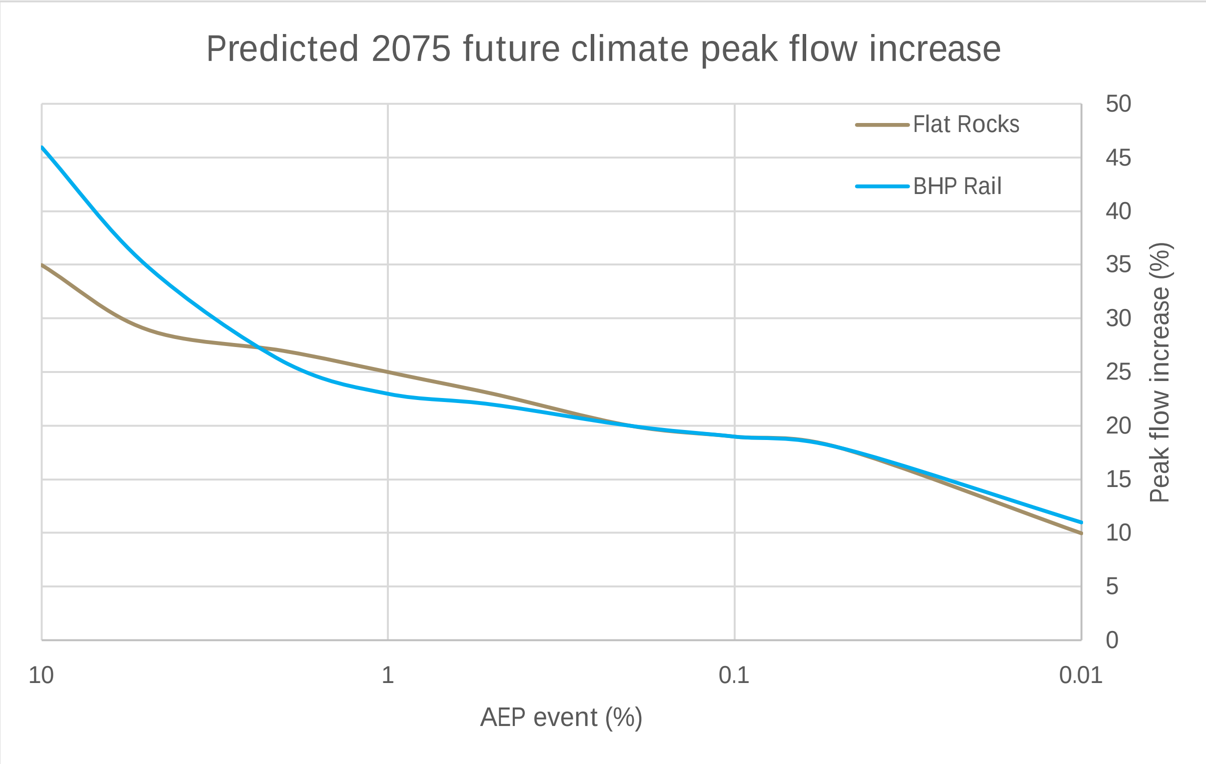

Figure 8-1: Predicted 2075 future climate peak flow increase percentage at Flat Rocks and BHP Rail

In order to gain an appreciation of the relevant reduction in design standard that the future climate predictions may have on the Yandi closure landform design, a log-linear interpolation was undertaken using current climate AEP peak flows on the future climate AEP predictions. Table 8-5 summarises the potential impact of the 2075 future climate on the design standard when adopting current day inputs. It was noted results were consistent at both the upstream and downstream extents of the BHP mine lease.

Table 8-5: Current and future climate equivalency

Current day AEP	2075 Future climate AEP equivalency (Flat Rocks and BHP Rail)
1% (1 in 100)	1.7% (1 in 58)
1 in 10,000	1 in 5,900

8.4 Major tributary design flows

Peak flow predictions from the major tributaries resulting from the 2075 future climate are shown in Table 8-6.

Table 8-6: Adopted design event peak flows for SPS Landform Closure Design – Marillana Creek major tributaries (current and 2075 future climate)

Location	AEP event						
	10% (m^3/s)	5% (m^3/s)	2% (m^3/s)	1% (m^3/s)	1 in 200 (m^3/s)	1 in 500 (m^3/s)	1 in 1000 (m^3/s)
Lamb Creek current climate	156	265	384	484	616	776	893
Lamb Creek 2075 future climate	205 (+31%)	319 (+20%)	473 (+23%)	586 (+21%)	710 (+15%)	885 (+14%)	1014 (+14%)
Herberts Creek current climate	92	138	205	248	273	332	375
Herberts Creek 2075 future climate	111 (+20%)	171 (+23%)	241 (+17%)	290 (+17%)	315 (+15%)	377 (+14%)	425 (+13%)
Iowa Creek current climate	244	374	534	646	766	965	1,109
Iowa Creek 2075 future climate	326 (+34%)	465 (+24%)	633 (+19%)	757 (+17%)	882 (+15%)	1,098 (+14%)	1,256 (+13%)

Increases in peak flow rates in all major tributaries show similar trends to the overall Marillana Creek system. That is, a consistent trend of reducing peak flow impact with increasing event magnitude is observed in all major tributaries, with a consistent increase of approximately 13-14% predicted in all three tributaries for the 1 in 1,000 AEP design event.

9 Baseline Hydraulic Model Development

9.1 Background

The hydrologic estimates detailed in Sections 6 and 7 have ultimately been derived for use as inflow boundary conditions into a hydraulic model to detail flood behaviour through the Study Area and allow for design of closure landforms.

To gain an appreciation of the resultant hydraulic behaviours of the design flow estimates with the current mine landform, a detailed 2D hydrodynamic flood model has been developed.

It is noted that this is not intended to be a detailed hydraulic assessment of baseline hydraulic conditions (separate scope item), but rather serve as a visual reference to the current landform performance with respect to the updated design flows for operations (1% AEP) and closure (1 in 10,000 AEP) design events.

It is noted that further refinement of the model extent and arrangement is expected in subsequent scope items as part of this SPS study, including assessment of model sensitivities to key parameter inputs.

9.2 Modelling software

Hydraulic modelling of the Marillana Creek system and tributaries was undertaken using TUFLOW HPC (version 2023-03-AA).

TUFLOW is a linked 1D/2D hydrodynamic computational engine for simulating free-surface long wave propagation processes (tides, floods, tsunamis, dam breaks) by solving the full one- and two-dimensional versions of the Navier-Stokes equations incorporating all physical terms including inertia (1D and 2D) and sub-grid turbulence (2D) (BMT, 2018).

9.3 Model details

9.3.1 Model terrain and resolution

The model terrain was developed using the BHP provided 1 m LiDAR-derived DEM. Given the model area and large ponding depth potential within the pits, the model adopts a base resolution of 20 m with 1 m resolution Sub Grid Sampling (SGS). To detail flood behaviours to a fine level of detail within the Marillana Creek mainstream as well as any potential spill locations into pit voids, a large area of 5 m resolution has been included using TUFLOW's Quadtree functionality.

9.3.2 Floodplain roughness

Due to the detailed nature of the hydraulic model and refined Study Area, mainstream roughness delineation was undertaken manually using the high-resolution aerial imagery provided by BHP. Parameterisation of the delineated areas was based on review of aerial and oblique site photographic record using the values presented in Section 9.3.5.

9.3.3 Culverts

Culvert details within and surrounding the Marillana Creek mainstream were estimated from high resolution aerial imagery and LiDAR data supplied by BHP.

All culvert features were included in the hydraulic model as 1D (ESTRY) inserts hydrodynamically linked to the 2D domain within the TUFLOW model. Table 9-1 summarises the parameters used for all culverts in the Study Area.

Table 9-1: Adopted culvert hydraulic parameters

Culvert/Headwall Type	Manning's '*n*'	Adopted Inlet Loss (K_e)	Adopted Outlet Loss (K_o)
Circular Steel Pipe (CSP) / Protruding (no headwall)	0.024	0.9	1

9.3.4 Bridges

The downstream BHP Rail bridge was modelled using the Layered Flow Constriction Shape (lfcsh) approach in TUFLOW in the 2D domain. The bridge parameterisation was undertaken as prescribed in *Hydraulic Design of Safe Bridges* (2012). Lower level (below soffit) waterway area blockages and form losses were derived based on the bridge opening cross section from the LiDAR based DEM and pier details measured from aerial imagery and observed in oblique photographic record. The adopted parameters are presented in Table 9-2.

Table 9-2: Adopted bridge hydraulic parameters

Parameter	BHP Rail Bridge
Bridge cross section	DEM
Width (m)	6
Estimated Soffit Level (mAHD)	544.2
Estimated Blockage (Piers)	7%
Estimated Below Deck (L1) Form Loss	0.175
Estimated Deck Thickness (m)	2.1
Adopted L2 Form Loss	1.56
Handrail/Armco Height (m)	N/A
Blockage	N/A

9.3.5 TUFLOW parameter summary

The TUFLOW model's key input parameters are summarised in Table 9-3.

Table 9-3: TUFLOW model parameter summary

Item	Overall Marillana Creek Model
Terrain	
Terrain	2022 1 m resolution LiDAR derived DEM (Section 2.1)
Total model area	91 km²
Base grid size (SGS sample distance) Quadtree grid size for mainstream (SGS sample distance)	20 m (1 m) 5 m (1 m)
Manning's '*n*' value	Clear alluvials or smooth bedrock (0.025) Cleared land or alluvials with tussock grasses (0.030) Typical Pilbara tussock grasslands/hillslope areas (0.040) Typical Pilbara tussock grasslands and minor vegetation (0.050) Medium density riparian vegetation (0.060) High density riparian vegetation (0.080) Thick riparian vegetation (0.100)
Boundary conditions	
Inflow boundaries	Flow-Time (QT) boundary – Flat Rocks inflow hydrograph (upstream extent) Source /Area boundary (SA) – intermediary hydrograph additions on mainstream
Outflow boundary	Automated stage-discharge curve (HQ) with stream bed slope used as a proxy for water surface slope. Located sufficient distance downstream as to not potentially impact Study Area.

9.4 Results

9.4.1 GIS mapping

Peak flood depth, velocity and depth/velocity product mapping for the 1% AEP and 1 in 10,000 AEP events is presented in Appendix D.

9.4.2 Results discussion

Due to the natural topographic variation and mining landforms in the Study Area, flood behaviours within the Marillana Creek mainstream are very intense for both events detailed in this study.

In the 1% AEP event, flood waters are predicted to be typically contained within the creek by the Flood Protection Bunds (FPB) and natural landforms. One exception is Eastern 7 pit, where some very minor ingress (<1 m^3/s peak inflow) in the 1% AEP is observed at the flood peak at a low point in the flood protection bund on the downstream southeast facing alignment of the FPB. As a result, this FPB does not meet the operational requirements of DESC-000-C-00002/2 which stipulates a freeboard requirement of 300 mm from the design flood level.

In the 1 in 10,000 AEP event, significant ingress into a number of pits occurs with the current mining landform due to the large flow magnitudes associated with this design event. Table 9-4 provides indicative ingress volumes for each pit based on the 2022 mine landform.

Table 9-4: Approximate flood ingress volumes (1 in 10,000 AEP – 2022 operational landform)

Pit ID	1 in 10,000 AEP flood ingress volume (GL)
Western 1 South (north of creek)	17.0
Western 1 South (south of creek)	5.2
Western 3	<0.1
Western 4	<0.1
Western 5	27.4
Western 6	12.5
Central 1	<0.1
Eastern 4	10.0
Eastern 3,5,6	1.9
Eastern 7	7.9

10 Conclusion

This study represents a baseline assessment of the hydrologic conditions throughout the Marillana Creek mainstream (the Study Area) using the latest industry assessment methods and data and ensures compliance with the procedures outlined in ARR2019.

The assessment has used regional characterisation of losses to determine appropriate design event loss parameterisation for rain-on-grid hydraulic modelling to estimate the hydrologic and resultant hydraulic conditions across the site. The assessment approach and methods are consistent with ARR2019, the latest industry guidance on the derivation of hydrologic estimates and flood risk.

It can be concluded from the analysis that:

- The DWER rating table at Flat Rocks underpredicts flow rates for a given flood stage at both old and new sensor locations based on detailed 2D modelling of the gauge sites undertaken for this study.
- The re-rated AM series flows and inclusion of the last eight water years of data in a FFA has resulted in similar flow quantile predictions to that described by GHD (2014). This would agree with the marginally higher rating of mid-level AM flows when compared to GHD, offset by the inclusion of the most recent eight years of data which represent a relatively quiet period of record when compared to the complete gauge record.
- This study has successfully used detailed rain-on-grid TUFLOW modelling of the contributing catchment to Flat Rocks to aid in accurate parameterisation of the RORB storage-discharge parameter. In particular, prescriptive depiction of the storage effects of Munjina Flats has been captured and included in the RORB model, as well as accurately detailing major tributary storage-discharge characteristics.
- The RORB model has been parameterised with location-specific design rainfall inputs to estimate peak flows at the upper and lower extents of BHPs mine lease. The model adopts the TUFLOW-validated storage-discharge parameterisation.
- A strong match between the RORB Monte Carlo peak flow quantiles and FFA quantiles was achieved using regionally consistent and probability neutral loss parameters, the preferred approach to loss reconciliation as defined by ARR2019.
- Peak flow predictions from the rainfall-runoff modelling at Flat Rocks (upstream extent of BHPs mine lease) are similar to those previously predicted by GHD (2014). This is to be expected as model calibration in both studies has been undertaken based on FFA quantiles at this location, limiting the potential for substantial changes based on the similarity of precited FFA quantiles between studies.
- Larger differences were observed at the lower extent of BHPs mining lease for the 5% and 2% AEP events, likely due to the differences in all inputs and derivation procedures between studies. 1% AEP peak flow predictions however were very similar.
- Using the procedures defined in ARR2019, hydrologic response for the 1 in 10,000 AEP (closure design) event was also undertaken with peak flow predictions at Flat Rocks in the 1 in 10,000 AEP event (7,240 m^3/s) remaining similar (a 2% increase) to the previous estimate.
- Assessment of the potential impacts of the predicted future climate (2075) (increased rainfall intensity) for Marillana Creek were assessed, with peak flows predicted to increase by on average

24% for the 1% AEP and 10% for the 1 in 10,000 year design events respectively. This results in a reduction in design standard for the current day 1% AEP and 1 in 10,000 AEP in the 2075 future climate scenario to a 1.7% AEP and 1 in 5,900 AEP standard respectively.

- Similarly, climate change impacts were assessed for the three major tributaries contributing to the Marillana Creek mainstream, with a consistent peak flow increase of between 13 and 14% predicted in the 1 in 1,000 AEP design event.
- Indicative baseline hydraulic modelling of the current mine landform (2022) has indicated that most Flood Protection Bunds (FPB) provide adequate flood immunity and freeboard from the 1% AEP event to achieve the design requirements of DESC-000-C-00002/2. However, Eastern 7 pit is predicted to experience some flood ingress in the 1% event due to a low point in the FPB on the downstream/south-eastern facing façade and hence currently does not meet the BHP design requirements.
- Significant flood ingress of several pits is predicted in the 1 in 10,000 AEP event, with up to 27 GL of floodwater predicted to flow into some pits (W5).
- The management of the large flow rates and discharge volumes associated with the 1 in 10,000 AEP closure design event is the subject of subsequent study scope items to detail hydraulic behaviours and design appropriate closure landforms.

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Appendix A
Flood Frequency Analysis data and results

Table A-1: Flat Rocks stream gauge AM data re-rating

Water Year	Gauge Location	DWER Rated Flow (m^3/s)	Advisian Rated Flow (m^3/s)
1968	Original	137.2	188.1
1969	Original	81.4	118.4
1970	Original	9.7	9.7
1971	Original	375.0	477.8
1972	Original	4.0	4.0
1973	Original	796.0	953.4
1974	Original	95.0	136.3
1975	Original	10.5	10.5
1976	Original	1327.5	1502.7
1977	Original	2.7	2.7
1978	Original	173.6	233.7
1979	Original	118.6	165.4
1980	Original	127.1	175.7
1981	Original	30.8	28.7
1982	Original	105.9	148.1
1983	Original	80.9	107.3
1984	Current	208.6	274.0
1985	Current	84.6	118.5
1986	Current	0.1	0.1
1987	Current	58.4	80.9
1988	Current	193.8	256.7
1989	Current	74.1	99.7
1990	Current	91.7	130.2
1991	Current	1.2	1.2
1992	Current	78.2	107.2
1993	Current	66.3	91.0
1994	Current	55.5	76.8
1995	Current	864.6	1117.2

Water Year	Gauge Location	DWER Rated Flow (m^3/s)	Advisian Rated Flow (m^3/s)
1996	Current	6.0	6.0
1997	Current	319.4	406.3
1998	Current	0.0	0.0
1999	Current	115.6	162.4
2000	Current	502.9	641.3
2001	Current	39.0	53.8
2002	Current	127.5	175.7
2003	Current	726.4	938.4
2004	Current	71.6	97.0
2005	Current	3.6	3.6
2006	Current	102.1	145.4
2007	Current	28.1	37.9
2008	Current	190.9	253.1
2009	Current	87.8	123.9
2010	Current	3.5	3.5
2011	Current	70.1	95.4
2012	Current	85.0	119.3
2013	Current	91.8	130.4
2014	Current	83.5	116.7
2015	Current	38.5	52.9
2016	Current	26.5	35.8
2017	Current	33.6	45.8
2018	Current	105.1	149.4
2019	Current	8.4	8.4
2020	Current	152.2	199.4
2021	Current	88.0	124.3
2022	Current	21.7	28.7

Report created on 30/ 5/2023 at 10:35

FLIKE program version 5.0.300.0
FLIKE file version 3.10

Data file: I:\Projects\311012-01707 Yandi Closure Landform SPS\5_Engineering\HY-Hydrology\04_Marillana_Hydrology\01_FFA\20230112_708001_FlatRocks\FLIKE\Revised_AM_Flows_AM_FINAL.fld

Title:

Input Data for Flood Frequency Analysis for Model: Log Pearson III

Gauged Annual Maximum Discharge Data

Obs	Discharge	Year	AEP plot position	AEP 1 in Y yrs
1	1502.72	1976	0.98913	92.00
2	1117.18	1995	0.97101	34.50
3	953.45	1973	0.95290	21.23
4	938.36	2003	0.93478	15.33
5	641.32	2000	0.91667	12.00
6	477.81	1971	0.89855	9.86
7	406.26	1997	0.88043	8.36
8	274.03	1984	0.86232	7.26
9	256.74	1988	0.84420	6.42
10	253.11	2008	0.82609	5.75
11	233.70	1978	0.80797	5.21
12	199.43	2020	0.78986	4.76
13	188.07	1968	0.77174	4.38
14	175.67	2002	0.75362	4.06
15	175.66	1980	0.73551	3.78
16	165.37	1979	0.71739	3.54
17	162.44	1999	0.69928	3.33
18	149.43	2018	0.68116	3.14
19	148.09	1982	0.66304	2.97
20	145.44	2006	0.64493	2.82
21	136.29	1974	0.62681	2.68
22	130.40	2013	0.60870	2.56
23	130.21	1990	0.59058	2.44
24	124.34	2021	0.57246	2.34
25	123.94	2009	0.55435	2.24
26	119.35	2012	0.53623	2.16
27	118.54	1985	0.51812	2.08
28	118.38	1969	0.50000	2.00
29	116.72	2014	0.48188	1.93
30	107.28	1983	0.46377	1.86
31	107.20	1992	0.44565	1.80
32	99.69	1989	0.42754	1.75
33	97.02	2004	0.40942	1.69
34	95.39	2011	0.39130	1.64
35	90.97	1993	0.37319	1.60
36	80.88	1987	0.35507	1.55

37	76.81	1994	0.33696	1.51
38	53.79	2001	0.31884	1.47
39	52.88	2015	0.30072	1.43
40	45.82	2017	0.28261	1.39

The following gauged flows were censored:

Obs	Discharge	Year
41	37.86	2007
42	35.75	2016
43	28.70	2022
44	28.67	1981
45	10.54	1975
46	9.70	1970
47	8.39	2019
48	5.97	1996
49	4.02	1972
50	3.56	2005
51	3.46	2010
52	2.67	1977
53	1.19	1991
54	0.07	1986
55	0.01	1998

Censored Data

Obs	Threshold	Number of floods Above	Number of floods Below	Correlated error group	Error coefficient of variation	AEP plot position	AEP 1 in Y yrs
1	45.82	0	15	1	0.000	0.26449	1.36

Flood model: Log Pearson III

Zero flow threshold: 0.000
Number of gauged flows at or below flow threshold = 0

Summary of Posterior Moments from Importance Sampling

No	Parameter	Mean	Std dev	Correlation		
1	Mean (loge flow)	4.58323	0.19668	1.000		
2	loge [Std dev (loge flow)]	0.23676	0.15157	-0.322	1.000	
3	Skew (loge flow)	0.02191	0.49732	0.338	-0.490	1.000

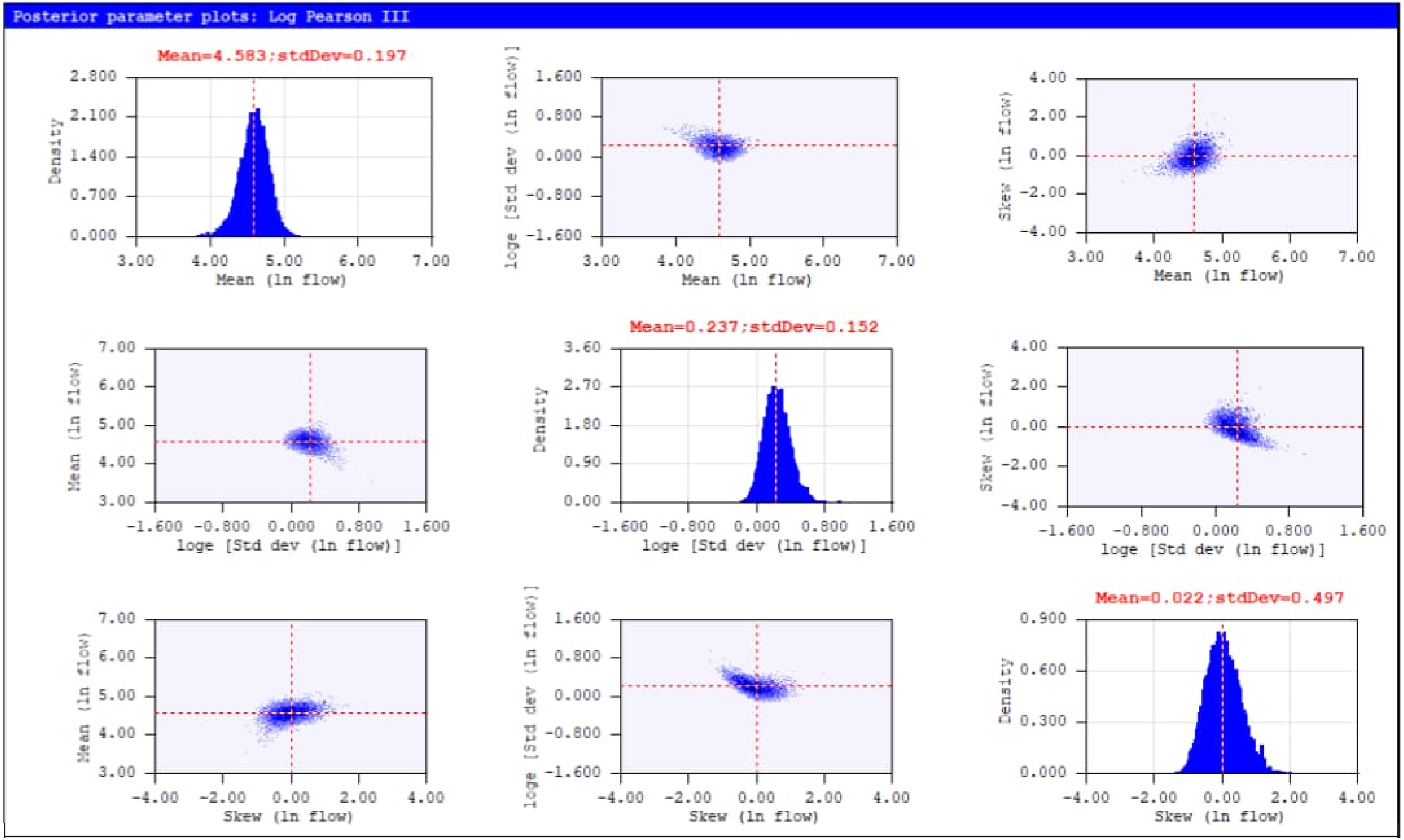
Note: Posterior expected parameters are the most accurate in the mean-squared-error sense.
They should be used in preference to the most probable parameters

Lower bound = 0.576256E-48

AEP 1 in Y	Exp parameter quantile	Monte Carlo 90% quantile probability limits		Mean(log10(q))	Stdev(log10(q))
1.010	5.21	0.87	16.9	0.6890	0.4074
1.100	18.08	8.00	31.7	1.2528	0.1887
1.250	33.63	20.38	49.6	1.5277	0.1217
1.500	56.47	39.83	77.9	1.7549	0.0907
1.750	77.53	56.99	106.0	1.8931	0.0827
2.000	97.38	72.50	132.9	1.9921	0.0809
3.000	168.21	124.51	233.8	2.2286	0.0840
5.000	283.81	204.17	407.6	2.4542	0.0921
10.000	497.74	341.85	761.6	2.6961	0.1091
20.000	792.62	509.90	1386.1	2.8966	0.1350
50.000	1340.07	775.92	2902.1	3.1234	0.1812
100.000	1903.48	996.51	4978.0	3.2754	0.2225
200.000	2626.06	1219.80	8398.1	3.4153	0.2675
500.000	3881.57	1523.93	16496.5	3.5859	0.3308
1000.000	5108.18	1745.51	26876.9	3.7064	0.3809
2000.000	6623.24	1955.28	44286.4	3.8208	0.4323
5000.000	9159.00	2219.28	82593.0	3.9644	0.5019
10000.000	11559.57	2409.50	133941.6	4.0680	0.5555
20000.000	14454.44	2579.58	216331.0	4.1680	0.6098
50000.000	19180.78	2806.43	403748.4	4.2952	0.6823
100000.000	23559.10	2957.16	636770.6	4.3882	0.7376

Flood magnitude	Expected probability	<------------AEP------------> 1 in Y	90% limits	
5.21	0.01657	1.02	1.00	1.1
18.08	0.08908	1.10	1.01	1.2

33.63	0.19419	1.24	1.12	1.4
56.47	0.32880	1.49	1.31	1.7
77.53	0.42518	1.74	1.50	2.1
97.38	0.49722	1.99	1.67	2.4
168.21	0.66453	2.98	2.33	4.0
283.81	0.79826	4.96	3.54	7.6
497.74	0.89901	9.90	6.16	19.
792.62	0.94937	19.75	10.45	53.
1340.07	0.97906	47.76	19.17	0.29E+03
1903.48	0.98869	88.44	29.52	0.17E+04
2626.06	0.99352	154.36	44.10	0.24E+05
3881.57	0.99663	296.80	72.89	0.17E+08
5108.18	0.99784	461.94	103.42	0.10E+11
6623.24	0.99856	692.84	145.34	0.10E+11
9159.00	0.99911	1129.65	225.64	0.10E+11
11559.57	0.99937	1587.17	307.93	0.10E+11
14454.44	0.99954	2181.98	417.30	0.10E+11
19180.78	0.99969	3229.01	622.69	0.10E+11
23559.10	0.99977	4261.66	830.93	0.10E+11


Posterior parameter plots: Log Pearson III
Mean=4.583;stdDev=0.197
Density
Mean (ln flow)
loge [Std dev (ln flow)]
Skew (ln flow)
Mean=0.237;stdDev=0.152
Mean=0.022;stdDev=0.497

DWER Flat Rocks Report

MARILLANA CREEK - FLAT ROCKS GAUGING STATIONS

INTRODUCTION

In August 1967 the Flat Rocks Gauging Station was established to measure streamflows from Marillana Creek. This station operated alone until 1983 when a replacement station, was installed. The original station produced poor quality record thought to be due to extreme turbulence, and high velocities experienced at the orifice.

Both stations have operated concurrently since 1983.

LOST RECORD

Due to expiry of the nitrogen supply at the primary station, in late January 1992, a loss of data occurred until early March 1992 (Clearly seen in Plot N°.1). Data reconstruction was required for the lost period of data. In this case the data from the secondary station could be used.

The primary station is approximately 360m downstream from the secondary station. Between the two stations, there is considerable slope, and a bend in the river. Therefore data could not be directly transferred from station to station. and a stage-stage correlation was required to accurately re-define the record for the lost period.

STAGE - STAGE CORRELATION

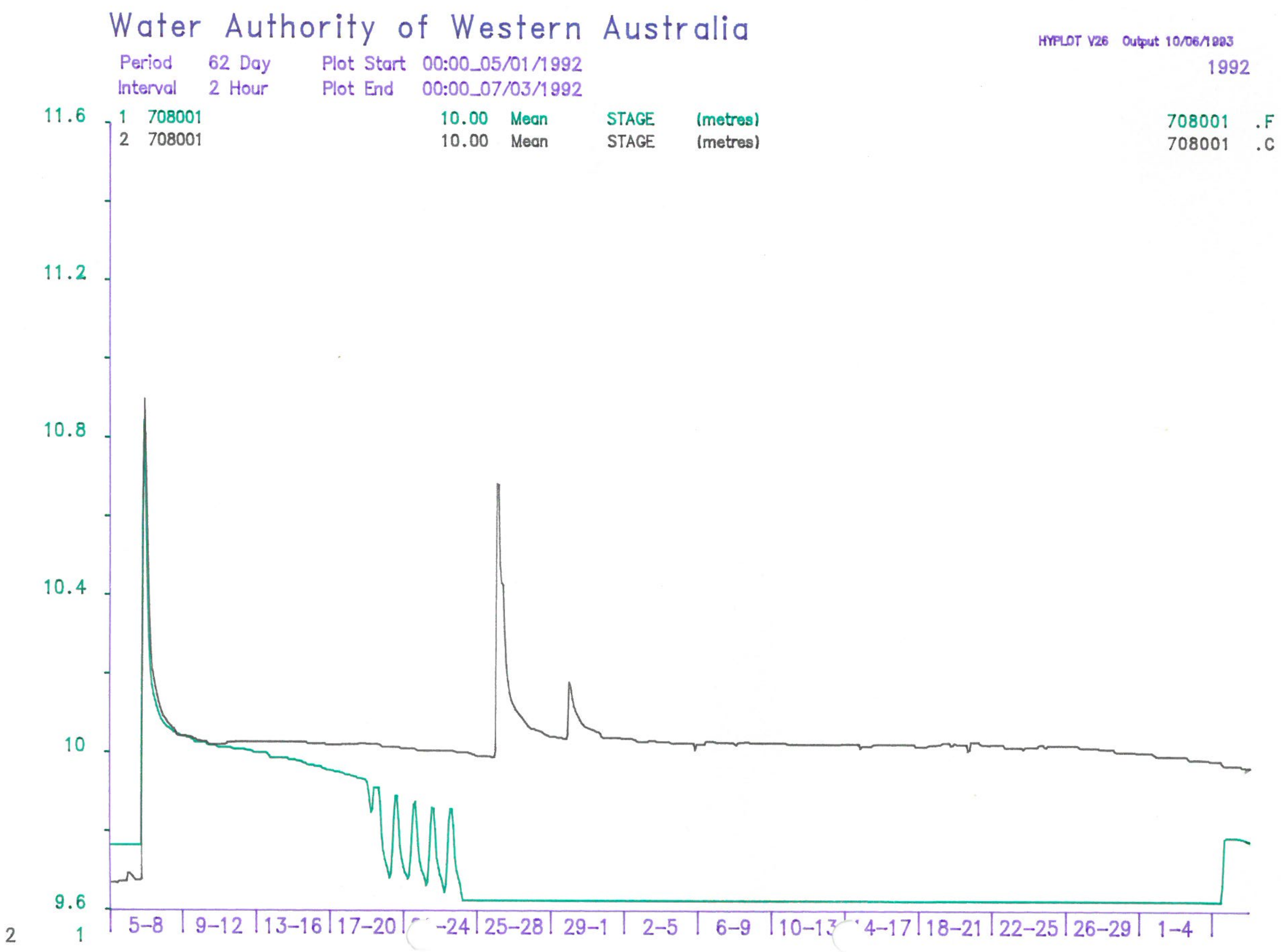
Data was reviewed, from both primary and secondary stations, to formulate a stage - stage correlation, (see Table N°.1 for details).

A closer inspection of the stage information was made, outlining a number of anomalies. On occasions the peaks occurring at the primary station were occurring; before, of greater magnitude, or instead of; peaks at the secondary station.

Due to the fact that the primary station is only 360m downstream of the original station, under ideal conditions the peaks would be expected to occur at similar times and approximately the same magnitude.

The following plots outline some of the differences found in the record.

PLOT N°1

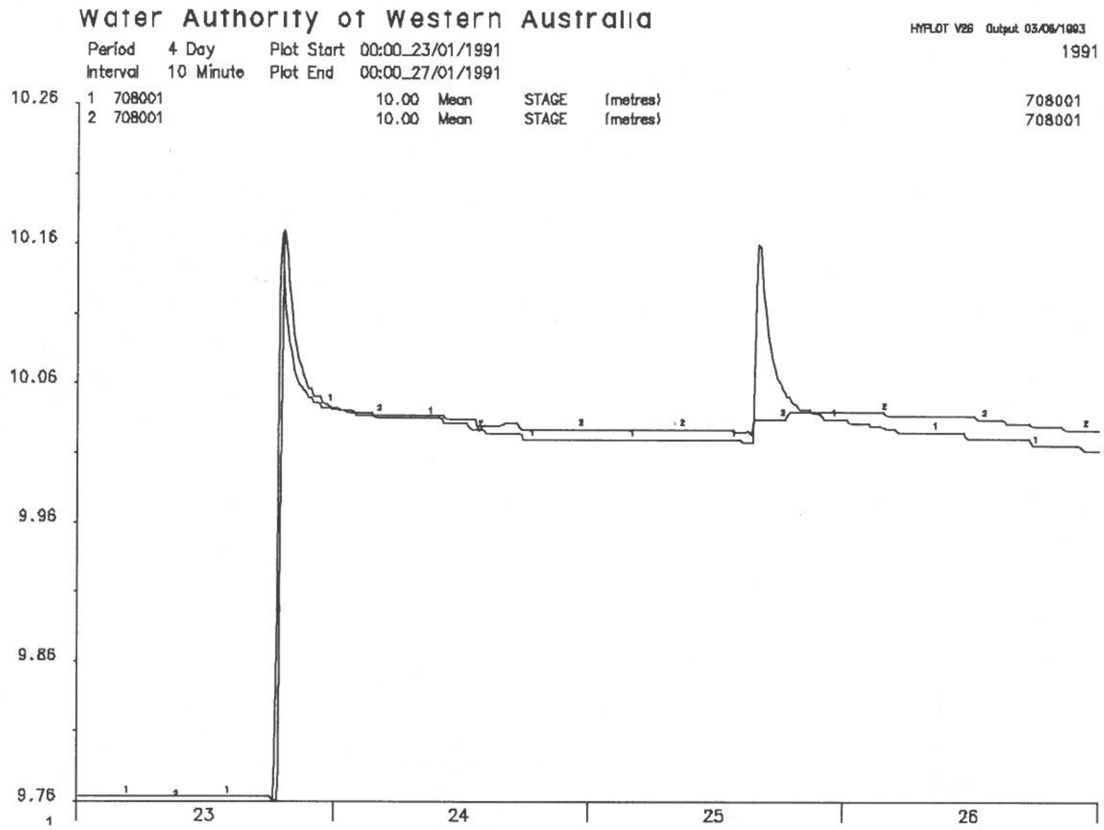


Water Authority of Western Australia
Period 62 Day
Interval 2 Hour
Plot Start 00:00_05/01/1992
Plot End 00:00_07/03/1992
HYPLOT V26 Output 10/06/1993
1992
1 708001 10.00 Mean STAGE (metres) 708001 .F
2 708001 10.00 Mean STAGE (metres) 708001 .C
11.6
11.2
10.8
10.4
10
9.6
5-8
9-12
13-16
17-20
-24
25-28
29-1
2-5
6-9
10-13
4-17
18-21
22-25
26-29
1-4
2
1

TABLE N°.1

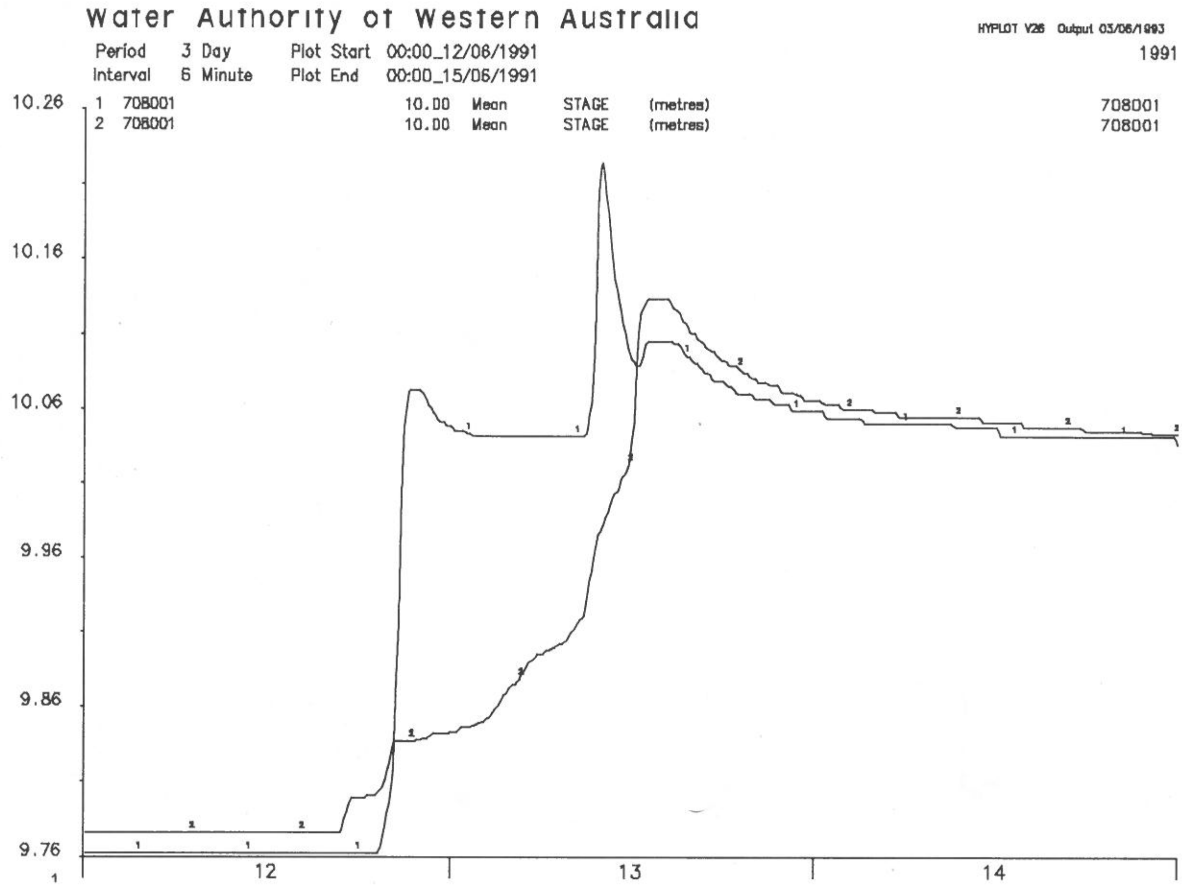
DATE	STAGE(PRI)	STAGE(SEC)
09/03/83	10.025	10.048
18/04/83	10.032	10.049
15/06/83	10.010	10.028
26/01/84	10.005	10.032
09/05/84	10.032	10.049
12/07/84	10.022	10.041
13/10/84	10.013	10.027
03/01/85	10.026	10.037
21/04/85	10.017	10.031
23/12/86	10.439	10.562
23/12/86	10.378	10.481
30/12/86	10.516	10.620
19/01/87	10.796	10.872
05/02/87	10.635	10.705
05/02/87	11.121	11.273
11/02/87	10.305	10.371
20/04/88	10.500	10.530
18/01/90	11.395	11.769
19/01/90	11.067	11.201
19/01/90	10.915	11.030
19/01/90	10.882	10.869
22/01/90	10.585	10.634
25/01/90	10.377	10.494
27/01/90	10.734	10.827
28/01/90	10.818	10.916
23/01/91	10.185	10.182
13/06/91	10.105	10.133
27/04/92	10.124	10.133

PLOT No.2



From this plot, the first peak at both stations has been accurately recorded (Difference 0.003m). However the second peak, approximately the same magnitude as the previous peak, only occurs at the primary station. Only a small change in stage occurring at the secondary station.

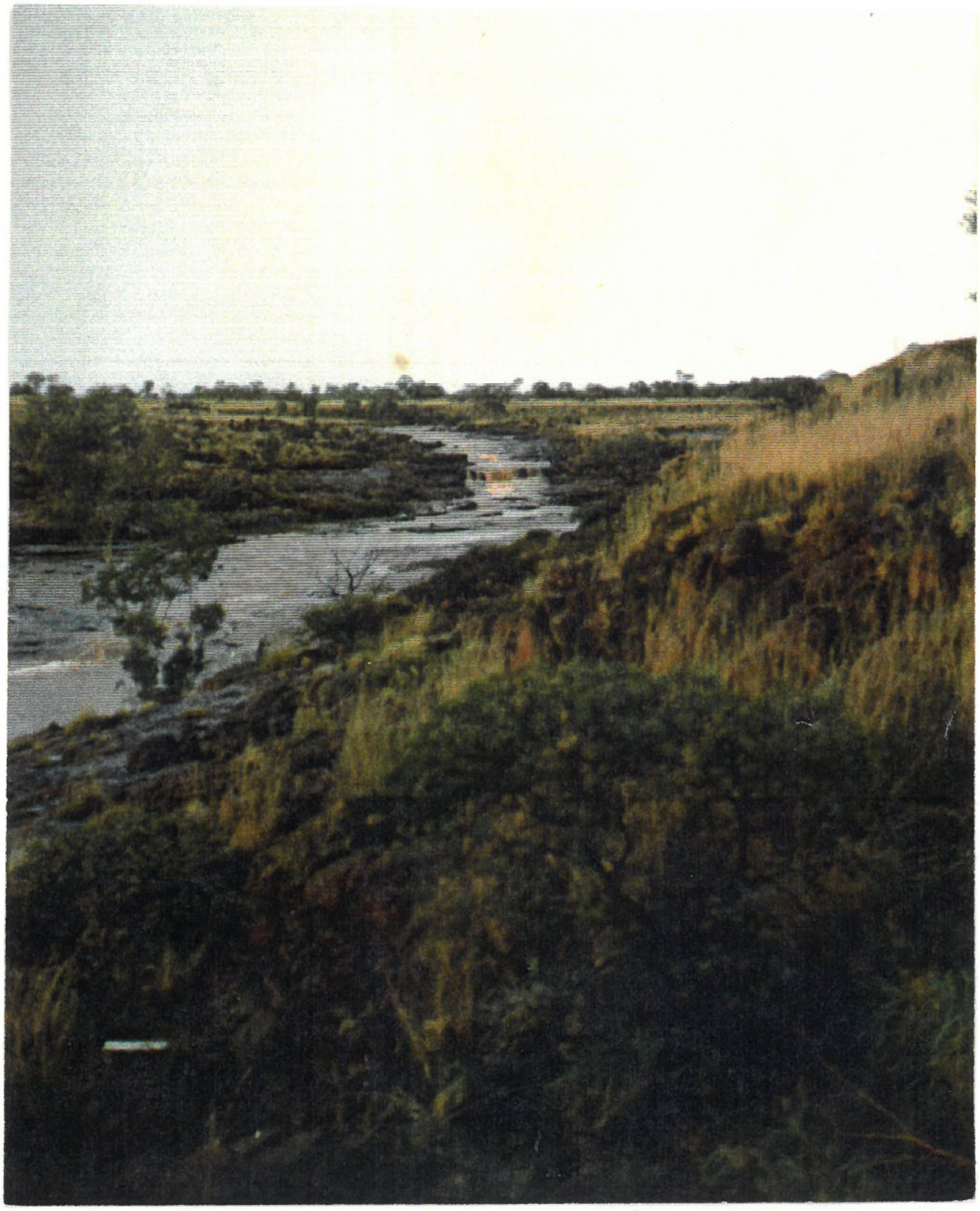
PLOT No.3



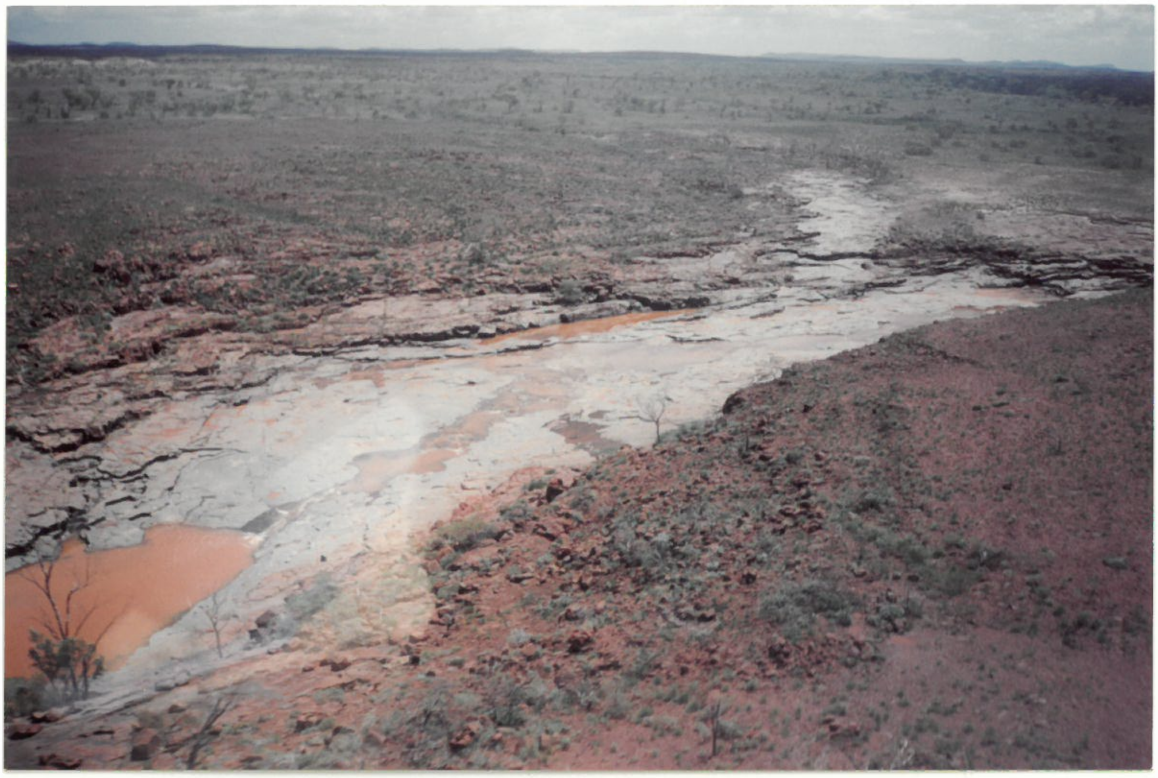
Two peaks occur during this period at the Primary station, whilst stage at the secondary station is still rising. The third peak is then recorded by both stations (Difference +0.023m).

From the plots it can be seen that water is possibly entering the stream, under certain conditions, at a point between the two stations. This however does not occur all the time and some peaks are recorded accurately at both stations (See Plots 1,2, and 3).

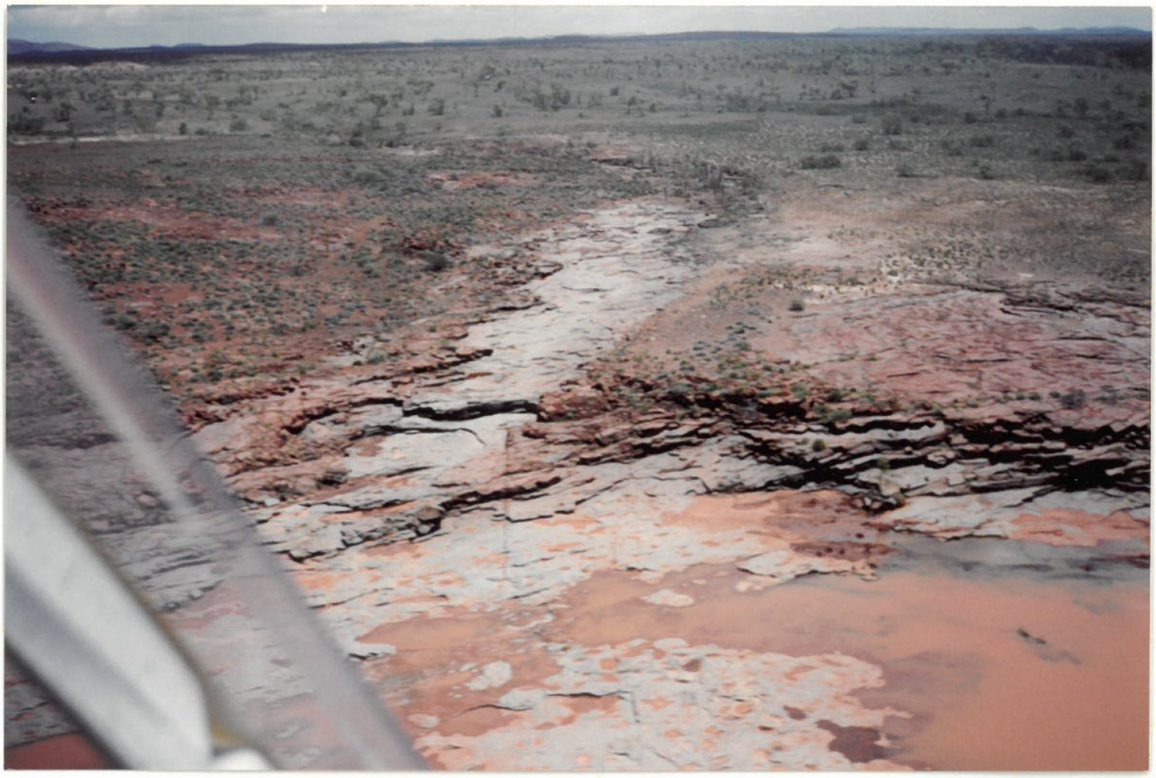
From observations (See supplied photographs) there is a definite channel converging with the creek, midway between the two stations. From a photograph of the area during the 82/83 wet season, an extensive amount of water can be seen flowing down this channel, whilst there is little or no flow from the main channel.



82/83 Wet season, inflow between stations



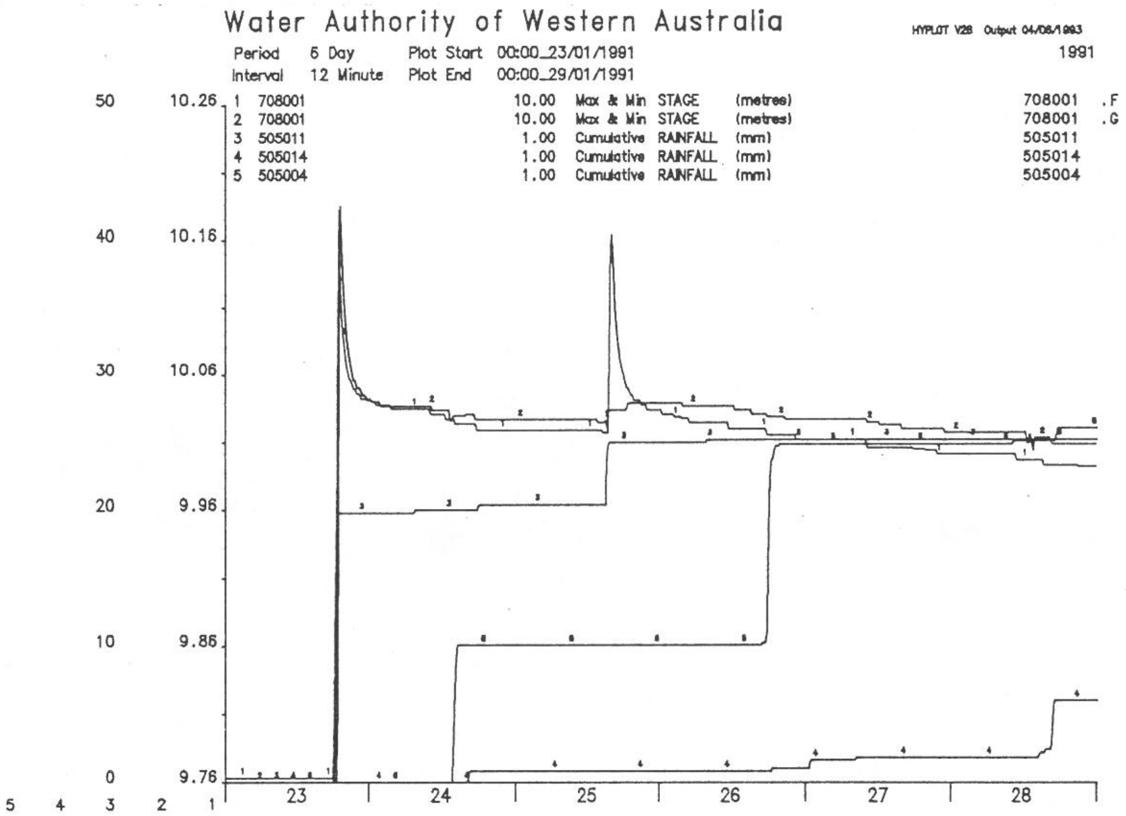
February 1993, Aerial View of inflow channel
Note Primary Station pool in bottom left hand corner



February 1993 Aerial View of inflow channel
Note Secondary Station pool bottom right corner

Conditions that would possibly cause flow in this channel are:

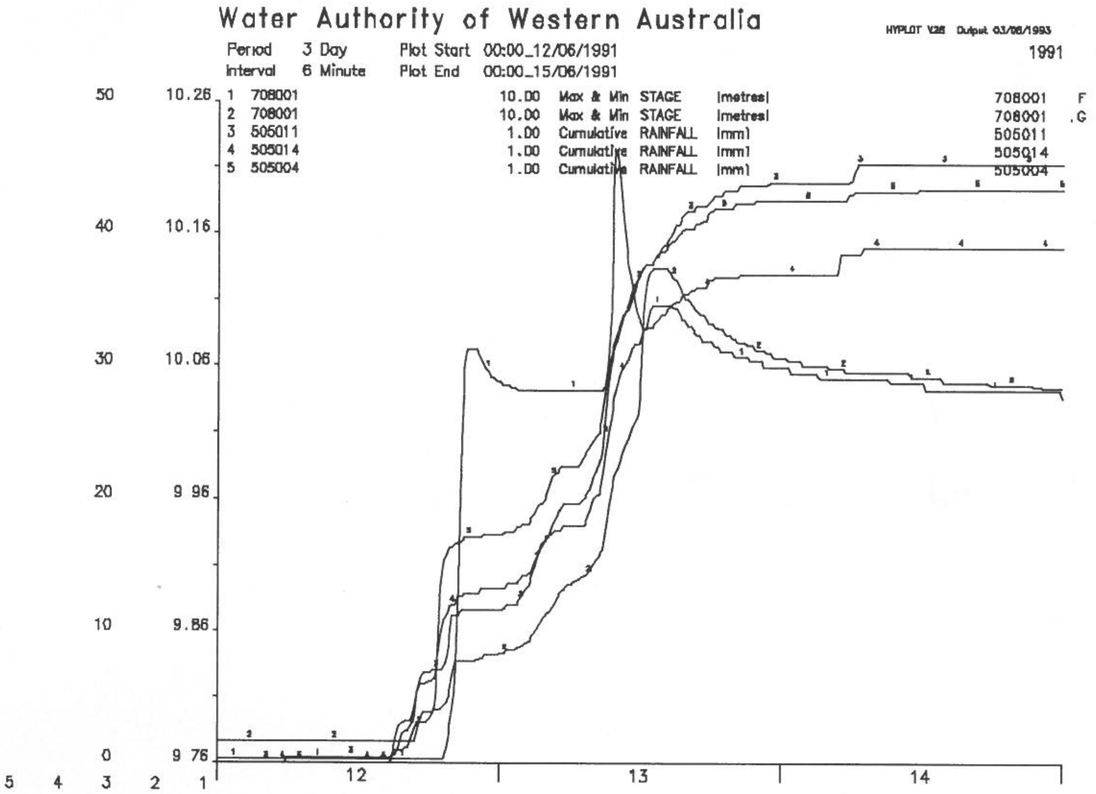
- Heavy localised rainfall in area, causing small channel to flow and fill downstream pool. Secondary pool would fill slowly due to little or no widespread rainfall across catchment, and slower runoff from soil upstream. Runoff to the downstream pool would also be increased by the large area of rock, between stations.



From the plot, the pluvio connected to the Primary station, has recorded rainfall corresponding to the flow at that station. Data from Packsaddle Pluvio (M505014), approx 21km SW from Flat Rocks, and Munjina (M505004), 30km WNW of Flat Rocks, indicates that the rainfall in only localised and not widespread.

- Widespread rain occurs across catchment and the inflow channel flows, however peak from catchment runoff has not occurred, thus causing peak or peaks at primary station, Finally corresponding peaks are then recorded at both stations.

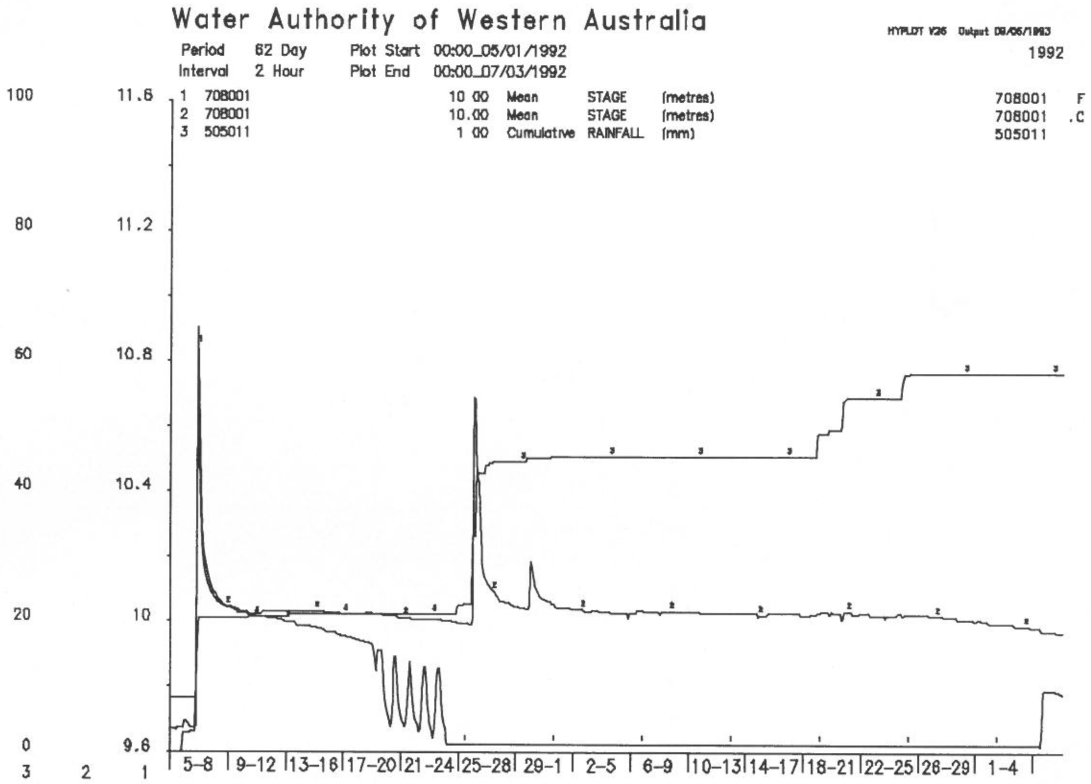
  This can be seen in the following plot.Rainfall is widespread, occurring at the gauging station (M 505011), and around the catchment Packsaddle (M505014) and Munjina (505004).



RECONSTRUCTING DATA

Accurately reconstructing data from the Secondary station, becomes increasingly difficult, due to the flow in the inflow channel. Even though data is available from surrounding raingauges, it is difficult to determine whether the channel flow has had an influence on the flow or not. The influence of the inflow would also be more apparent at low flows ie less than 10.500, where the majority of flow occurs.

Data from the secondary station, should be treated with caution, when carrying out reconstruction, due to the problems mentioned. An example of this can be seen in the following plot. Due to localised rainfall at station, it is impossible to determine if flow has occurred at the primary station, even though no flow has been recorded at the secondary station.



RECORDING INACCURACIES - SECONDARY STATION

A History of problems has also existed at the secondary site. Between 1978 and 1982 the manometer was unable to record peaks above 10.450mSL (See numerous reports Secondary Station History File 67- 92). This was attributed to be turbulence and high velocities at orifice during high flow events.The orifice position was changed a number of times to overcome this. This did not prove to be effective and the orifice was returned to its original position. A possibility of gas leaks was also investigated. No leaks were found and replacement of all the manometer equipment was made, and high pressure tests carried out (See History File Note) 7/1/85). Note that three peaks have been recorded above 11.000 between 1989 and 1992.

DATA QUALITY

Currently the secondary station records backup data for the primary station. However, as indicated by the plots and faults, the data from the backup station is, at times, completely different to that recorded at the primary station, and not a true indication of the flow from the catchment. Therefore the overall quality of the data, from the secondary station is low, in comparison to the data from the primary station.

CONCLUSIONS

The purpose of the secondary station, is to provide good quality backup data. However as can be seen from the information given, the quality of the data is suspect due to inflow and other faults. The ability to obtain an accurate stage-stage correlation for the entire range of stages, from both stations is also not possible. Therefore the data from the secondary station has no overall value, and continued operation of the station would not provide any benefits.

RECOMMENDATIONS

Due to the low value of the data from the secondary station, presently and in the future, the recommendation would be to close the secondary station. All equipment removed from the site, the shed dismantled and the concrete pad broken up, returning the area, as best, to its natural environment.

The data from Flat Rocks - Marillana Creek is important to the 'Port Headland - Newman Railway Investigation' for B.H.P.Iron Ore. Due to this, some form of backup should be used. A cost effective alternative would be to use a 1.0m Wesdata capacitance probe(s), to record data at the primary station. These probes can be mounted inside the PLI tube, with the fluorescein die tubing, replacing the existing pole. Therefore providing a dual purpose, accurate definition of peaks and backup data if required.

Michael Whiting, Water Resources Officer - Karratha
10th June 1993

TO: Regional Water Resources Officer

FROM: Senior Water Resources Officer, Pilbara

SUBJECT: CLOSURE OF 708001 SECONDARY GAUGING STATION

As discussed on 10 June, attached is a copy of a report by Michael Whiting on the value of continuing to operate Flat Rocks secondary gauging station.

It is quite a comprehensive report on the problems associated with the station. He particularly focuses on the inability to correlate the low flows. This was a source of frustration when trying to reconstruct lost record at the primary station.

As you are aware this station has produced poor results in the past and is continuing to do so.

Continued operation of the station, I think, is fruitless.

I concur with Mick's suggestion to close the station. This will be done in the week 14 June to 18 June unless you have any objections.

For your consideration please.

Ross Doherty

11 June, 1993.

```
----------------------------- PROGRAM SFBRSE ------------------------------SFBROP00
                          Browse operating periods

station number (WR)                      S 708001
station name                             MARILLANA CREEK       FLAT ROCKS
alternative reference:    type           WR           station number    S708001
operating period:         open           15 08 1967            close    18 04 1983
general site details                     MAN-SERVO(SITE1)TRAV
information recorded                     30                    status   (bores only)

general comments for this period
```

~~[illegible]~~
Can't say what this date refers to but it is not entirely correct.

```
<PF20> next operating period         <PF23> next station          <PF1> help
<PF3>  return to option selection screen
4B                 Aa                  B0--SESSION1    R 4   C 34       11:33 16/07/93
```

Rolly,

① These details are a bit confusing & I think incorrect.

② The HISTORY IS AS FOLLOWS:-

15/8/67 – ORIGINAL STATION OPENNED.

23/2/83 – NEW STATION COMMISSIONED, ORIGINAL STN BECOMES THE SECONDARY SITE, TRAVELLERWAY RE-LOCATED TO NEW (PRIMARY) SITE).

17/6/93 – OLD STATION CLOSED, PRIMARY SITE CONTINUES AS BEFORE.

③ Could you please arrange to have the necessary changes made to the registration details, if necessary.

Thanks.

ROSS
16/7/93.

WATER AUTHORITY OF W.A. — WRS 1

WATER RESOURCES INVESTIGATION

REPORT ON CHANGES THAT COULD AFFECT STATION RATING
OR FAULTS THAT COULD AFFECT ACCURACY OF RECORDED DATA

Station: FLAT ROCKS (SECONDARY) No. 708001 Date: 16/7/93.

Instrument Type: MAN-SERVO + ASSOCIATED INSTRUMENTS. Inventory No.

Estimate of Period Affected FROM .... hrs 17 / 6 / 93 to .... hrs / /

(1) On this date the SECONDARY Station was CLOSED. The decision was made after concluding that the record produced from the site over the years was of little value.

(2) ~~[illegible]~~ All instrumentation, shelter, pipe etc has been removed from the site. The site has been left in as natural condition as possible.

(3) The logger has been unloaded and dealt with in the normal way.

(4) The downstream site (PRIMARY STN) will continue to operate. As this station has some interest to BHP, a Wesdata Probe will be mounted alongside to lowest PLI as a backup recorder.

Observer: [signature] Dist Hydrographer: [signature]

THIS FORM SHOULD BE COMPLETED ON SITE

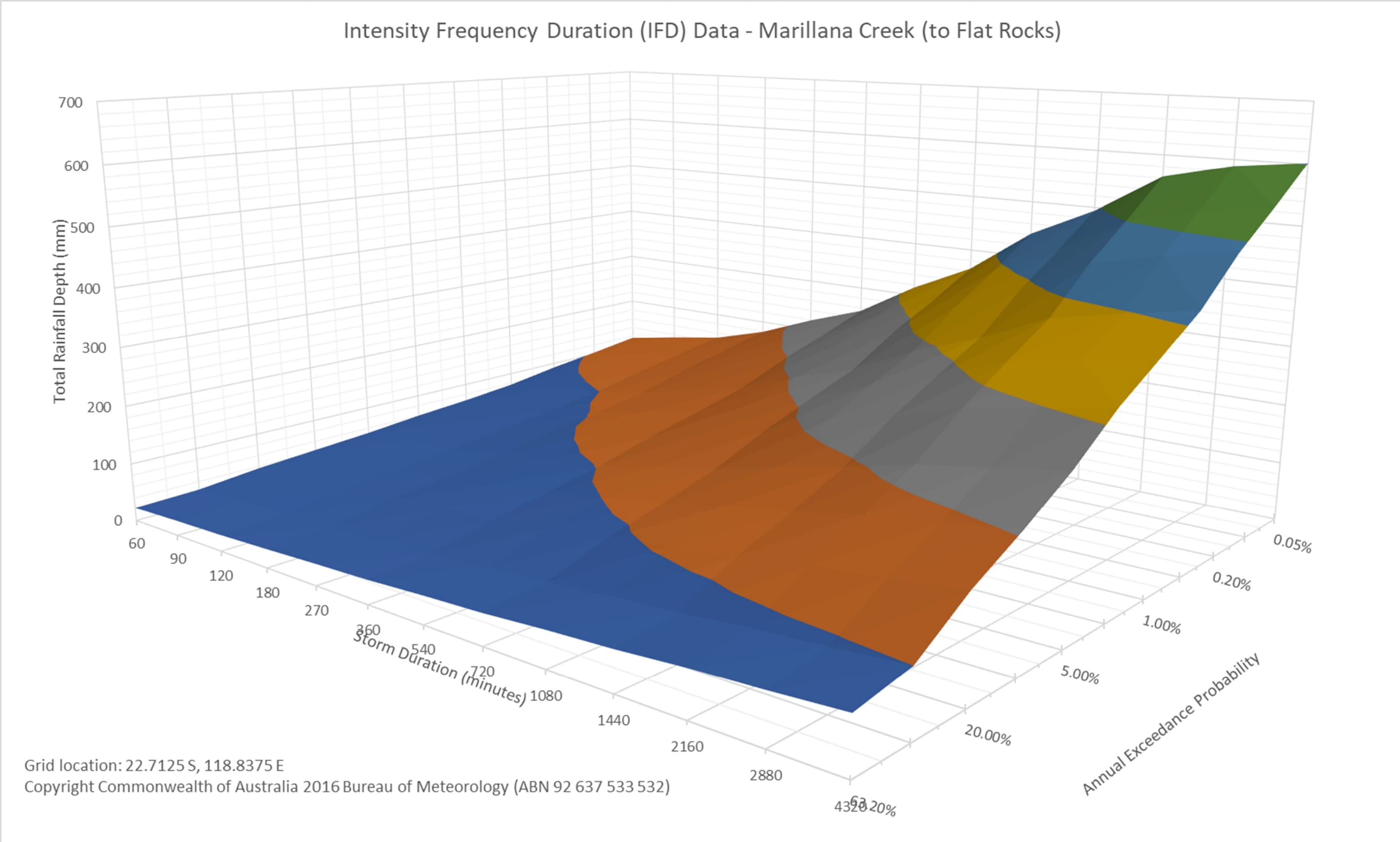
FIELD COPY

02822/7/91—50PDS—AS/4636

Appendix B
Design rainfall inputs and calculations

IFD data for catchment to Flat Rocks

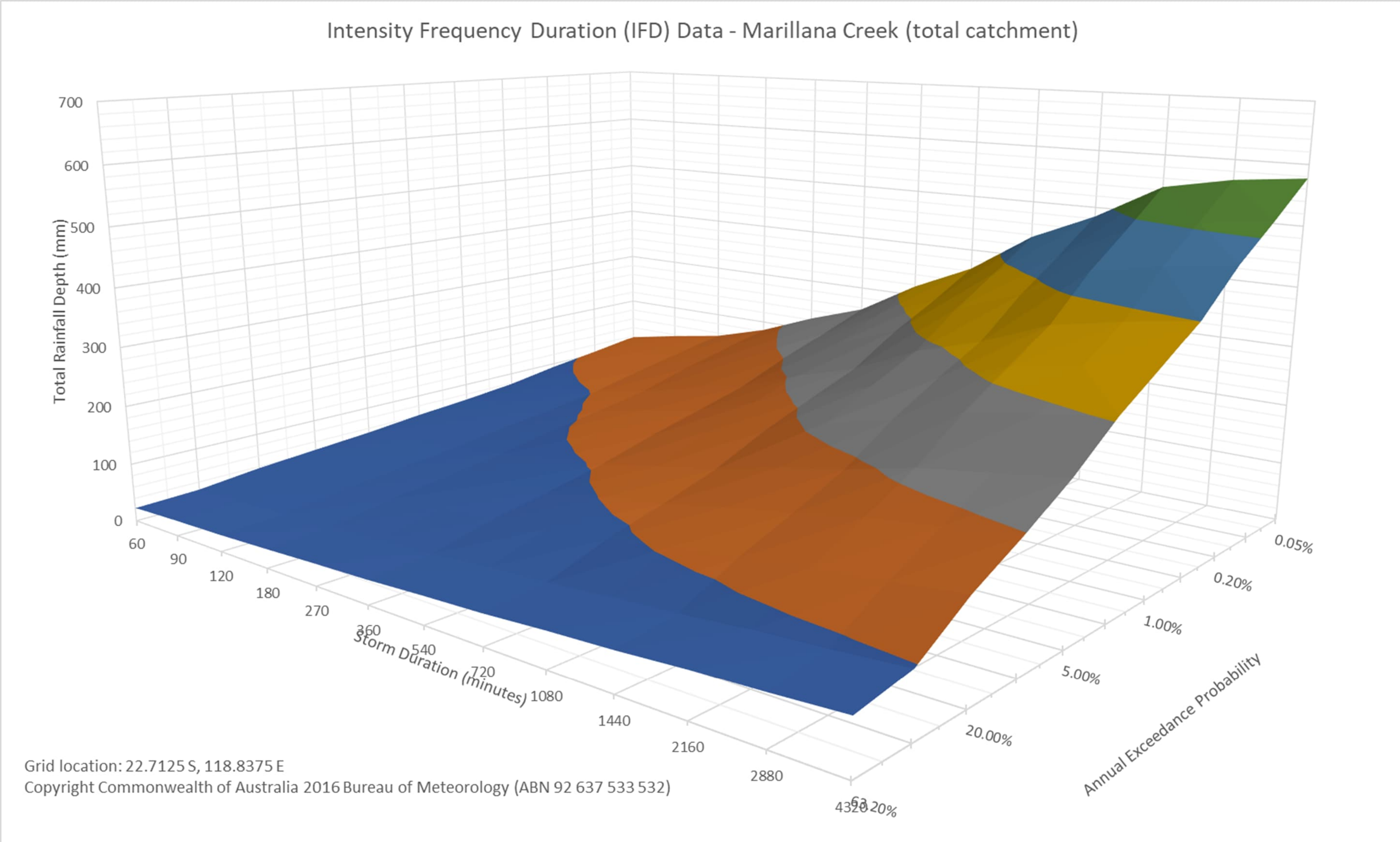
Storm Duration (hours)	AEP event										
	63.2%	50%	20%	10%	5%	2%	1%	1 in 200	1 in 500	1 in 1000	1 in 2000
1	22.4	25.8	36.4	43.6	50.7	60.1	67.3	76.7	91.3	103	116
1.5	25.5	29.3	41.5	49.9	58.1	69.2	77.8	88.7	106	119	134
2	27.8	32	45.6	55	64.4	77.1	87	99.2	118	134	150
3	31.4	36.4	52.5	63.8	75.2	91	103	118	141	159	179
4.5	35.6	41.6	61	75	89.3	109	126	143	171	194	219
6	39.1	45.9	68.3	84.7	102	126	145	166	198	225	254
9	44.9	53	80.6	101	123	154	180	205	245	279	315
12	49.5	58.8	90.7	115	141	178	208	237	285	323	365
18	56.8	67.8	107	137	169	215	253	288	345	391	442
24	62.4	74.8	119	153	191	242	285	325	388	439	494
36	70.5	84.7	135	175	219	278	326	374	445	502	563
48	76.1	91.5	146	189	237	298	348	397	470	527	589
72	83.3	100	159	205	256	318	367	417	487	543	602



Intensity Frequency Duration (IFD) Data - Marillana Creek (to Flat Rocks)
Total Rainfall Depth (mm)
0
100
200
300
400
500
600
700
Storm Duration (minutes)
60
90
120
180
270
360
540
720
1080
1440
2160
2880
4320
Annual Exceedance Probability
63.20%
20.00%
5.00%
1.00%
0.20%
0.05%
Grid location: 22.7125 S, 118.8375 E
Copyright Commonwealth of Australia 2016 Bureau of Meteorology (ABN 92 637 533 532)

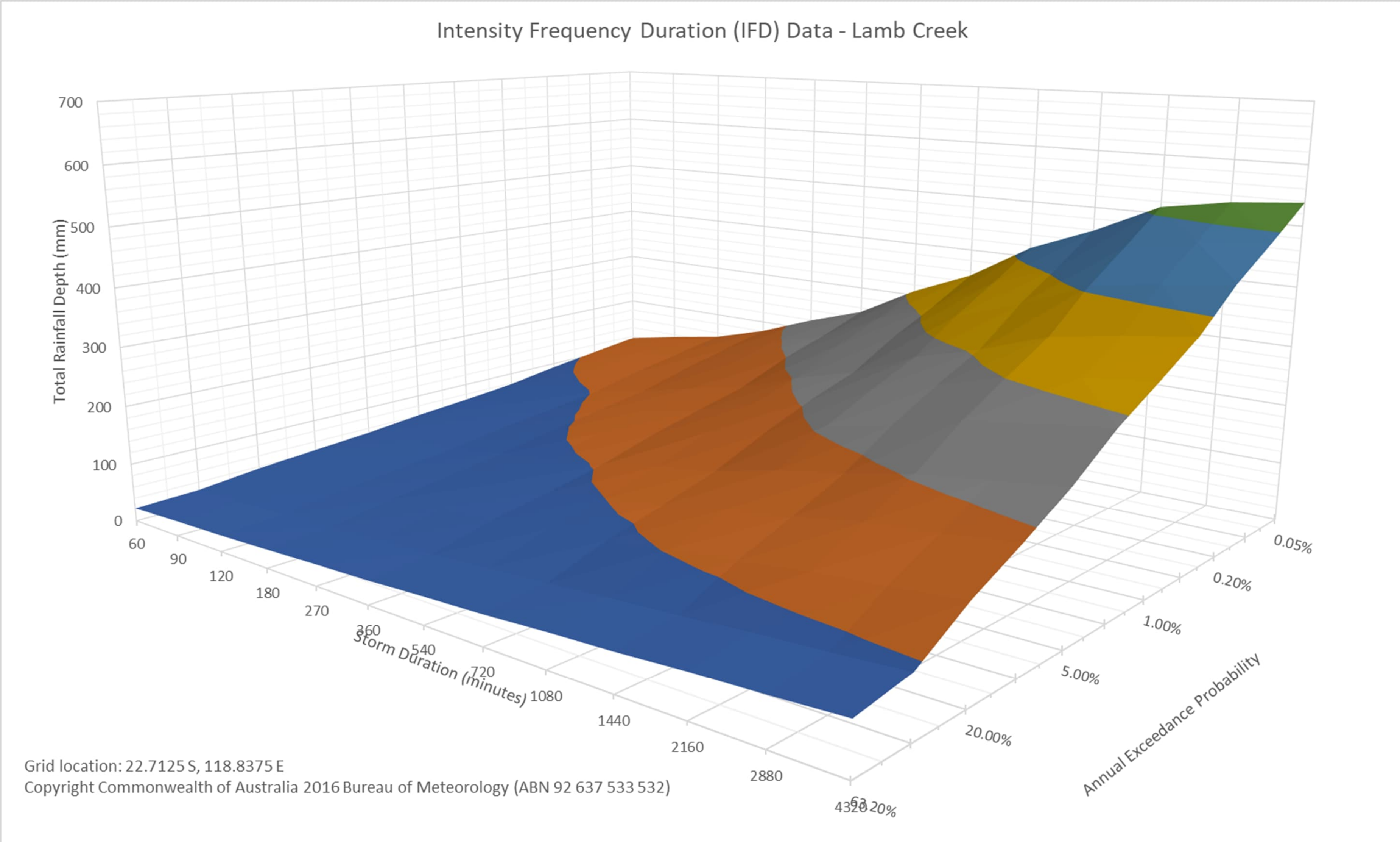
IFD data for total catchment to BHP Rail Crossing (total catchment)

Storm Duration (hours)	AEP event										
	63.2%	50%	20%	10%	5%	2%	1%	1 in 200	1 in 500	1 in 1000	1 in 2000
1	22.9	26.3	37.2	44.6	51.9	61.5	69	78.5	93.3	105	118
1.5	26	29.9	42.5	51.1	59.6	71.1	80	91.1	108	122	137
2	28.3	32.7	46.7	56.4	66	79.2	89.5	102	121	137	154
3	31.9	37.1	53.6	65.3	77.1	93.4	106	121	144	163	183
4.5	36.1	42.2	62.1	76.5	91.2	112	129	146	175	198	223
6	39.6	46.4	69.2	86	104	128	148	169	201	228	257
9	45	53.2	81.1	102	124	156	182	207	247	280	317
12	49.4	58.7	90.7	115	142	179	209	238	285	323	365
18	56.2	67.2	106	136	168	214	251	286	341	387	436
24	61.4	73.6	117	151	188	239	281	319	380	430	484
36	68.8	82.7	132	171	214	271	317	363	432	487	545
48	74	88.9	142	184	230	289	337	384	453	509	566
72	80.7	96.8	154	198	247	306	353	401	468	521	577


Intensity Frequency Duration (IFD) Data - Marillana Creek (total catchment)
Total Rainfall Depth (mm)
700
600
500
400
300
200
100
0
Storm Duration (minutes)
60
90
120
180
270
360
540
720
1080
1440
2160
2880
4320
Annual Exceedance Probability
63.20%
20.00%
5.00%
1.00%
0.20%
0.05%
Grid location: 22.7125 S, 118.8375 E
Copyright Commonwealth of Australia 2016 Bureau of Meteorology (ABN 92 637 533 532)

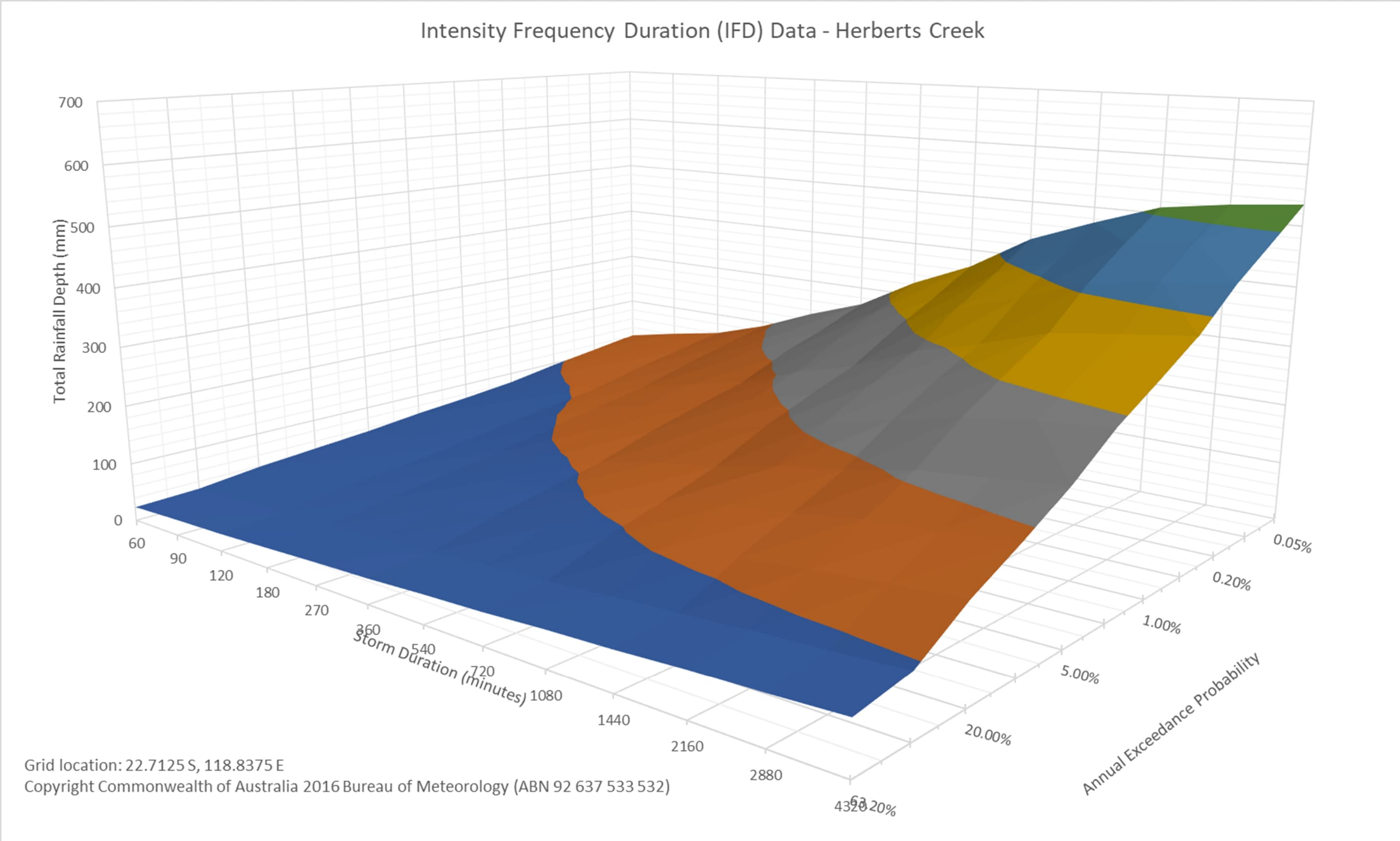
IFD data for Lamb Creek Catchment

Storm Duration (hours)	AEP event										
	63.2%	50%	20%	10%	5%	2%	1%	1 in 200	1 in 500	1 in 1000	1 in 2000
1	22.4	25.8	36.7	44.2	51.5	61.3	68.9	78	92.4	104	116
1.5	25.5	29.4	42	50.7	59.3	71	80.2	90.8	108	121	135
2	27.8	32.2	46.3	56.1	65.8	79.3	89.9	102	121	136	152
3	31.4	36.5	53.1	64.9	76.9	93.5	107	121	143	162	181
4.5	35.5	41.5	61.4	75.9	90.8	112	129	146	173	195	219
6	38.8	45.6	68.4	85.2	103	128	148	167	199	224	252
9	44.1	52.1	79.7	100	123	154	180	203	242	273	308
12	48.2	57.3	88.7	113	139	175	206	232	276	312	352
18	54.6	65.2	103	132	164	208	244	276	328	370	416
24	59.3	71.1	113	146	182	230	270	306	363	409	459
36	66.1	79.4	127	164	205	259	302	344	407	458	511
48	70.8	85	135	175	219	274	319	362	426	477	529
72	76.9	92.2	146	188	234	289	332	377	439	487	538


Intensity Frequency Duration (IFD) Data - Lamb Creek
Total Rainfall Depth (mm)
700
600
500
400
300
200
100
0
Storm Duration (minutes)
60
90
120
180
270
360
540
720
1080
1440
2160
2880
4320
Annual Exceedance Probability
63.20%
20.00%
5.00%
1.00%
0.20%
0.05%
Grid location: 22.7125 S, 118.8375 E
Copyright Commonwealth of Australia 2016 Bureau of Meteorology (ABN 92 637 533 532)

IFD data for Herberts Creek Catchment

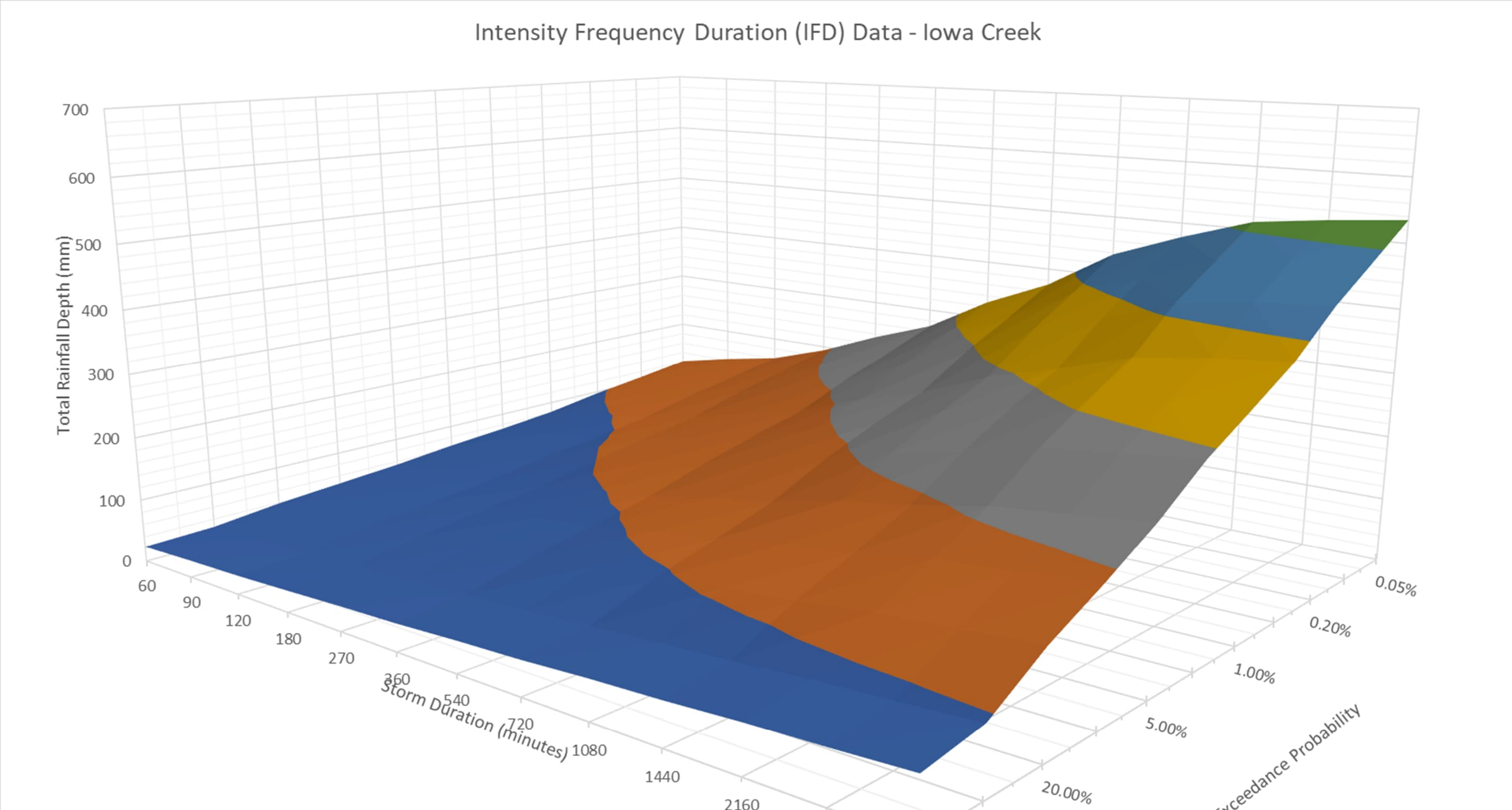
Storm Duration (hours)	AEP event									
	63.2%	50%	20%	10%	5%	2%	1%	1 in 200	1 in 500	1 in 1000	1 in 2000
1	23.5	27.1	38.5	46.3	53.9	64.2	72.1	81.6	96.6	109	122
1.5	26.8	31	44.2	53.4	62.4	74.7	84.2	95.5	113	127	142
2	29.3	34	48.8	59.1	69.4	83.5	94.7	107	127	143	160
3	33.2	38.6	56.2	68.6	81.2	98.8	113	128	151	171	191
4.5	37.6	43.9	64.9	80.2	95.9	118	136	154	183	206	232
6	41	48.2	72.2	89.9	108	135	156	176	210	237	267
9	46.4	54.8	83.8	106	129	162	189	214	254	288	324
12	50.6	60	92.9	118	145	184	215	243	289	327	369
18	56.8	67.8	107	137	170	215	253	286	340	384	432
24	61.3	73.4	116	150	187	237	279	315	374	422	473
36	67.7	81.2	129	168	210	264	308	350	413	464	510
48	72	86.4	138	178	222	278	322	365	429	479	525
72	77.7	93.1	147	189	235	290	333	378	438	486	535



Intensity Frequency Duration (IFD) Data - Herberts Creek
Total Rainfall Depth (mm)
700
600
500
400
300
200
100
0
Storm Duration (minutes)
60
90
120
180
270
360
540
720
1080
1440
2160
2880
4320
Annual Exceedance Probability
63.20%
20.00%
5.00%
1.00%
0.20%
0.05%
Grid location: 22.7125 S, 118.8375 E
Copyright Commonwealth of Australia 2016 Bureau of Meteorology (ABN 92 637 533 532)

IFD data for Iowa Creek Catchment

Storm Duration (hours)	AEP event										
	63.2%	50%	20%	10%	5%	2%	1%	1 in 200	1 in 500	1 in 1000	1 in 2000
1	23.6	27.2	38.7	46.5	54.2	64.4	72.3	82	97	109	122
1.5	27	31.2	44.5	53.7	62.7	75	84.6	95.9	113	128	143
2	29.5	34.2	49.1	59.5	69.8	84	95.2	108	128	144	161
3	33.5	39	56.6	69.2	81.9	99.6	114	129	153	172	193
4.5	38	44.4	65.6	81	96.9	119	137	155	185	209	234
6	41.5	48.7	73	90.9	110	136	158	178	212	240	270
9	47	55.5	84.8	107	130	164	191	216	257	292	328
12	51.2	60.8	94	120	147	186	218	246	293	332	373
18	57.5	68.6	108	138	172	218	256	289	344	389	437
24	62	74.3	118	152	189	240	281	318	377	426	477
36	68.3	82	131	169	211	266	310	352	416	464	512
48	72.6	87.1	139	179	224	279	324	367	430	478	525
72	78.1	93.7	148	190	236	291	334	378	438	486	535



Grid location: 22.7125 S, 118.8375 E

WORKSHEET 2: Generalised Tropical Storm Method Revised (GTSMR)

LOCATION INFORMATION	
Catchment Name: **Marillana Creek – Flat Rocks**	State WA
GTSMR zone(s): Coastal	

CATCHMENT FACTORS		
Topographical Adjustment Factor	**TAF** = 1.162	(1.0 – 2.0)
Decay Amplitude Factor	**DAF** = 0.929	(0.7 – 1.0)
Annual Moisture Adjustment Factor	$MAF_a = EPW_{catchment}/120.00$	
Extreme Precipitable Water ($EPW_{catchment}$) = 100.56	$\mathbf{MAF_a}$ = 0.838	(0.4 – 1.1)
Winter Moisture Adjustment Factor (where applicable)	$MAF_w = EPW_{catchment\_winter}/82.30$	
Winter EPW ($EPW_{catchment\_winter}$) = …………	$\mathbf{MAF_w}$ = ………………	(0.4 – 1.1)

PMP VALUES (mm) - Annual

Duration (hours)	Initial Depth ($\mathbf{D_a}$)	PMP Estimate $=D_a x TAF x DAF x MAF_a$	Preliminary PMP Estimate (nearest 10mm)	Final PMP Estimate (from envelope)
1	Where applicable, calculate GSDM (Bureau of Meteorology, 2003) depths		230	230
2			370	370
3			440	440
4			500	500
5			540	540
6			570	570
12	(no preliminary estimates available)			750
24	1213.9	1098.1	1100.0	1100.0
36	1432.2	1295.6	1300.0	1300.0
48	1635.2	1479.2	1480.0	1480.0
72	1993.1	1803.0	1800.0	1800.0
96	2261.9	2046.2	2050.0	2050.0
120	2386.5	2158.9	2160.0	2160.0

PMP VALUES (mm) – Winter (where applicable)

Duration (hours)	Initial Depth ($\mathbf{D_w}$)	PMP Estimate $=D_w x TAF x DAF x MAF_w$	Preliminary PMP Estimate (nearest 10mm)	Final PMP Estimate (from envelope)
1	Where applicable, calculate GSDM (Bureau of Meteorology, 2003) depths			
2				
3				
4				
5				
6				
12	(no preliminary estimates available)			
24				
36				
48				
72				
96				

Prepared by Josh Kraan Date 17/03/2023 Checked by ……………………………. Date ……/……/……

WORKSHEET 2: Generalised Tropical Storm Method Revised (GTSMR)

LOCATION INFORMATION	
Catchment Name: **Marillana Creek – BHP Outlet**	State: WA
GTSMR zone(s): Coastal Zone	
CATCHMENT FACTORS	
Topographical Adjustment Factor	**TAF** = 1.158 (1.0 – 2.0)
Decay Amplitude Factor	**DAF** = 0.928 (0.7 – 1.0)
Annual Moisture Adjustment Factor	$MAF_a = EPW_{catchment}/120.00$
Extreme Precipitable Water ($EPW_{catchment}$) = 100.53	**MAF_a** = 0.838 (0.4 – 1.1)
Winter Moisture Adjustment Factor (where applicable)	$MAF_w = EPW_{catchment\_winter}/82.30$
Winter EPW ($EPW_{catchment\_winter}$) = NA	**MAF_w** = ……………… (0.4 – 1.1)

PMP VALUES (mm) - Annual

Duration (hours)	Initial Depth (D_a)	PMP Estimate $=D_a x TAF x DAF x MAF_a$	Preliminary PMP Estimate (nearest 10mm)	Final PMP Estimate (from envelope)
1	Where applicable, calculate GSDM (Bureau of Meteorology, 2003) depths		230	230
2			370	370
3			440	440
4			500	500
5			540	540
6			570	570
12	(no preliminary estimates available)			740
24	1188.9	1070.6	1070.0	1070
36	1394.4	1254.8	1250.0	1250
48	1585.6	1427.9	1430.0	1430
72	1923.0	1731.7	1730.0	1730
96	2188.9	1971.2	1970.0	1970
120	2311.4	2081.5	2080.0	2080

PMP VALUES (mm) – Winter (where applicable)

Duration (hours)	Initial Depth (D_w)	PMP Estimate $=D_w x TAF x DAF x MAF_w$	Preliminary PMP Estimate (nearest 10mm)	Final PMP Estimate (from envelope)
1	Where applicable, calculate GSDM (Bureau of Meteorology, 2003) depths			
2				
3				
4				
5				
6				
12	(no preliminary estimates available)			
24				
36				
48				
72				
96				

Prepared by Josh Kraan Date 17/03/2023 Checked by …………………………. Date …../…../…...

Appendix C
BHP guidance note – climate change

BHP

Memorandum

Date	19 May 2023
To	Matt Rafty
From	Johanna Richards and Iain Rea - Water Engineering and Modelling - WAIO
CC	
Subject	**Recommended Approach for Estimating Non-stationary Probable Maximum Precipitation – Yandi Mine**

1 Problem Statement

Various studies have highlighted that precipitable water is predicted to increase on a global level due to climate change, which in turn will affect the precipitation associated with the Probable Maximum Precipitation (PMP). This increase in precipitable water is driven by projected increased temperatures which in turn will drive higher levels of water vapor in the atmosphere.

2 Summary of Current Approach for Closure Design

BHP uses the 1-in-10,000 year Annual Exceedance Probability (AEP) for design of any pertinent (i.e. high-consequence) infrastructure expected to remain in place after closure. This event is determined based on a log-log interpolation between the 1-in-2000 AEP and the PMP (1 x 10^6 AEP). The PMP has traditionally been ascertained based on the procedure outlined by WMO (1986)[1], and has not taken into account potential uplifts occurring as a result of climate change.

3 Considerations for Updated Approach in Closure Design

3.1 Climate Change Uplift

The consideration of climate change should be considered if (i) the asset will still be functional as of 2035 and beyond and (ii) consequences of failure are medium or high (Ball et al., 2019)[2]. A range of climate scenarios be considered, in line with the consequence of failure of the asset. The minimum basis for design should be the Representative Concentration Pathway (RCP) 4.5 scenario (Ball et al., 2019). This concentration pathway is recommended as the less-conservative RCP2.6 concentration pathway requires ambitious global emissions reductions (Ball et al., 2019). Where additional expense can be justified based on socioeconomic and environmental grounds, the high concentration pathway RCP8.5 should also be considered.

Given recent global efforts in reducing carbon emissions such as the US Inflation reduction act, Europe's Green Deal and Australia's target of 82% renewables for 2030, the medium RCP4.5 (SSP2-4.5) is considered appropriate for Yandi's diversion channels.

[1] World Meteorological Organization (WMO). 1986. Manual for estimation of probable maximum precipitation, WMO Rep. 332, Geneva, Switzerland.
[2] Ball J, Babister M, Nathan R, Weinmann E, Retakllick M, Testoni I (Editors). 2019. Australian Rainfall and Runoff: A Guide to Flood Estimation, Commonwealth of Australia (Geoscience Australia).

In support of the Asset Climate Change Plan (BHP 2021)[3], BHP's Climate Adaptation Group commissioned Willis Towers Watson (WTW) to develop asset-specific climate-related hazards data across its operations. The data developed by WTW included increases in average temperature, average precipitation and projected temperature increase. The Rainfall Intensity Scaling Factor is directly proportional to the projected temperature increase, and is derived by applying a 5% increase in rainfall depth per projected increase in median temperature (T_m). WTW calculated the projected temperature increases across each of the WAIO sites for the years 2035, 2055 and 2075 for three different shared socioeconomic pathways (SSPs). SSPs describe plausible socioeconomic narratives, each of which represents various challenges for mitigation and adaptation to climate change (Riahi et al., 2017)[4]. WTW calculated the temperature increases for SSP1 (corresponding to RCP2.5), SSP2 (corresponding to RCP 4.5) and SSP5 (corresponding to RCP8.5).

Examination of WTW temperature increase predictions shows a high agreement between the WAIO sites, and as such the Whaleback site was chosen to provide representative temperature increase. Table 1 summarises the projected temperature increases for Whaleback, along with the predicted Rainfall Intensity Scaling Factor. Note that only the values for SSP2 (RCP4.5) and SSP5 (RCP8.5) are presented, as SSP1 represents the plausible best-case scenario and is not relevant to this climate change impact assessment.

Table 1: Rainfall Intensity Scaling Factors by decade for WAIO based on WTW Climate Data

Year	**Predicted Temperature Increase (°C)**		**Rainfall Intensity Scaling Factor 1.05^{T_m}**	
	SSP2 (RCP4.5)	**SSP5 (RCP8.5)**	**SSP2 (RCP4.5)**	**SSP5 (RCP8.5)**
2035	0.9 °C	1.1 °C	1.04	1.06
2055	1.5 °C	2.3 °C	1.08	1.12
2075	2.1 °C	3.8 °C	1.11	1.20

It should be noted that the WTW predicted temperature increases have been compared to those presented in ARR2019 (Ball et al., 2019), and close alignment is noted between both approaches. It should be noted that for 2090 (the farthest year for which temperature predictions are available), the rainfall intensity scaling factor based on ARR2019 is 1.12 for RCP 4.5.

3.2 Adjustment of PMP (Non-stationarity)

Recent publications by Visser et al (2022)[5] highlight expected increases in the PMP across Australia due to thermodynamic considerations. Whereas limited information is available for Western Australia, increases in the PMP depths would be expected to increase between approximately 15% on average (Australia-wide) for the SSP1-2.6 scenario and approximately 35% on average (Australia-wide) for the SSP5 (RCP8.5) scenario.

Assuming a median value of 25% uplift for the SSP2 (RCP4.5) scenario is a possible approach to accounting for the climate change uplift in the PMP. An AEP of 1 x 10^6 would be assigned to the PMP, in line with current practice.

An alternate approach is to apply the climate change Rainfall Intensity Scaling Factors directly to the 10,000 year AEP, as a proxy to increasing the PMP. This would result in an 11% increase to the 10,000 year AEP (as calculated based on the traditional approach using the stationary PMP).

It should be noted that several studies have highlighted that for catchments with critical durations of 12 hours or more, increases in runoff due to climate change are negligible, and so the application of a 5% increase in rainfall depth per unit increase in projected temperature is conservative.

[3] BHP Billiton. 2021. Asset Climate Change Plan WAIO (Version A).
[4] Riahi, K, Vuuren, D, Kriegler E., (et al). The Shared Socioeconomic Pathways and their energy, land use, and greenhouse gas emissions implications: An overview. Global Environmental Change. Volume 42, January 2017, Pages 153- 168.
[5] Visser, J.B., Kim, S., Nathan, R and Sharma, A. 2022. The Impact of Climate Change in Operational Probable Maximum Precipitation Estimates. Water Resources Research. *10.1029/2022WR032247*

4 Recommended Approach

In summary, BHP recommends the following approach for incorporating the impacts of climate change on the PMP at Yandi:

1) Utilize the WTW temperature indices for determining the temperature uplift for 2075 (furthest time currently available for temperature projections). The 2075 timeframe is deemed appropriate given the permanent nature of the diversions.

2) Ascertain the 1-in-10,000 year AEP based on the traditional methods currently outlined in ARR2019 (excluding any uplifts due to climate change).

3) Apply 11% uplift to the 1-in-10,000 year AEP design depth based on the WTW predicted temperature indices for 2075 for the SSP2-4.5 scenario.

Appendix D
Current Yandi Mine Landform – Preliminary Flood Mapping

YANDI CLOSURE LANDFORM SPS

FIGURE 1A

MARILLANA CREEK MAINSTREAM CURRENT (2022) OPERATIONS LANDFORM 1% AEP PEAK FLOOD DEPTH

Legend

- Hydraulic Model Extent
- Rail Network
- State Road
- Local Road
- Miscellaneous Road
- BHP Mining Tenements
- 2 m interval ground surface contours

Peak Flood Depth (m)

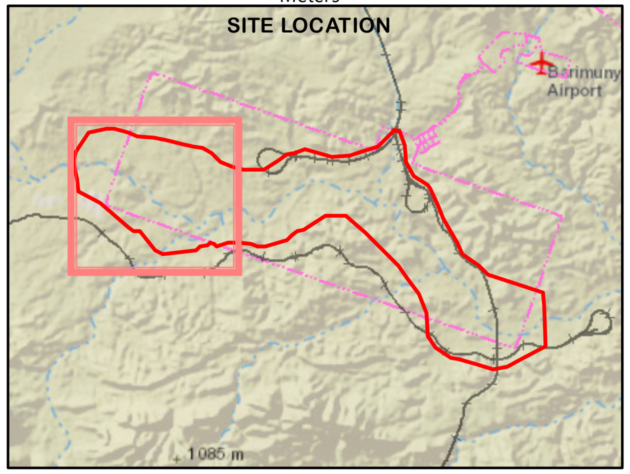
- 0 - 0.5
- 0.5 - 1
- 1 - 3
- 3 - 5
- 5 - 8
- >8

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994
False Easting: 500,000.0000

N

Scale at A3 - 1:24,000

0 400 800 1,200 1,600
Meters



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YANDI CLOSURE LANDFORM SPS

FIGURE 1B

MARILLANA CREEK MAINSTREAM CURRENT (2022) OPERATIONS LANDFORM 1% AEP PEAK FLOOD DEPTH

Legend

- Hydraulic Model Extent
- Rail Network
- State Road
- Local Road
- Miscellaneous Road
- BHP Mining Tenements
- 2 m interval ground surface contours

Peak Flood Depth (m)

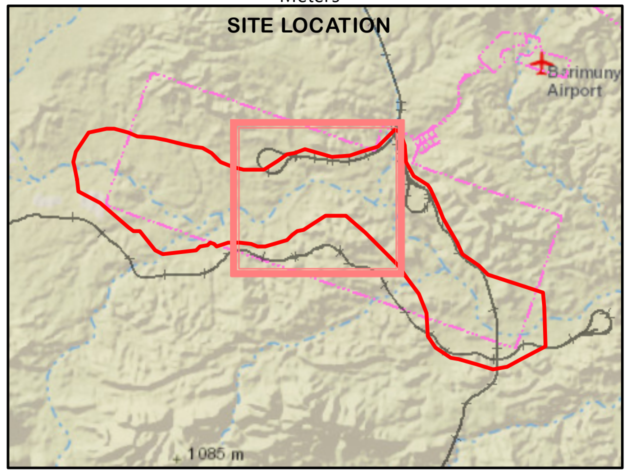
- 0 - 0.5
- 0.5 - 1
- 1 - 3
- 3 - 5
- 5 - 8
- >8

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994
False Easting: 500,000.0000

N

Scale at A3 - 1:24,000

0 400 800 1,200 1,600
Meters



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29/05/2023 Rev: A ISSUED FOR INFORMATION Org: PC Chk: PC

YANDI CLOSURE LANDFORM SPS

FIGURE 1C

MARILLANA CREEK MAINSTREAM CURRENT (2022) OPERATIONS LANDFORM 1% AEP PEAK FLOOD DEPTH

Legend

- Hydraulic Model Extent
- Rail Network
- State Road
- Local Road
- Miscellaneous Road
- BHP Mining Tenements
- 2 m interval ground surface contours

Peak Flood Depth (m)

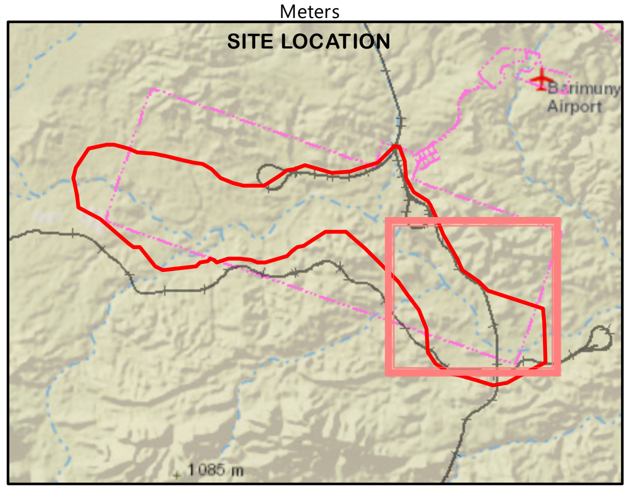
- 0 - 0.5
- 0.5 - 1
- 1 - 3
- 3 - 5
- 5 - 8
- >8

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994
False Easting: 500,000.0000

N

Scale at A3 - 1:24,000

0 400 800 1,200 1,600
Meters



Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community
National Geographic, Esri, Garmin, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO,

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YANDI CLOSURE LANDFORM SPS

FIGURE 2A

MARILLANA CREEK MAINSTREAM CURRENT (2022) OPERATIONS LANDFORM 1 in 10,000 AEP PEAK FLOOD DEPTH

Legend

- Hydraulic Model Extent
- Rail Network
- State Road
- Local Road
- Miscellaneous Road
- BHP Mining Tenements
- 2 m interval ground surface contours

Peak Flood Depth (m)

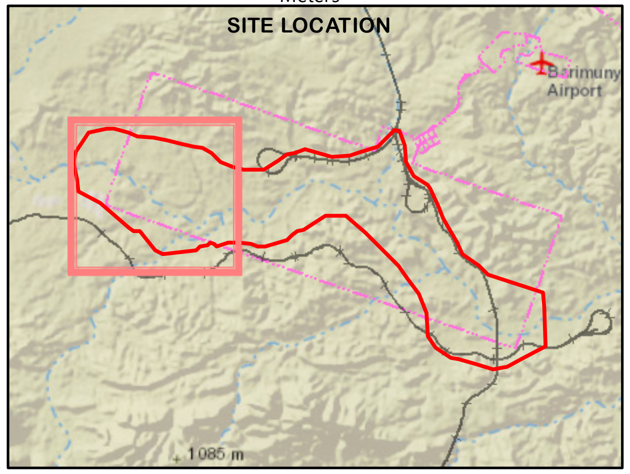
- 0 - 0.5
- 0.5 - 1
- 1 - 3
- 3 - 5
- 5 - 8
- >8

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994
False Easting: 500,000.0000

N

Scale at A3 - 1:24,000

0 400 800 1,200 1,600
Meters



Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community
National Geographic, Esri, Garmin, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO,

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YANDI CLOSURE LANDFORM SPS

FIGURE 2B

MARILLANA CREEK MAINSTREAM CURRENT (2022) OPERATIONS LANDFORM 1 in 10,000 AEP PEAK FLOOD DEPTH

Legend

- Hydraulic Model Extent
- Rail Network
- State Road
- Local Road
- Miscellaneous Road
- BHP Mining Tenements
- 2 m interval ground surface contours

Peak Flood Depth (m)

- 0 - 0.5
- 0.5 - 1
- 1 - 3
- 3 - 5
- 5 - 8
- >8

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994
False Easting: 500,000.0000

N

Scale at A3 - 1:24,000

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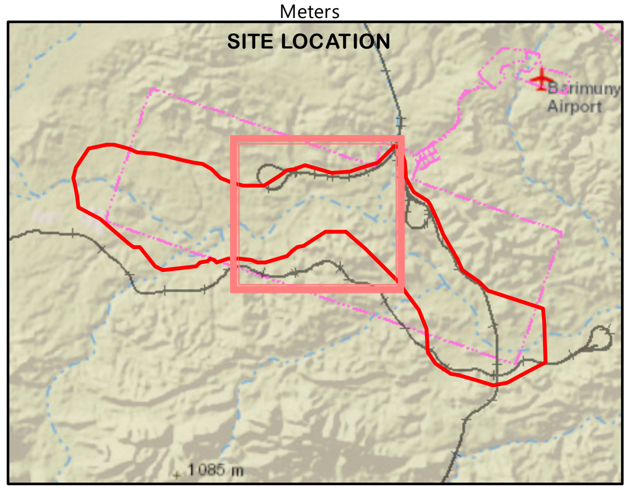
Meters



Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community
National Geographic, Esri, Garmin, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO,

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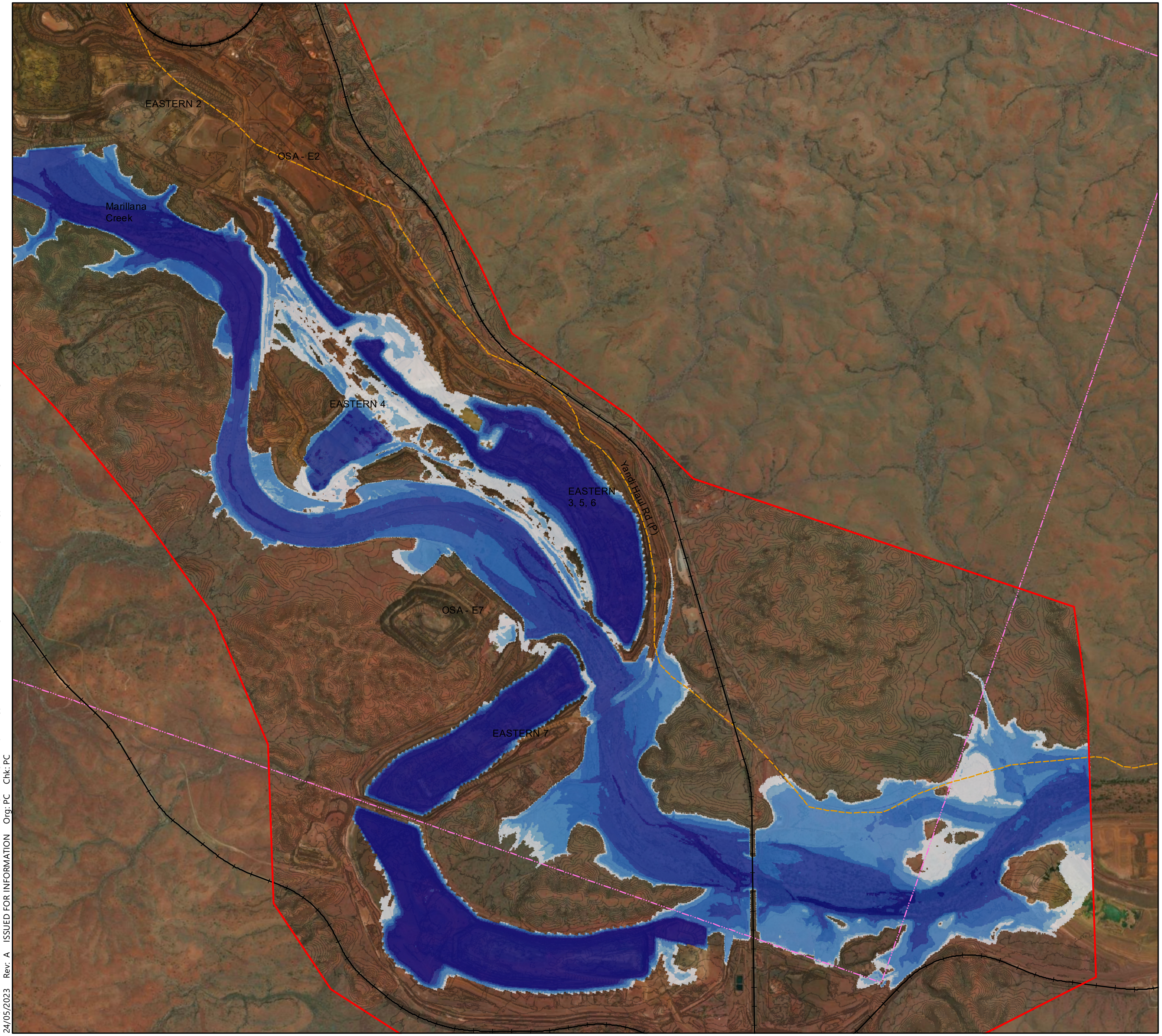
YANDI CLOSURE LANDFORM SPS

FIGURE 2C

MARILLANA CREEK MAINSTREAM CURRENT (2022) OPERATIONS LANDFORM 1 in 10,000 AEP PEAK FLOOD DEPTH



Legend

- Hydraulic Model Extent
- Rail Network
- State Road
- Local Road
- Miscellaneous Road
- BHP Mining Tenements
- 2 m interval ground surface contours

Peak Flood Depth (m)

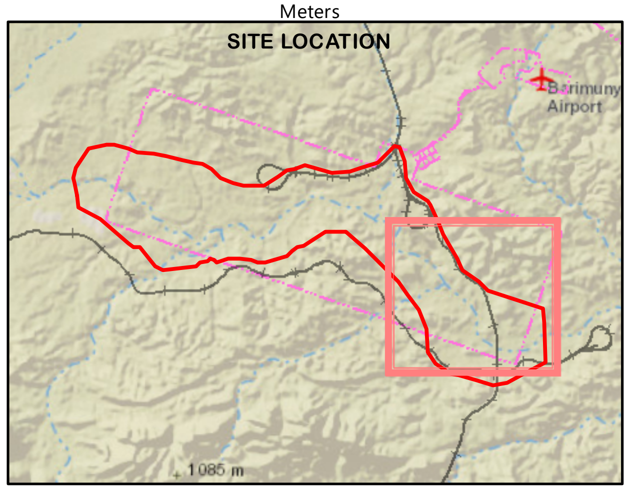
- 0 - 0.5
- 0.5 - 1
- 1 - 3
- 3 - 5
- 5 - 8
- >8

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994
False Easting: 500,000.0000

N

Scale at A3 - 1:24,000

0 400 800 1,200 1,600
Meters



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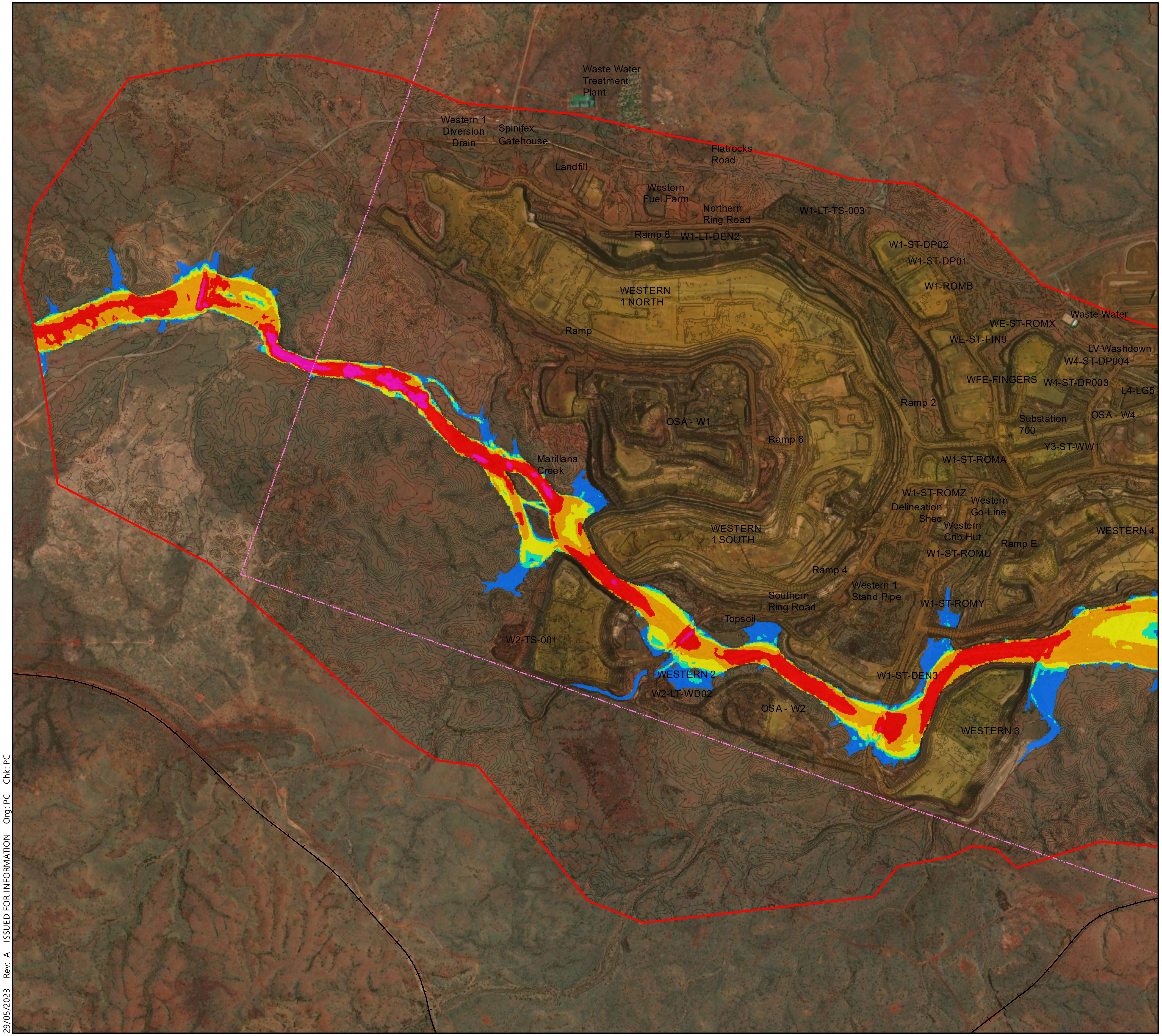


YANDI CLOSURE LANDFORM SPS

FIGURE 3A

MARILLANA CREEK MAINSTREAM CURRENT (2022) OPERATIONS LANDFORM 1% AEP PEAK FLOOD VELOCITY

Legend

- Hydraulic Model Extent
- Rail Network
- State Road
- Local Road
- Miscellaneous Road
- BHP Mining Tenements
- 2 m interval ground surface contours

Peak Flood Velocity (m/s)

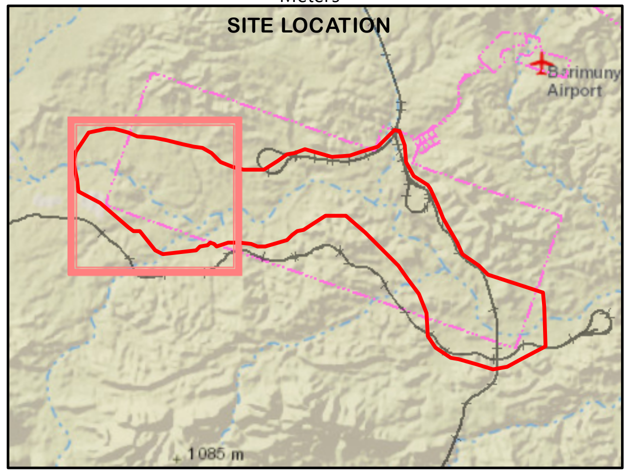
- 0 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 5
- >5

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994
False Easting: 500,000.0000

N

Scale at A3 - 1:24,000

0 400 800 1,200 1,600
Meters



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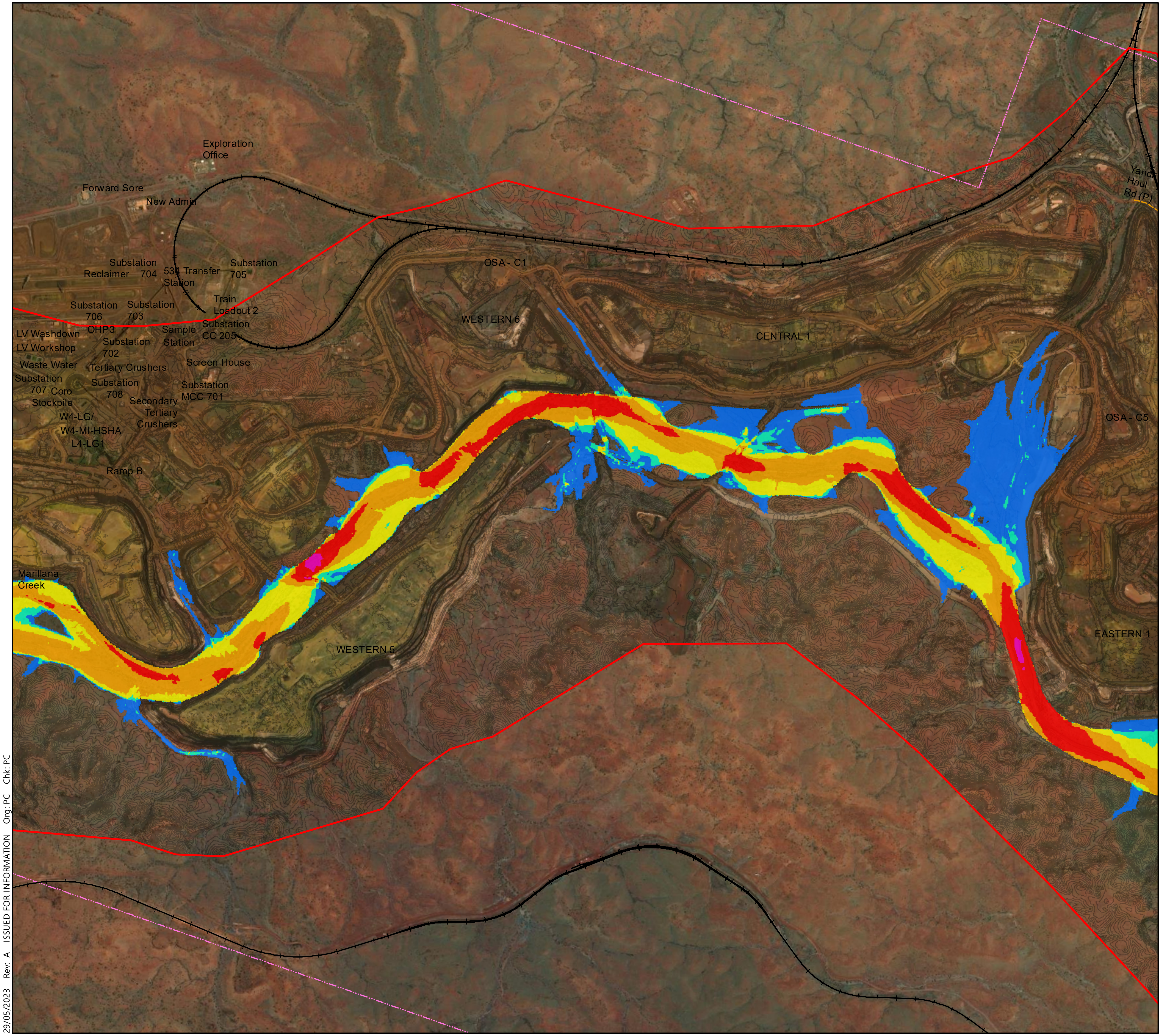
YANDI CLOSURE LANDFORM SPS

FIGURE 3B

MARILLANA CREEK MAINSTREAM CURRENT (2022) OPERATIONS LANDFORM 1% AEP PEAK FLOOD VELOCITY



Legend

- Hydraulic Model Extent
- Rail Network
- State Road
- Local Road
- Miscellaneous Road
- BHP Mining Tenements
- 2 m interval ground surface contours

Peak Flood Velocity (m/s)

- 0 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 5
- >5

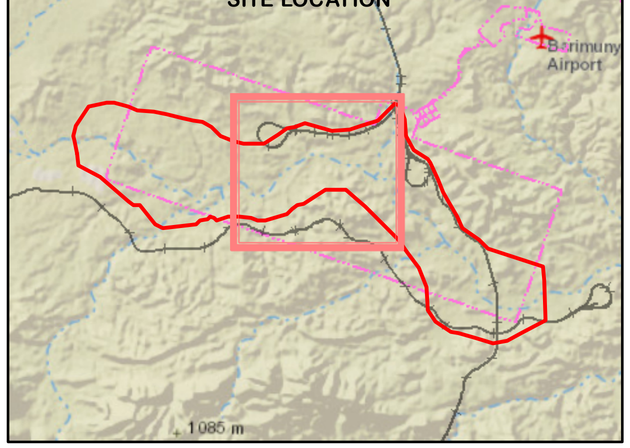
Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994
False Easting: 500,000.0000

N

Scale at A3 - 1:24,000

0 400 800 1,200 1,600
Meters

SITE LOCATION



Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community
National Geographic, Esri, Garmin, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO,

BHP

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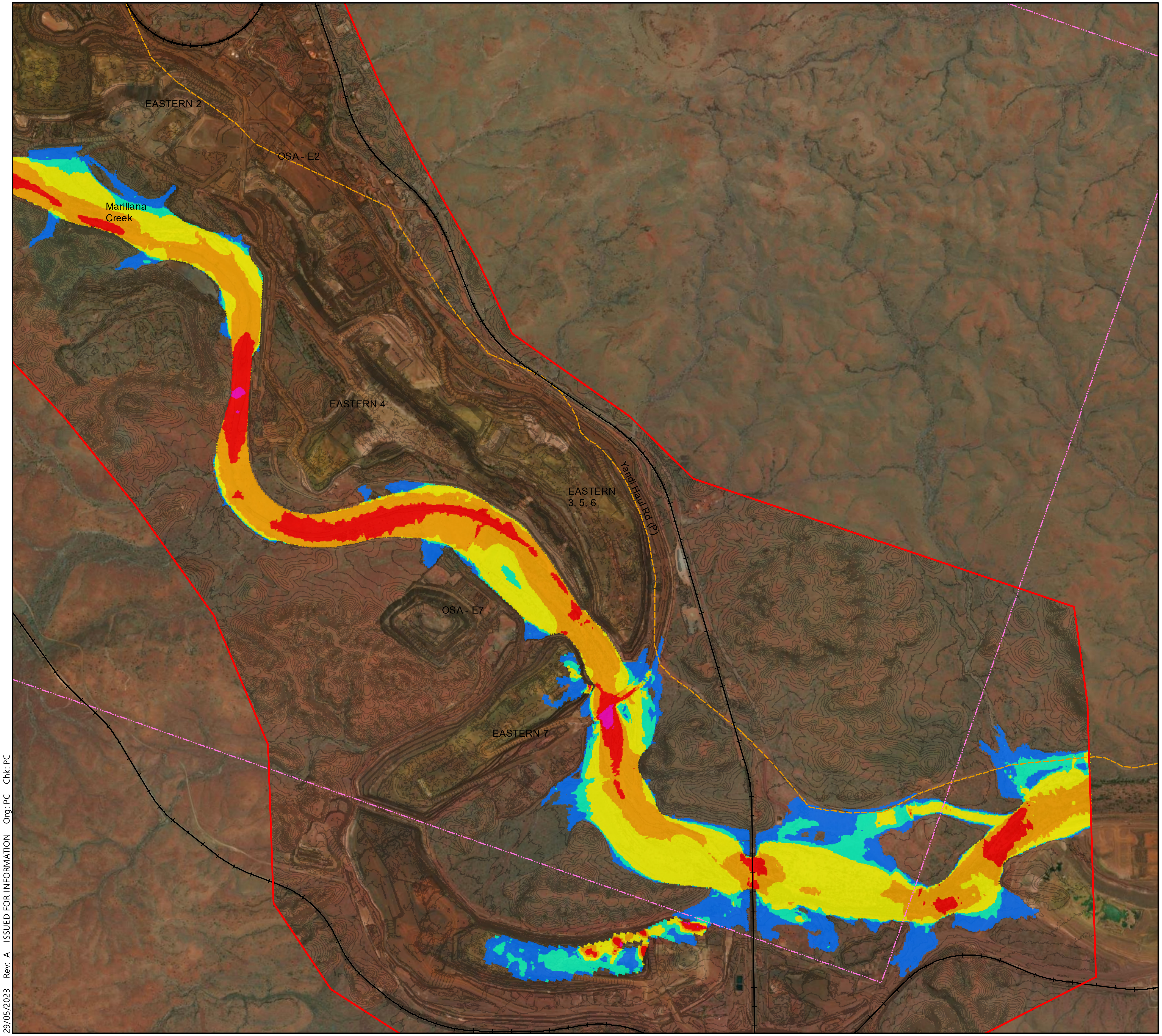


YANDI CLOSURE LANDFORM SPS

FIGURE 3C

MARILLANA CREEK MAINSTREAM CURRENT (2022) OPERATIONS LANDFORM 1% AEP PEAK FLOOD VELOCITY

Legend

- Hydraulic Model Extent
- Rail Network
- State Road
- Local Road
- Miscellaneous Road
- BHP Mining Tenements
- 2 m interval ground surface contours

Peak Flood Velocity (m/s)

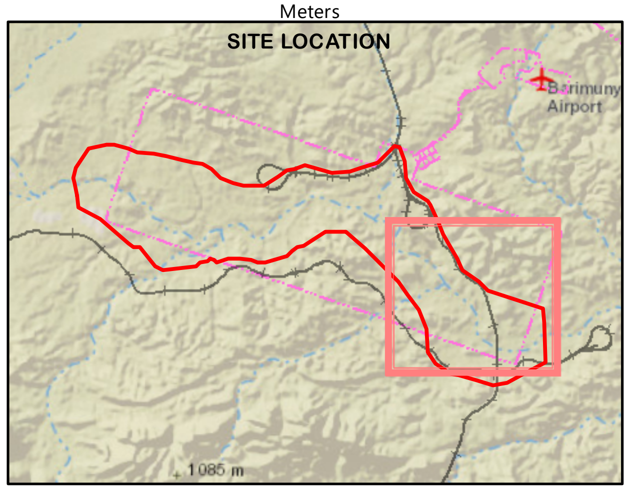
- 0 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 5
- >5

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994
False Easting: 500,000.0000

N

Scale at A3 - 1:24,000

0 400 800 1,200 1,600
Meters



Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community
National Geographic, Esri, Garmin, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO,

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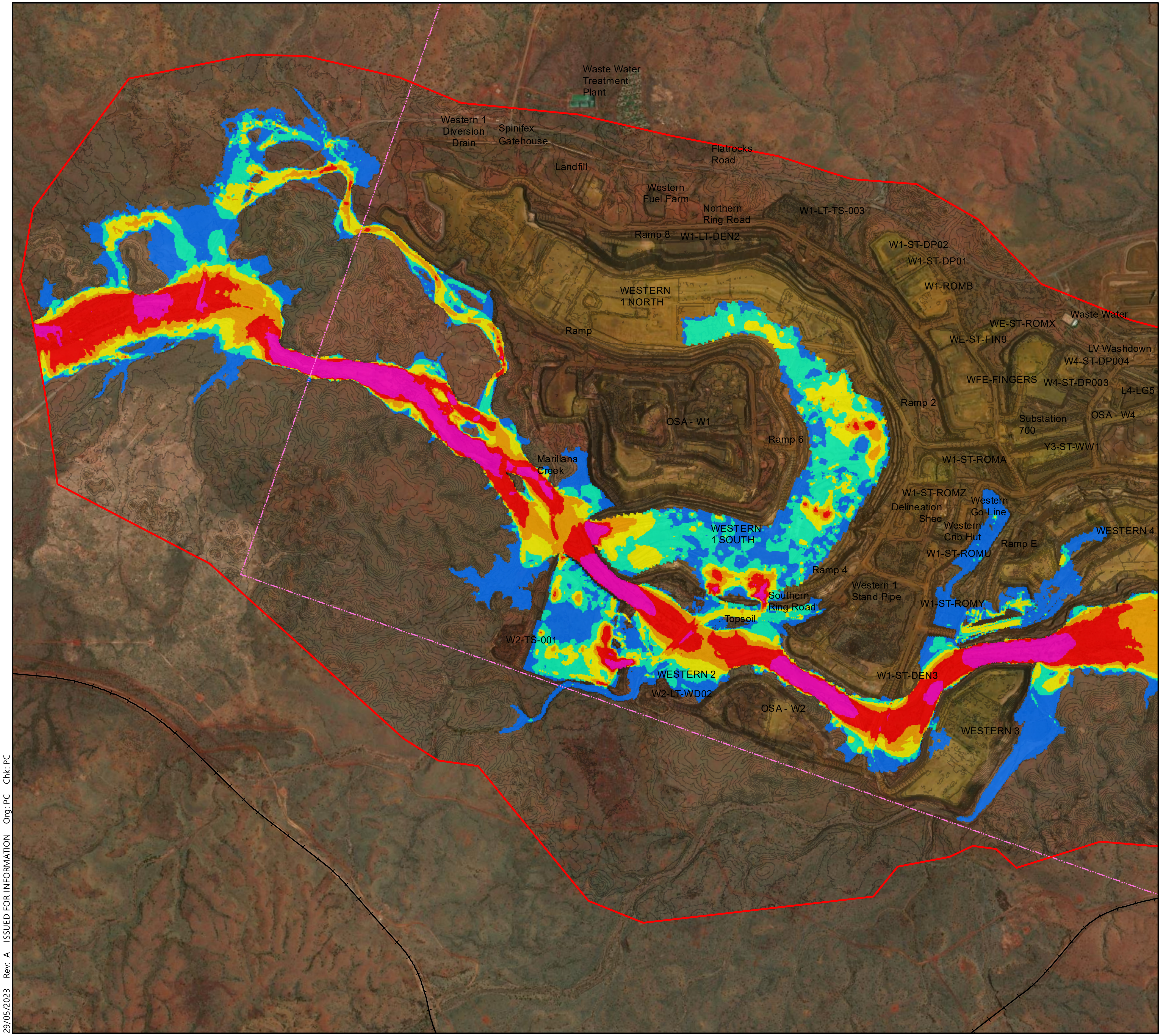


YANDI CLOSURE LANDFORM SPS

FIGURE 4A

MARILLANA CREEK MAINSTREAM CURRENT (2022) OPERATIONS LANDFORM 1 in 10,000 AEP PEAK FLOOD VELOCITY

Legend

- Hydraulic Model Extent
- Rail Network
- State Road
- Local Road
- Miscellaneous Road
- BHP Mining Tenemants
- 2 m interval ground surface contours

Peak Flood Velocity (m/s)

- 0 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 5
- >5

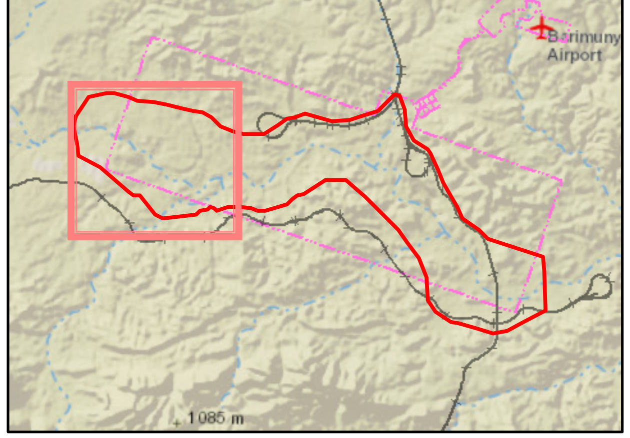
Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994
False Easting: 500,000.0000

N

Scale at A3 - 1:24,000

0 400 800 1,200 1,600
Meters

SITE LOCATION



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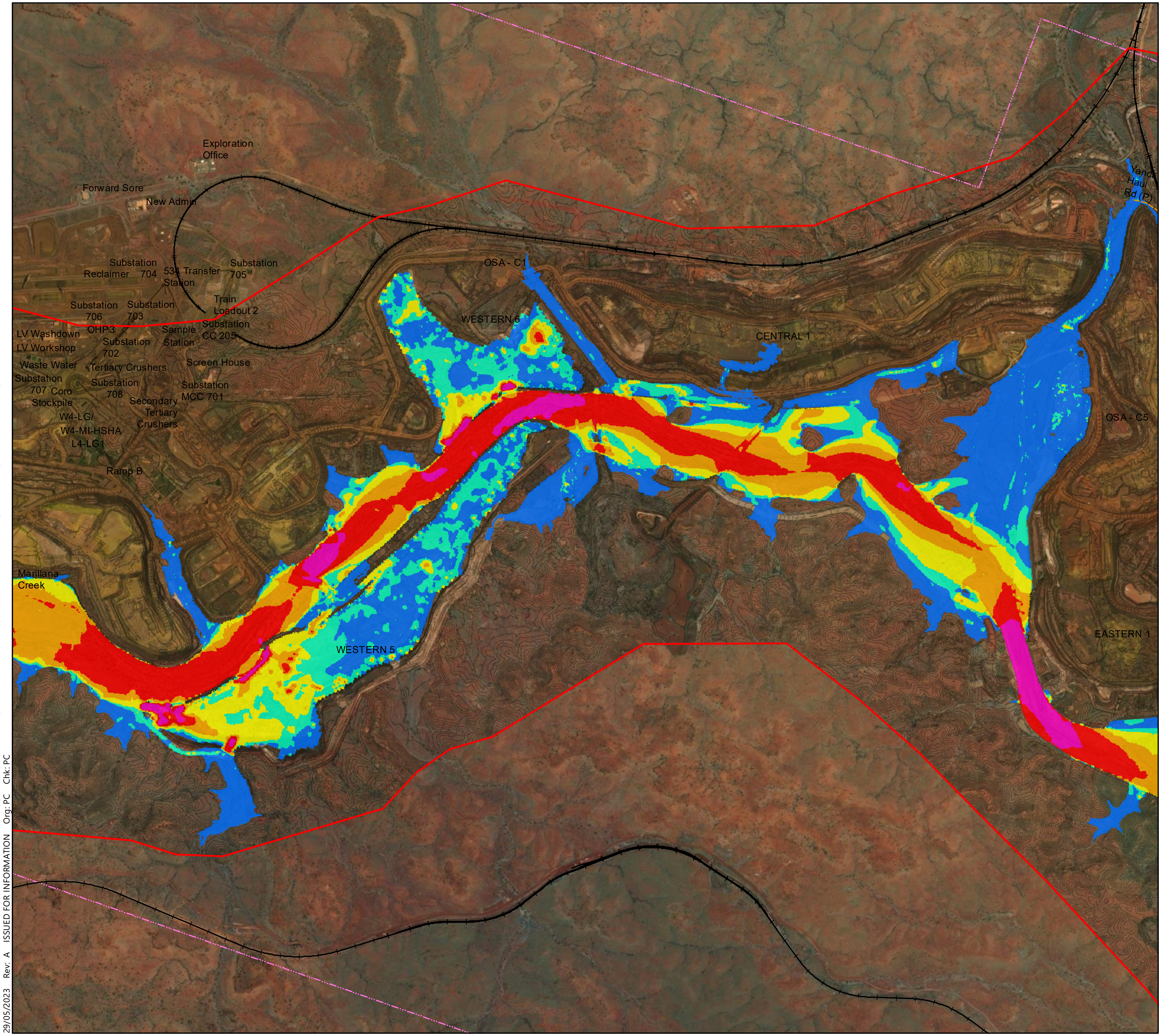


YANDI CLOSURE LANDFORM SPS

FIGURE 4B

MARILLANA CREEK MAINSTREAM CURRENT (2022) OPERATIONS LANDFORM 1 in 10,000 AEP PEAK FLOOD VELOCITY

Legend

- Hydraulic Model Extent
- Rail Network
- State Road
- Local Road
- Miscellaneous Road
- BHP Mining Tenements
- 2 m interval ground surface contours

Peak Flood Velocity (m/s)

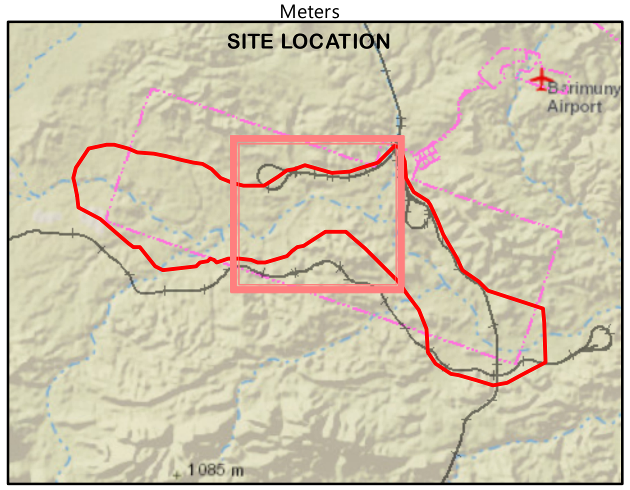
- 0 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 5
- >5

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994
False Easting: 500,000.0000

N

Scale at A3 - 1:24,000

0 400 800 1,200 1,600
Meters



Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community
National Geographic, Esri, Garmin, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO,

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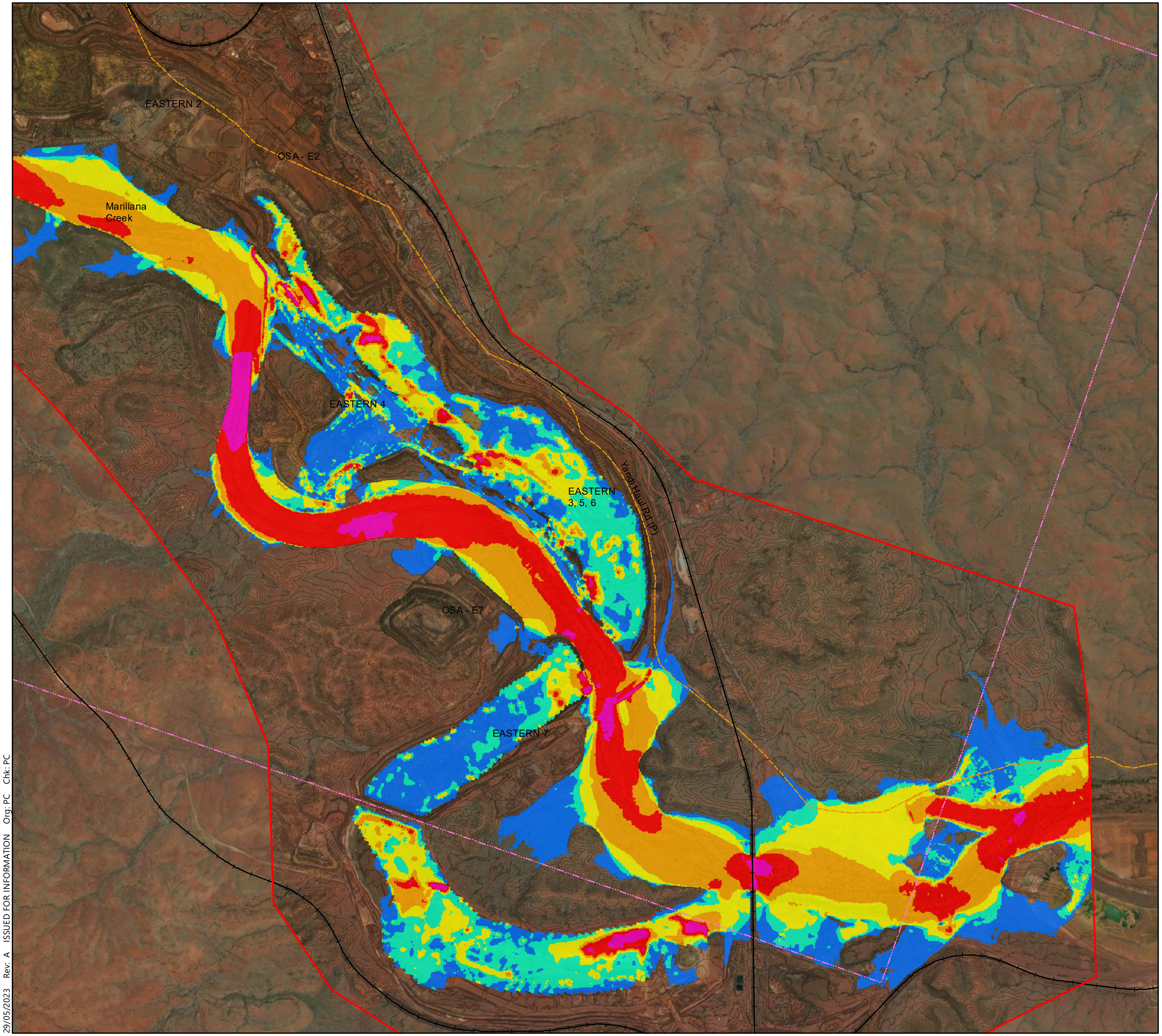
YANDI CLOSURE LANDFORM SPS

FIGURE 4C

MARILLANA CREEK MAINSTREAM CURRENT (2022) OPERATIONS LANDFORM 1 in 10,000 AEP PEAK FLOOD VELOCITY



Legend

- Hydraulic Model Extent
- Rail Network
- State Road
- Local Road
- Miscellaneous Road
- BHP Mining Tenements
- 2 m interval ground surface contours

Peak Flood Velocity (m/s)

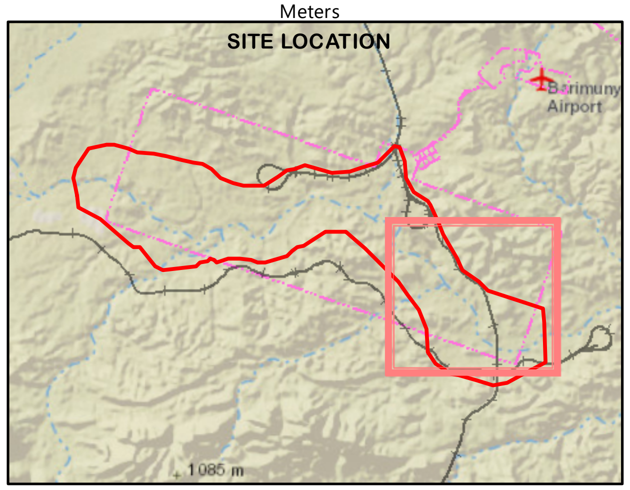
- 0 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 5
- >5

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994
False Easting: 500,000.0000

N

Scale at A3 - 1:24,000

0 400 800 1,200 1,600
Meters



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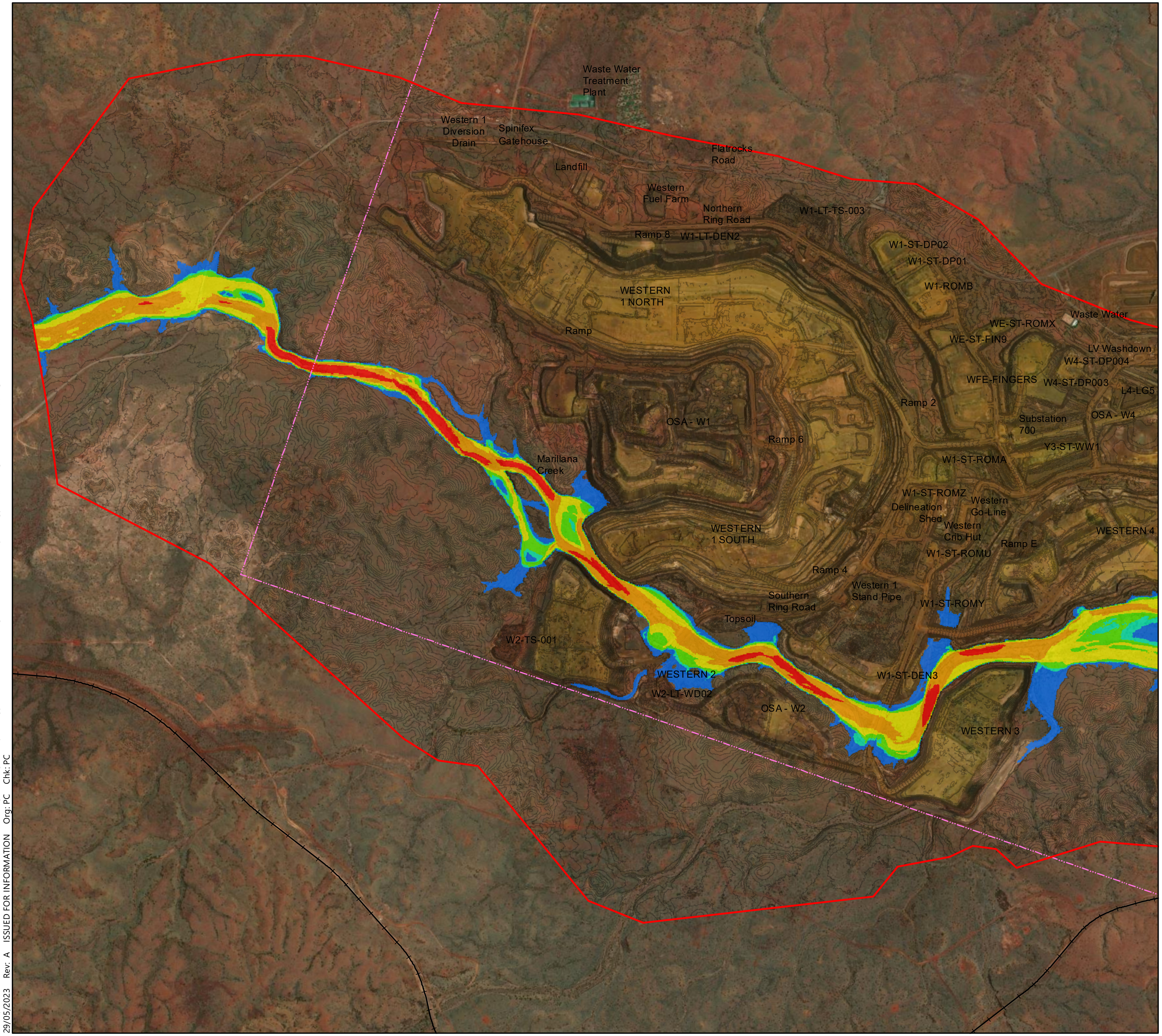
YANDI CLOSURE LANDFORM SPS

FIGURE 5A

MARILLANA CREEK MAINSTREAM CURRENT (2022) OPERATIONS LANDFORM 1% AEP PEAK DEPTH VELOCITY PRODUCT



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Legend

- Hydraulic Model Extent
- Rail Network
- State Road
- Local Road
- Miscellaneous Road
- BHP Mining Tenements
- 2 m interval ground surface contours

Peak Flood DV Product (m²/s)

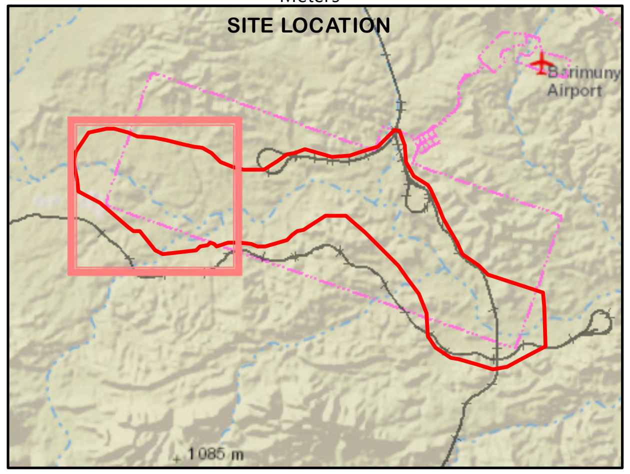
- 0 - 1
- 1 - 2
- 2 - 5
- 5 - 10
- 10 - 20
- >20

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994
False Easting: 500,000.0000

N

Scale at A3 - 1:24,000

0 400 800 1,200 1,600
Meters



Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community
National Geographic, Esri, Garmin, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO,

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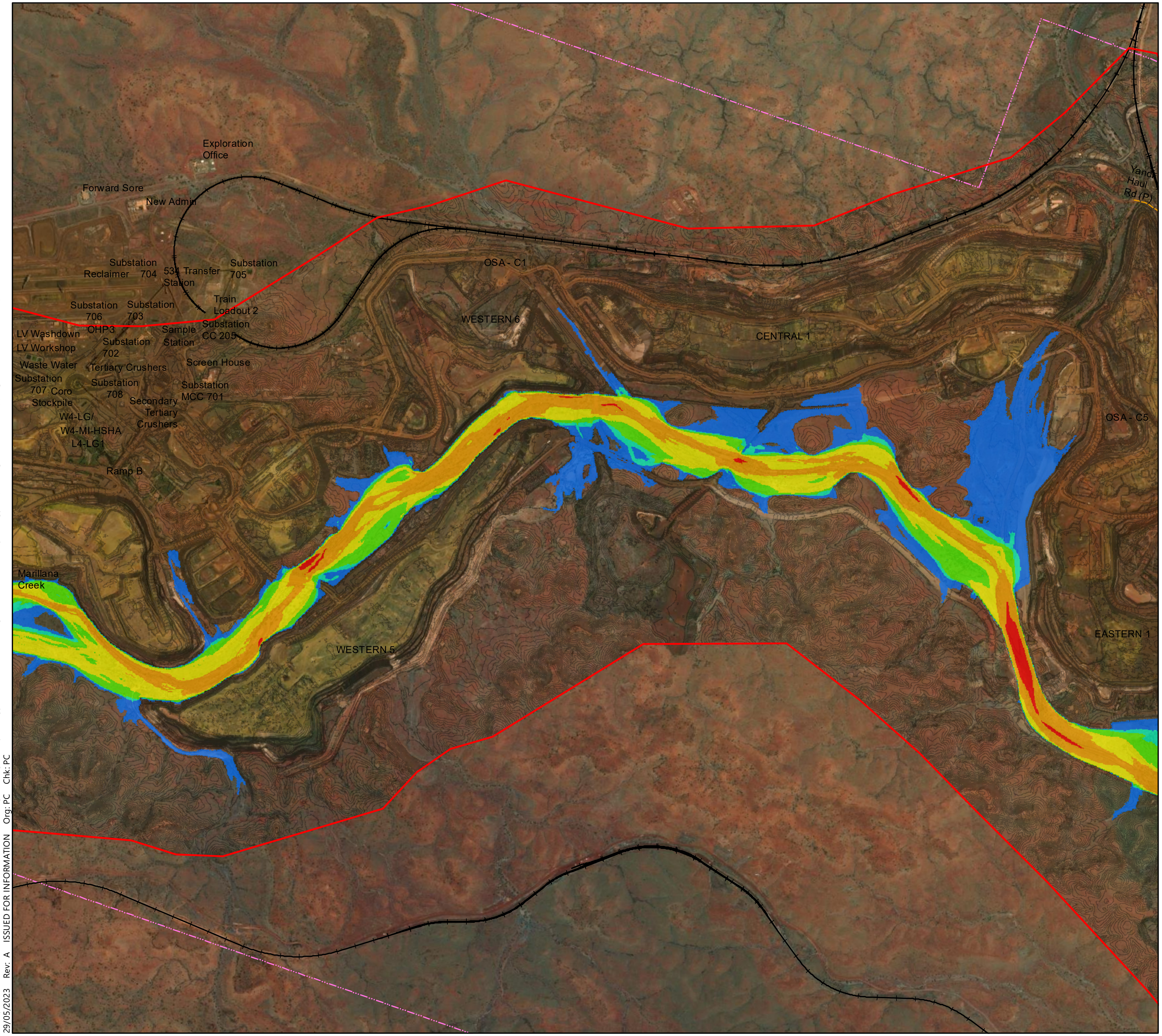
YANDI CLOSURE LANDFORM SPS

FIGURE 5B

MARILLANA CREEK MAINSTREAM CURRENT (2022) OPERATIONS LANDFORM 1% AEP PEAK DEPTH VELOCITY PRODUCT



Legend

- Hydraulic Model Extent
- Rail Network
- State Road
- Local Road
- Miscellaneous Road
- BHP Mining Tenements
- 2 m interval ground surface contours

Peak Flood DV Product (m²/s)

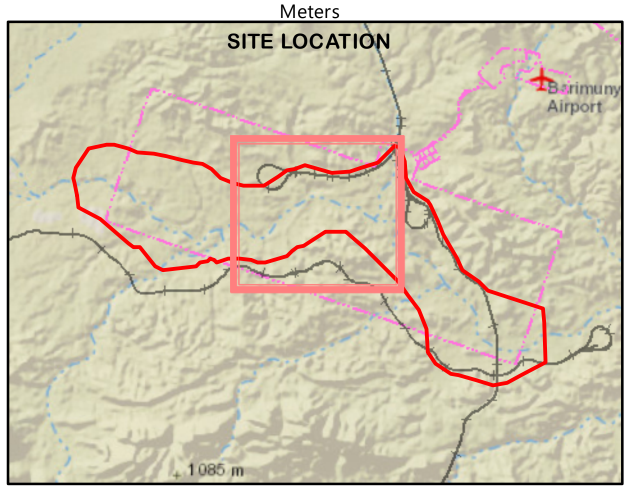
- 0 - 1
- 1 - 2
- 2 - 5
- 5 - 10
- 10 - 20
- >20

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994
False Easting: 500,000.0000

N

Scale at A3 - 1:24,000

0 400 800 1,200 1,600
Meters



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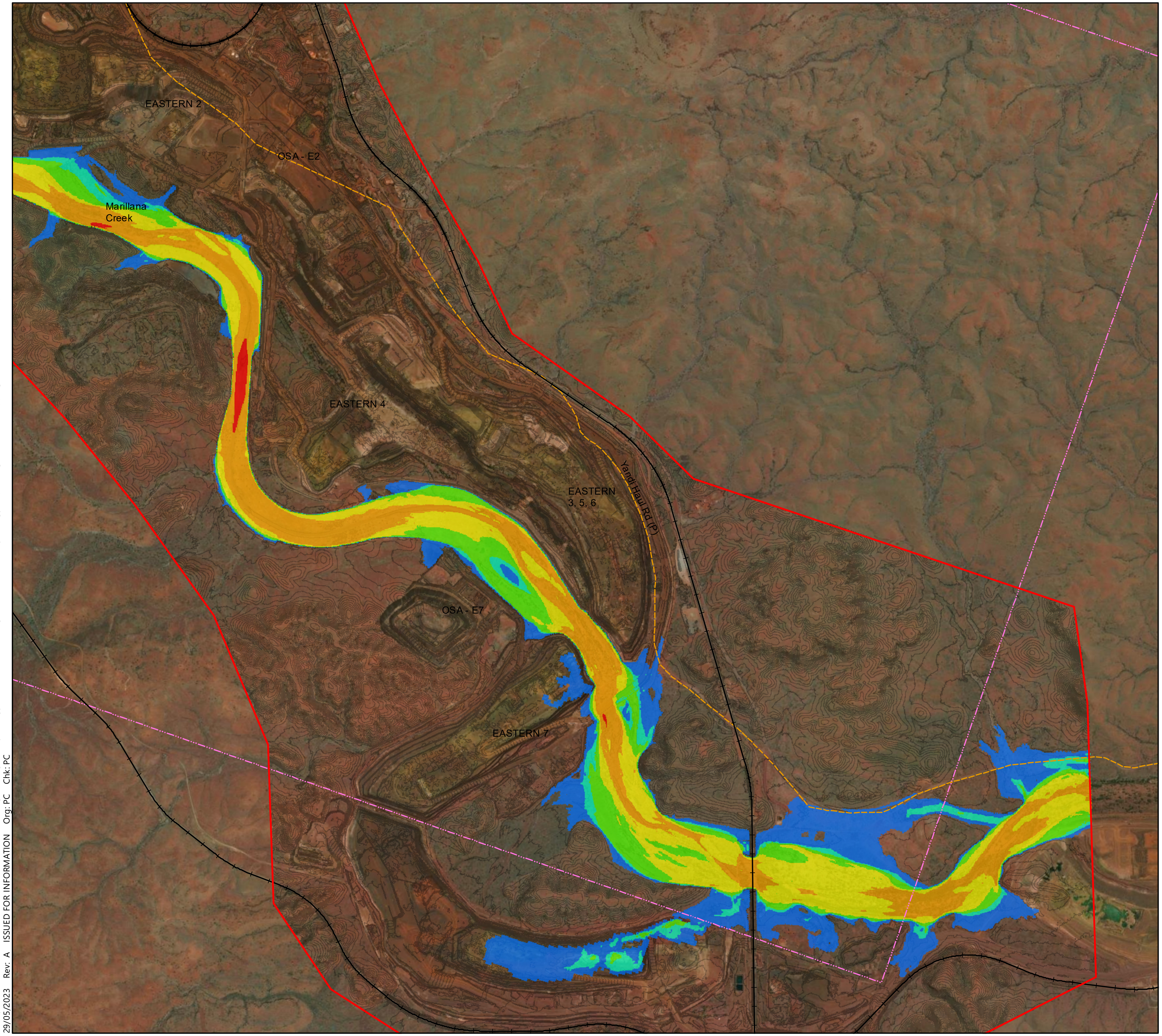


YANDI CLOSURE LANDFORM SPS

FIGURE 5C

MARILLANA CREEK MAINSTREAM CURRENT (2022) OPERATIONS LANDFORM 1% AEP PEAK DEPTH VELOCITY PRODUCT

Legend

- Hydraulic Model Extent
- Rail Network
- State Road
- Local Road
- Miscellaneous Road
- BHP Mining Tenements
- 2 m interval ground surface contours

Peak Flood DV Product (m²/s)

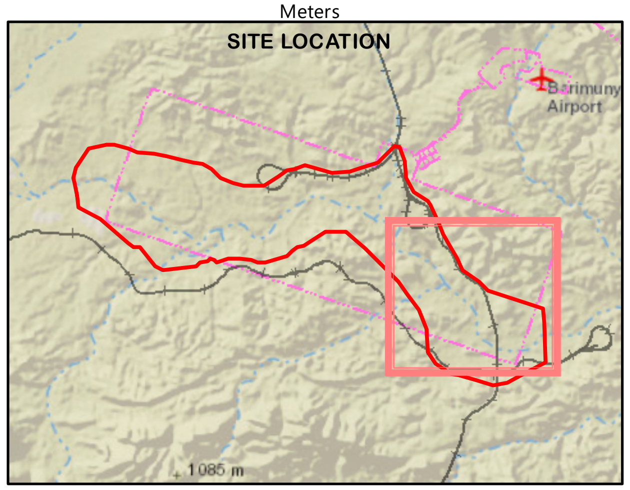
- 0 - 1
- 1 - 2
- 2 - 5
- 5 - 10
- 10 - 20
- >20

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994
False Easting: 500,000.0000

N

Scale at A3 - 1:24,000

0 400 800 1,200 1,600
Meters



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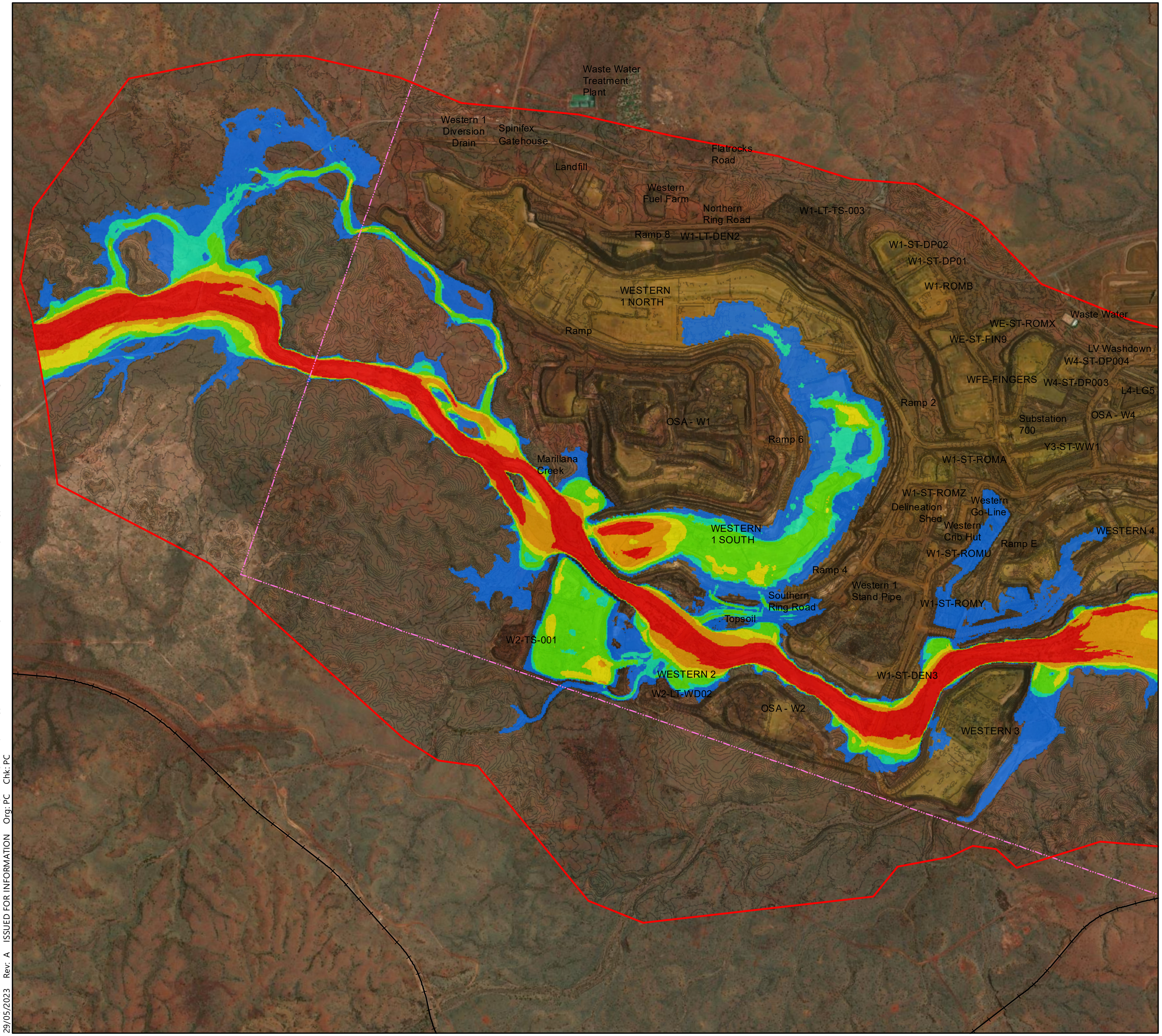


YANDI CLOSURE LANDFORM SPS

FIGURE 6A

MARILLANA CREEK MAINSTREAM CURRENT (2022) OPERATIONS LANDFORM 1 in 10,000 AEP PEAK DEPTH VELOCITY PRODUCT

Legend

- Hydraulic Model Extent
- Rail Network
- State Road
- Local Road
- Miscellaneous Road
- BHP Mining Tenements
- 2 m interval ground surface contours

Peak Flood DV Product (m²/s)

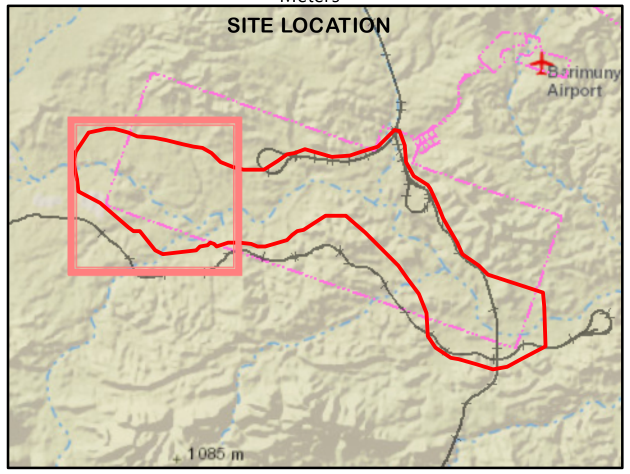
- 0 - 1
- 1 - 2
- 2 - 5
- 5 - 10
- 10 - 20
- >20

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994
False Easting: 500,000.0000

N

Scale at A3 - 1:24,000

0 400 800 1,200 1,600
Meters



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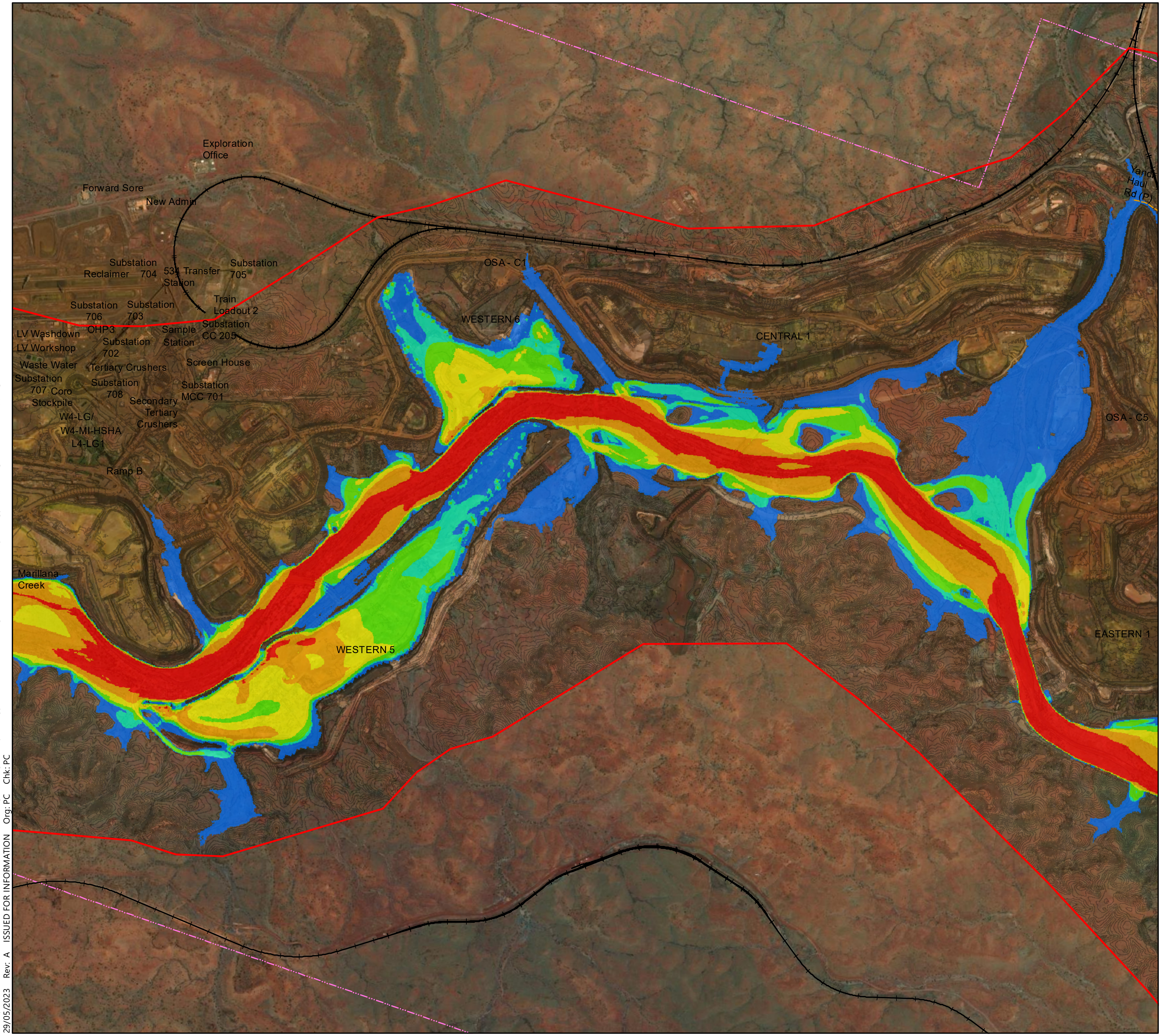


YANDI CLOSURE LANDFORM SPS

FIGURE 6B

MARILLANA CREEK MAINSTREAM CURRENT (2022) OPERATIONS LANDFORM 1 in 10,000 AEP PEAK DEPTH VELOCITY PRODUCT

Legend

- Hydraulic Model Extent
- Rail Network
- State Road
- Local Road
- Miscellaneous Road
- BHP Mining Tenements
- 2 m interval ground surface contours

Peak Flood DV Product (m²/s)

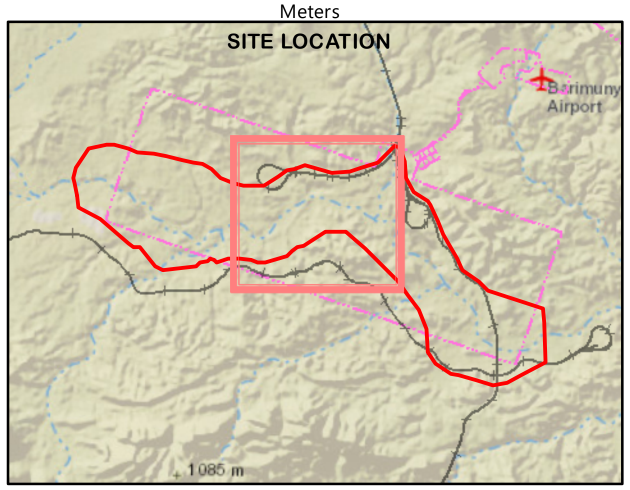
- 0 - 1
- 1 - 2
- 2 - 5
- 5 - 10
- 10 - 20
- >20

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994
False Easting: 500,000.0000

N

Scale at A3 - 1:24,000

0 400 800 1,200 1,600
Meters



Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community
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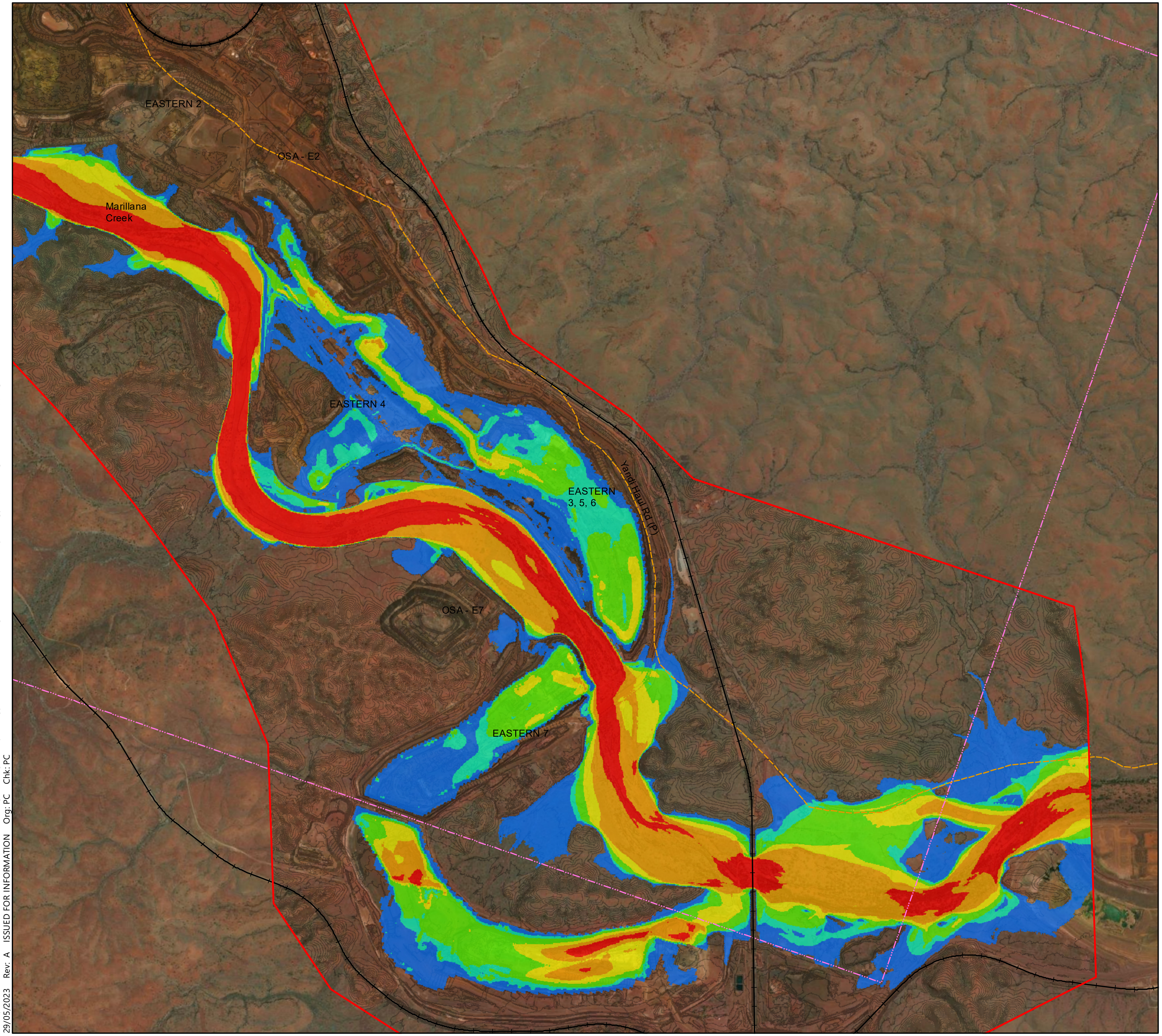


YANDI CLOSURE LANDFORM SPS

FIGURE 6C

MARILLANA CREEK MAINSTREAM CURRENT (2022) OPERATIONS LANDFORM 1 in 10,000 AEP PEAK DEPTH VELOCITY PRODUCT

Legend

- Hydraulic Model Extent
- Rail Network
- State Road
- Local Road
- Miscellaneous Road
- BHP Mining Tenements
- 2 m interval ground surface contours

Peak Flood DV Product (m^2/s)

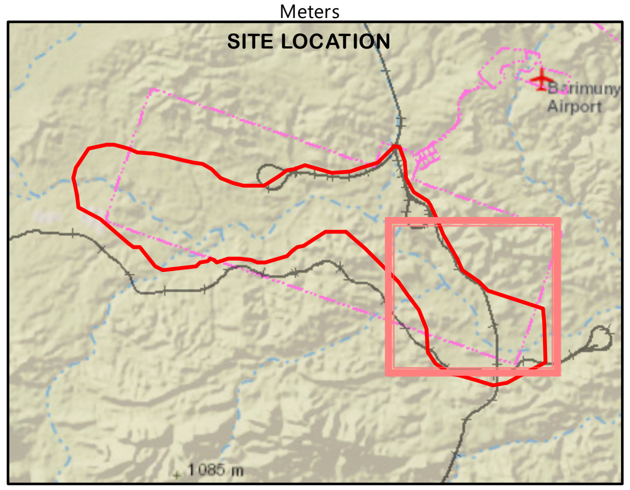
- 0 - 1
- 1 - 2
- 2 - 5
- 5 - 10
- 10 - 20
- >20

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994
False Easting: 500,000.0000

N

Scale at A3 - 1:24,000

0 400 800 1,200 1,600
Meters



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