbank cross-sections to define the flow area (input HEC-GeoRAS geometric data).
- Manning's roughness parameter 'n' for the main channel and overbank areas. As indicated previously, a value of 0.030 for the main channel and 0.035 for the overbank areas has been adopted based on field observations.
- Steady flow data for 5, 10 and 100 year ARIs (flood peak discharge data from Table 4).
- Downstream boundary conditions: a normal flow slope of 0.001 m/m was assumed based on local channel gradients study.

The hydraulic model domain relative to an assumed pit shell for the project is available in Figure 4.

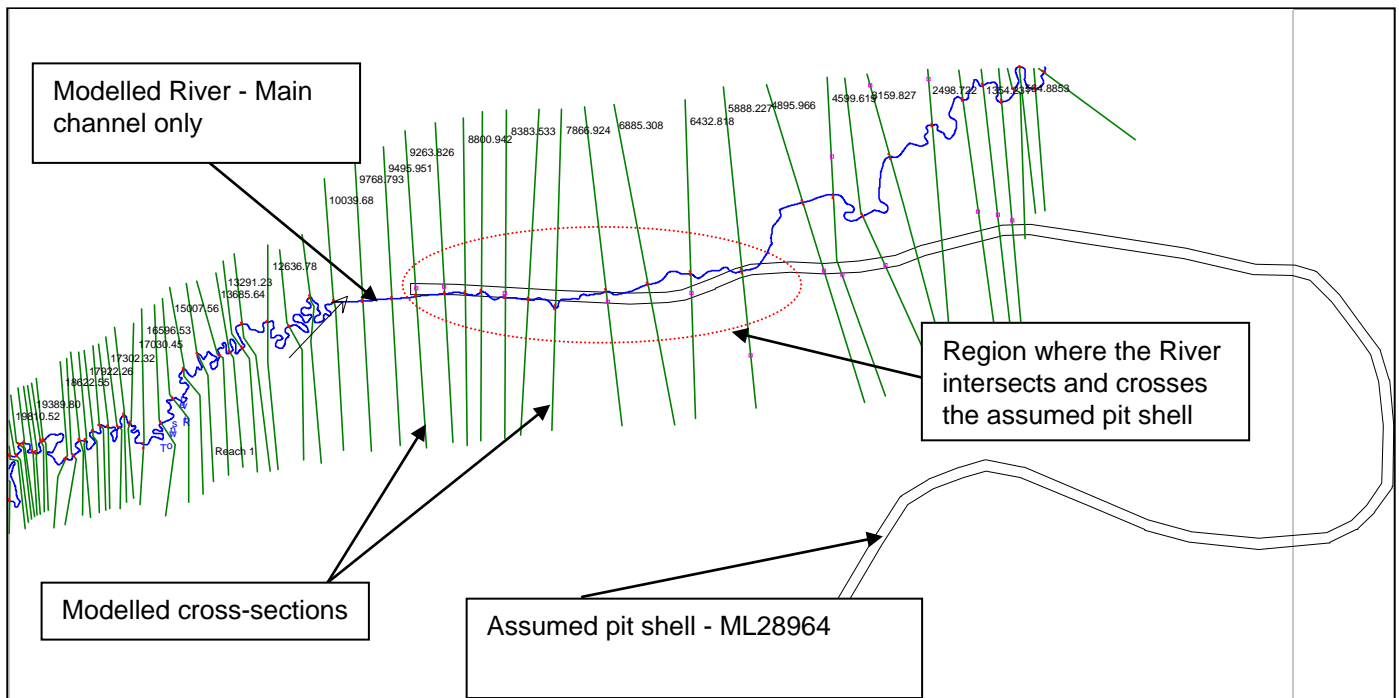


Figure 4: HECRAS - Hydraulic Modelling Cross-Sections and Model Domain

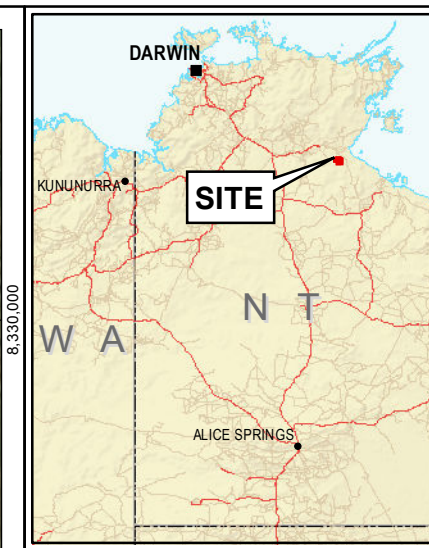
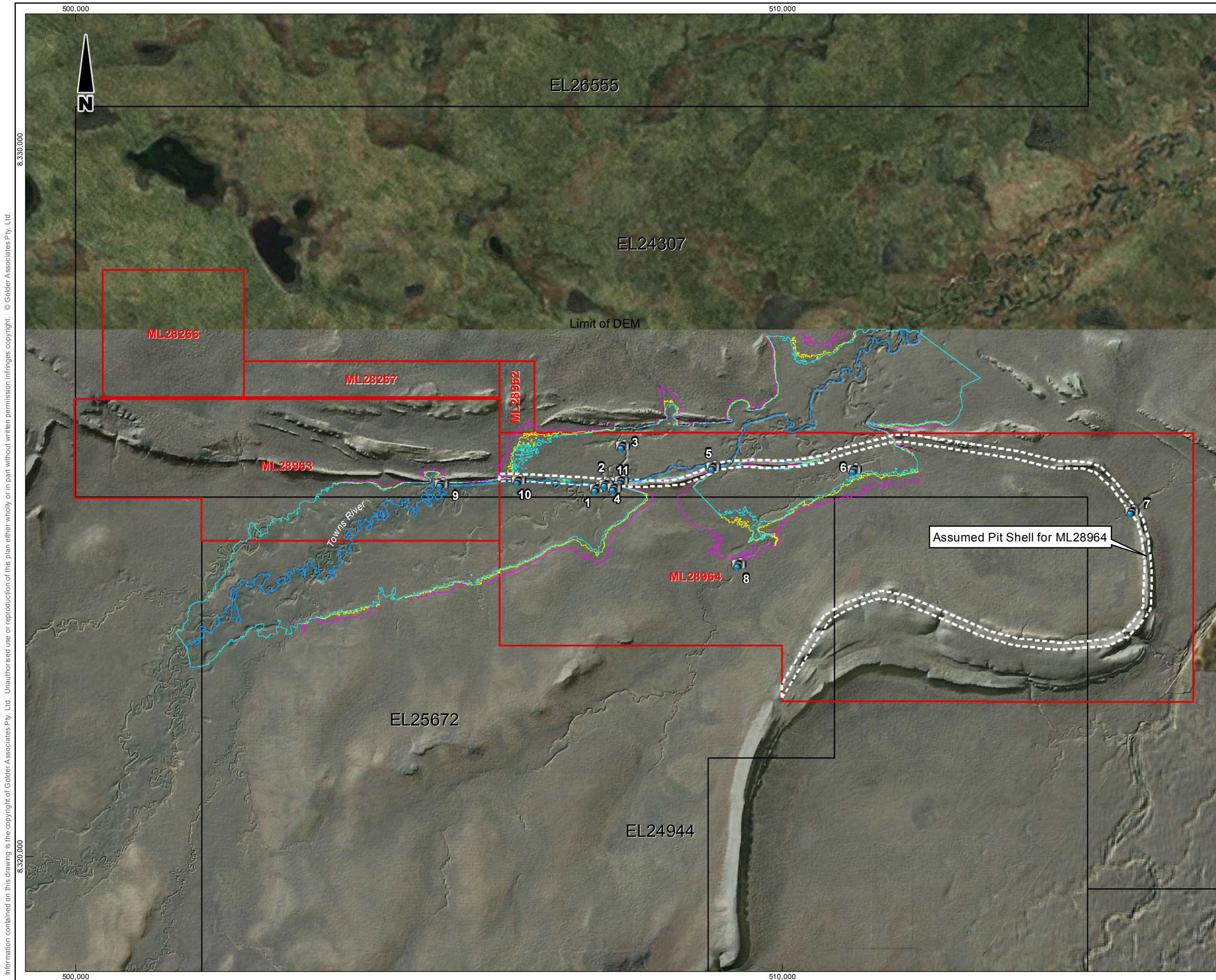
After inputting the required data into the HEC-RAS model, hydraulic simulations were performed to estimate flood levels in the creek and adjacent overbank areas. The results were then imported into ArcMap to produce flood maps of the project area for the different rainfall events. WDR provided Golder with a conceptual outline of a pit shell (ML28964), which was used to support a preliminary assessment of the implications of flooding to future mine operations and downstream users. The estimated flood maps are shown on Figure 5. Relevant photographs taken during the recent site visit and included in Appendix A are also referenced in Figure 5. Modelled cross-sections along the region where the Towns tributary intersects the assumed pit shell are shown in Appendix B. The estimated flood depth and peak velocities at each of these cross-sections are summarised in Table 5 below.



Table 5: Estimated Flood Depth and Peak Velocities

Cross-Section	ARI	Flooding Width (m)	Max. Channel Depth (m)	Max. Velocity (m/s)		
				Left Overbank	Main Channel	Right Overbank
9263.826	5	1247	2.8	0.63	1.47	0.80
	10	1271	3.1	0.69	1.51	0.86
	100	1339	3.7	0.82	1.67	1.03
8998.541	5	1179	3.3	0.63	1.70	1.08
	10	1196	3.5	0.72	1.73	1.15
	100	1238	4.2	0.82	1.85	1.32
8800.942	5	1541	3.0	0.42	1.68	1.00
	10	1762	3.2	0.48	1.62	1.00
	100	1872	3.9	0.66	1.52	1.01
8636.489	5	1511	3.2	0.51	1.21	0.75
	10	1614	3.5	0.55	1.27	0.79
	100	1764	4.2	0.71	1.34	0.88
8383.533	5	897	2.9	0.52	1.98	1.18
	10	930	3.2	0.51	1.98	1.23
	100	1695	4.0	0.72	1.33	0.89
8163.077	5	1461	3.4	0.51	1.19	0.71
	10	1531	3.7	0.56	1.21	0.74
	100	1702	4.5	0.68	1.26	0.81
7866.924	5	1665	3.6	0.63	1.07	0.49
	10	1709	3.9	0.65	1.07	0.52
	100	1872	4.7	0.72	1.11	0.60
7302.933	5	785	3.4	0.84	1.16	0.54
	10	788	3.6	0.96	1.29	0.63
	100	796	4.5	1.30	1.70	0.90
6885.308	5	781	3.4	1.18	1.72	0.79
	10	785	3.7	1.30	1.85	0.89
	100	796	4.4	1.66	2.24	1.22
6432.818	5	704	3.6	1.13	1.58	0.80
	10	706	3.8	1.28	1.76	0.94
	100	712	4.5	1.74	2.31	1.36
5888.227	5	1315	3.4	0.88	1.53	0.63
	10	1344	3.6	0.95	1.60	0.73
	100	1907	4.3	1.17	1.84	0.88

In areas where the peak velocity is predicted to exceed 2.0 m/s, erosion protection measures would be provided in accordance with Tables 5.1 and 5.2 of the Floodway Design Guide (Main Roads Western Australia, 2006).



LEGEND

- Mining Lease Boundary (approximate)
- Exploration Lease Boundary
- Modelled Channel

Flood Modelling

- 5 Year ARI Flood Extent
- 10 Year ARI Flood Extent
- 100 Year ARI Flood Extent
- Photo Location

NOTES
Coordinate System: GDA 1994 MGA Zone 53

COPYRIGHT
Detailed shaded Relief generated from Digital Elevation Model (DEM) supplied by Client.
World shaded Relief © Esri (2009)
Aerial Photography sourced from Google Earth Pro
Mining Lease boundaries digitized from plans sourced online from the Department of Resources - Northern Territory Government.
Exploration Lease boundaries supplied by Client.

0 0.45 0.9 1.35 1.8 2.25
Kilometers
SCALE (at A3) 1:50,000

Golder Associates

CLIENT Western Desert Resources Ltd
DOCUMENT 117666004-001-R-REV0
DATE 04 Apr 2012
COMPILED SR
APPROVED MG

**Roper Bar
Iron Ore Project**

FLOOD MAP

FIGURE 5

Information contained on this drawing is the copyright of Golder Associates Pty. Ltd. Unauthorised use or reproduction of this plan either wholly or in part without written permission infringes copyright. © Golder Associates Pty. Ltd.

This page has been intentionally left blank.



Flow velocities are relatively low as would be expected from the low gradients in the project area. Flow velocities for the 10 year ARI rainfall event, as an example, are presented in Figure 6. The pit area extent and respective channel and overbank average velocities are highlighted.

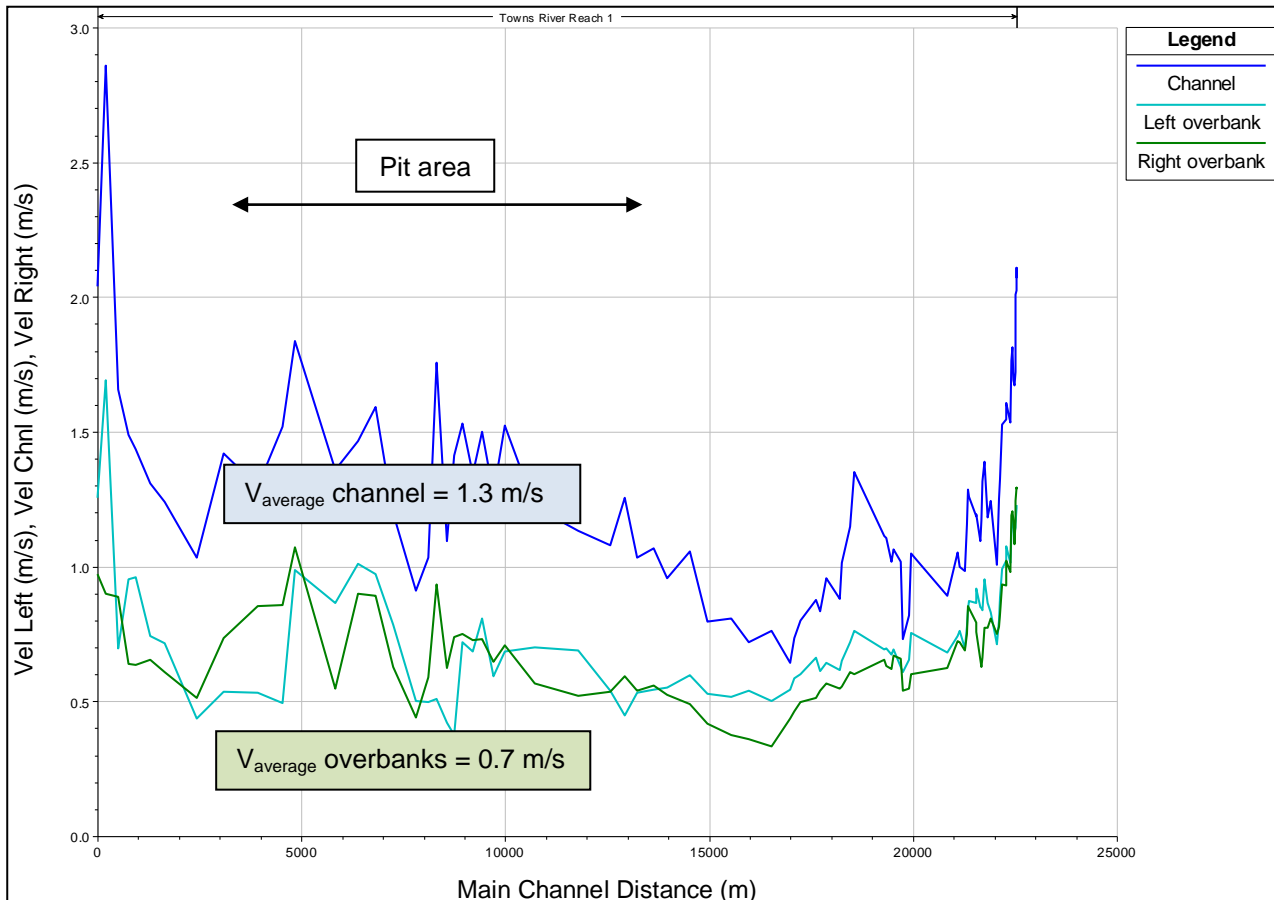


Figure 6: Flow Velocities during the 10 Year ARI Rainfall Event

7.0 POTENTIAL SURFACE WATER IMPLICATIONS TO MINE DEVELOPMENT

Given the position of the proposed pit relative to the River, it is likely that some form of flood protection measures will be required. In addition, open pit mining, in itself, will result in the accumulation of substantial quantities of runoff water within the pits that will need to be disposed of.

The form and scale of measures needed to reduce flooding risks and manage in-pit runoff waters will be dependent on the final pit arrangements and mining schedules. For example, if mining is to occur on a year-round basis then high rate pumping systems and substantial river diversions will be needed. Alternatively, if a “campaign mining” strategy and/or above-water table mining strategy are to be employed then less substantial pumping/flood mitigation systems will be needed. Other factors for consideration include WDR’s risk profile, water quality and water disposal guidelines and community and regulatory expectations (relating to river diversions, pit water disposal and post-closure pit management).

Regional scale flooding has the potential to require the largest capital investment to allow mining to continue efficiently (e.g. river diversion, pumping equipment). The results of preliminary regional scale flood modelling, undertaken as part of this study, suggests that extensive flooding of the proposed mining area will occur during larger flood events (5, 10 and 100 year ARIs). Anecdotal evidence gleaned during the site visit supports the results of the preliminary flood modelling. The main active channel is unlikely to be able to convey the larger flood events; modelling suggests that a 5 year ARI rainfall event would result in overflow of the main channel and broad scale flooding of the overbanks and flood plain.



It should be noted that a 5 year ARI rainfall event has a 20% chance of being exceeded in any one year; it does not mean that it can only occur once every 5 years. Large scale diversion was undertaken for the MRM. The associated report may provide a framework for comparable works for the Roper Bar Project, if required.

In general, a permanent and sustainable diversion solution is preferable to the use of temporary infrastructure. The progressive diversion and reinstatement of impacted watercourses (e.g. on a seasonal basis) is advantageous only in certain circumstances. The feasibility of this approach will be investigated once final pit arrangements and mining schedules are available.

8.0 CONCLUSIONS AND RECOMMENDATIONS

8.1 Conclusions

The aim of the surface water study was to gain a clearer understanding of the regional scale flooding in the upper reaches of the Towns River. Flood maps have been provided, which indicate that under certain flooding conditions the entire area is likely to be subject to inundation. It should be noted that the flood estimation approach used in this study is preliminary and not appropriate for detailed design purposes. However, it is useful for studies of this type as an order-of-magnitude assessment.

This preliminary assessment indicates the main active channel of the Towns River can accommodate only smaller flows, and the larger flood events overtop the riverbanks with flood water inundating the floodplain areas. Depths of water across the floodplain could be approximately 1 m for the 10 yr ARI flood event.

Estimated flow velocities, both within the channel and in the overbank regions, are relatively low. This is to be expected given the low gradient across the area. Potentially, this has positive (cost and design) implications for any future flood protection measures.

8.2 Recommendations

To allow mining to continue efficiently there are a number of key surface water management issues that should be addressed to feasibility level. This would only be appropriate once mine plans, pit shell arrangements, infrastructure plans and risk management assumptions have been finalised and regulatory requirements confirmed.

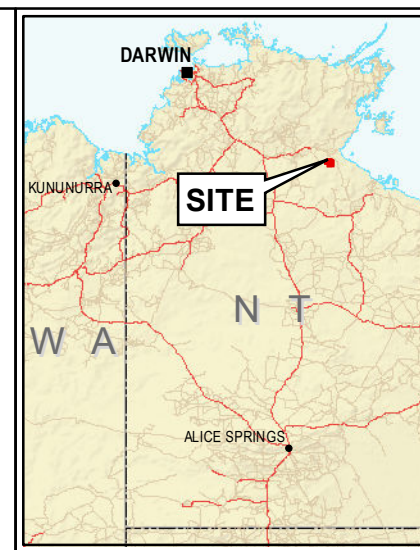
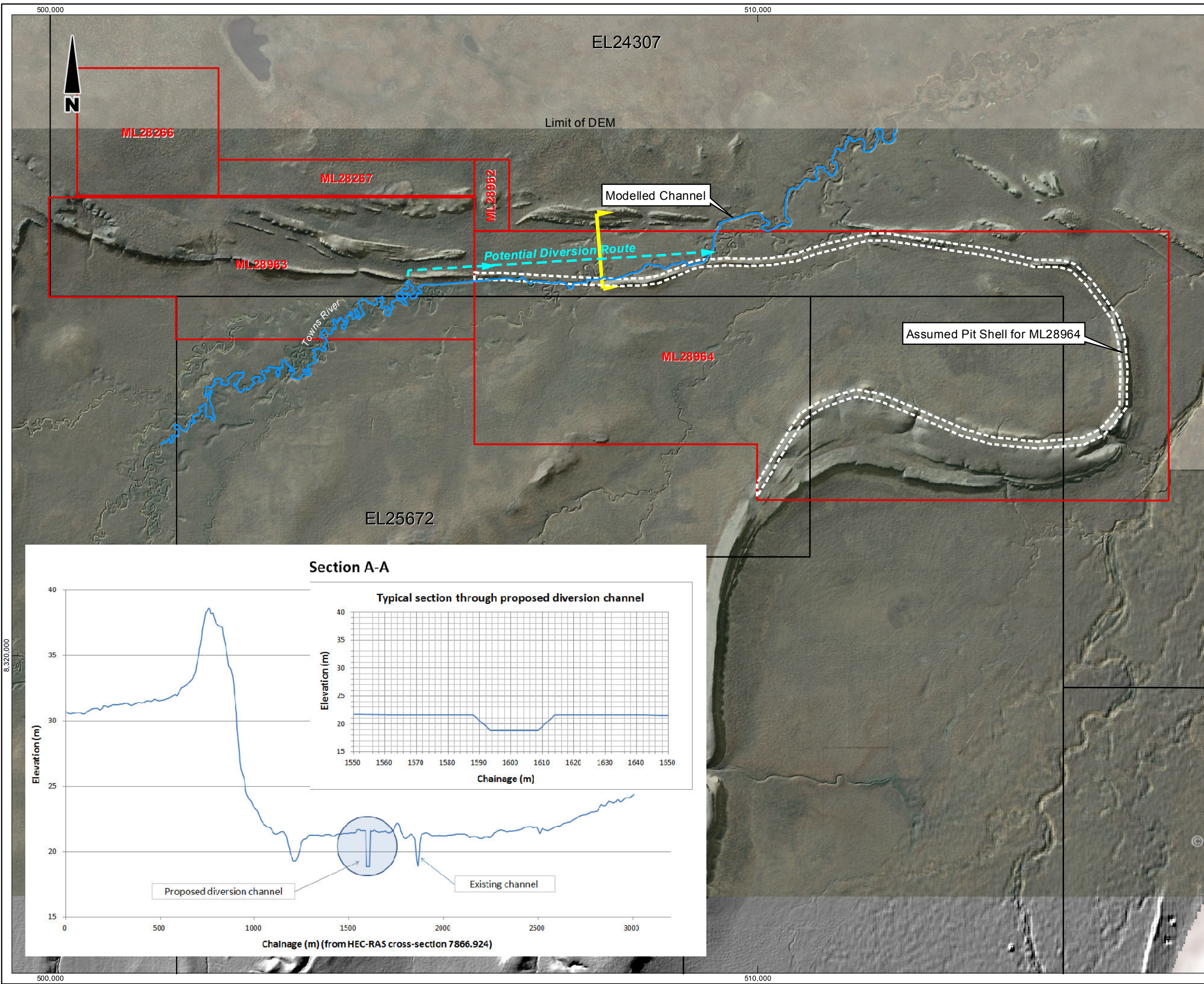
8.2.1 Regional Scale Flooding

Flooding from the river has the potential to adversely impact mining. Flood protection measures and diversion of flood waters is likely to be required.

Considering the topography of the area, there appears to be an option, at least at conceptual level, to divert floods through the natural break in the ridgeline (northwards) and then allow the water to drain eastwards back into the main active channel of the Towns River downstream of the proposed mine developments (refer to Figure 7). The flood protection works would likely comprise designed flood protection embankments and diversion channels to “force” the flood water in this direction. Additional field surveys/mapping of the project site and appropriate hydrologic and hydraulic modelling will be required to enable an optimum design for these flood protection measures. It will be important to consider mine planning, schedules and regulatory requirements at this stage.

A typical cross-section through the proposed diversion route is shown in Figure 7. A conceptual overview of the proposed diversion channel is also provided and reflects the geometry of the existing watercourse. The exact dimensions of this channel will be confirmed upon completion of more detailed hydraulic analysis.

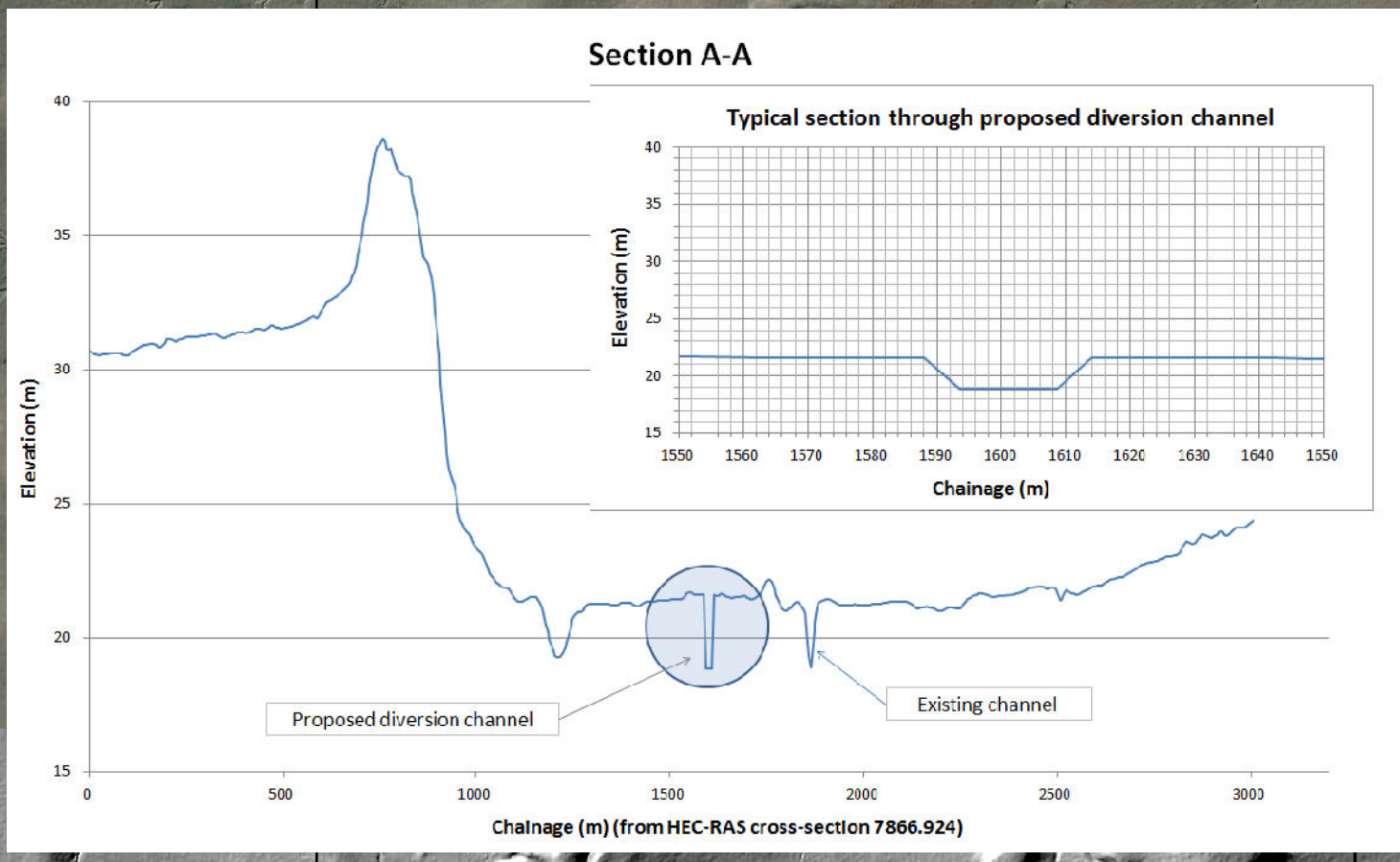
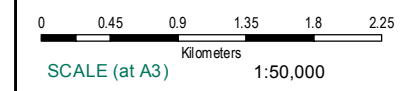
Information contained on this drawing is the copyright of Golder Associates Pty. Ltd. Unauthorised use or reproduction of this plan either wholly or in part without written permission infringes copyright. © Golder Associates Pty. Ltd.



- LEGEND**
- Section Line
 - Potential Diversion Route
 - Mining Lease Boundary (approximate)
 - Exploration Lease Boundary
 - Modelled Channel

NOTES
 Coordinate System: GDA 1994 MGA Zone 53

COPYRIGHT
 Detailed shaded Relief generated from Digital Elevation Model (DEM) supplied by Client.
 World shaded Relief © Esri (2009)
 Aerial Photography sourced from Google Earth Pro
 Mining Lease boundaries digitized from plans sourced online from the Department of Resources - Northern Territory Government.
 Exploration Lease boundaries supplied by Client.



CLIENT Western Desert Resources Ltd
DOCUMENT 117666004-001-R-REV0
DATE 04 Apr 2012
COMPILED SR
APPROVED MG

**Roper Bar
Iron Ore Project**

CONCEPT PLAN

FIGURE 7

This page has been intentionally left blank.



8.2.2 Local Scale Flooding

Local scale flooding includes runoff generated from the smaller catchments located in the immediate vicinity of the mine area. This needs to be assessed under a site specific surface water management plan. This plan would address the issues under this heading and also issues expected from regional scale flooding. Local scale flood protection facilities would comprise smaller scale diversion channels, culverts, protection bunds, floodway crossings, etc.

8.2.3 Runoff from Pit, Stockpile and Infrastructure Areas

Rainfall that lands immediately on the pit area, and on infrastructure or stockpiles resulting in water quality modification, will require management through sump collection points and pumping of waters to discharge points at ground level. Substantial infrastructure to support in-pit pumping, mine dewatering, water treatment (if required) and disposal will be required. An assessment of these water volumes is required to enable the effective management of these volumes of waters.

These recommendations need to be considered in the context of mine planning, infrastructure design and layout, and overall mine water balance.

9.0 LIMITATIONS

Your attention is drawn to the document “Limitations”, which is included as Appendix C of this report. This document is intended to assist you in ensuring that your expectations of this report are realistic, and that you understand the inherent limitations of a report of this nature. If you are uncertain as to whether this report is appropriate for any particular purpose please discuss this issue with us.



REFERENCES

- Bonzle Digital Atlas of Australia. 2011. Map of Towns River, NT. Viewed on 2 December 2011. <http://www.bonzle.com/c/a?a=p&p=204703&cmd=sp&c=1&x=134.841405&y=-15.312075&w=104571&mpsec=0>
- Bureau of Meteorology. 2011a. Commonwealth of Australia 2011. Viewed on 1 December 2011. <http://www.bom.gov.au/climate/data/>
- Bureau of Meteorology. 2011b. Commonwealth of Australia 2011. Viewed on 30 November 2011. <http://www.bom.gov.au/hydro/has/cdirswebx/cdirswebx.shtml>
- Institution of Engineers Australia. 1998. *Australian Rainfall and Runoff. Volume One - A guide to flood estimation*. Barton: The Institution of Engineers, Australia.
- Shaw, E. M. 1994. *Hydrology in Practice* (3rd edition). Oxon: Routledge.
- URS. 2005. *McArthur River Mine Open Cut Project - Draft Environmental Impact Statement*.
- Zaar, U. 2009. *Gulf Water Study - Water Resources of the Roper River Region*. Report 16/2009D. Darwin: Northern Territory of Australia. ISBN 978-1-921519-64-2.
- Main Roads Western Australia, 2009. *Floodway Design Guide*. Prepared by Main Roads Western Australia Waterways Section and BG&E Pty Ltd, authorised by ER Smith. Perth, WA.



Report Signature Page

GOLDER ASSOCIATES PTY LTD

A blue ink signature of Matt Goode, consisting of a large, sweeping initial 'M' followed by a long horizontal line.

Matt Goode
Senior Hydrologist, Team Leader

A blue ink signature of Greg Hookey, written in a cursive style.

Greg Hookey
Associate, Manager Water Services

AP-MG/GRH/hsl

A.B.N. 64 006 107 857

Golder, Golder Associates and the GA globe design are trademarks of Golder Associates Corporation.

j:\hydro\2011\roper bar_surface water\reports\117666004-001-r-rev0.docx



APPENDIX A

Site Visit: Photographs and Approximate River Geometries



APPENDIX A

Site Visit: Photographs and Approximate River Geometries

Coordinates	Photo	Approximate Channel Dimensions	Notes
1) 0507370 E 8325211 N			
2) 0507507 E 8325276 N			
3) 0507746 E 8325821 N			
4) 0507724 E 8325323 N			
5) 0509020 E 8325524 N			
6) 0511019 E 8325490 N			broad flat poorly defined channel



APPENDIX A
Site Visit: Photographs and Approximate River Geometries

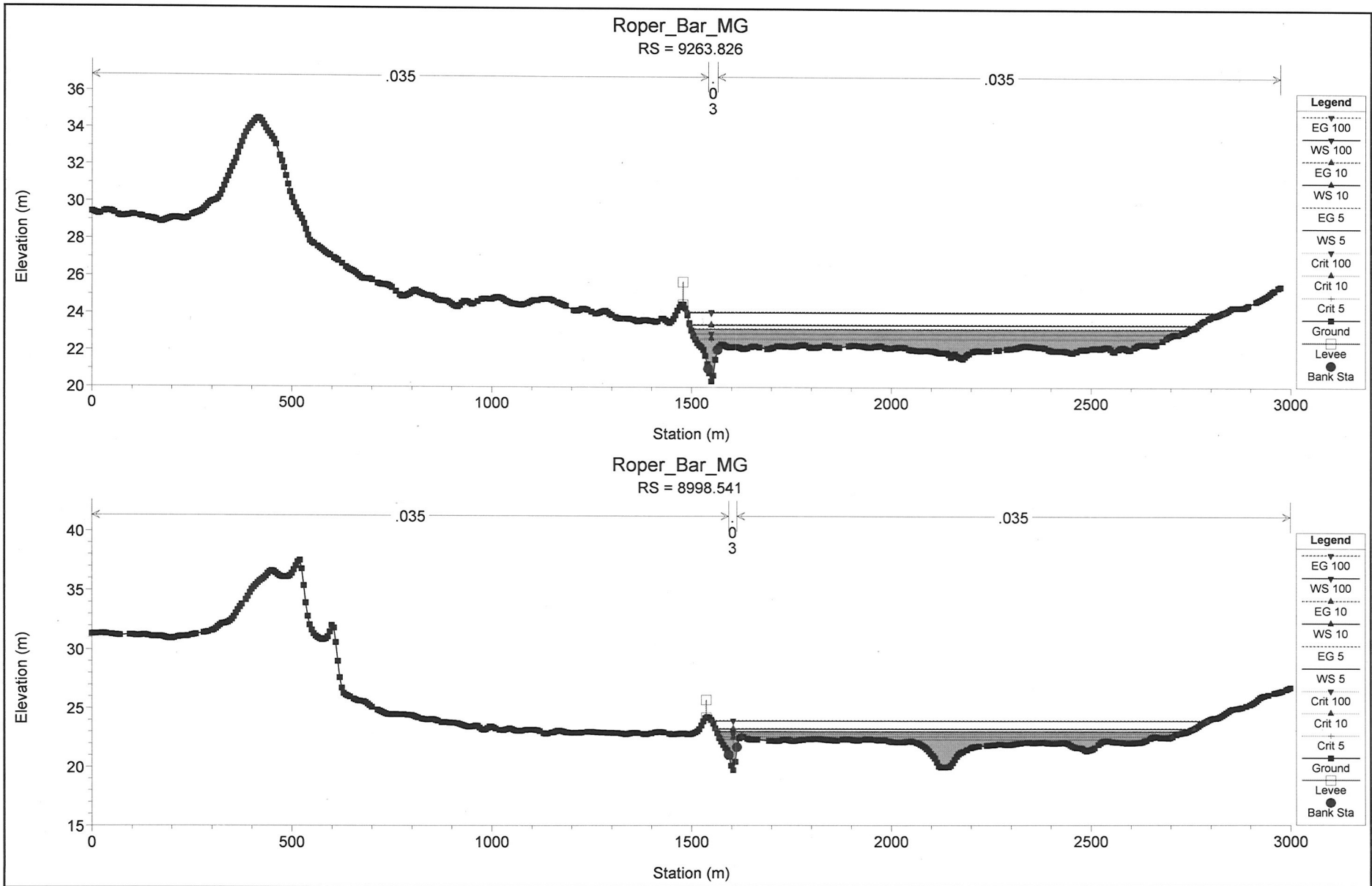
Coordinates	Photo	Approximate Channel Dimensions	Notes
7) 0514947 E 8324889 N			very "swampy" area; no defined channel; photo shows RC hole that has been artesian for 2 years, plugged with cement now
8) 0509388 E 8324140 N			swampy, no defined channel
9) 0505181 E 8325277 N			
10) 0506268 E 8325326 N			channel almost looks man made
11) 0507626 E 8325216 N			joins main creek; shows how street flows; turns to channel in small area

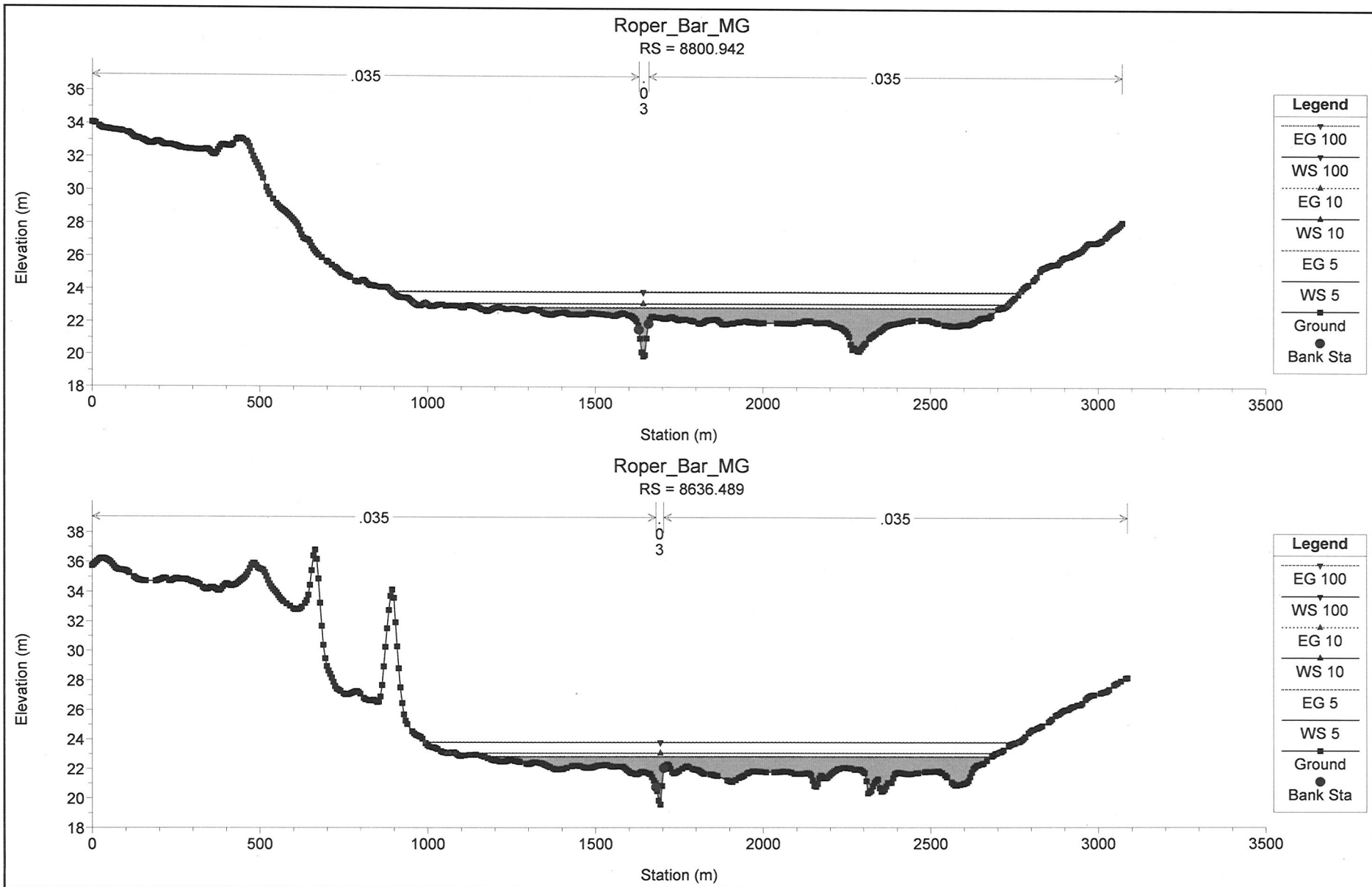
j:\hydro\2011\roper bar_surface water\reports\appendix a rev0.docx

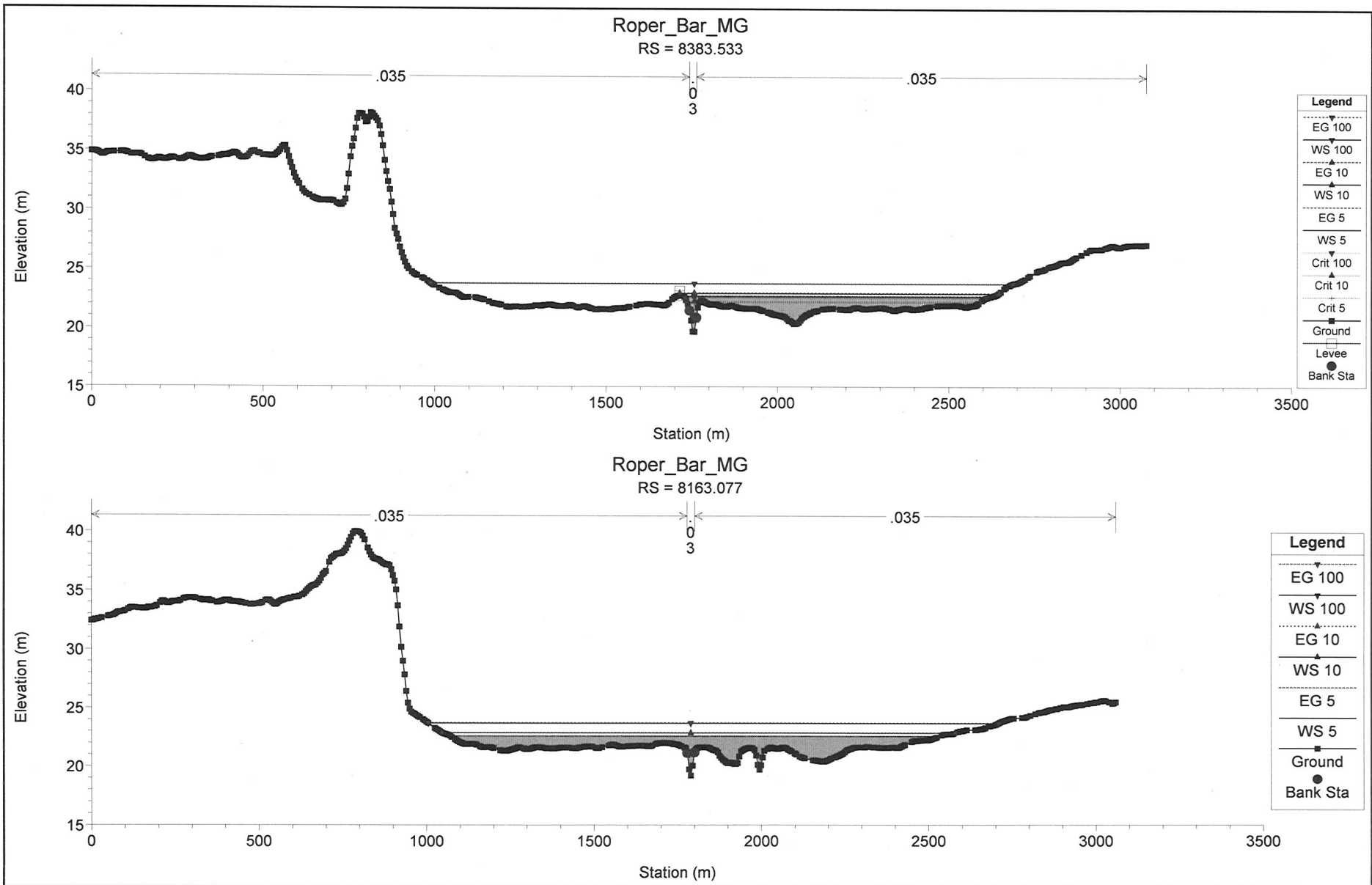


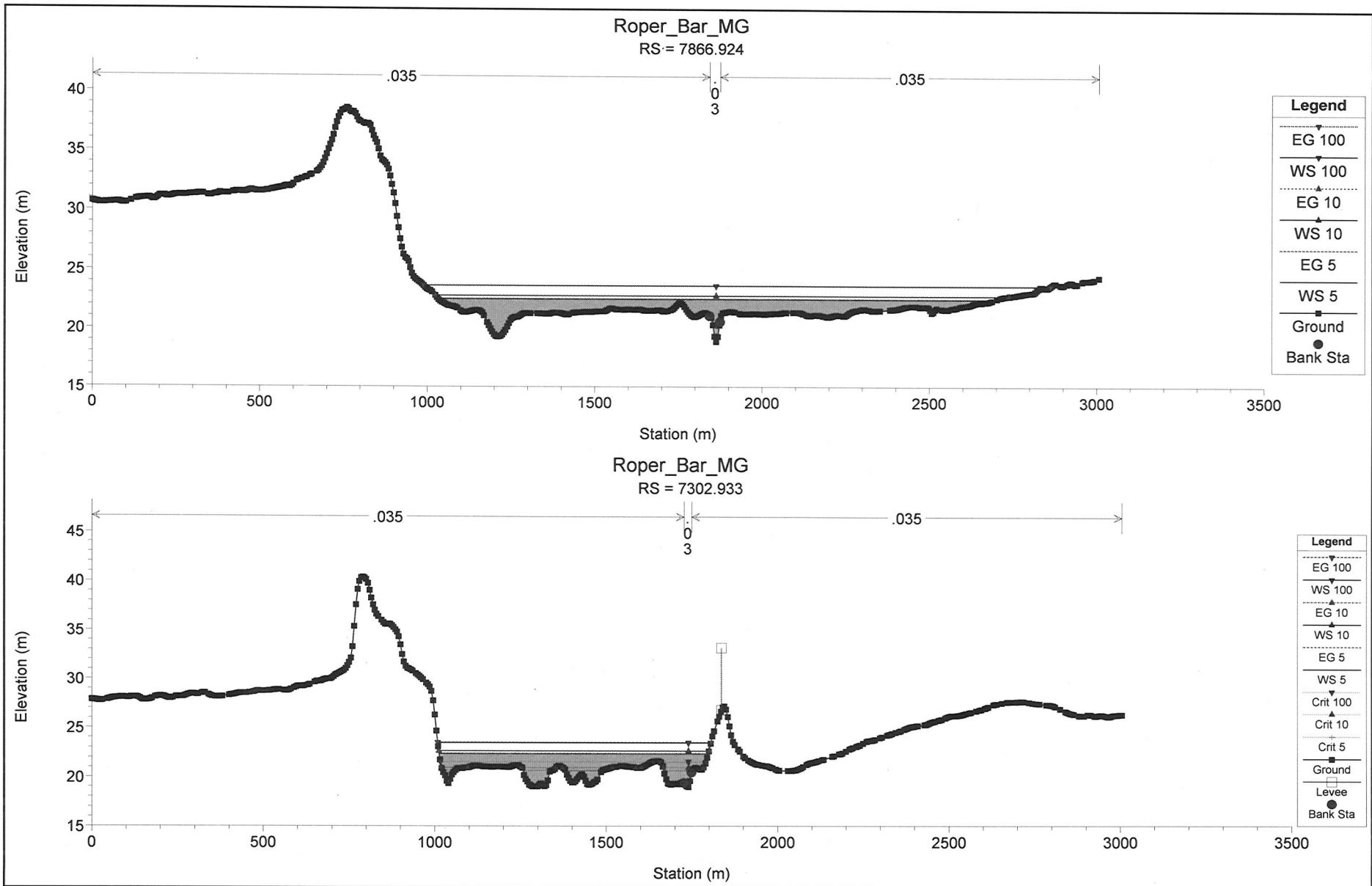
APPENDIX B

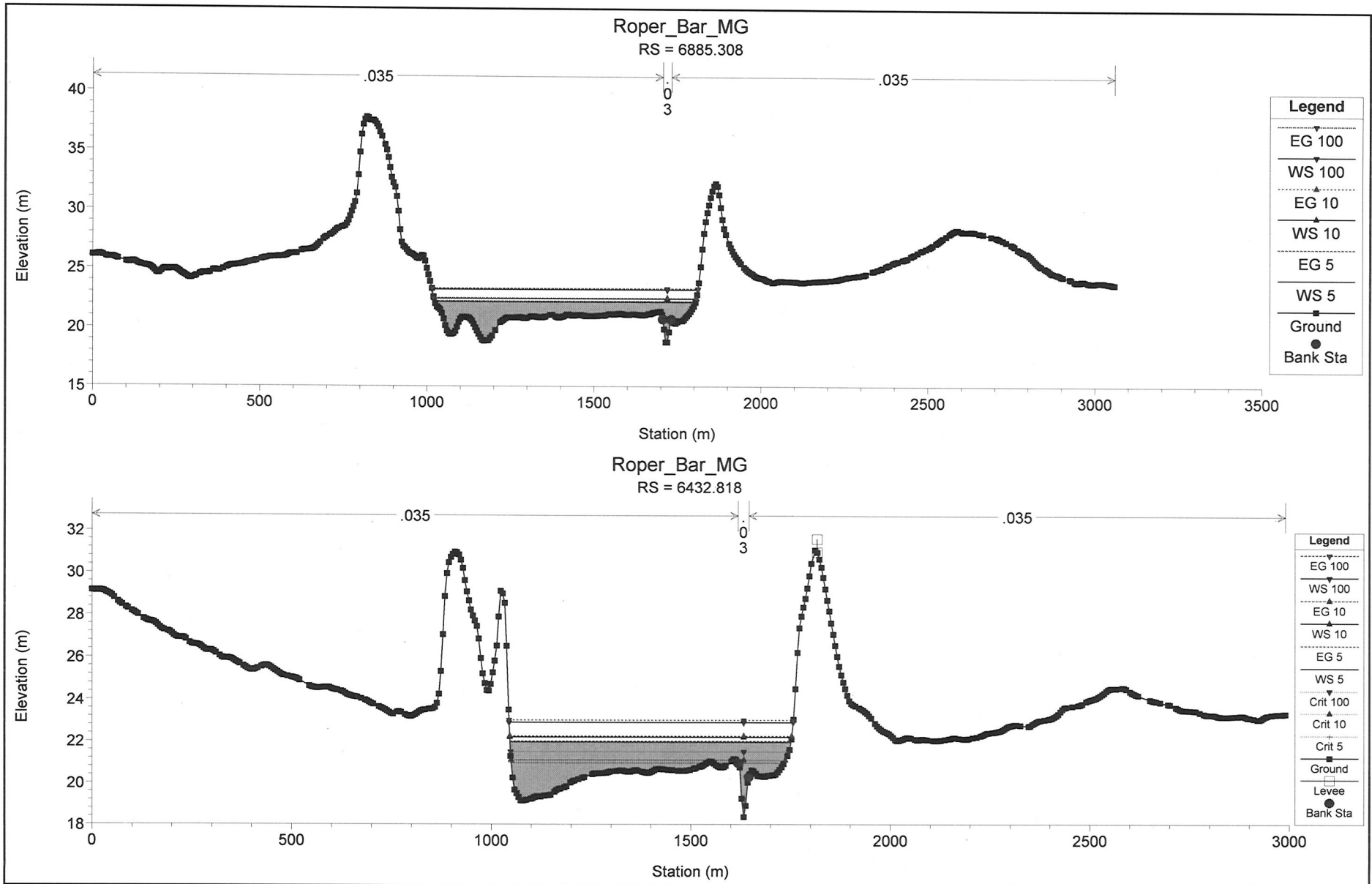
Hydraulic Analysis





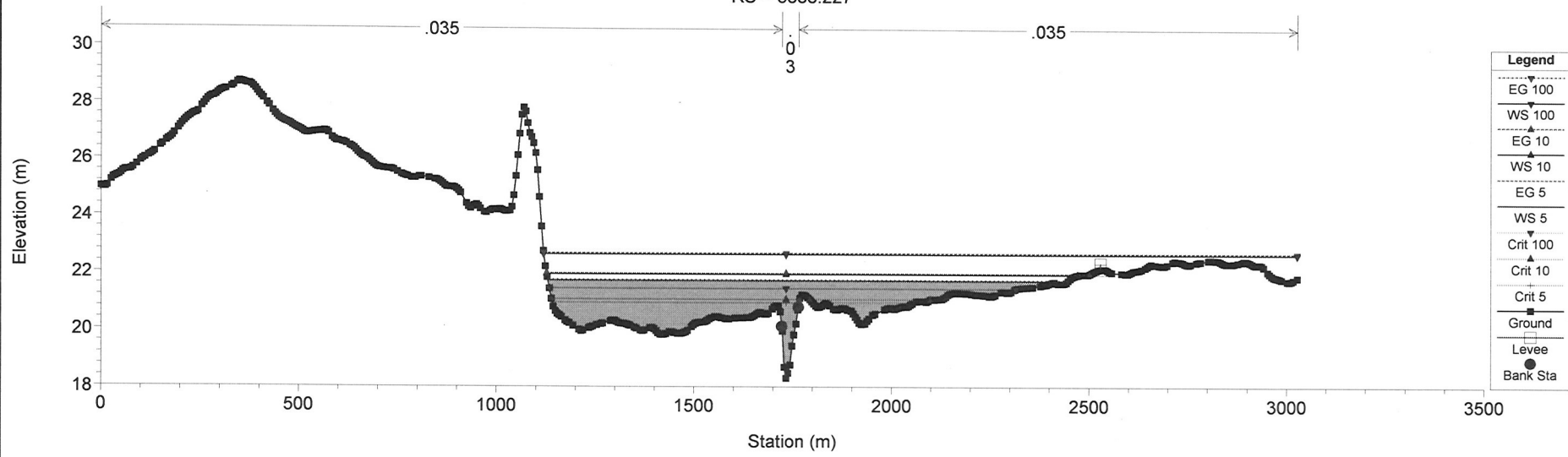






Roper_Bar_MG

RS = 5888.227





APPENDIX C

Limitations



LIMITATIONS

This Document has been provided by Golder Associates Pty Ltd ("Golder") subject to the following limitations:

This Document has been prepared for the particular purpose outlined in Golder's proposal and no responsibility is accepted for the use of this Document, in whole or in part, in other contexts or for any other purpose.

The scope and the period of Golder's Services are as described in Golder's proposal, and are subject to restrictions and limitations. Golder did not perform a complete assessment of all possible conditions or circumstances that may exist at the site referenced in the Document. If a service is not expressly indicated, do not assume it has been provided. If a matter is not addressed, do not assume that any determination has been made by Golder in regards to it.

Conditions may exist which were undetectable given the limited nature of the enquiry Golder was retained to undertake with respect to the site. Variations in conditions may occur between investigatory locations, and there may be special conditions pertaining to the site which have not been revealed by the investigation and which have not therefore been taken into account in the Document. Accordingly, additional studies and actions may be required.

In addition, it is recognised that the passage of time affects the information and assessment provided in this Document. Golder's opinions are based upon information that existed at the time of the production of the Document. It is understood that the Services provided allowed Golder to form no more than an opinion of the actual conditions of the site at the time the site was visited and cannot be used to assess the effect of any subsequent changes in the quality of the site, or its surroundings, or any laws or regulations.

Any assessments made in this Document are based on the conditions indicated from published sources and the investigation described. No warranty is included, either express or implied, that the actual conditions will conform exactly to the assessments contained in this Document.

Where data supplied by the client or other external sources, including previous site investigation data, have been used, it has been assumed that the information is correct unless otherwise stated. No responsibility is accepted by Golder for incomplete or inaccurate data supplied by others.

Golder may have retained subconsultants affiliated with Golder to provide Services for the benefit of Golder. To the maximum extent allowed by law, the Client acknowledges and agrees it will not have any direct legal recourse to, and waives any claim, demand, or cause of action against, Golder's affiliated companies, and their employees, officers and directors.

This Document is provided for sole use by the Client and is confidential to it and its professional advisers. No responsibility whatsoever for the contents of this Document will be accepted to any person other than the Client. Any use which a third party makes of this Document, or any reliance on or decisions to be made based on it, is the responsibility of such third parties. Golder accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this Document.

At Golder Associates we strive to be the most respected global company providing consulting, design, and construction services in earth, environment, and related areas of energy. Employee owned since our formation in 1960, our focus, unique culture and operating environment offer opportunities and the freedom to excel, which attracts the leading specialists in our fields. Golder professionals take the time to build an understanding of client needs and of the specific environments in which they operate. We continue to expand our technical capabilities and have experienced steady growth with employees who operate from offices located throughout Africa, Asia, Australasia, Europe, North America, and South America.

Africa	+ 27 11 254 4800
Asia	+ 86 21 6258 5522
Australasia	+ 61 3 8862 3500
Europe	+ 356 21 42 30 20
North America	+ 1 800 275 3281
South America	+ 55 21 3095 9500

solutions@golder.com
www.golder.com

Golder Associates Pty Ltd
Level 3, 1 Havelock Street
West Perth, Western Australia 6005
Australia
T: +61 8 9213 7600

