CHAPTER 7- Water management

7.1 Risks to groundwater and surface water quality

The following chapter describes the existing surface water and groundwater conditions at the Twin Bonanza project. It identifies the potential impacts and associated risks to the hydrology and water quality associated with the project, and details the management measure planned for mitigation of these risks.

This chapter should be read in conjunction with Chapter 9: Waste management and Chapter 10: Tailings and waste rock management.

The proposed operation will include the development of infrastructure such as tailings dams, waste rock dumps, a processing plant and power, accommodation, workshops and office infrastructure.

It is understood that the project will require a water supply of at least 960 m3/d, corresponding to an average extraction rate of 11.1 L/s. Whilst mining activities are currently exempt from requiring a groundwater extraction license and do not fall under the provisions of the Water Act 2004 (NT), an application for an authorisation to carry out mining activities must be accompanied by a mining management plan (MMP), which in turn must include a consideration of water resources.

Mine water requirements include, but are not limited to, ore processing, dust suppression, laundering, showers and a wash-down bay.

For trial mining and processing, water requirements will be in the order of 15t per hour. For processing at a nominal 240 000t per annum, water requirements will be in the order of 40t per hour, including loss to tailings, loss at the processing plant, camp use and mining.

To accommodate water needs ABM will seek to utilise at least two bore locations within the mineral lease and also water resources adjacent to the south western corner of the mineral lease where a borefield and connecting pipeline are anticipated. It is expected these areas would also be secured by the grant of an interest in the land (pursuant to section 19 of the Aboriginal Land Rights Act 1976 (Cth)) in question by the relevant land trust. Two large paleochannels encircle the project area; these have been identified as the most logical place to find further water in good quantities if required.

Additional bores will need to be established for mining and processing and further hydrological work and assessment is required.

ABM will not take, direct or use surface water without first notifying all relevant stakeholders. No rivers or creeks will be diverted as part of the project.

7.2 Existing environment

7.2.1 Climate

The project area is located within the Tanami Desert region, which has a semi-arid climate characterised by hot, wet summers and mild, relatively dry winters. Average annual rainfall in the region ranges from 400-500mm, and approximately 85% of this falls between November and April (Figure 7-1). Summer rainfall is characterised by infrequent, but intense rainfall events, with single events delivering > 50 mm in 24 hours on average at least once per year (Table 7-1). Average pan evaporation for the region is approximately 3 000 mm/yr, far exceeding the average annual rainfall.

Table 7-1: Rainfall frequency data for the project area (depth, mm) (BOM, 2013)

Duration	1:1 yr	1:5 yr	1:10 yr	1:20 yr	1:50 yr	1:100 yr	1:1,000-yr
5Mins	6.3	10.4	11.8	13.5	15.8	17.6	23.1
10Mins	9.9	16.4	18.5	21.3	24.8	27.7	36.3
30Mins	19.4	31.9	35.9	41.3	48.2	53.5	55.3
1Hr	26.4	43.8	49.5	57.0	66.8	74.2	97.5
6Hrs	38.8	70.8	82.8	98.4	119.4	136.2	182.5
24Hrs	57.6	109.4	130.1	156.2	192.0	220.3	297.5
72Hrs	83.5	157.7	187.2	223.9	274.3	313.9	423.7

7.2.2 Environmental values

The Twin Bonanza project falls within the Tanami bioregion (Figure 7-2) (Baker et al. 2005). The terrain is mostly flat red sand plains with minor dunes and exposed rock occurring at hills and low lying ranges. The dominant vegetation is hummock grassland with paths of open Eucalyptus forests on a grassy understory. The habitat of the Tanami palaeodrainage system and the relative absence of exotic animals and plants make this area a refuge to a high concentration of threatened species (Harrison et al. 2009).

Despite the arid climate, this bioregion is home to two nationally significant wetlands (all ephemeral): Lake Surprise (Yinapaka) and the Lake Gregory area, which are both over 100 km from the project area. Additionally, there are a range of smaller ephemeral wetlands over 20 km away. No permanent surface water is located in the region. There are no Ramsar listed wetlands in the area concerned.

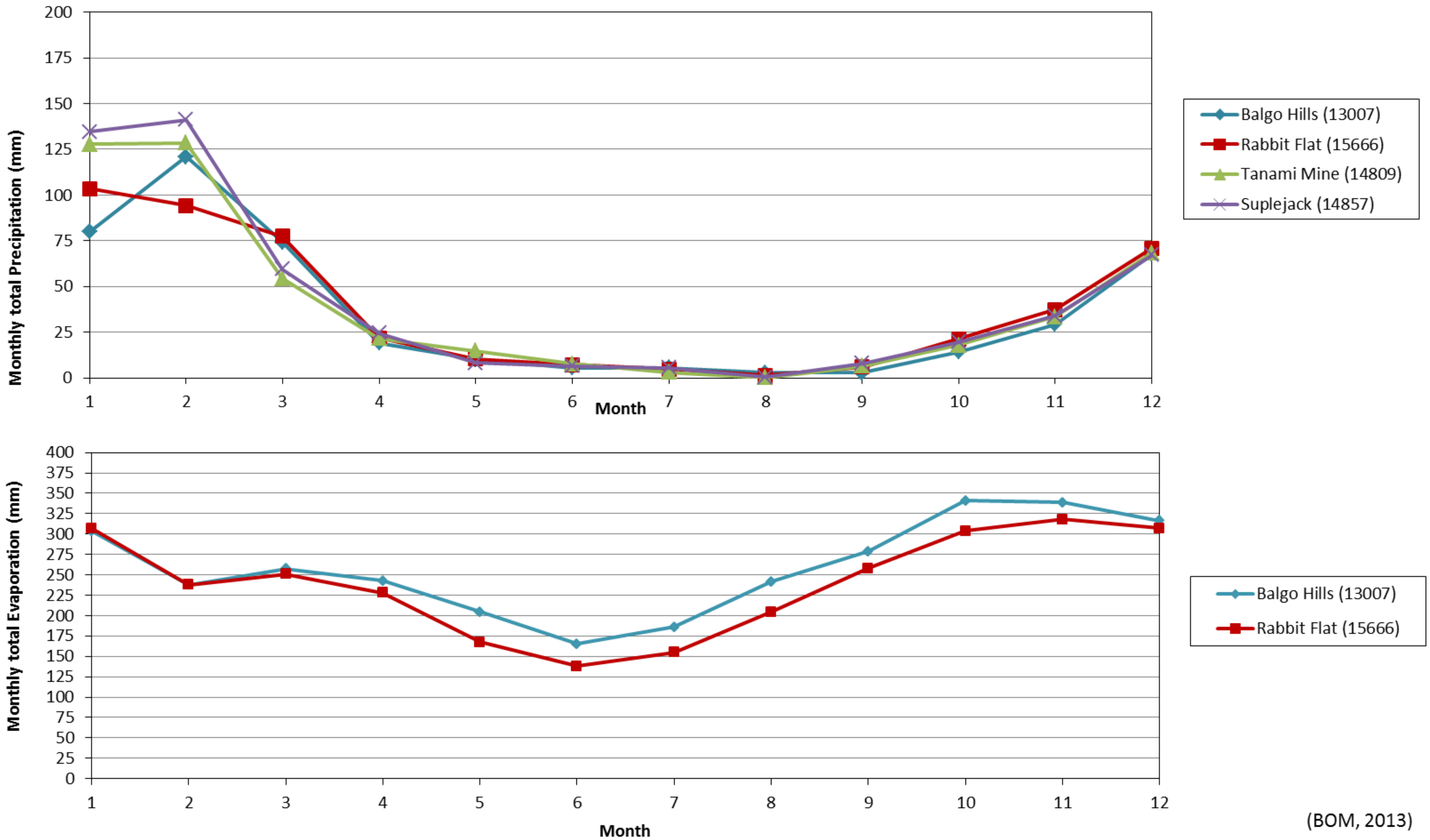
The paleodrainage channels are a habitat to the great desert skink (Liopholis kintorei) and the greater bilby (Macrotis lagotis) which are listed as two of the six threatened species listed under the *Environment Protection and Biodiversity Conservation Act 1999* (Cth).

The great desert skink species is known to occur in the region, however it specialises in palaeodrainage channels which are not present within the direct footprint of the mining proposal. Surveys have not detected any sign of this species within the proposed mining footprint or surrounds. Any bore field development will take into account management of the threatened species. Onsite surveys located one greater bilby individual and three active warrens in a palaeochannel approximately 2km to the north of the mine footprint.

Refer to Chapter 6: Biodiversity for risk, management, mitigation and monitoring measures ABM proposes to undertake to reduce the environmental effect on these areas.

7.2.3 Surface water

A precursory surface flow analysis and flood risk assessment has been conducted for the Twin Bonanza gold project (Appendix G). This assessment used both regional and local digital elevation model information to delineate catchment boundaries, and to assess surface flow patterns and flood risk areas across the project area. In general, the project area is located relatively high in the landscape (Figure 7-2), and surface flow processes are dominated by sheet flow. The majority of the main infrastructure areas are located on topographic highs or diverging slope areas, where the potential for converging local surface water flows is minimal (Figure 7-3). There are no significant streams or springs identified within the vicinity of the project area, and there are no known current users of surface water in the area. As there are no permanent surface water features present within the proposed mining lease, no assessment of natural surface water quality has been made.



(BOM, 2013)

Figure 7-1. Precipitation and evaporation data for weather stations near the Twin Bonanza project.

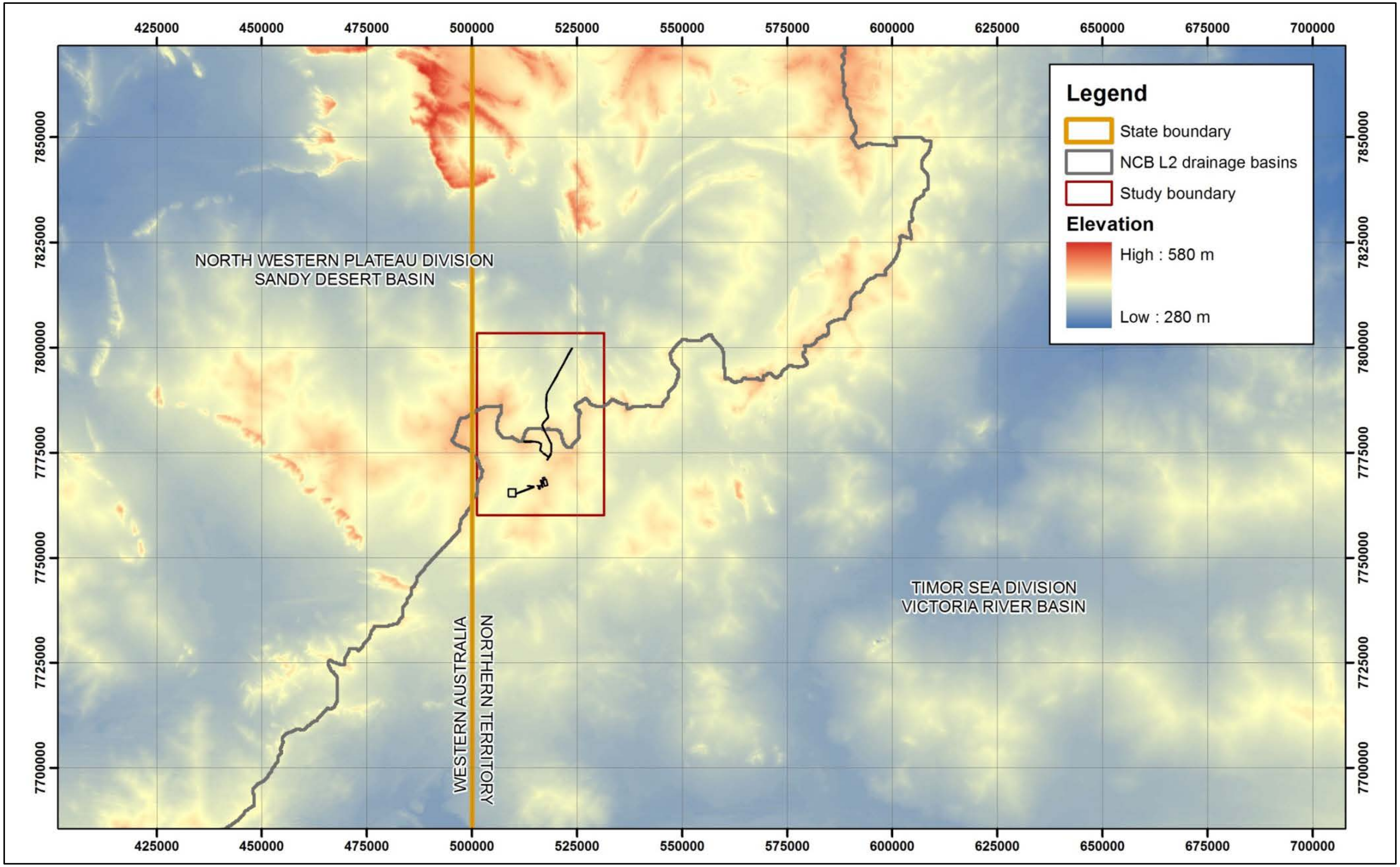


Figure 7-2. Location of the Twin Bonanza gold project within the regional landscape.

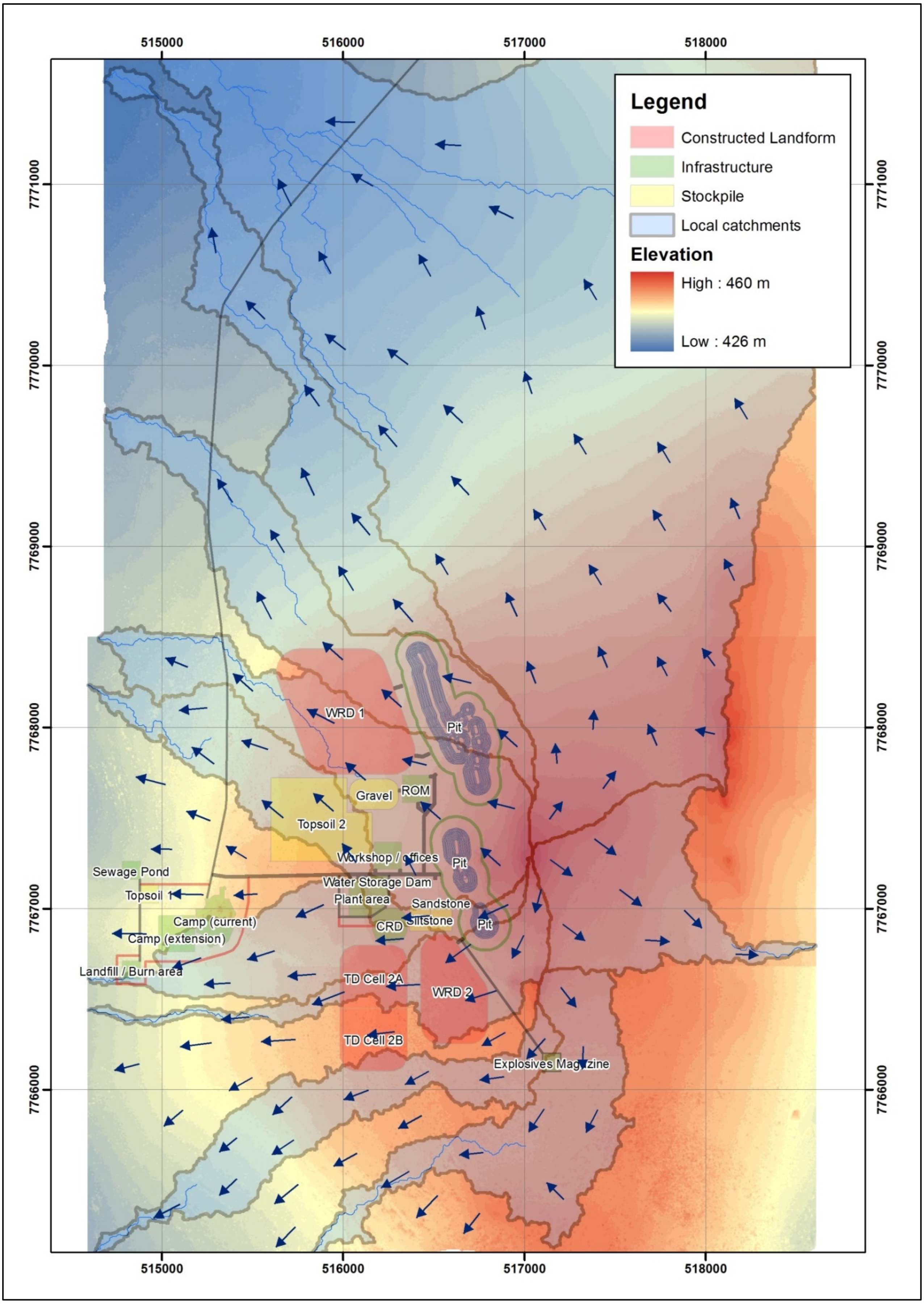


Figure 7-3.Location of infrastructure in respect to surface water flows and catchments

7.2.4 Groundwater

A detailed description of the hydrogeological setting is provided in Appendix J: Preliminary Groundwater Resource Assessment report. In summary, two types of aquifers have been identified within the project area, including hard-rock aquifers and an unconsolidated sedimentary aquifer hosted within a tertiary to recent palaeochannel system (Figure 7-4).

All pre-existing registered bores within a 40 km radius are shown on Figure 7-4. These bores are primarily located ≥ 20 km from the project area, and are installed in both hard-rock and palaeochannel aquifer systems. The available hydrogeological data for these sites suggest that yields are generally very low (<1 L/s) in the bedrock and that these boreholes are often described as dry. Higher yields have been identified in bedrock within the project area (Corsair Bore) but the long-term trend in water levels, and hence estimation of the sustainability of extraction from this aquifer, has yet to be determined. The palaeochannel system is considered a major aquifer capable of providing good yields, and none of the registered bores in this aquifer are recorded as being dry. Alluvial channels within the Tanami mine borefield are considered to be capable of delivering borehole yields of ≥ 5 L/s.

Groundwater recharge is understood to generally only occur after larger rainfall events (i.e. more than 50 mm in 24-48 hours). A figure of 4.5 mm/year, or 1 % of the total annual average rainfall, was considered to be a reasonable estimate of recharge to the palaeochannels (Appendix J). Estimates of groundwater recharge to the bedrock aquifer have not been determined.

The chemical makeup of existing groundwater in the region is not well established (Earth Systems, 2013), with the majority of available water quality data having been collected in the 1960s and 1970s, primarily from locations > 10 km down-gradient from the Twin Bonanza gold project. The existing regional data set does not indicate a clear difference in chemistry between the bedrock and palaeovalley aquifer systems (see Table 7-2), with both systems being generally moderately alkaline (pH = 7.3 – 8.1), moderately fresh to brackish (TDS = 420 – 9,710 mg/L), and with a moderate to high total hardness (201 – 6,360 mg/L as $CaCO3$). Elevated levels of Arsenic (As) and Selenium (Se) have been detected in the bedrock aquifer, although these elements have not been assessed in any of the available data sets for the palaeochannel bores.

ABM has recently recommenced sampling in Corsair Bore and Wilson's Bore. These bores are being assessed as the primary production bores for the early stages of the development. Water monitoring results from two sampling events in late 2013 are presented in Table 7-3. Results from these monitoring events indicate similar water quality to the historic sampling events. Wilson's Bore was shown to host the more saline water of the two bores (total dissolved solids (TDS) of approximately 7,800 mg/L), and had elevated levels of sulfate, chromium, and selenium when compared to the Australian drinking water guidelines (NRMMC, 2011). Corsair Bore was less saline (TDS of approximately 2,300 mg/L), and had elevated levels arsenic. Concentrations of uranium exceeded the guideline values for uranium in both bores (NRMMC, 2011)

No local assessment of the extent of groundwater sensitive ecosystems (GSE) has been completed, and it is possible that GSE exists within the palaeochannel areas, given that groundwater has been encountered at ≤ 10 mblg. However, the high salinity values recorded in many of the registered palaeochannel bores (i.e. EC > 5,000 µS/cm) indicates that the water quality may not be sufficient to support GSE, even if the water can be physically accessed by plant roots.

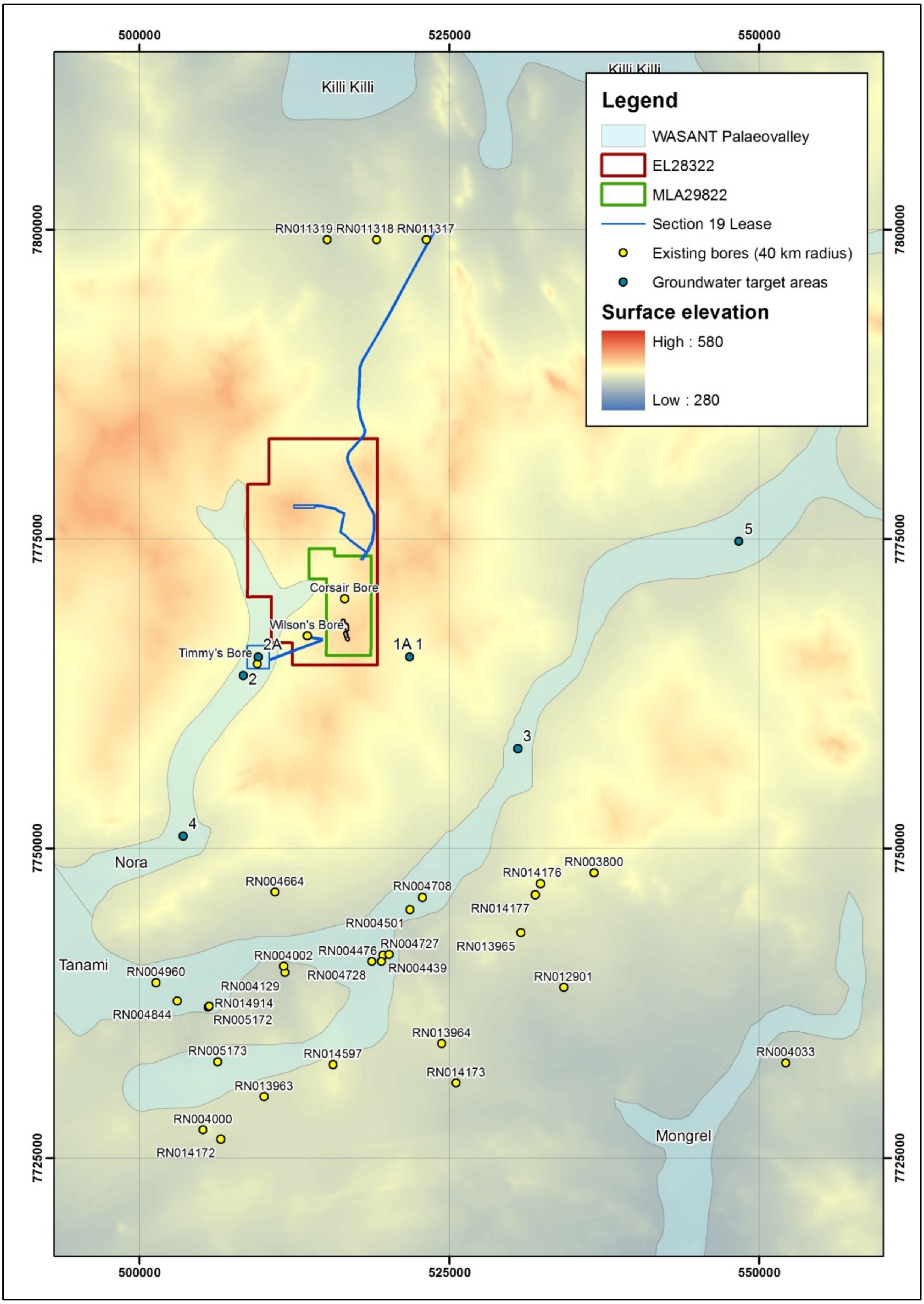


Figure 7-4. Existing groundwater environment.

Table 7-2: Summary of historical groundwater quality data

Analyte	Registered bores		Wilson's	Corsair	Timmy's	NRMMC (2011)[1]
	Bedrock	Palaeovalley	Palaeovalley	Bedrock	Palaeovalley	
pH	7.3 – 7.6	7.6 – 8.1	7.8	7.9	7.8	n/a
EC (µS/cm)	1,570 – 9,860	9,100 – 14,070	13,000	3,670	574	n/a
TDS (mg/L)	955 – **7,610**	**4,700 – 9,710**	**7,330**	**2,140**	421	1,200
Total hardness (mg/L)	421 – **6,360**	**939 – 2,100**	**1,830**	**1,030**	201	500
Total alkalinity (mg/L)	210 – 462	221 – 424	590	237	230	n/a
Na (mg/L)	148 – 1,435	1,204 – 2,135	1,680	305	27	n/a
K (mg/L)	26 – 128	163 – 330	192	44	33	n/a
Ca (mg/L)	76 – 948	100 – 173	233	172	41	n/a
Mg (mg/L)	49 – 1,019	143 – 339	303	145	24	n/a
Fe (mg/L)	0.2 – 1.3	< 0.1 – 5.3	<0.05	<0.05	<0.1	n/a
SiO_2 (mg/L)	13 – 38	76 – 80	-	-	106	n/a
Cl (mg/L)	**260 – 8,260**	**400 – 3,724**	**2,480**	**807**	**24**	5
SO_4 (mg/L)	103 – **4,464**	428 – **1,690**	**1,760**	360	21	500
NO_3 (mg/L)	0 – **53**	**158 – 252**	-	-	23	50
HCO_3 (mg/L)	243 – 431	269 – 517	-	-	281	n/a
CO_3 (mg/L)	0 – 31	-	-	-	0	n/a
F (mg/L)	0.7 – 1.8	1.5 – 2.3	-	-	1.3	n/a
PO_4 (mg/L)	< 1	< 1	-	-	-	n/a
NaCl (mg/L)	-	659 – 6,137	-	-	40	n/a
Al (mg/L)	-	-	0.04	<0.01	-	0.2
As (mg/L)	-	-	0.002	**0.197**	-	0.01
Be (mg/L)	-	-	<0.001	<0.001	-	0.06
Ba (mg/L)	-	-	0.017	0.03	-	2
Cd (mg/L)	-	-	<0.0001	0.0013	-	0.002
Cr (mg/L)	-	-	0.012	<0.001	-	0.05
Co (mg/L)	-	-	<0.001	0.001	-	n/a
Cu (mg/L)	-	-	0.006	0.001	-	2
Pb (mg/L)	-	-	<0.001	<0.001	-	0.01
Mn (mg/L)	-	-	0.001	0.28	-	0.5
Mo (mg/L)	-	-	<0.001	<0.001	-	0.05
Ni (mg/L)	-	-	0.004	<0.001	-	0.02
Se (mg/L)	-	-	**0.02**	<0.01	-	0.01
Sr (mg/L)	-	-	4.5	2.88	-	n/a
Ti (mg/L)	-	-	<0.01	<0.01	-	n/a
V (mg/L)	-	-	<0.01	<0.01	-	n/a
Zn (mg/L)	-	-	0.041	0.016	-	3
B (mg/L)	-	-	1.32	<0.05	-	4

Notes: [1] Australian Drinking Water Guidelines (bolded values exceed the guidelines)

Table 7-3: Recent groundwater quality data

Analyte	Wilsons Bore		Corsair Bore		NRMMC (2011)1
	04/09/13	**17/10/13**	**04/09/13**	**17/10/13**	
pH	7.49	7.33	7.68	7.43	n/a
EC (µS/cm)	11,300	11,100	3,410	3,280	n/a
TDS (mg/L)	**7,750**	**7,820**	**2,480**	**2,120**	1,200
Total alkalinity (mg/L)	594	604	250	263	n/a
Ca (mg/L)	156	255	144	168	n/a
Mg (mg/L)	334	339	142	140	n/a
Na (mg/L)	1,940	1,780	337	316	n/a
K (mg/L)	195	180	43	43	n/a
SO4 (mg/L)	**1,830**	**1,620**	368	326	500
Cl (mg/L)	**2,760**	**2,290**	**741**	**750**	5
Total P (mg/L)	< 0.01	0.02	< 0.01	0.04	n/a
Total Anions (meq/L)	128	110	33.6	33.2	n/a
Total Cations (meq/L)	125	123	34.6	34.8	n/a
Ionic Balance (%)	1.28	5.25	1.57	2.29	n/a
DOC (mg/L)	< 1	6	4	1	n/a
TOC (mg/L)	< 1	2	2	< 1	n/a
Aluminium (mg/L)	< 0.01	< 0.01	< 0.01	0.02	0.2
Antimony (mg/L)	<0.001	< 0.001	< 0.001	< 0.001	0.003
Arsenic (mg/L)	0.001	0.003	**0.184**	**0.196**	0.01
Cadmium (mg/L)	< 0.0001	< 0.0001	0.0011	0.0010	0.002
Chromium (mg/L)	0.014	**0.11**	0.003	0.001	0.05
Copper (mg/L)	0.004	0.008	0.001	0.002	2
Nickel (mg/L)	0.002	0.002	< 0.001	0.010	0.02
Lead (mg/L)	< 0.001	< 0.001	< 0.001	< 0.001	0.01
Zinc (mg/L)	< 0.005	0.023	0.010	0.124	3
Manganese (mg/L)	0.002	< 0.001	0.030	0.029	0.5
Selenium (mg/L)	**0.01**	**0.02**	< 0.01	< 0.01	0.01
Uranium (mg/L)	**0.105**	**0.091**	**0.029**	**0.027**	0.017
Vanadium (mg/L)	< 0.01	<0.01	< 0.01	< 0.01	n/a
Boron (mg/L)	1.28	1.42	0.65	0.65	4
Iron (mg/L)	< 0.05	< 0.05	< 0.05	< 0.05	n/a
Mercury (mg/L)	< 0.0001	< 0.0001	< 0.0001	< 0.0001	0.001
Fluoride (mg/L)	1.2	1.1	0.4	0.4	1.5
TPH (µg/L)	< 50	< 50	< 50	90	n/a

Notes: [1] Australian Drinking Water Guidelines (bolded values exceed the guidelines)

7.3 Planned infrastructure

7.3.1 Surface water

The proposed surface water infrastructure includes:

- tailings dam, consisting of two cells
- concentrate residual dam (CRD)
- water storage dam
- sewage pond / waste water treatment facility
- sediment traps
- surface water diversions

The proposed location of each of these features is shown on Figure 7-5, and a description of their key design features is included in Table 7-4.

Table 7-4: Summary of proposed surface water management infrastructure

Infrastructure item	Purpose	Physical attributes
Tailings dam cells	Receives tailings slurry from the processing plant. Decant water is collected and returned to the process circuit.	Two cells, above and below ground components, staged construction. Each above ground cell 370 x 370 m (500,000 m^3) ≥ 150 cm freeboard
Water storage dam (existing)	Temporary storage of water used in the processing plant. This may be groundwater, or recycled water from other areas of site	Fully lined with HDPE 91 x 91 m (10,000 t) > 150 cm freeboard
CRD	Temporary storage of dense tailings concentrate that has undergone cyanide leaching. 1-2 tonnes deposited daily, and evaporated.	Fully lined with HDPE 190 x 190 m (50,000 m^3) ≥ 150 cm freeboard
Sewage pond / waste water treatment	Storage and treatment of domestic waste from the accommodation camp	Earth-lined turkeys nest pond for disposal of treated sewage effluent
Sediment traps	Temporary storage of runoff water from the main infrastructure areas. These are designed as flow-through systems during intense rainfall.	Earth-lined ponds See Appendix E: Erosion and Sediment Control Plan for design details
Diversion banks / drains	Divert clean stormwater around the main disturbance areas	See Appendix F: Water Management Plan

All of the surface water storage facilities (i.e. the tailings dam, CRD, and water storage dam) will be designed, constructed, and managed to prevent the release of water into the surrounding environment. In general, the facilities will utilise conditioned earth, clay, or

HDPE liners to achieve a permeability of ≤ 10 8 m/s to prevent seepage into groundwater (Appendix I: Tailings storage facility geotechnical conceptual design report summarises the results of conceptual seepage modelling). Each facility will also be designed, constructed, and monitored to maintain a minimum freeboard sufficient to hold a 1:100-yr, 72-hr rainfall event of approximately 150 cm. All of the water being pumped out of these facilities will either be reused within the processing circuit (the preferred choice), or treated for subsequent disposal. No surface water will be released into the surrounding environment from any of the surface water storage facilities.

The Erosion and Sediment Control Plan (ESCP) (Appendix E) and the Water Management Plan (WMP) (Appendix F), outline the design of diversion banks and drains that will be constructed throughout the site to divert the local surface water flows around the main infrastructure areas (Figure 7-6). The main site diversion banks have been designed to convey a 1:1,000-yr peak flow event, and all temporary drains have been designed for a 1:100-yr peak flow event. The key design features for each diversion structure are summarised in Table 7-5. Discharge from each diversion structure will be via a level spreader or rock chute, to ensure that the concentrated surface flow is transitioned back to sheet flow in a way that minimises erosion downslope of the outlet.

Sediment control structures (i.e. “sediment traps” or “sediment basins”) will be installed in each of the main infrastructure areas to collect and remove sediment from runoff water. Four sediment traps are required, and these will be installed at the processing plant, workshop / office area, ROM pad, and camp (Figure 7-5). These have been designed in accordance with the Best Practice Erosion and Sediment Control Guidelines (IECA, 2008) as “Type 1” basins, capable of removing ≥ 90% of particles ≥ 0.045 mm in diameter (fine sands) during storm events as large as the 1:20-yr peak flow event. The sediment traps are designed as flow-through cells, and are sized such that the retention time of water in the basin is matched to the settling velocity of the critical particle size. Key design features for each sediment trap are summarised in Table 7-6.

Table 7-5: Summary of surface water diversion design parameters

Catchment No.	Site area	Diversion length (m)	Channel slope (m/m)	“Left bank” slope	“Right bank” slope	Design flow rate (m^3/s)	Design flow velocity (m/s)	Diversion height + depth (m)
A1	North Pit	760	0.004	0.33	0.10	9.8	1.42	1.3
A2	North Pit	350	0.006	0.33	0.10	11.5	1.72	1.3
B1	South Pit	340	0.012	0.33	0.10	6.3	1.92	1.0
B2	ROM	150	0.005	0.13	0.13	6.3	1.31	1.1
B3	WRD 1	750	0.005	0.13	0.13	12.0	1.55	1.3
C1	South Pit	400	0.008	0.33	0.10	7.1	1.71	1.1
C2	WRD 2	550	0.004	0.33	0.10	14.9	1.58	1.5
C3	TD Cell 2B	230	0.004	0.33	0.10	17.8	1.66	1.6

Catchment No.	Site area	Diversion length (m)	Channel slope (m/m)	“Left bank” slope	“Right bank” slope	Design flow rate (m^3/s)	Design flow velocity (m/s)	Diversion height + depth (m)
D1	Plant	480	0.004	0.13	0.13	4.6	1.12	1.0
D2	Camp	440	0.005	0.13	0.13	7.8	1.39	1.1
E	Workshop	180	0.003	0.13	0.13	3.1	0.91	1.0
F	Landfill	230	0.004	0.13	0.13	3.9	1.08	1.0

Table 7-6: Sediment trap design parameters

Domain	Catchment Area (ha)	Settling zone depth (m)	Storage zone depth (m)	Pond Area (m^2)	Required Dimensions (depth / width / length)
Plant	3.00	0.6	0.6	1,000	1.5 x 18 x 54 m
Workshops / Offices	2.25	0.6	0.6	620	1.5 x 14 x 43 m
ROM pad	2.25	0.6	0.6	620	1.5 x 14 x 43 m
Camp	8.80	0.6	0.6	2,300	1.5 x 28 x 82 m

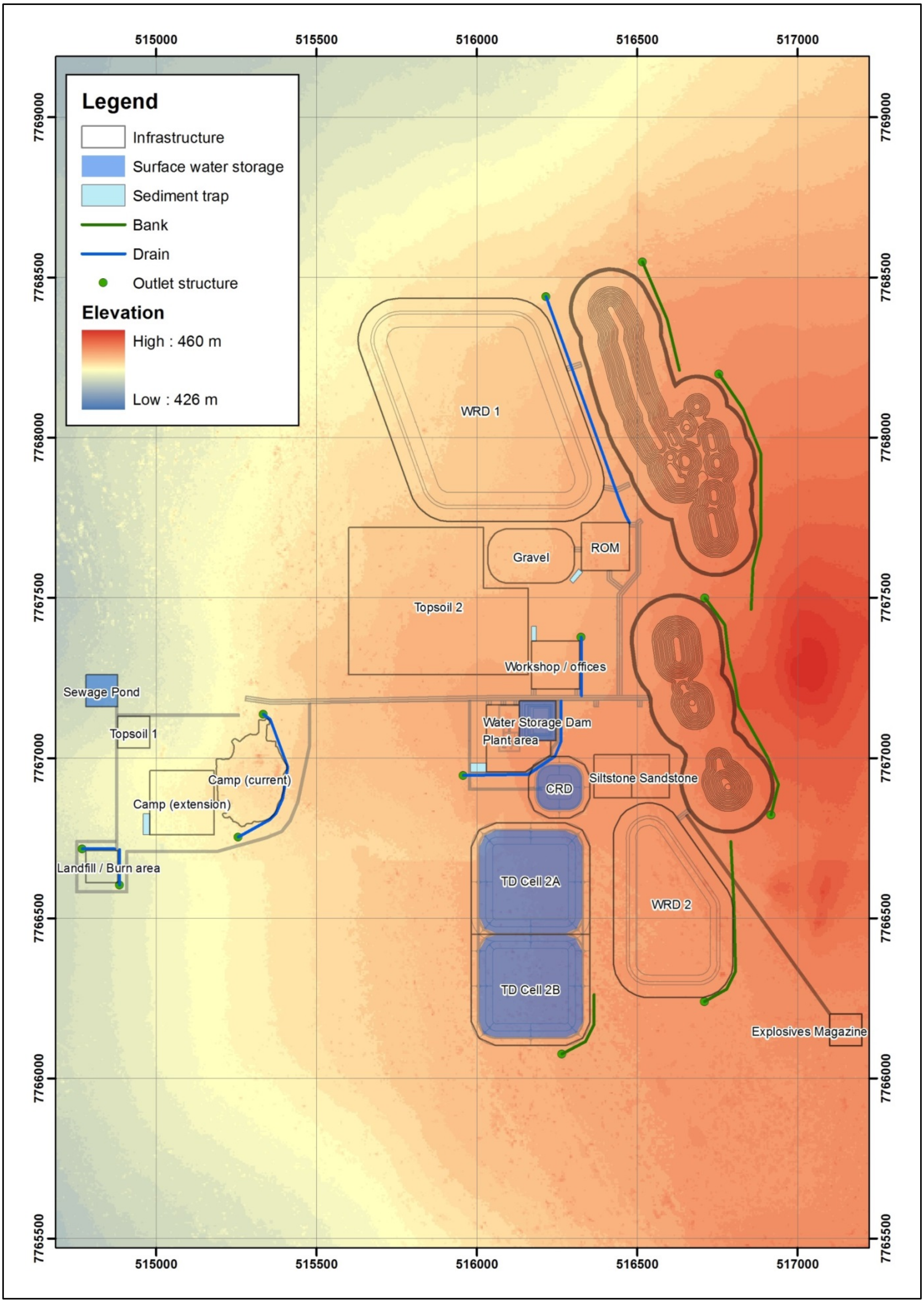


Figure 7-5. Planned surface water infrastructure.

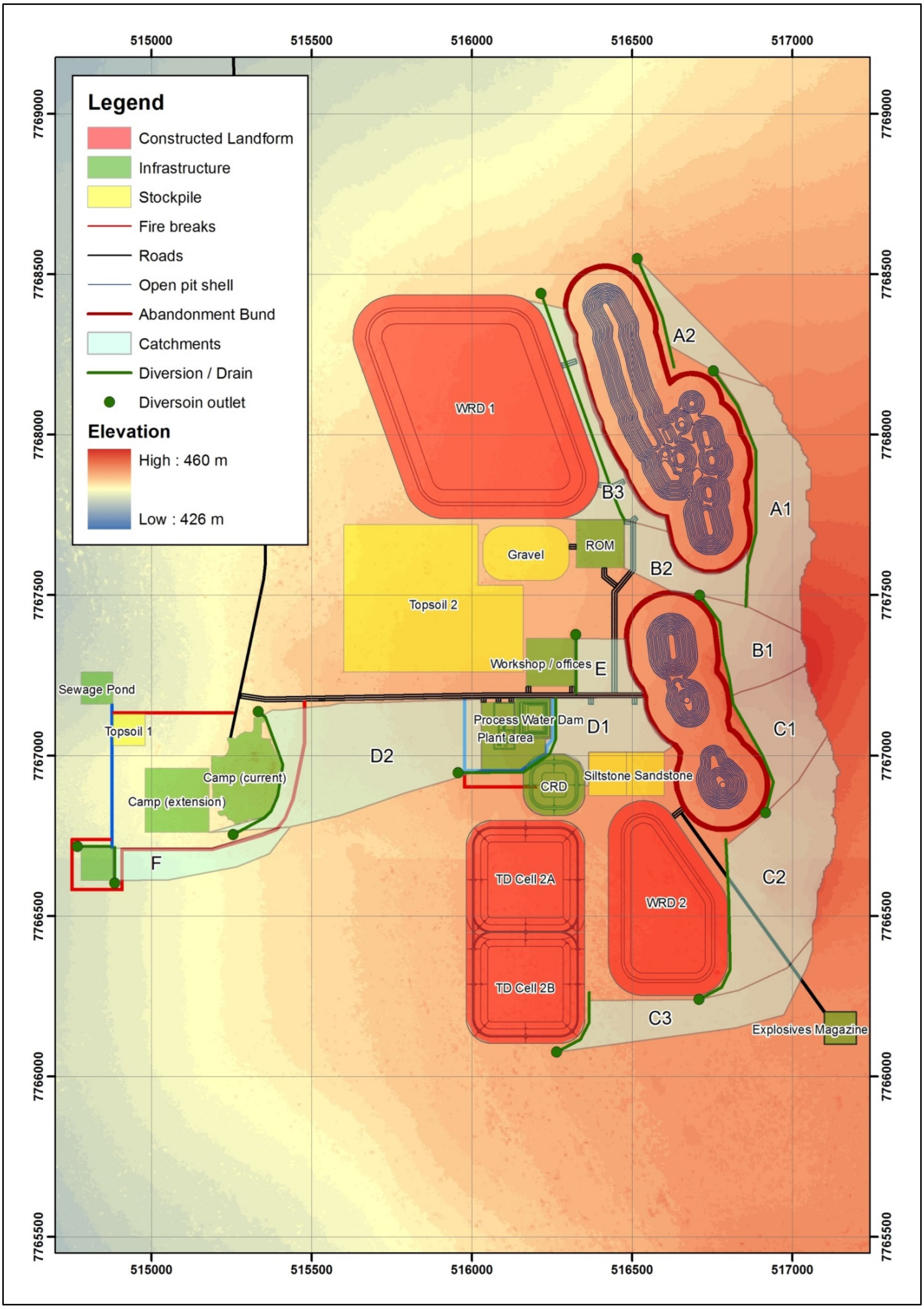


Figure 7-6. Diversion catchment areas.

7.3.2 Groundwater

The Twin Bonanza project includes three existing groundwater extraction bores, known as "Timmy's Bore" (or "Strezza's"), "Corsair Bore", and "Wilson's Bore". The location of these existing bores is shown on Figure 7-7, and their construction details are listed in Table 7-7. Wilson's Bore is located within the exploration lease area and a section 19 lease under the Aboriginal Land Rights Act 1976, and Corsair Bore is located within the mineral lease application area. Corsair is thought to be installed within a deep bedrock aquifer (90 150 metres below ground level (mbgl)), while Wilson's is installed in the upper reaches of the palaeochannel system. Both of these bores are currently being utilised to provide water for the Twin Bonanza pilot processing plant, at a combined rate of approximately 2 L/s. Timmy's Bore is located approximately 5 km to the West of the main project area within the Nora Palaeochannel, and a pipeline corridor has been established from the bore location to the Old Pirate mine site. This bore is not currently in use, as it has collapsed. Depth to water in Timmy's Bore has previously been recorded at a depth of less than 6 mbgl. The three existing bores are understood to have a combined maximum yield of up 10 L/s, although this maximum extraction rate is not likely to be sustainable (Appendix J).

A number of options are being considered for the development of additional production bores to diversify the water supply and boost the available flow rate to the estimated peak requirement of approximately 11 L/s. Earth Systems (Appendix J) identified six potential bore field locations within palaeochannel areas surrounding the project area, and these are shown on Figure 7-7, and described in Table 7-7. As the project is to be developed in a staged approach the 11 L/s will not be required at start up, giving an opportunity to monitor sustainability of the current bores. Groundwater target areas #2A and #3 are the primary candidates for further exploration. Target area #2A has the advantage of being relatively close to the project area, and within the existing section 19 lease used for access to Timmy's Bore. The existing Timmy's Bore pipeline corridor could also be utilised to supply water from target area #2A to the processing plant. Groundwater target area #3 is considered the best candidate for a long-term sustainable supply because of its location within one of the main branches of the Tanami Palaeochannel, with a large upstream catchment area of approximately 170 km2. However, land access rights would likely need to be obtained in order to explore the groundwater resource or operate production bores in target area #3.

There are currently no dedicated monitoring bores located within the project area, and limited monitoring data is available from Timmy's Bore, Corsair Bore, and Wilson's bore as well as a number of other registered bores within a 40 km radius (see Figure 7-7). Details of the planned monitoring bore network are discussed in the Water Management Plan (Appendix F) and in section 7.6.2.

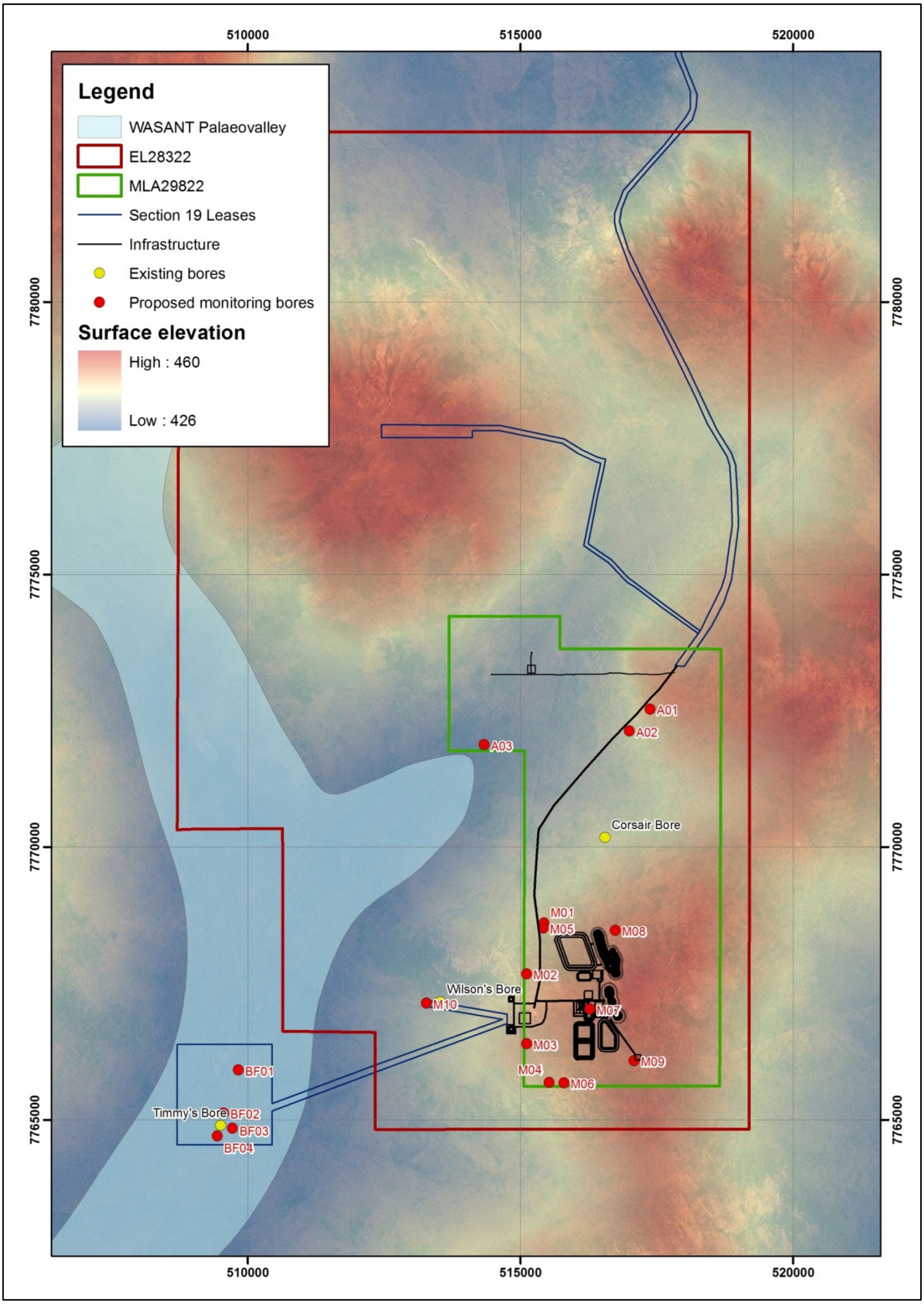


Figure 7-7. Location of potential bores.

Table 7-7: Existing and proposed production bore construction (adapted from Earth Systems, 2013).

Bore	Easting	Northing	Casing elevation (mAHD)	Geology	Depth (m) (approximate)	Approximate water level (mbgl)	Notes
Timmy's Bore (Strezza's)	509507	7764901	424	Palaeochannel	10	6	Borehole was 34.7m deep in earlier assessment, but has since collapsed Borehole is registered (RN016568). Also known as Strezza's Bore.
Corsair Bore	516550	7770180	438	Fractured bedrock	150	95	Drilled in 2010 near high yielding exploration borehole. Yield understood to be 2-3 L/s (possibly up to 4 L/s) but sustainability of this is unknown. Previous water level recorded as 110 mbgl.
Wilson's Bore	513529	7767170	430	Unknown (palaeochannel branch?)	92	40	Understood to have run dry in 2012 after 2.5 years of use in previous operation. Yielded up to 4L/s. Further onsite investigation discovered the pump was poorly positioned in a mud layer at the base of the bore resulting pumping issues. Pumping resumed in 2013 for pilot processing operation.
Target Area 1	521800	7765470	432	Palaeochannel sub-catchment	(40)	unknown	Closest potential catchment to the project area. Relatively small catchment area may limit sustainability of groundwater supply.
Target Area 1A	521800	7765470	432	Palaeochannel Sub-catchment	(40)	unknown	Closest potential catchment to the project area. Limited catchment size and narrow width may restrict size of potential well field.
Target Area 2	508360	7763970	424	Palaeochannel	(40)	6	Close to Timmy's Bore (Strezza's), which was recorded to yield approx. 2 L/s, prior to its collapse. Water quality is likely to be good. 8.5 km from site, with an established pipeline corridor.
Target Area 2A	514880	7767030	424	Palaeochannel	(40)	6	Similar to Target Area 2, but falling within the Section 19 Lease area.
Target Area 3	530520	7758060	404	Palaeochannel	(40)	unknown	Within the main branch of the Tanami Palaeochannel – i.e., has a large catchment area (170 km^2), and likely more sustainable yield. 17 km from site.
Target Area 4	503520	7751000	410	Palaeochannel	(40)	unknown	Within the main branch of the Nora Palaeochannel. Has a large catchment area (83 km^2), and likely sustainable yield. 20 km from site.
Target Area 5	548370	7774790	397	Palaeochannel	(40)	unknown	Within a relatively wide section of the main branch of the Tanami Palaeochannel, potentially allowing for a larger borefield. 33 km from site.

7.4 Assessment of risks

7.4.1 Surface water

The following have been identified as the primary risks to surface water associated with mining activities within the project area:

- **Overtopping of water storages:** The water stored in the surface water storage facilities (i.e. tailings dam, CRD, water storage dam, and sewage pond) may have properties that would be harmful to natural environments (see Table 7-8). This water has the potential to contact the surrounding surface environment if the storage capacity (including the operational freeboard) is exceeded, and the storage is overtopped (e.g. if a pond is full and then a large rainfall event occurs).
- **Erosion of constructed landforms:** Erosion of disturbed land areas has the potential to cause sedimentation of the surrounding environment. Constructed landforms are considered at increased risk of erosion, as these will be constructed with disturbed soil materials, and with slope angles that are steeper than the surrounding natural landscape. Depending on the nature of the eroded sediment, and the extent of the sedimentation, this can have negative effects on vegetation growth and down-slope surface water quality.
- **Flooding of low-lying roads and infrastructure:** A preliminary flood risk assessment identified areas within the project area that are considered at increased risk of flooding during extreme rainfall events (Appendix G). This assessment identified the borefield, borrow pit, and sections of the access track, which exist in the lowest-lying areas of the landscape (see Table 7-3 and Figure 7-8), as being at highest risk of flooding. In addition to the operational risks associated with flooding (i.e. blocked site access, loss of equipment, etc.), inundation of these areas has the potential to result in scouring and erosion of any disturbed land surfaces, and is likely to result in downslope sedimentation.
- **Chemical spills:** Any spillage of chemicals stored on site (e.g. hydrocarbons or cyanide) has the potential to come into contact with surface water flows, and to be distributed to the surrounding environment. Release of some chemicals may be toxic to vegetation and could degrade soil quality as well as down-slope surface and groundwater quality. Due to the nature of the topography and the absence of permanent surface water features within the project area, the effects of any potential chemical spills are likely to be localised.
- **Modification of natural surface flow regimes:** The construction of mine site infrastructure (e.g. processing plant, waste rock dump, tailings dam, diversion drains) is likely to cause the diversion of natural surface water flows. These diversions will affect the final destination of surface water flows, and some

downslope environments may receive a smaller total volume of water than is required to support current vegetation types (i.e. a 'shadowing effect'). Further, diversion drains are likely to convert surface sheet flow into concentrated flow channels that have a greater potential for causing erosion.

- **Land degradation (salinity):** At least some of the water to be used for dust suppression within the project area is likely to be saline (i.e. EC > 5,000 µS/cm). Continued application of saline water will stabilise road surfaces against erosion, but may render the soil incapable of supporting revegetation species. Over-spraying with saline dust suppression water, and/or runoff from sprayed areas can also degrade soils outside of the intended spray area.

As there are no pastoral operations in the vicinity of the project no livestock will be exposed to salts or other elements liberated from mine waste.

Further detail of the risks with associated mitigation and management measures are detailed in Chapter 5: Risk assessment.

Table 7-8: Potential sources of contamination and risks associated with surface water

Domain	**Potential contaminants**	**Environmental risks**	**Safety risks**
Tailings dam	Fine tailings material Elevated metal and metalloid contents	Smothering of vegetation. Vegetation toxicity and degradation of surface and groundwater quality	Drowning
CRD	Fine tailings material Elevated metal and metalloid contents Cyanide (CN)	Smothering of vegetation. Vegetation toxicity and degradation of surface and groundwater quality	Inhalation of CN gas Drowning
Water storage dam	NaCl (salinity) Elevated metal and metalloid contents	Vegetation toxicity	Drowning
Sewage pond	Elevated metals and metalloid contents Pathogens Nutrients	Vegetation toxicity and degradation of surface and groundwater quality	Exposure to pathogens Drowning
Constructed landforms	Sediment	Smothering of vegetation Reduced revegetation establishment due to loss of growth medium	n/a
Access roads	Sediment	Smothering of vegetation Flood waters backing up against the road	Vehicle inundation Blocked site access
Borefield and borrow pit	Sediment	Smothering of vegetation Loss of growth medium	Vehicle inundation

Table 7-9: Flood risk matrix for major infrastructure items

	Catchment area	Slope	Landform	Landscape position	Soil type	Overall
North Pit	Low	Low	Low	Low	Low	Low
Central Pit	Low	Low	Low	Low	Low	Low
South Pit	Low	Low	Low	Low	Low	Low
Plant	Low	Medium	Low	Low	Low	Low
Workshops	Low	Medium	Low	Low	Low	Low
Tailings dam Cell 1	Low	Low	Low	Low	Low	Low
Tailings dam Cell 2	Low	Low	Low	Low	Low	Low
WRD 1	Low	Low	Low	Medium	Low	Low
WRD 2	Low	Low	Low	Medium	Low	Low
Camp	Low	Low	Low	Low	Low	Low
Airstrip	Low	Low	Low	Low	Low	Low
Borefield	High	High	High	High	Low	High
Borrow Pit	High	High	High	High	Low	High
Access roads	Low – High	Low – High	Low – High	Low – High	Low	Low - High

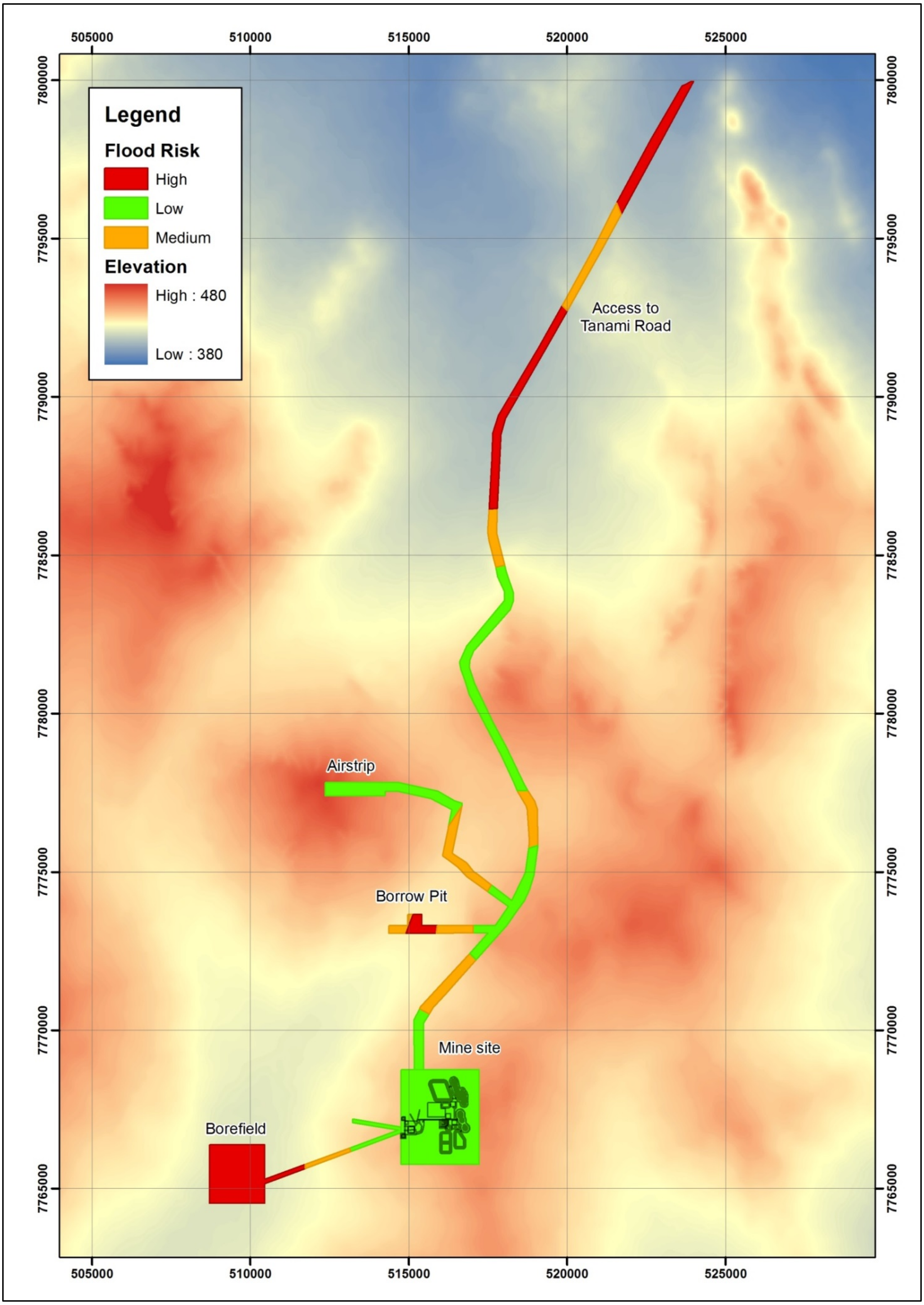


Figure 7-8. Assessed flood risk.

7.4.2 Groundwater

The following have been identified as the primary risks to groundwater associated with mining activities within the project area:

- **Potential leachates:** While the materials to be extracted from the pits have been generally been classified as Non-Acid-Forming (NAF) (Appendix M), some materials have been identified with limited potential to leach arsenic (i.e. arsenopyrite, pyrite, and galena) and lead under certain conditions; and will thus be considered potential sources of pollution within the proposed waste rock dump (WRD).
- **Seepage from water storages:** Water stored in the surface water storage facilities (i.e. tailings dam, CRD, water storage dam, and sewage pond) is likely to have properties that would degrade natural water quality if it were to come into contact with the groundwater system (see Table 7-8). This water has the potential to come into contact with the groundwater system if any seepage occurs from the storage facilities and is subsequently transported through the unsaturated zone.
- **Chemical spills:** Any chemicals stored on site (e.g. hydrocarbons or cyanide) have the potential to come into contact with the groundwater system if they are allowed to seep into the ground in the event of an uncontrolled spill. This could degrade the quality of surface soils that come into contact with the spilled material, and would have the potential to limit future uses of the groundwater if seepage occurs.
- **Drawdown effects on other groundwater users:** Abstraction of groundwater from an aquifer lowers the potentiometric head within the aquifer, and can thus reduce the abstraction rates achieved by other users within the zone of influence of the abstraction. Abstraction from one part of an aquifer can have an effect on the sustainability of supply in another part of the aquifer. As all of the production bores for the project have yet to be developed and tested, the potential impact on other groundwater users is currently unknown. However, given that the nearest registered bore is > 20 km away, drawdown effects on other users are expected to be minimal.
- Drawdown effects on GSE: Abstraction of groundwater from the surficial aquifer system within any GSE areas has the potential to draw down the water table in these areas, and thus to affect water availability to the plants and threaten the viability of the GSE. The extent of potential effects on GSE is dependent on the degree and extent of drawdown caused by the groundwater abstraction, and this has yet to be characterised. Presence of GSE are also yet to be confirmed.

Further detail of the risks with associated mitigation and management are detailed in Chapter 5: Risk assessment.

7.5 Mitigation

7.5.1 Surface water

The following strategies will be implemented to mitigate the risks to surface water identified in Section 7.4.1:

- **Overtopping of water storages:** In order to avoid overtopping of the water storages, each of these facilities (i.e. tailings dam, CRD, water storage dam, and sewage pond) will be constructed and operated with a minimum freeboard sufficient to hold the entire volume of a 1:100-yr, 72-hr rainfall event. The water level within each of these facilities will be monitored (daily at minimum) to ensure that the maximum operating level is not exceeded, and that the minimum freeboard is always available in the event of an extreme rainfall event.
- **Erosion of constructed landforms:** An Erosion and Sediment Control Plan (Appendix E) has been prepared for the Twin Bonanza gold project, which outlines in detail specifically how erosion and sedimentation will be minimised and managed across the project area. The main steps taken will include:
    1. the use of diversion drains and banks to redirect any "clean" surface water flows, thus minimising the potential for erosion by limiting the amount of water flowing through the site
    2. the use of erosion-resistant materials to construct the tailings dam and WRDs, as identified by a soil assessment
    3. limiting constructed slope gradients to angles that have been demonstrated to be stable for the given construction materials (i.e. ≤15° for the sandstone material).
- **Flooding of low-lying roads and infrastructure:** Areas that have been identified as "high" flood risk areas (i.e. the borefield, borrow pit, and sections of the access track) (Appendix G) will be constructed and managed to minimise this risk. Land disturbance within the borefield is expected to be minimal, and thus erosion is not expected to be a large issue in this area. Any sensitive equipment installed within the borefield will however need to be installed outside of the flood risk area, or be able to handle sustained periods of inundation. Once the required materials have been removed from the borrow pit, the internal batters will be re-contoured to 14° into the surrounding landscape, ripped, and covered with topsoil to encourage water infiltration and provide adequate conditions for the establishment of revegetation. Where practicable the re-contouring will aim to minimize the amount of water that will be stored in the depression. The main access road is already established, and has low pass crossings in areas with a high likelihood of seasonal flooding. This is expected to be adequate for maintaining the integrity of the road

surfaces.

- **Chemical spills:** A Hazardous Substances Management Plan is in effect (Appendix Q) in conjunction with the Water Management Plan (Appendix F). These documents detail how spills of hydrocarbons and other chemicals will be managed. The general strategies adopted will include:
  1. bunding of all fuel and chemical storage areas to contain the potential volume of spillage plus the 1:100-yr, 72-hr rainfall event if not self bunded
  2. the use of grease traps in all workshop and wash-down areas where small spills or leaks are more likely to occur
  3. a site-specific spill response procedure will be developed once the final site layout is finalised.
- **Modification of natural surface flow regimes:** The benefits of the diversion banks and drains (in terms of minimising erosion) are considered to outweigh any minor negative effects of surface water flow shadowing, and surface water flow shadowing effects will thus not be managed during the life of mine. The smaller diversion drains will be removed upon site closure to re-establish surface flow patterns though the centre of the project area, but the main site diversion banks will remain in place for continued protection of the pit abandonment bunds against erosion. All discharges from the diversions will occur via rock chute or level-spreader onto native slopes, in order to restore the natural sheet flow conditions in these areas.
- **Land degradation (salinity):** The use of saline water for dust suppression will be limited to the haul roads, where its use will help to stabilise road surfaces against erosion. Over-spraying and runoff will be minimised through operator training in best-practice operation, and through proper equipment maintenance. Only non-saline or brackish water will be used in the vicinity of topsoil stockpiles in order to avoid degrading their quality for rehabilitation. Any soil areas that are affected by elevated salinity resulting from dust suppression practices will be addressed through remediation activities implemented at closure.

7.5.2 Groundwater

The following strategies will be implemented to mitigate the risks to groundwater identified in Section 7.4.2:

- **Potential leachates:** The proposed construction of the WRD has been designed specifically to manage pH and availability of oxygen to reduce the risk of leaching potential contaminants into the environment (Appendix M). In general, the most benign and stable waste materials (i.e. sandstone) will be used as the outer embankment of the WRD, and those with the higher level of veining containing trace sulphide concentrations will be isolated in the centre of the landform and surrounded by more inert material (i.e. sandstone) (Figure 7-9). Further details on waste rock management are provided in Chapter 10: Tailings and waste rock management.

- **Seepage from water storages:** Contamination of groundwater from surface activities is considered very unlikely, as the main groundwater aquifer within the project area is thought to exist at ≥ 100 m depth. However, a conservative approach will be taken to prevent any contamination of the surface soils and the upper reaches of the surficial aquifer. The CRD and water storage dam will be constructed using an HDPE liner to prevent all seepage from these facilities. The lining of the CRD is a conservative approach as cyanide is removed from the tailings as part of gold processing operation, and all water reporting to the CRD will be neutralised. The tailings dam cells (which will contain the bulk of the tailings that has undergone gravity separation only, with heavy minerals removed by a Knelson concentrator for cyanide leaching) will likely utilise a conditioned earth base and walls, or clay-lined base and walls, compacted to achieve permeability of 1x10-8 m/s to prevent seepage into groundwater. However, the design work (including assessment of in situ material suitability) for these structures is still ongoing, and if the local materials are not deemed suitable, then other options to prevent or minimise seepage will be explored.
- **Chemical spills:** A Hazardous Substances Management Plan is in effect (Appendix Q) in conjunction with the Water Management Plan (Appendix F). These documents detail how spills of hydrocarbons and other chemicals will be managed. The general strategies adopted will include:
    1. bunding of all fuel and chemical storage areas to contain the potential volume of spillage if not self bunded
    2. the use of grease traps in all workshop and wash-down areas where small spills or leaks are more likely to occur
    3. a site-specific spill response procedure will be developed once the final site layout is finalised.
- **Drawdown effects on other groundwater users:** At this stage, sustainable extraction rates are yet to be characterised in the palaeochannel aquifers, as these areas have been largely undeveloped to-date, and only limited groundwater testing and monitoring data is available. Activities in the upcoming period will primarily focus on filling information gaps, particularly around defining aquifer depth and extent, and measuring key aquifer properties such as transmissivity and storativity so that the effects on downstream groundwater users can be predicted and minimised. A groundwater monitoring bore network will be established to:

a. collect "background" data on groundwater quality,

b. measure changes in groundwater quality during the active mine phase, and

c. monitor water levels to establish whether or not a sustainable groundwater pumping rate is being used that will not impact on other groundwater users.

- **Drawdown effects on GSE:** Vegetation and groundwater monitoring will be conducted concurrently to measure the effects of water extraction on vegetation within the vicinity of any production bores installed in palaeochannel aquifers. This will be implemented once the final locations are chosen for installation of the production bores. A groundwater monitoring bore network will be used in association with vegetation monitoring to detect potential habitat degradation. If triggered, this will direct management actions (e.g. reducing pumping rates) or the development of additional water sources to reduce the effect on the aquifer. Further details are provided in Appendix D: Biodiversity Management Plan.

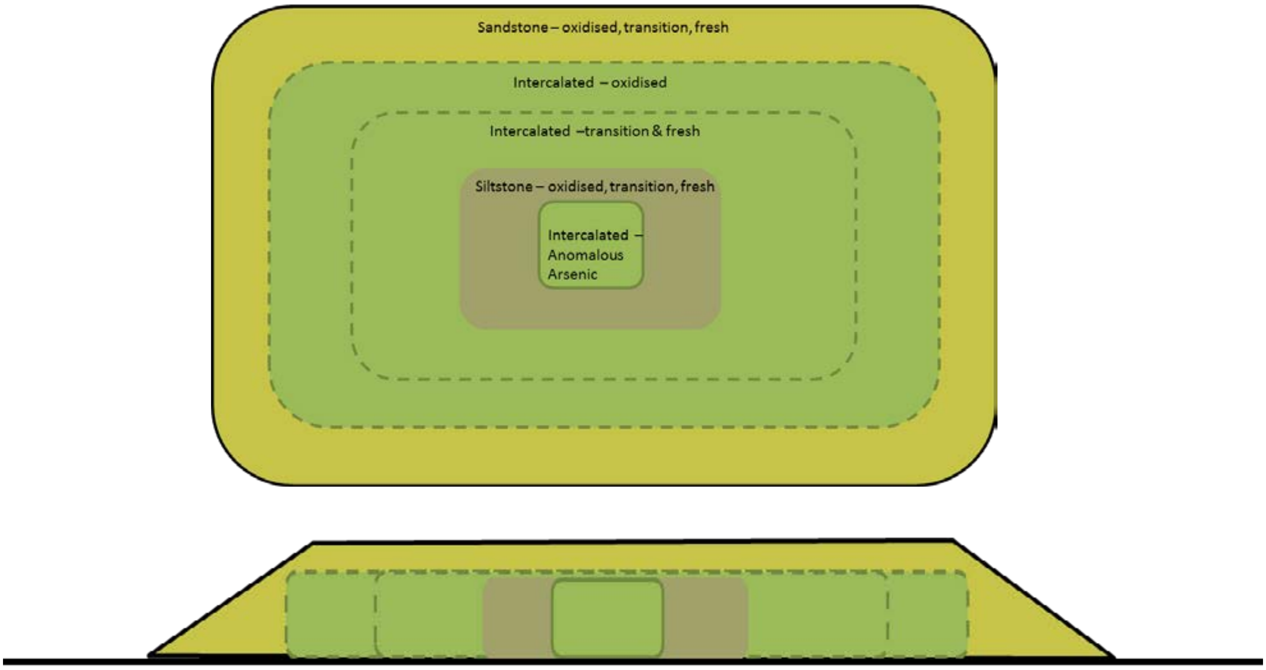


Figure 7-9: Conceptual diagrams of the Waste Rock Dump construction

7.6 Monitoring

Surface water and groundwater monitoring programs have been developed with the aim of:

- ensuring water is available for ongoing production
- assessing the impacts of the operation on water resources
- providing early warning capability by identifying environmental changes
- validating modelling (actual vs. predicted)

- contributing to reviews of environmental management procedures and performance, and
- demonstrating compliance with permits and licences.

These monitoring programs are described in detail in the Water Management Plan (Appendix F), and specific monitoring procedures are outlined in the Standard Operating Procedure for Surface Water Monitoring (Appendix F and G) and the Standard Operating Procedure for Groundwater Monitoring (Appendix F and H).

In general, most monitoring activities will be conducted monthly, by following the relevant Standard Operating Procedure (SOP). Monitoring results will be compared against site-specific trigger values to determine if any contingency measures are necessary. Monitoring results will be reported annually.

7.6.1 Surface water

Monitoring of surface water storages, sediment traps, and other surface water infrastructure will be conducted according to the Australian Guidelines for Water Quality Monitoring and Reporting (ARMCANZ, 2000) at the locations specified in the Water Management Plan (Appendix F) and shown on Figure 7-9. As previously discussed, there are no natural surface water features within an appreciable distance of the project area, and thus no natural features were selected for monitoring.

The Water Management Plan (Appendix F) summarises the chemical analysis to be completed for each of the monitoring locations. The analysis for the tailings dam, CRD, and water storage dam focuses primarily on metals and detecting the presence of cyanide, as this is aimed at characterising water that has been used within the gold processing circuit. The analysis of sediment trap discharge water is aimed at quantifying suspended solids and testing the effectiveness of the upstream oil and grease traps.

In addition to this chemical analysis, water depth / level and inflow and outflow rates will be monitored in the surface water storage facilities. This will be achieved by installing flow meters and depth measuring devices, ideally capable of logging the information automatically. This will allow for the continuous and accurate recording of process flow data, and will provide early warning for freeboard exceedances. Flow totals and water depths will also be recorded manually during monitoring events.

The ESCP (Appendix E) outlines an Infrastructure Test Plan (ITP) that will be incorporated as part of site monitoring activities. The ITP describes a procedure for inspection of all surface water diversions and outlet structures to ensure an acceptable level of performance throughout the life of mine.

7.6.2 Groundwater

Groundwater monitoring sites have been selected according to the Australian Guidelines for Water Quality Monitoring and Reporting (ARMCANZ, 2000) so that representative samples of the un-impacted (native or control) and potentially impacted groundwater may be collected both in the pre-mine period and throughout the life of mine. The monitoring program has been designed as a “Before-After, Control-Impact” (BACI) program, with priority applied to early detection, and assessment of biodiversity or ecosystem level response.

The proposed groundwater monitoring locations are detailed in the Water Management Plan (Appendix F), and shown on Figure 7-10, and each of these falls into one of the following categories:

- The existing production bores (Wilson’s and Corsair), Timmy’s Bore (which is planned to be redeveloped), and any future production bores within groundwater Target Area #2A. The production bores will be used to monitor groundwater quality within the areas surrounding the mine site. Corsair Bore will be used to monitor the bedrock aquifer north of the mine site, and Wilson’s and Timmy’s Bore will be used to monitor palaeovalley water quality down-gradient of the mine site.
- Four monitoring Bores (M01–M04) are intended to intercept the primary potential contaminant pathways down-gradient from the site. These will be installed in the surficial aquifer, which constitutes the upper catchment of palaeochannel system. The properties and extent of this surficial aquifer are not well known at this stage, and these locations are therefore preliminary; they have been proposed within the intended mineral lease area, and as far downslope as possible. If it is determined that no surficial aquifer system is present this far up-slope, then these monitoring locations may be moved down-slope and additional access agreements may be necessary.
- Five deep bores within the vicinity of the site will also be monitored (M05–M09). One of these monitoring bores (M07) will be installed central to the site (adjacent to the plant and CRD), while the other four will be installed around all four sides of the infrastructure to enable monitoring of groundwater flow in all directions.
- Three “background” or “analogue” sites (A01–A03) are intended to provide monitoring data for areas similar to those being monitored within the project area. These are located in areas outside of the potential influence of site activity, and will provide a means of distinguishing measured changes in the primary monitoring bores (M01– M04) from natural fluctuations or variability. Bore A01 will be installed into the bedrock aquifer, while bores A02 and A03 will be installed within the palaeochannel aquifer at similar landscape positions to the monitoring bores.

- Four monitoring bores (BF01–BF04) are proposed for the palaeochannel borefield, in the vicinity of Timmy's Bore, with another located adjacent to Wilson's Bore (M10). These will be used primarily to monitor water levels within the palaeochannel aquifer. These are likely to be installed at the time of exploration pump-testing, and will remain in place if the pump testing returns favourable results.

A standard set of monitoring parameters will be implemented for all monitoring locations, and summarised in the Water Management Plan (Appendix F). In addition to the chemical analysis, groundwater elevations and extraction rates will be monitored. Depth to groundwater will be recorded at all locations, and production bores will be fitted with a flow measuring device capable of continuous recording of the extracted flow rate and volume.

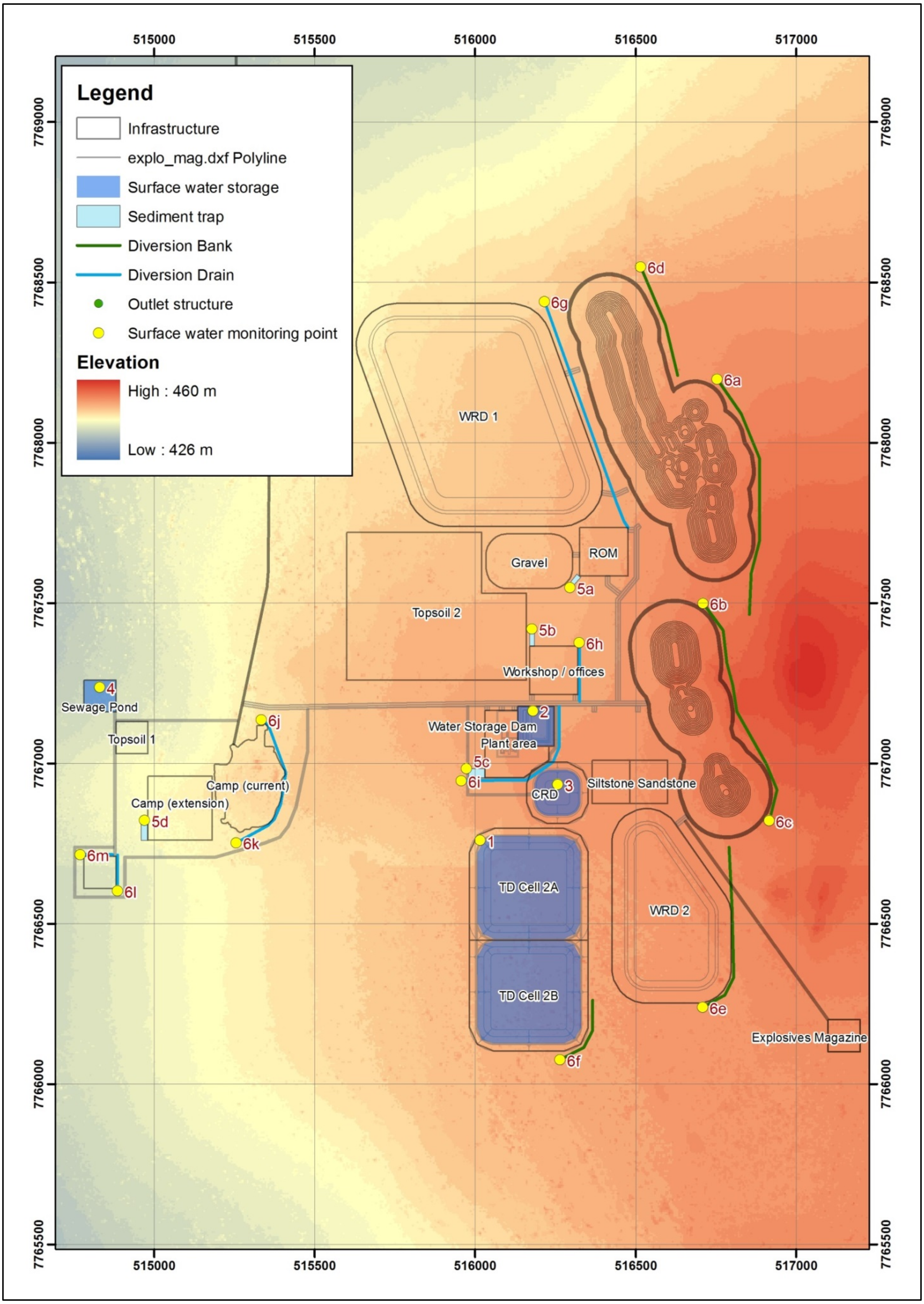


Figure 7-9. Surface water monitoring plan.

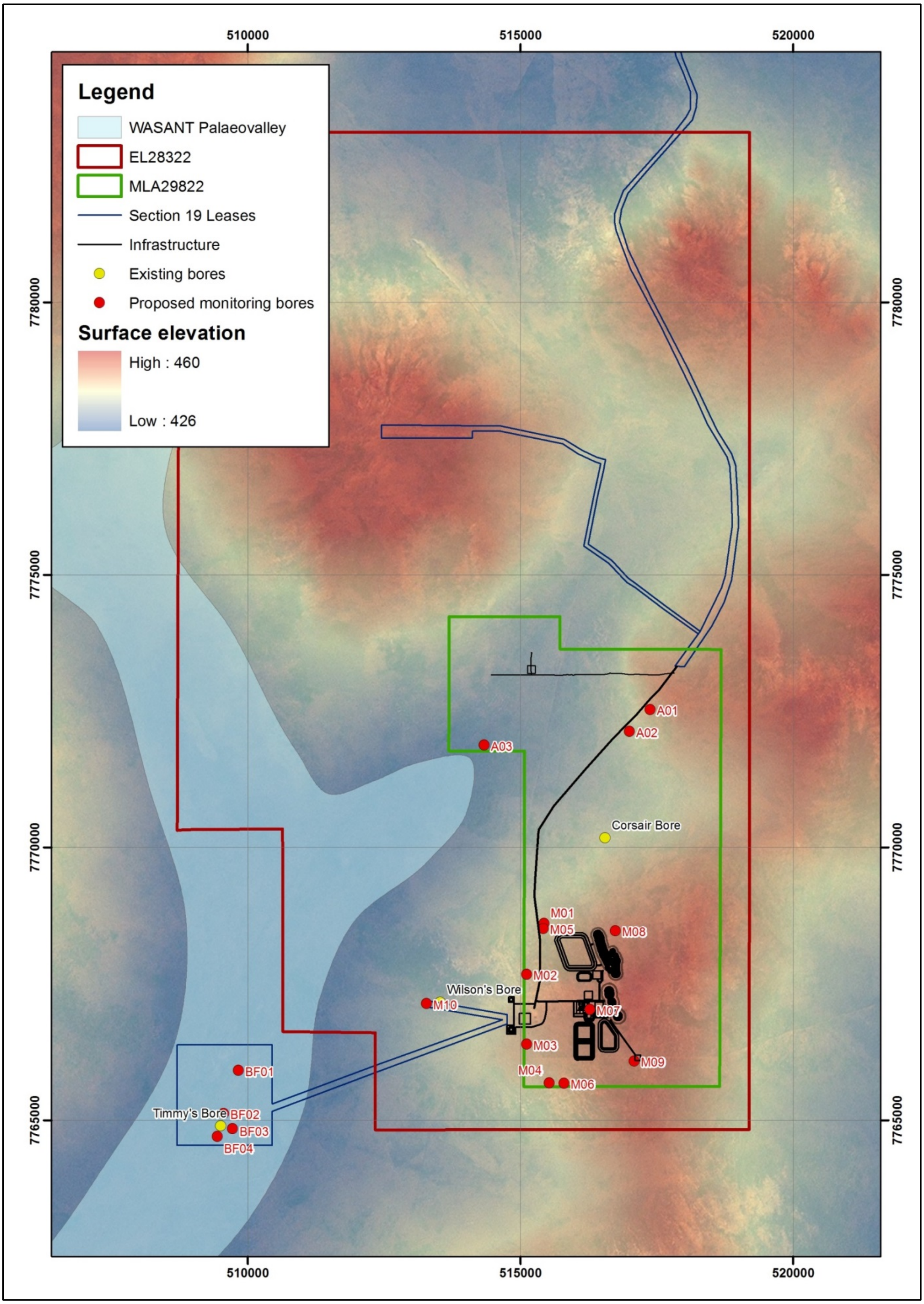


Figure 7-10. Groundwater monitoring plan.

7.7 Conceptual water account

A conceptual water account has been prepared for the Twin Bonanza gold project, which outlines all of the major water inflows and outflows (Appendix F). The level of detail in this water account reflects the early stage of development of the project, and it is intended that it will be updated as the site water requirements and available resources (i.e. groundwater supply) are further developed. The water account will be used to ensure that water usage is optimised and re-use is maximised.

A conceptual site flow diagram is shown in Figure 7-11. In summary, the majority of water supplied to the site is expected to be made up of groundwater, with a significant contribution to the water storages from rainfall during the wet season. All surface water runoff will either be diverted around the main disturbance areas, or directed into one of the four sediment traps to be installed within the infrastructure areas. Evaporation will likely account for a major proportion of water outflows, with the majority of the remainder being used in the processing circuit. Water that is not consumed in the processing circuit will be recycled back into the water storage dam, and subsequently reused in the processing plant.

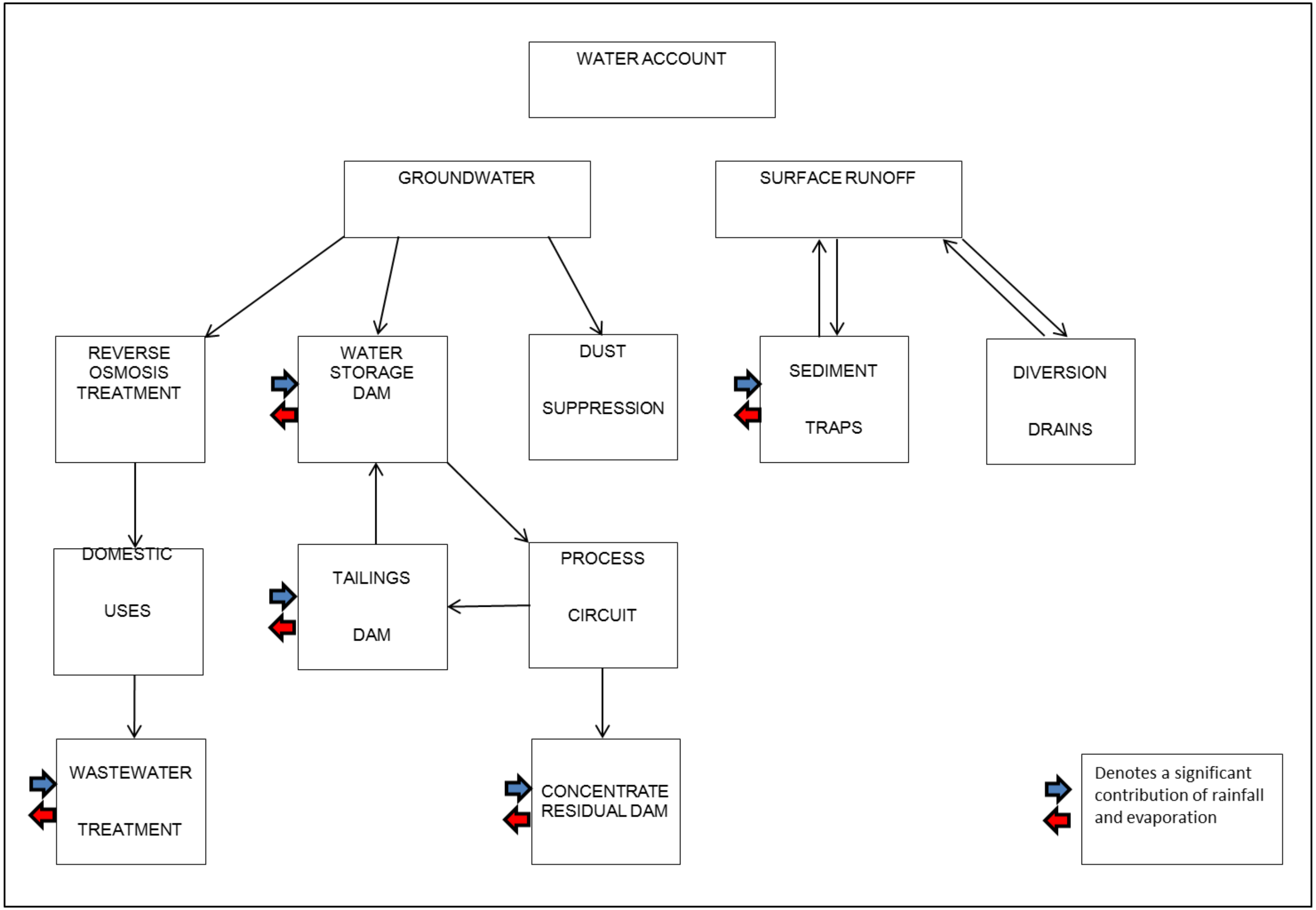


Figure 7-11. Water account flow diagram.