MEMORANDUM

To:	**Salt Lake Potash**	**Date:**	11 March 2019
Attn:	David Linton	**Our Ref:**	PE19-00240
		KP File Ref.:	PE801-00349/04-A dss M19004
cc:	Lloyd Edmunds	**From:**	Dean Sawyer/Dave Morgan

RE: LAKE WAY PROJECT – DEMONSTRATION PLANT FLOOD STUDY

EXECUTIVE SUMMARY

Knight Pièsold Pty Limited (KP) is currently assisting Salt Lake Potash (SO4) as part of the Demonstration Study of the Lake Way Sulphate of Potash (SOP) Project. The project is located on Lake Way approximately 20 km southeast of Wiluna in Western Australia.

KP was requested to assess the hydrology and flooding assessment of Lake Way and the potential interaction with proposed evaporation ponds which will be located on the lake surface. A nominal 700 Ha of pond is required in the vicinity of the existing Williamson Pit.

Lake Way has a considerable and varied catchment with no known flow gauging within the catchment. Due to this, accurately estimating the runoff characteristics of the catchment and its hydrologic response to rainfall is difficult and cannot be calibrated. As such this assessment is indicative to compare pre and post development flood levels. The flood levels for the lake were assumed based on work previously completed by RPS in 2015 (Ref 1). The inflow hydrographs were estimated in order to provide an indication of the impact of the proposed infrastructure on the surface water flows of the lake.

The assessment shows that the proposed ponds for the Demonstration Layout may result in an increase in the water surface elevation during flood events of 0.02 m for the 10% AEP flood and 0.04 m for the 1% AEP flood. With the ponds being located away from the edges of the lake and major inflow channels, the proposed pond layout should not have a significant impact on the ability of the flood water to flow around the lake.

1. PREVIOUS STUDIES

KP previously completed a Climatology and Hydrologic Assessment (Ref. 2) in May 2018 to form baseline storm events and design flood levels. Reference was made to the TORO Energy assessment by RPS (Ref. 1) in regards to a flooding assessment of Lake Way which was based on the effects of Cyclone Bobby in 1995.

It is noted that there is no known publically available catchment gauging in the Lake Way catchment with the nearest gauged catchment being over 500 km away in the Pilbara. Creek level gauging posts were noted in West Creek (adjacent to the Goldfields Highway floodways) but may be of limited use on their own as the creek is ephemeral.

2. STUDY OBJECTIVES

The primary objectives of the study are as follows:

- Characterise existing inflow creeks around the lake perimeter;
- Characterise existing on lake flow regimes including flood extents, velocities and depths; and
- Estimate changes to the existing on lake flow regimes due to the infrastructure required for the Demonstration Layout.

The key piece of infrastructure included in the assessment is the proposed evaporation ponds as shown on Figure 2.1. These were provided by SO4 on the 27th February 2019.

It is noted that dewatering trenches are planned on the lake surface. These were not modelled as they are not planned to be protected from flood events by any formal bund and will be allowed to flood.

3. CATCHMENT DELINEATION

Previous work had estimated the total potential catchment area of Lake Way as 11,000 km^2 (Ref. 1 & 2). However, it is noted by KP that significant areas are considered to be ineffective catchment, that is, typically during storm events the catchment does not actively produce runoff that flows into Lake Way. This is evident from the sandy surfaces in the region and defined creeks in the upper reaches disappearing in the aerial images.

The water may eventually flow into the lake via groundwater recharge, but during storms these catchments will not produce surface water runoff. KP estimates the total area of ineffective catchment as approximately 1,283 km^2 by examining the aerial images. The total catchment area and sub-catchments of Lake Way along with the areas considered to be ineffective catchment are shown on figures 3.1 and 3.2.

There are a number of other smaller lakes in the Lake Way Catchment. The most significant lakes are Lake Violet and Uramurdah Lake to the north. Both of these lakes will capture some runoff, reducing the total inflows into Lake Way. This storage has not been considered in the Lake Way runoff calculations.

Topography data of Lake Way was provided by SO4 using Lidar obtained in early 2019. The remaining regional catchments in the area used the publicly available hydrologically enforced Digital Elevation Model (DEM-H). This topographic surface was derived from data from the Shuttle Radar Topography Mission (SRTM) (Ref. 4). Geoscience Australia provides the National Surface Hydrology Database consisting of surface water hydrology lines in the region.

4. PEAK FLOW ESTIMATION

The catchments that potentially contribute runoff to Lake Way are not only vast but are also ungauged. As such, typical hydrologic modelling was not completed, instead KP developed an alternative methodology in order to estimate hydrographs for the eight most significant catchments that flow into Lake Way. This methodology utilised the previous work by RPS (Ref. 1) as well as the Australian Rainfall & Runoff (ARR) Regional Flood Frequency Estimation Model (RFFE) published in 2016.

The peak flow estimation involved a number of assumptions regarding the catchments' response. This included not taking into account Lake Violet and Uramurdah Lake. Both of these lakes, if empty during a storm event, would reduce the flow volumes that reach Lake Way. In addition, it is noted that the impact of the Goldfields Highway on catchment C01 was not taken into account. The Goldfields Highway is a raised road which has a number of culverts and floodways. The highway and these structures would attenuate flows from West Creek, likely reducing the peak flow and perhaps reducing the inflow volumes into Lake Way as well. It is also noted that West Creek splits into two distinct flow paths upstream of the Goldfields Highway, with some flow going to the south and into Lake Way while the rest of the flow goes to the East and into Lake Violet. Due to a lack of topography it was assumed the entire West Creek reports to Lake Way directly.

From the work completed by RPS, the resulting flood level on the lake for the 1% AEP event and the PMP were sourced. RPS also estimated the flood level from Cyclone Bobby and used it as a calibration check. The flood level for Cyclone Bobby was found to be 0.1 m lower than the estimated 1% AEP flood level. Using a horizontal stage storage of the lake, these flood levels were converted to flood volumes assuming no outflow from the lake occurs during events. These two data points were used to extrapolate down to what is considered to be a reasonable estimate of the 10% AEP lake volume, from which a flood level was determined. The flood levels and resulting flood volumes are listed in Table 4.1.

Table 4.1: Flood levels and volumes

Storm Event	Flood Level (m)	Flood Volume (Mm^3)
Cyclone Bobby	491.6	153.0
10% AEP	490.3	43.8
1% AEP	491.7	171.9
PMP	493.4	556.1

For each of the sub-catchments identified in Section 3, the ARR RFFE model was utilised to estimate the peak flows for a range of return intervals. It is noted that two of the catchments (C01 and C02) exceed the recommended maximum catchment size of 1,000 km^2. As such the resulting values are only indicative of what the possible peak inflows may be.

Table 4.2: ARR RFFE Peak Flows

Catchment ID	Catchment Area (m^2)	Peak Flow (m^3/s) for a given AEP	
		10% AEP	1% AEP
C01	6,400	358	923
C02	1,265	148	380
C03	31	13.7	35.2
C04	17	9.2	23.6
C05	7	4.89	12.5
C06	460	94.3	241
C07	223	63.3	162
C08	974	159	407

It is noted that RPS estimated peak flows for three sub-catchments in their study which are reasonably similar to C02, C07 and C08 of this study. The RFFE peak flow was compared to the peak flow estimated by RPS. Comparing these three catchments and the results was done as part of a cross check via different methods. The comparison is summarised in Table 4.3.

Table 4.3: Peak flow comparison

Catchment ID	RFFE Peak Flow (m^3/s)	RPS Peak Flow (m^3/s)
C02	380	344
C07	162	104
C08	407	475

Utilising the volumes listed in Table 4.1 (pro-rated to each catchment by area) and the peak flows listed in Table 4.2, hydrographs for the eight assessed catchments were developed. The hydographs were assumed to be triangular, peaking at the calculated RFFE value with an overall duration long enough so that the required volume (area under the hydrograph) from each catchment was achieved.

The durations selected were rounded up to the nearest 0.1 hour for modelling purposes. This resulted in a slight overestimation of the flood volume. Rainfall directly onto the lakes surface was not taken into account. The resulting hydrograph durations and total volumes for each catchment are summarised in tables 4.4 and 4.5.

Table 4.4: Hydrograph Inputs – 10% AEP

Catchment ID	Peak Flow (m^3/s)	Hydrograph Duration (h)	Volume (m^3)
C01	358	46.6	30,029,000
C02	148	22.2	5,914,000
C03	13.7	6.0	148,000
C04	9.2	5.0	83,000
C05	4.89	3.6	32,000
C06	94.3	12.8	2,173,000
C07	63.3	9.2	1,048,000
C08	159	16.0	4,579,000
		Total Volume	44,006,000

Table 4.5: Hydrograph Inputs – 1% AEP

Catchment ID	Peak Flow (m^3/s)	Hydrograph Duration (h)	Volume (m^3)
C01	923	70.8	117,627,000
C02	380	34.0	23,256,000
C03	35.2	9.2	583,000
C04	23.6	7.4	314,000
C05	12.5	5.4	122,000
C06	241	19.6	8,502,000
C07	162	14.0	4,082,000
C08	407	24.4	17,875,000
		Total Volume	172,361,000

The triangular hydrographs developed are shown on Figure 4.1. All were assumed to commence at the same time. This resulted in the West Creek (C01) having the longest time to peak but the overall peak occurring between 6 – 12 hours.

5. HYDRAULIC ASSESSMENT

A total of four scenarios were assessed hydraulically using the two dimensional hydrodynamic modelling software Riverflow2D. The four scenarios are pre-existing conditions for the 10% AEP and 1% AEP inflow hydrographs and the post construction conditions (assuming the Demonstration Layout ponds) for the same events.

The model assumed the hydrographs as described in Section 4 applied independently to each catchment reach. A uniform Manning's roughness of 0.025 was applied to the model area. Transient flow models were run until the water surface elevation in the lake equalised after inflow ceases, noting there is no outflow from the model.

The maximum flow velocities for the four scenarios are shown on figures 5.1 to 5.4. The maximum flow depths for the four scenarios are shown on figures 5.5 to 5.8.

The change in final Water Surface Elevation (WSE) between the pre-existing and post construction hydraulic models is summarised in Table 5.1. The difference is essentially the subtraction of storage volume due to the Demonstration Layout ponds.

Table 5.1: Change in Water Surface Elevation

Return Interval (years)	Pre-existing Conditions WSE (m)	Post Construction Conditions WSE (m)	Change in WSE (m)
10	490.93	490.95	0.02
100	491.72	491.76	0.04

This change in water surface elevation was also checked by comparing horizontal stage storages of the lake with and without the Demonstration Layout ponds. The resulting relationship between lake volume and increase in flood level due to the ponds is shown on Figure 5.9.

6. FLOOD IMPACTS

Reviewing the results of the hydraulic modelling shows that the impact to Lake Way is that the flood levels will be slightly higher (40 mm) during significant flood events. The increase is directly proportional to the proposed Demonstration Layout pond area compared to the flooded lake area.

This may equate to a wider inundation area in the very flat terrain around some edges of the lake. Given the limited lake level monitoring and low return interval of events, the effects would be difficult to measure in the field. Any events smaller than 10% AEP would likely be too small and only inundate the lower portions of the lake and may be affected by wind direction.

The duration of this increased impact may only be short due to the increased infiltration into the lake bed during brine abstraction. There will generally be a thicker unsaturated zone above the water table during operation.

With the location selection of the ponds, flow paths around the lake are not significantly impacted, with flood water still able to flow around the lake system. Creek inflows from the west, specifically West Creek, can still navigate to the deeper portions of the lake in the southeast. The trenches have not been modelled on the assumption that they are allowed to flood.

Only slight elevated velocities are noted at the sharp corners of pond but well below erosion protection requirements or the need to round off pond corners. The pond embankments should be constructed to a nominal 300mm above the 1% AEP flood level to prevent inflow of flood water in to the pond.

We trust this is sufficient information for your current requirements. If you have any questions please contact us.

Yours faithfully
KNIGHT PIÉSOLD PTY LTD

DEAN SAWYER
Senior Engineer

DAVID MORGAN
Managing Director

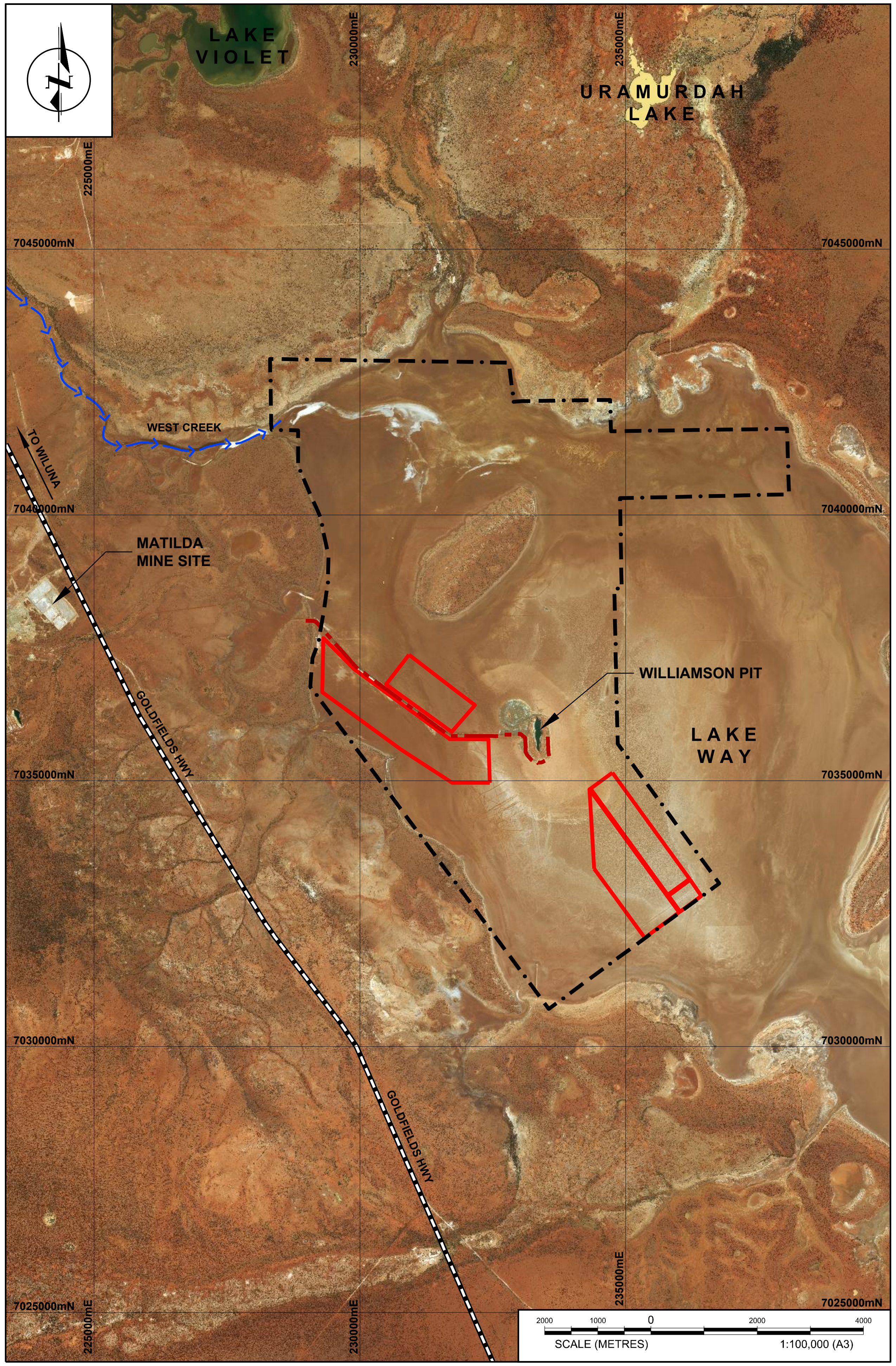
REFERENCES

1. RPS Group 2015, "*Wiluna Uranium Project – Surface Hydrology Studies*", Rev C.
2. Knight Piésold, May 2018, "*Lake Way Project – Climatology and Hydrologic Assessment*", Rev 1.
3. Commonwealth of Australia (Geosciences Australia) 2011, "*1 arc second SRTM DEM-H*".

FIGURES

SITE LOCATION MAP

N.T.S.



PROJECT AREA LAYOUT

1:100,000

LEGEND:

- LEASE BOUNDARY
- ACCESS ROAD ALIGNMENT
- DEMONSTRATION POND EXTENT

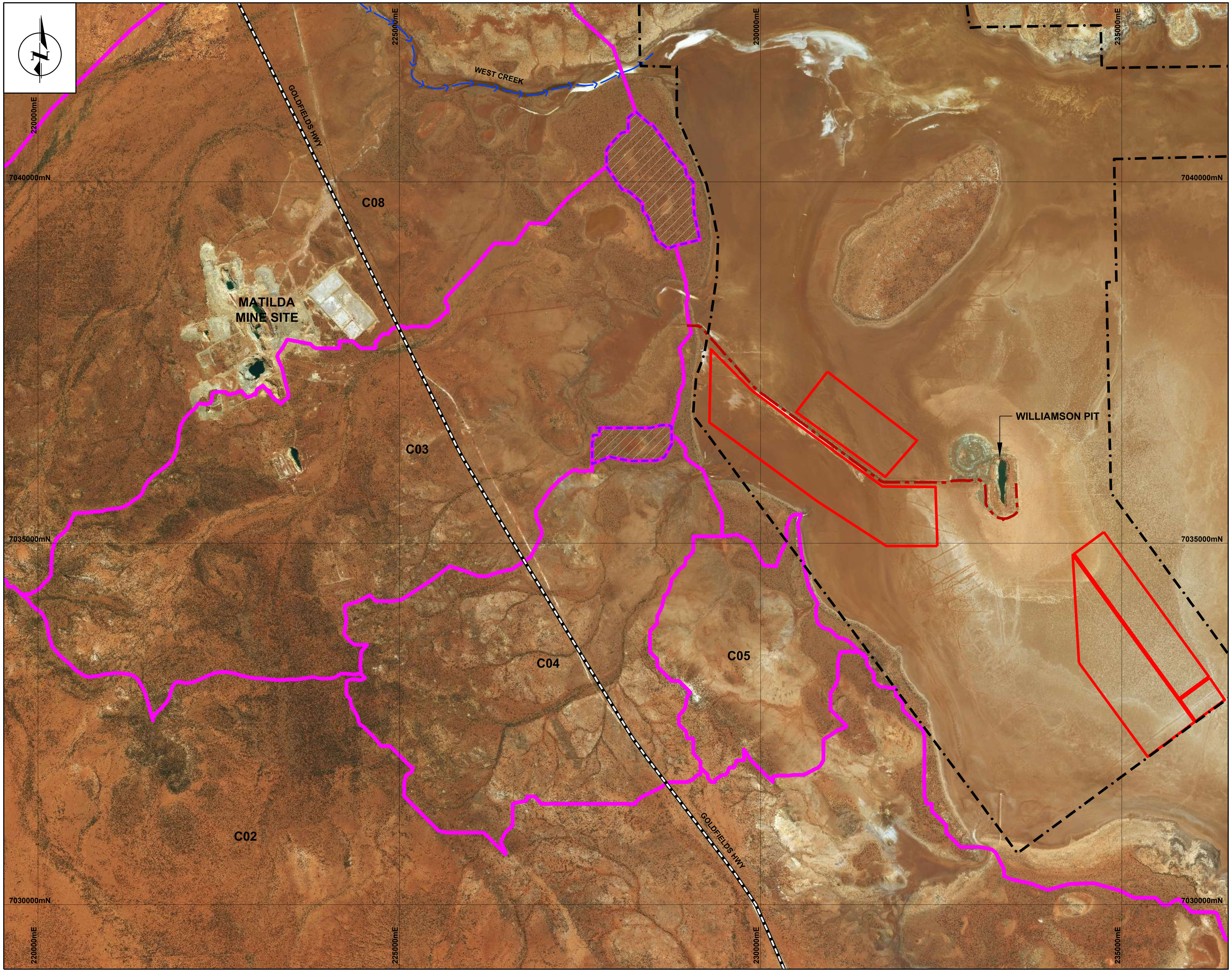
NOTES:

1. ALL COORDINATES SHOWN IN GRID PROJECTION MGA94 ZONE 51.
2. AERIAL IMAGERY COURTESY OF MICROSOFT CORPORATION, DIGITAL GLOBE, CNES, DISTRIBUTION AIRBUS DS.

Knight Piésold CONSULTING

LAKE WAY PROJECT
UPDATED FLOOD STUDY
SITE LOCATION AND LAYOUT

PE801-00349 M19004
Figure 2.1



LEGEND:

- LEASE BOUNDARY
- CATCHMENT BOUNDARY (EFFECTIVE)
- CATCHMENT BOUNDARY (INEFFECTIVE)
- ACCESS ROAD ALIGNMENT
- DEMONSTRATION POND EXTENT

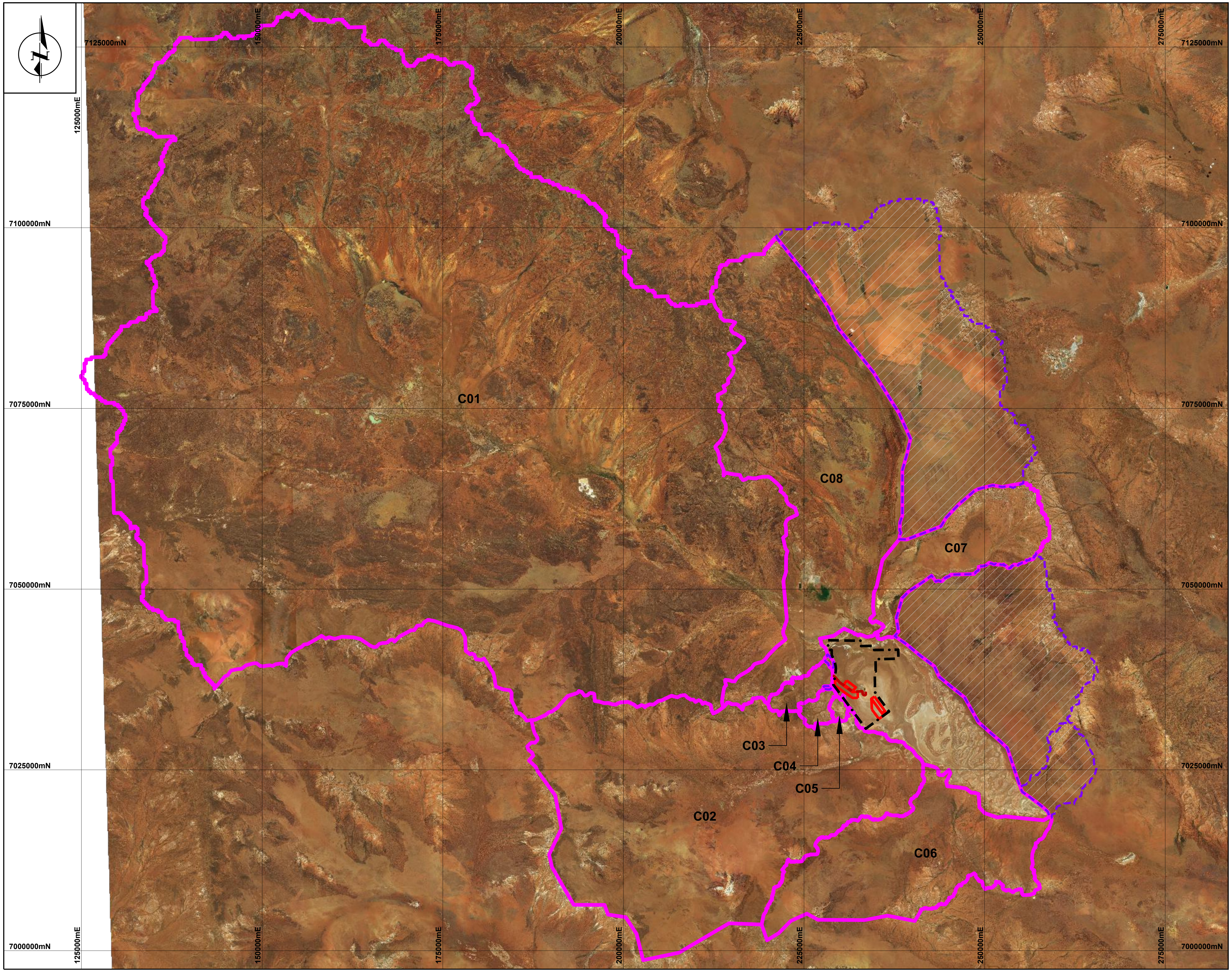
NOTES:

1. ALL COORDINATES SHOWN IN GRID PROJECTION MGA94 ZONE 51.
2. AERIAL IMAGERY COURTESY OF MICROSOFT CORPORATION, DIGITAL GLOBE, CNES, DISTRIBUTION AIRBUS DS.

Knight Piésold CONSULTING

LAKE WAY PROJECT
UPDATED FLOOD STUDY
LOCAL CATCHMENTS LAYOUT

PE801-00349 M19004
Figure 3.2



LEGEND:

- LEASE BOUNDARY
- CATCHMENT BOUNDARY (EFFECTIVE)
- CATCHMENT BOUNDARY (INEFFECTIVE)
- ACCESS ROAD ALIGNMENT
- DEMONSTRATION POND EXTENT

NOTES:

1. ALL COORDINATES SHOWN IN GRID PROJECTION MGA94 ZONE 51.
2. AERIAL IMAGERY COURTESY OF MICROSOFT CORPORATION, DIGITAL GLOBE, CNES, DISTRIBUTION AIRBUS DS.

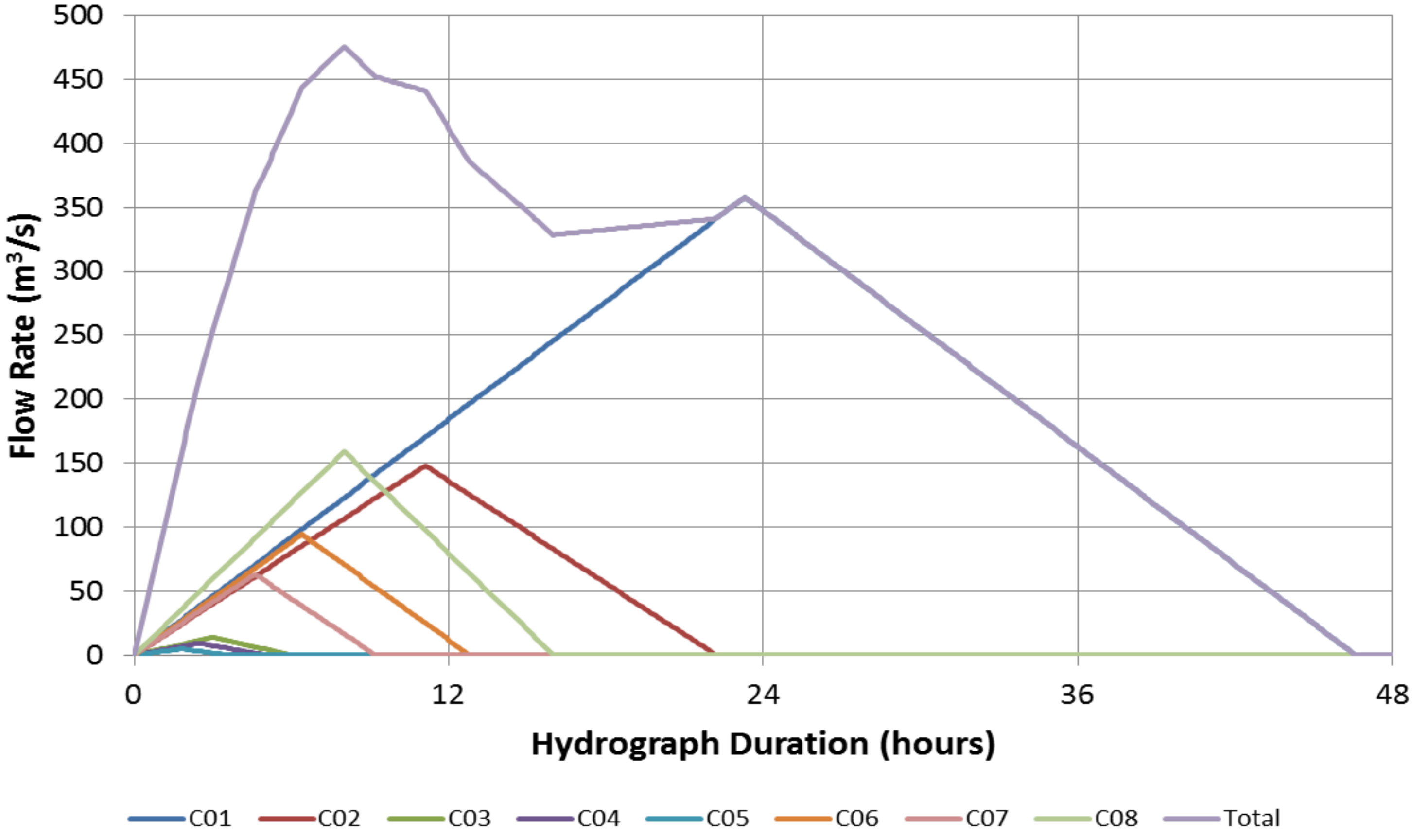
10000 5000 0 5000 10000 15000 20000

SCALE (METRES) 1:500,000 (A3)

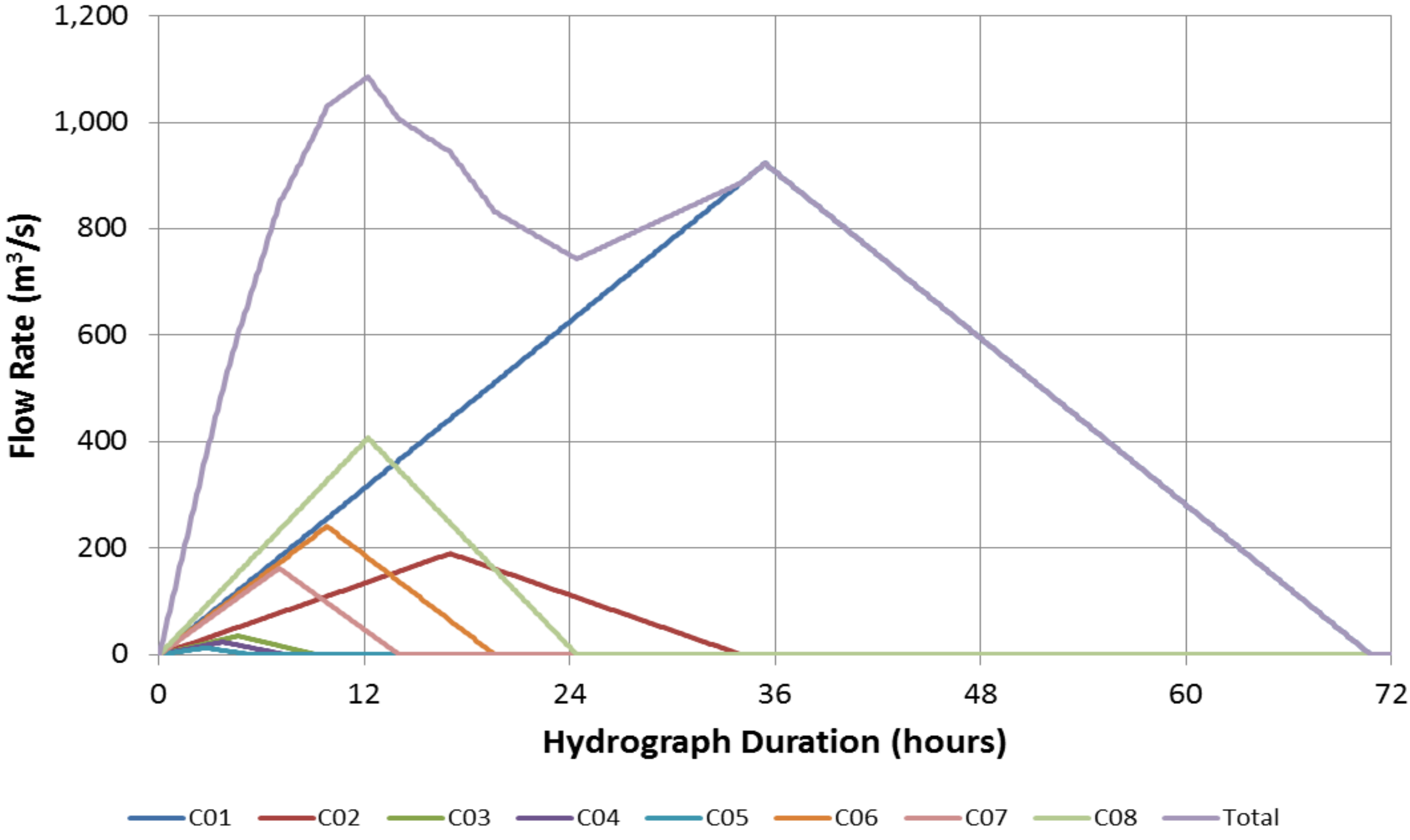
Knight Piésold CONSULTING

LAKE WAY PROJECT
UPDATED FLOOD STUDY
OVERALL SITE CATCHMENTS LAYOUT

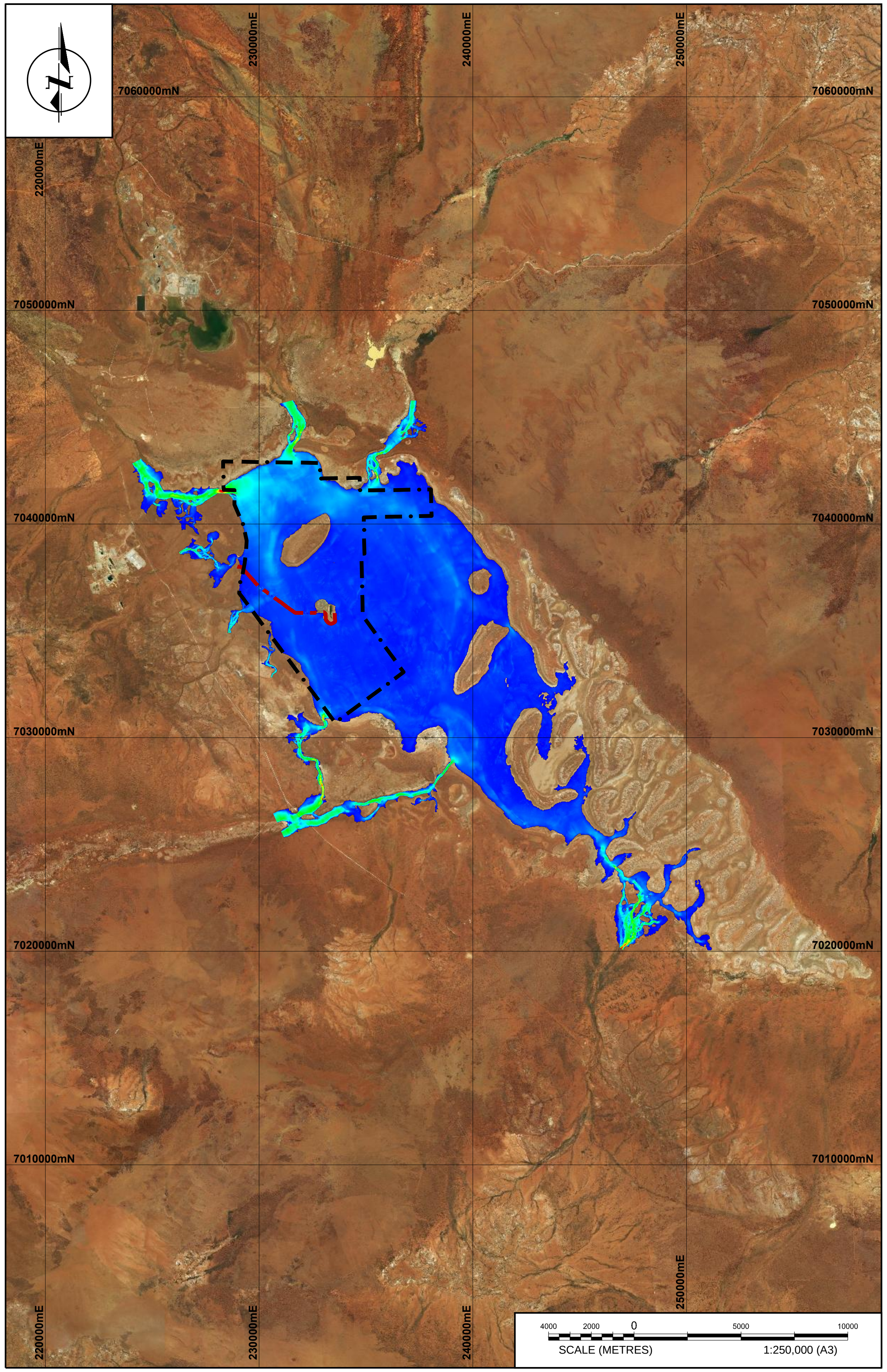
PE801-00349 M19004
Figure 3.1



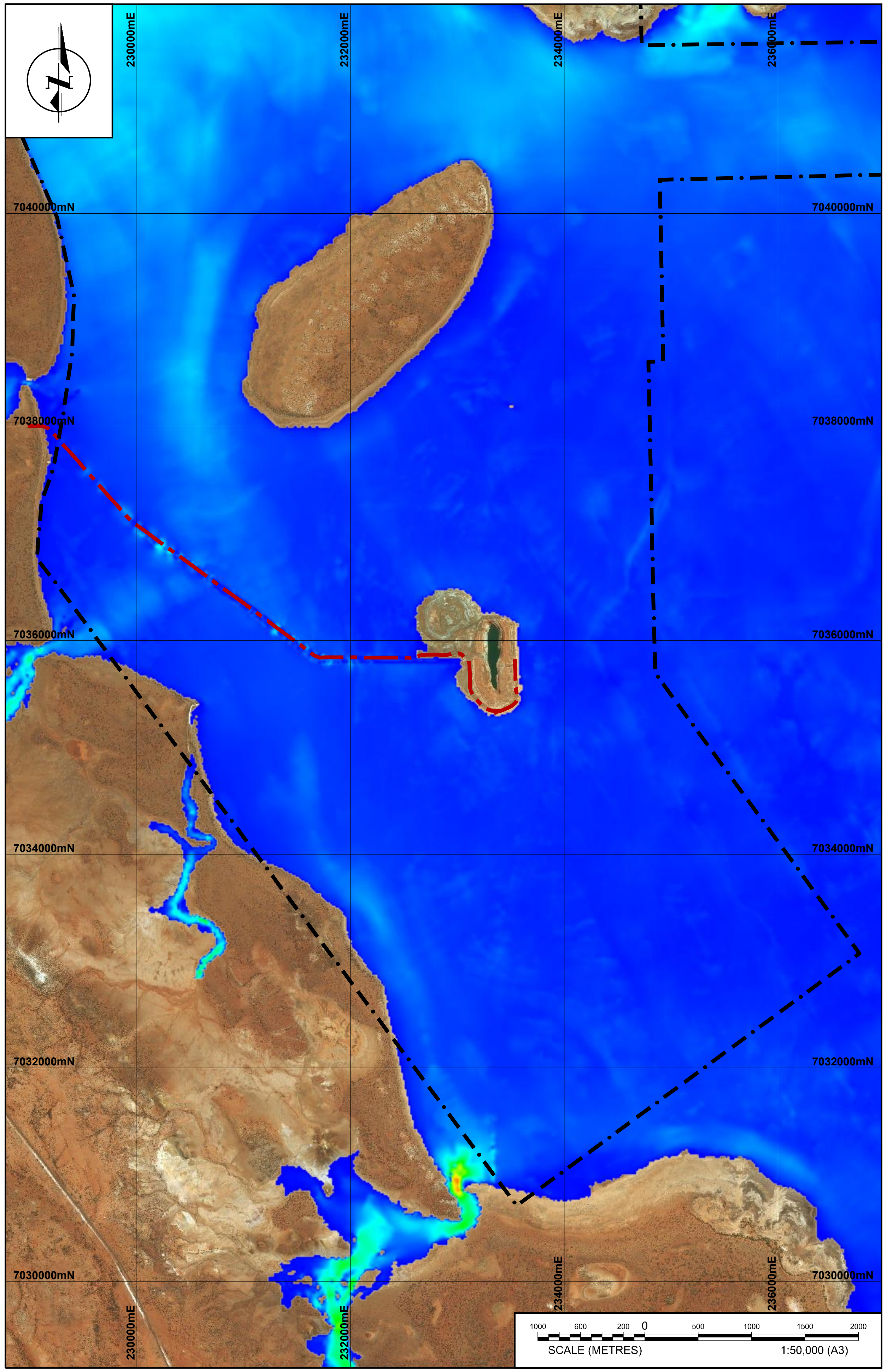
10 YEAR ARI HYDROGRAPHS



100 YEAR ARI HYDROGRAPHS



SITE OVERVIEW LAYOUT
1:250,000



FOCUS AREA LAYOUT
1:50,000

LEGEND:

- LEASE BOUNDARY
- ACCESS ROAD ALIGNMENT

MAXIMUM VELOCITY KEY:

≥ 2.0
1.5
1.0
0.5
0.0

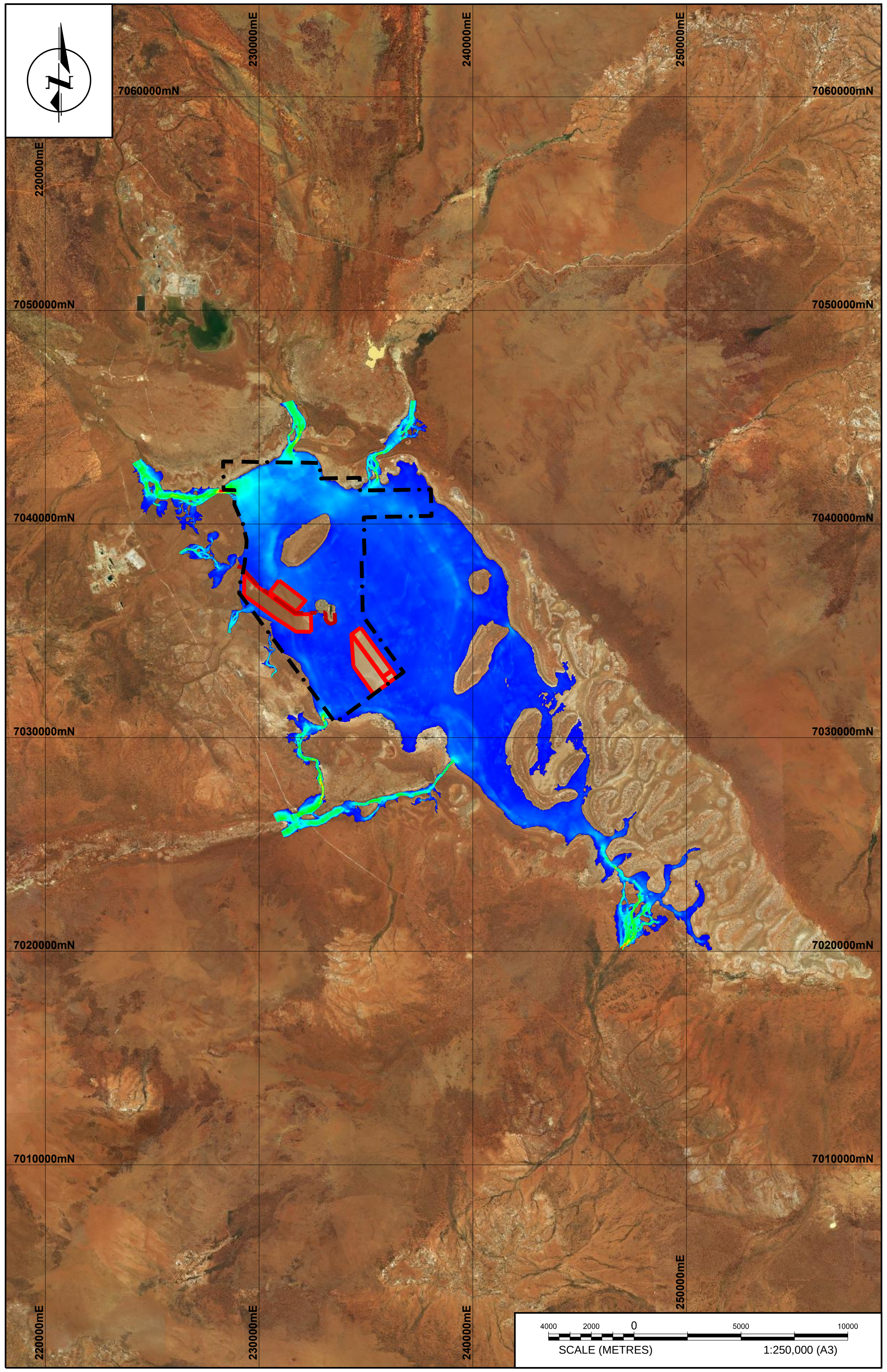
NOTES:

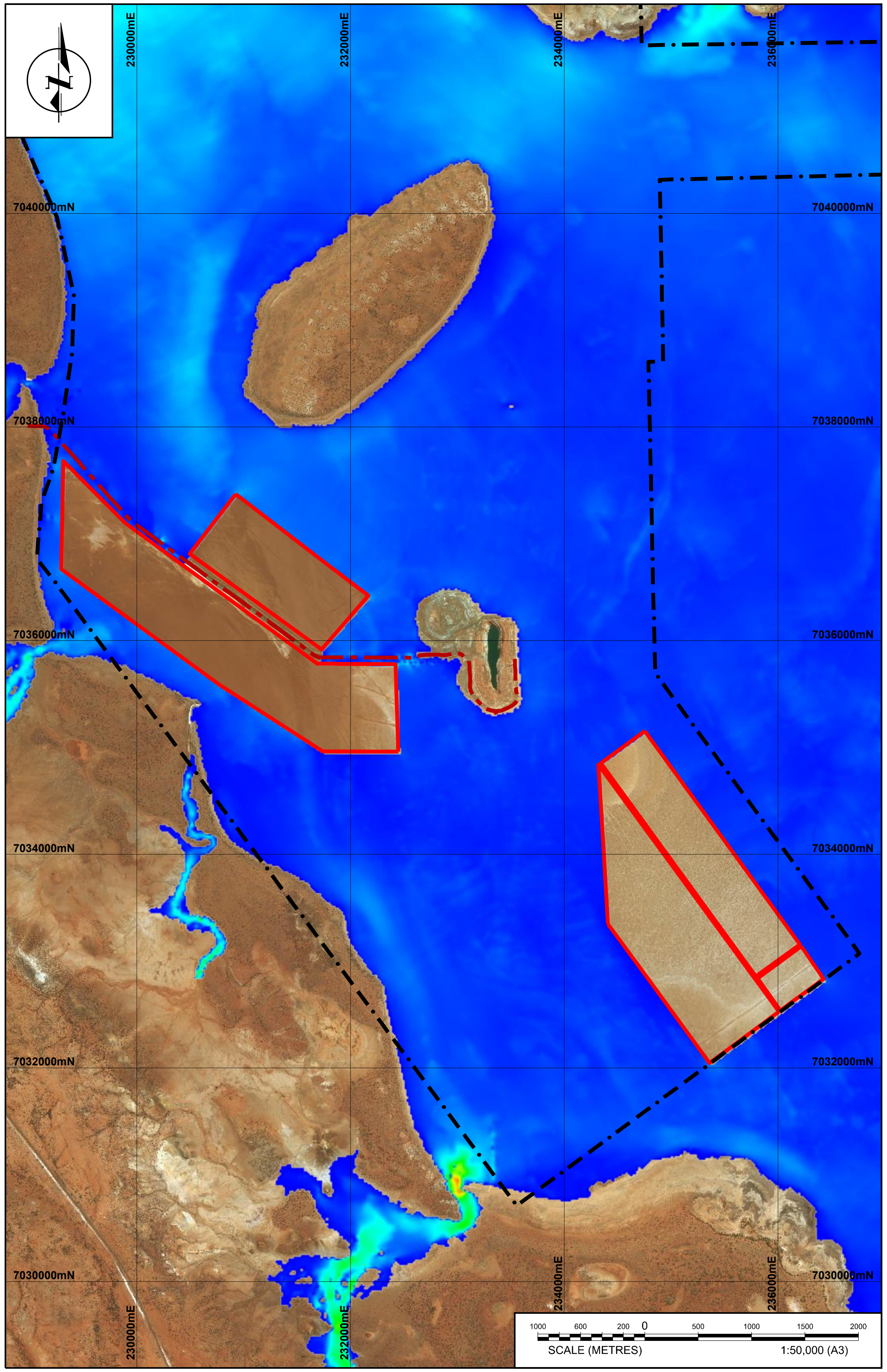
1. ALL COORDINATES SHOWN IN GRID PROJECTION MGA94 ZONE 51.
2. AERIAL IMAGERY COURTESY OF MICROSOFT CORPORATION, DIGITAL GLOBE, CNES, DISTRIBUTION AIRBUS DS.

Knight Piésold CONSULTING

LAKE WAY PROJECT
UPDATED FLOOD STUDY
MAXIMUM VELOCITY PRE-EXISTING CONDITIONS (10% AEP)

PE801-00349 M19004
Figure 5.1





LEGEND:

- LEASE BOUNDARY
- ACCESS ROAD ALIGNMENT
- DEMONSTRATION POND EXTENT

MAXIMUM VELOCITY KEY:

≥ 2.0
1.5
1.0
0.5
0.0

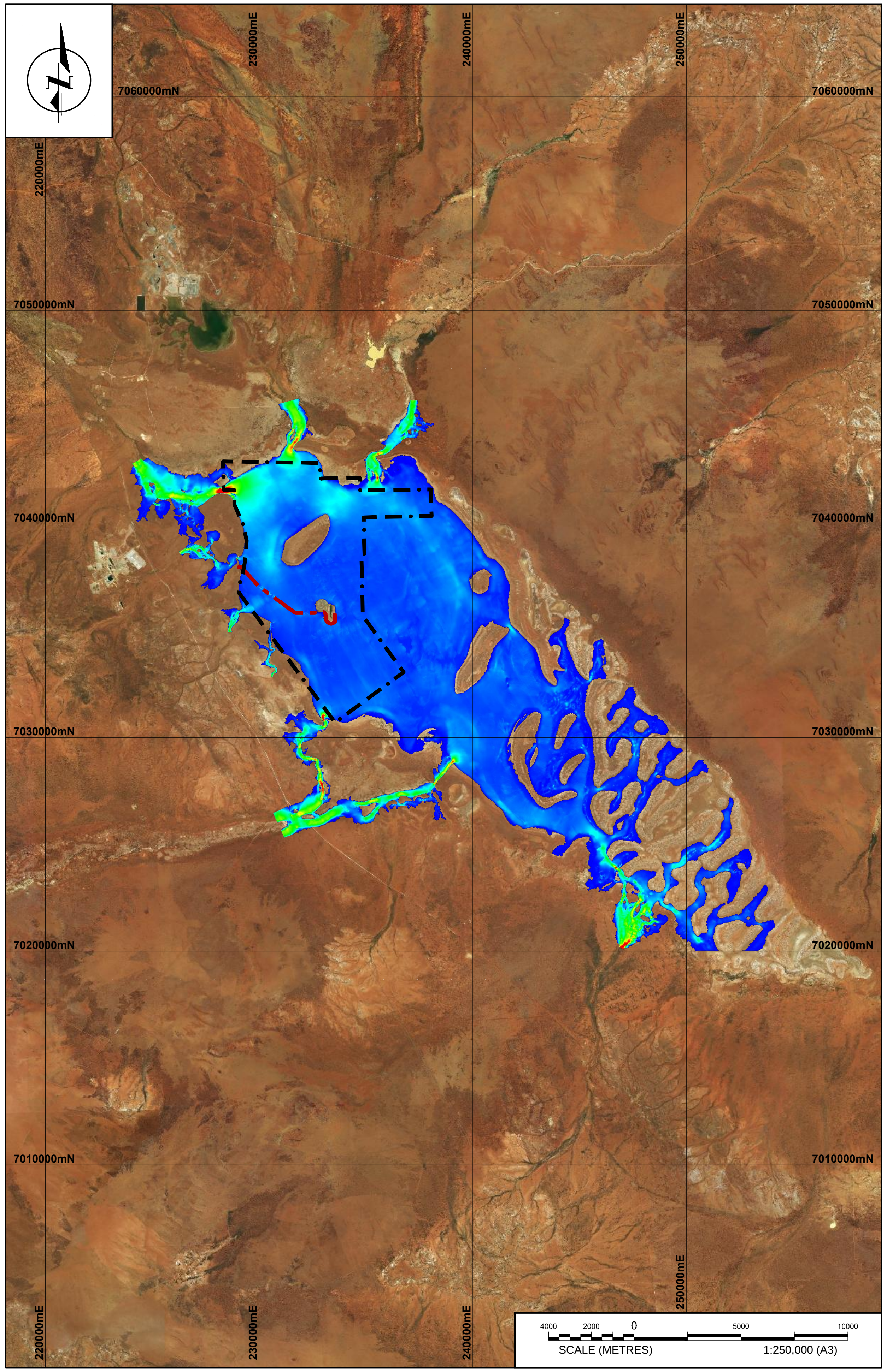
NOTES:

1. ALL COORDINATES SHOWN IN GRID PROJECTION MGA94 ZONE 51.
2. AERIAL IMAGERY COURTESY OF MICROSOFT CORPORATION, DIGITAL GLOBE, CNES, DISTRIBUTION AIRBUS DS.

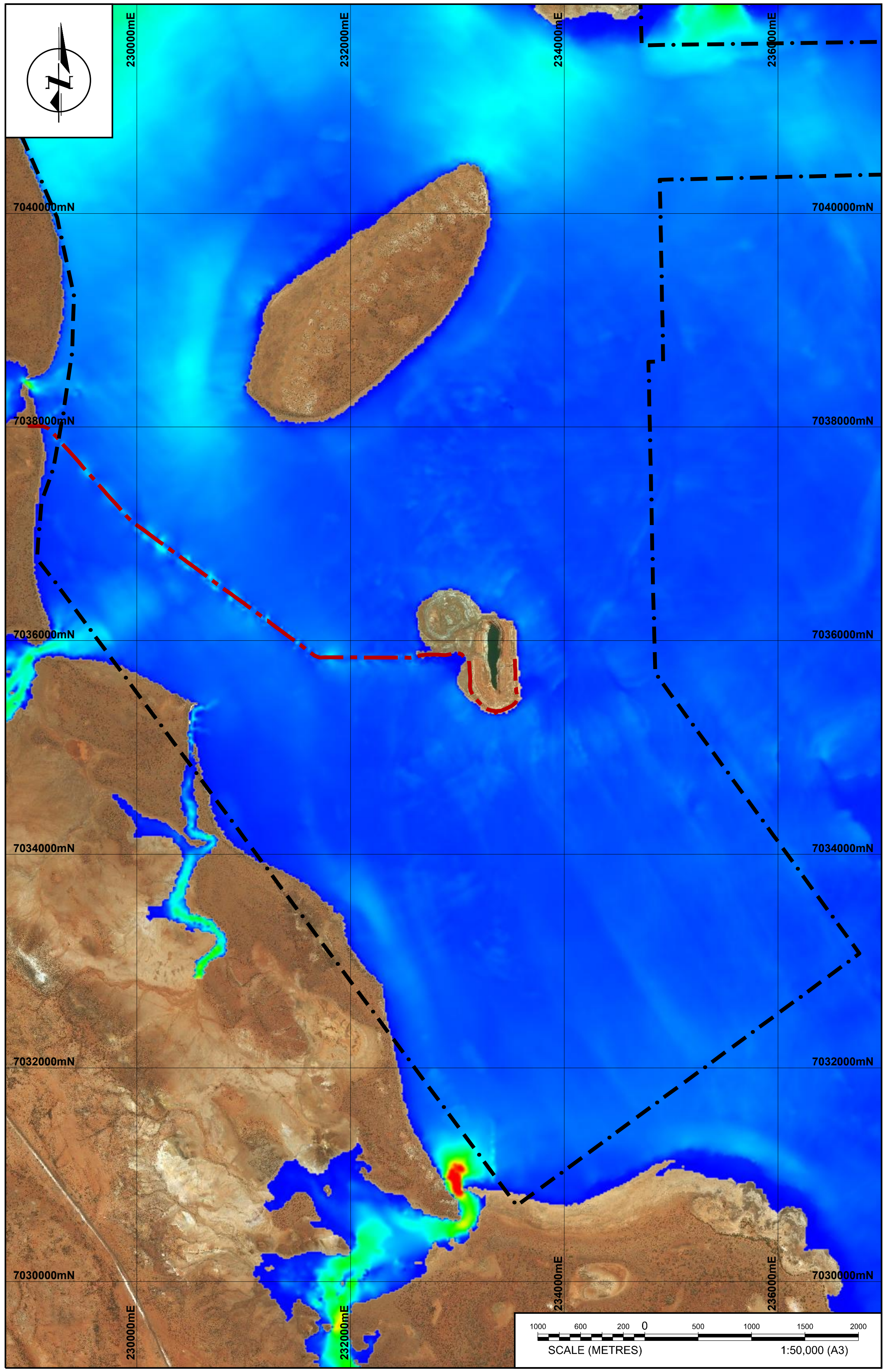
Knight Piésold CONSULTING

LAKE WAY PROJECT
UPDATED FLOOD STUDY
MAXIMUM VELOCITY POST POND CONSTRUCTION CONDITIONS (10% AEP)

PE801-00349 M19004
Figure 5.2



SITE OVERVIEW LAYOUT
1:250,000



FOCUS AREA LAYOUT
1:50,000

LEGEND:

LEASE BOUNDARY

ACCESS ROAD ALIGNMENT

MAXIMUM VELOCITY KEY:

≥ 2.0
1.5
1.0
0.5
0.0

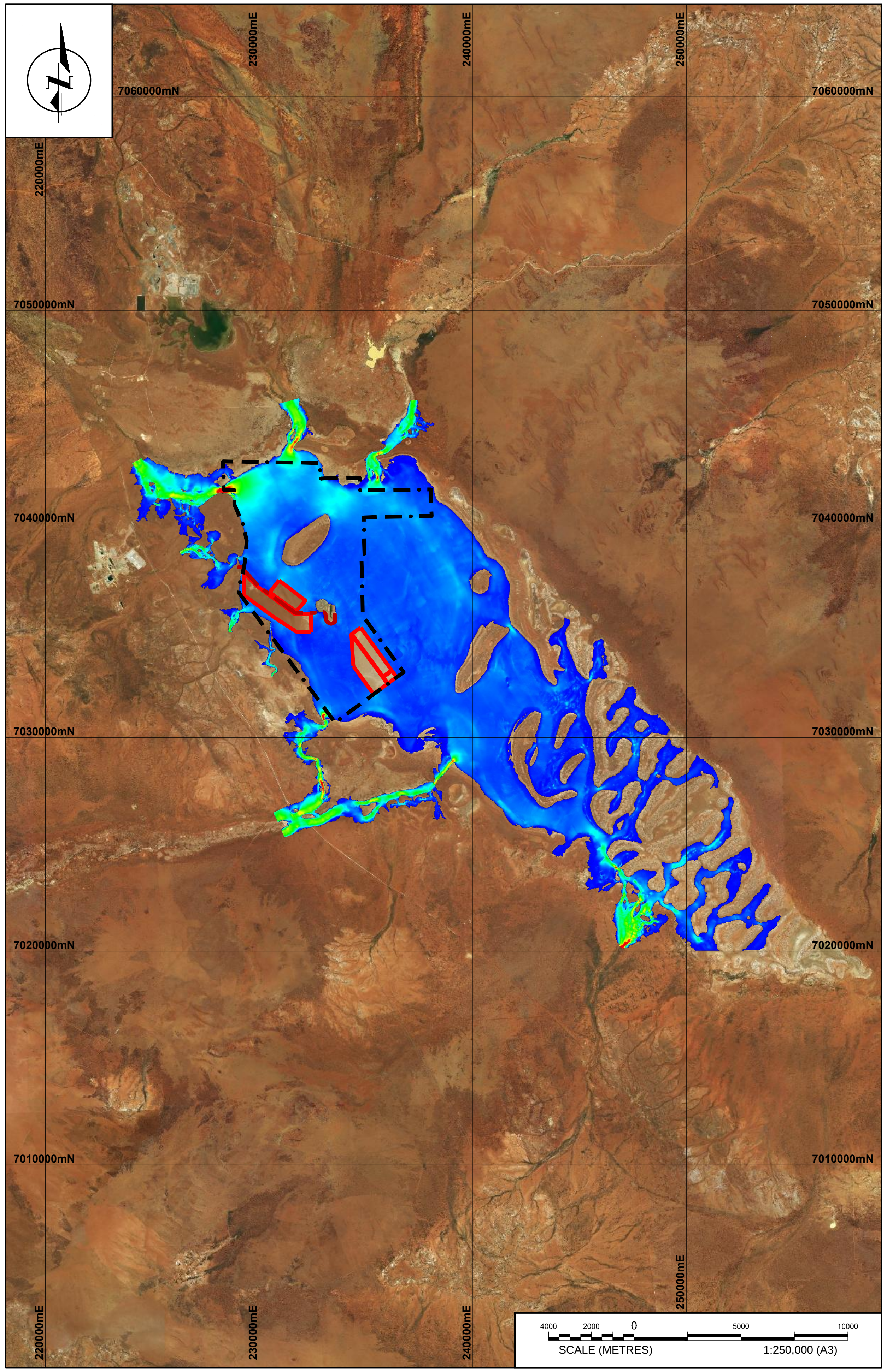
NOTES:

1. ALL COORDINATES SHOWN IN GRID PROJECTION MGA94 ZONE 51.
2. AERIAL IMAGERY COURTESY OF MICROSOFT CORPORATION, DIGITAL GLOBE, CNES, DISTRIBUTION AIRBUS DS.

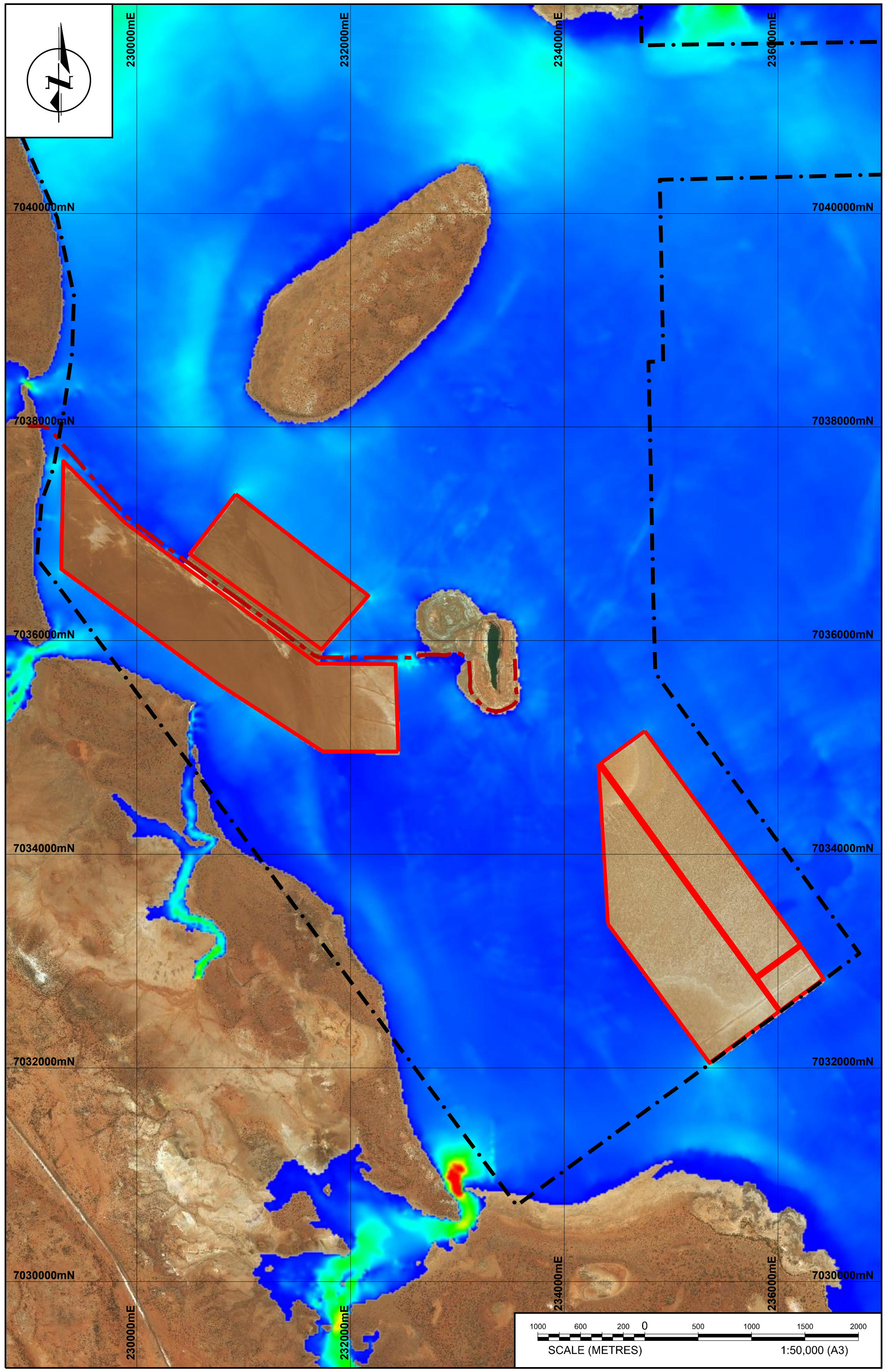
Knight Piésold CONSULTING

LAKE WAY PROJECT
UPDATED FLOOD STUDY
MAXIMUM VELOCITY PRE-EXISTING CONDITIONS (1% AEP)

PE801-00349 M19004
Figure 5.3



SITE OVERVIEW LAYOUT
1:250,000



FOCUS AREA LAYOUT
1:50,000

LEGEND:

- LEASE BOUNDARY
- ACCESS ROAD ALIGNMENT
- DEMONSTRATION POND EXTENT

MAXIMUM VELOCITY KEY:

≥ 2.0
1.5
1.0
0.5
0.0

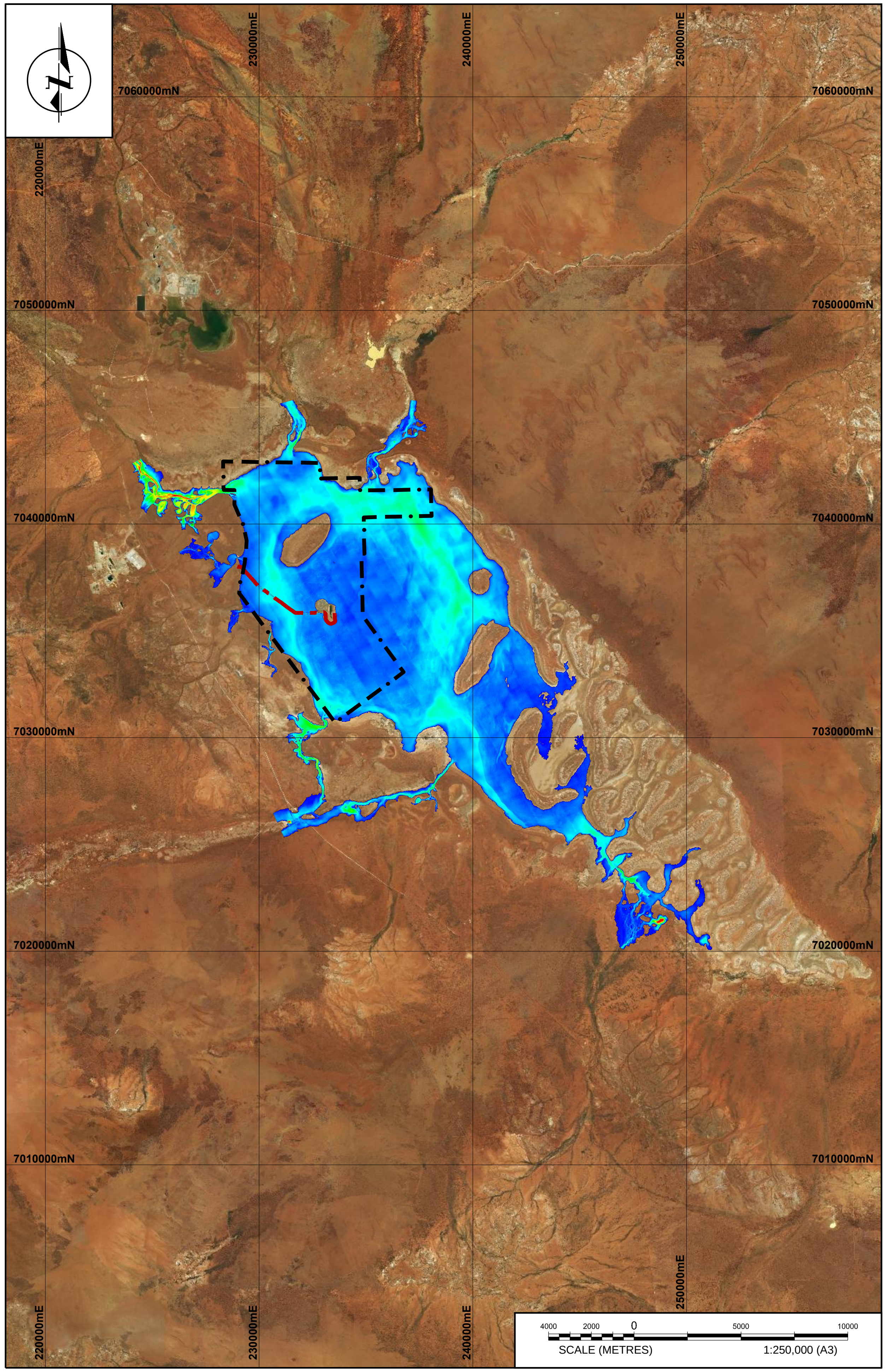
NOTES:

1. ALL COORDINATES SHOWN IN GRID PROJECTION MGA94 ZONE 51.
2. AERIAL IMAGERY COURTESY OF MICROSOFT CORPORATION, DIGITAL GLOBE, CNES, DISTRIBUTION AIRBUS DS.

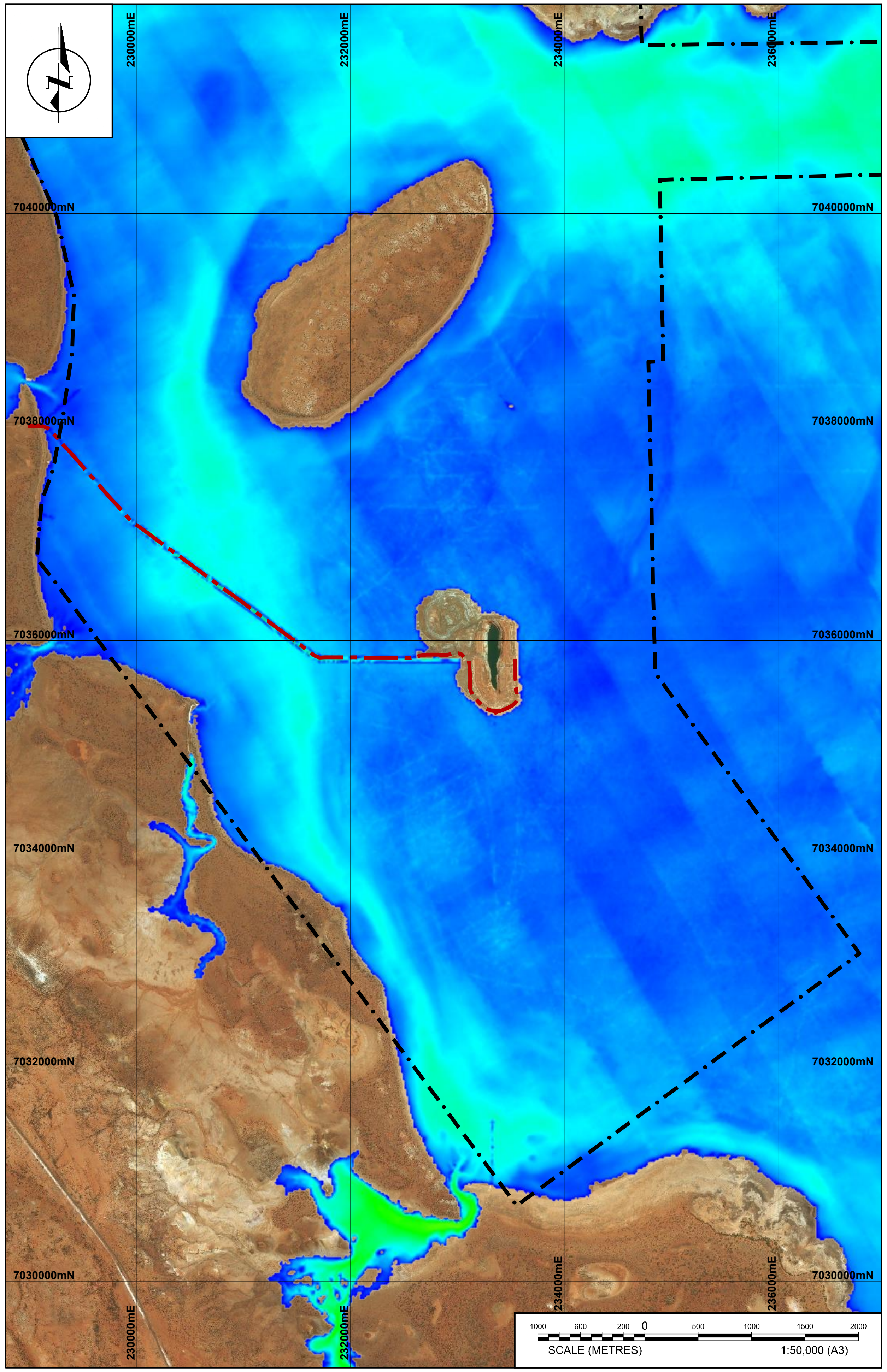
Knight Piésold CONSULTING

LAKE WAY PROJECT
UPDATED FLOOD STUDY
MAXIMUM VELOCITY POST POND CONSTRUCTION CONDITIONS (1% AEP)

PE801-00349 M19004
Figure 5.4



SITE OVERVIEW LAYOUT
1:250,000



FOCUS AREA LAYOUT
1:50,000

LEGEND:

- LEASE BOUNDARY
- ACCESS ROAD ALIGNMENT

MAXIMUM DEPTHS KEY:

≥ 2.0
1.5
1.0
0.5
0.0

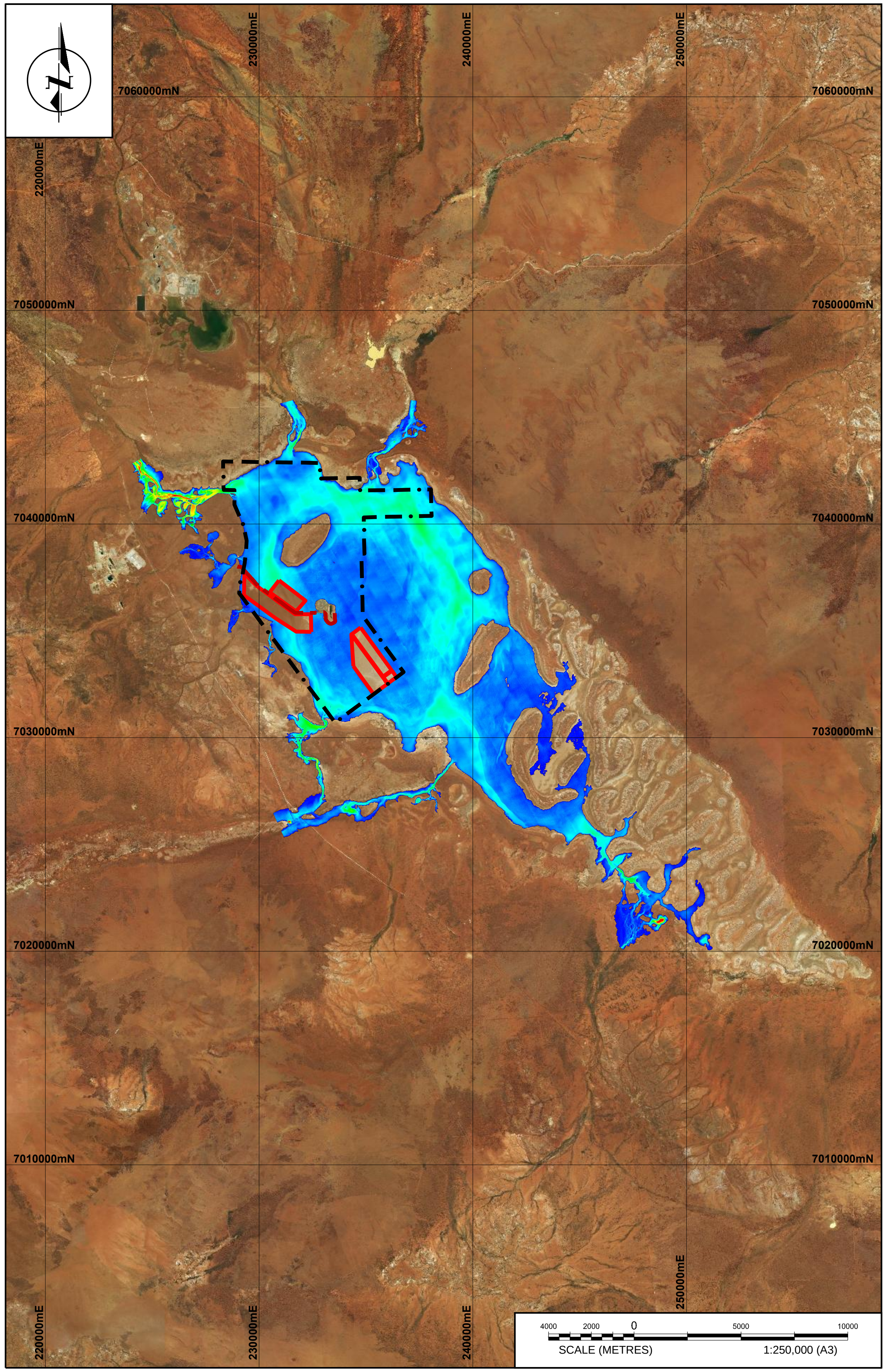
NOTES:

1. ALL COORDINATES SHOWN IN GRID PROJECTION MGA94 ZONE 51.
2. AERIAL IMAGERY COURTESY OF MICROSOFT CORPORATION, DIGITAL GLOBE, CNES, DISTRIBUTION AIRBUS DS.

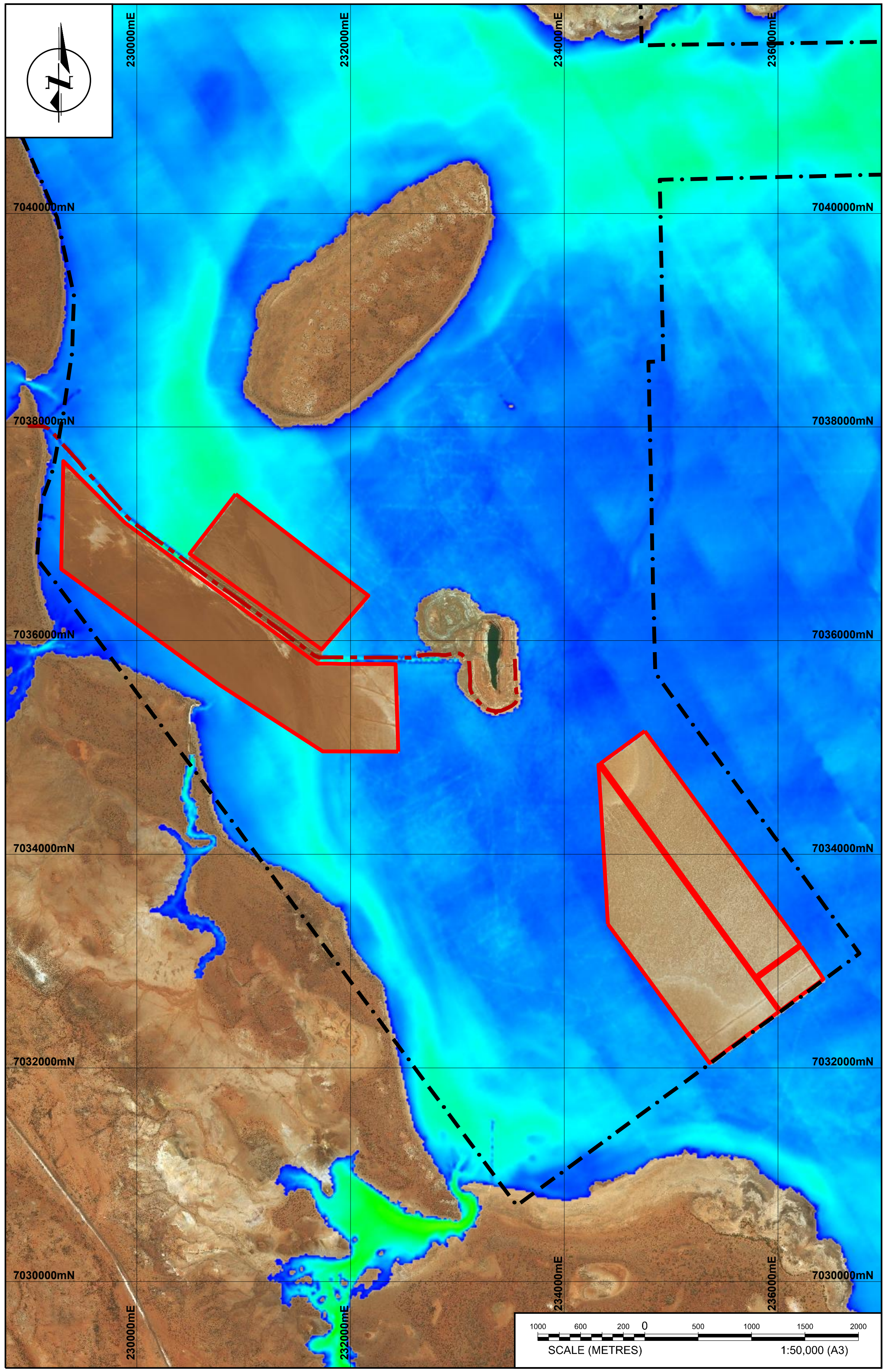
Knight Piésold CONSULTING

LAKE WAY PROJECT
UPDATED FLOOD STUDY
MAXIMUM DEPTHS PRE-EXISTING CONDITIONS (10% AEP)

PE801-00349 M19004
Figure 5.5



SITE OVERVIEW LAYOUT
1:250,000



FOCUS AREA LAYOUT
1:50,000

LEGEND:

- LEASE BOUNDARY
- ACCESS ROAD ALIGNMENT
- DEMONSTRATION POND EXTENT

MAXIMUM DEPTHS KEY:

≥ 2.0
1.5
1.0
0.5
0.0

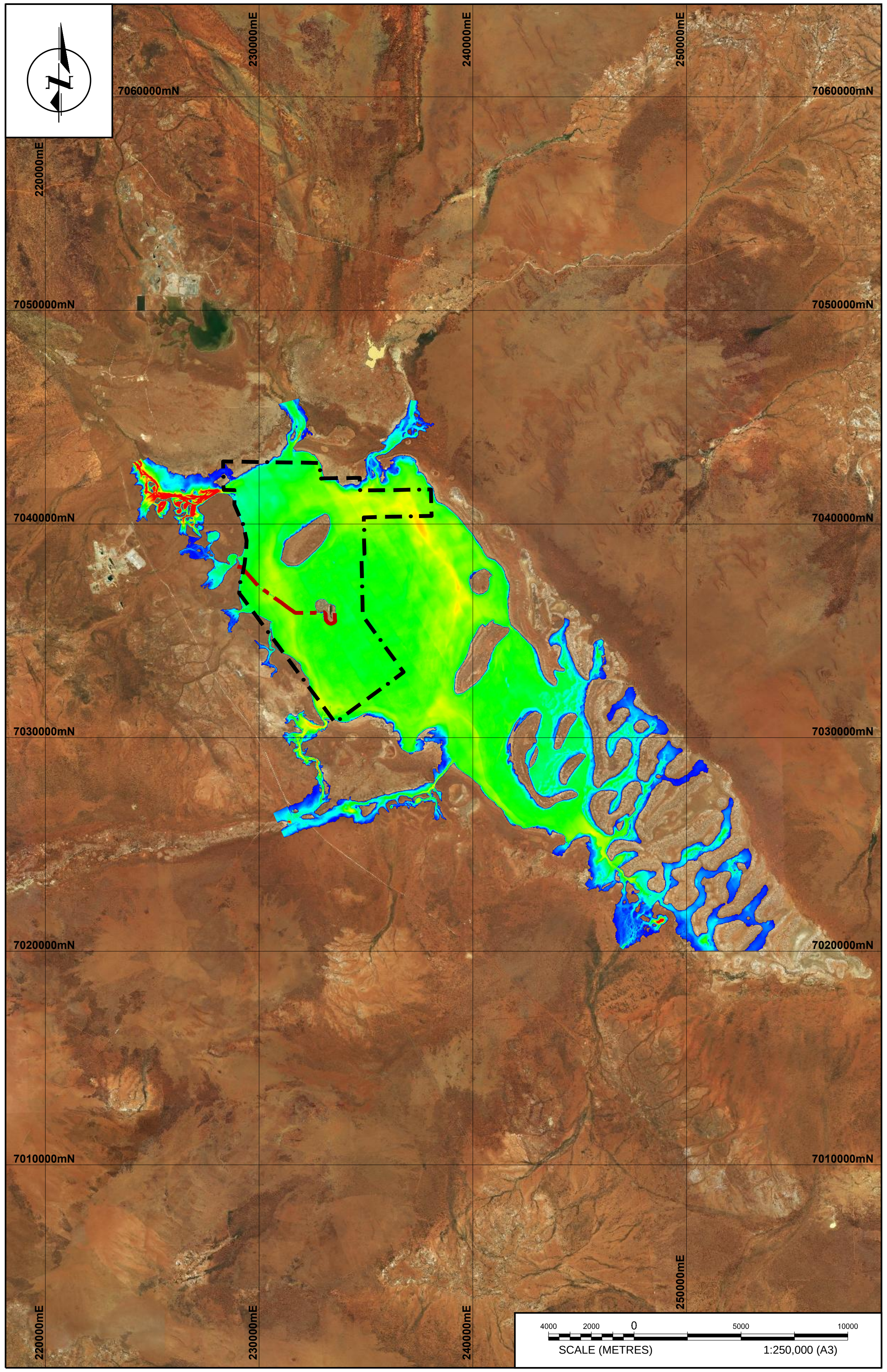
NOTES:

1. ALL COORDINATES SHOWN IN GRID PROJECTION MGA94 ZONE 51.
2. AERIAL IMAGERY COURTESY OF MICROSOFT CORPORATION, DIGITAL GLOBE, CNES, DISTRIBUTION AIRBUS DS.

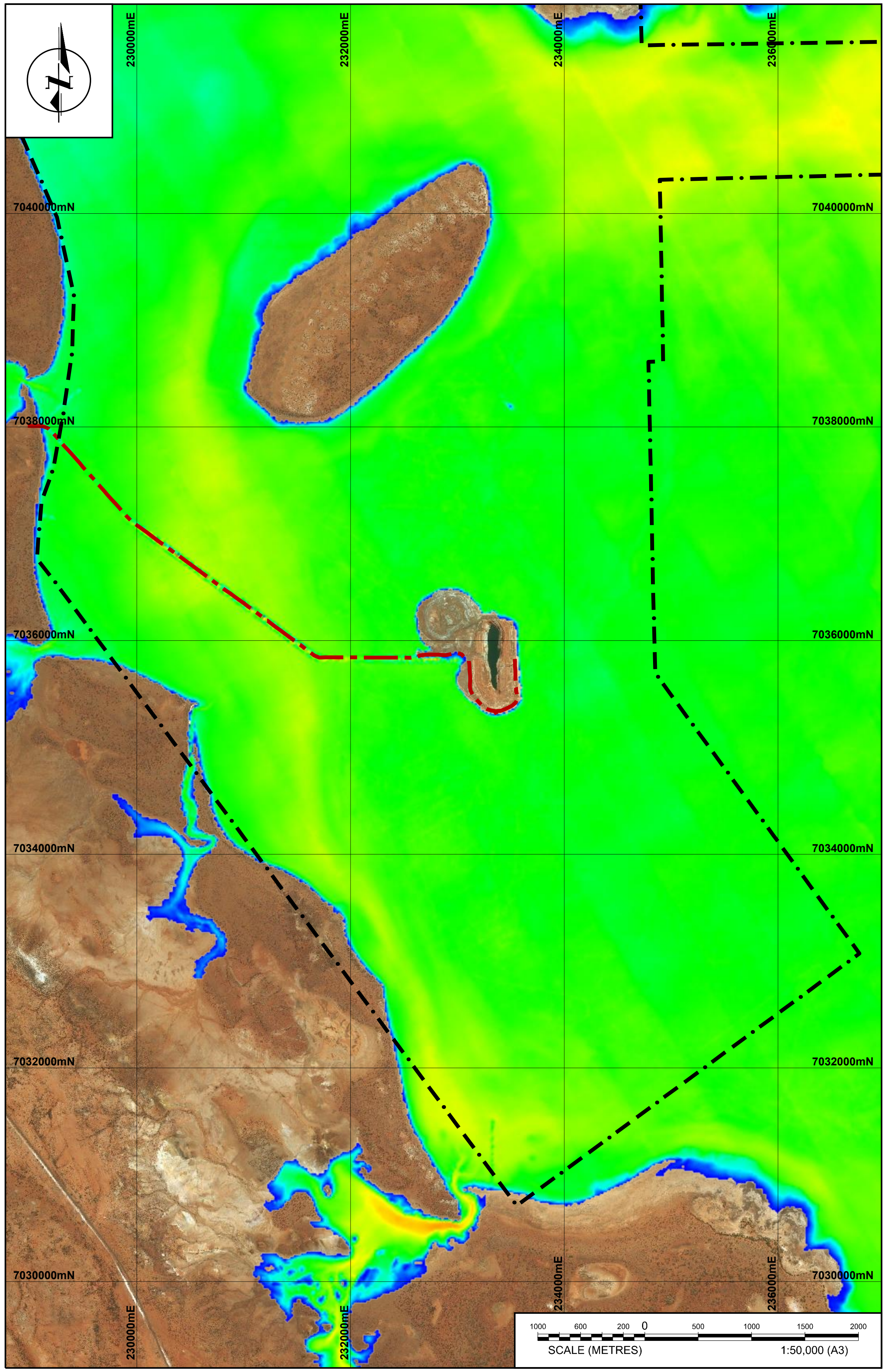
Knight Piésold CONSULTING

LAKE WAY PROJECT
UPDATED FLOOD STUDY
MAXIMUM DEPTHS POST POND CONSTRUCTION CONDITIONS (10% AEP)

PE801-00349 M19004
Figure 5.6



SITE OVERVIEW LAYOUT
1:250,000



FOCUS AREA LAYOUT
1:50,000

LEGEND:

LEASE BOUNDARY

ACCESS ROAD ALIGNMENT

MAXIMUM DEPTHS KEY:

≥ 2.0
1.5
1.0
0.5
0.0

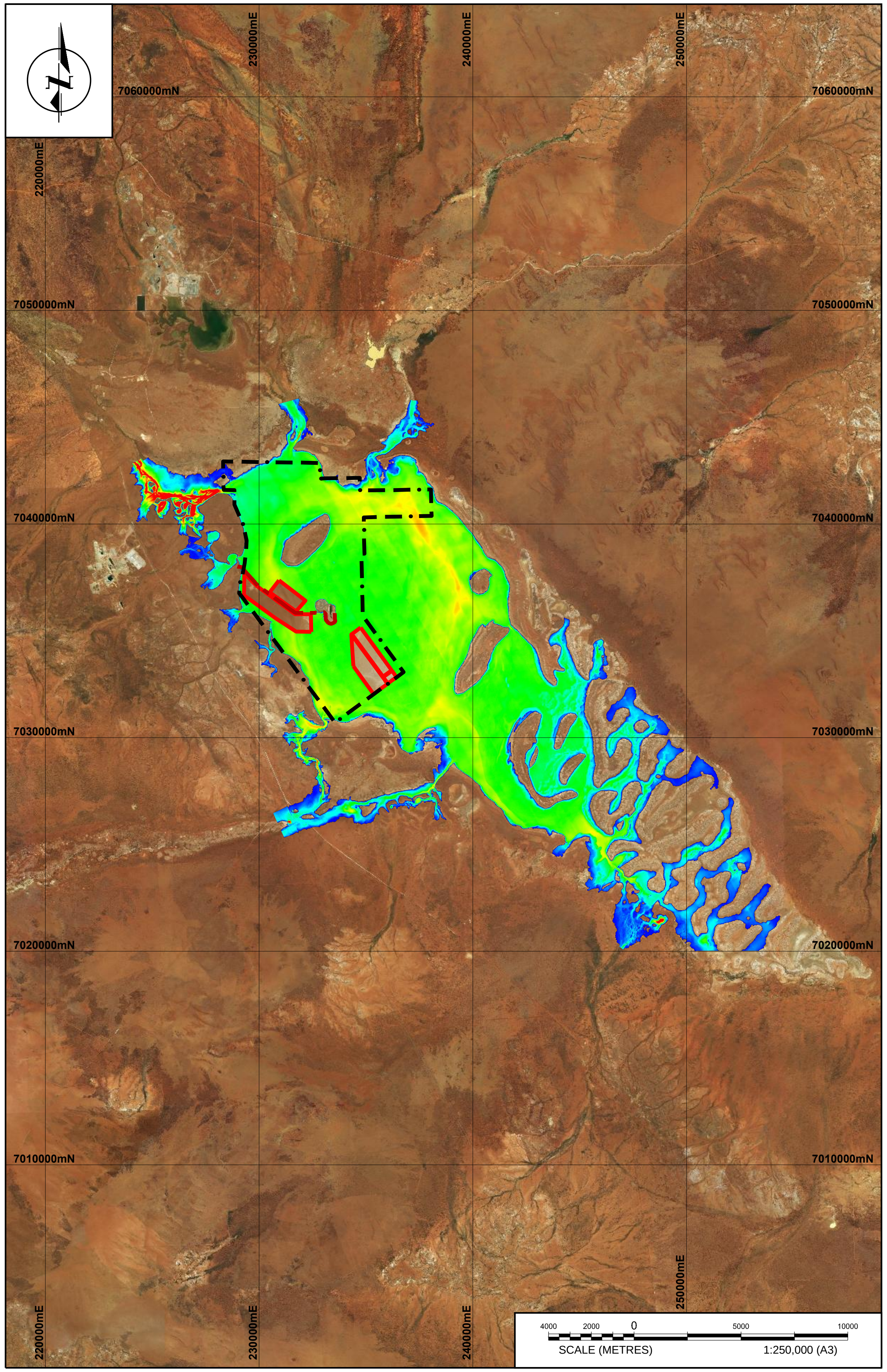
NOTES:

1. ALL COORDINATES SHOWN IN GRID PROJECTION MGA94 ZONE 51.
2. AERIAL IMAGERY COURTESY OF MICROSOFT CORPORATION, DIGITAL GLOBE, CNES, DISTRIBUTION AIRBUS DS.

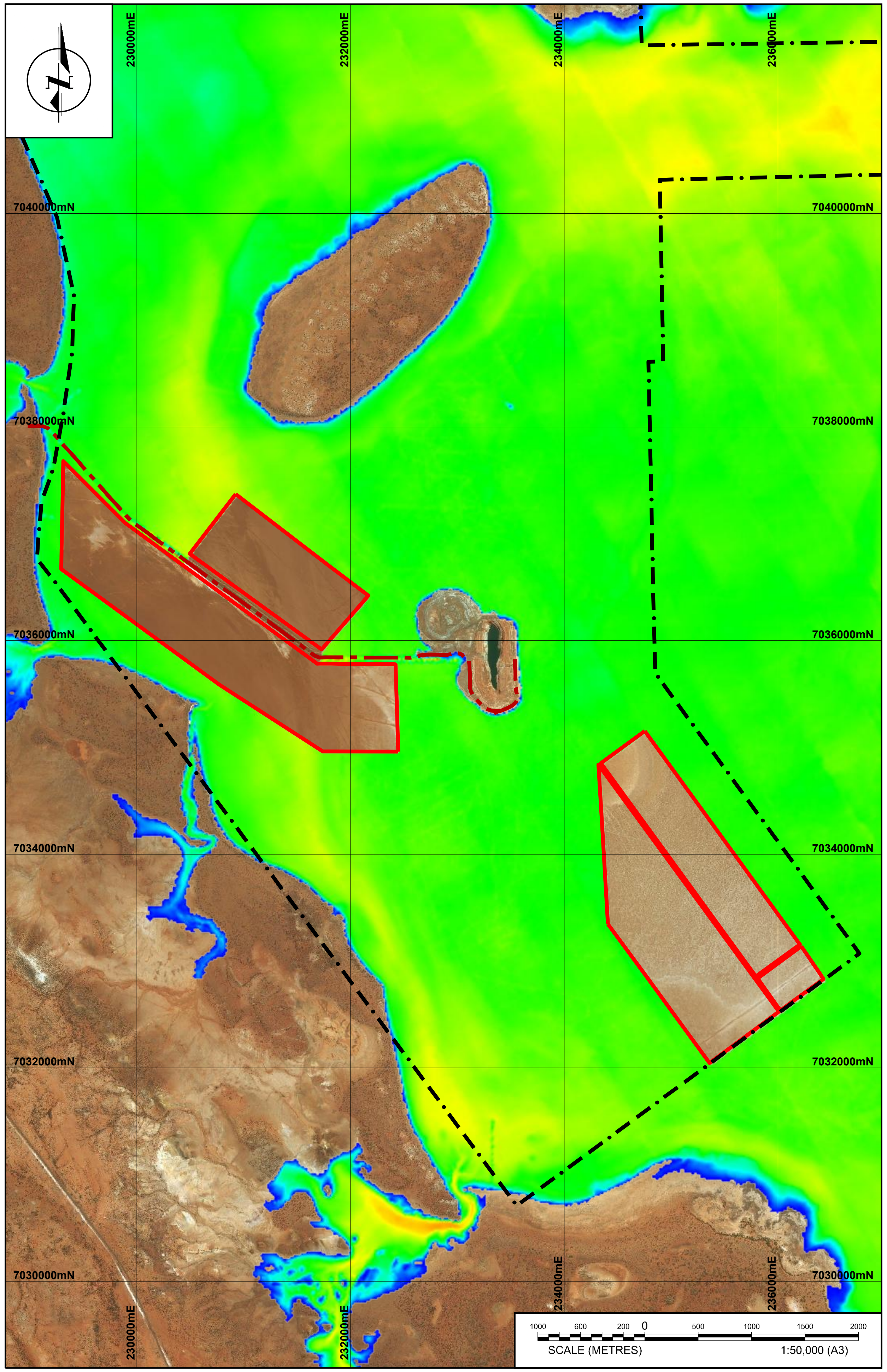
Knight Piésold CONSULTING

LAKE WAY PROJECT
UPDATED FLOOD STUDY
MAXIMUM DEPTHS PRE-EXISTING CONDITIONS (1% AEP)

PE801-00349 M19004
Figure 5.7



SITE OVERVIEW LAYOUT
1:250,000



FOCUS AREA LAYOUT
1:50,000

LEGEND:

- LEASE BOUNDARY
- ACCESS ROAD ALIGNMENT
- DEMONSTRATION POND EXTENT

MAXIMUM DEPTHS KEY:

≥ 2.0
1.5
1.0
0.5
0.0

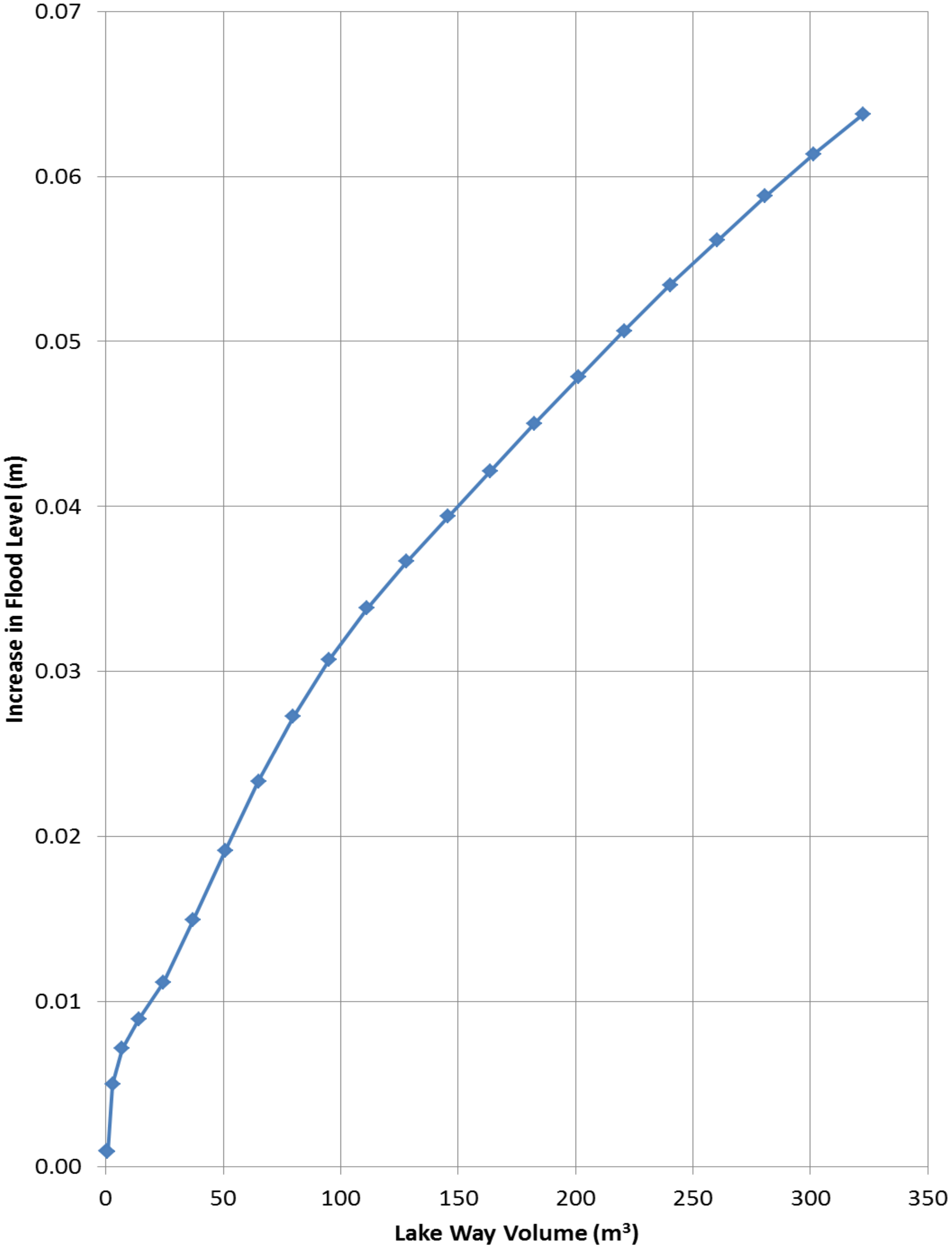
NOTES:

1. ALL COORDINATES SHOWN IN GRID PROJECTION MGA94 ZONE 51.
2. AERIAL IMAGERY COURTESY OF MICROSOFT CORPORATION, DIGITAL GLOBE, CNES, DISTRIBUTION AIRBUS DS.

Knight Piésold CONSULTING

LAKE WAY PROJECT
UPDATED FLOOD STUDY
MAXIMUM DEPTHS POST POND CONSTRUCTION CONDITIONS (1% AEP)

PE801-00349 M19004
Figure 5.8


0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
Increase in Flood Level (m)
0
50
100
150
200
250
300
350
Lake Way Volume (m³)