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6.9 Groundwater Resources

6.9.1 Introduction

An assessment of the potential impacts to groundwater as a result of the Amulsar Project has been undertaken and is discussed in the following sections. The potential impacts on the various groundwater receptors are discussed and mitigation measures presented to avoid or limit adverse effects.

The impact assessment addresses the following Project facilities that may impact groundwater:

- The Tigranes-Artavazdes and Erato open pits. The Tigranes-Artavazdes pit will be backfilled during the later years of operation leaving a small southerly pit partially unbackfilled. The Erato pit will be partially backfilled at closure;
- The Barren Rock Storage Facility (BRSF);
- The Heap Leach Facility (HLF) and associated adsorption-desorption recovery (ADR) plant; and
- Additional supporting infrastructure including water storage ponds, water treatment systems, crushers, haul roads, material stockpiles, conveyor and mine buildings.

Each of these facilities has design engineering and operational measures to control the potential discharge of water during each phase of the mine life. The engineering controls incorporated into the facility designs, and which are included in this assessment, are described in Section 6.9.5.

Management of water through the mine life cycle is described in the water management plan. The objectives of the water management plan are:

- To route mine contact runoff water to ponds and collection sumps in order to minimise the release of mobilised sediment;
- To prevent natural ground runoff and non-contact water from entering disturbed areas and mixing with contact water;
- To capture contact water runoff from the mine facilities, use in process operations (if possible) and if necessary treat and discharge if the water cannot be used; and
- To minimise erosion of disturbed areas, and when erosion does occur, to minimise suspended sediment flow to streams.

During construction, the water management plan focusses on management of surface water runoff and sediment control; potentially impacted surface water will be routed to sediment ponds prior to discharge to surface water.

During operations, runoff from haul roads, conveyor, crushers and truck stop areas will be routed to sediment ponds, and treated if required, prior to discharge to surface water. Runoff, and any discharge from the BRSF will be routed to a pond located downstream of the facility. Some of this water will be used for dust suppression while the majority will be piped to the HLF for use in the leaching process.

Water from the pits will be routed via in-pit sediment ponds and will then be combined with the water from the BRSF pond in a contact water pond at the HLF. The water in the contact water pond will be used to supply make-up water to the HLF during operation or treated to meet environmental standards and discharged to land application or the lower Arpa catchment below the Kechut reservoir. Make-up water for the HLF will be sourced from the Arpa River when required.

A passive water treatment systems (PTS) installed downstream of the of the contact water ponds and the second PTS after HLF closure will be used to treat water for discharge during operations, and to manage the discharge of residual waters from the BRSF (after year 4 of operation and post closure) and the HLF underdrain also post-closure. The water will be treated to meet environmental standards (RA Category II MACs for the Arpa River) and then discharged land application or to the Arpa. Water entering the open pit backfill post-closure will infiltrate to ground.

There will be three major water storages available to manage water in the Project area:

- The raw water pond (volume 20,450 m^3), which will receive runoff (non-contact water) from the haul and access roads, and conveyor corridor;
- The HLF contact water pond (maximum volume approximately 1,280,000 m^3), which will receive discharge from the BRSF Toe Pond and water from the pit sumps and truck shop storage pond; ; and
- Three storm ponds (maximum total volume approximately 630,000m^3) downstream of the HLF, which will be used for active storage of process water during operations and also contain storm storage capacity.

6.9.2 Assessment Scope

Technical Scope

The groundwater assessment relates to evaluation of impacts on groundwater resources. For the purposes of this report, groundwater is defined as all water that is below ground. On this basis, springs, perched water and regional groundwater will be considered as groundwater in this assessment.

Where groundwater is a key sustaining input to other resources (i.e. surface water, or aquatic or terrestrial habitats), the secondary impacts are addressed in the relevant chapters.

Geographical Scope

The groundwater Study Area is identified on Figure 6.9.1. This area forms the basis for the geographical area covered by the groundwater impact assessment.

Temporal Scope

The groundwater assessment considers the potential impacts to groundwater receptors during the following mine life stages:

- Construction (Pre-Operational) Phase;
- Operational Phase; and
- Closure and post closure.

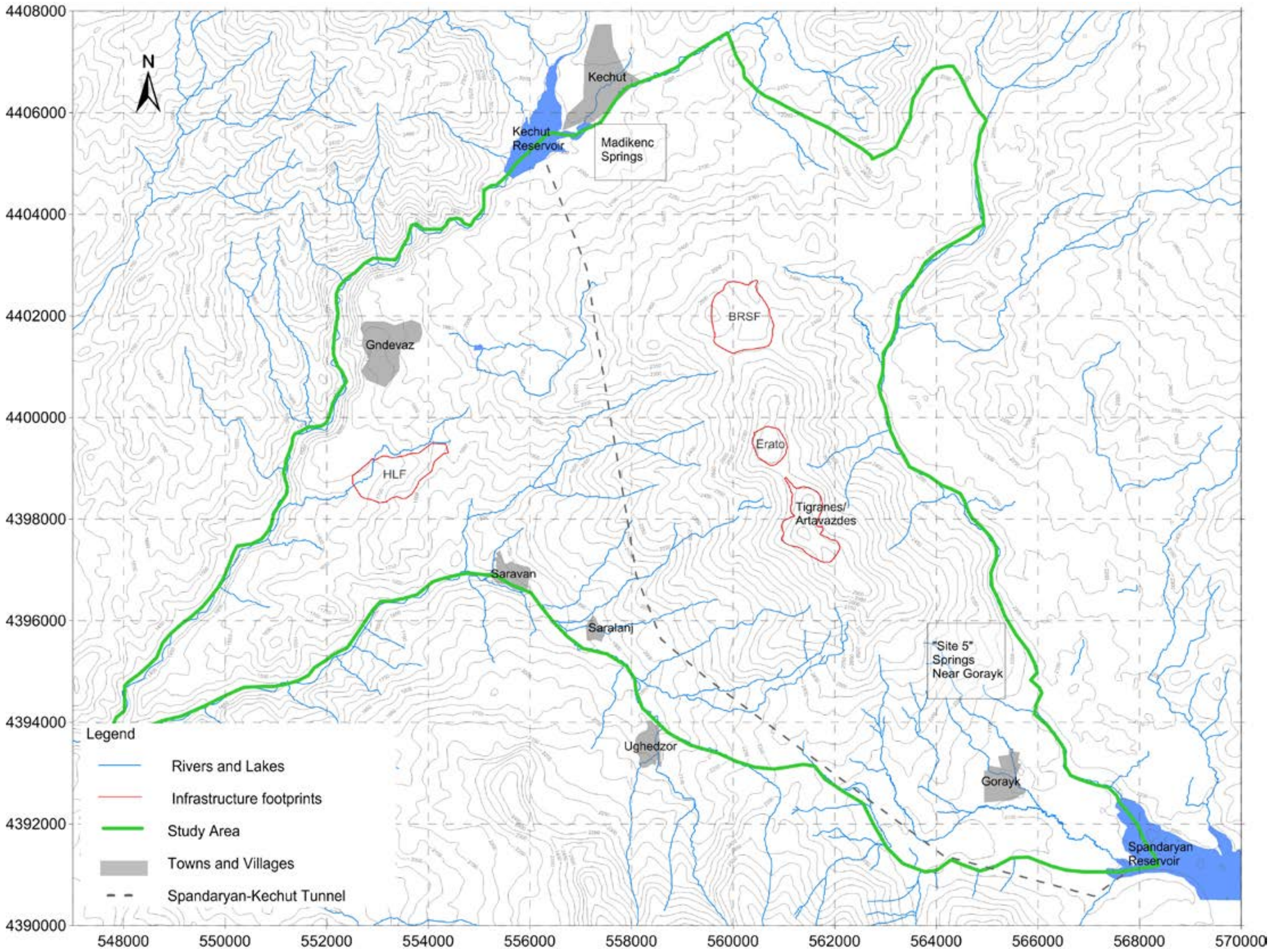

Figure 6.9.1: Groundwater Study Area

6.9.3 Impact Assessment Methodology

The general environmental impact assessment methodology is presented in Chapter 6.1. The methodology has been followed in order to complete the groundwater impact assessment.

Table 6.1.1 (Chapter 6.1) presents the general description of receptor sensitivity. For the purposes of the groundwater assessment the abundance, scale, resilience to change and potential for substitution of each receptor has been considered individually in order to determine the sensitivity of that receptor. Details of this process, and the results, are presented in Section 6.9.4.

Once the receptors and their sensitivity have been identified, the baseline groundwater conditions (Chapter 4.8) and project description (Chapter 3) are considered in order to determine if there is any potential impact to the groundwater receptor. The magnitude of any change to groundwater as a result of the impact is determined using the general method presented in Table 6.1.2 (Chapter 6.1). For the purposes of the groundwater assessment, specific degrees of change have been defined for each of the categories as presented in Table 6.9.1.

There are no national groundwater or drinking water quality standards in the Republic of Armenia against which to qualify changes in groundwater quality. The Project Assessment Criteria are MAC II Standards that apply to surface water. In the absence of groundwater quality standards, these MAC II Standards have been used for information purposes only for groundwater. This is considered appropriate as a preliminary assessment tool because groundwater ultimately discharges to surface water. However, any significant effects that result from assessment using these criteria should be used with caution. Surface water and the ecology that is supported by it are more relevant receptors than the change in groundwater quality. Therefore, the end receptors of the predicted change in groundwater quality are surface water and ecology. The sensitivity of the surface water and ecology receptors, the significance of the change in groundwater quality on these, and any relevant mitigation measures are considered in Chapters 6.10 and 6.11, respectively.

Table 6.9.1: Magnitude of Change Scale (Groundwater)

	Magnitude of change	Description of Change	
		Quality	Quantity
1	Negligible	No measurable changes from baseline conditions. Direct control is not required to manage potential impact.	No measureable changes from baseline conditions. Direct control is not required to manage potential impact.
2	Low	Measureable change to the baseline conditions. Where quality standards were not exceeded at the baseline, concentrations have measurably increased, but remain below the quality standards. If quality standards were exceeded at the baseline, the predicted concentration is less than 20 % over the baseline and change is temporary. During construction, operations or closure there would be ongoing change in the underlying characteristics or quality of the baseline conditions.	Detectable change to the baseline conditions or resource. Permanent or temporary changes are less than 10% of flow under baseline conditions.
3	Moderate	Degree of change is such that adverse alteration to baseline conditions would occur. Predictions indicate a change in groundwater quality from below the environmental standard at baseline to above the environmental standard as a result of development. The environmental standard is exceeded by up to 100 %. Changes are not permanent and improvement will occur over time in post-closure.	Degree of change is such that loss of, or adverse alteration to, the baseline conditions would occur. A permanent alteration in flow of less than 20% from baseline conditions is predicted, or a temporary change of less the 50% of baseline conditions.
4	High	Degree of change is such that adverse alteration to baseline conditions would occur. Predictions indicate a change in groundwater quality from below the environmental standard at baseline to above the environmental standard as a result of development. The environmental standard is exceeded by over 100 %. Post-development quality would be fundamentally and irreversibly changed.	Degree of change is such that total loss of, or adverse alteration to, the baseline conditions of a specific resource would occur. Development is predicted to result in a permanent change of more than 20% from baseline conditions, or a temporary change of more than 50% from baseline conditions.

As well as the magnitude of change to groundwater, the direction (positive or adverse) and duration of the impact are also presented. It should be noted that this initial potential impact assessment takes into account mitigation measures incorporated into the design presented in Section 6.9.5.

The matrix presented in Table 6.1.3 (Chapter 6.1) is then used to determine the significance of the impact, and Table 6.1.4 (Chapter 6.1) is used to determine whether the effect of the impact is significant.

For any significant effects, additional (i.e. non-design) mitigation measures are presented and the residual impact and effect is then evaluated using the process outlined above.

6.9.4 Identification of Key Groundwater Receptors

Groundwater Receptors

This assessment considers impacts on groundwater resources only. Groundwater users in the Project area are described in the groundwater baseline (Chapter 4.8). Based on this information, and the conceptual understanding of the hydrologic environment, the key groundwater receptors are grouped as follows:

- Ephemeral springs that support surface water flow and ecology;
- Perennial springs that support surface water flow and ecology;
- Perennial springs in Jermuk that are used for therapeutic/recreational use and for water supply;
- Groundwater used for drinking water supply and irrigation; and
- Groundwater that supports surface water baseflow.

Only two community water supply springs (or group of springs) are within the Project area: the Madikenc springs that are located near to Kechut Reservoir (see Figure 6.9.2) and are used to supply domestic water to Kechut; and the springs north of Gorayk (see Figure 6.9.2) used by seasonal herders between May and October. These will be considered as the community drinking water spring receptors in this assessment.

There are no communities or individuals using wells for domestic water supply within the Project area. Therefore, groundwater wells are not considered to be a receptor in this assessment.

Receptor Sensitivity

The five groups of individual receptors are presented in Table 6.9.2. This table presents an assessment of receptor distribution, geographical importance (scale), resilience to change and potential for substitution. These elements have been combined to determine the sensitivity of each receptor.

Table 6.1.1 (Chapter 6.1) has been referred to when assigning receptor sensitivity. As groundwater resource is the receptor being considered, the greatest weighting in the determination of sensitivity has been assigned to the geographical importance of the resource (i.e. what water users over what area rely on the groundwater). The resilience to change and the potential for substitution are considered to have the next level of weighting in the determination of receptor sensitivity.

The determination of sensitivity considers groundwater resource alone as the receptor, not the sensitivity of any dependent hydrological or ecological features. The associated hydrological and ecological receptors that may be sensitive to changes in groundwater quantity or quality are addressed in Chapters 6.10 (Surface Water) and 6.11 (Biodiversity).

Table 6.9.2: Receptor Sensitivity (Groundwater)							
Receptor	**Area**	**Location**	**Distribution**	**Geographical Importance**	**Resilience to Change**	**Potential for Substitution**	**Receptor Sensitivity**
Perched Water/ Ephemeral Springs	Pit areas of Amulsar Peak	Amulsar Peak - Elevation Band 2500 to 2900 m (excluding BRSF area)	Between 12 and 25 snowmelt-driven springs that flow seasonally - originate in nearly all headwater drainages on all slopes. **Localised**	Perched springs are localised in the elevation band surrounding Amulsar Mountain. They are of **local importance** as they provide flow to local surface watercourses.	Perched springs have small headwater catchments (less than a sq. km). **Susceptible to relatively small changes within their catchment particularly at low flows**.	Perched springs cannot be substituted.	Medium
	BRSF and Surroundin g Area	Headwater tributary to Vorotan River and Arpa River. Found primarily below BRSF footprint	At least 11 snowmelt-driven springs that flow seasonally are located beneath the BRSF. There are at least six ephemeral springs located in the valley to the west of the BRSF. **Localised**	**Local,** relatively small volume, input to Vorotan and Arpa rivers.	Perched springs have small headwater catchments (less than a sq. km). **Susceptible to relatively small changes within their catchment particularly at low flows.**	Perched springs cannot be substituted.	Medium

Table 6.9.2: Receptor Sensitivity (Groundwater)							
Receptor	**Area**	**Location**	**Distribution**	**Geographical Importance**	**Resilience to Change**	**Potential for Substitution**	**Receptor Sensitivity**
	HLF and Surroundin g Area	Headwater tributary to Arpa River	One ephemeral spring located within the footprint and four in the surrounding area. **Localised**	**Local,** relatively small volume, input to Arpa River.	Perched springs have small headwater catchments (less than a sq. km). **Susceptible to relatively small changes within their catchment particularly at low flows.**	Perched springs cannot be substituted.	Medium
Perennial Springs	Pit areas of Amulsar Peak	Amulsar Peak - Elevation Band 2500 to 2900 m (excluding BRSF area)	At least 5, and possibly up to 17, springs could flow year-round mapped on Amulsar Mountain. **Localised**	Year-round springs are localized to the mid-elevation range on Amulsar Mountain. They are of **local importance** as they provide flow to local surface watercourses.	Springs have larger catchments than perched springs. Sustained by year-round groundwater discharge from low permeability rocks thus **reasonably resilient** to changes in their catchment.	Springs cannot be substituted.	Minor

Table 6.9.2: Receptor Sensitivity (Groundwater)							
Receptor	**Area**	**Location**	**Distribution**	**Geographical Importance**	**Resilience to Change**	**Potential for Substitution**	**Receptor Sensitivity**
	BRSF and Surroundin g Area	Headwater tributary to Vorotan River and Arpa River. Found primarily below BRSF footprint	Two flowing springs are present all year round within the BRSF footprint area. One flowing spring (SP68) located in the valley to the west of the BRSF. **Localised**	**Local,** relatively small volume, input to Vorotan and Arpa rivers.	Springs have larger catchments than perched springs. Sustained by year-round groundwater discharge from low permeability rocks thus **reasonably resilient** to changes in their catchment.	Springs cannot be substituted	Minor
	HLF and Surroundin g Area	Headwater tributary to Arpa River	No perennial flowing springs in HLF footprint. Four areas of ground that are wet all year around identified in the immediate surrounding area (within 250 m). **Localised**	**Local,** relatively small volume, input to Arpa River.	Springs have larger catchments than perched springs. Sustained by year-round groundwater discharge from low permeability rocks thus **reasonably resilient** to changes in their catchment.	Springs cannot be substituted	Minor

Table 6.9.2: Receptor Sensitivity (Groundwater)

Receptor	Area	Location	Distribution	Geographical Importance	Resilience to Change	Potential for Substitution	Receptor Sensitivity
Hydrothermal Springs	Jermuk	Jermuk - used for recreational/medicinal purposes, and water supply	Selected springs used. **Localised**	**National importance** (commercial and tourism)	Springs feed by deep regional large-scale thermal groundwater system that is not connected to the Project area - thus **resilient to changes** in the Project area	Springs cannot be substituted	High
Groundwater Used for Water Supply Purposes	Kechut/ Madikenc Springs	Madikenc springs approximately 2 km E of Kechut. Supply to Kechut	Madikenc group of springs only. **Localised**	**Local importance** for village water supply	Springs sourced from groundwater within the Cenazoic Basalt Flows. Will to be sensitive to changes in recharge within their catchment area.	Alternative supplies could be sourced, but must be a practical supply to Kechut	Medium
	Springs North of Gorayk	Springs used by seasonal herders	Small group of springs only. Most springs in the area are ephemeral. Very few are perennial. **Localised**	**Local importance** as seasonal water supply	Springs sourced from groundwater. Will to be sensitive to changes in recharge from surface within their catchment area.	Alternative supplies could be sourced or herders could locate to more preferable areas	Minor

Table 6.9.2: Receptor Sensitivity (Groundwater)							
Receptor	**Area**	**Location**	**Distribution**	**Geographical Importance**	**Resilience to Change**	**Potential for Substitution**	**Receptor Sensitivity**
	Spandaryan -Kechut Tunnel	21.7 km tunnel located between the Spandaryan Reservoir and the Kechut Reservoir	Long linear feature influencing groundwater in the area to the west of the Amulsar Ridge. **Local** to the Project area.	**National importance** (drinking water distribution to Kechut Reservoir and Lake Sevan)	Supply comes from Spandaryan Reservoir. No dependence on groundwater inflow to sustain supply. Flow in the tunnel is large so it is resilient to localised changes in groundwater flow and quality that may reach the tunnel.	Tunnel could be modified to prevent groundwater inflow	High
Groundwater Component of Surface Water Baseflow	Darb River catchment	Baseflow from the southern and western Project areas feed lower elevation tributaries and baseflow in the Darb river	Groundwater baseflow discharge derived from groundwater recharge within the Project area. Discharge occurs along large reaches of river. **Regionally extensive.**	Baseflow contribution from the Project area is small in relation to the baseflow feeding the major rivers upstream of the Project area. Baseflow from within the Project Area is of **regional importance.**	The major rivers have large catchments, much of which are located up gradient of and outside the Project area, and are therefore **resilient to changes** in baseflow within the Project area.	Groundwater baseflow cannot be substituted	Medium

Table 6.9.2: Receptor Sensitivity (Groundwater)

Receptor	Area	Location	Distribution	Geographical Importance	Resilience to Change	Potential for Substitution	Receptor Sensitivity
	Arpa River Catchment	Baseflow from the northern and western Project areas feed lower elevation tributaries and baseflow in the Arpa river	Groundwater baseflow discharge derived from groundwater recharge within the Project area. Discharge occurs along large reaches of river. **Regionally extensive.**	Baseflow contribution from the Project area is small in relation to the baseflow feeding the major rivers upstream of the Project area. Baseflow from within the Project area is of **regional importance.**	The major rivers have large catchments, much of which are located up gradient and outside the Project area, and are therefore **resilient to changes** in baseflow within the Project area.	Groundwater baseflow cannot be substituted	Medium
	Vorotan River Catchment	Baseflow from the eastern Project areas feed lower elevation tributaries and baseflow in the Vorotan river	Groundwater baseflow discharge derived from groundwater recharge within the Project area. Discharge occurs along large reaches of river. **Regionally extensive.**	Baseflow contribution from the Project area is small in relation to the baseflow feeding the major rivers upstream of the Project area. Baseflow from within the Project area is of **regional importance.**	The major rivers have large catchments, much of which are located up gradient and outside the Project area, and are therefore **resilient to changes** in baseflow within the Project area.	Groundwater baseflow cannot be substituted	Medium

Based on the assessment of receptor sensitivity, the ephemeral springs have been assigned a medium sensitivity as, although they are local to the project and are of local importance, they are susceptible to changes in their catchments and cannot be substituted.

The perennial springs are similar to the ephemeral springs in their distribution and geographic importance. They cannot be substituted, but are supplied by larger groundwater catchments so are not as sensitive to changes in their catchments. On this basis, the perennial springs have been assigned minor sensitivity.

The hydrothermal springs in Jermuk are locally distributed and because they are fed from deep groundwater (as evidenced by their warm temperature) will be resilient to changes in the Project area, but are of national importance and cannot be substituted. On this basis, they have been assigned a high sensitivity.

The community water supplies to Kechut are of local importance, and the sources are currently restricted to two springs (the Madikenc springs) so are likely to be sensitive to any changes that might affect those two springs. An alternative supply may be restricted in location so that it would be practical and cost-effective for the village to source, transport and use; therefore, these springs have been assigned a medium sensitivity.

In contrast, the springs used by herders have been assigned a minor sensitivity. Although they are also of local importance and likely to be sensitive to changes in their catchment areas, the water users report (Gone Native, 2013[1]) indicates that the springs used are not the herders' only options and they would be more flexible in their source of an alternative supply than the village.

The Spandaryan-Kechut Tunnel has been included in this assessment because it links the Spandaryan Reservoir and the Kechut Reservoir, which in turn supplies water to Lake Sevan. The main source of water in this tunnel is planned to be surface water from the Spandaryan Reservoir. However, while there is no current inflow to the tunnel from the Spandaryan Reservoir, there is some outflow from the tunnel that appears to be groundwater. Groundwater modelling suggests that groundwater from the Project area may enter the tunnel. Groundwater is not the main source of the water supply for the Spandaryan-Kechut Tunnel so there is no concern over the need for substitution. However, because groundwater

[1] Gone Native LLC (2013) Summary Report: Springs and Water Users Study

currently enters the tunnel and the tunnel discharges to the Kechut Reservoir, and the supply is of national importance, this receptor has been assigned a high sensitivity.

Groundwater that supports surface water baseflow is assigned a medium sensitivity, largely based on its regional importance as an input to surface water. The surface water receptor sensitivity and the assessment of effects on the surface water receptors are presented separately in the surface water impact assessment chapter (Chapter 6.10).

6.9.5 Design and Management Mitigation

The design of the Project is presented in Chapter 3. The mitigation measures that are implemented in the Project design and evaluated in the impact assessment are described below.

Pits

Water in the open pits which has contacted the pit walls has the potential to be impacted both by acid rock drainage and by ammonium and nitrate from the residue of ammonium nitrate-based explosives. During operation water in the pits will be managed to minimise infiltration to ground by pumping water to the contact water management system. For the purposes of the impact assessment, it is assumed that water may accumulate in the pits in the spring, possibly remaining for two or three months. At other times of the year it is assumed that each pit will have a volume of no more than 300 m^3.

Material from the pits that is awaiting processing will be stored temporarily in stockpiles. Run-off from these piles will be managed as part of the water management plan. The ground beneath these stockpiles will be compacted to limit leakage of any water on, or in, the stockpiles to ground.

As part of closure, the Tigranes-Artavazdes pit will be partially backfilled with barren rock. The barren rock will comprise permeable loose mixed Upper Volcanics and Lower Volcanics and is estimated to have a permeability of approximately 1×10^{-4} m/s (BRSF Seepage Model, GRE, 2014[2]). The backfill will be capped with an engineered evapotranspiration cover, comprising cover soils, a layer of compacted clay and a gravel drainage layer, to reduce infiltration. Infiltration through this cover and leakage through the base of the facility over

[2] Global Resource Engineering (GRE), Ltd, 2014. Technical Memorandum, Amulsar BRSF Seepage Model. Reference 13-1064, 14 July 2014.

the life cycle of the mine has been modelled using an unsaturated flow model (BRSF Seepage Model, GRE, 2014[2]).

As part of closure, the Erato pit will be partially backfilled with barren Non-Acid Generating (NAG) rock comprising permeable loose Upper Volcanics estimated to have a permeability of more than $1x10^{-4}$ m/s. The backfill will not have a soil cover to allow infiltration of pit runoff into the backfill. A backfill volume of 414,980 m^3 is estimated (Erato Post-Closure Pit Water Balance, Golder Associates, 2014[3]).

BRSF

The BRSF will be constructed to prevent Potentially Acid Generating (PAG) waste from coming into contact with water as much as possible, and use NAG barren rock to serve as a contact buffer between PAG material and the natural environment.

The engineered containment will comprise the following elements:

- The existing subsoil in the footprint of the BRSF will be compacted in place to act as a low-permeability soil liner. This soil liner will restrict infiltration and will direct water that comes into contact with the barren rock to the toe of the BRSF, where the outflow will be collected in the BRSF toe pond and then piped to the contact water pond for treatment and/or piped to the HLF for use or treated through a passive treatment system (PTS) and then discharged. At closure, all flow from the BRSF toe pond will continue to be piped to the contact water ponds, with overflow to the PTS (see Appendix 3.1);
- A NAG barren rock drainage layer placed over the compacted soil liner will inhibit natural groundwater from seeps and springs located beneath the prepared soil liner of the BRSF from coming into contact with PAG waste rock. Any water emanating through the foundation of the dump (from potential seeps and springs) will travel through this layer towards the toe of the facility;
- The low grade ore stockpile is similar to NAG barren rock in terms of leachate chemistry (see Appendix 8.19) and will be treated as such (see above);
- PAG waste will be placed in engineered cells that will be surrounded by NAG waste on all sides. As a result, the PAG waste will be in contact with neither the bottom soil

[3] Golder Associates, 2014. Technical Memorandum, Erato Post-Closure Pit Water Balance. Reference 14514150095.503/B.4, 4 August 2014.

liner nor the atmosphere. Amulsar PAG waste consists of argillized rock and contains a significant clay fraction. This clay fraction makes the PAG a low-permeability material. As a result, any water entering the body of the BRSF will flow preferentially through NAG waste that will be placed around the PAG cells; and

- The BRSF cover will be an engineered evapotranspiration (E/T) cover designed for the conditions found at the site. The components of the cover from top to bottom will be: topsoil to provide a vegetative growth medium; a layer of naturally-compacted clay to reduce the influx of water into the cover system; and a layer of gravel that will act as a capillary break between the cover soil and the waste rock of the dump. This cover will reduce infiltration to the BRSF in the long term.

HLF

The design of the HLF is described in Chapter 3. The design incorporates engineered containment comprising:

- A composite liner beneath the heap leach pad;
- A drainage system within the heap leach pad to control head on the basal liner to a maximum of 0.6 m;
- Underdrains beneath the leach pad footprint to drain groundwater/subsurface leakage to a collection sump located downgradient of the pad, where the underdrain discharge water quality will be monitored as required;
- A double liner system with intermediate leakage capture and recovery system underlying the solutions pond(s);
- Managed source term attenuation during the closure phase of the facility to reduce concentrations in cyanide in the leach solution to within acceptable discharge standards prior to closure; and
- Placement of an engineered evapotranspiration cover following closure to minimise infiltration to and leakage from the heap in closure. This cover will comprise cover soils overlying a compacted clay cap with underlying drainage layer of the leach pad rock to act as a capillary break.

The liner will be constructed according to international industry-accepted standards with onsite construction quality assurance/quality control. In addition, electric leak location surveys will be performed after the liner and overliner drain gravel have been placed to determine whether there are any defects in the liner requiring repair prior to leaching operations.

In addition to the mitigation measures incorporated into the facility designs, the mitigation measures presented in the management plans (Chapter 8) will be used to avoid or limit the effects of potential impacts to the groundwater system. The management mitigation measures that are considered in this assessment include:

- Management of run-off and leakage during construction;
- Minimum 110 % tank capacity of bunds for storage of fuel/oils;
- Use of sediment/grease traps;
- Provision of spill kits and training of employees and contractors in spill prevention measures;
- No uncontrolled discharge to the water environment of effluent from facilities and wheel washes; and
- Capture of sewage effluent in sealed tanks and appropriate disposal.

In addition, a groundwater and surface water monitoring plan will be implemented during operations and closure. The purpose of the monitoring will be to evaluate the operational performance of the Project and identify any adverse trends in surface water and groundwater quality or quantity potentially exceeding those estimated by modelling that would require modifications to the mitigation measures.

6.9.6 Potential Impact Assessment

This section presents a discussion of the potential impacts to groundwater resources, how these impacts are assessed (with reference to the quantitative technical assessment where applicable), and the predicted direction, duration and magnitude of the changes.

Following the determination of the magnitude of change, the significance of the effect and the scale of significance have been defined using the matrices presented in Chapter 6.1 (Table 6.1.3 and 6.1.4). The summary of construction effect significance is presented in Table 6.9.3. The summary of operational effect significance is presented in Table 6.9.4. The summary of closure effect significance is presented in Table 6.9.5.

Groundwater quantity impacts are based on assessments of leakage from the BRSF and backfilled/restored T/A pit areas (Amulsar Pit Seepage Model, GRE, 2014[4]; and BRSF Seepage Model, GRE, 2014[2]) and the post-closure water balance for the Erato pit (Golder Associates, 2014[3]).

The impact assessment is supported by the following technical studies, which should be read in conjunction with this assessment:

- Appendix 6.9.1 - Groundwater modelling study (Golder Associates, 2014[5]);
- Appendix 6.9.2 - Assessment of nitrate and ammonium release from blasting (Golder Associates, 2014[6]);
- Appendix 6.9.3 - Assessment of risk to groundwater quality from the Tigranes-Artavazdes and Erato Pits (Golder Associates, 2014[7]);
- Appendix 6.9.4 - Assessment of risk to groundwater quality from the HLF (Golder Associates, 2014[8]); and
- Appendix 6.9.5 - Assessment of groundwater impacts from the BRSF (Golder Associates, 2014[9]).

The objective of each study and a summary of the key findings are presented in the following section.

Summary of Supporting Studies

Appendix 6.9.1 - Groundwater Modelling Study

The groundwater modelling study supports this groundwater impact assessment by evaluating the hydrogeological regime in the area of the proposed mine and associated infrastructure. The groundwater flow model represents the groundwater pathways from mine sources to the potential receptors identified in Section 6.9.4. The groundwater flow

[4] Global Resource Engineering (GRE), Ltd, 2014a. Technical Memorandum, Amulsar Pit Seepage Model, Reference 13-1064. 7 July 2014.

[5] Golder Associates, 2014. Groundwater Modelling Study. Report Reference 14514150095.506, August 2014.

[6] Golder Associates, 2014. Technical Memorandum, Amulsar Gold Project: Estimate Of Nitrate And Ammonia Concentrations In Mine Water As A Product Of Blasting. Reference 14514150095.508, July 2014

[7] Golder Associates, 2014. Assessment of risk to groundwater quality from the Tigranes-Artavazdes and Erato Pits. Reference 14514150095.512, August 2014.

[8] Golder Associates, 2014. Hydrogeological Risk Assessment Proposed Heap Leach Facility. Report Reference 14514150095.509, August 2014.

[9] Golder Associates, 2014. Technical Memorandum, Assessment of groundwater impacts from the BRSF. Reference 14514150095.511, August 2014.

model is used to predict changes in groundwater flow direction, groundwater level, spring discharge and baseflow in response to the changes induced by the Project.

The groundwater flow model uses a 3-D numerical approach to represent the conceptual hydrogeological understanding. The model combines information available on the climate/meteorology, topography, geology, baseline hydrology (Chapter 4.8), hydrology (Chapter 4.9), project description (Chapter 3), and predicted leakage/infiltration quantities beneath the main facilities. The model was constructed and calibrated to current conditions (i.e. groundwater levels and baseflow in the Spandaryan-Kechut Tunnel). The calibrated model uses values for hydraulic conductivity and recharge that are representative given the results of hydraulic testing and the climatic and hydrologic data for the Project Area. The model was also calibrated to the measured baseflows along river reaches. Following the completion of model calibration, three steady state model scenarios were developed: one to represent the baseline conditions (i.e. the current groundwater regime); one to represent operations at the maximum extent of mining; and one to represent post-closure when the pits have been backfilled and reclaimed.

The model was first used to determine the large-scale baseline hydrogeological conditions (i.e. before construction and operation). The key findings of the baseline model are summarised below:

- The water table largely mirrors topography, being highest beneath the Amulsar ridge and decreasing to the main river valleys;
- Groundwater flows radially away from the Amulsar ridge. Flow from the Tigranes-Artavazdes peaks is eastward to the Vorotan River and westward to the Darb River. Flow from Erato peak is predominantly to the west to the Arpa River;
- There is a shallow near-surface water table in the bottom of the BRSF valley underlain by argillized Lower Volcanics;
- There is a deep water table (in excess of 100 m below ground level) in the basalts to the northwest and west of the Amulsar ridge;
- Groundwater below the BRSF site flows northwestwards before turning west to discharge predominantly to the Arpa River downstream of the Kechut Reservoir;
- Groundwater flow is westward from the HLF site toward the Arpa River;
- The Spandaryan-Kechut Tunnel intersects the water table throughout its length, but overall the groundwater contribution area of the tunnel is localised. Simulated

groundwater flow pathlines indicate that groundwater flow originating from below the Erato, Tigranes and Artavazdes peaks and from the BRSF site flows beneath the tunnel to discharge to the Darb River; and

- The model shows groundwater discharge zones in river and stream valleys, and on the flanks of the Amulsar ridge below an elevation of approximately 2,700 m asl. The groundwater discharge on the flanks of Amulsar ridge is relatively well matched to observed areas of perennial spring discharge.

In the operational model, the groundwater flow direction from beneath each of the facilities is predicted to be similar to the baseline case. Figure 6.9.2 presents the predicted groundwater flow pathlines from each of the main mine areas.

The groundwater flow model indicates that recharge to groundwater in the BRSF area provides water to the BRSF springs, the Kechut springs, and the Arpa River. These locations are, therefore, considered to be potential receptors to changes in the quantity and quality of groundwater during operation of the BRSF.

The groundwater flow pathlines from the BRSF predicted by the model indicate that any groundwater quality changes as a result of leakage from the BRSF could potentially influence the quality of groundwater discharge to the Arpa River; thereby identifying groundwater baseflow to the Arpa River as the key groundwater receptor for the BRSF during operation.

Groundwater flow from the HLF is westward toward the Arpa River; thereby identifying baseflow to the Arpa River as the key groundwater receptor for the HLF during operation.

The operational model indicates that water infiltrating through the Tigranes-Artavazdes pit footprint will discharge both eastward to the Vorotan River and tributaries and westward to the Darb River and tributaries; thereby identifying groundwater fed springs and baseflow to these rivers as receptors. Water infiltrating through the Erato pit is predicted to discharge westward towards the Arpa River and tributaries during operation; thereby identifying groundwater fed springs and baseflow to the Arpa River and tributaries as receptors.

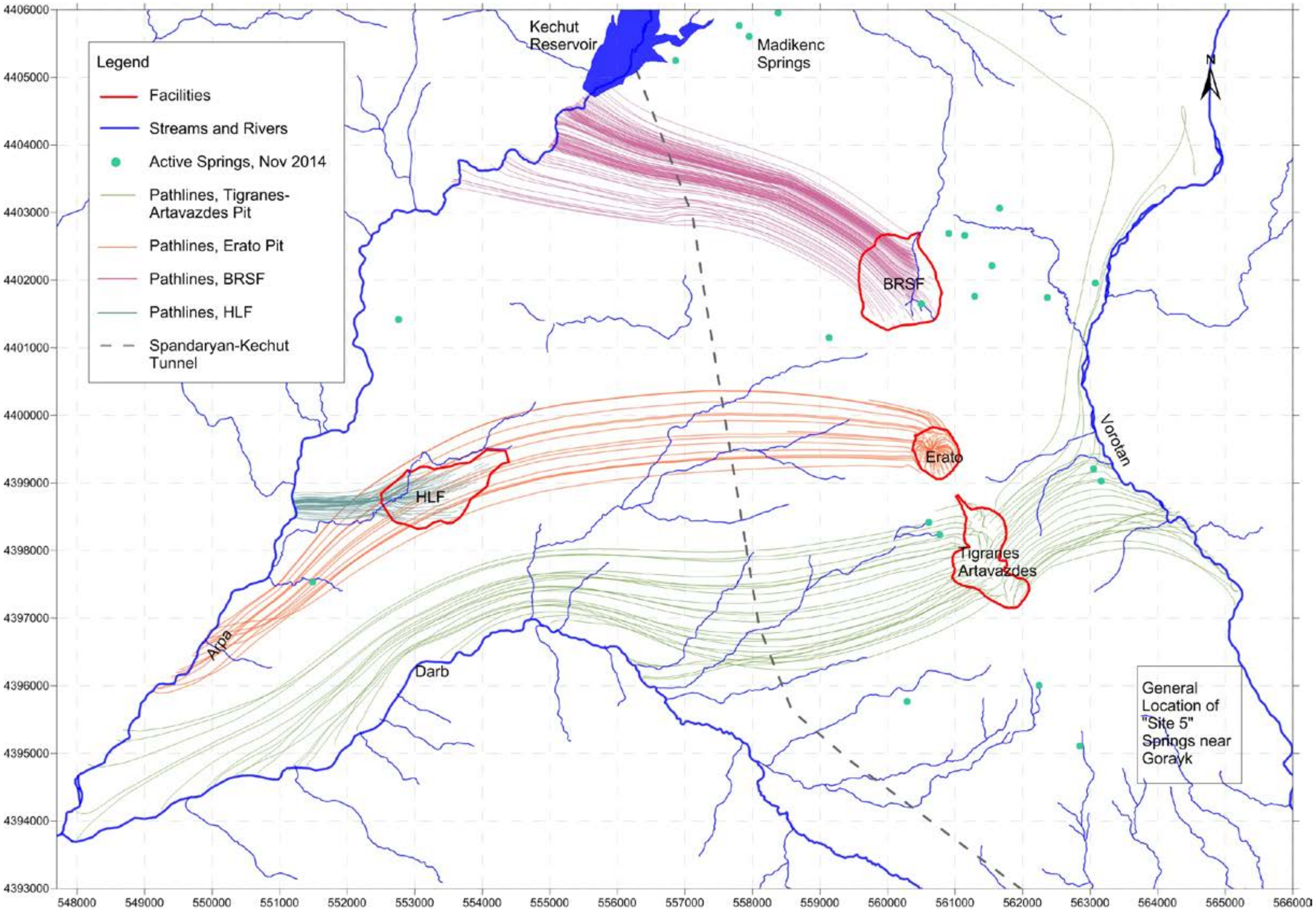

Figure 6.9.2 Groundwater Flow Pathlines during Operational Period

The Spandaryan-Kechut Tunnel intercepts groundwater, as is shown by discharge from the tunnel when the Spandaryan sluice is not open. The groundwater flow model predicts that groundwater originating from below the Erato and Tigranes-Artavazdes pits, and from the BRSF site, will flow beneath the Spandaryan-Kechut Tunnel. Under these conditions, the Kechut Reservoir and the Arpa River into which the Spandaryan-Kechut Tunnel discharges would not be secondary receptors for changes in groundwater. However, because of potential uncertainty in model results and the high sensitivity of the Spandaryan-Kechut water supply (Table 6.9.2), a worst-case analysis of groundwater inflow into the Spandaryan-Kechut Tunnel originating from the pits has been evaluated. The Spandaryan-Kechut assessment has been undertaken by combining potential impacts to groundwater quality from both the Tigranes-Artavazdes and Erato Pits and the BRSF assessment.

The operational model predicts a decrease in groundwater elevations of between 30 and 60 m in the vicinity of the BRSF because of reduced recharge. As a result, springs in the BRSF site may no longer flow. The groundwater discharge to the stream in the BRSF valley is also predicted to decline by approximately 24 %. A decrease in flow of 36 % is predicted in the spring cluster west of the BRSF.

Reduced recharge around the HLF results in a predicted decrease in groundwater elevations of between 3 m and 10 m. There are no perennial springs in this area that are predicted to be affected by this change.

None of the perennial springs present on the Amulsar flanks are located above the elevation of the pit bases and all of the springs lie within the seepage/surface discharge zone predicted by the operational model. This suggests that none of the perennial springs on the mountain flanks will be lost. However, capture and use of pit water and the consequent decrease in groundwater recharge will result in a slight reduction in spring flow of about 10 %. Ephemeral springs located above the pit floor elevation are likely to see a reduced flow because of changes in the surface water catchment area (Section 6.10).

A reduction in recharge in the BRSF area is predicted to result in a reduction in water supply to the catchment of the Kechut (Madikenc) springs. The groundwater model predicts a 10 % reduction in flow at these springs during operation.

The operational modelling indicates that by the end of mining there could be a small decrease in the amount of baseflow discharging to the major rivers and their tributaries draining from Amulsar. The decrease is estimated to be approximately 3 % of the current baseflow from the catchments within the Project Area in the Vorotan River, approximately 2 % in the Arpa River and approximately 1 % in the Darb River.

The groundwater flow model predicts that the reduction in groundwater input to the Spandaryan-Kechut Tunnel will be approximately 1 % of the current input. This reduction is predominately caused by a reduction in recharge in the area of the pits and the BRSF.

The groundwater flow model results indicate that similar receptors will potentially be impacted during both operational and closure phases. The post-closure groundwater flow pathlines are shown in Figure 6.9.3.

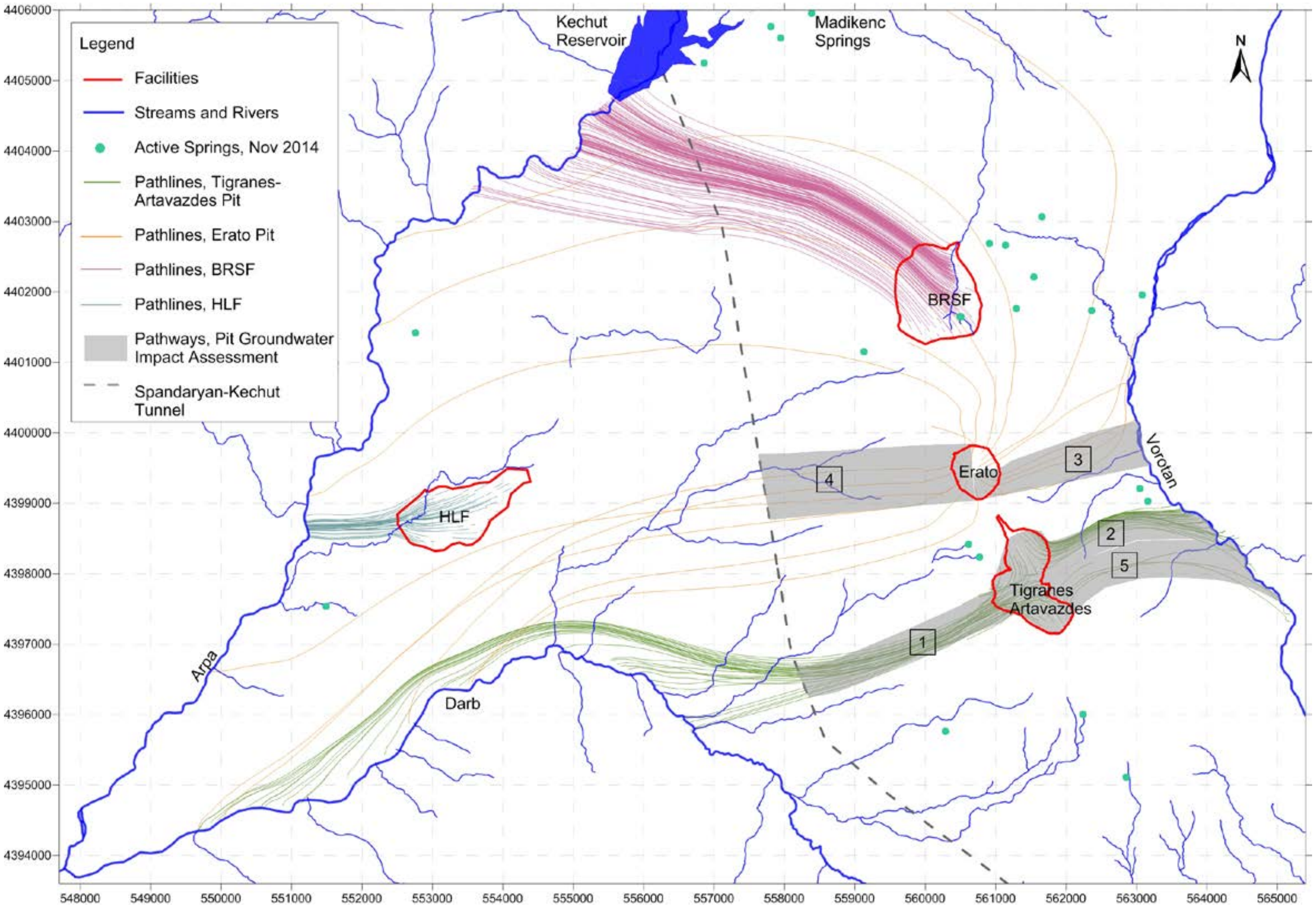

Figure 6.9.3: Groundwater Flow Pathlines during Post Closure

The key findings of the post-closure model are summarised below:

- There is predicted to be an increase in groundwater levels and perennial spring flow downgradient of the Erato pit as a result of increased infiltration in the pit footprint compared to baseline conditions. Locally (adjacent to the pit), groundwater levels are predicted to increase progressively by approximately 9 m to 16 m;
- There is predicted to be a decrease in groundwater levels and perennial spring flow, downgradient of Tigranes-Artavazdes as a result of decreased infiltration compared to baseline conditions. Locally, groundwater levels are predicted to progressively decrease by up to 40 m;
- Some perennial springs that currently flow at a very low rate during winter, particularly in the vicinity of Tigranes-Artavazdes, may become ephemeral (dry during the winter months);
- The flow in the perennial springs around the peak could progressively decrease by between 1 % and 6 % from baseline conditions;
- No perennial springs will be lost around the peak;
- Reduced recharge in the BRSF site may result in a progressive decrease in groundwater levels of up to 60 m in the southern portion of the BRSF, the decrease is anticipated to begin within a few years of construction of the facility due to the reduction in recharge within the footprint, but may occur over many years (see Appendix 6.9.1);
- Groundwater discharge to surface will likely cease in the southern part of the BRSF site;
- Discharge from springs in the valley west of the BRSF (which includes perennial spring SP68) is predicted to progressively reduce in the post-closure scenario by between 14 % and 20 % in comparison to baseline conditions;
- Groundwater discharge to the Kechut (Madikenc) springs is conservatively predicted to progressively decrease by approximately 7 % to 8 % over the long term. This change in flow is sensitive to several parameters including the interpreted hydrogeological conditions at and surrounding the BRSF, the recharge rate on the northern end of the Amulsar ridge and the rate of leakage from the BRSF (and, therefore, the change in groundwater elevation beneath the BRSF and the hydraulic gradient in the basalts feeding these springs);
- Groundwater discharge to the stream in the valley east of the BRSF is predicted to progressively decrease by between 11 % and 21 %;

- Groundwater discharge to the Spandaryan-Kechut Tunnel is predicted to progressively decrease by between 2 % and 3 %;
- Reduced recharge across the HLF footprint is predicted to result in a progressive decrease in groundwater levels of up to 13 m on the southeastern boundary. Similar to the BRSF, this decrease is anticipated to begin a within a few years of construction of the facility due to the reduction in recharge within the footprint, but may occur over many years (see Appendix 6.9.1); and
- The change in groundwater recharge is predicted to have minimal impact on groundwater baseflow to the Vorotan, Darb and Arpa Rivers. Model results predict a decrease in groundwater baseflow from catchments within the Project Area of approximately 2 % in the Vorotan River, approximately 2 % in the Arpa River and approximately 1 % in the Darb River.

Appendix 6.9.2 - Assessment of Nitrate and Ammonium Release from Blasting

The planned use of ammonium nitrate based blasting agents at the Erato and Tigranes-Artavazdes pits at the Amulsar site has the potential to affect groundwater quality. The potential concentrations of nitrogen in mining-influenced water based on the proposed use of explosives is presented in Table 6.9.3.

Table 6.9.3: Calculated Concentrations of Nitrate and Ammonium (as N) in Mine Water During Operations

	Nitrate Concentration (mg N/l)*		Ammonium Concentration (mg N/l)*	
Area	**Minimum**	**Maximum**	**Minimum**	**Maximum**
Pit Sumps	12 – 30	>1,000*	12 - 30	>1,000*
Pit Backfill Fluids	70	440	70	440
BRSF Fluids	13	420	13	420

Notes:
* Significant uncertainty in this high concentration, low volume sump water. Biological and chemical reactions in the pit sumps may result in lower concentrations, but cannot be predicted with confidence[10].

The ranges shown in the case of the pit sumps reflect seasonal fluctuations in water quality, as well as the range attributable to uncertainty regarding the proportion of ammonium nitrate-fuel oil based explosives (ANFO) that will contribute to nitrogen in the mine water. Maximum concentrations are predicted for small quantities of water during early autumn;

[10] Henrich, S. et. al., June 2011: The iron-oxidising proteobacteria. Microbiology volume 157, no. 6 pg 1551-1564.

minimum concentrations are predicted associated with the greatest quantities of water in June. For the pit backfill leakage and fluids within the BRSF engineered containment system, the range presented incorporates uncertainty regarding the degree of contact between the barren rock and infiltrating water and the proportion of ANFO which will contribute to nitrogen in mine water. These numbers represent a conservative estimate and concentrations could be reduced by applying management methods during operation and closure.

In the absence of relevant groundwater standards, and due to the fact groundwater reports to surface water in the form of springs, surface water Republic of Armenia Surface Water MACs have been used only **for information purposes** (and not as groundwater compliance targets) for the project. Calculated concentrations indicate that there is the potential for both ammonium and nitrate concentrations to exceed the MAC of 0.4 mg/l ammonium as N and 2.5 mg/l nitrate as N, in water infiltrating to groundwater from the pit sumps, and from the Tigranes-Artavazdes pit backfill. Concentrations of ammonium and nitrate in fluids within the engineered containment of the BRSF are predicted to exceed the Republic of Armenia MAC of 0.4 mg/l as N and 2.5 mg/l as N, respectively.

The results of this assessment are used to determine the source concentrations for mining-influenced water infiltrating from the Tigranes-Artavazdes and Erato Pits (Appendix 6.9.3) and the risk to groundwater quality from the BRSF (Appendix 6.9.5).

Appendix 6.9.3 - Assessment of Risk to Groundwater Quality from the Tigranes-Artavazdes and Erato Pits

Reactions between water and the exposed rock in the pits during operation have the potential to impact groundwater quality. The groundwater quality may potentially be affected by the interaction between water and the material used to backfill the pits during reclamation and onwards into the post closure phase. The purpose of this assessment was to determine the risk to drinking water supplies and the hydrologic system presented by the leakage of mine-influenced water from the pits.

The groundwater flow model indicates that leakage from the backfilled pits is most likely to flow towards Darb River and the Vorotan River. Therefore, the change in groundwater quality at the point of discharge to the Darb River and the Vorotan River has been calculated.
Predominant flow in the groundwater flow model is via Study Area-wide pathways to the

major rivers. However, the groundwater flow model represents a simplification of the complex intensely faulted geological conditions surrounding the pits. Due to the uncertainty introduced by the simplification of the geological model, the potential for infiltrating pit water to flow in shallow groundwater to springs surrounding the pits has also been considered in the pit groundwater quality impact assessment.

Given the sensitivity of the Spandaryan-Kechut water supply, its location downgradient of the pits and potential model uncertainty, the groundwater in the Spandaryan-Kechut Tunnel has also been considered as a receptor for flow from the pits.

The risk assessment predicts that because of the long groundwater travel time from the pit area to potential receptors, the peak impacts to receptor groundwater quality is not likely to be observed until the post-closure phase.

The predicted peak concentrations of the main constituents evaluated in groundwater are presented in Table 6.9.4. Figure 6.9.3 shows the flowpaths between sources and receptors. The predicted change in spring water quality has been determined for groups of springs, which are shown in Figure 6.9.4. The predicted peak concentrations of the main constituents evaluated in groundwater discharging to the springs are presented in Table 6.9.5.

In this and all subsequent tables, the colours assigned to the results relate to the magnitude of change assigned to each value using Table 6.9.1. Negligible changes have been highlighted in green; low impacts have been highlighted in yellow; moderate impacts have been highlighted in orange; and high impacts have been highlighted in red. These changes are discussed in the operational impacts and post closure impact assessment sections later in this chapter.

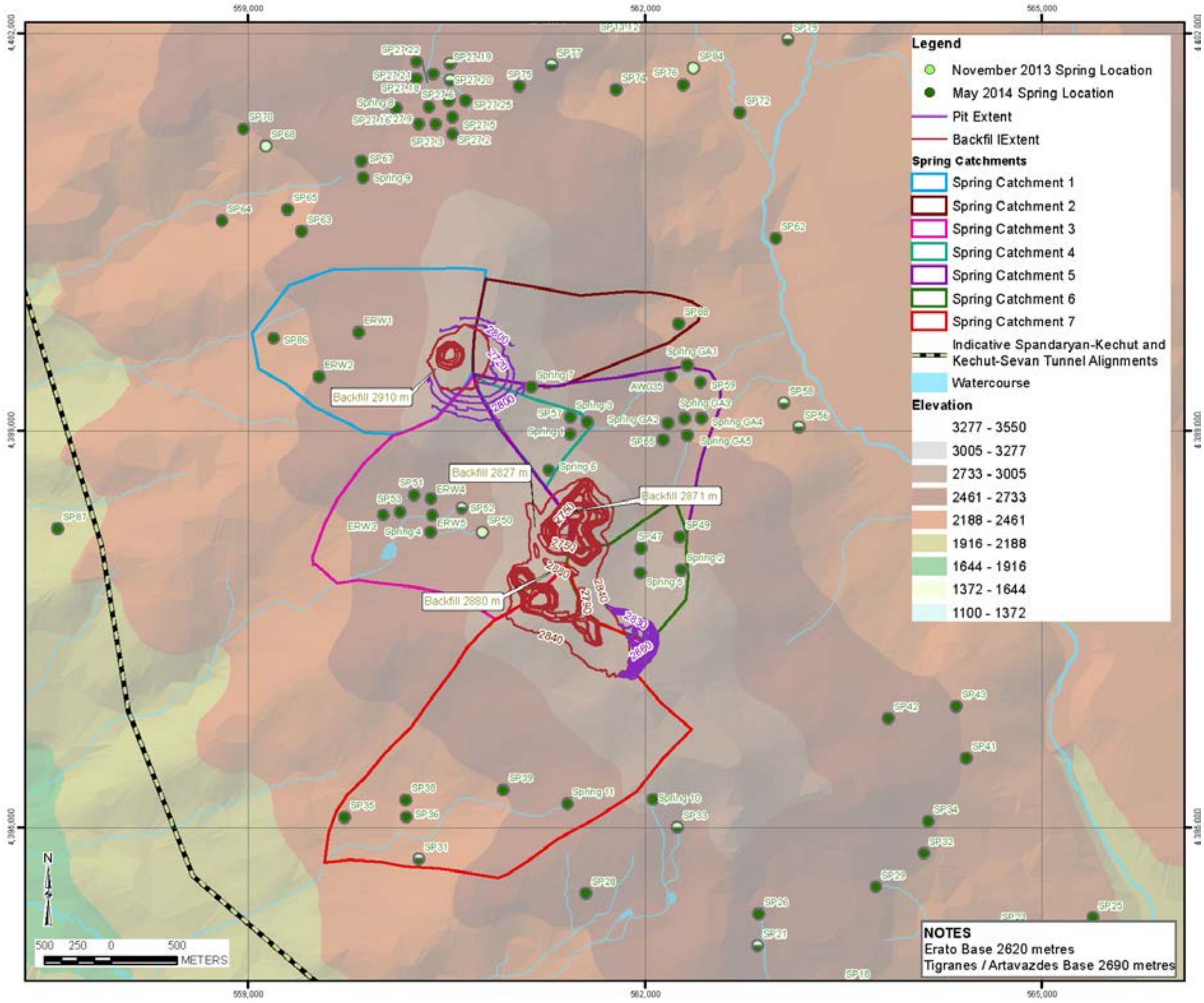

Figure 6.9.4: Spring Catchments used in Pit Risk Assessment

Table 6.9.4: Predicted Changes in Groundwater Concentrations in the Spandaryan-Kechut Tunnel and Prior to Discharge to the Rivers as a Result of Leakage from the Pits

Constituent	MAC II (mg/l) for Vorotan Catchment	Groundwater prior to discharge to Vorotan River			MAC II (mg/l) for Darb/Arpa Catchment	Groundwater in Spandaryan-Kechut Tunnel – Average Flow	Groundwater prior to discharge to Darb River	
		Predicted peak concentration from Pathway 2 Tigranes-Artavazdes Pit Source in mg/l (% change from baseline)	Predicted peak concentration from Pathway 5 Tigranes-Artavazdes Pit Source in mg/l (% change from baseline)	Predicted peak concentration from Pathway 3 Erato Pit Source in mg/l (% change from baseline)		Predicted peak concentration from combined Pathway 1 and 4 pit sources in mg/l (% change from baseline)	Predicted peak concentration from Pathway 1 Tigranes-Artavazdes Pit Source in mg/l (% change from baseline)	Predicted peak concentration from Pathway 4 Erato Pit Source in mg/l (% change from baseline)
Nitrate as N	2.5	5.79 (459%)	1.13 (9%)	n/a	2.5	0.57 (14.1%)	1.87 (274%)	n/a
Sulphate	17.02	34.02 (53%)	22.71 (2%)	25.12 (13%)	16.04	126.14 (0.1%)	127.2 (1%)	126.45 (0%)
Beryllium	5.4 $\times 10^{-5}$	0.00023 (0%)	0.00023 (0%)	0.0002 (0%)	3.8 $\times 10^{-5}$	0.0002 (0%)	0.0002 (0%)	0.0002 (0%)
Nickel	0.0105	0.0039 (0%)	0.0039 (0%)	0.0039 (0%)	0.0103	0.003 (0%)	0.003 (0%)	0.003 (0%)
Antimony	0.0005	n/a	n/a	0.001 (0%)	0.00028	0.001 (0%)	n/a	0.001 (0%)
Arsenic	0.02	0.001 (0%)	0.001 (0%)	0.001 (0%)	0.02	0.0068 (0%)	0.0068 (0%)	0.0068 (0%)
Cobalt	0.00028	0.0038 (0%)	0.0038 (0%)	0.0038 (0%)	0.00036	0.00051 (0%)	0.00051 (0%)	0.00051 (0%)
Cadmium	0.00101	0.0005 (0%)	0.0005 (0%)	0.0005 (0%)	0.00101	0.0005 (0%)	0.0005 (0%)	0.0005 (0%)
Chromium	0.0105	0.004 (0%)	0.004 (0%)	0.004 (0%)	0.011	0.005 (0%)	0.005 (0%)	0.005 (0%)
Molybdenum	0.002	n/a	n/a	0.0008 (0%)	0.00082	0.003 (0%)	n/a	0.003 (0%)

Table 6.9.4: Predicted Changes in Groundwater Concentrations in the Spandaryan-Kechut Tunnel and Prior to Discharge to the Rivers as a Result of Leakage from the Pits

Constituent	MAC II (mg/l) for Vorotan Catchment	Groundwater prior to discharge to Vorotan River			MAC II (mg/l) for Darb/Arpa Catchment	Groundwater in Spandaryan-Kechut Tunnel – Average Flow	Groundwater prior to discharge to Darb River	
		Predicted peak concentration from Pathway 2 Tigranes-Artavazdes Pit Source in mg/l (% change from baseline)	Predicted peak concentration from Pathway 5 Tigranes-Artavazdes Pit Source in mg/l (% change from baseline)	Predicted peak concentration from Pathway 3 Erato Pit Source in mg/l (% change from baseline)		Predicted peak concentration from combined Pathway 1 and 4 pit sources in mg/l (% change from baseline)	Predicted peak concentration from Pathway 1 Tigranes-Artavazdes Pit Source in mg/l (% change from baseline)	Predicted peak concentration from Pathway 4 Erato Pit Source in mg/l (% change from baseline)
Lithium	0.002	0.0017 (19%)	0.0016 (9%)	0.0059 (308%)	0.003	0.0044 (3.1%)	0.0044 (2%)	0.005 (17%)
Tin	0.00016	n/a	n/a	0*	8.00×10^{-5}	0.00011*	n/a	3.92×10^{-6} *

Notes:
n/a – not present in source term. * no baseline concentration to report percentage change. See text for shading categories.
MAC II concentrations provided for information only since does not apply directly to groundwater.

Table 6.9.5: Predicted Peak Changes in Spring Water Discharge as a Result of Leakage from the Pits									
Constituent	**MAC II (mg/l) for Catchments 1, 3 and 7**	**MAC II (mg/l) for Catchments 2, 4, 5 and 6**	**Predicted Concentration at Springs in mg/l (% change from baseline)**						
			Spring Catchment 1	**Spring Catchment 2**	**Spring Catchment 3**	**Spring Catchment 4**	**Spring Catchment 5**	**Spring Catchment 6**	**Spring Catchment 7**
Sulphate	16.04	17.02	7.54 (1%)	36.95 (0%)	20.03 (16%)	5.08 (2%)	5.23 (5%)	9.99 (100%)	6.17 (23%)
Antimony	0.00028	0.0005	0.00022 (7%)	0.00021 (2%)	0.00021 (3%)	0.00022 (11%)	0.0002 (1%)	0.0002 (0%)	0.0002 (0%)
Arsenic	0.02	0.02	0.001 (1%)	0.0014 (0%)	0.0011 (18%)	0.00096 (2%)	0.00096 (2%)	0.00093 (43%)	0.0011 (7%)
Beryllium	3.8×10^{-5}	5.4×10^{-5}	3.95×10^{-5} (32 %)	0.00028 (1%)	0.00038 (89%)	4.37×10^{-5} (46%)	4.48×10^{-5} (49%)	0.00033 (996%)	0.0001 (248%)
Cadmium	0.00101	0.00101	0.0005 (0%)	0.0005 (0%)	0.00053 (6%)	0.0005 (0%)	0.0005 (1%)	0.00056 (11%)	0.00051 (3%)
Cobalt	0.00036	0.00028	0.00059 (12%)	0.0086(0%)	0.0096 (1714%)	0.00056 (20%)	0.0012 (154%)	0.016 (4051%)	0.0043 (760%)
Chromium	0.011	0.0105	0.005 (1%)	0.005 (0%)	0.0044 (1%)	0.0033 (2%)	0.0032 (0%)	0.0027 (0%)	0.005 (0%)
Lithium	0.003	0.002	0.0011 (8%)	0.0022 (1%)	0.0013 (21%)	0.0011 (12%)	0.001 (2%)	0.0015 (52%)	0.0011 (8%)
Molybdenum	0.00082	0.002	0.00085 (6%)	0.00081 (2%)	0.0009 (2%)	0.00068 (11%)	0.00062 (1%)	0.00051 (0%)	0.0008 (0%)
Nickel	0.0103	0.0105	0.0031 (2%)	0.0061 (0%)	0.0098 (126%)	0.0025 (3%)	0.0029 (18%)	0.011 (526%)	0.0053 (76%)
Nitrate as N	2.5	2.5	0.53 (0%)	0.51 (0%)	3.66 (632%)	0.41 (0%)	0.66 (60%)	5.63 (1274%)	1.83 (266%)
Tin*	8.00×10^{-5}	0.00016	0.00042	0.00013	0.00018	0.00061	3.78×10^{-5}	0	0

Notes:
* No percentage change calculated as there is no baseline data for this constituent. See text for shading categories. No baseline data for tin, values shown represent predicted change only. MAC II concentrations provided for information only since this standard does not apply directly to groundwater.

Appendix 6.9.4 - Assessment of Risk to Groundwater Quality from the HLF

The construction, operation, reclamation and closure of the HLF have the potential to affect groundwater quality. Groundwater is not used as a drinking water resource in the vicinity of the HLF, and no groundwater use occurs between the HLF and the downgradient area of groundwater discharge to surface water at the Arpa River. Groundwater as a source of supply is therefore not considered to be a receptor in the context of this assessment. However, groundwater discharging to surface water (baseflow) is considered to be a receptor. Therefore, an assessment of the potential risk to groundwater as a result of the HLF was completed using a probabilistic solute transport model.

The concentration of constituents of potential concern in the HLF leakage as predicted by the solute transport model are mixed with the groundwater underflow from up gradient of the HLF facility at baseline groundwater concentrations in order predict the quality of groundwater downgradient of the HLF before it discharges to surface water. The model takes into account advection, dispersion, retardation and biodegradation in the groundwater pathways. The model does not represent unsaturated zone flow and transport processes. Based on the results of the groundwater flow model, two pathways are evaluated; one through deeper groundwater within the volcanic rocks towards the River Arpa; and one through shallow groundwater within colluvium and the upper volcanic rocks towards the stream in the HLF valley.

The results of the assessment of the predicted change in groundwater quality are summarised below. The 50th percentile value is considered the 'most likely' outcome, whilst the 95th percentile concentration is the conservative estimate of the possible maximum impact. Details behind the calculation of the results and any assumptions made are presented in the Appendix 6.9.4. The impact to surface water receptors as a result of the groundwater contributing to surface water flow is considered separately in Chapter 6.10.

The maximum calculated change in concentration in deep groundwater at the point of discharge to the Arpa River is presented in Table 6.9.6. The total discharge from deep groundwater to the Arpa River (i.e. including existing underflow from up gradient groundwater and the contribution of leakage from the HLF) at those predicted concentrations is between 2.1 L/s and 19.4 L/s.

Table 6.9.6: Calculated Maximum Change in Concentration in Deep Groundwater at Point of Discharge to the Arpa River				
Constituent	**50%ile Peak Concentration (mg/l)**	**Time to Peak Concentration (years)**	**95%ile Peak Concentration (mg/l)**	**Time to Peak Concentration (years)**
Arsenic	$<1x10^{-10}$	1000	$5.6x10^{-6}$	1000
Copper	N/A	>1000	N/A	>1000
Cobalt	N/A	>1000	N/A	>1000
Antimony	N/A	>1000	$<1x10^{-10}$	1000
Sodium	0.015	59	0.064	81
WAD Cyanide	N/A	>1000	$<1x10^{-10}$	840
NH3+NH4 as N	$<1x10^{-10}$	780	$<1x10^{-10}$	384
Nitrate as N	0.018	41	0.11	33
Notes: N/A – not applicable, parameter did not arrive at receptor inside the simulation period. >1000 – travel time to the receptor for the parameter is more than 1000 years. Positive values indicate an increase in concentration above existing conditions				

The potential peak concentrations in deep groundwater discharging to the Arpa River for the constituents of potential concern were then calculated based on the predicted change shown in Table 6.9.6 and mean baseline groundwater concentration. The peak predicted impact on the quality of groundwater discharging to the Arpa River of the values presented in Table 6.9.7.

Table 6.9.7: Peak Impact on Groundwater Quality discharging to Arpa River						
Constituent	**Unit**	**Arpa MAC Category II**	**Average Baseline Concentration**	**95%ile Change in Concentration**	**Predicted Peak Conc'n**	**Percentage Change**
Arsenic	mg/L	0.02	0.0042	$5.6x10^{-6}$	0.0042	0%
Copper	mg/L	0.021	0.0021	0	0.0021	0%
Cobalt	mg/L	$3.6x10^{-4}$	$3.0x10^{-4}$	0	$3.0x10^{-4}$	0%
Antimony	mg/L	0.00028	$2.0x10^{-4}$	0	$2.0x10^{-4}$	0%
Sodium	mg/L	10	27.1	0.064	27.1	0%
WAD Cyanide	mg/L	0.01*	0.005	0	0.005	0%
Ammonium as N	mg/L	n/a	0.54	$<1x10^{-10}$	0.54	0%
Nitrate as N	mg/L	2.5	0.70	0.1	0.8	16%
* There is no MAC for cyanide: this is a Project-specific target (see Section 2.4)						

The maximum calculated change in concentration in shallow groundwater at point of discharge to the HLF stream is presented in Table 6.9.8. These maximum changes occur during the closure and post-closure phase. The total discharge from shallow groundwater to the HLF stream at those predicted concentrations is between 0.02 L/s and 0.24 L/s in operation and 0.02 L/s and 0.08 L/s in closure.

Table 6.9.8: Calculated Maximum Change in Concentrations in Shallow Groundwater at Point of Discharge to the HLF Stream

Constituent	50%ile Peak Concentration (mg/l)	Time to Peak Concentration (years)	95%ile Peak Concentration (mg/)	Time to Peak Concentration (years)
Arsenic	$<1x10^{-10}$	1000	0.006	960
Copper	N/A	>1000	N/A	>1000
Cobalt	$<1x10^{-10}$	1000	$<1x10^{-10}$	1000
Antimony	$<1x10^{-10}$	1000	$<1x10^{-10}$	1000
Sodium	80.5	20	168	15
WAD Cyanide	$<1x10^{-10}$	1000	$9.30x10^{-5}$	960
NH3+NH4 as N	$2.10x10^{-4}$	1000	0.57	470
Nitrate as N	152	28	319	14.9

Notes:
N/A – not applicable, parameter did not arrive at receptor inside the simulation period. >1000 – travel time to the receptor for the parameter is more than 1000 years.

The potential peak concentrations in shallow groundwater discharging to the HLF stream for the constituents of potential concern were then calculated based on the predicted change shown in Table 6.9.8 and mean baseline groundwater concentration. The peak predicted impact on the quality of groundwater discharging to the HLF stream of the values is presented in Table 6.9.9. The significant increase in sodium and nitrate concentrations will be addressed during the final design process for the HLF. At this time, modification may be implemented in the HLF design to reduce seepage quantities/qualities and/or identify additional mitigation measures to contain and collect seepage prior to discharge to surface water.

Table 6.9.9: Peak Impact on Groundwater Quality discharging to HLF Stream						
Constituent	**Unit**	**Arpa MAC Category II**	**Average Baseline Concentration**	**95%ile Change in Concentration**	**Predicted Peak Conc'n**	**Percentage Change**
Arsenic	mg/L	0.02	0.0049	0.006	0.011	124%
Copper	mg/L	0.021	0.0013	0	0.0013	0%
Cobalt	mg/L	$3.6x10^{-4}$	$3.0x10^{-4}$	0	$3.0x10^{-4}$	0%
Antimony	mg/L	0.00028	$2.0x10^{-4}$	$<1x10^{-10}$	$2.0x10^{-4}$	0%
Sodium	mg/L	10	17.0	168	185	990%
WAD Cyanide	mg/L	0.01*	0.005	$9.3x10^{-5}$	0.0051	2%
Ammonium as N	mg/L	n/a	0.1	0.6	0.7	481%
Nitrate as N	mg/L	2.5	1.1	319.0	320.1	>1000%

Notes:
MAC II concentrations provided for information only since does not apply directly to groundwater.
*There is no MAC for cyanide: this is a Project-specific standard (see Section 2.4)

The colours assigned to the results tables relate to the magnitude of change assigned to each value using Table 6.9.1. These changes are discussed in the operational impacts and post closure impact assessment sections later in this chapter.

Appendix 6.9.5 - Assessment of Groundwater Impacts from the BRSF

An assessment has been undertaken to determine the potential risk to hydrologic receptors as a consequence of leakage from the BRSF.

Groundwater is not used as a drinking water resource in the vicinity of the BRSF, and no groundwater use occurs between the BRSF and the area of discharge to surface water (the Kechut Reservoir and the Arpa River). Groundwater as a source of supply is, therefore, not considered to be a receptor in the context of this assessment.

The groundwater flow model indicates that some leakage from the BRSF flows beneath the Spandaryan-Kechut Tunnel. Given the sensitivity of the Spandaryan-Kechut water supply, its location downgradient of the BRSF and potential model uncertainty, the groundwater in the Spandaryan-Kechut Tunnel has also been considered as a receptor for flow from the BRSF.

The potential groundwater flowpath to the Spandaryan-Kechut Tunnel is the shortest flow path from groundwater originating at the BRSF. The assessment presented in Appendix 6.9.5 assumes that the leakage from the BRSF enters groundwater, mixes with natural recharge along the flow path, enters the tunnel and mixes with the groundwater in the tunnel. The results of the assessment are reproduced in Table 6.9.10.

Table 6.9.10: Potential Change in Concentrations in the Spandaryan-Kechut Tunnel from BRSF Leakage

Constituent	Units	Arpa MAC Standards (II)	Average Quality in AWJ6 (representing current groundwater conditions in the tunnel)	Estimated Concentration in Groundwater in the Tunnel (including input from BRSF leakage)	Increase in concentration as a result of input from BRSF leakage
Aluminium	µg/l	144	72	N/A	0%
Arsenic	µg/l	20	6.76	N/A	0%
Barium	µg/l	28	20.4	N/A	0%
Beryllium	µg/l	0.038	0.2	N/A	0%
Boron	µg/l	450	0.0542	0.1	94%
Cadmium	µg/l	1.014	0.5	N/A	0%
Calcium	mg/l	100	63.9	N/A	0%
Chloride	mg/l	6.88	3.07	3.1	0%
Chromium (III)	µg/l	11	5	N/A	0%
Cobalt	µg/l	0.36	0.505	N/A	0%
Iron(III)	mg/l	0.072	0.404	N/A	0%
Lead	µg/l	10.14	1.99	N/A	0%
Lithium	µg/l	3	4.27	4.3	1%
Magnesium	mg/l	50	9.35	9.4	0%
Manganese	µg/l	12	39.1	N/A	0%
Nickel	µg/l	10.34	3	N/A	0%
Nitrate	mg N/l	2.5	0.5	0.8	67%
Potassium	mg/l	3.12	3.12	3.2	1%
Selenium	µg/l	20	5	N/A	0%
Sulphate	mg/l	16.04	126	126.4	0%
Zinc	µg/l	100	3.78	N/A	0%

Notes:
N/A – constituent will not travel to the receptor within 1000 years.
MAC II concentrations provided for information only since does not apply directly to groundwater.

The groundwater flow model indicates that the more likely groundwater flow route is a longer pathway (along which greater mixing would occur) between the BRSF and groundwater discharge to the Arpa River downstream of the Kechut Reservoir. The results of the assessment of this pathway (i.e. the concentrations of constituents in groundwater immediately before discharge to the Arpa River) are presented in Table 6.9.11. Only results for constituents that are predicted to have travel times of less than 1000 years are presented. All other constituents are predicted to arrive at the point of discharge after more than 1000 years.

Table 6.9.11: Potential Increase in Groundwater Concentration from BRSF Leakage (Post Closure)

Constituent	Units	Arpa MAC Standards (II)	Average Quality in AWJ6 (representing current groundwater conditions)	Estimated Concentration in groundwater before discharge to Arpa River (including background)	% Increase in groundwater concentration
Boron	µg/l	450	0.0542	0.3	437%
Chloride	mg/l	6.88	3.07	3.1	0%
Lithium	µg/l	3	4.27	4.5	5%
Magnesium	mg/l	50	9.35	9.4	1%
Nitrate	mg N/l	2.5	0.5	2.1	311%
Potassium	mg/l	3.12	3.12	3.3	5%
Sulphate	mg/l	16.04	126	127.8	1%

Notes:
MAC II concentrations provided for information only since does not apply directly to groundwater.

The colours assigned to the results relate to the magnitude of change assigned to each value using Table 6.9.1. These changes are discussed in the operational impacts and post closure impact assessment sections later in this chapter.

Construction Phase Impacts

The construction phase will include the construction of the mine facilities (i.e. the ADR plant, crusher, stores, office/camp buildings, conveyors, retention and sediment ponds, and roads). There are no planned or engineered discharges to groundwater during the construction phase. This section considers the potential impacts and effects on the groundwater receptors as a result of the construction activities. The source of the potential impact and subsequent magnitude of change, effect of significance and scale of significance are presented in Table 6.9.12. Construction and operation of the BRSF and HLF will not take place until the operational phase; therefore, potential impacts from these facilities are evaluated later.

Perched Water/Ephemeral Springs

The mine facilities that are part of construction phase development, will affect small areas of the total ephemeral spring catchments so will result in a **negligible** change in the quantity of water from the springs.

During construction, the water management plan, combined with appropriate training of contractors, will ensure that surface water runoff is managed and sediment discharge is controlled. Therefore, potential impacts to spring water quality via infiltration to groundwater are anticipated to be limited, and only associated with accidental spillages or release. Accidental spillages would result in a negative impact; the source of which would be short-lived. Such spills would be rapidly remediated so the potential change in spring water quality is considered to be **negligible**.

This assessment related only to the predicted impact on the discharge of groundwater at springs. A discussion of how spring discharge quality and quantity changes affect watercourses, and of how other aspects such as changes in surface run-off quantity and quality affect watercourses, is presented in Chapter 6.10.

Perennial Springs

The potential construction-related impacts to the perennial springs are similar to those identified for the perched water/ephemeral springs.

Hydrothermal Springs

Baseline characterisation has concluded that these springs do not receive groundwater flow from the Project area. There will not be any changes in groundwater flow or quality at the hydrothermal springs. The potential change in the quantity and quality of discharge from the hydrothermal springs is considered to be **negligible**.

Groundwater Used for Supply Purposes

Kechut Springs

Construction activities will not take place in the area of the Madikenc group of springs. Therefore, the potential change to groundwater quantity and quality at this receptor is predicted to be **negligible**.

Springs North of Gorayk

Construction activities will not take place in the area these springs. Therefore, the potential change to groundwater quantity and quality at this receptor is predicted to be **negligible**.

Spandaryan-Kechut Tunnel

Construction phase activities with the potential to influence groundwater recharge rates (such as lining of ponds and building construction) and groundwater quality (such as localised and short-lived accidental spills from vehicle fuelling) will occur in a small proportion (likely to be less than 1 %) of the groundwater catchment contributing to the tunnel within the Project area. Any spills would be rapidly remediated. Therefore, the potential change to groundwater discharge and groundwater quality in the Kechut-Spandaryan Tunnel is considered to be **negligible**.

Groundwater Component of Surface Water Baseflow

Construction phase activities with the potential to influence groundwater recharge rates (such as lining of ponds and building construction) and groundwater quality (such as localised and short-lived accidental spills from vehicle fuelling) will occur in a small proportion of the groundwater catchment within the Project Area (likely to be less than 1 %). Any spills would be rapidly remediated. Therefore, the extent of influence of construction phase activities on groundwater baseflow quantity and the magnitude of any quality impact is considered to be **negligible**.

Table 6.9.12: Potential Construction Phase Groundwater Effect Significance (Including Mitigation Measures)					
Receptor	**Receptor Sensitivity**	**Potential Impact**	**Magnitude of Change**	**Effect Significance**	**Scale of Significance**
Perched Water/ Ephemeral Springs - Pit areas	Medium	Reduction in quantity as a result of spring, or spring catchment, removal.	Negligible	Negligible	Not significant
		Reduction in quality as a result of accidental spillages.	Negligible	Negligible	Not significant
Perched Water/ Ephemeral Springs - BRSF and Surrounding Area	Medium	Reduction in quantity as a result of spring, or spring catchment, removal.	Negligible	Negligible	Not significant
		Reduction in quality as a result of accidental spillages.	Negligible	Negligible	Not significant
Perched Water/ Ephemeral Springs - HLF and Surrounding Area	Medium	Reduction in quantity as a result of spring, or spring catchment, removal.	Negligible	Negligible	Not significant
		Reduction in quality as a result of accidental spillages.	Negligible	Negligible	Not significant
Perennial Springs - Pit areas	Minor	Reduction in quantity as a result of spring, or spring catchment, removal.	Negligible	Negligible	Not significant
		Reduction in quality as a result of accidental spillages.	Negligible	Negligible	Not significant
Perennial Springs - BRSF and Surrounding Area	Minor	Reduction in quantity as a result of spring, or spring catchment, removal.	Negligible	Negligible	Not significant
		Reduction in quality as a result of accidental spillages.	Negligible	Negligible	Not significant
Perennial Springs - HLF and Surrounding Area	Minor	Reduction in quantity as a result of spring, or spring catchment, removal.	Negligible	Negligible	Not significant
		Reduction in quality as a result of accidental spillages.	Low Negligible	Negligible	Not significant
Hydrothermal Springs - Jermuk	High	No activities that could impact the predicted quantity or quality of groundwater at this receptor.	Negligible	Minor	Not significant

Table 6.9.12: Potential Construction Phase Groundwater Effect Significance (Including Mitigation Measures)					
Receptor	**Receptor Sensitivity**	**Potential Impact**	**Magnitude of Change**	**Effect Significance**	**Scale of Significance**
Groundwater Used for Supply Purposes – Kechut Springs	Medium	No activities that could impact the predicted quantity or quality of groundwater at this receptor.	Negligible	Negligible	Not significant
Groundwater Used for Supply Purposes - Springs North of Gorayk	Minor	No activities that could impact the predicted quantity or quality of groundwater at this receptor.	Negligible	Negligible	Not significant
Groundwater Used for Supply Purposes - Kechut-Spandaryan Tunnel	High	Construction of buildings and lined ponds will locally reduce groundwater recharge.	Negligible	Minor	Not Significant
		Reduction in quality as a result of accidental spillages	Negligible	Minor	Not Significant
Groundwater Component of Surface Water Baseflow - Darb River catchment	Medium	Construction of buildings and lined ponds will locally reduce groundwater recharge.	Negligible	Negligible	Not Significant
		Reduction in quality as a result of accidental spillages	Negligible	Negligible	Not Significant
Groundwater Component of Surface Water Baseflow - Arpa River catchment	Medium	Construction of buildings and lined ponds will locally reduce groundwater recharge.	Negligible	Negligible	Not Significant
		Reduction in quality as a result of accidental spillages	Negligible	Negligible	Not Significant
Groundwater Component of Surface Water Baseflow - Vorotan River catchment	Medium	Construction of buildings and lined ponds will locally reduce groundwater recharge.	Negligible	Negligible	Not Significant
		Reduction in quality as a result of accidental spillages	Negligible	Negligible	Not Significant

Operational Phase Impacts

The operational phase includes the mining of the pits, the operation of the crusher and conveyor, the construction and operations of the HLF and BRSF, and the construction of additional topsoil and ore stockpiles as mining continues. Additional ponds will be added and existing ponds extended during operations. Access roads and ancillary facility (workshops, offices) may be expanded during operation.

During operations, the Project has the potential to impact groundwater quantity and groundwater quality. Water management activities and lining of facilities will reduce groundwater recharge and result in lower groundwater levels in parts of the Project area, and consequent reduction in baseflow to springs, streams and rivers. Management of acid generating barren rock (in the BRSF and backfilled pits) has the potential to impact groundwater quality, as does leakage of pregnant or barren leach solution from the HLF. Infiltration from the pit sumps, and from ore stockpiles also poses a potential risk to groundwater if stockpiles are not appropriately designed and managed.

This section considers the potential impacts and effects on the identified groundwater receptors during the operational phase. The source of the potential impact and subsequent magnitude of change are summarised in Table 6.9.13. The effect significance and scale of significance are also presented in Table 6.9.13. Any potential impacts from operational activities that are not predicted to occur or peak until the post-closure phase are presented in the post closure impact assessment section.

Perched Water/Ephemeral Springs

Pit Area of Amulsar Peak

There will be no direct loss of ephemeral springs due to mining. Where mining removes some of the catchment area supply to an ephemeral spring, there will be a reduction in catchment area leading to reduced flow. The maximum reduction would occur once the pits have been mined to their maximum extent and depth. The magnitude of potential changes in ephemeral spring discharge quantity in the pit area as a result of operation is considered to be low.

Ephemeral springs are mainly fed by small catchments and near surface flow from snow melt, consequently it is unlikely that quality of the spring water will be impacted unless an activity takes place within that catchment. During the operational phase, leakage from the pits could impact ephemeral spring water quality i.e. if the pit sump is above the elevation of the ephemeral spring. However, during operations, the majority of the water in the pits will be captured in a sump and pumped out for use in the closed water management system and leakage will be minimal. Therefore, the source of the change in quality will be minimised. Greater leakage would occur if water was temporarily stored for an extended period within the pits (e.g. after snow melt or an extreme rainfall event). However, the quality of that water would be improved by mixing with precipitation. Overall, the magnitude of potential changes in ephemeral spring discharge quality in the pit area as a result of operation is considered to be **low.**

BRSF and Surrounding Area

There are ephemeral springs located in the BRSF area and some of these springs lie within the footprint area of the BRSF. The springs located beneath the BRSF will decrease or cease to flow after the BRSF is constructed. Any temporary discharge from these springs will be captured by the BRSF underdrain and discharged to the closed water management system. Therefore, discharge will be lost from the local and Project area hydrologic system. The magnitude of potential changes in ephemeral spring discharge quantity in the BRSF area as a result of operation is considered to be **high**.

Any spring discharges that remain and are located beneath the BRSF will be captured by the underdrain and discharged to the closed water management system. There will be no release of this captured water to the environment; therefore, the potential impact on spring quality is not considered.

Ephemeral springs that are located in the area of the BRSF, but not beneath it (i.e. springs located in the valley to the west), are predominantly supported by snow melt and near-surface flow. If there is no change to their catchment area and the amount of snow in their catchments, and the management plans are followed, the impact to the quantity and quality of these springs will be **negligible**.

HLF and Surrounding Area

There are ephemeral springs located in the HLF area and some of these springs lie within the footprint area of the HLF. For the same reasons presented in relation to springs located beneath the BRSF, the magnitude of potential changes in ephemeral spring discharge quantity in the HLF area as a result of operation is considered to be **high** and the potential impact on spring quality is not appropriate because of the loss and/or collection of flow.

As with the springs located to the west of the BRSF, the impact to quantity and quality of the ephemeral springs that are located in the area of the HLF will be **negligible**.

Perennial Springs

Pit Area of Amulsar Peak

The perennial springs in the pit area are generally located below the elevation of the final pit floor and all of the springs lie within the seepage/surface discharge zone predicted by the groundwater flow model. This suggests that all of the perennial springs on the mountain flanks will continue to flow. However, because of a reduction in recharge, the groundwater flow model predicts a decrease in groundwater levels in the pit area. This decrease in groundwater levels in turn results in a predicted reduction in spring discharge of approximately 10 %. The magnitude of this change in quantity of discharge at the perennial springs in the pit area is considered to be **low**.

During the operational phase, leakage from the pit sump could impact perennial spring water quality. During operations, the majority of the water in the pits will be captured in sumps and pumped for use in the closed water management system and leakage will be minimal. Therefore, the source of the change in quality will be minimised. Greater leakage would occur if water was temporarily stored within the pits (e.g. after snow melt or an extreme rainfall event). However, the quality of that water would be improved by mixing with precipitation. Overall, the magnitude of potential changes in perennial spring discharge quality in the pit area is considered to be **low**.

BRSF and Surrounding Area

There are perennial springs located in the BRSF area and some of these springs lie within the footprint area of the BRSF. The operational model predicts a decrease in groundwater elevations of up to 60 m in the vicinity of the BRSF because of reduced recharge and perennial springs are likely to cease to flow. The magnitude of potential changes in perennial spring discharge quantity in the BRSF area as a result of operation is considered to be **high** and potential impact on spring quality is not considered.

There is one perennial spring located in the valley to the west of the BRSF. The groundwater model predicts a decrease in flow of 36 % as a result of reduced recharge at the BRSF. The impact on quantity is, therefore, predicted to be **moderate**. The groundwater flow model does not predict any flowpaths between any of the potential sources of impact (i.e. pits, and

BRSF) and these springs. Therefore, there is no source of impact on the quality at these springs and the change in quality is considered to be **negligible**.

HLF and Surrounding Area

There are no perennial springs located beneath the HLF footprint or the proposed adjacent PTS (two systems: one to treat contact water from the BRSF from year 5 and the second to treat seepage from the HLF post closure).

Reduced recharge around the HLF is predicted to decrease groundwater elevations of between 3 m and 10 m; therefore, the areas of wet ground near to the HLF could be affected. The potential impact on spring flow quantity is considered to be **moderate**. The groundwater flow model does not predict any flowpaths between any of the potential sources of impact (i.e. pits, and HLF) and these springs. Therefore, there is no source of impact on the quality at these springs and the change in quality is considered to be **negligible**.

Hydrothermal Springs

Hydrogeological characterisation indicates that these springs do not receive groundwater flow the Project area. It is not, therefore, possible for changes in groundwater flow or quality within the Amulsar Project area to influence the quantity or quality of discharge from the hydrothermal springs. The potential change in the quantity and quality of discharge from the hydrothermal springs is considered to be **negligible**.

Groundwater Used for Supply Purposes

Kechut (Madikenc) Springs

The groundwater flow model predicts a reduction in recharge to the catchment of these springs, mainly due to a reduction in recharge in the area of the BRSF. The reduction in flow between the baseline and operational phases is predicted to be approximately 10 %. This operational phase change is considered to be of **low** magnitude.

The groundwater flow model does not predict any flowpaths between any of the potential sources of impact (i.e. pits, BRSF or HLF) and these springs. Therefore, there is no source of impact on the quality at these springs and the change in quality is considered to be **negligible**.

Springs North of Gorayk

The groundwater flow model predicts that there will be no change in recharge to the catchment in the area of these springs, and no change in groundwater levels, as a result of the mine development. Therefore, there is no source of impact to the quantity of discharge at these springs and the change is considered to be **negligible**.

The groundwater flow model does not predict any flowpaths between any of the potential sources of impact (i.e. pits, BRSF or HLF) and these springs. Therefore, there is no source of impact to quality at these springs and the change in quality is considered to be **negligible**.

Spandaryan-Kechut Tunnel

Under baseline conditions the sluice at the Spandaryan entrance is closed and the tunnel is not in use. The water flowing out from the Kechut end of the tunnel is interpreted to be groundwater. This flow currently augments the water supply in the Kechut Reservoir. The groundwater flow model predicts that there will be a small reduction of recharge in the area that supplies groundwater inflow into the tunnel. This reduction is due to capture of precipitation in the pits for use in mine process water supply and due to reduction of infiltration associated with the construction of the BRSF. This change in recharge is predicted to reduce to groundwater inflow to the tunnel by approximately 1 %. The magnitude of change in flow quantity is considered to be **low**.

While the groundwater flow model predicts no pathways from the mine facilities to the tunnel, the water in the tunnel is considered a highly sensitive receptor and subject to considerable stakeholder concerns. Therefore, as a worst-case analysis it is assumed that infiltration flowing westwards from the pits and the BRSF has the potential to change the quality of groundwater entering the tunnel. The predicted changes in groundwater quality in the tunnel are not predicted to occur during the operational phase, so the magnitude of change in groundwater quality at the tunnel is considered to be **negligible**. The peak impact is predicted to occur during the closure phase, presented later in this chapter.

Groundwater Component of Surface Water Baseflow

Darb River Catchment

The groundwater flow model predicts that there will be a reduction in groundwater input to baseflow in the Darb River of approximately 1 %. This reduction in flow is predominantly caused by a reduction in recharge in the Darb River catchment area due to the pits capturing the precipitation that would have contributed to infiltration and groundwater recharge under baseline conditions. Pit water will enter the closed water management system during operations. The predicted change in baseflow will be of **low** magnitude.

The groundwater flow model predicts that there are potential flowpaths from the pits to the Darb River. A change in groundwater quality could be caused by infiltration from the pit sumps. Because of the long groundwater travel time (tens of years), the predicted impacts to groundwater at the Darb River are not predicted to occur during the operational phase, so the magnitude of change is considered to be **negligible**. The peak impact is predicted to occur during the closure phase, presented later in this chapter.

Arpa River Catchment

The groundwater flow model predicts that there will be a reduction in groundwater input to baseflow in the Darb River of approximately 2 %. This reduction in flow is predominantly caused by a reduction in recharge of precipitation to groundwater beneath the BRSF and HLF compared to baseline conditions. The predicted change will occur during the operational phase and will be of **low** magnitude.

The groundwater flow model predicts that there will be flowpaths towards the Arpa River from the HLF and the BRSF. Any change in groundwater quality beneath the HLF or BRSF due to leakage from these facilities has the potential to impact groundwater quality adjacent to the Arpa River. The changes in groundwater quality as a result of leakage from the HLF are predicted to affect groundwater adjacent to the Arpa River downgradient of the HLF (a zone approximately 8 km downstream of the Kechut Reservoir). If the groundwater affected by leakage from the BRSF were to enter the Spandaryan-Kechut Tunnel rather than discharge as baseflow then there would be no quality change in groundwater adjacent to the Arpa River; the only change would be due to the potential impact of the HLF.

Therefore, impacts due to leakage from both the HLF and the BRSF are considered in this assessment. Because of the long groundwater travel time, the assessment of potential impact from the BRSF (Appendix 6.9.5) and the assessment of potential impact from the HLF (Appendix 6.9.4) predict that the maximum change in groundwater quality adjacent to the Arpa River will not occur during the operational phase. Therefore, the magnitude of change is considered to be **negligible**. The peak impact is predicted to occur during the closure phase, presented later in this chapter.

Vorotan River Catchment

The groundwater flow model predicts that there will be a reduction in groundwater input to baseflow in the Vorotan River of approximately 3 %. This reduction in flow is predominantly caused by reduced recharge to groundwater beneath the BRSF, and by the capture and use of precipitation in the pits. The predicted change will occur during the operational phase and will be of **low** magnitude.

The groundwater flow model predicts that there are potential flowpaths from the pits to the Vorotan River. A change in groundwater quality could be caused by infiltration from the pit sumps. Because of the long groundwater travel time, the predicted impacts to groundwater at the Vorotan River are not predicted to occur during the operational phase, so the magnitude of change is considered to be **negligible**. The peak impact is predicted to occur during the closure, presented later in this chapter.

Table 6.9.13: Potential Operational Phase Groundwater Effect Significance (Including Mitigation Measures)

Receptor	Receptor Sensitivity	Potential Impact	Magnitude of Change	Effect Significance	Scale of Significance
Perched Water/ Ephemeral Springs - Pit areas	Medium	Possible reduction in flows as a result of changes within their localised catchment area.	Low	Minor	Not significant
		Leakage from water stored within the pits may decrease water quality.	Low	Minor	Not significant
Perched Water/ Ephemeral Springs - BRSF and Surrounding Area	Medium	Loss of springs under BRSF footprint.	High	Moderate	Significant
		No change in catchment area predicted for springs located in the BRSF area, but outside the BRSF footprint.	Negligible	Negligible	Not significant
		No predicted quality impact predicted for springs located in the BRSF area.	Negligible	Negligible	Not significant
Perched Water/ Ephemeral Springs - HLF and Surrounding Area	Medium	Loss of springs under HLF footprint	High	Moderate	Significant
		No change in catchment area predicted for springs located in the HLF area, bit outside the HLF footprint.	Negligible	Negligible	Not significant

Table 6.9.13: Potential Operational Phase Groundwater Effect Significance (Including Mitigation Measures)

Receptor	Receptor Sensitivity	Potential Impact	Magnitude of Change	Effect Significance	Scale of Significance
		No predicted quality impact predicted for springs located in the HLF area	Negligible	Negligible	Not significant
Perennial Springs - Pit areas	Minor	Reduction in flows of to the springs due to a reduction in recharge are and groundwater levels.	Low	Negligible	Not significant
		Leakage from water stored within the pits may decrease water quality.	Low	Negligible	Not significant
Perennial Springs - BRSF and Surrounding Area	Minor	Loss of springs under BRSF footprint	High	Moderate	Significant
		Reduction in flow to spring to the west of the BRSF.	Moderate	Minor	Not significant
		No predicted quality impact.	Negligible	Negligible	Not significant
Perennial Springs - HLF and Surrounding Area	Minor	Reduction of catchment for springs in immediate area.	Moderate	Moderate	Not significant
		No predicted quality impact.	Negligible	Negligible	Not significant
Hydrothermal Springs - Jermuk	High	No predicted change in flows.	Negligible	Minor	Not significant
		No predicted change in quality.	Negligible	Minor	Not significant
Groundwater Used for Supply Purposes – Kechut Springs	Medium	Small reduction in flows predicted as a result of reduced recharge in the BRSF area.	Low	Minor	Not significant
		No predicted change in quality.	Negligible	Negligible	Not significant
Groundwater Used for Supply Purposes - Springs North of Gorayk	Minor	No predicted change in flows.	Negligible	Negligible	Not significant
		No predicted change in quality.	Negligible	Negligible	Not significant
Groundwater Used for Supply	High	Predicted reduction in groundwater flow to tunnel of approximately	Low	Moderate	Significant^

Table 6.9.13: Potential Operational Phase Groundwater Effect Significance (Including Mitigation Measures)

Receptor	Receptor Sensitivity	Potential Impact	Magnitude of Change	Effect Significance	Scale of Significance
Purposes – Spandaryan-Kechut Tunnel		1 %.			
		Infiltration from pits and leakage from BRSF. No change in quality predicted during the operational phase. Change in quality predicted to occur in closure phase.	Negligible	Minor	Not significant
Groundwater Component of Surface Water Baseflow - Darb River catchment	Medium	Reduction in baseflow predicted to be approximately 1 %.	Low	Minor	Not significant
		Infiltration from pits. No change in quality predicted during the operational phase. Change in quality predicted to occur in closure phase.	Negligible	Negligible	Not significant
Groundwater Component of Surface Water Baseflow - Arpa River catchment	Medium	Reduction in baseflow predicted to be approximately 2 %.	Low	Minor	Not significant
		Leakage from HLF and BRSF. No change in quality predicted during the operational phase. Change in quality predicted to occur in closure phase.	Negligible	Negligible	Not significant
Groundwater Component of Surface Water Baseflow - Vorotan River catchment	Medium	Reduction in baseflow predicted to be approximately 3 %.	Low	Minor	Not significant
		Infiltration from pits and leakage from BRSF. No change in quality predicted during the operational phase. Change in quality predicted to occur in closure phase.	Negligible	Negligible	Not significant

Notes:
^ Groundwater inflow was not intended to be the main source of water in the Spandaryan-Kechut tunnel that provides supply, so this reduction in flows should not be considered as a material impact.

Closure Phase Impacts

During closure, reduced recharge rates in developed areas (the BRSF, HLF and backfilled pits) may result in a long term decrease in groundwater levels in some areas, whilst capture of precipitation in any open pits will result in enhanced recharge and locally increased groundwater levels. Groundwater baseflow to springs, streams and rivers may therefore be increased or decreased in closure, depending on the area considered.

Areas of barren rock backfill/storage will continue to pose a potential risk to groundwater quality in closure, as will the spent ore within the HLF.

Any impacts resulting from operational activities that are not predicted to be detected at the receptors until the post-closure phase, or that are predicted to be at their peak during the post closure phase, are also considered in this part of the impact assessment. The source of the potential impact and subsequent magnitude of change are summarised in Table 6.9.15. The effect significance and scale of significance are also presented in Table 6.9.15.

Perched Water/Ephemeral Springs

Pit Area of Amulsar Peak

There will be no direct loss of any ephemeral springs in this area. There will be a possible small permanent reduction of the catchment area as the southern end of the Tigranes/Artavazdes pit and Erato pit will not be backfilled completely, leading to a reduction in flow. The magnitude of any potential long-term post closure changes in ephemeral spring discharge quantity in the pit area is considered to be **low**.

Ephemeral springs are predominantly supported by snow melt and near-surface flow, consequently it is unlikely that quality of the spring water will be impacted unless leakage from the pits enters the spring catchment, which is considered unlikely given the hydrologic setting and elevation of the ephemeral springs. Therefore, the predicted impacts on the quality of these springs will be **negligible**.

BRSF and Surrounding Area

There are ephemeral springs located in the BRSF area and some of these springs lie within the footprint area of the BRSF.

The springs located beneath the BRSF will have substantially decreased or ceased to flow during construction of the BRSF. Any residual discharge from these springs will be captured by the BRSF underdrain, piped to the HLF drainage system, from which the overflow would treated through a PTS[11] and to ground, post-closure. Therefore, although the springs beneath the BRSF will not discharge to the same location, any small residual quantities of water from the BRSF will remain in the local hydrologic system. The magnitude of potential changes in ephemeral spring discharge quantity in the BRSF area during closure and post-closure is considered to be **moderate**.

Treatment of the captured groundwater will be to MAC II standards. This will represent a measureable change in quality where the baseline quality is different to the MAC II standards. This impact would be positive where the baseline quality was poorer than the MAC II standards. The worst predicted magnitude of the impact is **low** and would occur if the treated water quality is poorer than the baseline water quality but better than the MAC II standards. The treated groundwater will be discharged to surface water; the impacts are presented in Chapter 6.10.

Ephemeral springs that are located in the area of the BRSF, but not beneath it (i.e. springs located in the valley to the west), are predominantly supported by snow melt and near-surface flow. There are no activities that will take place during closure or post-closure that will result in a change in quality of the near surface flow. If there is no change to their catchment area, or the amount of snow in their catchments, there will be no change in the amount of water available for discharge. Therefore, the predicted impact to ephemeral spring discharge quantity and quality during closure and post-closure is considered to be **negligible**.

HLF and Surrounding Area

There are ephemeral springs located in the HLF area and some of these springs lie within the footprint area of the HLF. For the same reasons presented in relation to springs located beneath the BRSF, the magnitude of potential impact to ephemeral spring discharge quantity is considered to be **moderate** and the impact to quality during closure and post-closure is considered to be **low**. The changes in quantity and quality to ephemeral springs in the surrounding area will be **negligible**.

[11] Sovereign Consulting Inc., 2014 Amulsar BRSF Passive Treatment System (PTS) Design Basis. Technical Memorandum to GRE, Dated 7 August 2014.

Perennial Springs

Pit Area of Amulsar Peak

The groundwater flow model predicts an increase in groundwater levels in the area of the Erato pit in the post-closure phase of up to 16 m. This will increase the perennial spring flow in this area. A decrease in groundwater levels in the area of the Tigranes-Artavazdes pit in the post-closure phase of up to 40 m is predicted. This will decrease the perennial spring flow in this area. The net flow from the perennial springs around the peak is predicted to decrease by between 1 % and 6 % from baseline conditions as a result of these changes. Some perennial springs that currently flow at a very low rate during winter, particularly in the vicinity of Tigranes-Artavazdes, may become ephemeral (dry during the winter months). The impact is therefore considered to be **low**.

Leakage to groundwater from the backfill in the Tigranes-Artavazdes and seepage from backfill water body in the partially backfilled Erato pit presents a potential source of a change in the quality of the springs around the pit. The water quality change is presented in Appendix 6.9.3. The results summarised in Table 6.9.5 show that there is a predicted decline in groundwater quality flowing from the pit area to nearby springs during the closure/post-closure period. The constituents that are predicted to result in the greatest impact are beryllium, cobalt, nickel and nitrate. Beryllium, cobalt and nickel are natural geochemical constituents associated with the ore body. Nitrate concentrations in groundwater could potentially increase during closure as a result of the release of ammonium nitrate from blasting. In the longer term, these peak concentrations will decline.

It is important to note that the impact magnitude indicated in Table 6.9.5 is determined in relation to the MAC II standards. These are surface water standards and have been used in the groundwater assessment in the absence of applicable Armenian groundwater standards. The World Health Organisation (WHO) provides a drinking water guideline value for nickel of 0.07 mg/l and for nitrate is 50 mg/l (11 mg N/L). The predicted concentrations for these constituents at the springs are well below these standards. There are no WHO groundwater standards for beryllium or cobalt.

It is important to note that groundwater is not used as a resource, groundwater in this area is unlikely to be used for water supply, and there are no standards against which to classify the change of quality in groundwater. The surface water MAC II standards have been used as a tool to determine the magnitude of change. Based on this, there is a predicted decline in groundwater quality at the springs, which is classified as high. However, surface water and the ecology that is supported by groundwater discharge are the appropriate receptors with regard to change in groundwater quality. The impact of discharge of groundwater to the Votoran River on the quality of surface water is considered in Chapter 6.10.

BRSF and Surrounding Area

Reduced recharge in the area of the BRSF is predicted to decrease groundwater levels in the area by up to 60 m. Groundwater discharge to surface will likely cease in the southern part of the BRSF site. Therefore, the perennial springs that discharge in the area beneath the BSRF are predicted to be lost and the impact is considered to be **high**. As there is predicted to be no discharge from these springs, no assessment of change in quality is necessary.

In the valley to the west of the BRSF, there is predicted to be a reduction in groundwater levels that results in reduced discharge of up to 20 % from springs in the post-closure scenario (Appendix 6.9.1). This impact is considered to be **moderate**. The groundwater flow model does not predict any flowpaths between any of the potential sources of impact (i.e. backfilled pits or BRSF) and the perennial springs. Therefore, there is no source of impact to quality at these springs and the change in quality is considered to be **negligible**.

HLF and Surrounding Area

There are no perennial springs located beneath the HLF footprint.

Reduced recharge across the HLF footprint is predicted to result in a decrease in groundwater levels of up to 13 m resulting in a post-closure reduction or loss of wet areas of ground that are present all year round. Therefore, the impact is considered to be **high**. As there is predicted to be no discharge from these springs, no assessment of change in quality is necessary.

The groundwater flow model does not predict any flowpaths between any of the potential sources of impact (i.e. backfilled pits, BRSF or HLF) and the perennial springs. Therefore, there is no source of impact to quality at these springs and the change in quality is considered to be **negligible.**

Hydrothermal Springs

Baseline characterisation has concluded that these springs do not receive groundwater flow from the Project area. It is not, therefore, possible for changes in groundwater flow or quality within the Amulsar Project area to influence the quantity or quality of discharge from the geothermal springs. On this basis, the potential change in the quantity and quality of discharge from the geothermal springs is considered to be **negligible** for the closure phase of the Project lifecycle.

Groundwater Used for Supply Purposes

Kechut (Madikenc) Springs

The groundwater flow model predicts a reduction of recharge to the catchment of these springs, mainly due to a reduction in recharge in the area of the BRSF. The reduction in flow between the baseline and post-closure phases is predicted to be between approximately 7 % and 8 %. This post-closure phase change is considered to be of **low** magnitude.

The groundwater flow model does not predict any flowpaths between any of the potential sources of impact (i.e. backfilled pits, BRSF or HLF site) and these springs. Therefore, there is no source of impact to quality at these springs and the change in quality is considered to be **negligible.**

Springs North of Gorayk

The groundwater flow model predicts that there will be no change in recharge to the catchment in the area of these springs, and no notable change in groundwater levels, during the post closure phase. Therefore, there is no source of impact to the quantity of discharge at these springs and the change is considered to be **negligible**.

The groundwater flow model does not predict any flowpaths between any of the potential sources of impact (i.e. backfilled pits, BRSF or HLF site) and these springs. Therefore, there is no source of impact to quality at these springs and the change in quality is considered to be **negligible**.

Spandaryan-Kechut Tunnel

The groundwater flow model predicts that there will be a reduction of recharge in the area that supplies groundwater inflow into the tunnel. This reduction is due to the remaining pits capturing precipitation and groundwater, and due to the presence of the BRSF reducing infiltration. This change in recharge is predicted to reduce to groundwater inflow to the tunnel by approximately 2 % to 3 % during the post-closure phase. Based on this, the magnitude of change in flow quantity is considered to be low. It is important to note that groundwater inflow was not intended to be the main source of water in the tunnel that provides supply, so this reduction in flows should not be considered as a material impact.

Based on the groundwater flow model results, groundwater originating from the pits or BRSF does not enter the tunnel. However, given the sensitivity of the Spandaryan-Kechut water supply and potential model uncertainty, the groundwater in the Spandaryan-Kechut Tunnel has been considered as a potential receptor to changes in groundwater quality originating from the BRSF and pits in the operational and closure phases. Impacts to quality from both phases are predicted, with the peak being predicted in the post-closure phase. The results of both of these assessments have been combined to predict the change in groundwater quality in the tunnel presented in Table 6.9.14.

Table 6.9.14: Peak Combined Impacts on Groundwater Quality in the Spandaryan-Kechut Tunnel from the BRSF and Pits

Constituent	Unit	Arpa MAC Category II	Average Baseline Concentration	Predicted Peak Conc'n	Percentage Change
Nitrate as N	mg/L	2.5	0.5	0.9	81%
Sulphate	mg/L	16.04	126	126.52	0.4%
Beryllium	mg/L	3.8×10^{-5}	0.00003	0.00003	0%
Nickel	mg/L	0.0103	0.003	0.003	0%
Arsenic	mg/L	0.02	0.0068	0.0068	0%
Cobalt	mg/L	0.00036	0.0051	0.00051	0%
Cadmium	mg/L	0.00101	0.0005	0.0005	0%
Chromium III	mg/L	0.011	0.005	0.005	0%
Lithium	mg/L	0.003	0.00427	0.00445	4.2%
Tin	mg/L	8.00×10^{-5}	n/a	0.00011	n/a

Notes:
MAC II concentrations provided for information only since does not apply directly to groundwater.

Based on the above predicted changes in groundwater quality in the tunnel, the magnitude of impact is considered to be **<u>low</u>**.

The groundwater flow in the tunnel discharges to the Kechut Reservoir. An assessment of the potential effects on that receptor is discussed in the Surface Water Impact Assessment (Chapter 6.10). However, it is more likely that the tunnel will not capture groundwater originating from the pits and BRSF, and there would be no change in water quality. In this case, the impact originating from the pits and BRSF would only have the potential to affect the concentrations in groundwater before discharge to the Darb River (see below).

Groundwater Component of Surface Water Baseflow

Darb River Catchment

The groundwater flow model predicts that there will be a reduction in groundwater input to baseflow in the Darb River of approximately 1 % during post-closure. This reduction in flow is predominantly caused by a change in recharge rates and hydraulic gradient in the area of the pits. The predicted change will occur during the operational phase and will be of **low** magnitude.

It is most likely that the Spandaryan-Kechut Tunnel will not capture groundwater affected by leakage from the pits; therefore, the pits represent a source of potential impact to groundwater quality adjacent to the Darb River. The assessment of the peak change in groundwater quality as a result of leakage from the pits is presented in Appendix 6.9.3 and summarised in Table 6.9.4. The magnitude of the peak impact is considered to be **low**. In the longer term these peak concentrations will decline and the change in quality will reduce.

Arpa River Catchment

The groundwater flow model predicts that there will be a reduction in groundwater input to baseflow in the Darb River of approximately 2 %. This reduction in flow is predominantly caused by a reduction of recharge to groundwater beneath the remaining elements of the BRSF and HLF. The predicted change will occur during the operational phase and will be of **low** magnitude.

The groundwater flow model predicts that the BRSF and HLF represent potential sources of impact to the Arpa River in the closure period. It is most likely that the Spandaryan-Kechut Tunnel will not capture groundwater affected by leakage from the BRSF; therefore, groundwater quality adjacent to the Arpa River could be impacted by leakage from the BRSF. Predicted changes in the quality of groundwater adjacent to the Arpa River as result of leakage from the BRSF are presented in Appendix 6.9.5 and summarised in Table 6.9.11.

Predicted changes in the quality of groundwater adjacent to the Arpa River as result of leakage from the HLF are presented in Appendix 6.9.4 and summarised in Table 6.9.7.

The impacts from each source will take place in groundwater in different parts of the Arpa catchment, so are localised to different areas. This is shown by the predicted pathlines from the BRSF and HLF (see Figure 6.9.3). The changes in groundwater quality as a result of leakage from the HLF are predicted to affect groundwater adjacent to the Arpa River downgradient of the HLF (a zone approximately 8 km downstream of the Kechut Reservoir). These changes are considered to be **low** in magnitude. The changes in groundwater quality as a result of leakage from the HLF are predicted to affect groundwater adjacent to the Arpa River downgradient of the HLF (a zone approximately 8 km downstream of the Kechut Reservoir). These changes are also considered to be **low** in magnitude. In the longer term these peak concentrations will decline and the change in quality will reduce.

The combined impacts of discharge of groundwater to the Arpa River on the overall quality of the Arpa River are considered in Chapter 6.10.

Vorotan River Catchment

The groundwater flow model predicts that there will be a reduction in groundwater input to baseflow in the Vorotan River of approximately 2 % in post-closure. This reduction in flow is predominantly caused by a change in recharge due to capture of precipitation in the remaining pit voids, and a change in hydraulic gradient in the pit and BRSF areas. The predicted change will occur during the operational phase and will be of **low** magnitude.

The predicted pathlines (see Figure 6.9.3) indicate that the pits represent a potential source of impact to groundwater quality adjacent to the Vorotan River. The assessment of the peak change in groundwater quality as a result of leakage from the pits is presented in Appendix 6.9.3 and summarised in Table 6.9.4. There is a high impact change in water quality predicted along pathway 3 from the Erato Pit in relation to lithium, and a moderate change predicted along pathway 2 from the Tigranes-Artavazdes Pit in relation to nitrate and sulphate. The magnitude of the peak impact is considered to be **high**. In the longer term these peak concentrations will decline and the change in quality will reduce.

It is important to note that groundwater is not used as a resource and there are no standards against which to classify the change of quality in groundwater. The surface water MAC II standards have been used as a tool to determine the magnitude of change, but surface water, and the ecology that is supported by it, are more relevant receptors than the change in groundwater quality. The impact of discharge of groundwater to the Vorotan River on the quality of surface water is considered in Chapter 6.10.

Table 6.9.15: Predicted Closure Phase Groundwater Effect Significance (Including Design Mitigation)

Receptor	Receptor Sensitivity	Potential Impact	Magnitude of Change	Effect Significance	Scale of Significance
Perched Water/ Ephemeral Springs - Pit areas	Medium	Potential small reduction in recharge to catchments.	Low	Minor	Not significant
		Springs fed by seasonal snow melt from a small local catchment. No predicted quality impacts in catchment.	Negligible	Negligible	Not significant
Perched Water/ Ephemeral Springs - BRSF and Surrounding Area	Medium	Reduction in spring flow due to reduced recharge.	Moderate	Moderate	Significant
		Potential impact from BRSF leakage, but captured water will be treated and discharged water will be MAC II quality or better.	Low	Minor	Not significant
		Springs fed by seasonal snow melt from a small local catchment. No change in catchments predicted.	Negligible	Negligible	Not significant
		Springs fed by seasonal snow melt from a small local catchment. No predicted quality impacts in catchment.	Negligible	Negligible	Not significant
Perched Water/ Ephemeral Springs - HLF and Surrounding Area	Medium	Reduction in spring flow due to reduced recharge.	Moderate	Moderate	Significant
		Potential impact from HLF leakage, but captured water will be treated and discharged water will be MAC II quality or better.	Low	Minor	Not significant
		Springs fed by seasonal snow melt from a small local catchment. No change in catchments predicted.	Negligible	Negligible	Not significant
		Springs fed by seasonal	Negligible	Negligible	Not

Table 6.9.15: Predicted Closure Phase Groundwater Effect Significance (Including Design Mitigation)

Receptor	Receptor Sensitivity	Potential Impact	Magnitude of Change	Effect Significance	Scale of Significance
		snow melt from a small local catchment. No predicted quality impacts in catchment.			significant
Perennial Springs - Pit areas	Minor	Decrease in water levels leading to up to 6 % reduction in spring flow.	Low	Negligible	Not significant
		Decline in predicted water quality with respect to beryllium, cobalt, nickel and nitrate.	High	Moderate	Significant*
Perennial Springs - BRSF and Surrounding Area	Minor	Reduction of groundwater levels and a loss of springs under BRSF footprint	High	Moderate	Significant
		Predicted reduction in flow at perennial springs located to the west of the BRSF.	Moderate	Minor	Not significant
		No predicted pathway from any source to the springs located west of the BRSF.	Negligible	Negligible	Not significant
Perennial Springs - HLF and Surrounding Area	Minor	Reduction of groundwater levels and likely loss of wet areas of ground in HLF area.	High	Moderate	Significant
		No predicted pathway from any source to the springs located west of the BRSF.	Negligible	Negligible	Not significant
Hydrothermal Springs - Jermuk	High	No predicted change in flows.	Negligible	Minor	Not significant
		No predicted change in quality.	Negligible	Minor	Not significant
Groundwater Used for Supply Purposes – Kechut Springs	Medium	Small reduction in spring flow predicted.	Low	Minor	Not significant
		No predicted pathway from any source to the springs.	Negligible	Negligible	Not significant
Groundwater Used for Supply Purposes - Springs North	Minor	No change in recharge in this area predicted, so no reduction in spring flow.	Negligible	Negligible	Not significant
		No predicted pathway from any source to the	Negligible	Negligible	Not significant

Table 6.9.15: Predicted Closure Phase Groundwater Effect Significance (Including Design Mitigation)

Receptor	Receptor Sensitivity	Potential Impact	Magnitude of Change	Effect Significance	Scale of Significance
of Gorayk		springs.			
Groundwater Used for Supply Purposes - Spandaryan - Kechut Tunnel	High	Slight reduction in groundwater input to tunnel predicted.	Low	Moderate	Significant^
		Slight decline in the quality of groundwater inflow into the tunnel if flow from the BRSF and pits is captured.	Low	Moderate	Significant^
Groundwater Component of Surface Water Baseflow - Darb River catchment	Medium	Small reduction in flow predicted.	Low	Minor	Not significant
		Small decrease in groundwater quality as a result of leakage from the pits.	Low	Minor	Not significant
Groundwater Component of Surface Water Baseflow - Arpa River catchment	Medium	Small reduction in flow predicted.	Low	Minor	Not significant
		Small decrease in groundwater quality as a result of leakage from the BRSF and HLF.	Low	Minor	Not significant
Groundwater Component of Surface Water Baseflow - Vorotan River catchment	Medium	Small reduction in flow predicted.	Low	Minor	Not significant
		Decline in groundwater quality as a result of leakage from the pits.	High	Moderate	Significant*

Notes:
* Surface water and the ecology that is supported by groundwater are the relevant receptors. See Chapter 6.10 for assessment of surface water as the end receptor, and Chapter 6.11 for ecology.
^ Groundwater inflow was not intended to be the main source of water in the tunnel that provides supply, so this reduction in flows should not be considered as a material impact.

6.9.7 Mitigation Measures

There are no significant impacts to flow or quality predicted at the Jermuk Springs, Kechut Springs or the Springs North of Gorayk.

Throughout the Project construction, operation, and closure there are some predicted total losses of springs due to construction of the BRSF and the HLF. These impacts are considered significant. However, the impacts cannot be avoided as the facilities are optimally located. The associated effects on surface water and ecology that result from these spring losses are considered in Chapters 6.10 and 6.11, respectively.

Elsewhere, where springs are impacted, the predicted decrease in spring flows is not significant.

Significant impact to water quality at springs located around the pits is predicted with respect to beryllium, cobalt, nickel and nitrate as a result of leakage from the pits. Nitrate originates from blasting. The blasting assessment is conservative and assumes the use of ANFO explosives and a residual nitrogen load from unexploded conditions. Monitoring is recommended to determine the actual scale of the impact from nitrates on groundwater. If monitoring identifies an increasing trend in nitrate concentrations, mitigation options (such as promotion of microbiological reactions[10] or a change in explosive type), will be evaluated. The increase in beryllium, cobalt and nickel are a result of the release of these constituents from the backfill. These constituents are naturally present in this mineralised area. Design mitigation measures are proposed to limit the leakage from the pits. No further groundwater mitigation options are presented.

There is also a significant impact predicted to groundwater quality adjacent to the Vorotan River as a result of leakage from the pits. The change in groundwater quality is high, and the moderate sensitivity of this receptor results in the significant impact. As noted previously, the end receptors of the predicted change in groundwater quality are surface water and ecology. Therefore, no additional mitigation is presented here to limit or avoid this impact. The sensitivity of the surface water and ecology receptors, the significance of the change in groundwater quality on these, and any relevant mitigation measures are considered in Chapters 6.10 and 6.11, respectively.

There is a potentially significant predicted impact to groundwater input to the Spandaryan-Kechut Tunnel. However, groundwater inflow is not intended to be the main source of water in the tunnel that provides supply to the Kechut Reservoir, so this reduction in quality should not be considered as a material impact to water resources in the area. Therefore, no additional mitigation is presented to limit or avoid this impact.

Cover test plots, incorporating lysimeters, will be conducted during the operational phase to determine and confirm the long-term infiltration rates through the proposed cover systems (at sites where cover is to be placed, e.g. BRSF and HLF). These tests will be used to confirm the proposed cover or recommend modifications to limit recharge.

General good practice measures that will be followed include:

- Use of appropriate explosives handling techniques during transport and storage to minimise explosives loss, immediate containment and clean-up of any spillages, appropriate charge loading procedures to minimise explosives loss, and appropriate procedures to manage blasting to minimise misfires;
- Minimising use of water and recycling water;
- Diverting water of appropriate quality back to the environment;
- Appropriate storage of chemicals; and
- Water quality monitoring (see below).

These measures will not change the significance of the predicted impacts, but will strengthen the on-going operational assessment of mitigation measures.

6.9.8 Residual Impact Assessment

No additional mitigation measures are presented that will alter the outcome of the initial assessment. The surface water and ecology impact assessment chapters (Chapter 6.10 and 6.11) should be read in conjunction with this groundwater impact assessment in order to understand the overall significance of the predicted changes in groundwater quantity or quality.

6.9.9 Monitoring and Audit

The predicted changes in groundwater quantity or quality will be confirmed by the monitoring programme. The monitoring will enable further mitigation measures if changes are greater than predicted. Monitoring requirements identified through the assessment process are outlined below and in Table 6.9.16. Details of the proposed monitoring programme (monitoring locations, schedule, metrics and methods) are included in the Environmental Monitoring Plan (EMP) and include:

- Baseline, construction, operational and post-closure monitoring of groundwater levels and groundwater quality (wells and springs) surrounding the pits;
- Baseline, construction, operational and post-closure monitoring of groundwater levels and groundwater quality (wells and springs) hydraulically up- and down-gradient of the BSRF;
- Baseline, construction, operational and post-closure monitoring of groundwater levels and groundwater quality (wells and springs) hydraulically up- and down-gradient of the HLF;
- Monitoring of spring flow and quality in:
  - The Madikenc Springs, adjacent to Kechut Reservoir;
  - Springs above Gorayk used for seasonal water supply; and
  - Sentinel springs surrounding the pit area;
- Monitoring of water quantity and quality in the Spandaryan-Kechut Tunnel; and
- During the construction phase, participatory monitoring of ground and surface water will be encouraged through consultation with local communities, such that field sampling, on-site lab analysis and recording of environmental data is shared with representatives, to compliment participation in other aspects of environmental and social monitoring during the operational phase of the Project.

The Environmental Monitoring Plan (EMP) is a live document that will be updated during the mine development to allow for adaption as a result of monitoring location loss and replacement, and improvement in the understanding of the water environment. The most current version of the monitoring plan should be referenced for the monitoring applicable to each phase of mine development.

The mine is designed to reuse all mine contact water. Operational Management Plans for the BRSF, BRSF toe pond, contact water pond and HLF process and storm ponds will be developed to confirm that there are no discharges to the groundwater environment. Non-contact water will be discharged to the environment and will be monitored as necessary prior to discharge. Monitoring requirements for these discharges will be incorporated in Operational Management Plans. Monitoring strategies will be based on the source of non-contact water and volume of discharge.

Monitoring of operational flow and water quantity (water balance) and quality within the HLF (in the heap, leakage collection and recovery system and underdrain) and in the pit sumps is a key part of environmental management during operations. This is not a component of the EMP, but will be incorporated in Operational Management Plans.

<table>
<tr><th colspan="3">Table 6.9.16: Monitoring and Audit Programme</th></tr>
<tr><th colspan="3">Water Resources - Monitoring and Audit Programme</th></tr>
<tr><td rowspan="3">Monitoring approach</td><td>Baseline</td><td>Pre-construction baseline monitoring has been undertaken between 2007 and 2015 to define the baseline surface water and groundwater conceptual model of the Project area, as outlined in Section 4.8. Baseline investigations and impact assessment have identified sensitive receptors and potential risks associated with aspects of the proposed mine development, which will require monitoring and mitigation during construction, operation and post-closure phases.
Baseline water quality data has been used in conjunction with RA Category II MACs to derive quality targets, included in the Environmental Monitoring Plan, against which construction and operation monitoring data will be assessed.</td></tr>
<tr><td>Construction and operation phases</td><td>Surface water and groundwater monitoring will continue to be undertaken during the construction and operation phases and compared with quality targets defined in the EMP to verify that any impacts are similar those predicted through the ESIA process and to give an advanced warning (where possible) of any potential deviation from the predicted conditions that could negatively impact surface water and groundwater receptors.</td></tr>
<tr><td>Post-closure phase</td><td>Surface water and groundwater monitoring should continue beyond the cessation of mining activities and mine closure for aftercare purposes. Post closure monitoring requirements will be defined through development of the EMP.</td></tr>
<tr><th colspan="3">Significant Effects</th></tr>
<tr><td colspan="2">Modification of groundwater flow</td><td>• Changes in groundwater characteristics (level and distribution) due to mining activities.
• Reduced flow to high elevation springs surrounding the pits.
• Reduction in surface water base flows in major tributaries and in rivers.
• Reduction in flow of water supply at Madikenc Springs and in the Spandaryan-Kechut Tunnel</td></tr>
<tr><td colspan="2">Modification of groundwater quality</td><td>• Changes to groundwater quality arising from blasting residues.
• Changes to groundwater quality from mining-influenced water in the open pit walls and floor.
• Changes in groundwater quality arising from leakage from the BRSF and HLF to groundwater.
• Changes to groundwater quality from accidental spills.</td></tr>
<tr><th colspan="3">Specific Actions</th></tr>
<tr><td rowspan="2">Level 2 Management Plans</td><td colspan="2">The Construction Environmental Management Plan (CEMP) will be prepared by the E-PCM Contractor. The CEMP will include best practice mitigation procedures to minimise as far as possible the risk of adverse impact to the local water environment as a result of the construction phase.</td></tr>
<tr><td colspan="2">The Mine Closure Management Plan (MRCRP) defines the management of water resources from the construction phase through to the mine closure plan, so that on reclamation water resources will have been maintained to achieve the objectives of the Plan.</td></tr>
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<tr><th colspan="4">Table 6.9.16: Monitoring and Audit Programme</th></tr>
<tr><th colspan="4">Water Resources - Monitoring and Audit Programme</th></tr>
<tr><td rowspan="2"></td><td colspan="3">The Water Management Plan (WMP) provides an outline design for water management which complies with the relevant effluent discharge standards; and proposes a monitoring and mitigation scheme for prevention of any adverse impacts to the local and regional surface water and groundwater regime as a result of Project activities.</td></tr>
<tr><td colspan="3">The Spill Prevention and Response Plan (SPRP) defines the measures that will be taken to manage, control and monitor substances that have the potential to adversely affect water resources.</td></tr>
<tr><td>Level 3 SOPs</td><td colspan="3">The Level 2 plans will be underpinned by the following SOPs that will provide specific guidance on sampling and/or monitoring locations and procedures during the construction, operational and closure phases. The Level 3 SOPs for groundwater are incorporated in the EMP, and include the following:
• Groundwater well design and installation: procedures for the design and installation for new monitoring wells required as a result of findings of the baseline monitoring program, or well failure.
• Groundwater level monitoring (construction, operation and post-closure phases): procedures for point and continuous monitoring of groundwater (levels) within existing monitoring boreholes across the open pit, WDF and HLF areas.
• Groundwater quantity monitoring: procedures for the quantitative monitoring of spring flows, condition of springs and seepages will be monitored qualitatively where appropriate (i.e. springs are dry or with undetectable flow).
• Groundwater quality monitoring (construction, operation and post-closure phases): procedures for sampling for in situ field parameter measurement and ex situ laboratory quality analyses, from existing monitoring locations (springs and monitoring boreholes) across the open pits, BRSF and HLF areas, Spandaryan-Kechut Tunnel discharge, and springs.</td></tr>
<tr><th colspan="2">Groundwater Monitoring SOP</th><th>Strategy</th><th>Monitoring</th></tr>
<tr><td>Groundwater level</td><td>Open pit, BRSF and HLF areas</td><td>Construction and operational phase monitoring to identify any changes to the groundwater system.</td><td>Procedures for collection, recording, storage, quality assurance and evaluation of groundwater level data in the baseline and construction phase are incorporated in the EMP. The EMP is a live document and operational and closure phase monitoring requirements will be developed as appropriate during the life of the mine.</td></tr>
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Water Resources - Monitoring and Audit Programme			
	Spring conditions	Construction, operational and post-closure monitoring to identify any changes to the groundwater system.	Procedures for collection, recording, storage, quality assurance and evaluation of spring condition data in the baseline and construction phase are incorporated in the EMP. The EMP is a live document and operational and closure phase monitoring requirements will be developed as appropriate during the life of the mine.
Groundwater quality	Main infrastructure areas	Up-gradient and down-gradient monitoring of groundwater quality within the vicinity of each of the main infrastructure areas, during baseline, construction and operational phases.	Procedures for collection, recording, storage, quality assurance and evaluation of groundwater quality data in the baseline and construction phase are incorporated in the EMP. The EMP is a live document and operational and closure phase monitoring requirements will be developed as appropriate during the life of the mine.