SOILWATER CONSULTANTS

Twin Bonanza Erosion and Sediment Control Plan (ESCP)	
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Revision Code*

A - Report issued for internal review

B - Draft report issued for client review

C - Final report issued to client

LIMITATIONS

The sole purpose of this report and the associated services performed by Soil Water Consultants (SWC) was to develop an Erosion and Sediment Control Program (ESCP) for the Twin Bonanza Project. This work was conducted in accordance with the Scope of Work presented to ABM Resources ('the Client'). SWC performed the services in a manner consistent with the normal level of care and expertise exercised by members of the earth sciences profession. Subject to the Scope of Work, the ESCP was confined to Twin Bonanza Project Area. No extrapolation of the results and recommendations reported in this study should be made to areas external to this project area. In preparing this study, SWC has relied on relevant published reports and guidelines, and information provided by the Client. All information is presumed accurate and SWC has not attempted to verify the accuracy or completeness of such information. While normal assessments of data reliability have been made, SWC assumes no responsibility or liability for errors in this information. All conclusions and recommendations are the professional opinions of SWC personnel. SWC is not engaged in reporting for the purpose of advertising, sales, promoting or endorsement of any client interests. No warranties, expressed or implied, are made with respect to the data reported or to the findings, observations and conclusions expressed in this report. All data, findings, observations and conclusions are based solely upon site conditions at the time of the investigation and information provided by the Client. This report has been prepared on behalf of and for the exclusive use of the Client, its representatives and advisors. SWC accepts no liability or responsibility for the use of this report by any third party.

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1 INTRODUCTION

1.1 PURPOSE OF THIS DOCUMENT

This document has been prepared to describe the Erosion and Sediment Control (ESC) measures planned for the proposed Twin Bonanza Project Gold Project (TBGP). The plan is intended to help minimise environmental harm by specifying best practice ESC measures that are specific to the soils, topography, and hydrological setting of the site. These measures aim to minimise sediment generation at the source, reducing the need for downstream control measures.

This document provides an overview of the site-specific conditions relevant to ESC planning, describes the ESC measures chosen, provides justification for the selection and design of these measures, and suggests a timeline for implementation.

1.2 SCOPE OF THIS DOCUMENT

This ESC Plan (ESCP) applies to the Twin Bonanza Gold Mine, located in the central Northern Territory, and as described in Section 2.1. The operation is currently in the planning stages, with no commencement of mining or construction of infrastructure undertaken, except for infrastructure associated with an approved Bulk Sample program and exploration activities. The level of detail in this ESCP reflects this early stage of development – it is intended that this plan will be updated as the site is further developed.

The document demonstrates that the proposed ESC measures are appropriate for the specific site conditions, and that they take into consideration the layout of the site, the properties of the soil, the shape of the proposed land surfaces, and the condition and sensitivity of the receiving environment. This document was developed using the following preliminary studies and background data:

- Preliminary Surface Flow Analysis (SWC, 2013a)
- Preliminary Soils Assessment (SWC, 2013b)
- Proposed site layout, as of the 4th October 2013.

This document was developed in accordance with the relevant sections of the *Best Practice Erosion and Sediment Control* guidelines ("ESCP guidelines"; IECA (2008)). It should be noted that these guidelines were developed primarily for the urban construction industry, and do not strictly apply to mine sites in every aspect. However, the key design principles outlined in the guidelines were followed where appropriate, and advice for "rural" practitioners was followed wherever it was available.

1.3 COMPLIMENTARY DOCUMENTS

The following complimentary documentation was produced concurrently with this document as part of the mine planning process:

- Environmental Impact Statement (EIS) (ABM, 2013)
- Water Management Plan (WMP) (SWC, 2013c)
- Surface Water Sampling Standard Operating Procedure (SOP) (SWC, 2013d)

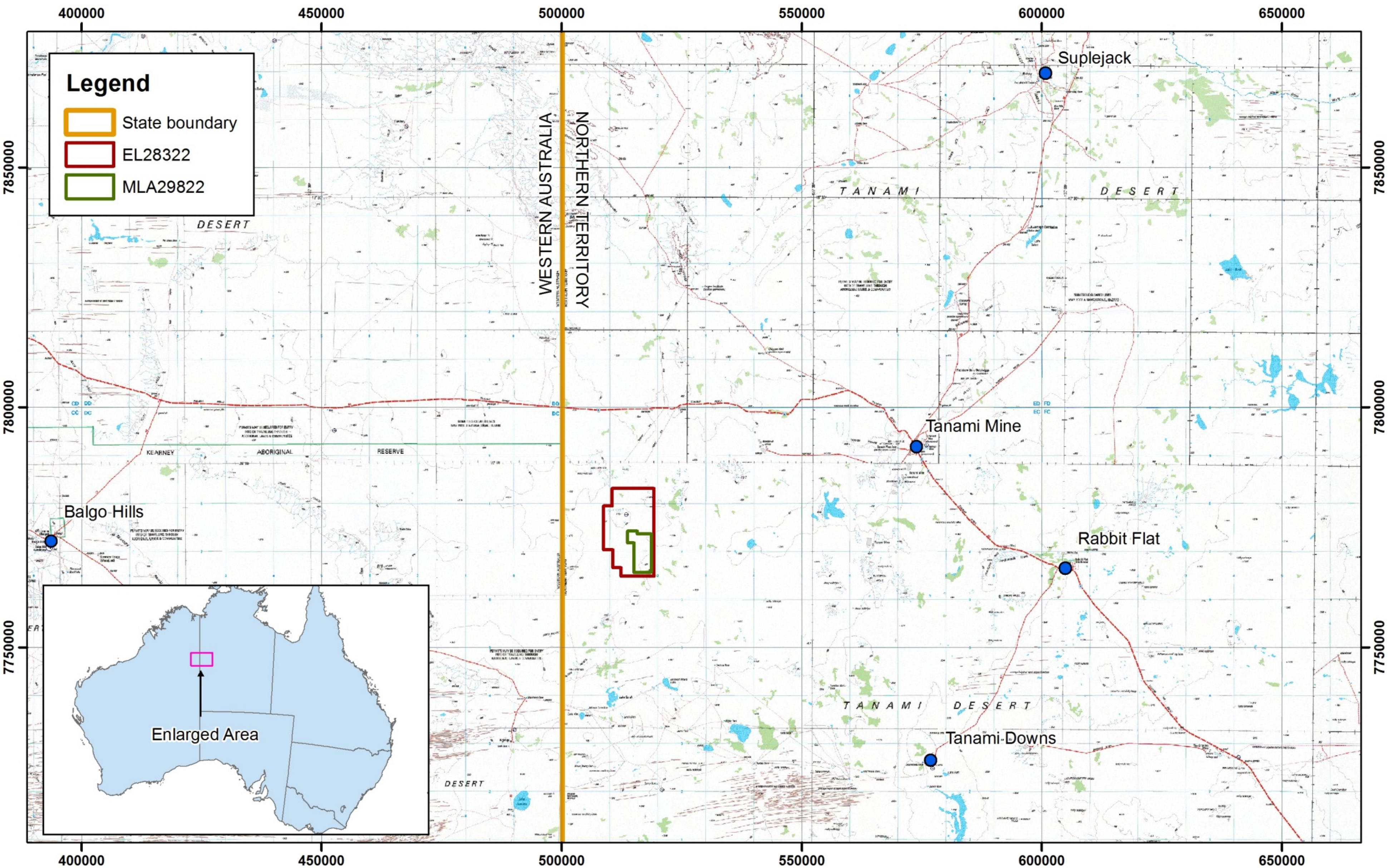
2 SITE DESCRIPTION

2.1 GENERAL SITE DESCRIPTION

The proposed Twin Bonanza Gold Mine is located in the Tanami Desert Region of the Northern Territory (NT), approximately 625 km north-west of Alice Springs and 16 km east of the NT and Western Australian (WA) border (Figure 2.1). ABM hold an exploration lease (EL28322) and have submitted an application for a mineral lease (MLA29822) which encompasses the Old Pirate Deposit and surrounding prospects, including Golden Hind, Old Glory, and other ore zones that may be identified or confirmed by continued exploration and mining activity in the region. This project is still at the approvals stage, with a Notice of Intent (NOI) having been submitted to the NT Department of Lands Planning and Environment (DLPE) in January 2013.

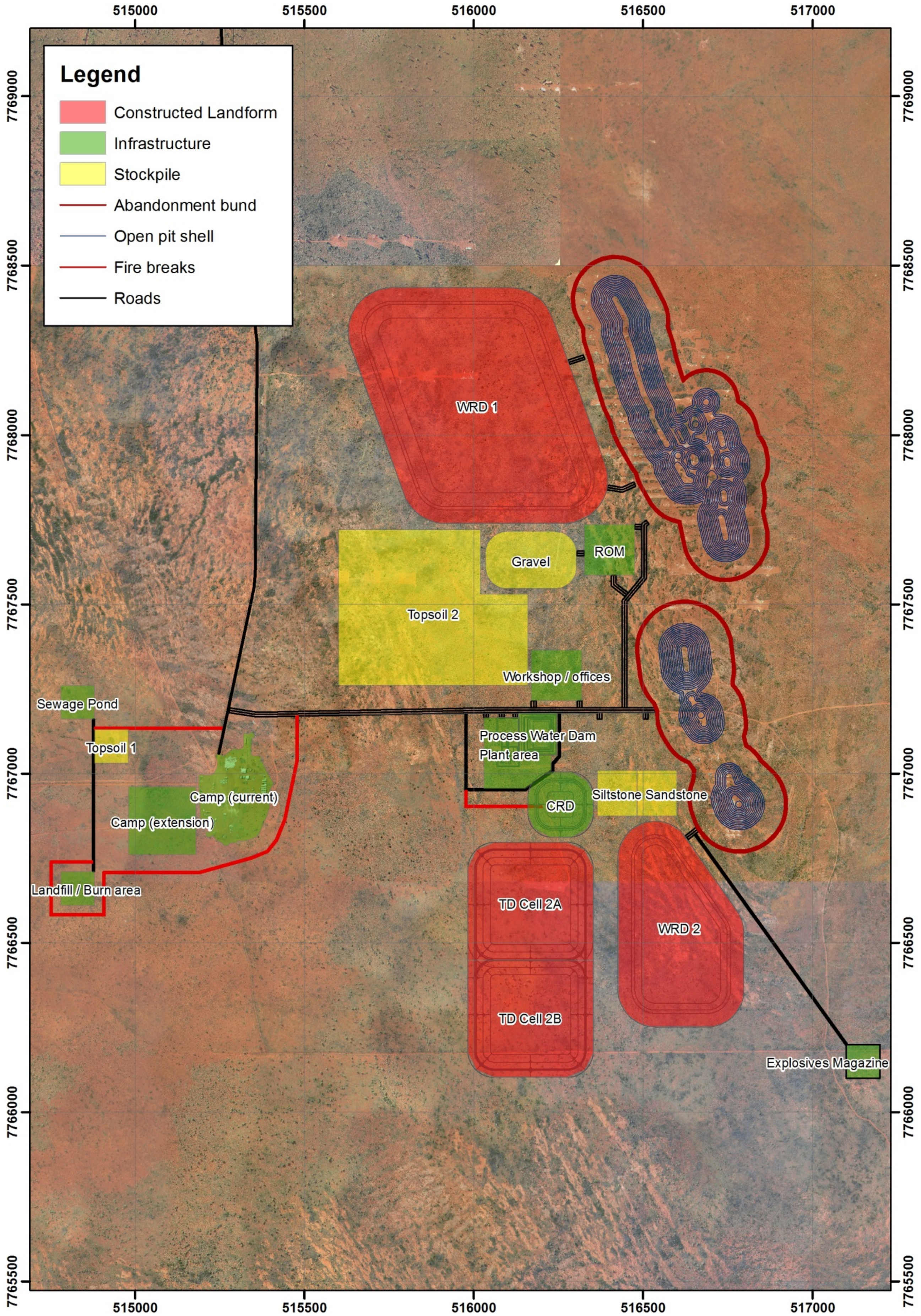
The proposed site layout is shown in Figure 2.2, and consists of three open pits, onsite processing facilities and associated Tailings Dam (TD), two Waste Rock Dumps (WRDs), Concentrate Residual Dam (CRD), and required infrastructure including power station, accommodation, workshops, and offices. Trial mining and on-site trial processing are planned, to be followed by open pit mining, and potential underground mining. Life of mine is expected to be at least 3–4 years, with the expectation that further exploration activities will indicate that this can be extended significantly.

The total disturbance (including existing disturbed areas) within the Twin Bonanza Project Area is estimated at 255.8 ha (Figure 2.2). The ESCP described in this document is aimed at appropriate design and management of this entire disturbance area in order to minimise erosion of the disturbed surfaces and to minimise potential effects on the surrounding environment.



ABM Resources – Twin Bonanza Gold Mine	Figure 2.1: Site location of the Twin Bonanza Gold Project
Erosion and Sediment Control Plan	

soilwater GROUP



ABM Resources – Twin Bonanza Gold Mine	Figure 2.2: Proposed site layout	soilwater GROUP
Erosion and Sediment Control Plan		

2.2 CLIMATE

The Tanami Desert Region has a semi-arid climate, characterised by hot, wet summers and mild, relatively dry winters. Average annual rainfall in the region ranges from 400-500 mm, and approximately 85 % of this falls between November and April (Figure 2.3). Summer rainfall is characterised by infrequent, but intense rainfall events, with single events delivering > 50 mm in 24 hrs on average at least once per year (Table 2.1). Average pan evaporation for the region is approximately 3,000 mm/yr, far exceeding the average annual rainfall (Figure 2.4).

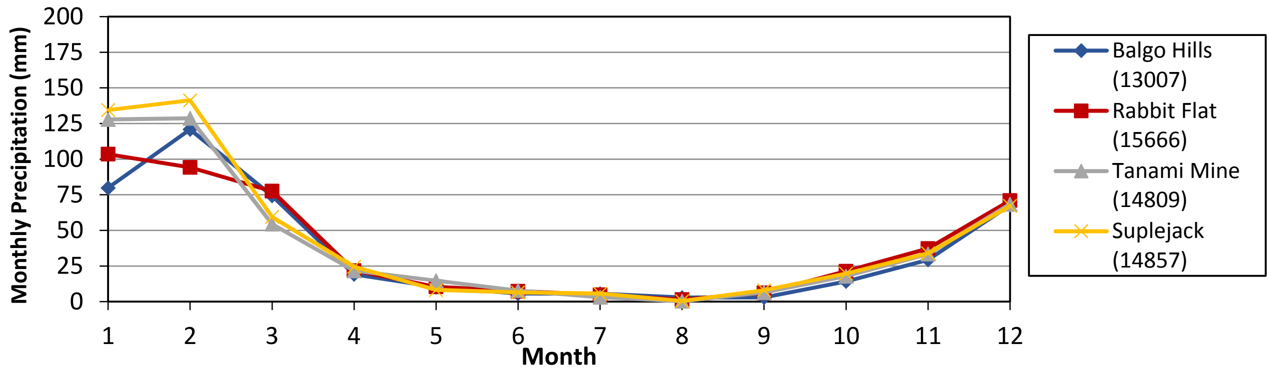


Figure 2.3: Average monthly precipitation totals for the Twin Bonanza Project Area (BOM, 2013)

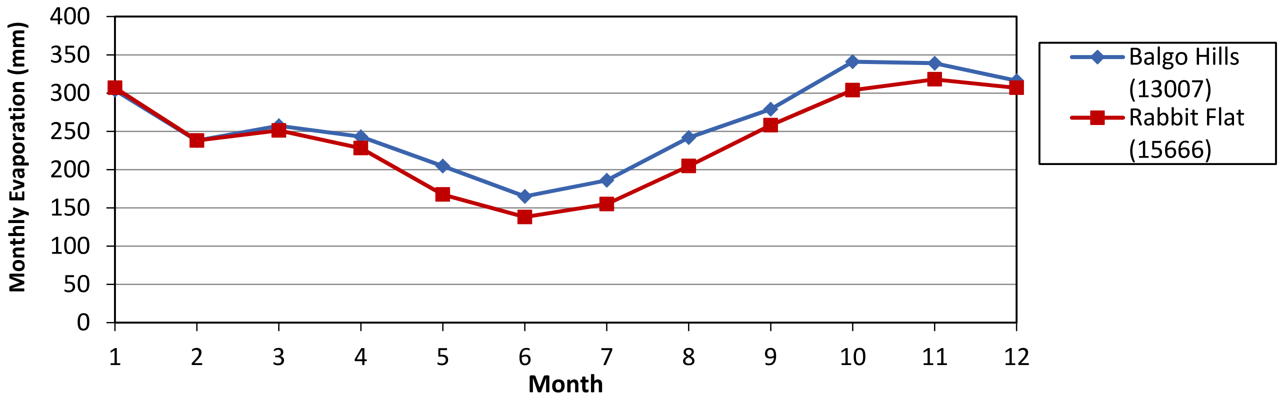


Figure 2.4: Average monthly pan evaporation totals for the Twin Bonanza Project Area (BOM, 2013)

Table 2.1: 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

2.3 SITE HYDROLOGY

A desktop surface water study was recently conducted by SWC (SWC, 2013a). This assessment showed that the Project Area was located on the topographical divide between two National Catchment Boundary (Level 1) Divisions (the North Western Plateau Division and the Timor Sea Division), indicating one of the furthermost upstream positions possible. No permanent water courses intersect the proposed mining lease area, so only local surface runoff is expected.

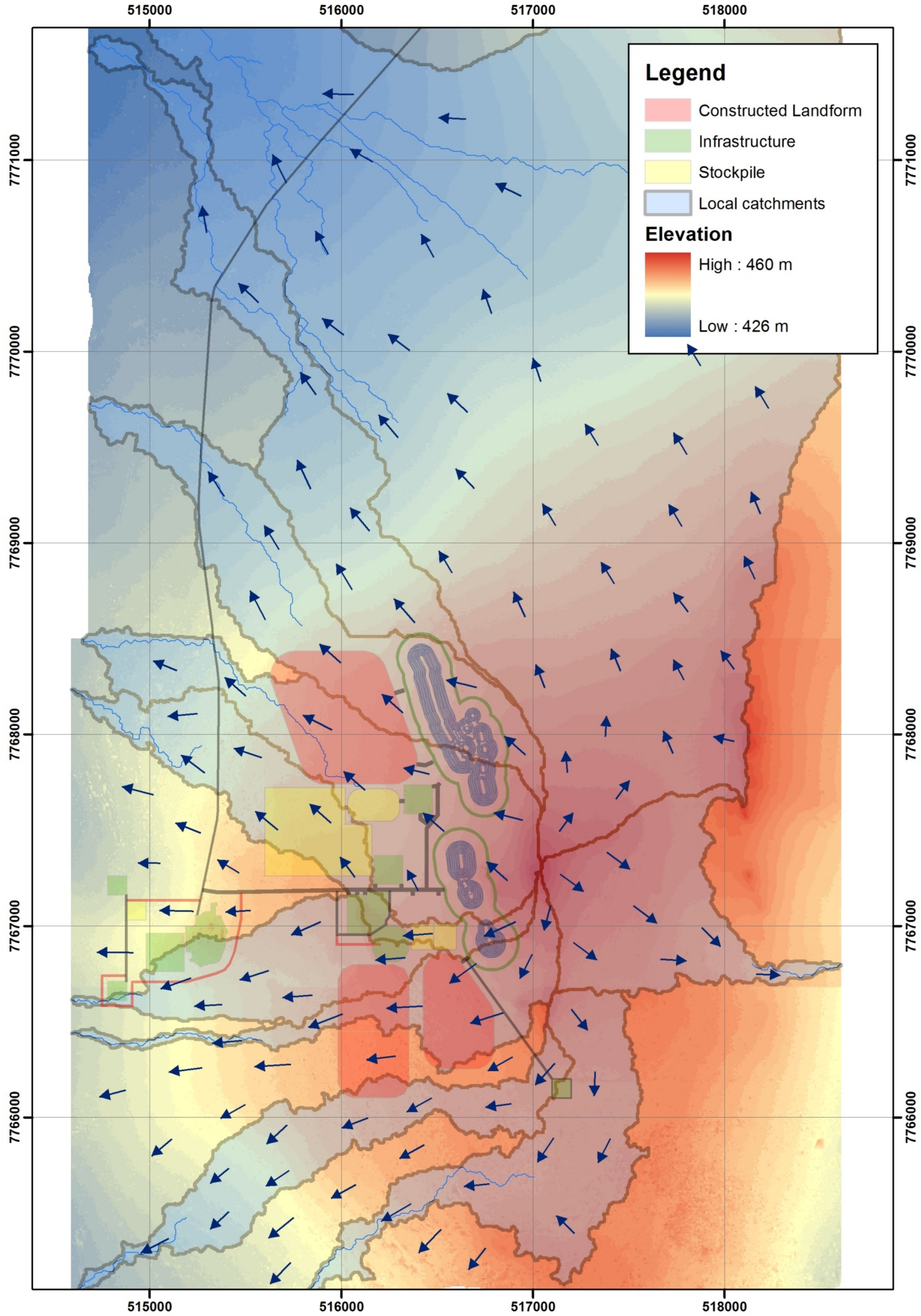
The majority of the main infrastructure areas are located on local topographic highs or diverging slope areas, where the potential for converging surface water flows is minimal (Figure 2.5). The shape of the landscape indicates that sheet flow is the dominant surface water flow process in the undisturbed landscape, with some accumulation of flows occurring in lower-lying areas, primarily after large storm events.

Catchment boundaries and local-scale flow lines were derived for the main disturbance areas using a Topographic Paramaterization (TOPAZ) model within the Watershed Modelling System (WMS) software (Water Modelling Solutions, 2013). Two scenarios were modelled: 1) Pre-mine catchments (Figure 2.5), and 2) The main site catchments with the proposed flow diversions in-place (Figure 2.6). The Rational and Index Flood Methods (Pilgrim, 2003) were then used to predict peak flow rates for each of the surface water diversion catchments for a range of storm events (i.e. 1:1-yr, 1:20-yr, 1:100-yr, and 1:1,000-yr ARI). The results of this modelling are presented in Table 2.2, and this information is considered adequate for preliminary sizing of both temporary and permanent diversion structures.

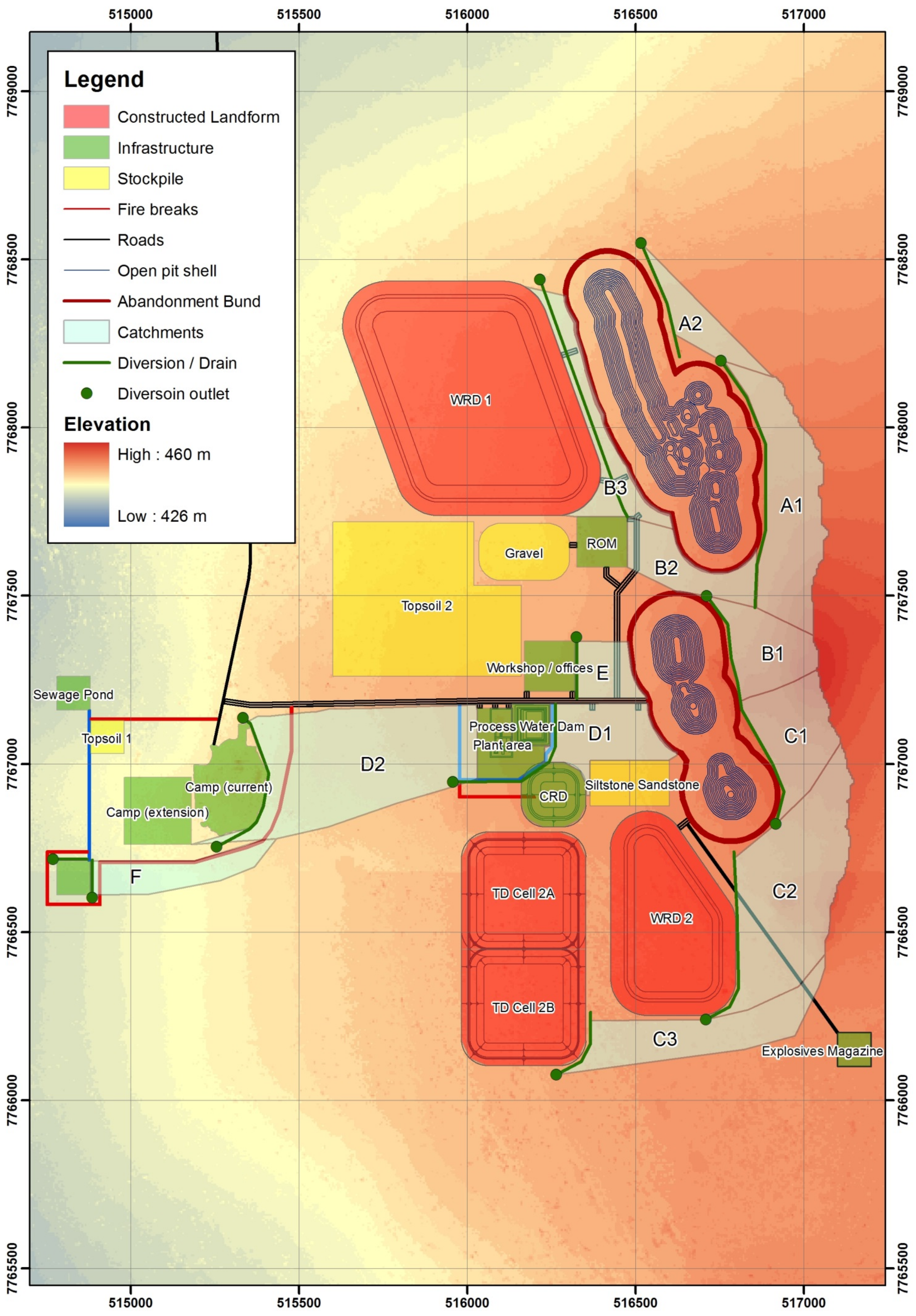
Peak flow rates predicted by the Index Flood Method were greater than those predicted by the Rational Method. As such, the results of the Index Flood Method were used to size the diversion drains to provide for a more conservative design.

Table 2.2: Peak flow estimations for the proposed surface water diversions, for a range of event frequencies (m^3/s)

No	Site area	Rational Method				Index Flood Method			
		1:1 yr	1:20 yr	1:100-yr	1:1,000-yr	1:1 yr	1:20 yr	1:100-yr	1:1,000-yr
A1	North Pit	0.6	2.1	3.3	5.4	0.9	4.7	6.8	9.8
A2	North Pit	0.6	2.2	3.4	5.6	1.0	5.5	8.0	11.5
B1	South Pit	0.4	1.4	2.2	3.5	0.6	3.0	4.4	6.3
B2	ROM	0.6	2.0	3.1	5.0	0.8	4.4	6.3	9.1
B3	WRD 1	0.6	2.1	3.4	5.6	1.0	5.7	8.3	12.0
C1	South Pit	0.4	1.5	2.4	3.9	0.6	3.4	4.9	7.1
C2	WRD 2	1.0	3.6	5.7	9.4	1.3	7.1	10.3	14.9
C3	TD Cell 2B	1.1	3.9	6.2	10.1	1.5	8.5	12.4	17.8
D1	Plant	0.4	1.3	2.1	3.4	0.6	3.2	4.6	6.6
D2	Camp	0.5	1.8	2.9	4.7	1.0	5.3	7.8	11.1
E	Workshop	0.2	0.7	1.1	1.7	0.4	2.1	3.1	4.4
F	Landfill	0.2	0.9	1.3	2.2	0.5	2.7	3.9	5.6



ABM Resources – Twin Bonanza Gold Mine	Figure 2.5: Pre-mine surface flow diagram	soilwater GROUP
Erosion and Sediment Control Plan		



ABM Resources – Twin Bonanza Gold Mine	Figure 2.6: Diversion drain and infrastructure catchments	soilwater GROUP
Erosion and Sediment Control Plan		

2.4 SOIL PROPERTIES

A soil assessment was recently conducted for the Twin Bonanza Project Area (SWC, 2013b) to identify the surficial soil materials present, and to characterise their physical, chemical, and hydraulic properties. This included an assessment of erosion potential.

The typical soil profile (Figure 2.7), is characterised as a shallow sandy loam, consisting of red sandy loams in the upper 30 – 50 cm, and overlying sandstone. A transition zone of highly weathered sandstone is present between approximately 40 – 70 cm depth. Plant roots were present throughout the sampled profile and were observed to extend below 1.35 m (maximum sampling depth in that study).

The upper portion of the profile (0 – 30 cm) contains a significant gravel fraction (15 – 40 % gravel), with generally fewer gravels present in the weathered transition zone (5 – 25 %). The underlying *in situ* sandstone is considered to be well cemented, but a high proportion of gravel (55 – 65 %) was measured in the laboratory sample, which is thought to be representative of the properties of this material once broken up during excavation.

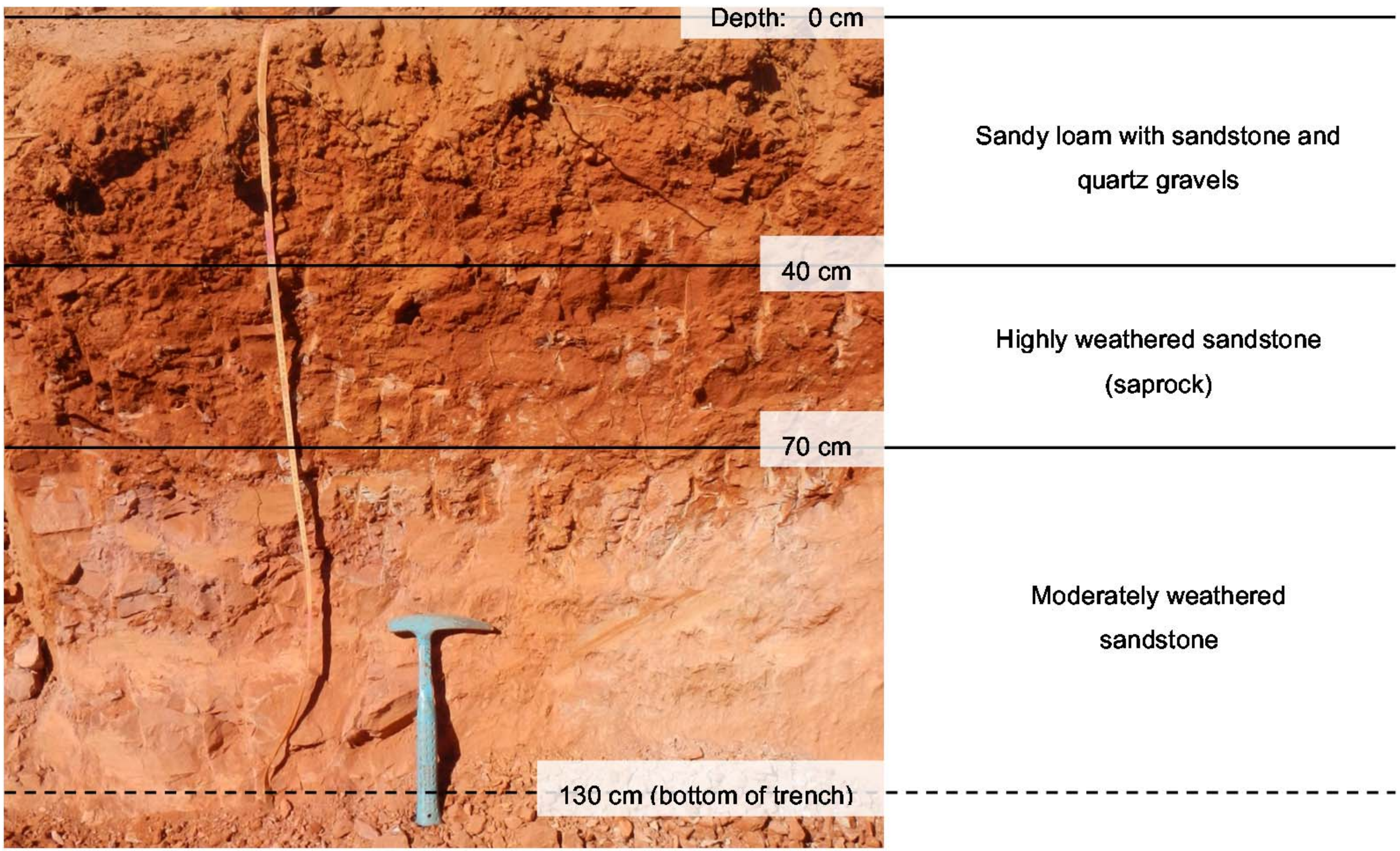
The upper 70 cm of the soil profile was found to be acidic (pH = 4.0 – 4.9), while the underlying sandstone was alkaline (pH = 8.2 at 135 cm depth). The majority of salts appear to have been leached from the measured portion of the profile, and the surface soils are subsequently considered non-saline (EC < 40 mS/m), and non-sodic (ESP > 6 %). Cation exchange capacity (CEC) of the surface soils was low (< 5 meq/100g), with the exchange complex dominated by calcium and magnesium cations (50 – 70 % Ca and 20 – 30 % Mg).

The topsoils are considered to be potentially dispersive after mechanical disturbance of the soil structure (i.e. after excavation and stockpiling). This is mainly attributed to the lack of salts within the soil solution to facilitate aggregation and flocculation of clays. Thus, soils containing larger fractions of clay (i.e. the weathered "transition" layer) are at the greatest risk of dispersion. Conversely, soils containing larger fractions of gravel will be at least risk of the effects of dispersion. The topsoils (0 – 30 cm depth) and sandstone (> 100 cm depth) are therefore expected to be the least affected by dispersion because of the moderate clay content and significant gravel content in these soil horizons.

Erosion testing and modelling results indicated low erosion rates of approximately 5 t/ha/yr (Table 2.3), primarily due to the armouring effects of the large gravel fraction and high infiltration rate of the sandstone materials. Predicted erosion rates on WRD batter slopes increased with increasing slope angle and with increasing lift height, and therefore a post-mine landform slope angle of ≤ 18° and lift height of 10 m was recommended (SWC, 2013b). The predicted average erosion rate for near-flat surfaces (i.e. pads, roads, etc.) was negligible, at < 0.2 t/ha/yr. Approximately 90 % of the predicted erosion is expected in the months of December, January, and February (Figure 2.8). Expected extreme erosion event frequencies are presented in Table 2.4 for the WRD, assuming 15° batter slope angles, and a 10 m lift height.

Table 2.3: Predicted annual average erosion rates

Modelled landform	Erosion rate (t/ha/yr)	Erosion rate (mm/yr)
Near-flat disturbance areas (1% grade)	< 0.2	< 0.1
15° batter slopes, with10 m lifts	5.1	0.3
18° batter slopes, with10 m lifts	5.3	0.3
15° batters lopes, with 20 m lifts	9.7	0.6



ABM Resources – Twin Bonanza Gold Mine	Figure 2.7: The sampled soil profile	soilwater GROUP
Erosion and Sediment Control Plan		

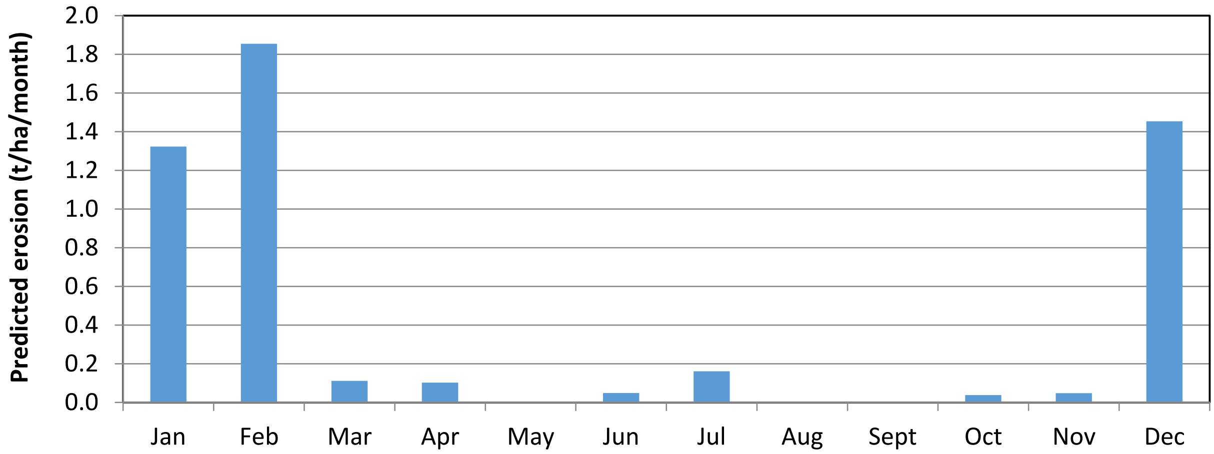


Figure 2.8: Predicted average monthly erosion rates for a landform with 15° batter slopes, and 10 m lifts

Table 2.4: Predicted extreme erosion events for a landform with 15° batter slopes, and 10 m lifts

Event frequency	Single-event erosion rate (t/ha)	Single-event erosion rate (mm)
1:1 yr	2	0.1
1:10 yr	13	0.8
1:20 yr	17	1.1
1:50 yr	25	1.6
1:100-yr	30	1.9

3 EROSION AND SEDIMENT CONTROL DURING ACTIVE MINE PHASE

3.1 OVERVIEW OF ESC STRATEGY

An effective ESC strategy considers the interrelated processes of drainage control (minimising water flows through erosion prone areas), erosion control (minimising the detachment of sediment), and sediment control (trapping sediment displaced by up-slope erosion processes). Thus, the key strategies adopted in this ESCP involve (1) diversion of water flowing into disturbance areas, (2) minimising erosion of disturbance areas by water that falls within the disturbance areas, and (3) trapping the majority of sediment that is generated before it moves offsite.

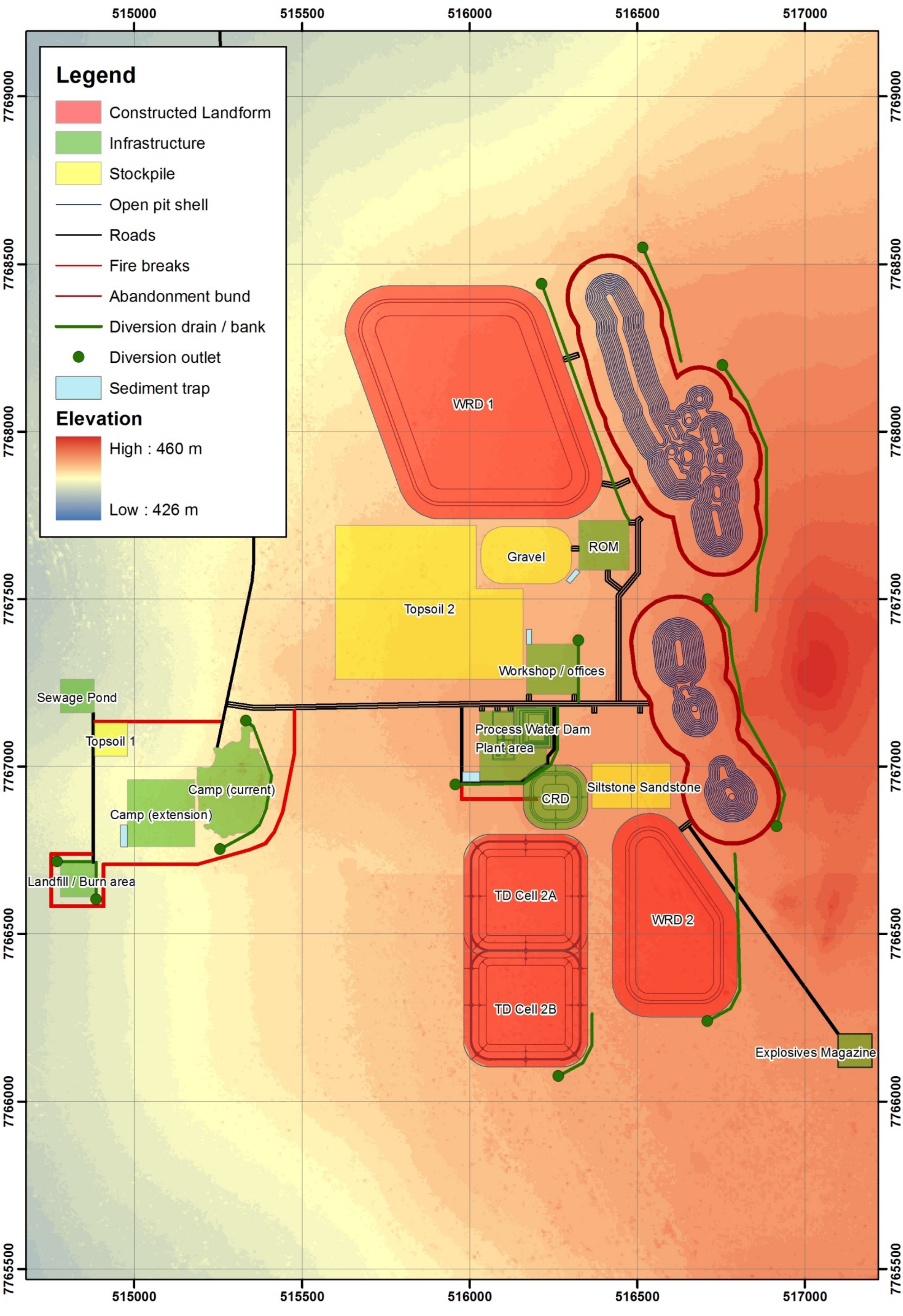
The following steps will be taken to minimise sediment fluxes during the active phase of the site:

- The site layout has been designed specifically to minimise interaction with surface water flows. As discussed in Section 2.3, the majority of the main infrastructure areas are located on local topographic highs or diverging slope areas, where the potential for converging surface water flows is minimal.
- Diversion drains and banks will be used to redirect any “clean” surface water flows around the main site areas. This minimises the potential for erosion by limiting the amount of water flowing through the disturbance areas, and also protects infrastructure from flooding during extreme events. Design of diversion drains is discussed further in Section 3.4. Some infrastructure areas (e.g. the ROM pad) may alternatively be constructed on a raised pad to eliminate the need for diversion drains by elevating the operational areas out of the flood risk zone.
- Exposed soil surfaces will be engineered to minimise erosion potential. This will be achieved through careful material selection, slope grading, and other surface treatments, as discussed in Section 3.5.
- Any sediment-laden water within the disturbance areas will be captured and treated in a manner which minimises amount of sediment released into the surrounding environment. This is discussed further in Section 3.6.

The key ESC infrastructure proposed for this site includes:

- Main site diversion banks incorporated along the eastern extent of the pit abandonment bunds
- Diversion banks along the TD cells and WRD 2
- Diversion drain between the Northern pit and WRD 1
- Diversion drains for the Plant area, Workshop / Offices, Burn Area, and Camp
- Sediment traps for the Plant area, Workshop / Offices, ROM pad, and Camp

The location of these items is shown on Figure 3.1, and their design is discussed further in the following sections.



ABM Resources – Twin Bonanza Gold Mine	Figure 3.1: Erosion and Sediment Control Infrastructure (active mine phase)	soilwater GROUP
Erosion and Sediment Control Plan		

3.2 LEVEL OF PROTECTION

The following factors were taken into consideration when determining the level of ESC protection required:

- The properties of the surface materials
- Local rainfall patterns (depths, intensities, recurrence intervals)
- The nature of the landforms being protected
- The sensitivity of the receiving environment
- The risk rating guidelines described in IECA (2008)
- Stakeholder requirements

ESC diversion drains will be designed to withstand a 1:100-yr peak flow event. This level of protection is above and beyond the 1:10-yr design standard recommended in the ESCP guidelines (IECA, 2008), and has been adopted to ensure that more than adequate protection is provided throughout the life of mine. Temporary structures include all diversion drains and sediment traps that will be removed at mine closure, such as those installed around the plant area.

All permanent ESC structures (i.e. the main site diversion banks) will also be designed to withstand a 1:1,000-yr peak flow event. This level of protection has been agreed with the Central Land Council (traditional owners) as part of the stakeholder consultation process. There is no recommendation for permanent structures in the ESCP guidelines (IECA, 2008), but given the relatively small catchment sizes, the lack of defined flow channels, and the predominance of sheet flow across the site, 1:1,000-yr peak flow protection is considered to exceed mining industry best practice.

All sediment traps will be designed as “Type 1” basins. These are flow-through type basins, designed to remove 90 % of material > 0.045 mm in diameter (silts), and sized to hold at least one month’s worth of trapped sediment under average site conditions. Sediment traps have been designed in accordance to the ESCP Guidelines (IECA, 2008). Sediment trap discharge will be monitored according to the procedures described in Section 4.4.

3.3 STAGING OF WORK

The installation of all ESC measures has been scheduled to maximise protection throughout all phases of site development. The generalised plan for staging of work is set out in Table 3.1. Control measures will be put in place prior to soil disturbance (wherever practicable), and will remain in place for the duration of the expected disturbance. Land clearing will be scheduled for the dry season to minimise exposure to rainfall, wherever practicable.

The main site diversion banks in particular have been designed to be installed in stages. The main diversion banks will be installed progressively as the pits are developed, with catchments A1, B1, C1 (Figure 2.6) being the first to be diverted. Catchments C2 and C3 will likely be some of the last catchments to be diverted, as the WRD 2 and TD Cell 2B will not be constructed until the later stages of site development. These features will remain in place after site closure.

The smaller diversion drains associated with each of the infrastructure areas will be installed shortly after the areas are cleared and reshaped for construction. These features will be removed after the infrastructure areas are decommissioned and the areas are ready for rehabilitation.

Table 3.1: Staging of works for installation of ESC measures

Sequence	Task
1	As per the staged development approach, clear and reshape infrastructure areas, incorporating a diversion drain to divert inflowing surface water, as required. Stockpile topsoil material in designated stockpile areas.
2	Install sediment traps in the infrastructure areas, as the infrastructure is developed.
3	Build plant, workshops, offices, and camp, as each element is required.
4	Staged construction of main site diversion banks / pit abandonment bunds using waste rock excavated from pits, as each pit is developed.
5	Clear TD Cell 2A area progressively in accordance to the staged design. Stockpile topsoil material in designated stockpile area
6	Construct TD Cell 2A in accordance to the staged design
7	Progressive clearing of WRD area Stockpile topsoil and sandstone subsoil in designated areas
8	Construction of WRD using waste rock
9	Clear TD Cell 2B area Stockpile topsoil material in designated stockpile area
10	Construct TD Cell 2B as per the staged design
11	Possible progressive rehabilitation of WRD slopes, using stockpiled materials.

3.4 DESIGN OF DIVERSION BANKS AND DRAINS

Flow diversion banks and drains will be constructed to divert all “clean water” surface flows around the main work areas in order to minimise the potential volume water that will need to be managed within the site (Figure 3.1). The following diversions have been designed:

- Diversion banks will be constructed along the eastern edge of the pits to divert the majority of “clean” surface water around the site. These will be constructed in stages, as the pits are developed.
- Smaller diversion drains are planned for the management of surface water flowing into the Plant area, Workshops / Offices, Camp, and Landfill / Burn areas. Alternatively, these smaller areas may be constructed on raised pads to place all sensitive infrastructure above the expected 1:100-yr flood level, thus avoiding any need for diversion drains.
- No diversion drain is required for the ROM pad, as it will be sufficiently built-up such that no surface water will be able to flow into the area.

The critical design factor for surface water diversions is the expected peak flow rate. Peak flow rates typically occur during short, intense storms (e.g. a 1:100-yr, 10 min event at 166 mm/hr) rather than during longer storm events (e.g.

1:100-yr, 72 hr event averaging 4 mm/hr). As discussed in Section 3.2, 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, and critical rainfall durations ranged from approximately 5-70 min. All diversion banks and drains will be constructed from compacted native soil materials, as these contain a significant gravel fraction, and are considered to be sufficiently erosion resistant (see Section 2.4).

Design calculations for all surface water diversions are included in APPENDIX A, while the key design features are summarised in Table 3.2. Typical diversion cross-sections are shown in Figure 3.2. All diversion banks have been designed assuming a 10:1 gradient (0.10 m/m slope) on the upslope side, and a 3:1 gradient (0.33 m/m slope) for the constructed bank. All diversion drains have been designed assuming an 8:1 gradient (0.13 mm/m slope) on both sides of the drain. Gentler construction angles will increase the design capacity of these features so long as the design flow depth is maintained

All diversion structures can be constructed with a standard grader, and graded surfaces will ideally be compacted to increase erosion resistance. Re-vegetation of diversion banks with ground cover vegetation or grasses will add further stability. Where appropriate materials are available to construct the abandonment bund from sufficiently stable materials (i.e. competent rock), diversion banks may be integrated with the abandonment bunds.

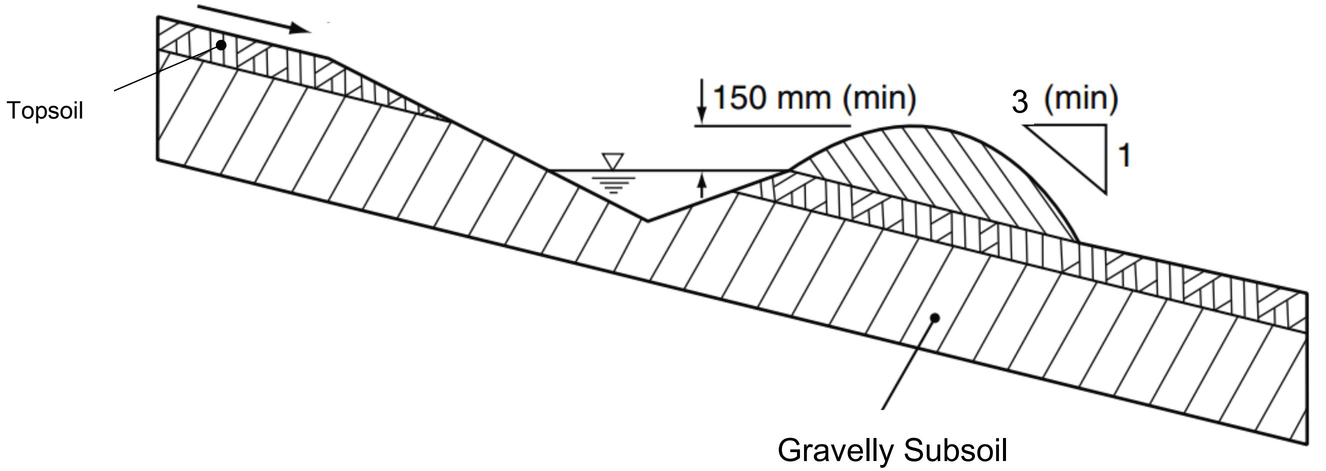
Discharge from each diversion structure will be via a level spreader or rock chute, to ensure that the concentrated surface flow is transitioned back to sheet flow in a way that minimises erosion downslope of the outlet. Conceptual diagrams of a level spreader and rock chute are shown in Figure 3.3.

Any access or haul roads crossing the surface water diversion structures (e.g. the explosive magazine access road, and haul roads between the northern pit and WRD 1) will be constructed in such a way that they do not interfere with the functioning of the diversions (e.g. use of whoa-boys, bridges, or culverts).

Table 3.2: 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
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

A.



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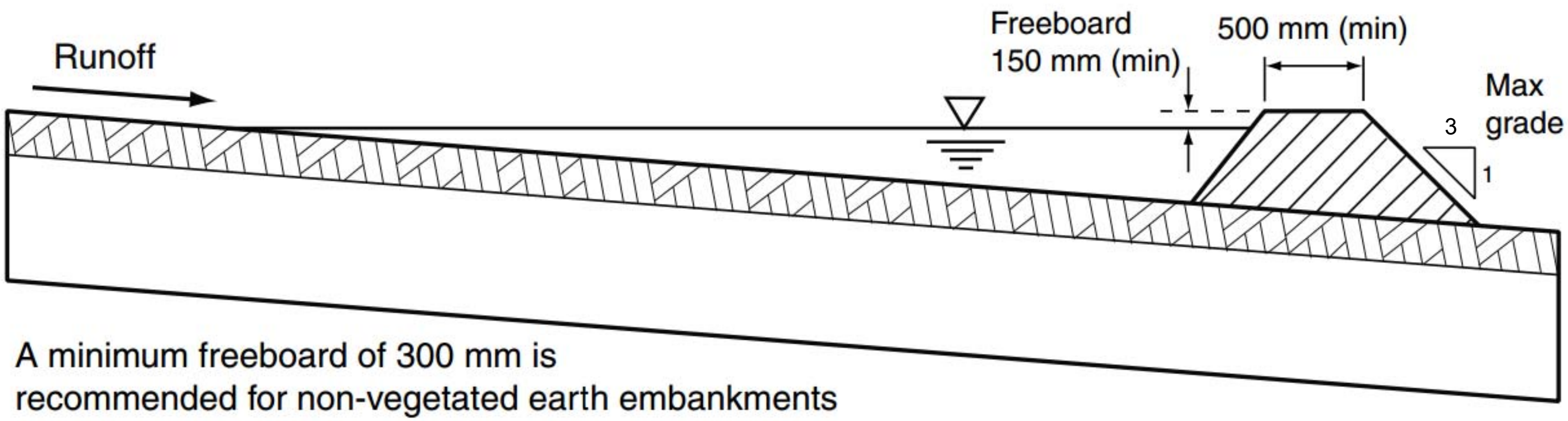
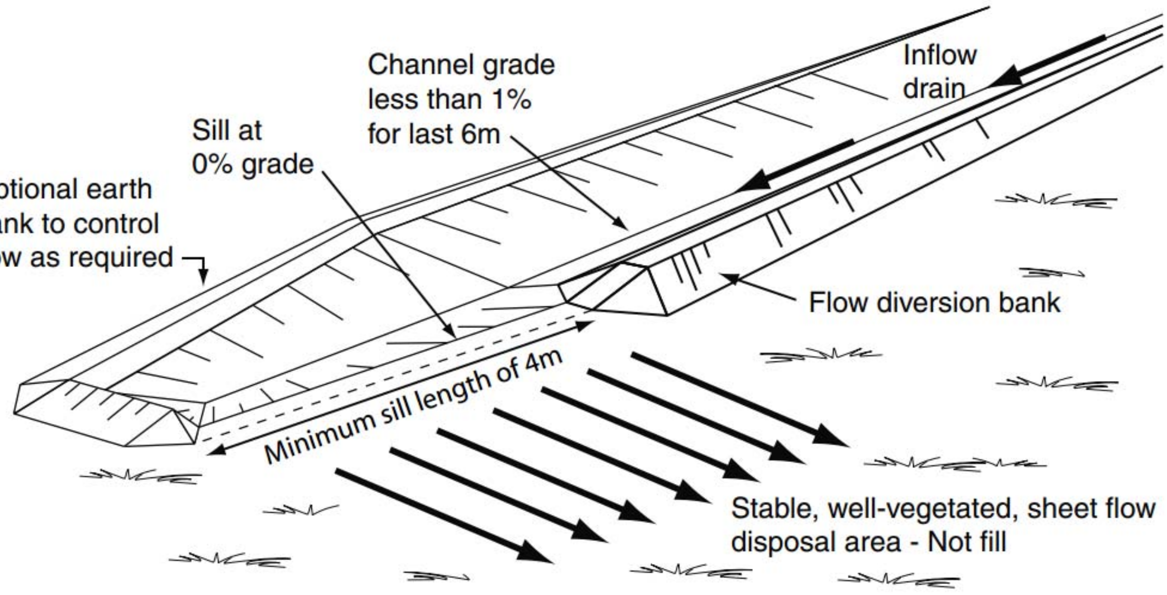


A minimum freeboard of 300 mm is
recommended for non-vegetated earth embankments

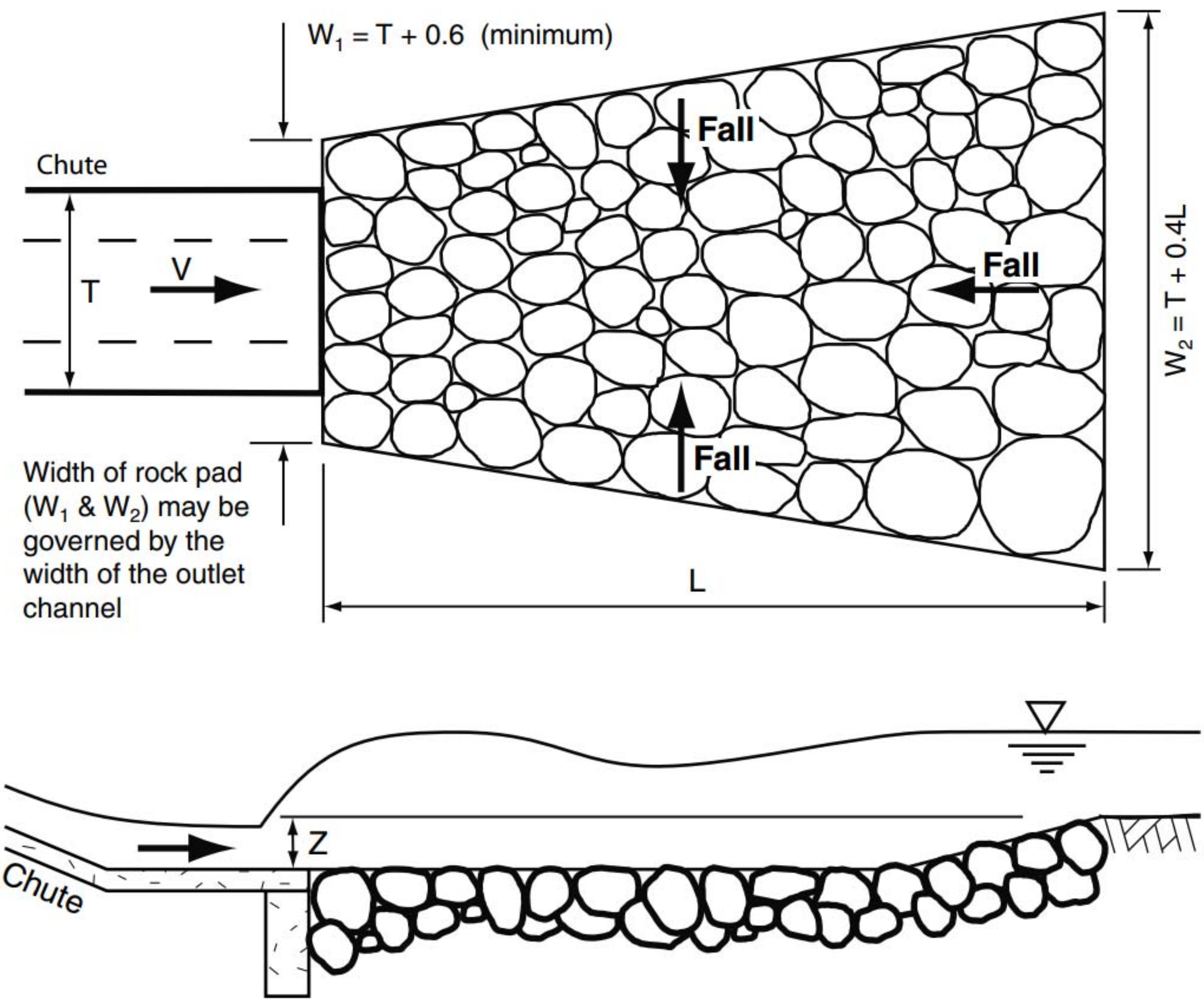
Adapted from IECA (2008)

ABM Resources – Twin Bonanza Gold Mine	Figure 3.2: Typical diversion drain (a) and diversion bank (b) cross-sections
Erosion and Sediment Control Plan	

A.



B.



Adapted from IECA (2008)

ABM Resources – Twin Bonanza Gold Mine	Figure 3.3: Conceptual diagrams of level spreader (a) and rock chute (b).	soilwater GROUP
Erosion and Sediment Control Plan		

3.5 MINIMISING EROSION ON DISTURBED LAND SURFACES

3.5.1 CONSTRUCTED LANDFORMS

The constructed landforms (i.e. the WRD and TD cells) represent the largest areas of disturbance and will be constructed with slope angles that are steeper than the surrounding natural land surfaces, and are therefore considered the largest potential sources of eroded sediment. The primary strategy for minimising erosion on these landforms is to construct them with low batter slope angles, and using erosion-resistant materials.

During the active mining phase, the majority of the WRD upper surface and outer embankments will be constructed of sandstone material. This material has been demonstrated to be relatively stable (see Section 2.4), so potential erosion of slopes is expected to be minimal. The outer slopes will consist of up to two ≤ 10 metre-high lifts. Each lift will be shaped to a 15° slope angle. The upper surface will be designed to be inward sloping to keep any rainfall on the upper surface from running down the slopes. Some progressive rehabilitation may occur (e.g. placement of topsoils, revegetation, etc.) during the active mine phase. The risks and management strategies associated with the rehabilitation phase are discussed in Section 4, *Erosion and Sediment Control for Mine Closure*.

The outer embankments of the TD and CRD will also be constructed using sandstone material, and the outer slopes will be constructed with 15° slope angles and will extend to approximately between 5-10 m in height, so potential erosion of slopes is expected to be minimal. The TD cells will be constructed and managed such that there is enough freeboard to hold a 1:100-yr, 72 hr rainfall event, and thus minimise the water from the upper surface which will be able to run down the slopes. The risks and management strategies associated with the rehabilitation phase are discussed in Section 4, *Erosion and Sediment Control for Mine Closure*.

3.5.2 OPERATIONAL WORK AREAS

The main operational work areas, such as the plant and stockpile areas, will be gently sloping to flat. Generally, the control of raindrop impact erosion is more important than the control of surface water velocity on flat land (IECA, 2008), and thus these areas will be constructed by compacting the native soil profile, which is expected to naturally armour itself, given the high gravel content in these soils (see Section 2.4). Sediment traps will be installed to collect and remove any sediment that is generated from these areas (see Section 3.6).

3.5.3 STOCKPILES

Topsoil stockpiles will be constructed no higher than 2 m and subsoil stockpiles no higher than 10 m with a slope of ≤ 15° This will help to minimise erosion from the stockpiles by limiting the length and steepness of the outer stockpile slopes. Stockpiles to be retained for a period of greater than 3 months, and which have not naturally established a groundcover, will be bunded around the perimeter to minimise sediment liberation.

3.5.4 ROADS

Haul roads will be built up in most areas, so that they are above the natural land surface. They will be designed to be water shedding to avoid flow accumulation which can lead to scouring, and erosion of the road surface and embankments. Haul roads will be constructed using compacted native soil materials, which are generally high in gravel content and are therefore considered to be relatively erosion resistant. Sandstone or waste rock material will be additionally utilised where the upper soil profile is found to be unsuitable for road construction.

The haul roads are expected to be sprayed with saline water to minimise dust generation, and this saline water will improve the structural integrity of the roads, such that negligible sediment will be available for erosion and runoff.

Any access or haul roads crossing the surface water diversion structures (e.g. the explosive magazine access road, and haul roads between the northern pit and WRD 1) will be constructed in such a way that they do not interfere with the functioning of the diversions (e.g. use of whoa-boys, bridges, or culverts).

Compacted low pass floodways will be installed along the main access road in the lowest-lying areas to maintain the integrity of the road surface.

3.5.5 DUST CONTROL

Wind erosion will be controlled through a combination of rock cover and water spraying. Rock cover on WRD and TD surfaces will be achieved through the placement of waste rock material. Most of the other disturbance areas are to be constructed using compacted native soils, which consist of a significant fraction of gravels to help armour the surfaces.

Surfaces that require additional dust control measures, particularly areas that receive a significant volume of vehicle traffic, will also be periodically sprayed with water, as required. Only non-saline or brackish water will be used wherever practicable, particularly in the vicinity of topsoil stockpiles; however, saline water is expected to be used along the main haul roads due to the sheer volume of water and frequency to which dust suppression will likely occur.

Any additional cleared areas that are not required during the operation of the mine will be progressively rehabilitated according to the site rehabilitation strategy. This will restore a native plant cover to the land surface, thus reducing the risk of dust generation from exposed bare soil surfaces.

3.6 DESIGN OF SEDIMENT CONTROL STRUCTURES

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 Plant, Workshop / Office area, ROM pad, and Camp (Figure 3.1). Each of the sediment traps will be located at an elevation below the associated disturbance area, and each disturbance area (where required) will be reshaped and bunded so that all drainage is directed into the sediment traps.

As discussed in Section 3.2, all sediment traps have been designed as “Type 1” sediment traps, according to the ESCP Guidelines (IECA, 2008). As discussed in the ESCP Guidelines, these types of sediment control measures *“should be designed to maximise the “filtration” of sediment-laden water during periods of light rainfall, and the “settlement” of sediment-laden water during periods of moderate to heavy rainfall. In general, the lighter the rainfall, the higher the expected quality of discharge water. In other words, because it is generally easier to control sediment runoff during light rainfall, it is reasonable to expect a higher degree of treatment and a lower risk of failure.”*

All sediment traps have therefore been designed to remove ≥ 90% of particles ≥ 0.045 mm in diameter (fine sands) during storm events as large as the 1:20-yr peak flow event. This is above and beyond the design level outlined in the ESCP Guidelines (IECA, 2008), which recommend the sediment traps be designed for “average” site conditions (i.e. sized for half of the 1:1-yr peak flow even). As ≥ 70 % of the soil volume is made up of sand-sized particles, the sediment traps will be able to remove the majority of sediment generated during larger storm events. This design further allows for the removal of particles as small as 0.02 mm diameter (silts) under *average* flow conditions (i.e. the 1:1-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. A minimum length to width ratio of 3:1, a settling zone depth of 0.6 m, a sediment storage zone depth of 0.6 m, and a freeboard requirement of 0.3 m have been assumed in the design calculations. Discharge from the sediment traps will be via a rock-armoured spillway, sized for the 1:100-yr peak flow rate, and these will be approximately 5 m wide for the Workshop/ Office and ROM pad catchments, 6 m wide for the Plant catchment, and 12 m wide for the Camp catchment.

A typical cross-section through a sediment trap is provided as Figure 3.4. Design calculations for all sediment traps are included in APPENDIX A, while the key design features are summarised in Table 3.3.

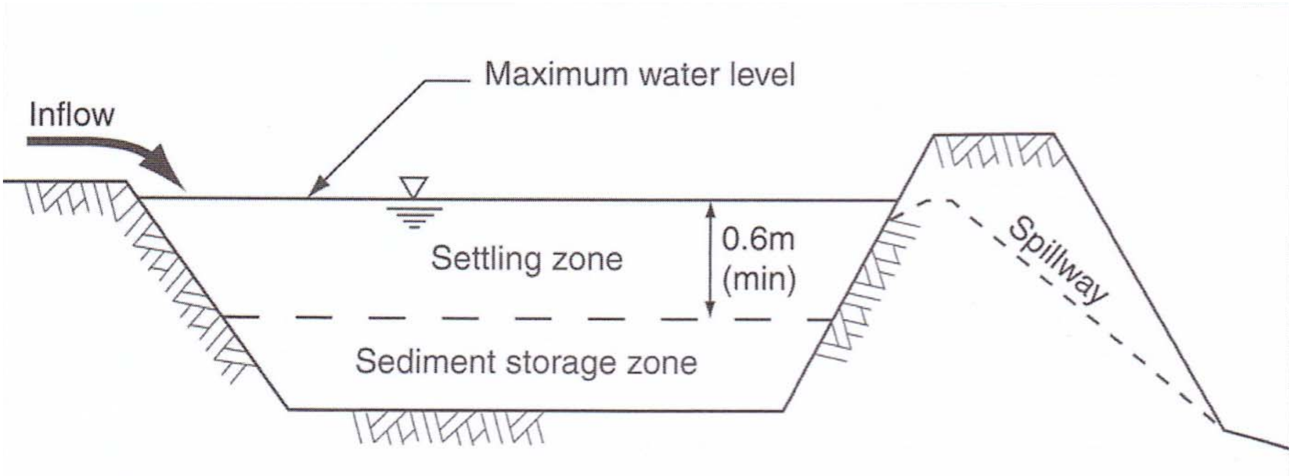


Figure 3.4: Example sediment trap design section (IECA, 2008)

Table 3.3: 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

4 EROSION AND SEDIMENT CONTROL FOR MINE CLOSURE

4.1 OVERVIEW OF ESC STRATEGY

The majority of ESC infrastructure described in Section 3 was designed for the active phase of the mine site, and will be removed at closure (Figure 4.1). All infrastructure items, including the Plant, ROM pad, Workshop / Offices, Camp, and Burn area will be removed, and the areas rehabilitated. This means that all sedimentation traps and temporary diversion drains will also be removed from these areas.

The primary ESC measures to be implemented at closure are therefore related to the constructed landforms (i.e the open cut pits, WRDs and TD cell), which will remain in place after mine closure. The general strategy for these landforms is to ensure that their design and construction results in a land surface that is stable enough in the short term to allow for the establishment of revegetation species, which will further stabilise the landforms in the long-term.

The main site diversion banks will remain in place after closure to further protect the WRDs and pit abandonment bunds from erosion during extreme rainfall-runoff events (Figure 4.1).

4.2 LEVEL OF PROTECTION

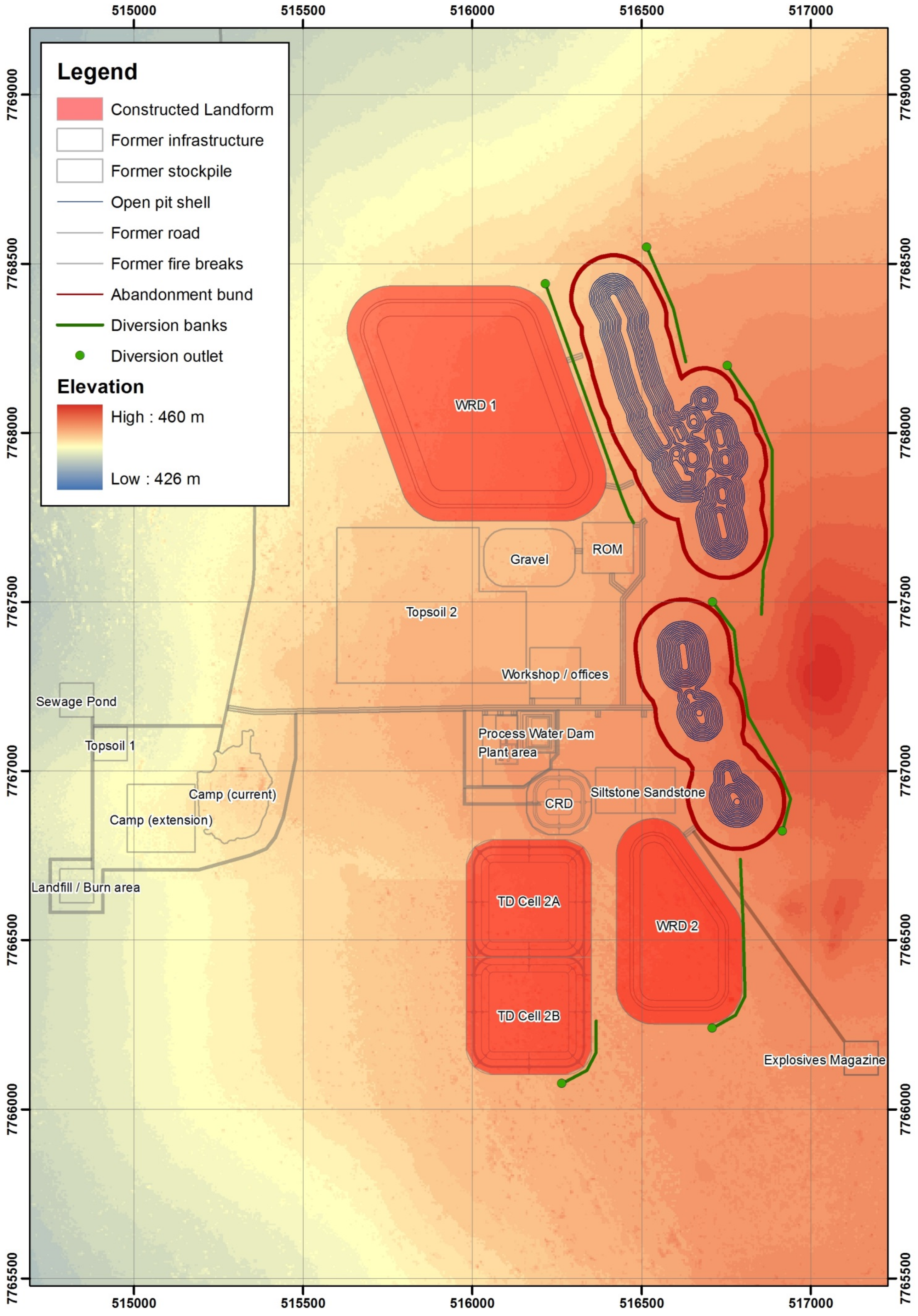
The main site diversion banks have been designed to withstand the 1:1,000-yr peak flow event. This level of protection has been agreed with the Central Land Council (traditional owners) as part of the stakeholder consultation process. There is no recommendation for permanent structures in the ESCP guidelines (IECA, 2008), but given the relatively small catchment sizes, the lack of defined flow channels, and the predominance of sheet flow across the site, 1:1,000-yr peak flow protection is considered to exceed mining industry best practice.

The constructed landforms have been designed to ensure slope stability throughout the rehabilitation process. The shape of the landforms has been designed, based on the properties of the available materials, to contain any appreciable eroded sediment within the footprint of the landform for a 100 year period (SWC, 2013b). This is expected to allow more than sufficient time for mature revegetation species to become established and further stabilise the landforms in the long-term.

4.3 STAGING OF THE WORK

The specifics of work staging for mine closure will be developed in more detail in the Conceptual Mine Closure Pan (MCP). In general, removal of any temporary ESC measures should occur after the removal all other infrastructure, as part of the final reshaping and rehabilitation of each domain. For example, the Processing Plant should be fully decommissioned and removed prior to the removal of the diversion drain and sediment trap in this area. The sediment trap and drain can simply be pushed in and graded back to the natural land contour when the Processing Plant area is reshaped. Land reshaping will ideally occur during the Dry Season, to minimise contact of bare, loosened soils with potentially erosive rainfall.

Rehabilitation of the outer surfaces of the WRDs can be done on an on-going basis (‘progressive rehabilitation’), where sections of the constructed landform are not likely to be disturbed again. Otherwise, the majority of rehabilitation will be completed during the mine closure phase.



ABM Resources – Twin Bonanza Gold Mine	Figure 4.1: Erosion and Sediment Control Infrastructure (post-closure)	soilwater GROUP
Erosion and Sediment Control Plan		

4.4 MINIMISING EROSION ON DISTURBED LAND SURFACES

4.4.1 CONSTRUCTED LANDFORMS

The general closure strategy for the constructed landforms (i.e. the WRDs and TD cell) is to ensure that their design and construction result in a land surface that is stable enough in the short term to allow for the establishment of revegetation species, which will further stabilise the landforms in the long-term. This will be accomplished by taking the following steps:

- The use of suitably erosion-resistant materials to construct the outer land surfaces. The upper surface and outer embankments of the WRD will be constructed of local sandstone material, which has been demonstrated to exhibit good erosion resistance (see Section 2.4). Additional testing of soil materials will be conducted to ensure the best available materials are used on the outer landform surfaces.
- Batter slopes will be shaped to a maximum slope angle of 15°, with a maximum lift height of 10 m, and 10-metre-wide back-sloping berms installed between each lift (Figure 4.2). This configuration has been demonstrated to be suitably stable, given the known material properties (SWC, 2013b). However, construction of both batters and berms must be conducted carefully to ensure that contouring is accurate and to avoid incorporating any flow concentrating dips and/or rises.
- The upper surface of the landforms will be designed to be inward sloping to trap any rainfall that falls on the upper surface and to prevent it from running down the slopes. The upper surface will be designed to hold a 1:100-yr, 72-hr rainfall event, without overtopping.
- If necessary, a toe bund may be constructed to trap any eroded sediment within the landform footprint area.
- Suitable revegetation species will be established to further stabilise the land surface. The final specifications and completion criteria for revegetation will be included in the Conceptual MCP.

Given these design parameters, a SIBERIA landscape evolution model was developed to test long-term landform stability (SWC, 2013b). Overall, the current WRD designs are expected to perform well in terms of erosion resistance, with a worst-case model (i.e. no armouring, no vegetation growth, and no overtopping protection) predicting that the majority of generated sediment would be contained within the landform footprint for at least 100 years post-construction. Thus, as long as adequate vegetation cover is re-established within this 100-year period, minimal sediment loss is expected to occur, and a safe and stable landform will remain in the long-term.

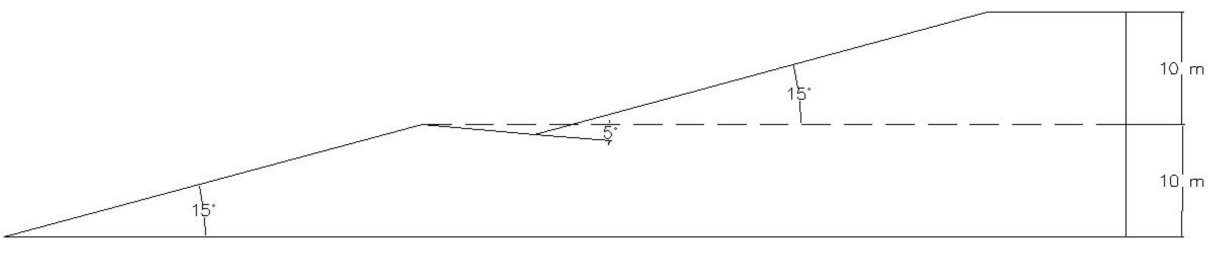


Figure 4.2: Design section of a waste rock dump (WRD) slope

5 MONITORING AND MAINTENANCE PROGRAM

5.1 INFRASTRUCTURE INSPECTION AND TEST PLAN (ITP)

This Infrastructure Inspection and Test Plan (ITP) has been developed to ensure that all drainage, erosion, and sediment control measures are maintained in a manner that prevents or minimises safety risks. Best practice site management requires all ESC measures to be inspected by the Environmental Manager, Site General Manager, or environmental officer at weekly intervals during the wet season (November – March), and monthly during the dry period.

The site inspections must check:

- The physical condition of all drainage, erosion, and sediment control measures
- Occurrences of litter or sediment that may interfere with the functioning of these measures
- Sediment deposition within all sediment traps and the need for its removal
- Occurrences of excessive sediment deposition
- All site discharge points

All maintenance (e.g. de-silting and repairs) or amendments necessary to achieve the required performance standard must be recorded and appropriate steps taken to inform those responsible for any required actions. An inspection checklist is provided in APPENDIX B, and this should be used to identify if / when ESC items require additional attention or maintenance. All site inspections and maintenance activities must be conducted only when it is safe to do so, and only in a manner that minimises safety risks to site personnel and the general public.

All monitoring will be reported annually in the Mining Management Plan (MMP) under the *Mining Management Act 2001*. Reporting to regulatory authorities (through the MMP) and stakeholders at the appropriate level of detail is important to demonstrate the effective implementation of the ESCP on site.

Records will be filed in the onsite administration office, with all electronic data stored on the onsite and head office server.

5.2 EROSION MONITORING

Visual assessments of slope erosion will occur weekly during the wet season, and monthly during the dry season, as described in the ITP (Section 5.1). In addition, quantitative erosion monitoring will be conducted on the constructed landforms at least once each year, in order to determine actual rates of soil movement, to verify design assumptions, and to assist with final closure of the landforms. This annual monitoring program will not begin until the constructed landforms have been established, and are completed to a sufficient stage that meaningful monitoring can commence. The monitoring program will be outlined in more detail in the Conceptual MCP, as it relates primarily to the later stages of site development.

5.3 WATER QUALITY MONITORING

Surface water quality in the sediment traps will be tested in accordance with the Water Management Plan (SWC, 2013c).

5.4 VEGETATION MONITORING

Rehabilitation monitoring is important to ensure that stabilisation of constructed landforms is being achieved as planned. An annual monitoring program will begin once the constructed landforms have been established, and are completed to a sufficient stage that progressive rehabilitation may occur. The monitoring program will be outlined in more detail in the Conceptual MCP, as it relates primarily to the later stages of site development. Monitoring will decrease and subsequently end as completion criteria are satisfied.

6 REFERENCES

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APPENDICES

APPENDIX A

DESIGN CALCULATIONS FOR DIVERSION DRAINS AND SEDIMENT TRAPS

A.1 Diversion Drain Sizing Calculations

Diversion	Diversion length (m)	Average slope (m/m)	Design flow rate (m^3/s)	Max Flow velocity (m/s)	Maximum flow depth (m)	Freeboard (m)	Diversion height + depth (m)
A1	760	0.004	9.8	1.42	1.03	0.30	1.3
A2	350	0.006	11.5	1.72	1.01	0.30	1.3
B1	340	0.012	6.3	1.92	0.71	0.30	1.0
B2	150	0.005	6.3	1.31	0.77	0.30	1.1
B3	750	0.005	12.0	1.55	0.98	0.30	1.3
C1	400	0.008	7.1	1.71	0.80	0.30	1.1
C2	550	0.004	14.9	1.58	1.21	0.30	1.5
C3	230	0.004	17.8	1.66	1.28	0.30	1.6
D1	480	0.004	4.6	1.12	0.72	0.30	1.0
D2	440	0.005	7.8	1.39	0.84	0.30	1.1
E	180	0.003	3.1	0.91	0.65	0.30	1.0
F	230	0.004	3.9	1.08	0.67	0.30	1.0

Used Manning's formula to solve for flow depth in a triangular channel:

$Q = (1 / n) * A * R_h^{2/3} * S_0^{1/2}$

Q = flow rate (m^3/s)

A = cross-sectional area of flow

n = Manning's n value (assumed 0.028)

R_h = hydraulic radius (based on channel geometry)

S_0 = average slope of the channel

A.2 Sediment Trap Sizing Calculations

Particle settline velocity (V_p) and required retention time (t_R) for a range of critical particle sizes:

d (mm)	s	g (m/s^2)	μ (m^2/s)	V_p (mm/s)	D (m)	t_R (s)	t_R (min)
0.02	2.65	9.81	1.0E-06	0.3597	0.6	1668	28
0.045	2.65	9.81	1.0E-06	1.8210	0.6	329	5
0.14	2.65	9.81	1.0E-06	17.6253	0.6	34	1
0.42	2.65	9.81	1.0E-06	158.6277	0.6	4	0

d = particle diameter
s = specific gravity of particle
g = acceleration due to gravity
μ = kinematic viscosity of the water at a given temperature (20°C)
V_p = particle falling velocity, defined as: $V_p = (g.(s-1).)d^2)/(18.\mu)$
D = depth of the settling zone (recommended default design value is 0.6 m)
t_R = required retention time to settle a particle of size d

Pond surface area (A_s) required to settle the selected critical particle size, for a range of peak flow rates (Q):

d (m)	V_p (mm/s)	V_p (m/s)	Q (m^3/s)	A_s (m^2)	L (m)	W (m)
0.02	0.36	0.00036	0.089	247	27	9
0.02	0.36	0.00036	0.145	403	35	12
0.02	0.36	0.00036	0.355	987	54	18
0.045	1.82	0.001821	1.13	621	43	14
0.045	1.82	0.001821	1.76	967	54	18
0.045	1.82	0.001821	4.12	2,262	82	27
0.14	17.63	0.017625	1.13	64	14	5
0.14	17.63	0.017625	1.76	100	17	6
0.14	17.63	0.017625	4.12	234	26	9

d = particle diameter
V_p = particle falling velocity, defined as: $V_p = (g.(s-1).)d^2)/(18.\mu)$
Q = design storm peak flow rate for the catchment area
A_s = surface area of the sediment basin at the base of the settling zone, calculated by: $A_s = Q/V_p$
L = sediment basin length, based on the recommended 3:1 length to width ratio
W = sediment basin width, based on the recommended 3:1 length to width ratio

APPENDIX B

SITE INSPECTION CHECKLIST

Erosion and Sediment Control (ESC) Site Inspection Checklist

Inspection officer: ______________________ Date: ______________

Signature: ______________________

Legend: ✓ OK ✗ Not OK N/A Not applicable

Item	Consideration	Assessment
1	Site dust is being adequately controlled	
2	All drains are free of soil scour and sediment deposition	
3	All diversion bunds are free from damage	
4	All drain outlets are free of soil scour and sediment deposition	
5	Landform slopes are free of visible gully erosion	
6	All runoff from disturbed areas is directed into sediment traps	
7	No areas of exposed soil are in need of erosion control	
8	All sediment traps are free from excessive sediment deposition	
9	All sediment traps are free from damage	
10	All ESC measures are in proper working order	
11	The site is adequately prepared for imminent storms	

Additional comments