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AMULSAR GOLD PROJECT

Assessment of Groundwater Quality Impacts arising from Pit Development

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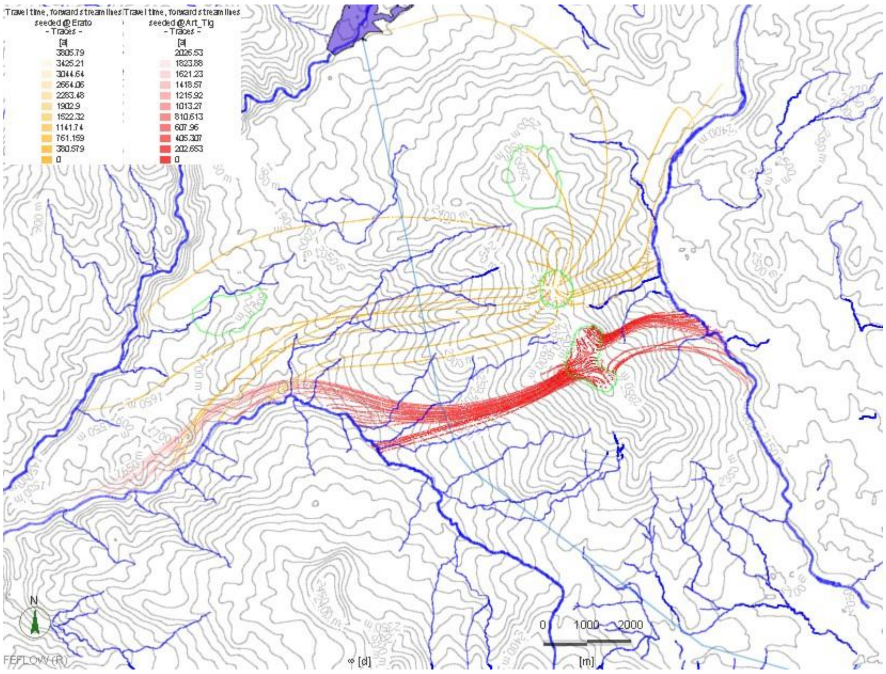

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REPORT

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1.0 INTRODUCTION

Lydian International Ltd (Lydian) has commissioned Golder Associates UK Ltd (Golder) to complete groundwater and surface water impact assessments for the Amulsar Gold Project (Project) as part of the Project Environmental and Social Impact Assessment (ESIA). This report presents the assessment of potential groundwater quality impacts arising from the mining closure and reclamation of the Tigranes-Aravazdes and Erato pits. This study forms one of five technical studies which support the groundwater impact assessment.

The RA Category II Maximum Acceptable Concentrations (MACs) in surface water are presenting in this document for comparison purposes in order to provide a context for the predicted changes in groundwater quality. These standards are not considered to apply directly to groundwater, but are applicable to major water courses which receive groundwater discharge.

1.1 Site Setting

The Project is described in Chapter 3 of the ESIA. The Tigranes-Artavazdes and Erato open pits are located along the Amulsar Mountain ridge. The pits will be mined starting at elevations between 2,800 m asl and 2,950 m asl. The end-of-mining pit floor elevations will be approximately 2,680 m asl in Tigranes-Artavazdes and 2,620 m asl in Erato. Final pit depths are approximately 270 m for Tigranes-Artavazdes and 200 m for Erato. The topography drops steeply to the east and west of the pits, toward the Darb River to the southwest, the Arpa River to the west and the Vorotan River to the east.

The Spandaryan-Kechut tunnel connects the Spandaryan Reservoir, located approximately 7.3 km southeast of Artavazdes in the Vorotan catchment, to the Kechut Reservoir, located approximately 6.7 km northwest of Erato. The tunnel passes to the west of Amulsar Mountain. Under current conditions, it is not operational, and groundwater discharges from the tunnel at an average rate of about 0.19 m^3/s.

1.2 Pit Development

The mining of the Tigranes-Artavazdes and Erato pits is described in the Project Description (Chapter 3 of the ESIA) as follows:

- Mining at Tigranes-Artavazdes begins in Year 1 as two pits, merging in the later years of operation;
- Mining at Erato commences in Year 5 of operation;
- Backfilling of the Tigranes-Artavazdes pit with mixed Upper Volcanics and Lower Volcanics barren rock commences in Tigranes late in Year 4 of operation, continuing in Tigranes and Artavazdes through Years 5, 6, 7 and 8, ultimately filling approximately two thirds of the pit footprint and extending to approximately pre-mining ground surface.
- Non-Acid Generating (NAG) Upper Volcanics backfill will be placed in the base of Erato at the end of operations to an estimated elevation of 2650 m asl;
- The southern portion of the Tigranes-Artavazdes pit (Arshak) will not be backfilled and will remain open at closure.

2.0 CONCEPTUAL MODEL OF GROUNDWATER FLOW AND SOLUTE TRANSPORT FROM PIT AREAS

The hydrogeology of the pit areas and hydrogeological conceptual model for groundwater flow is described in detail in the ESIA Chapter 4.8, Groundwater Baseline.

The geological setting of the pit area is lithologically and structurally complex with interleaved volcanic units and discrete faults and fractures. This geological framework has by necessity been simplified in the models used to simulate groundwater flow and solute transport.

The migration of solutes introduced to the groundwater system as part of the mining activities through the two major lithological units, the Upper Volcanics to the east of the pits and Lower Volcanics to the west of the pits is simulated based on the large-scale average hydraulic and geochemical properties for these units. A discussion of the possible influence of these assumptions on the results of the impact assessment is presented in this report.

The purpose of the conceptual model presented in this report is to describe the groundwater pathways linking the source (constituents in water infiltrating to groundwater beneath the pits) to potential groundwater receptors (groundwater abstractions or groundwater-fed surface water bodies (springs, streams, etc.) located hydraulically downgradient of the pit areas), and the mechanisms of solute migration and attenuation in each pathway to determine the concentration and load of constituents reaching these receptors during mining and closure/post-closure.

2.1 Summary of Findings of the Groundwater Flow Model

The understanding of potential solute migration pathways from the pit areas is substantially based on groundwater flow modelling of operational and closure conditions presented in Golder (2014a). The predicated pathways for solute migration are slightly different during mining operations to those in closure. Solute migration has been assessed up to 1000 years following closure. Given the much greater period of closure than operation, and the comparatively short distance over which migration is likely to occur during operation (because of the generally low permeability of the surrounding rock), emphasis has been placed on assessment of the pathways during closure rather than during operations. The migration pathways from the pits during post closure are illustrated in Figure 1.

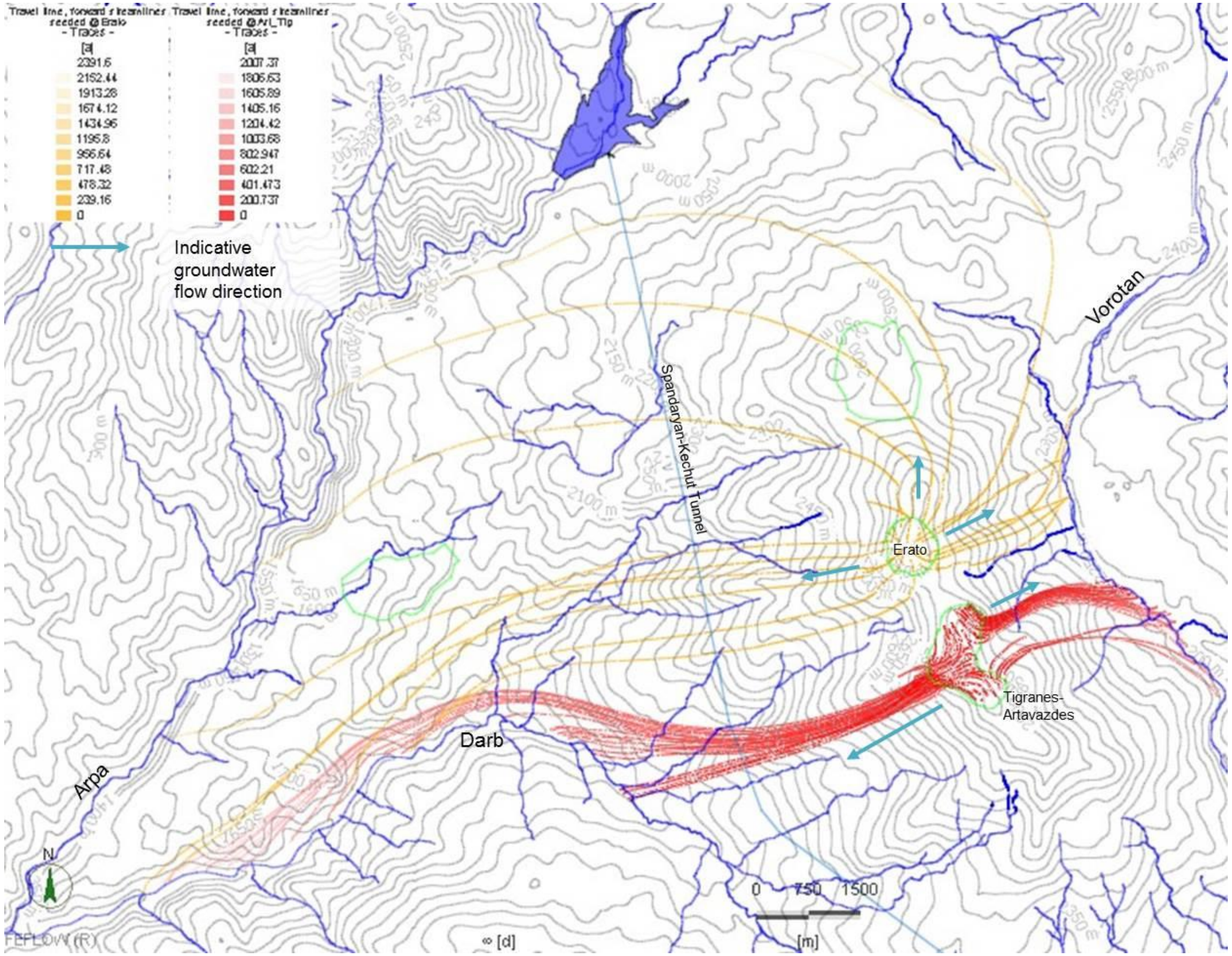

Figure 1: Post-Closure Groundwater Particle Pathlines from Pit Area (Golder, 2014a)

The groundwater flow model indicates that groundwater originating from recharge in the pit footprints will flow to some depth within the geological sequence, flowing west beneath the Kechut Spandaryan tunnel and discharging to the Arpa and Darb Rivers. Based on the geological conceptual model, argillically altered Lower Volcanic andesites occur at depth beneath both pit areas, and groundwater infiltrating and flowing westward will pass through this unit before flowing into the unaltered Lower Volcanics. To the east, the groundwater flow model suggests that groundwater is more likely to flow to depth and flow laterally in the deeper Lower Volcanics than to flow within the shallow (more permeable) Upper Volanics which outcrop at surface in this area. A small number of particle pathlines originating in the Erato and Artavazdes-Tigranes pits terminate at surface to the west of the pits, though none flow directly to perennial springs represented in the model. This suggests that some shallow groundwater flow to springs may occur, but most of the infiltration in pit footprints will discharge to depth during closure.

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, for the purposes of assessment of solute migration the following assumptions have been made:

- Migration in the shallow groundwater flow system to high-elevation springs (generally between 2300 m asl and 2750 m asl) to the east and west of the pits may be greater than indicated by the model, facilitated by permeable fault and fracture zones;
- Groundwater migrating west from the pits may pass directly into the higher permeability unaltered Lower Volcanics;
- Groundwater migrating east from the pits may pass directly into the Upper Volcanics and flow through this unit to the Vorotan River; and
- Groundwater migrating west from the pits may be intersected and captured by the Kechut-Spandaryan tunnel.

Based on these assumptions, the assessment has considered the following scenarios:

- Scenario 1 - The Study Area-wide impact scenario assumes 100% of the infiltration and associated solute mass (mining influenced groundwater) from the pit footprint migrating via the deep groundwater pathways illustrated in Figure 1. For the westward flowing pathway two variants are evaluated:
  - A. The mining influenced groundwater flowing westward from the pits does not reach the Spandaryan-Kechut tunnel; and
  - B. The mining influenced groundwater flowing westward from the pits reaches and enters the Spandaryan-Kechut tunnel.
- Scenario 2 - The local area impact scenario assumes 100% of the mining influenced groundwater migrates to perennial springs in close proximity to the pits.

In Scenario 1A, groundwater originating in the pit area discharges to the Darb River. In Scenario 1B, groundwater originating in the pit area enters the Kechut-Spandaryan tunnel and discharges to the Kechut Reservoir.

2.2 Source

The mining influenced water (source) associated with the pits in post-closure is based on geochemical modelling completed by GRE (2014) and Golder (2014b), unsaturated flow modelling completed by GRE (2014) and a water balance for the post-closure Erato pit completed by Golder (2014c).

2.2.1 Erato Pit

The rate of infiltration from the Erato pit during post-closure has been calculated in the Erato post-closure water balance (Golder, 2014c). The water balance indicates that a water body will develop within the permeable NAG backfill in the base of the pit, but the volume of water in the pit base will be strongly seasonal and the water body will be ephemeral in most years, infiltrating to groundwater over the course of the year.

The calculated average annual infiltration through the pit base is shown in Table 1 and Figure 2.

Table 1: Average Annual Infiltration, Erato Pit, Post Closure

Month	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Annual Total (m^3/yr, mm/yr)**
Infiltration Volume m^3/month	11102	7580	8392	8122	34948	46431	43095	36237	20075	12002	12993	12709	253686
Infiltration Per Unit Area* mm/ month	23	16	18	17	74	98	91	77	42	25	27	27	537

**Infiltration rate expressed as a distributed recharge rate over the entire pit footprint.*

Geochemical modelling has been completed to predict solute concentrations within the water body in the NAG backfill within the Erato pit (Golder, 2014b). This study assesses a range of input parameter values resulting in prediction of ‘average’ case and ‘maximum’ case concentrations. The full transient geochemical model is evaluated for both the ‘average’ and ‘maximum’ cases. For clarity in the following text, these two cases will be referred to as Source Model 1 (average), and Source Model 2 (maximum). Source Model 1 (average) and Source Model 2 (maximum) are considered in this assessment as the possible range in concentration of infiltration from the pit base.

The seasonal nature of the pit water body results in a strongly seasonal cycle of water quality. Figure 2 illustrates the average concentration of sulphate in the pit water body in each month of the year (based on a simulated 160 year record) for Source Model 1 and Source Model 2. The concentration of constituents shows an approximately two month lag behind the infiltration rate (which is proportional to water depth). The highest concentrations occur in mid-summer, as a result of the constituent mass released during the Spring snowmelt, and summer evaporation has begun to concentrate the water. In autumn, additional precipitation dilutes the water body as it simultaneously decreases in volume.

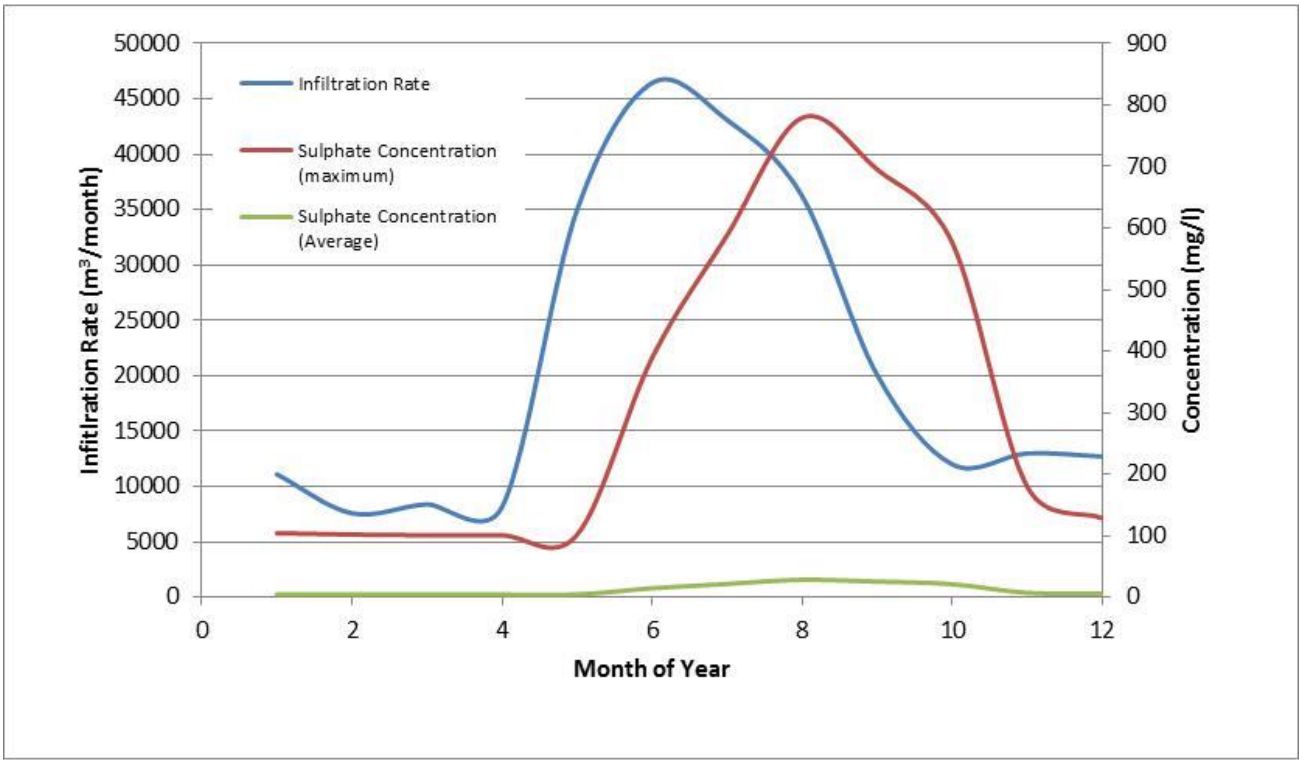

Figure 2: Monthly Average Infiltration Rate and Sulphate Concentrations (Golder, 2014b, 2014c)

Ephemeral springs surrounding the pit area at elevations ranging from 2,300 to 2,900 m show a rapid increase in flow rate associated with snow melt in the Spring, and are fed by shallow subsurface interflow from very localised catchments. These ephemeral, melt water fed springs (particularly those located at elevations greater than the pit bases), are less likely to be affected by infiltration from the pit area.

Infiltration from the pits has the potential to influence groundwater quality at perennial (groundwater fed) springs, creeks and/or at the major rivers at lower elevations on Amulsar. The seasonal water quality effects in the in-pit source water (Figure 2) will be attenuated (physically smoothed) in their passage through the unsaturated zone because of the relatively low permeability of the volcanic rocks. This will result in a mining-influenced source water that more closely represents the annual average source concentrations upon reaching groundwater

Annual average concentrations (based on the annual mass flux predicted to infiltrate through the base of the Erato pit) calculated from transient results for Source Model 1 (average) and Source Model 2 (maximum) are presented in Table 2. The impact assessment considers the midpoint of the range indicated as the source concentration. This is conservative, as it can be inferred that concentrations below the 'average' scenario are possible. Values have been screened against the RA Category II MAC for surface waters to provide an indication of the potential risk to surface water associated with the source water.

Table 2: Annual Average Constituent Concentration of Infiltration from the Erato Pit Base

Constituent	Unit	Category II MAC, Arpa	Category II MAC, Vorotan	Concentration Source Model 1 (Average)	Concentration Source Model 2 (Maximum)
pH	s.u.	6.5 - 9	6.5 - 9	4.34	2.87
Aluminium	mg/L	0.144	0.284	1.58	36.5
Antimony	mg/L	0.00028	0.0005	0.002	0.037
Arsenic	mg/L	0.02	0.02	0.005	0.110

Constituent	Unit	Category II MAC, Arpa	Category II MAC, Vorotan	Concentration Source Model 1 (Average)	Concentration Source Model 2 (Maximum)
Boron	mg/L	0.45	0.45	0.014	0.311
Barium	mg/L	0.028	0.012	0.018	0.008
Beryllium	mg/L	0.000038	0.000054	0.003	0.071
Calcium	mg/L	100	100	1.04	19.02
Cadmium	mg/L	0.001014	0.00101	0.001	0.012
Chloride	mg/L	6.88	8	1.52	32.8
Cobalt	mg/L	0.00036	0.00028	0.021	0.478
Copper	mg/L	0.021	0.022	0.093	2.12
Chromium	mg/L	0.011	0.0105	0.014	0.315
Fluoride	mg/L	No standard	No standard	0.41	9.23
Iron	mg/L	0.072	0.16	0.004	0.050
Lead	mg/L	0.01014	0.01014	0.057	1.25
Lithium	mg/L	0.003	0.002	0.028	0.625
Magnesium	mg/L	50	50	0.35	7.30
Manganese	mg/L	0.012	0.008	0.026	0.58
Mercury	mg/L	0.0003	0.0003	$2.8x10^{-4}$	0.006
Molybedum	mg/L	0.00082	0.002	0.016	0.35
Nitrogen	mg/L-N	2.5	2.5	0.050	1.10
Nickel	mg/L	0.01034	0.01045	0.019	0.43
Phosphorus	mg/L-P	0.2	0.2	0.198	4.42
Potassium	mg/L	3.12	4.46	0.58	12.47
Selenium	mg/L	0.02	0.02	0.001	0.019
Sodium	mg/L	10	8.46	0.47	9.98
Strontium	mg/L			0.015	0.33
Sulphate	mg/L	16.04	17.02	15.32	408
Vanadium	mg/L	0.01	0.016	0.009	0.20
Tin	mg/L	0.00008	0.00016	0.14	3.12
Zinc	mg/L	0.1	0.1	0.034	0.75

Shaded – concentration exceeds Category II MAC for inorganic constituents or less than the MAC for pH

Unsaturated flow modelling completed by GRE (2014) suggests that infiltration rates through the walls of the open pits at Amulsar will be very low, generally less than 2 mm/yr. The rate of infiltration through the base of the Erato pit is therefore likely to be very much greater than through the sidewall area. Assuming that the pit wall infiltration rate could be up to ten times higher than anticipated, infiltration from the transient water body in backfill in the pit base would account for 96.5% of annual infiltration from the pit.

Given the conservatism introduced by representation of the source term based on the average of the two source scenarios, only the pit water body infiltration has been considered to contribute to the Erato source, the mass associated with infiltration through the pit walls is neglected in the transport calculation.

2.2.2 Tigranes-Artavazdes Pit

In post-closure, backfilling of the Tigranes-Artavazdes pit will result in reduced infiltration to groundwater (compared to baseline conditions) from the backfilled pit footprint area. The rate of infiltration from the backfill along the pit walls and in the pit base, predicted through unsaturated flow and soil water balance modelling (GRE, 2014) is shown in Figures 3 and 4.

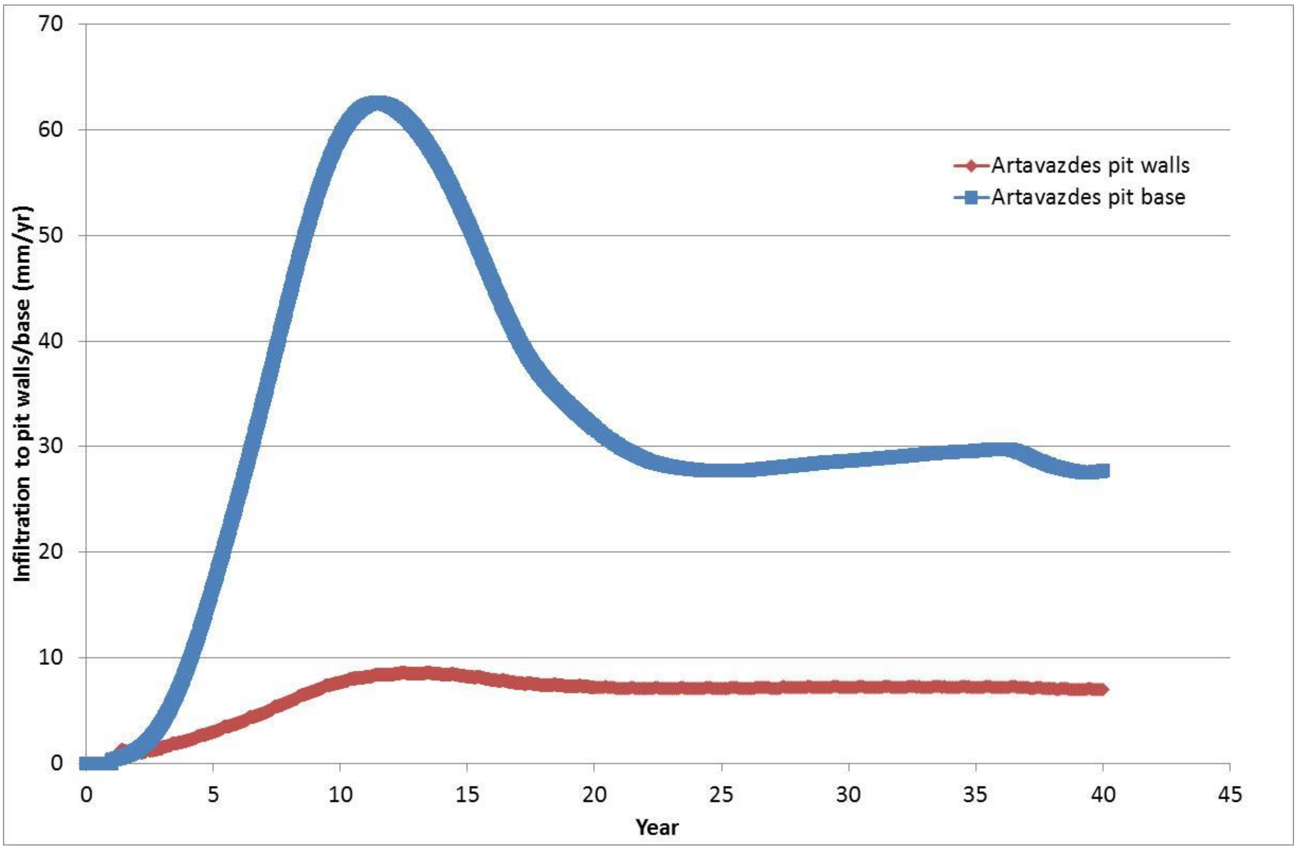

Figure 3: Predicted Infiltration Rates from Artavazdes Pit (GRE, 2014)

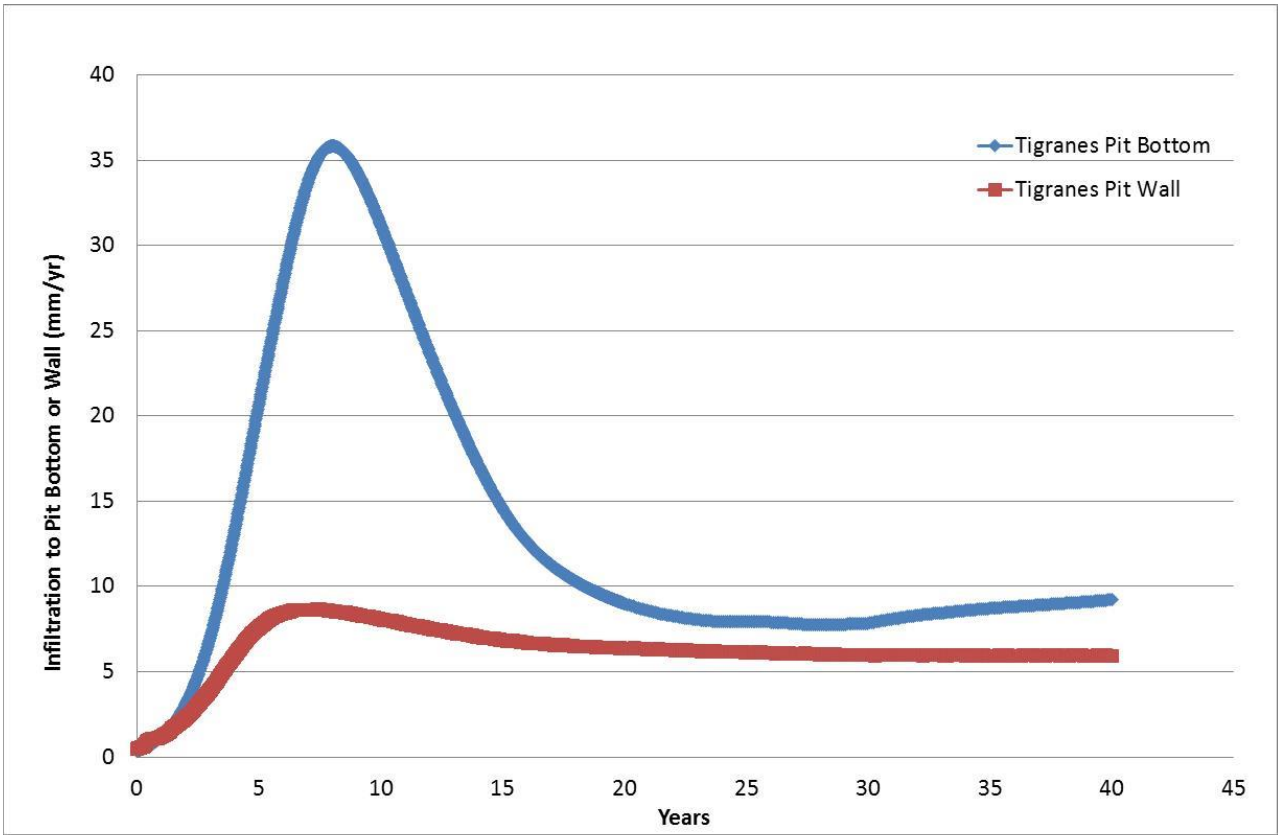

Figure 4: Predicted Infiltration Rates from Tigranes pit (GRE, 2014)

An initial pulse of recharge occurs as a result of high infiltration rates prior to placement of the engineered cover over the pit backfill. Whilst this pulse is significantly above the long term post closure infiltration rate, it is less than the rate of infiltration under existing conditions.

The southern portion of the Tigranes-Artavazdes pit (known as Arshak), extending towards Artavazdes peak, will not be backfilled at closure. Modelling of infiltration in closure (GRE, 2014) indicates that a seasonal water body may develop, dependent on the hydraulic conductivity of the bedrock underlying the pit. Modelling suggests that infiltration rates may be high for a short period during operations. Over the modelled period from 15 years to 40 years post-closure, the average annual infiltration rate from the pit base is between 136 mm/yr and 142 mm/yr, with a multi-year average of 139 mm/yr.

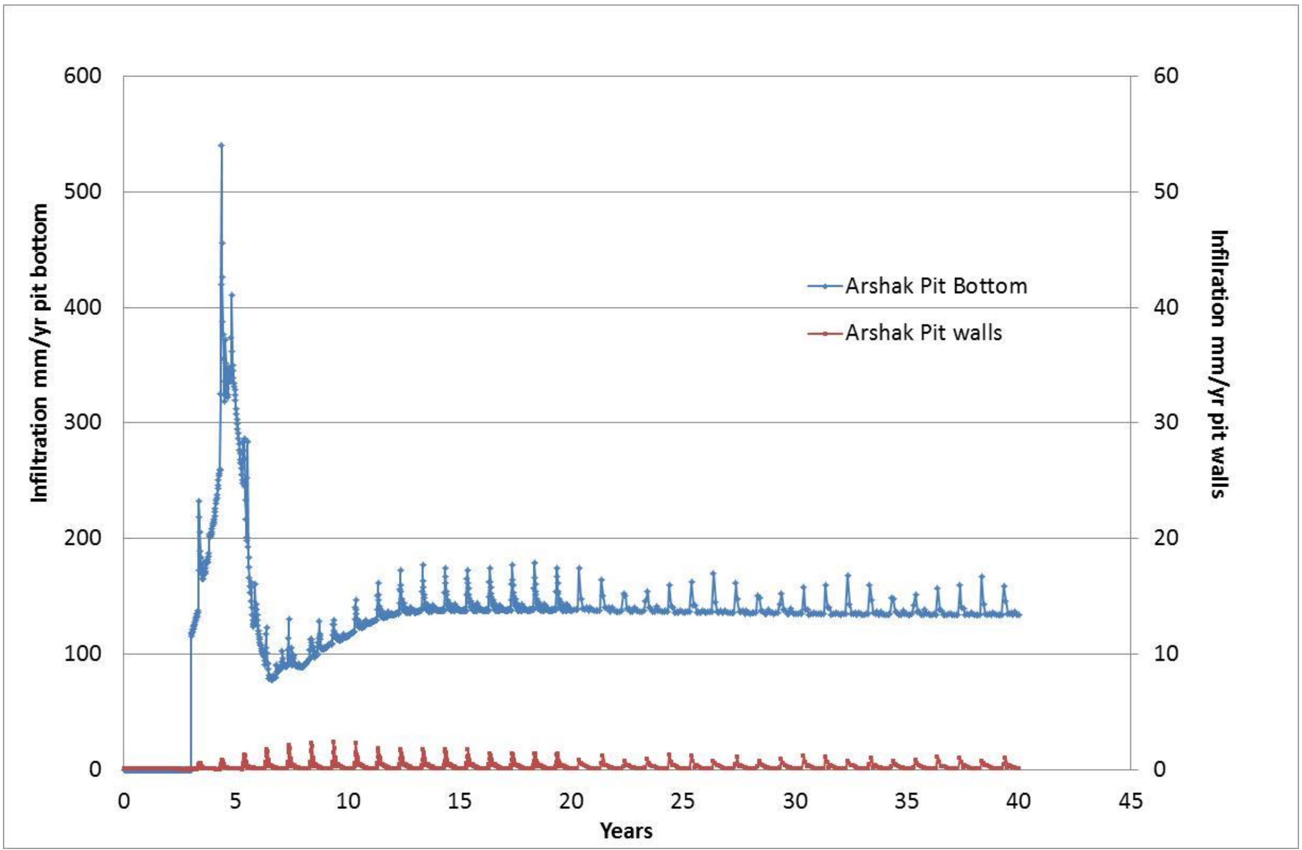

Figure 5: Predicted Operational and Post Closure Infiltration, Tigranes-Artavazdes (Arshak) Open Pit (GRE, 2014b)

Section 2.3 discusses the application of the infiltration rates to specific pit footprint areas.

Geochemical modelling of water quality in the backfilled and open portions of the Tigranes-Artavazdes pit is presented in GRE (2014). Predicted concentrations of constituents associated with leakage from the backfilled area and concentrations in water infiltrating into the Arshak open pit are presented in Table 3. Surface water quality standards (RA Category II MACs) are presented for comparison.

Risk to surface water will be governed by the mobility and ecotoxicity of the substances and their concentration under natural (baseline) conditions. However, the concentration in comparison to the MAC provides an indication of species which are significantly above typical baseline concentrations and likely to pose a risk to surface water.

Table 3: Water Quality, Tigranes-Artavazdes Backfill Leakage and Arshak Open Pit Infiltration (GRE, 2014)

Constituent	Unit	Category II MAC Arpa	Category II MAC Vorotan	Tigranes-Artavazdes Concentration	Arshak Concentration
pH	s.u.	6.5 - 9	6.5 - 9	2.7	3.3
Aluminium	mg/L	0.144	0.284	376	7.17
Arsenic	mg/L	0.02	0.02	0.026	0.0017
Boron	mg/L	0.45	0.45	0.081	0.0175
Barium	mg/L	0.028	0.012	0.009	0.02818
Beryllium	mg/L	0.000038	0.000054	0.028	0.0011
Calcium	mg/L	100	100	32.17	1.39
Cadmium	mg/L	0.001014	0.00101	0.005	0.0004
Chloride	mg/L	6.88	8	2.9	2.0
Cobalt	mg/L	0.00036	0.00028	1.43	0.0336
Copper	mg/L	0.021	0.022	$<1x10^{-10}$	$<1x10^{-10}$
Chromium	mg/L	0.011	0.0105	0.00091	1.86E-06
Iron	mg/L	0.072	0.16	$<1x10^{-10}$	$<1x10^{-10}$
Lead	mg/L	0.01014	0.01014	0.56	0.0341
Lithium	mg/L	0.003	0.002	0.029	0.0199
Magnesium	mg/L	50	50	34.2	0.4273
Manganese	mg/L	0.012	0.008	0.65	0.0051
Nitrogen	mg/L-N	2.5	2.5	11.63	See notes
Nickel	mg/L	0.01034	0.01045	0.86	0.0258
Phosphorus	mg/L-P	0.2	0.2	11.99	0.0916
Potassium	mg/L	3.12	4.46	40.78	1.24
Selenium	mg/L	0.02	0.02	0.12	0.0090
Sulphate	mg/L	16.04	17.02	437	57.0
Vanadium	mg/L	0.01	0.016	0.033	0.0050
Zinc	mg/L	0.1	0.1	4.17	0.0591

Shaded – concentration exceeds Category II MAC

Nitrate was not assessed as a contaminant of potential concern in closure for the Arshak open pit, residual nitrate from blasting will be short lived following the end of operations.

The use of ammonium nitrate fuel oil (ANFO) explosives at the Amulsar mine has the potential to result in the release of ammonium nitrate to the environment. The possible concentrations of nitrogen in the seepage from the pit backfill as a result of mobilisation of explosives residues with the barren rock has been assessed in Golder (2014d). This assessment is considered conservative, as it neglects the effect of chemical and biologically mediated reactions on nitrate concentrations. However, inclusion of this conservative source term in the impact assessment is considered appropriate given the potential hydrological and ecological sensitivity of nearby surface water receptors.

2.2.3 Constituents of Potential Concern

The Republic of Armenia (RA) has no defined standards for groundwater protection and there are no groundwater users located between the pits and the water courses and springs receiving groundwater base flow. Constituents entering groundwater beneath the pits may ultimately discharge to surface water. The Project Assessment Criteria protective of surface water are considered appropriate for assessment of the potential impacts of the pits on the water environment.

Based on the analysis presented in Tables 2 and 3, a number of metals and major ions exceed the Project Assessment Criteria in the infiltrating mining-influenced water.

It is not considered necessary to model the transport of all species present in the infiltrating pit water in order to characterise the risk to the water environment, as this risk will be defined by the constituents which are most mobile, present at highest concentration in comparison to assessment criteria, or more toxic. Based on their ecotoxicity, mobility, source concentration and ratio to water quality standards (themselves based on baseline concentrations) in both sources, the following constituents were evaluated in the solute transport modelling:

- **Sulphate**: an unretarded (mobile) species present in both source terms at significant concentrations. Sulphate is an indicator of acid rock drainage, and therefore is a key parameter for assessment of the combined impacts from the pits;
- **Nitrate**: an unretarded (mobile) species potentially present at high concentrations in barren rock used for pit backfill as a result of explosives residues;
- **Arsenic**: a comparatively mobile ecotoxic metaloid, incorporated to facilitate assessment of ecological impacts;
- **Antimony, beryllium, cobalt, molybdenum and tin**: moderately mobile metals present in high concentrations in the mining-influenced water in comparison to Project Assessment Criteria. . Molybendum and tin are only evaluated at Erato given the source concentrations;
- **Lithium**: an unretarded (mobile) species present at concentration in the source water significantly exceeding the Project Assessment Criteria; and
- **Cadmium**: highly toxic and moderately mobile metal present above Project Assessment Criteria in the source water.

Nitrate is not a constituent of potential concern in the Erato pit during closure. It is considered that nitrate released as a result of blasting will be rapidly flushed from the permeable Upper Volcanics backfill material in Erato and will not persist in closure, and the small quantity of backfill placed in Erato in closure will not represent a significant long term source.

2.3 Pathways

The assessment is based on the groundwater flow model predictions and evaluates the potential migration of solutes from the pits within two pathways:

1. In The Study Area-wide bedrock groundwater flow system that extends from Amulsar to the Vorotan, Darb and Arpa Rivers; and
2. In the local area shallow flow systems to perennial springs in proximity to the pits on Amulsar.

2.3.1 Study Area-Wide Flow Pathways – Scenario 1

The Study Area-wide groundwater flow pathways assessed are based on particle pathlines simulated in the regional groundwater flow model (Golder, 2014a) are illustrated in Figure 6. Groundwater will flow predominately to the east and west from the Tigranes-Artavazdes pit. Three pathways from Tigranes-Artavazdes have been evaluated:

- Pathway 1 – Westward flow to the Darb River;
- Pathway 2 – Eastward flow from the northern end of the T/A pit to the Vorotan River; and
- Pathway 5 – Eastward flow from the southern end of the T/A (Arshak) pit to the Vorotan River.

Two pathways have been evaluated from the Erato pit:

- Pathway 3 – eastward flow to the Vorotan River; and
- Pathway 4 – westward flow to the Darb River.

These five flow paths represent the majority of the infiltration from the closed pits as seen by the concentration in flow lines for these pathways. Infiltration from the pit entering other pathways will be widely dispersed and undergo greater mixing over an extended groundwater travel time within the groundwater flow system resulting in lower concentrations that for the main pathways.

Groundwater flowing west from the pit area is assumed to discharge to the Darb River in Scenario 1A, and to reach the Spandaryan-Kechut tunnel in Scenario 1B. Scenario 1A is considered the most probable scenario based on the migration pathways simulated in the groundwater flow model

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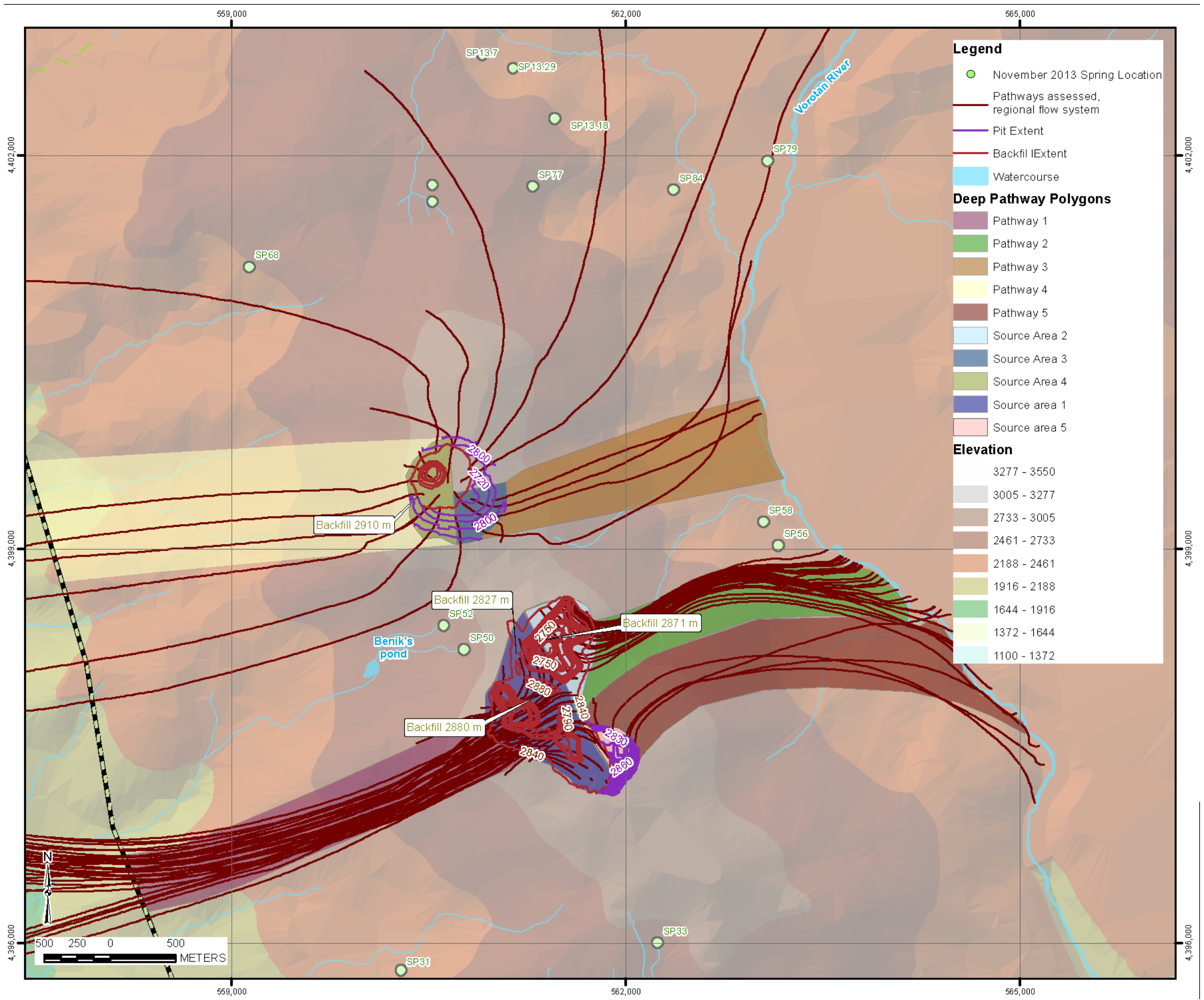


Figure 6: Pathways in Groundwater Flow from Pit Areas

2.3.2 Local Groundwater Flow Pathways – Scenario 2

This scenario assumes that water infiltrating from the pits does not flow to significant depth (as demonstrated by the groundwater flow model) and instead primarily discharges via local shallow groundwater flow pathways to the perennial springs surrounding the mountain peak. Under this scenario seven spring clusters located on Amulsar Mountain between an approximate elevation of 2300 m asl and 2750 m asl could potentially be affected. The catchments of these seven spring clusters are shown in Figure 7, catchment properties are summarised in Table 4.

Ephemeral springs on Amulsar Mountain located at elevations of approximately 2300 m asl to 2900 m asl. These springs are considered to be fed by direct snow melt water infiltration in close proximity to the point of spring discharge, and are unlikely to be influenced by groundwater infiltrating into the base of the pits. They will primarily be affected by changes in surface water management (ESIA Chapter 6.10).

2.4 Receptors

The following potential receptors were evaluated:

- Amulsar Perennial Springs;
- Spandaryan-Kechut Tunnel;
- Vorotan River; and
- Darb River.

2.4.1 Amulsar Perennial Springs

Seven perennial spring clusters have been identified as potentially affected by shallow groundwater affected by mining influenced water infiltrating from the pits. These clusters, and their associated catchment areas, are shown in Figure 7. Catchments 4 and 6 are sub-catchments of catchment 5, but have been evaluated separately as clear spring clusters are present higher in catchment 5. The properties of the catchments are summarised in Table 4. Little if any flow was measured in the springs in November 2013 corresponding to low flow conditions. Flows recorded in May 2014 represent the effects of snowmelt.

Baseline groundwater quality in each spring catchment has been calculated based on the average concentration in all spring water samples collected within that catchment and is summarised in Table 5.

Table 4: Properties of Assessment Spring Catchments

Catchment	Area (m^2)	Elevation Range (m asl)	Flow Recorded, November 2013 (L/s)	Flow Recorded, May 2014 (L/s)	Locations Providing Baseline Water Quality
Catchment 1	1686270	2350 – 2850	Not visited November 2013, active flow reported in December 2010	15.6	ERW1, ERW2
Catchment 2	958890	2400 – 2850	No active flow recorded	0.9	Spring GA1, AW035*
Catchment 3	2052830	2400 – 2850	active springs recorded, measureable flow <100 L/s	10.3	ERW3, ERW4, ERW5, Spring 4
Catchment 4**	310420	2675 – 2850	Not visited in November 2013, flow reported in December 2010	6.4	Spring 1, Spring 3, Spring 6, Spring 7
Catchment 5	1606170	2400 - 2900	No active flow, active flow reported in December 2010	35.7	Springs GA1 to GA5, AW035
Catchment 6**	618410	2675 - 2900	No active flow, active flow reported in December 2010	22	Spring 2, Spring 5
Catchment 7	3446420	2275 - 2925	active springs recorded, measureable flow <100 L/s	10.4	Spring 11

** No springs have been directly sampled, the nearest sampled springs are Spring GA1 and AW035*

***Catchments 4 and 6 are subcatchments of catchment 5*

Table 5: Baseline Water Quality, Spring Catchments 1 to 7

Constituent	Average Concentration (mg/L)**						
	Catchment 1	Catchment 2	Catchment 3	Catchment 4	Catchment 5	Catchment 6	Catchment 7
Antimony*	*0.0002*	*0.0002*	*0.0002*	*0.0002*	*0.0002*	*0.0002*	*0.0002*
Arsenic	0.001	0.00143	0.000925	0.000943	0.000943	0.00065	0.001
Beryllium*	*0.00003*	0.00028	0.000201	*0.00003*	*0.00003*	*0.00003*	*0.00003*
Cadmium	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
Cobalt	0.000523	0.0086	0.00053	0.00047	0.00047	0.00037	0.0005
Chromium	0.005	0.005	0.0044	0.0032	0.0032	0.0027	0.005
Lithium	0.001	0.0022	0.0010	0.001	0.001	0.001	0.001
Molybdenum*	*0.0008*	*0.0008*	0.00088	0.00061	0.00061	0.00051	*0.0008*
Nickel	0.003	0.0061	0.0043	0.0024	0.0024	0.0017	0.003
Nitrate as N	0.53	0.51	0.5	0.41	0.41	0.41	0.5
Sulphate	7.4	36.9	17.3	5.0	5.0	5.0	5.0

** Italics: the baseline value has been replaced as detection limit exceeded the Project Assessment Criteria and all samples were below detection, see text.*

***Less than detection limit results have been considered at the detection limit in calculation of average concentration.*

Italicized constituent concentrations represent non-detects (i.e., below laboratory detection limits) however the laboratory detection limit exceeded the Project Assessment Criteria. For these constituents, a concentration slightly less than the Category II MAC has been applied as the baseline concentration: 0.0002 mg/L for antimony, 0.00003 mg/L for beryllium and 0.0008 mg/L for molybdenum. For the key parameters (see Section 2.2.3), baseline quality is not available for tin.

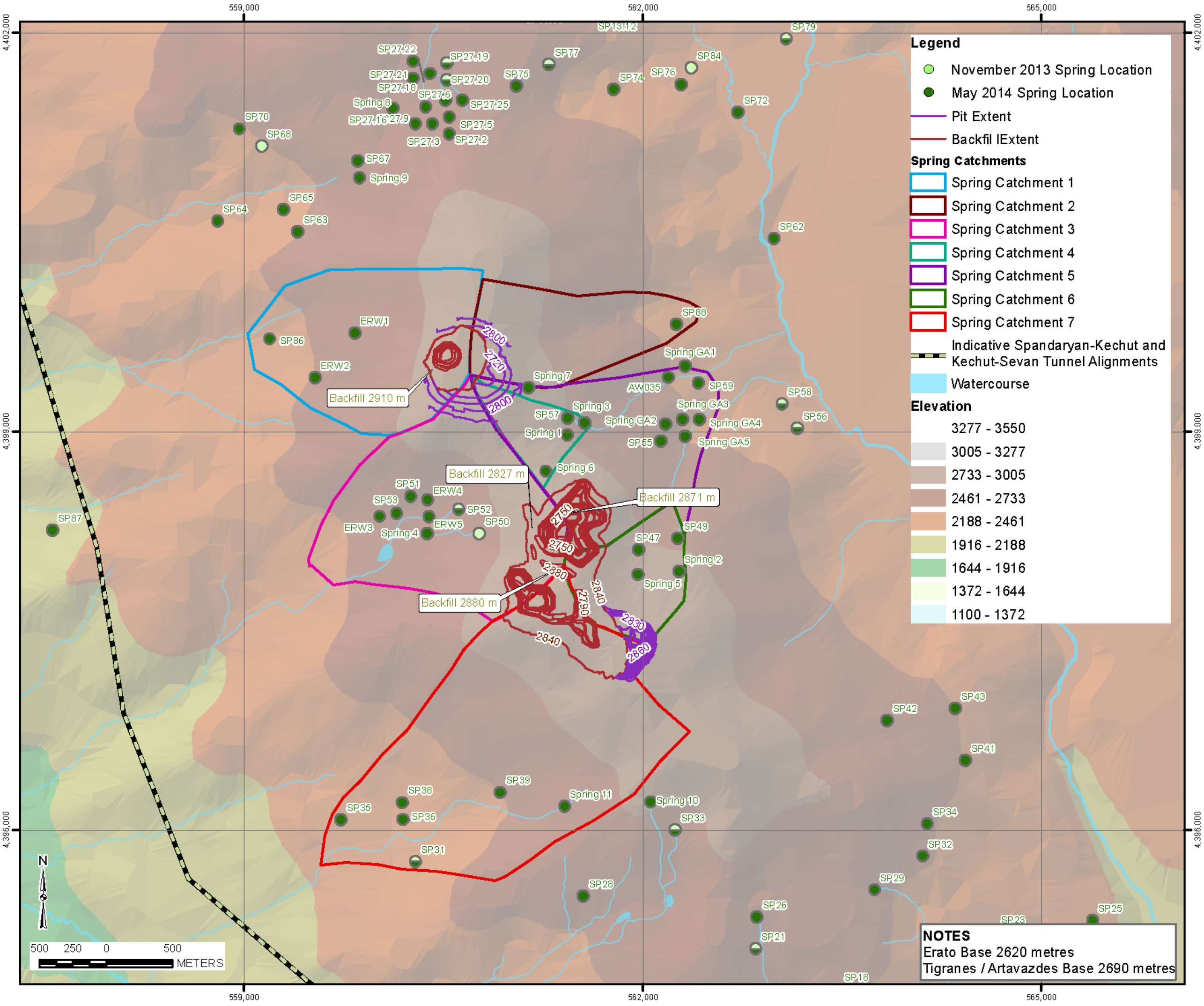


Figure 7: Spring Catchments Potentially Impacted by Infiltration from the Pits

2.4.2 Spandaryan-Kechut Tunnel

The Spandaryan-Kechut tunnel is potentially influenced by groundwater flowing west from Tigranes-Artavazdes and Erato in Pathways 1 and 4.

Baseline groundwater quality to the west of Amulsar Mountain is best represented by the water quality in the Spandaryan-Kechut tunnel, which is likely to reflect groundwater quality over the large area. Baseline water quality (mean concentration at AWJ6) is presented in Table 6.

2.4.3 Darb and Vorotan Rivers

Baseline water quality in the Darb River is represented by quality at AW005 in Pathway 1 and AW006 in Pathway 4. Baseline quality is presented in Table 6.

The Vorotan River is potentially influenced by groundwater flowing east from Erato and Tigranes-Artavazdes in Pathways 2, 3 and 5. Typical baseline groundwater quality to the east of Amulsar Mountain has been estimated based on the water quality at locations DDAW007, RCAW286, Spring 1, Spring 2, Spring 3, Spring 5, Spring 6, Spring 7, Springs GA1 to GA5 and AW035. The average concentration of all samples at these locations is presented in Table 6. Baseline water quality in the Vorotan River is represented by quality at AW015. No baseline quality is available for tin.

Table 6: Average Concentration in Baseline Water Quality, Study-Area wide Groundwater Pathway Receptors

Constituent	Spandaryan-Kechut Tunnel (AWJ6)	Amulsar Mountain East (Aggregated)	Darb River (AW005)	Darb River (AW006)	Vorotan River (AW015)
Antimony (mg/L)	0.001	0.001	0.0016	0.001	0.001
Arsenic (mg/L)	0.0068	0.00102	0.00254	0.0068	0.0015
Beryllium (mg/L)*	*0.00003*	0.00023	*0.00003*	*0.00003*	*0.00003*
Cadmium (mg/L)	0.0005	0.0005	0.00060	0.0005	0.00047
Cobalt (mg/L)	0.00051	0.0038	0.00057	0.00051	0.00047
Chromium (mg/L)	0.0050	0.0040	0.0037	0.0050	0.0029
Lithium (mg/L)	0.0043	0.0014	0.0015	0.0043	0.0015
Molybdenum (mg/L)	0.0030	0.00081	0.0011	0.0030	0.00097
Nickel (mg/L)	0.0030	0.0039	0.0024	0.0030	0.0019
Nitrate as N (mg N/L)	0.50	1.0	0.34	0.53	0.38
Sulphate (mg/L)	126	22	896	126	5.2

** italics: the baseline value has been replaced as detection limit exceeded the Project Assessment Criteria and all samples were below detection, see text.*

Beryllium was reported below laboratory detection limits in all samples analysed at AWJ6, but the detection limit applied exceeded the Project Assessment Criteria. A concentration of 0.00003 mg/L, slightly less than the Category II MAC, has been applied as the baseline concentration.

3.0 ASSESSMENT APPROACH

3.1 Study Area-Wide Groundwater Flow Pathways

The impacts on groundwater quality and receiving surface water courses have been evaluated using modelling of advection, dispersion, and where appropriate, retardation in groundwater from the source (infiltration to groundwater below the pit) to the point of discharge to surface water. Impacts on surface water courses are evaluated based on mixing of groundwater discharge in surface water flow under low-flow conditions.

3.1.1 Solute Transport Calculations

The spreadsheet model “Remedial Targets Worksheet Release 3.1” (Environment Agency, 2006a) has been used to calculate the travel time in groundwater to the point of discharge to area-wide groundwater receptors and the concentration of constituents of potential concern at the point of discharge from the two pits. The methodology is described in full in “Remedial Targets Methodology” (Environment Agency, 2006b).

The spreadsheet model was developed in part for the assessment of the risk to downgradient receptors due to the migration of poor-quality groundwater. The model predicts the distribution of constituent concentrations in groundwater downgradient from a continuous source at a known location. The methodology is based on tiered assessment methodology or which the Level 3 tier is applicable to the situation at Amulsar:

- Level 3 Groundwater: Calculation of concentration of constituents of potential concern in groundwater at an identified downgradient receptor as a result of migration of a continuous source of mining-influenced groundwater using the Ogata Banks (1961) solution. The analytical solutions are described in Appendix D of Environment Agency (2006b).

In addition to advection and dispersion of dissolved constituents, the model also simulates attenuation through the processes of retardation (sorption) and biodegradation. Retardation of sorbed metallic contaminants is calculated using a linear isotherm.

3.1.2 Surface Water Impacts

Concentrations in surface water and in groundwater flow in the Spandaryan-Kechut tunnel have been calculated based on mixing of groundwater discharge at the concentration calculated at the point of discharge with flow in the receiving water.

The volume of groundwater discharge for pathways discharging to rivers is assumed to equal the annual recharge to the groundwater pathway area being evaluated. The volume of groundwater discharging to the Spandaryan-Kechut tunnel has been calculated based on the proportion of the 21.7 km tunnel length which intersects the groundwater flowpaths and the total tunnel discharge of 0.19 m^3/s.

3.1.3 Model Parameterisation

The derivation of source concentrations for pathways influenced by the Tigranes-Artavazdes pit is described below. Other input parameters to the regional flow pathway calculations are presented in Appendix A.

3.1.3.1 Source Concentration in Tigranes-Artavazdes Pathways (1, 2 and 5)

The average concentration of water originating in the Tigranes-Artavazdes pit area in each pathway has been calculated based on the mass load and infiltration to each pathway from the source area. Average concentration in each pathway source area has been calculated based on average infiltration rates over years 1 to 20 reported from pit seepage models for pit wall and pit base areas (GRE, 2014) summarised in Table 7, concentrations in Table 3 and the areas delineated as indicated in Figure 8.

Table 7: Average Infiltration Rates, Tigranes-Artavazdes Pit, Used in Calculation of Average Concentration in Pathways

Area	Interval Period (Years)	Cumulative infiltration (m)	Average infiltration rate (mm/yr)
Tigranes Base	20	0.36	18.0
Artavazdes Base	20	0.71	35.7
Arshak Base	20	2.77	138.7
Tigranes Wall	20	0.13	6.5
Artavazdes Wall	20	0.11	5.7
Arshak Wall	23	0.005	0.3

For example, Pathway 1 includes:

- 2130 m^2 area of the base of Tigranes pit and 14320 m^2 area of the base of Artavazdes pit, which have average infiltration rates over the 20 year simulated operational and post-closure period of 18 mm/yr and 36 mm/yr respectively and a quality as described for 'Tigranes-Artavazdes' in Table 3.
- 129620 m^2 area of the wall of Tigranes pit and 291070 m^2 of the wall of Artavazdes pit, which have average infiltration rates over the 20 year simulated operational and post-closure period of 6.5 mm/yr and 5.7 mm/yr respectively and a quality as described for 'Tigranes-Artavazdes' in Table 3.
- 190365 m^2 area of the sidewall of Arshak pit, which has an average infiltration rate of 0.3 mm/yr and a quality as described for 'Arshak' in Table 3.

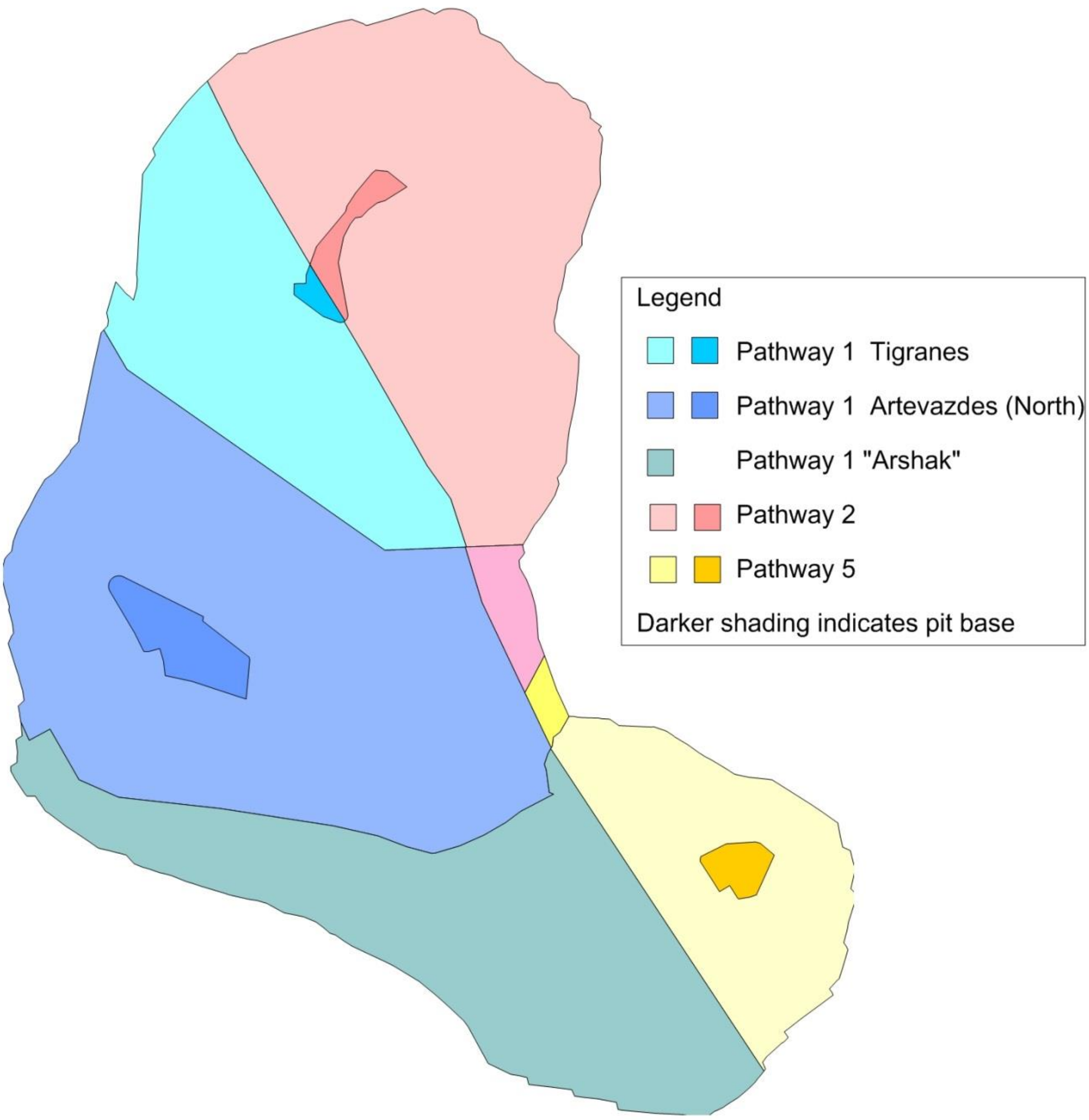


Figure 8: Tigranes-Artavazdes Pit Areas Contributing to Study Area Wide Groundwater Pathways

The resulting average concentrations of each of the constituents modelled in each pathway is presented in Table 8.

Table 8: Source Concentrations Averaged by Pathway Source Area, Tigranes-Artavazdes Pit

Constituent	Unit	Pathway 1	Pathway 2	Pathway 5
Arsenic	mg/l	0.025	0.026	0.0023
Beryllium	mg/l	0.027	0.028	0.0018
Cobalt	mg/l	1.40	1.43	0.069
Cadmium	mg/l	0.0049	0.0050	0.0005
Chromium	mg/l	0.0009	0.0009	2.5E-05
Lithium	mg/l	0.029	0.029	0.020
Nickel	mg/l	0.84	0.86	0.047
Nitrate*	mg N/l	492	500	13.8
Sulfate	mg/l	431	437	66.7

**Based on Golder (2014d).*

The model does not consider any attenuation in the mining-influenced source water in the unsaturated zone between the pit and groundwater. The model does not consider any attenuation in nitrate concentrations along the flow path due to denitrification within the groundwater flow system.

3.2 Impacts via Local Flow Pathways

The predicted concentration in groundwater in springs in the lower parts of the seven affected catchments has been calculated based on mixing of the solute mass released from the source area into groundwater recharge within the catchment. This calculation is conservative, as it considers dilution only in a single year, and therefore potentially under-estimates the dilution available if the solute takes many years to reach the spring location. At each spring, in each modelled year, the following equation is applied to calculate the change in concentration as a result of pit infiltration in the affected catchment:

$$Concentration = \frac{\sum pit\ area\ x\ unit\ area\ infiltration\ rate\ x\ concentration}{recharge\ rate\ x\ 'background'\ catchment\ area + \sum pit\ area\ x\ unit\ area\ infiltration\ rate}$$

‘Background’ catchment area is the catchment area outside the source zone. For Erato, the infiltration rate into each catchment is calculated as the annual average infiltration rate calculated by the Erato post-closure water balance (Golder, 2014c), multiplied by the fraction of the pit area which lies in the affected catchment.

3.2.1.1 Distribution of Solute Mass into Spring Catchments

The solute mass released into each spring catchment has been calculated as a time variant source on an annual basis for the 40 year period evaluated in GRE (2014). The end of this period is considered to be representative of long-term steady state. The areas attributed to each spring catchment in Tigranes-Artavazdes are illustrated in Figure 9.

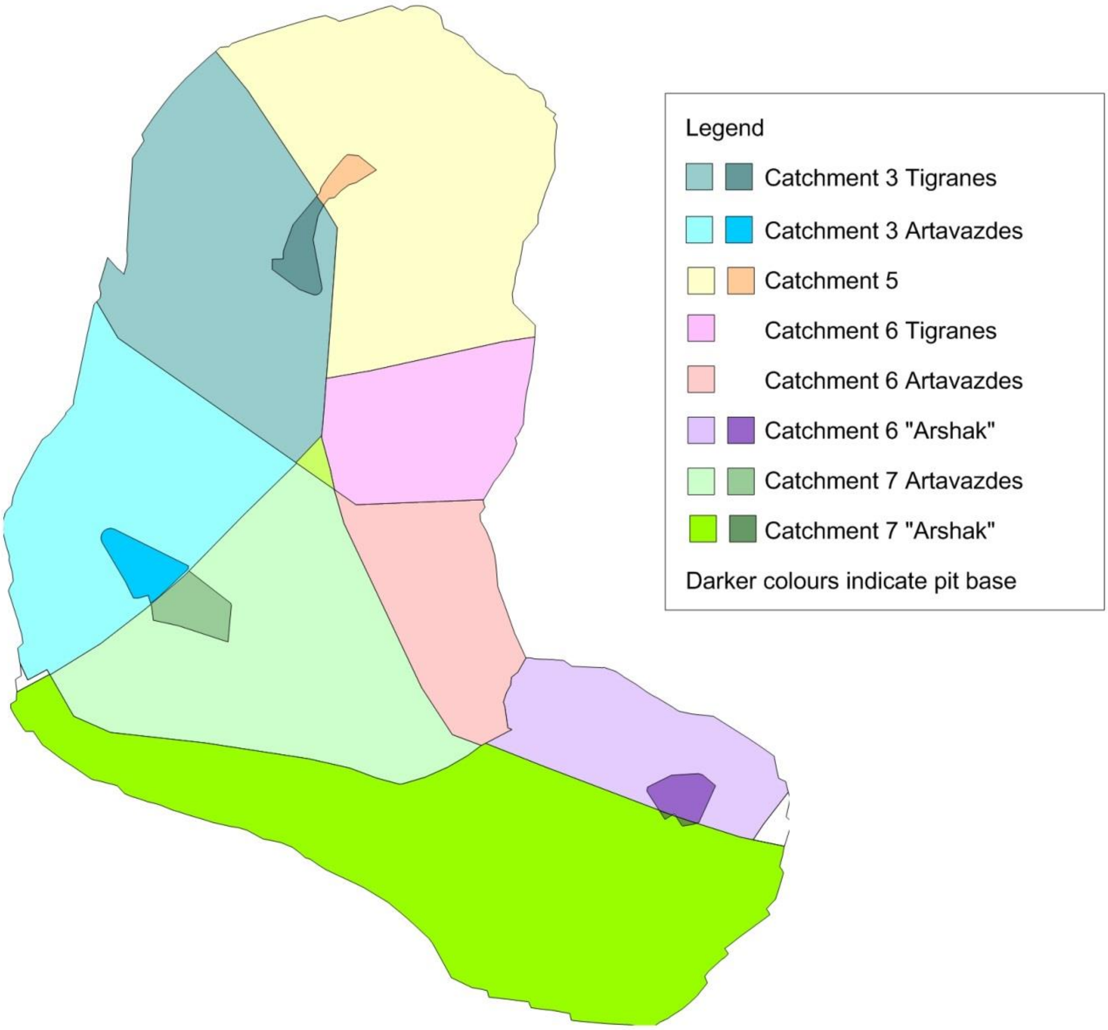


Figure 9: Tigranes-Artavazdes Pit Areas Contributing to Spring Catchments

3.2.2 Model Parameterisation

A recharge rate of 200 mm/yr has been applied in the affected catchments. The basis for this value is described in the Groundwater Baseline: This is estimated to be the regional recharge rate, based on the findings of the groundwater modelling study, and on surface water yields in gauged catchments.

The areas applied in the dilution calculation completed for each spring catchment are presented in Table 9.

Table 9: Spring Catchment Areas

Spring Catchment	Total Catchment (m^2)	Source Area (m^2)
Catchment 1	1686270	191430
Catchment 2	958890	131270
Catchment 3	2052830	322120
Catchment 4	310420	56080
Catchment 5	1606170	245760
Catchment 6	618410	182050
Catchment 7	3446420	370220

4.0 RESULTS

Table 10 summarises the Project Assessment Criteria and baseline water quality applied in assessment of impact in each pathway evaluated.

Table 10: Summary of Assessment Criteria and Baseline Quality Applied in Impact Assessment

	Pathway	Assessment Criteria	Location providing Baseline Receiving Water Quality	Location providing Baseline Groundwater Quality
Study-Area Wide Pathways	Pathway 1 Scenario 1	Arpa Basin	AW005	AWJ6
	Pathway 1 Scenario 2	Arpa Basin	AWJ6	AWJ6
	Pathway 2	Vorotan Basin	AW015	Amulsar Mountain East*
	Pathway 3	Vorotan Basin	AW015	Amulsar Mountain East
	Pathway 4 Scenario 1	Arpa Basin	AW006	AWJ6
	Pathway 4 Scenario 2	Arpa Basin	AWJ6	AWJ6
	Pathway 5	Vorotan Basin	AW015	Amulsar Mountain East
Local Area Pathways	Catchment 1	Arpa Basin	ERW1, ERW2	
	Catchment 2	Vorotan Basin	Spring GA1, AW035	
	Catchment 3	Arpa Basin	ERW3, ERW4, ERW5, Spring 4	
	Catchment 4	Vorotan Basin	Spring 1, Spring 3, Spring 6, Spring 7	
	Catchment 5	Vorotan Basin	Springs GA1 to GA5, AW035	
	Catchment 6	Vorotan Basin	Spring 2, Spring 5	
	Catchment 7	Arpa Basin	Spring 11	

**Amulsar Mountain East is an aggregation of all samples obtained at locations DDAW007, RCAW286, Spring 1, Spring 2, Spring 3, Spring 5, Spring 6, Spring 7, Springs GA1 to GA5 and AW035.*

4.1 Influence on Groundwater and Surface Water Quality, Study-Area Wide Flow Pathways

4.1.1 Impacts on Groundwater at the Point of Discharge

Peak concentrations in groundwater at the point of discharge to receiving water bodies are described for each pathway in the following sections.

For unretarded contaminants, the travel time to discharge at the Darb River calculated by the solute transport model is approximately 20 years in Pathway 1 and approximately 40 years in Pathway 4. Unretarded travel time to the Vorotan River is calculated to be between 100 years and 200 years. Unretarded travel time to the Spandaryan-Kechut tunnel is between 15 years and 20 years. These travel times are in very much shorter than those predicted by the groundwater model, which predicts the following approximate unretarded travel times:

- In Pathway 1 from Tigranes-Artavazdes to the Spandaryan Kechut tunnel, minimum of 200 years;
- In Pathway 4 from Tigranes-Artavazdes to the Spandaryan Kechut tunnel, between 200 and 450 years;
- In Pathway 1 from Tigranes-Artavazdes to the Darb River, between 250 to 350 years;
- In Pathway 4 from Tigranes-Artavazdes to the Darb River, between 650 to 700 years;
- In Pathway 2 from Tigranes-Artavazdes to the Vorotan River, between 350 to 450 years;

- In Pathway 3 from Erato to the Vorotan River, between 230 to 300 years; and
- In Pathway 5 from Tigranes-Artavazdes to the Vorotan River, between 800 to 1000 years.

The discrepancy in travel times is due primarily to the assumption that groundwater may discharge directly into the Upper Volcanics and the unaltered Lower Volcanics. In the groundwater model, flow in the vicinity of the pits travels to considerable depth, passing through the argillically altered Lower Volcanics before discharge to the more permeable formations. The longer flow path, combined with lower permeability of the argillic material results in a much slower groundwater flow rate. The conservative assumption made in the contaminant transport model is considered appropriate, given the geological complexity of the Amulsar deposit and the limited deep geological characterisation contained in the Lydian geological model.

Retarded travel times for antimony, beryllium, cobalt, chromium, molybdenum and nickel are calculated to be more than 1000 years based on solute transport assessment, and do not arrive at points of groundwater discharge.

Molybdenum, tin and antimony are not constituents of potential concern in the Tigranes-Artavazdes source, and therefore are not presented for pathways originating in this area. Nitrate is not a constituent of potential concern in the Erato source, and therefore is not presented for pathways originating in this area.

No groundwater quality standards exist in Armenian law; however groundwater ultimately will discharge to surface water. Groundwater at the point of discharge to surface water has therefore been compared to surface water discharge standards (RA Category II MAC).

4.1.1.1 Pathway 1

The change in groundwater quality at the point of discharge to the Darb River (Scenario 1) and to the Spandaryan-Kechut tunnel (Scenario 2) are shown in Tables 11 and 12.

Table 11: Pathway 1, Groundwater Quality at Point of Discharge to the Darb River (Scenario 1)

Constituent	Category II MAC (mg/L)	Baseline Concentration (mg/L)	Maximum Change in Concentration (mg/l)	Peak Concentration in Groundwater (mg/L)	Percentage Change
Nitrate as N	2.5	0.5	1.37	1.87	274%
Sulphate	16.04	126	1.20	127	1%
Beryllium	0.000038	0.0002	0	0.0002	0%
Nickel	0.01034	0.003	0	0.003	0%
Arsenic	0.02	0.00676	$1.5x10^{-10}$	0.0068	0%
Cobalt	0.00036	0.000505	0	0.00051	0%
Cadmium	0.00101	0.0005	$1.62x10^{-6}$	0.00050	0%
Chromium	0.011	0.005	0	0.005	0%
Lithium	0.003	0.00427	$8.08x10^{-5}$	0.0044	2%

Note: Category II MAC is not relevant for groundwater quality, only surface water. Only provided for information.

Table 12: Pathway 1, Groundwater Quality at Point of Discharge to the Spandaryan-Kechut Tunnel (Scenario 2)

Constituent	Category II MAC (mg/L)	Baseline Concentration (mg/L)	Maximum Change in Concentration (mg/l)	Peak Concentration in Groundwater (mg/L)	Percentage Change
Nitrate as N	2.5	0.5	3.1	3.6	626%
Sulphate	16.04	126	2.7	129	2%
Beryllium	0.000038	0.0002	0	0.0002	0%
Nickel	0.01034	0.003	0	0.003	0%
Arsenic	0.02	0.0068	$1.2x10^{-7}$	0.0068	0%
Cobalt	0.00036	0.00051	0	0.00051	0%
Cadmium	0.00101	0.0005	$1.3x10^{-5}$	0.00051	3%
Chromium	0.011	0.005	0	0.005	0%
Lithium	0.003	0.0043	0.000185	0.0045	4%

Note: Category II MAC is not relevant for groundwater quality, only surface water. Only provided for information.

Calculations indicate a localised change in groundwater quality in Pathway 1 with respect to nitrate assuming no denitrification occurs within the groundwater flow system. No measureable change is predicted with respect to other priority constituents of potential concern.

4.1.1.2 Pathway 2

The change in groundwater quality at the point of discharge to the Vorotan River are shown in Table 13.

Table 13: Pathway 2, Groundwater Quality at Point of Discharge to the Vorotan River

Constituent	Category II MAC (mg/L)	Baseline Concentration (mg/L)	Maximum Change in Concentration (mg/l)	Peak Concentration in Groundwater (mg/L)	Percentage Change
Nitrate as N	2.5	1.04	4.8	5.8	459%
Sulphate	17.02	22.3	11.8	34.0	53%
Beryllium	0.000054	0.00023	0	0.00023	0%
Nickel	0.01045	0.0039	0	0.0039	0%
Arsenic	0.02	0.0010	0	0.0010	0%
Cobalt	0.00028	0.0038	0	0.0038	0%
Cadmium	0.00101	0.0005	0	0.0005	0%
Chromium	0.0105	0.0040	0	0.0040	0%
Lithium	0.002	0.0014	0.00028	0.0017	19%

Note: Category II MAC is not relevant for groundwater quality, only surface water. Only provided for information.

Calculations indicate a localised change in groundwater quality in Pathway 2 with respect to nitrate (assuming no denitrification occurs within the groundwater system), sulphate and lithium. No measureable change is predicted with respect to other priority constituents of potential concern.

4.1.1.3 Pathway 3

The changes in groundwater quality at the point of discharge to the Vorotan River are shown in Table 14.

Table 14: Pathway 3, Groundwater Quality at the Point of Discharge to the Vorotan River

Constituent	Category II MAC (mg/L)	Baseline Concentration (mg/L)	Maximum Change in Concentration (mg/)	Peak Concentration in Groundwater (mg/L)	Percentage Change
Antimony	0.0005	0.001	0	0.001	0%
Sulphate	17.02	22.3	2.85	25.1	13%
Beryllium	0.000054	0.00023	0	0.00023	0%
Nickel	0.01045	0.0039	0	0.0039	0%
Molybdenum	0.002	0.00081	0	0.00081	0%
Arsenic	0.020	0.001	0	0.0010	0%
Cobalt	0.00028	0.0038	0	0.0038	0%
Cadmium	0.00101	0.0005	0	0.0005	0%
Chromium	0.0105	0.0040	0	0.0040	0%
Lithium	0.002	0.0014	0.0044	0.0059	308%
Tin	0.00016	N/A	0	0	N/A

N/A – no baseline concentration available, percentage change cannot be calculated.

Note: Category II MAC is not relevant for groundwater quality, only surface water. Only provided for information.

Calculations indicate a localised change in groundwater quality in Pathway 3 with respect to lithium. A measureable change in sulphate may also occur. No measureable change is predicted with respect to other priority constituents of potential concern.

4.1.1.4 Pathway 4

The change in groundwater quality at the point of discharge to the Darb River (Scenario 1) and to the Spandaryan-Kechut tunnel (Scenario 2) is shown in Table 15 and Table 16.

Table 15: Pathway 4, Groundwater Quality at the Point of Discharge to the Darb River

Constituent	Category II MAC (mg/L)	Baseline Concentration (mg/L)	Maximum Change in Concentration (mg/)	Peak Concentration in Groundwater (mg/L)	Percentage Change
Antimony	0.00028	0.001	0	0.001	0%
Sulphate	16.04	126	0.45	126	0%
Beryllium	0.000038	0.0002	0	0.0002	0%
Nickel	0.01035	0.003	0	0.003	0%
Molybdenum	0.00082	0.0030	0	0.0030	0%
Arsenic	0.02	0.0068	0	0.0068	0%
Cobalt	0.00036	0.00051	0	0.00051	0%
Cadmium	0.001014	0.0005	$1.4x10^{-8}$	0.0005	0%
Chromium	0.011	0.005	0	0.005	0%
Lithium	0.003	0.0043	0.00071	0.0050	17%
Tin	0.00008	N/A	$3.92x10^{-6}$	$3.9x10^{-6}$	N/A

N/A – no baseline concentration available, percentage change cannot be calculated.

Note: Category II MAC is not relevant for groundwater quality, only surface water. Only provided for information.

Table 16: Pathway 4, Groundwater Quality at the Point of Discharge to the Spandaryan-Kechut Tunnel

Constituent	Category II MAC (mg/L)	Baseline Concentration (mg/L)	Maximum Change in Concentration (mg/L)	Peak Concentration in Groundwater (mg/L)	Percentage Change
Antimony	0.00028	0.001	0	0.001	0%
Sulphate	16.04	126	2.09	128	2%
Beryllium	0.000038	0.0002	0	0.0002	0%
Nickel	0.01035	0.003	0	0.003	0%
Molybdenum	0.00082	0.0030	0	0.0030	0%
Arsenic	0.02	0.0068	$5.3x10^{-9}$	0.0068	0%
Cobalt	0.00036	0.00051	0	0.00051	0%
Cadmium	0.001014	0.0005	$1.0x10^{-5}$	0.00051	2%
Chromium	0.011	0.005	0	0.005	0%
Lithium	0.003	0.0043	0.0033	0.0075	76%
Tin	0.00008	N/A	0.0027	0.0027	N/A

N/A – no baseline concentration available, percentage change cannot be calculated.

Note: Category II MAC is not relevant for groundwater quality, only surface water. Only provided for information.

Calculations indicate a localised change in groundwater quality in Pathway 4 with respect to lithium. No measureable change is predicted with respect to other priority constituents of potential concern.

4.1.1.5 Pathway 5

The change in groundwater quality at the point of discharge to the Vorotan River (Scenario 2) is shown in Table 17.

Table 17: Pathway 5, Groundwater Quality at the Point of Discharge to the Vorotan River

Constituent	Category II MAC (mg/L)	Baseline Concentration (mg/L)	Maximum Change in Concentration (mg/)	Peak Concentration in Groundwater (mg/L)	Percentage Change
Nitrate as N	2.5	1.04	0.092	1.13	9%
Sulphate	17.02	22.3	0.44	22.7	2%
Beryllium	0.000054	0.00023	0	0.00023	0%
Nickel	0.01045	0.0039	0	0.0039	0%
Arsenic	0.02	0.0010	0	0.0010	0%
Cobalt	0.00028	0.0038	0	0.0038	0%
Cadmium	0.00101	0.0005	0	0.0005	0%
Chromium	0.0105	0.0040	0	0.0040	0%
Lithium	0.002	0.0014	0.00013	0.0016	9%

Note: Category II MAC is not relevant for groundwater quality, only surface water. Only provided for information.

Slight changes in groundwater quality in Pathway 5 at the point of discharge to the Vorotan River are predicted. These changes will not be statistically measureable against natural seasonal fluctuations in water quality.

4.1.2 Change in Water Quality, Receiving Waters

Changes in concentration in surface water have been calculated for each of the pathways presented above based on mixing of groundwater in the receiving water course, and the change in concentration summed to yield the impact on the receiving water from all pathways.

The predicted concentration in receiving waters for constituents which are discharged to surface water within 1000 years are shown in Appendix B.

4.1.2.1 Scenario 1

The predicted change in concentration and peak concentration in surface water in the Vorotan River is shown in Table 18.

Table 18: Calculated Peak Concentration in Surface Water, Vorotan River

Constituent	Category II MAC (mg/L)	Baseline Concentration (mg/L)	Maximum Change in Concentration (mg/)	Peak Concentration in Surface Water (mg/L)	Percentage Change
Antimony	0.0005	0.001	0	0.001	0%
Sulphate	17.02	5.24	0.26	5.50	5%
Beryllium	0.000054	0.0002	0	0.0002	0%
Nitrate	0.01045	0.0019	0	0.0019	0%
Molybdenum	0.002	0.00097	0	0.00097	0%
Arsenic	0.02	0.0015	0	0.0015	0%
Cobalt	0.00028	0.00047	0	0.00047	0%

Constituent	Category II MAC (mg/L)	Baseline Concentration (mg/L)	Maximum Change in Concentration (mg/)	Peak Concentration in Surface Water (mg/L)	Percentage Change
Cadmium	0.00101	0.00047	0	0.00047	0%
Chromium	0.0105	0.0029	0	0.0029	0%
Lithium	0.002	0.0015	0.00014	0.0017	9%
Tin	0.00016	N/A	0	0	N/A
Nitrate as N	2.5	0.37	0.067	0.44	18%

N/A – no baseline concentration available, percentage change cannot be calculated.

The predicted change in concentration and peak concentration surface water in the Darb River is shown in Table 19.

Table 19: Calculated Peak Concentration in Surface Water, Darb River (Scenario 1)

Constituent	Category II MAC (mg/L)	Baseline Concentration (mg/L)	Maximum Change in Concentration (mg/)	Peak Concentration in Surface Water (mg/L)	Percentage Change
Antimony	0.00028	0.0015	0	0.0015	0%
Sulphate	16.04	26.1	0.092	26.2	0%
Beryllium	0.000038	0.00020	0	0.00020	0%
Nitrate	0.01035	0.0025	0	0.0025	0%
Molybdenum	0.00082	0.0013	0	0.0013	0%
Arsenic	0.02	0.0029	$1.0x10^{-11}$	0.0029	0%
Cobalt	0.00036	0.00053	0	0.00053	0%
Cadmium	0.001014	0.00056	$1.1x10^{-7}$	0.00056	0%
Chromium	0.011	0.036	0	0.036	0%
Lithium	0.003	0.0015	$1.9x10^{-5}$	0.0015	1%
Tin	0.00008	N/A	$7.6x10^{-8}$	$7.6x10^{-8}$	N/A
Nitrate as N	2.5	0.46	0.095	0.55	21%

N/A – no baseline concentration available, percentage change cannot be calculated.

Water flowing in the Spandaryan-Kechut Tunnel is not affected in Scenario 1.

Calculations indicate that a slight change in water quality in the Vorotan River may occur with respect to lithium (0.14 µg/L change) and nitrate (0.07 mg/L change), these predicted changes are unmeasurable. Both constituents are predicted to remain below the Category II MAC for the Vorotan River.

A small potentially measureable change in water quality in the Darb River is predicted with respect to nitrate, although predicted peak nitrate concentrations remain below the Category II MAC. As described above, the nitrate source term considered in this assessment is considered highly conservative.

4.1.2.2 Scenario 2

Impacts on the Vorotan River are the same in Scenarios 1 and 2, predicted concentration in the Vorotan River is as shown in Table 18.

No impact on the Darb River is predicted in Scenario 2.

Potential impacts in surface water in the Kechut Reservoir and on water flowing in the Spandaryan-Kechut tunnel are shown in Tables 20 and 21. Impacts in the Kechut Reservoir are based on a low-flow (autumn-winter) through-flow rate of 2.0 m^3/s, the same as the estimated low flow for the downstream Arpa River. The rate of inflow to the reservoir is likely to be larger than this as some water is diverted to Lake Sevan, but this cannot be quantified.

Table 20: Calculated Peak Concentration in the Kechut Reservoir as a Result of Pit Infiltration, Scenario 2

Constituent	Category II MAC (mg/L)	Baseline Concentration (mg/L)	Maximum Change in Concentration (mg/l)	Peak Concentration in Surface Water (mg/L)	Percentage Change
Nitrate as N	2.5	0.51	0.0067	0.51	1%
Antimony	0.00028	0.001	0	0.001	0%
Sulphate	16.04	9.92	0.014	9.93	0%
Beryllium	0.000038	0.0002	0	0.0002	0%
Nickel	0.01035	0.003	0	0.003	0%
Molybdenum	0.00082	0.001	0	0.001	0%
Arsenic	0.02	0.0046	2.7×10^{-10}	0.0046	0%
Cobalt	0.00036	0.0005	0	0.0005	0%
Cadmium	0.001014	0.0005	6.6×10^{-8}	0.0005	0%
Chromium	0.011	0.005	0	0.005	0%
Lithium	0.003	0.0084	1.3×10^{-5}	0.0085	0%
Tin	0.00008	N/A	1.0×10^{-5}	1.0×10^{-5}	N/A

N/A – no baseline concentration available, percentage change cannot be calculated.

Table 21: Calculated Peak Concentration in the Spandaryan-Kechut Tunnel Flow Under Low Flow Conditions as a Result of Pit Infiltration, Scenario 2

Constituent	Category II MAC (mg/L)	Baseline Concentration (mg/L)	Maximum Change in Concentration (mg/l)	Peak Concentration in Tunnel Waters (mg/L)	Percentage Change
Nitrate as N	2.5	0.5	0.071	0.57	14%
Antimony	0.00028	0.001	0	0.001	0%
Sulphate	16.04	126	0.14	126	0%
Beryllium	0.000038	0.0002	0	0.0002	0%
Nickel	0.01035	0.003	0	0.003	0%
Molybdenum	0.00082	0.0030	0	0.0030	0%
Arsenic	0.02	0.0068	2.9×10^{-9}	0.0068	0%
Cobalt	0.00036	0.00051	0	0.00051	0%
Cadmium	0.001014	0.0005	7.0×10^{-7}	0.00051	0%
Chromium	0.011	0.005	0	0.005	0%
Lithium	0.003	0.0043	0.00013	0.0044	3%
Tin	0.00008	N/A	0.00011	0.00011	N/A

N/A – no baseline available, percentage change cannot be calculated.

No measureable change in water quality in the Kechut Reservoir is predicted as a result of infiltration to groundwater from the two reclaimed pit areas. A small change in nitrate concentration in waters in the Spandaryan-Kechut tunnel may occur; nitrate concentration is predicted to remain below the Category II MAC. As described above, the nitrate source term considered in this assessment is considered highly conservative.

Combined impacts on the Arpa River as a result of potential discharges from the pit area and from other facilities to the Spandaryan-Kechut tunnel and discharges directly to the Arpa River are evaluated as part of the surface water impact assessment, reported in Chapter 6.10 of the ESIA.

Combined impacts on water quality in the Spandaryan-Kechut tunnel as a result of discharge from the pit area and the BRSF is described in the groundwater impact assessment, reported in Chapter 6.9 of the ESIA.

4.2 Influence on Spring Quality, Local Flow Pathways

Change in quality at springs downgradient of the pit area, if affected, is likely to change over time as a result of changing concentrations in leakage from the pit areas. However, it is considered that migration in the groundwater pathway is likely to results in 'smoothing' of seasonal variability in source concentrations. Concentrations have therefore been predicted based in annual averages, and not seasonal ranges. Flows at perennial springs are greatly augmented in Spring by additional snow melt water recharge, which is likely to occur locally to the spring location. This spring snow melt will mix with the groundwater component of the spring flow, leading to lower concentrations in Spring than predicted by the impact calculations. Therefore, the water quality concentrations predicted and shown in Tables 22 and 23 are representative only for periods of low flow (the month of August, September, and November to March) when there is little contribution of surface runoff or interflow to spring flows.

Predicted changes in concentration are shown graphically in Appendix B.

The maximum change in concentration and predicted peak concentration in groundwater at the point of discharge to the springs in post-closure is shown in Table 22.

Long-term post-closure source concentrations are lower than in the years immediately following operation. The long-term (steady state) post-closure concentration in groundwater at the point of discharge to the springs is shown in Table 23.

As described above, RA Category II MACs do not apply to groundwaters, and are provided for comparison purposes only.

Table 22: Maximum Change and Predicted Maximum Concentration in Groundwater at Spring Discharge during Low Flow Conditions

Constituent	SO_4	Sb	As	Be	Cd	Co	Cr	Li	Mo	Ni	NO_3 as N	Sn
ARPA CATCHMENT												
Category II MAC	**16.04**	**$2.80x10^{-4}$**	**$2.00x10^{-2}$**	**$3.80x10^{-5}$**	**$1.01x10^{-3}$**	**$3.60x10^{-4}$**	**$1.10x10^{-2}$**	**$3.00x10^{-3}$**	**$8.20x10^{-4}$**	**$1.03x10^{-2}$**	**2.5**	**$8.00x10^{-5}$**
Catchment 1												
Baseline (mg/L)	7.49	$2.00x10^{-4}$	$1.00x10^{-3}$	$3.00x10^{-5}$	$5.00x10^{-4}$	$5.23x10^{-4}$	$5.00x10^{-3}$	$1.00x10^{-3}$	$8.00x10^{-4}$	$3.00x10^{-3}$	0.53	N/A
Increase (mg/L)	0.05	$1.47x10^{-5}$	$1.47x10^{-5}$	$9.46x10^{-6}$	$1.65x10^{-6}$	$6.39x10^{-5}$	$4.21x10^{-5}$	$8.35x10^{-5}$	$4.64x10^{-5}$	$5.70x10^{-5}$	0.00	$4.17x10^{-4}$
Maximum (mg/L)	7.54	$2.15x10^{-4}$	$1.01x10^{-3}$	$3.95x10^{-5}$	$5.02x10^{-4}$	$5.86x10^{-4}$	$5.04x10^{-3}$	$1.08x10^{-3}$	$8.46x10^{-4}$	$3.06x10^{-3}$	0.53	$4.17x10^{-4}$
%age Change	1%	7%	1%	32%	0%	12%	1%	8%	6%	2%	0%	N/A
Catchment 3												
Baseline (mg/L)	17.25	$2.00x10^{-4}$	$9.25x10^{-4}$	$2.01x10^{-4}$	$5.00x10^{-4}$	$5.28x10^{-4}$	$4.41x10^{-3}$	$1.03x10^{-3}$	$8.83x10^{-4}$	$4.32x10^{-3}$	0.5	N/A
Increase (mg/L)	2.78	$6.20x10^{-6}$	$1.70x10^{-4}$	$1.80x10^{-4}$	$3.21x10^{-5}$	$9.04x10^{-3}$	$2.34x10^{-5}$	$2.17x10^{-4}$	$1.96x10^{-5}$	$5.43x10^{-3}$	3.16	$1.76x10^{-4}$
Maximum (mg/L)	20.03	$2.06x10^{-4}$	$1.09x10^{-3}$	$3.81x10^{-4}$	$5.32x10^{-4}$	$9.57x10^{-3}$	$4.43x10^{-3}$	$1.25x10^{-3}$	$9.02x10^{-4}$	$9.75x10^{-3}$	3.66	$1.76x10^{-4}$
%age Change	16%	3%	18%	89%	6%	1714%	1%	21%	2%	126%	632%	N/A
Catchment 7												
Baseline (mg/L)	5.00	$2.00x10^{-4}$	$1.00x10^{-3}$	$3.00x10^{-5}$	$5.00x10^{-4}$	$5.00x10^{-4}$	$5.00x10^{-3}$	$1.00x10^{-3}$	$8.00x10^{-4}$	$3.00x10^{-3}$	0.5	N/A
Increase (mg/L)	1.17	0.00E+00	$6.91x10^{-5}$	$7.43x10^{-5}$	$1.33x10^{-5}$	$3.80x10^{-3}$	$2.42x10^{-6}$	$8.02x10^{-5}$	0	$2.28x10^{-3}$	1.33	0
Maximum (mg/L)	6.17	$2.00x10^{-4}$	$1.07x10^{-3}$	$1.04x10^{-4}$	$5.13x10^{-4}$	$4.30x10^{-3}$	$5.00x10^{-3}$	$1.08x10^{-3}$	$8.00x10^{-4}$	$5.28x10^{-3}$	1.83	0
%age Change	23%	0%	7%	248%	3%	760%	0%	8%	0%	76%	266%	N/A
VOROTAN CATCHMENT												
	SO4	**Sb**	**As**	**Be**	**Cd**	**Co**	**Cr**	**Li**	**Mo**	**Ni**	**N**	**Sn**
Category II MAC	**17.02**	**$5.00x10^{-4}$**	**$2.00x10^{-2}$**	**$5.40x10^{-5}$**	**$1.01x10^{-3}$**	**$2.80x10^{-4}$**	**$1.05x10^{-2}$**	**$2.00x10^{-3}$**	**$2.00x10^{-3}$**	**$1.05x10^{-2}$**	**2.5**	**$1.60x10^{-4}$**
Catchment 2												

Baseline (mg/L)	36.93	2.00×10^{-4}	1.43×10^{-3}	2.80×10^{-4}	5.00×10^{-4}	8.59×10^{-3}	5.00×10^{-3}	2.18×10^{-3}	8.00×10^{-4}	6.12×10^{-3}	0.51	N/A
Increase (mg/L)	0.02	4.51×10^{-6}	4.51×10^{-6}	2.90×10^{-6}	5.06×10^{-7}	1.96×10^{-5}	1.29×10^{-5}	2.56×10^{-5}	1.42×10^{-5}	1.75×10^{-5}	0.00	1.28×10^{-4}
Maximum (mg/L)	36.95	2.05×10^{-4}	1.44×10^{-3}	2.83×10^{-4}	5.01×10^{-4}	8.61×10^{-3}	5.01×10^{-3}	2.21×10^{-3}	8.14×10^{-4}	6.13×10^{-3}	0.51	1.28×10^{-4}
%age Change	0%	2%	0%	1%	0%	0%	0%	1%	2%	0%	0%	N/A
Catchment 4												
Baseline (mg/L)	5.00	2.00×10^{-4}	9.43×10^{-4}	3.00×10^{-5}	5.00×10^{-4}	4.65×10^{-4}	3.20×10^{-3}	1.00×10^{-3}	6.10×10^{-4}	2.41×10^{-3}	0.41	N/A
Increase (mg/L)	0.08	2.14×10^{-5}	2.14×10^{-5}	1.37×10^{-5}	2.4×10^{-6}	9.29×10^{-5}	6.13×10^{-5}	1.21×10^{-4}	6.74x10-5	8.28×10^{-5}	0.00	6.07×10^{-4}
Maximum (mg/L)	5.08	2.21×10^{-4}	9.64×10^{-4}	4.37×10^{-5}	5.02×10^{-4}	5.58×10^{-4}	3.26×10^{-3}	1.12×10^{-3}	6.78×10^{-4}	2.50×10^{-3}	0.41	6.07×10^{-4}
%age Change	2%	11%	2%	46%	0%	20%	2%	12%	11%	3%	0%	N/A
Catchment 456												
Baseline (mg/L)	5.00	2.00×10^{-4}	9.43×10^{-4}	3.00×10^{-5}	5.00×10^{-4}	4.65×10^{-4}	3.20×10^{-3}	1.00×10^{-3}	6.10×10^{-4}	2.41×10^{-3}	0.41	N/A
Increase (mg/L)	0.23	1.33×10^{-6}	1.44×10^{-5}	1.48×10^{-5}	2.66×10^{-6}	7.18×10^{-4}	4.26×10^{-6}	2.45×10^{-5}	4.2×10^{-6}	4.33×10^{-4}	0.25	3.78×10^{-5}
Maximum (mg/L)	5.23	2.01×10^{-4}	9.57×10^{-4}	4.48×10^{-5}	5.03×10^{-4}	1.18×10^{-3}	3.20×10^{-3}	1.02×10^{-3}	6.15×10^{-4}	2.85×10^{-3}	0.66	3.78×10^{-5}
%age Change	5%	1%	2%	49%	1%	154%	0%	2%	1%	18%	60%	N/A
Catchment 6												
Baseline (mg/L)	5.00	2.00×10^{-4}	6.50×10^{-4}	3.00×10^{-5}	5.00×10^{-4}	3.73×10^{-4}	2.73×10^{-3}	1.00×10^{-3}	5.08×10^{-4}	1.73×10^{-3}	0.41	N/A
Increase (mg/L)	4.99	0	2.82×10^{-4}	2.99×10^{-4}	5.48×10^{-5}	1.51×10^{-2}	9.48×10^{-6}	5.23×10^{-4}	0	9.11×10^{-3}	5.22	0
Maximum (mg/L)	9.99	2.00×10^{-4}	9.32×10^{-4}	3.29×10^{-4}	5.55×10^{-4}	1.55×10^{-2}	2.74×10^{-3}	1.52×10^{-3}	5.08×10^{-4}	1.08×10^{-2}	5.63	0
%age Change	100%	0%	43%	996%	11%	4051%	0%	52%	0%	526%	1274%	N/A

Note: Category II MAC is not relevant for groundwater quality, only surface water. Only provided for information.

Shading indicates value exceeds the MAC.

N/A – substance not analysed in baseline

Table 23: Predicted Change in Concentration and Concentration in Spring Quality, Long Term Closure

	SO_4	Sb	As	Be	Cd	Co	Cr	Li	Mo	Ni	NO_3 as N	Sn
ARPA CATCHMENT												
Category II MAC	**16.04**	**$2.80x10^{-4}$**	**$2.00x10^{-2}$**	**$3.80x10^{-5}$**	**$1.01x10^{-3}$**	**$3.60x10^{-4}$**	**$1.10x10^{-2}$**	**$3.00x10^{-3}$**	**$8.20x10^{-4}$**	**$1.03x10^{-2}$**	**2.5**	**$8.00x10^{-5}$**
Catchment 1												
Baseline (mg/L)	7.49	$2.00x10^{-4}$	$1.00x10^{-3}$	$3.00x10^{-5}$	$5.00x10^{-4}$	$5.23x10^{-4}$	$5.00x10^{-3}$	$1.00x10^{-3}$	$8.00x10^{-4}$	$3.00x10^{-3}$	0.53	N/A
Increase (mg/L)	0.05	$1.47x10^{-5}$	$1.47x10^{-5}$	$9.46x10^{-6}$	$1.65x10^{-6}$	$6.39x10^{-5}$	$4.21x10^{-5}$	$8.35x10^{-5}$	$4.64x10^{-5}$	$5.70x10^{-5}$	0.00	$4.17x10^{-4}$
Long Term (mg/L)	7.54	$2.15x10^{-4}$	$1.01x10^{-3}$	$3.95x10^{-5}$	$5.02x10^{-4}$	$5.86x10^{-4}$	$5.04x10^{-3}$	$1.08x10^{-3}$	$8.46x10^{-4}$	$3.06x10^{-3}$	0.53	$4.17x10^{-4}$
%age Change	1%	7%	1%	32%	0%	12%	1%	8%	6%	2%	0%	N/A
Catchment 3												
Baseline (mg/L)	17.25	$2.00x10^{-4}$	$9.25x10^{-4}$	$2.01x10^{-4}$	$5.00x10^{-4}$	5.28x10-4	$4.41x10^{-3}$	$1.03x10^{-3}$	$8.83x10^{-4}$	$4.32x10^{-3}$	0.50	N/A
Increase (mg/L)	2.02	$6.17x10^{-6}$	$1.24x10^{-4}$	$1.31x10^{-4}$	$2.34x10^{-5}$	6.54x10-3	$2.19x10^{-5}$	$1.67x10^{-4}$	$1.95x10^{-5}$	0.0039	2.28	$1.75x10^{-4}$
Long Term (mg/L)	19.27	$2.06x10^{-4}$	$1.05x10^{-3}$	$3.33x10^{-4}$	$5.23x10^{-4}$	7.07x10-3	$4.43x10^{-3}$	$1.20x10^{-3}$	$9.02x10^{-4}$	$8.25x10^{-3}$	2.78	$1.75x10^{-4}$
%age Change	12%	3%	13%	65%	5%	1240%	0%	16%	2%	91%	457%	N/A
Catchment 7												
Baseline (mg/L)	5.00	$2.00x10^{-4}$	$1.00x10^{-3}$	$3.00x10^{-5}$	$5.00x10^{-4}$	$5.00x10^{-4}$	$5.00x10^{-3}$	$1.00x10^{-3}$	$8.00x10^{-4}$	$3.00x10^{-3}$	0.50	N/A
Increase (mg/L)	0.86	0	$5.07x10^{-5}$	$5.45x10^{-5}$	$9.76x10^{-6}$	$2.79x10^{-3}$	$1.77x10^{-6}$	$5.90x10^{-5}$	0	$1.67x10^{-3}$	0.98	0
Long Term (mg/L)	5.86	$2.00x10^{-4}$	$1.05x10^{-3}$	$8.45x10^{-5}$	$5.10x10^{-4}$	$3.29x10^{-3}$	$5.00x10^{-3}$	$1.06x10^{-3}$	$8.00x10^{-4}$	$4.67x10^{-3}$	1.48	0
%age Change	17%	0%	5%	182%	2%	558%	0%	6%	0%	56%	195%	N/A
VOROTAN CATCHMENT												
	SO4	**Sb**	**As**	**Be**	**Cd**	**Co**	**Cr**	**Li**	**Mo**	**Ni**	**N**	**Sn**
Category II MAC	**17.02**	**$5.00x10^{-4}$**	**$2.00x10^{-2}$**	**$5.40x10^{-5}$**	**$1.01x10^{-3}$**	**$2.80x10^{-4}$**	**$1.05x10^{-2}$**	**$2.00x10^{-3}$**	**$2.00x10^{-3}$**	**$1.05x10^{-2}$**	**2.5**	**$1.60x10-^{4}$**
Catchment 2												

Baseline (mg/L)	36.93	$2.00x10^{-4}$	$1.43x10^{-3}$	$2.80x10^{-4}$	$5.00x10^{-4}$	$8.59x10^{-3}$	$5.00x10^{-3}$	$2.18x10^{-3}$	$8.00x10^{-4}$	$6.12x10^{-3}$	0.51	N/A
Increase (mg/L)	0.02	$4.51x10^{-6}$	$4.51x10^{-6}$	$2.90x10^{-6}$	$5.06x10^{-7}$	$1.96x10^{-5}$	$1.29x10^{-5}$	$2.56x10^{-5}$	$1.42x10^{-5}$	$1.75x10^{-5}$	0.00	$1.28x10^{-4}$
Long Term (mg/L)	36.95	$2.05x10^{-4}$	$1.44x10^{-3}$	$2.83x10^{-4}$	$5.01x10^{-4}$	$8.61x10^{-3}$	$5.01x10^{-3}$	$2.21x10^{-3}$	$8.14x10^{-4}$	$6.13x10^{-3}$	0.51	$1.28x10^{-4}$
%age Change	0%	2%	0%	1%	0%	0%	0%	1%	2%	0%	0%	N/A
Catchment 4												
Baseline (mg/L)	5.00	$2.00x10^{-4}$	$9.43x10^{-4}$	$3.00x10^{-5}$	$5.00x10^{-4}$	$4.65x10^{-4}$	$3.20x10^{-3}$	$1.00x10^{-3}$	$6.10x10^{-4}$	$2.41x10^{-3}$	0.41	N/A
Increase (mg/L)	0.08	$2.14x10^{-5}$	2.14x10-5	$1.37x10^{-5}$	$2.40x10^{-6}$	$9.29x10^{-5}$	$6.13x10^{-5}$	$1.21x10^{-4}$	$6.74x10^{-5}$	$8.28x10^{-5}$	0.00	$6.07x10^{-4}$
Long Term (mg/L)	5.08	$2.21x10^{-4}$	$9.64x10^{-4}$	$4.37x10^{-5}$	$5.02x10^{-4}$	$5.58x10^{-4}$	$3.26x10^{-3}$	$1.12x10^{-3}$	$6.78x10^{-4}$	$2.50x10^{-3}$	0.41	$6.07x10^{-4}$
%age Change	2%	11%	2%	46%	0%	20%	2%	12%	11%	3%	0%	N/A
Catchments 456												
Baseline (mg/L)	5.00	$2.00x10^{-4}$	$9.43x10^{-4}$	$3.00x10^{-5}$	$5.00x10^{-4}$	$4.65x10^{-4}$	$3.20x10^{-3}$	$1.00x10^{-3}$	$6.10x10^{-4}$	$2.41x10^{-3}$	0.41	N/A
Increase (mg/L)	0.18	$1.33x10^{-6}$	$1.12x10^{-5}$	$1.14x10^{-5}$	$2.05x10^{-6}$	$5.41x10^{-4}$	$4.15x10^{-6}$	$2.11x10^{-5}$	$4.20x10^{-6}$	$3.27x10^{-4}$	0.19	$3.77x10^{-5}$
Long Term (mg/L)	5.18	$2.01x10^{-4}$	$9.54x10^{-4}$	$4.14x10^{-5}$	$5.02x10^{-4}$	$1.01x10^{-3}$	$3.20x10^{-3}$	$1.02x10^{-3}$	$6.15x10^{-4}$	$2.74x10^{-3}$	0.60	$3.77x10^{-5}$
%age Change	4%	1%	1%	38%	0%	116%	0%	2%	1%	14%	45%	N/A
Catchment 6												
Baseline (mg/L)	5.00	$2.00x10^{-4}$	$6.50x10^{-4}$	$3.00x10^{-5}$	$5.00x10^{-4}$	$3.73x10^{-4}$	$2.73x10^{-3}$	$1.00x10^{-3}$	$5.08x10^{-4}$	$1.73x10^{-3}$	0.4095	N/A
Increase (mg/L)	4.15	0	$2.33x10^{-4}$	$2.46x10^{-4}$	$4.53x10^{-5}$	$1.24x10^{-2}$	$7.74x10^{-6}$	$3.98x10^{-4}$	0	0.00748	4.26	0
Long Term (mg/L)	9.15	$2.00x10^{-4}$	$8.83x10^{-4}$	$2.76x10^{-4}$	$5.45x10^{-4}$	$1.28x10^{-2}$	$2.74x10^{-3}$	$1.40x10^{-3}$	$5.08x10^{-4}$	$9.21x10^{-3}$	4.67	0
%age Change	83%	0%	36%	819%	9%	3320%	0%	40%	0%	432%	1041%	N/A

Shading indicates value exceeds the MAC.
N/A – substance not analysed in baseline

Calculations indicate that in the event that infiltration to the pits areas migrates in shallow groundwater surrounding the pits, changes in spring water quality are likely to occur under low flow conditions in all of the spring catchments assessed except Catchment 2.

No measurable change is predicted for Catchment 2 . Catchment 6 (east of Tigranes-Artavzdes) is most affected, with measurable change leading to an increase in groundwater concentrations above the surface water MAC with respect to beryllium, cobalt, nickel and nitrate (indicating that without additional dilution, groundwater has the potential to pose a risk to surface water). This catchment is small and at high elevation (between 2650 m asl and 2900 m asl), such that it is in close proximity to the source area and has high sensitivity to change.

Change in beryllium and cobalt concentrations are predicted in most catchments. Due to the low surface water MACs for these substances, predicted changes typically result in an increase in groundwater concentrations above the surface water MAC concentration. The maximum predicted concentrations of these substances are 0.4 µg/L of beryllium (Catchment 3) and 16 µg/L of cobalt (Catchment 6). Cobalt naturally exceeds the surface water MAC in spring discharges under baseline conditions in a number of the assessed catchments.

Measureable change in nitrate concentrations is predicted in Catchments 3, 5, 6 and 7. Maximum nitrate concentration in groundwater is predicted to exceed the surface water MAC in Catchments 3 and 6, indicating that without additional dilution groundwater discharge has the potential to pose a risk to surface waters. The maximum predicted concentration of nitrate is 5.6 mg N/L (24.8 mg/L as nitrate) in Catchment 6. Nitrate impacts are likely to decrease with time, as nitrate is leached from the backfill material.

Measureable change in nickel concentration is predicted in Catchment 3, 6 and 7, leading to concentrations exceeding the MAC in Catchment 6. The maximum predicted concentration of nickel is 11 µg/L in Catchment 6.

Measureable changes in groundwater with respect to other substances are predicted, but are not predicted to result in an increase above the surface water MAC in the affected catchments.

5.0 CONCLUSIONS

The pit impact assessment has considered two end-members of the potential hydrogeological conditions, in which infiltration from the pits migrates either to deep groundwater discharging to surface water courses at low elevations in the Study Area, or to shallow groundwater, discharging to spring catchments surrounding Amulsar Mountain.

5.1 Study Area-wide Flow Pathways

Assessment of the Study-Area wide flow paths in groundwater indicates that localised impacts on groundwater quality at the point of discharge are likely to occur:

- Calculations indicate a localised change in nitrate concentrations in groundwater in Pathway 1. No measureable change is predicted with respect to other priority constituents of potential concern.
- Calculations indicate a localised change in nitrate, sulphate and lithium concentrations in groundwater in Pathway 2. No measureable change is predicted with respect to other priority constituents of potential concern.
- Calculations indicate a localised change in lithium concentrations in groundwater in Pathway 3. A measureable change in sulphate may also occur. No measureable change is predicted with respect to other priority constituents of potential concern.
- Calculations indicate a localised change in lithium concentrations in groundwater in Pathway 4. No measureable change is predicted with respect to other priority constituents of potential concern.

- Slight but unmeasurable changes in groundwater quality in Pathway 5 at the point of discharge to the Vorotan River are predicted.

Calculations indicate that discharge via Study-Area wide flow pathways may result in a slight but unmeasurable change in water quality in the Vorotan River with respect to lithium (0.14 µg/L change) and nitrate (0.07 mg/L change). . Both constituents are predicted to remain below the Category II MAC for the Vorotan River.

A small potentially measureable change in water quality in the Darb River is predicted with respect to nitrate, although predicted peak nitrate concentrations remain below the Category II MAC. As described above, the nitrate source term considered in this assessment is considered highly conservative.

No measureable change in water quality in the Kechut Reservoir is predicted as a result of infiltration to groundwater from the two reclaimed pit areas. A small change in nitrate concentration in waters in the Spandaryan-Kechut tunnel may occur; nitrate concentration is predicted to remain below the Category II MAC. As described above, the nitrate source term considered in this assessment is considered highly conservative.

Combined impacts on the Arpa River as a result of potential discharges from the pit area and from other facilities to the Spandaryan-Kechut tunnel and discharges directly to the Arpa River are evaluated as part of the surface water impact assessment, reported in Chapter 6.10 of the ESIA.

Combined impacts on water quality in the Spandaryan-Kechut tunnel as a result of discharge from the pit area and the BRSF is described in the groundwater impact assessment, reported in Chapter 6.9 of the ESIA.

The concentration of nitrate as nitrogen reported in this assessment is based on a conservative evaluation of the potential source term and assumes a continuous high concentration source with no change in concentration over this time, and assuming no denitrification along the groundwater pathway; this is a very unlikely occurrence. Although predicted changes in nitrate concentration are small, they are also considered to represent an unlikely impact scenario which has a low probability of occurrence, such that the predicted impacts should be treated with caution in decision making or impact assessment. In the unlikely event that nitrate concentrations above those predicted in Golder (2014d) and evaluated in this assessment are identified during operations, mitigation measures can be implemented to control nitrogen release from explosives and to promote fixing of nitrates in barren rock storage areas.

5.2 Local Flow Pathways

Calculations indicate that in the event that infiltration to the pits areas is transported in shallow groundwater surrounding the pits, changes in spring water quality under low flow conditions are likely to occur (typically during the months of August, September and November to March), in all of the spring catchments assessed except Catchment 2.

Concentrations of beryllium, cobalt, nitrate and nickel in groundwater are predicted to exceed surface water Category II MACs in some catchments at high elevations surrounding Amulsar Mountain, suggesting that without additional dilution groundwater discharges have the potential to pose a risk to surface water quality and aquatic habitat. Mixing of these spring discharges will occur at lower elevations as the catchment areas of the drainages affected increase. The assessment of impacts on surface water at lower elevations as a result of changes to spring discharge are considered in Chapter 6.10 of the ESIA. The assessment ecological impacts associated with changes in water quality are considered in Chapter 6.19 of the ESIA.

As in the deeper flow pathway assessment described above, the assessment of spring impacts with regard to nitrate is based on a conservative and steady state source. Nitrate concentrations arising from backfill in the Tigranes-Artavazdes pit will decrease over time as a result of leaching from the pit backfill material. The predicted impacts should be treated with caution in decision making or impact assessment.

6.0 REFERENCES

1) Golder Associates, 2014a. Amulsar Groundwater Model Report, Report Reference 14514150095.506 Version B.0

2) Golder Associates, 2014b. Evaluation of Water Quality in the Post-Closure Erato Pit, Rev. 0, Ref. 1138159714. August 2014.

3) Golder Associates, 2014c. Amulsar Gold Project: Erato Post-Closure Water Balance. 14514150095.503/B.4. Dated 4 August 2014.

4) Golder Associates, 2014d Amulsar Gold Project: Estimate of nitrate and ammonia concentrations in mine water as a product of blasting, Dated July 2014.

5) Global Resource Engineering Ltd, 2014 Tigranes-Artavasdes Backfill and Arshak Pit Seepage Source Terms. Ref. 13-1064. 7 August 2014.

6) England and Wales Environment Agency, 2006a. Hydrogeological Risk Assessment for Land Contamination, Remedial Targets Worksheet, Release 3.1. October 2006.

7) England and Wales Environment Agency, 2006b. Remedial Targets Methodology: Hydrogeological Risk Assessment for Land Contamination. Product Code GEHO0706BLEQ-E-E.

Report Signature Page

GOLDER ASSOCIATES (UK) LTD

Hollie Garrick Hydrogeologist	Carl Nicholas Project Manager

Date: 22 August 2014

CHG/CN/ab

APPENDIX A

Input Parameters, Study-Area Wide Groundwater Impact Assessment

Input Parameters, Study-Area Wide Pathway Calculations

Parameter	Unit	Value	Justification
Bulk Density	g/cm3	2350	Average in situ density, AMC mine waste schedule
Bulk Density	g/cm3	2350	Average in situ density, AMC mine waste schedule
Effective porosity Lower Volcanics		0.03	Value for argillic Lower Volcanics, Groundwater Baseline Report 2014
Effective porosity, Upper Volcanics		0.04	Value for Upper Volcanics, Groundwater Baseline Report 2014
K Lower Volcanics	m/s	2.60E-06	Groundwater Baseline Report, 2014
K Upper Volcanics	m/s	2.00E-07	Groundwater Baseline Report, 2014
K Lower Volcanics	m/d	2.25E-01	Calculated
K Upper Volcanics	m/d	1.73E-02	Calculated
Source Concentration - Pathway 3 and 4 (Erato)			
Antimony	mg/l	0.019	Average annual concentration (annual mass flux over annual infiltration), Geochemical model of Erato Pit (Golder, 2014), mid-value between the average and maximum reported scenarios.
Arsenic	mg/l	0.06	
Beryllium	mg/l	0.037	
Cobalt	mg/l	0.25	
Cadmium	mg/l	0.006	
Chromium	mg/l	0.16	
Lithium	mg/l	0.33	
Molybedum	mg/l	0.18	
Nickel	mg/l	0.22	
Sulfate	mg/l	211.88	
Tin	mg/l	1.63	
Source Concentration - Pathway 1			
Arsenic	mg/l	0.025	
Beryllium	mg/l	0.027	
Cobalt	mg/l	1.40	
Cadmium	mg/l	0.0049	
Chromium	mg/l	0.0009	
Lithium	mg/l	0.029	
Nickel	mg/l	0.84	Average concentration over the 20 years following development, based on steady state concentration predicted for discharge from the Tigranes-Artevazdes pit areas and infiltration rates (total mass released divided by total infiltration)
Nitrate	mg N/l	492	
Sulfate	mg/l	431	
Source Concentration - Pathway 2			
Arsenic	mg/l	0.026	
Beryllium	mg/l	0.028	
Cobalt	mg/l	1.43	
Cadmium	mg/l	0.0050	
Chromium	mg/l	0.0009	
Lithium	mg/l	0.029	
Nickel	mg/l	0.86	Average concentration over the 20 years following development, based on steady state concentration predicted for discharge from the Tigranes-Artevazdes pit areas and infiltration rates (total mass released divided by total infiltration)
Nitrate	mg N/l	500	
Sulfate	mg/l	437	
Source Concentration - Pathway 5			
Arsenic	mg/l	0.0023	
Beryllium	mg/l	0.0018	
Cobalt	mg/l	0.069	
Cadmium	mg/l	0.0005	
Chromium	mg/l	2.5E-05	
Lithium	mg/l	0.020	
Nickel	mg/l	0.047	Average concentration over the 20 years following development, based on steady state concentration predicted for discharge from the Tigranes-Artevazdes pit areas and infiltration rates (total mass released divided by total infiltration)
Nitrate	mg N/l	13.8	
Sulfate	mg/l	66.7	
Kd			
Antimony	l/kg	45	USEPA 1994, pH 6.8
Arsenic	l/kg	9	Mid-value of range, USEPA 1994
Beryllium	l/kg	790	USEPA 1994, pH 6.8
Cobalt	l/kg	126	USEPA, 2005
Cadmium	l/kg	2.7	USEPA, 2005. Mean value for soil/soil water partitioning
Chromium	l/kg	19	Mid-value of range, USEPA 1994
Lithium	l/kg	0	Not retarded
Molybedum	l/kg	19.95	USEPA 2005, Mean value for soil/ soil water partitioning
Nitrate	l/kg	0	Not retarded
Nickel	l/kg	65	USEPA 1994, pH 6.8
Sulfate	l/kg	0	Not retarded
Tin	l/kg	2.7	USEPA 2005, Mean value for soil/ soil water partitioning
WQS - Arpa (Also apply to the Darb catchment)			
Antimony	mg/L	0.00028	RoA Decree N75-N Basin specific standards, Appendices 3 - 25
Arsenic	mg/L	0.02	RoA Decree N75-N Basin specific standards, Appendices 3 - 25
Beryllium	mg/L	0.000038	RoA Decree N75-N Basin specific standards, Appendices 3 - 25
Cobalt	mg/L	0.00036	RoA Decree N75-N Basin specific standards, Appendices 3 - 25
Cadmium	mg/L	0.001014	RoA Decree N75-N Basin specific standards, Appendices 3 - 25
Chromium	mg/L	0.011	RoA Decree N75-N Basin specific standards, Appendices 3 - 25
Lithium	mg/L	0.003	RoA Decree N75-N Basin specific standards, Appendices 3 - 25
Molybedum	mg/L	0.00082	RoA Decree N75-N Basin specific standards, Appendices 3 - 25
Nitrate	mg N/L	2.5	RoA Decree N75-N Basin specific standards, Appendices 3 - 25
Nickel	mg/L	0.01034	RoA Decree N75-N Basin specific standards, Appendices 3 - 25
Sulfate	mg/L	16.04	RoA Decree N75-N Basin specific standards, Appendices 3 - 25
Tin	mg/L	0.00008	RoA Decree N75-N Basin specific standards, Appendices 3 - 25

Input Parameters, Study-Area Wide Pathway Calculations

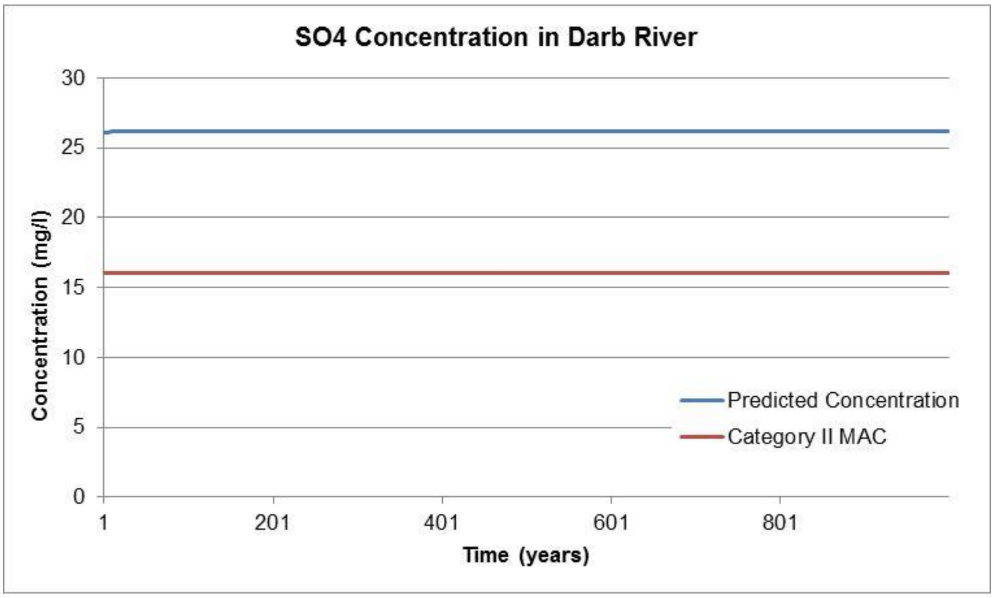
Parameter	Unit	Value	Justification
WQS - Vorotan			
Antimony	mg/L	0.0005	RoA Decree N75-N Basin specific standards, Appendices 3 - 25
Arsenic	mg/L	0.02	RoA Decree N75-N Basin specific standards, Appendices 3 - 25
Beryllium	mg/L	0.000054	RoA Decree N75-N Basin specific standards, Appendices 3 - 25
Cobalt	mg/L	0.00028	RoA Decree N75-N Basin specific standards, Appendices 3 - 25
Cadmium	mg/L	0.00101	RoA Decree N75-N Basin specific standards, Appendices 3 - 25
Chromium	mg/L	0.0105	RoA Decree N75-N Basin specific standards, Appendices 3 - 25
Lithium	mg/L	0.002	RoA Decree N75-N Basin specific standards, Appendices 3 - 25
Molybedum	mg/L	0.002	RoA Decree N75-N Basin specific standards, Appendices 3 - 25
Nitrate	mg N/L	2.5	RoA Decree N75-N Basin specific standards, Appendices 3 - 25
Nickel	mg/L	0.01045	RoA Decree N75-N Basin specific standards, Appendices 3 - 25
Sulfate	mg/L	17.02	RoA Decree N75-N Basin specific standards, Appendices 3 - 25
Tin	mg/L	0.00016	RoA Decree N75-N Basin specific standards, Appendices 3 - 25
Pathway Properties			
Pathway 1			
Width of plume	m	490	Groundwater flow model (Golder, 2014), particle pathlines
Aquifer Thickness	m	100	Assumption based on typical fractured systems and hydraulic conductivity testing results
Hydraulic Gradient		0.198	Average over pathway length based on baseline groundwater contours
Distance to Kechut-Spandaryan Tunnel	m	3030	Groundwater flow model (Golder, 2014), particle pathlines
Distance to Darb River	m	4650	Groundwater flow model (Golder, 2014), particle pathlines
Plume thickness at source	m	5	Release into groundwater from pit base - surface source.
Pathway 2			
Width of plume	m	390	Groundwater flow model (Golder, 2014), particle pathlines
Aquifer Thickness	m	100	Assumption based on typical fractured systems and hydraulic conductivity testing results
Hydraulic Gradient		0.234	Average over pathway length based on baseline groundwater contours
Distance to Vorotan River	m	2200	Groundwater flow model (Golder, 2014), particle pathlines
Plume thickness at source	m	5	Release into groundwater from pit base - surface source.
Pathway 3			
Width of plume	m	780	Groundwater flow model (Golder, 2014), particle pathlines
Aquifer Thickness	m	100	Assumption based on typical fractured systems and hydraulic conductivity testing results
Hydraulic Gradient		0.154	Average over pathway length based on baseline groundwater contours
Distance to Vorotan River	m	2450	Groundwater flow model (Golder, 2014), particle pathlines
Plume thickness at source	m	5	Release into groundwater from pit base - surface source.
Pathway 4			
Width of plume	m	850	Groundwater flow model (Golder, 2014), particle pathlines
Aquifer Thickness	m	100	Assumption based on typical fractured systems and hydraulic conductivity testing results
Hydraulic Gradient		0.143	Average over pathway length based on baseline groundwater contours
Distance to Kechut-Spandaryan Tunnel	m	3050	Groundwater flow model (Golder, 2014), particle pathlines
Distance to Darb River	m	6960	Groundwater flow model (Golder, 2014), particle pathlines
Plume thickness at source	m	5	Release into groundwater from pit base - surface source.
Pathway 5			
Width of plume	m	540	Groundwater flow model (Golder, 2014), particle pathlines
Aquifer Thickness	m	100	Assumption based on typical fractured systems and hydraulic conductivity testing results
Hydraulic Gradient		0.194	Average over pathway length based on baseline groundwater contours
Distance to Vorotan River	m	3100	Groundwater flow model (Golder, 2014), particle pathlines
Plume thickness at source	m	5	Release into groundwater from pit base - surface source.
Receptors			
Existing Flow in KS tunnel	m3/s	0.19	Groundwater Baseline 2014
Base Flow in River Vorotan	m3/s	0.4	Surface Water Baseline, 2014. Q95 Low flow
Base Flow in River Darb AW005	m3/s	0.192	Average of spot measurements in August and September 2010, 2011
Base flow in River Darb AW006	m3/s	0.845	Average of spot measurements in August and September 2010, 2011

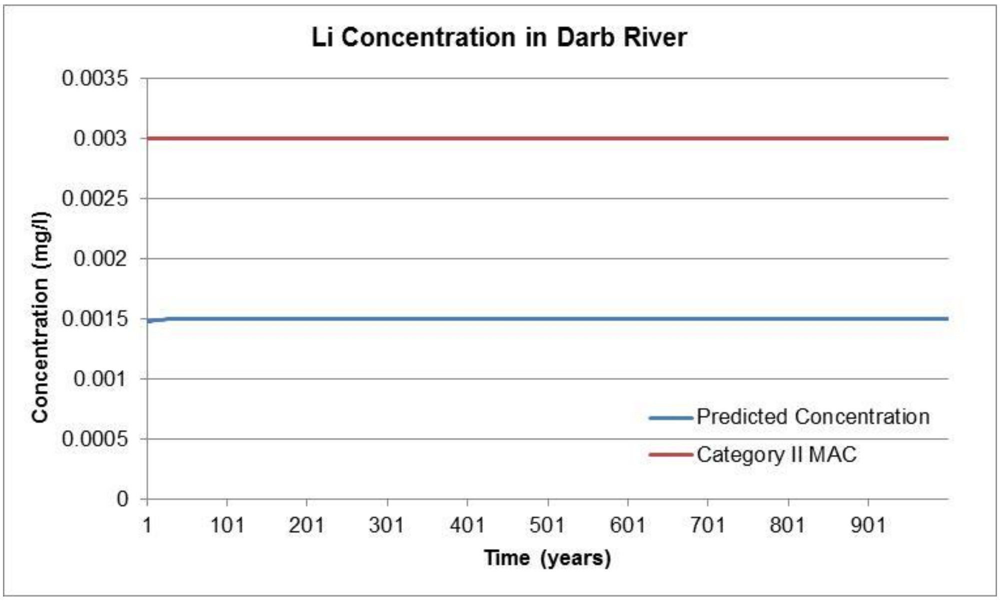
APPENDIX B

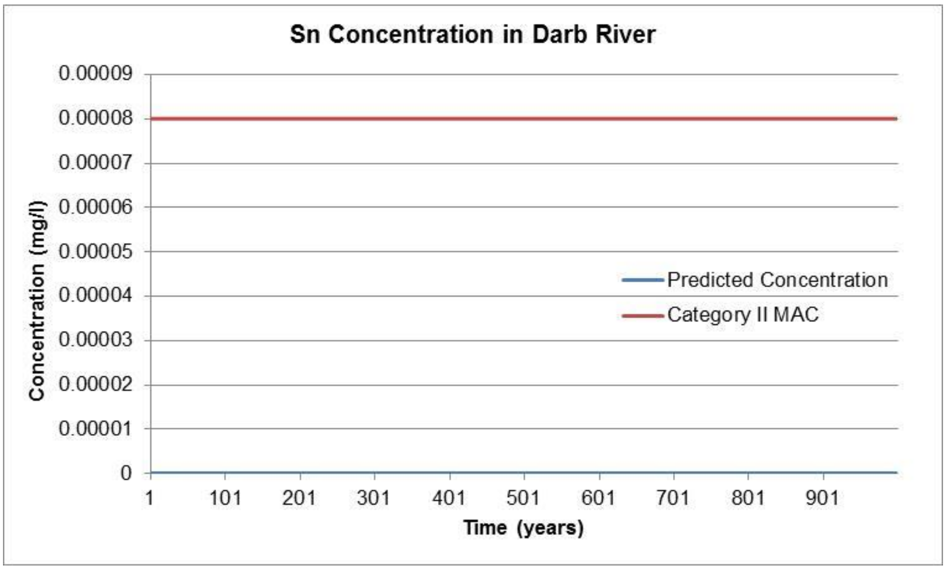
Concentration Time History Graphs

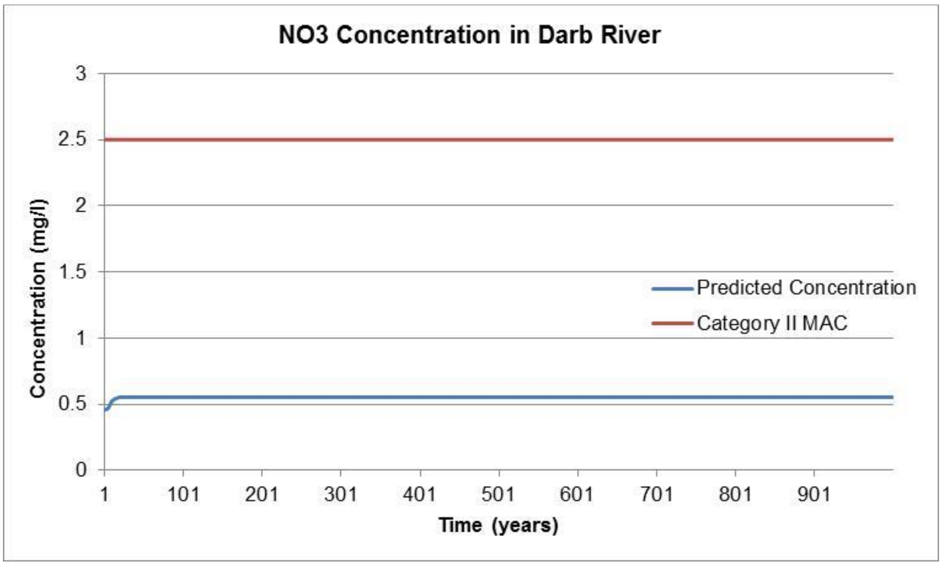
Concentration in Surface Waters, Study-Area Wide Pathways

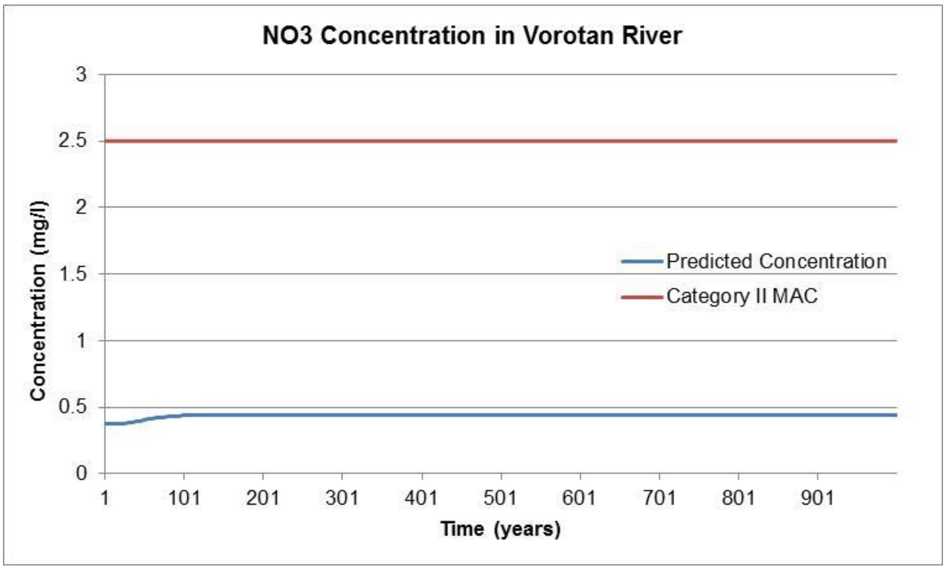
Graphs show total concentration (inclusive of baseline concentration) and are presented only for those substances which arrive at the point of discharge to receiving waters within 1000 years.

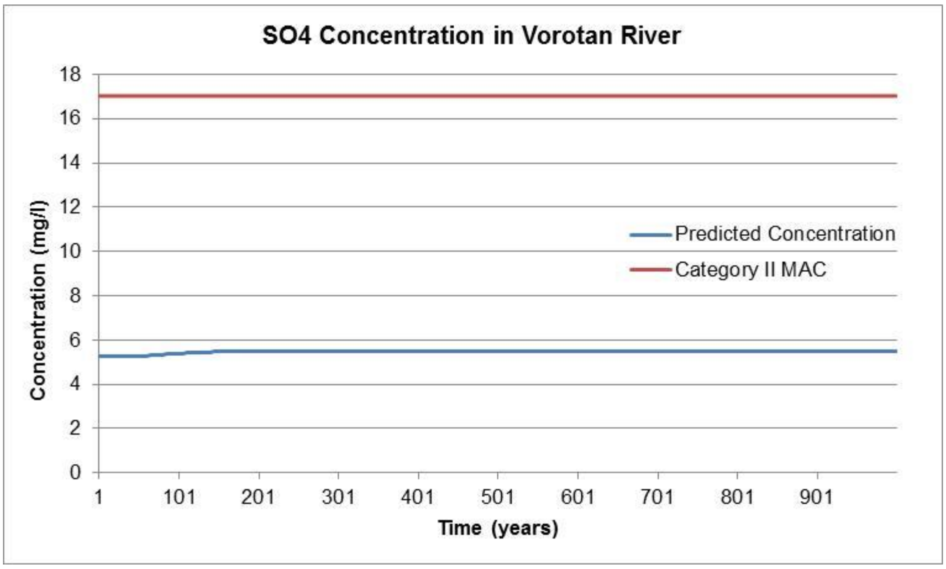


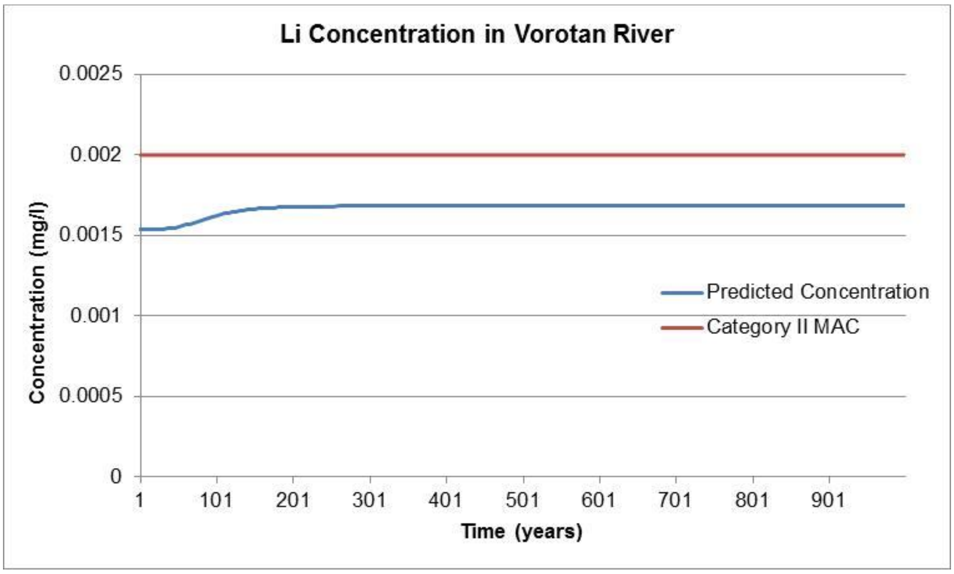


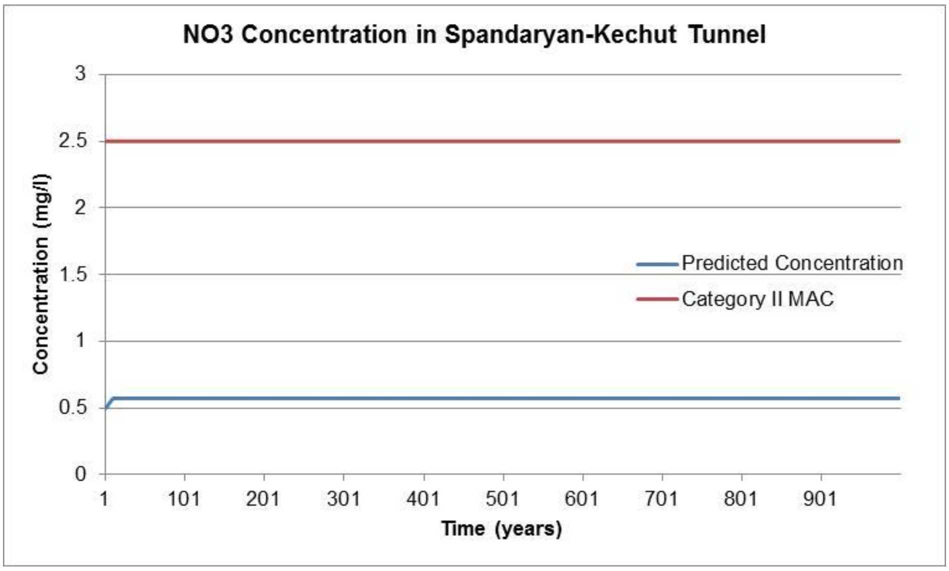

Sn Concentration in Darb River
0.00009
0.00008
0.00007
0.00006
0.00005
0.00004
0.00003
0.00002
0.00001
0
Concentration (mg/l)
Predicted Concentration
Category II MAC
1
101
201
301
401
501
601
701
801
901
Time (years)

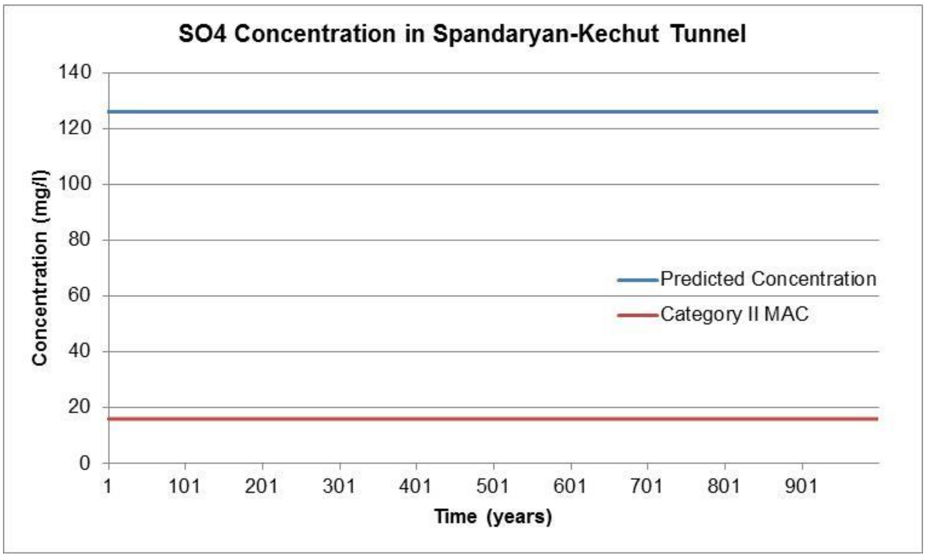

NO3 Concentration in Darb River
3
2.5
2
1.5
1
0.5
0
Concentration (mg/l)
Predicted Concentration
Category II MAC
1
101
201
301
401
501
601
701
801
901
Time (years)

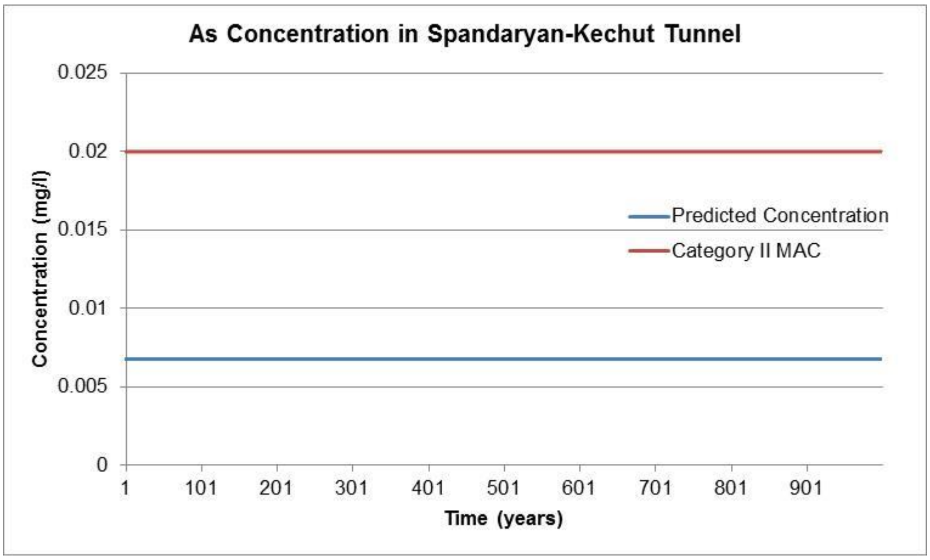

NO3 Concentration in Vorotan River
3
2.5
2
1.5
1
0.5
0
Concentration (mg/l)
Predicted Concentration
Category II MAC
1
101
201
301
401
501
601
701
801
901
Time (years)

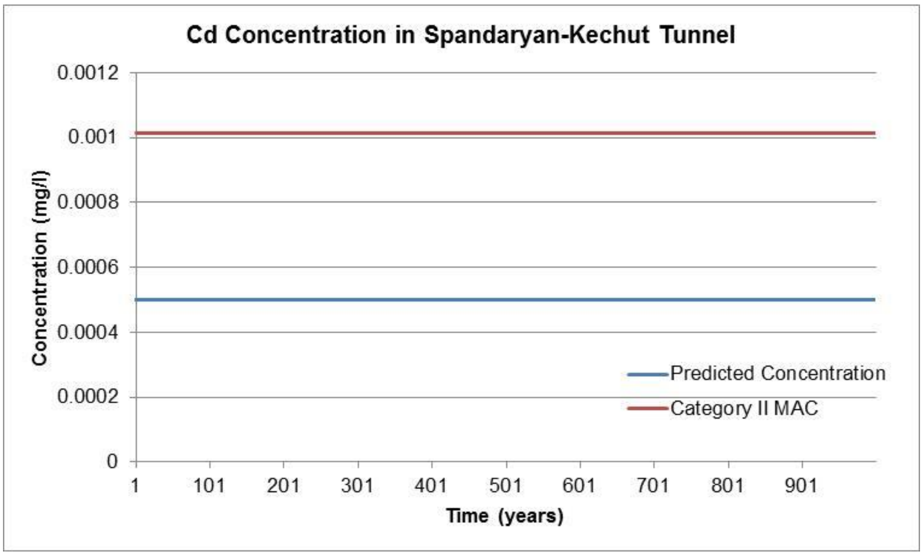

SO4 Concentration in Vorotan River
Concentration (mg/l)
Time (years)
Predicted Concentration
Category II MAC
0
2
4
6
8
10
12
14
16
18
1
101
201
301
401
501
601
701
801
901

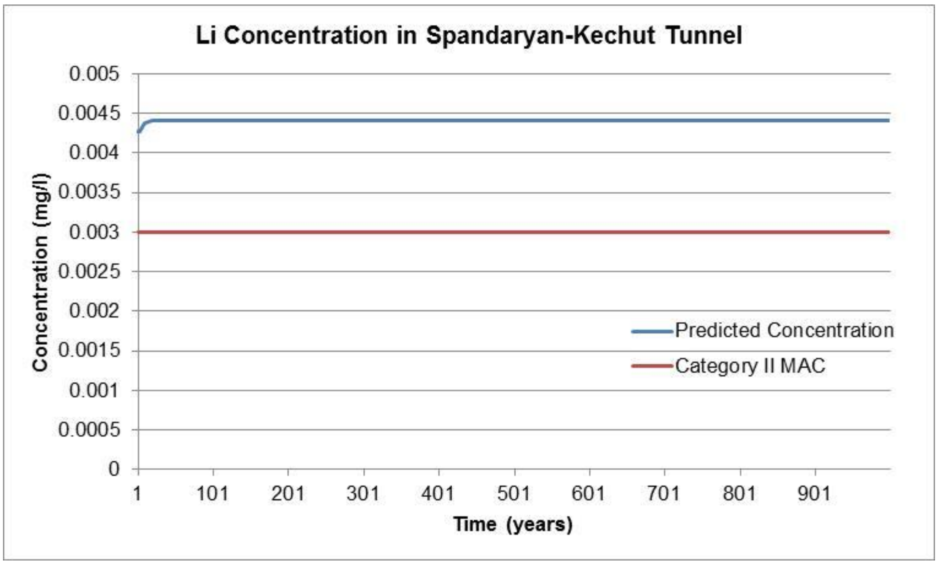

Li Concentration in Vorotan River
Concentration (mg/l)
Time (years)
Predicted Concentration
Category II MAC
0
0.0005
0.001
0.0015
0.002
0.0025
1
101
201
301
401
501
601
701
801
901

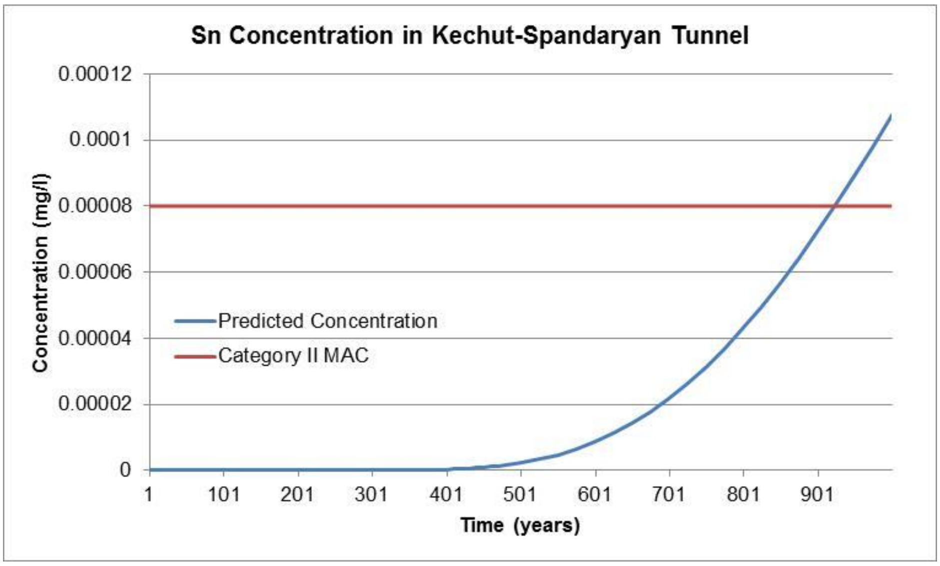

NO3 Concentration in Spandaryan-Kechut Tunnel
Concentration (mg/l)
Time (years)
Predicted Concentration
Category II MAC
0
0.5
1
1.5
2
2.5
3
1
101
201
301
401
501
601
701
801
901


SO4 Concentration in Spandaryan-Kechut Tunnel
Concentration (mg/l)
140
120
100
80
60
40
20
0
1
101
201
301
401
501
601
701
801
901
Time (years)
Predicted Concentration
Category II MAC


As Concentration in Spandaryan-Kechut Tunnel
Concentration (mg/l)
0.025
0.02
0.015
0.01
0.005
0
1
101
201
301
401
501
601
701
801
901
Time (years)
Predicted Concentration
Category II MAC

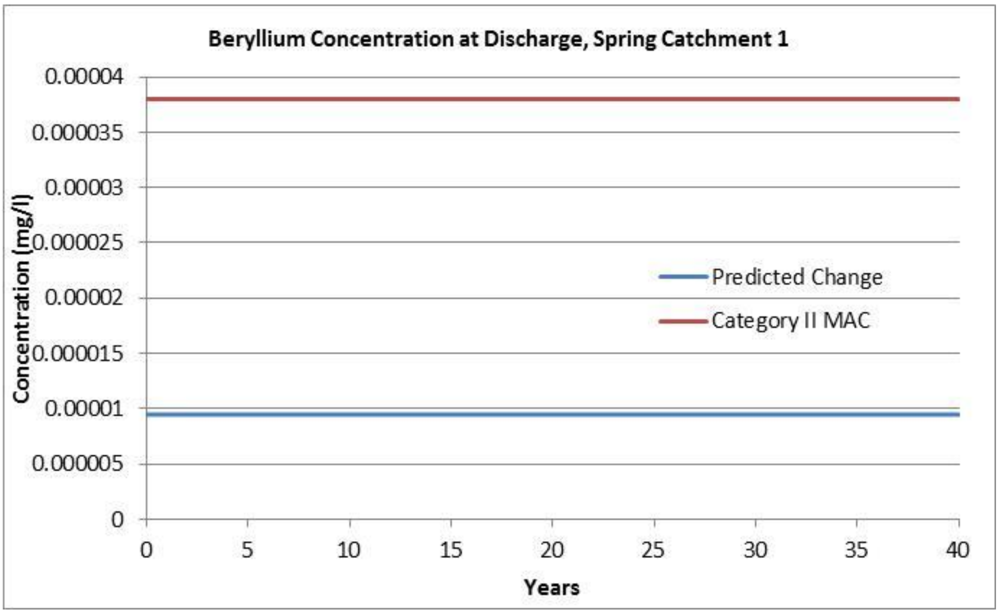

Cd Concentration in Spandaryan-Kechut Tunnel
Concentration (mg/l)
0.0012
0.001
0.0008
0.0006
0.0004
0.0002
0
1
101
201
301
401
501
601
701
801
901
Time (years)
Predicted Concentration
Category II MAC

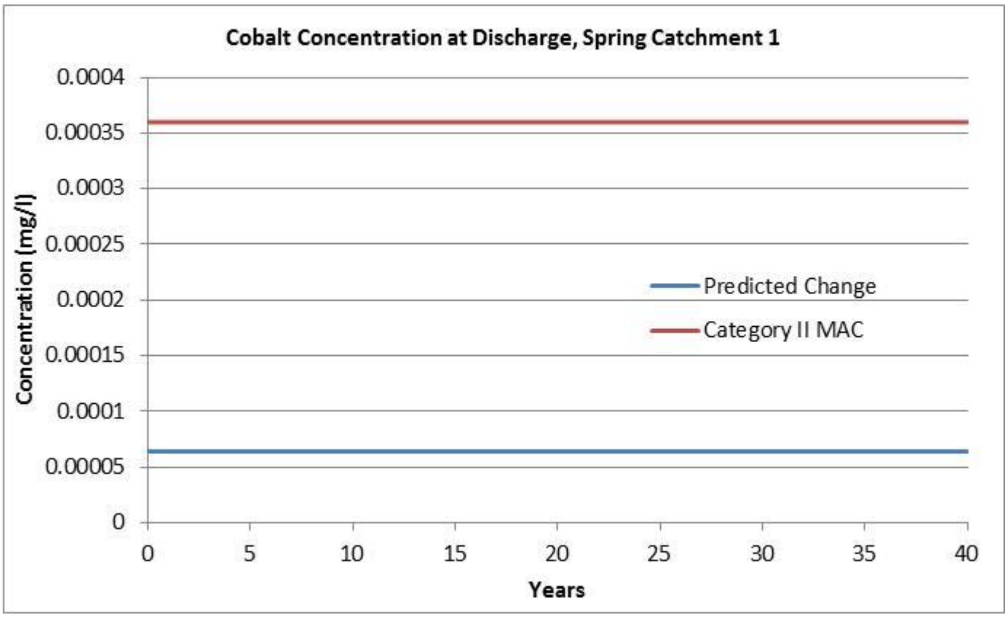

Li Concentration in Spandaryan-Kechut Tunnel
Concentration (mg/l)
0.005
0.0045
0.004
0.0035
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
1
101
201
301
401
501
601
701
801
901
Time (years)
Predicted Concentration
Category II MAC

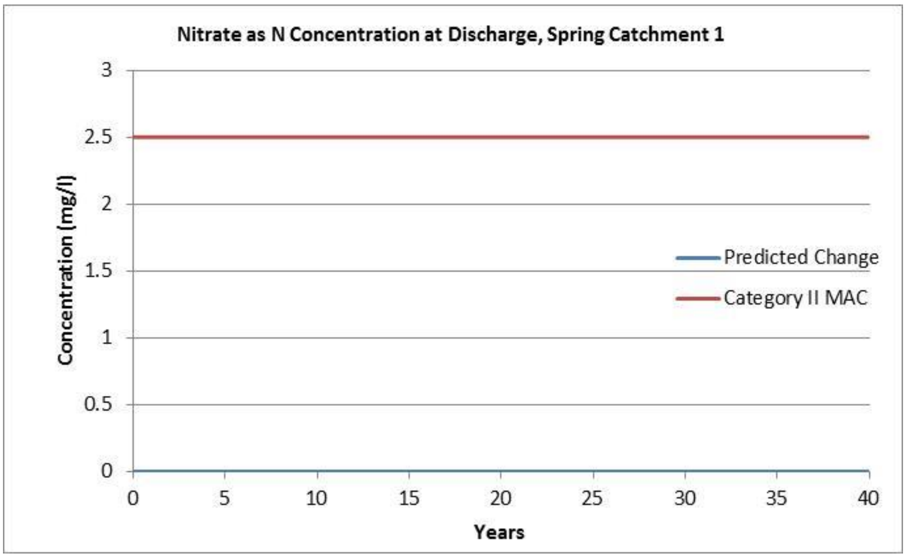

Sn Concentration in Kechut-Spandaryan Tunnel
Concentration (mg/l)
0.00012
0.0001
0.00008
0.00006
0.00004
0.00002
0
1
101
201
301
401
501
601
701
801
901
Time (years)
Predicted Concentration
Category II MAC

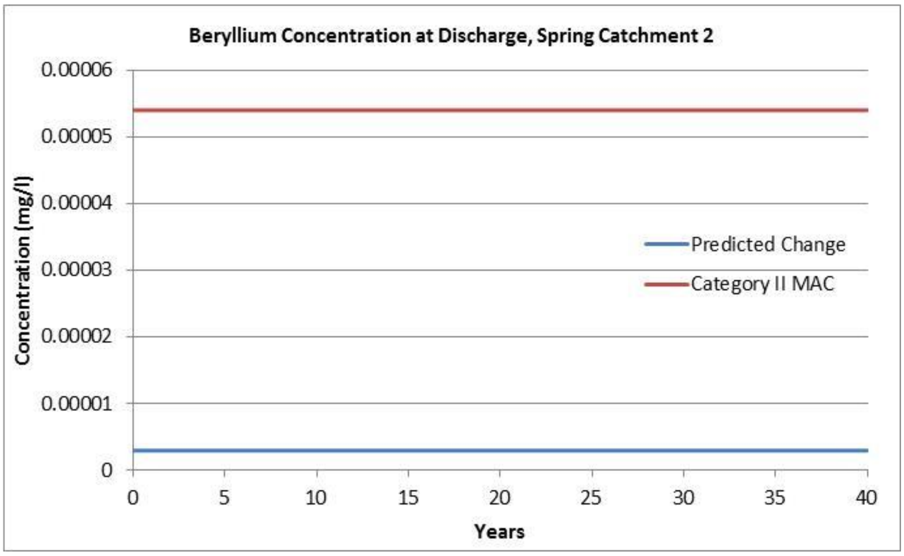
Change in Concentration in Groundwater at Point of Discharge to Springs, Local Area Pathways

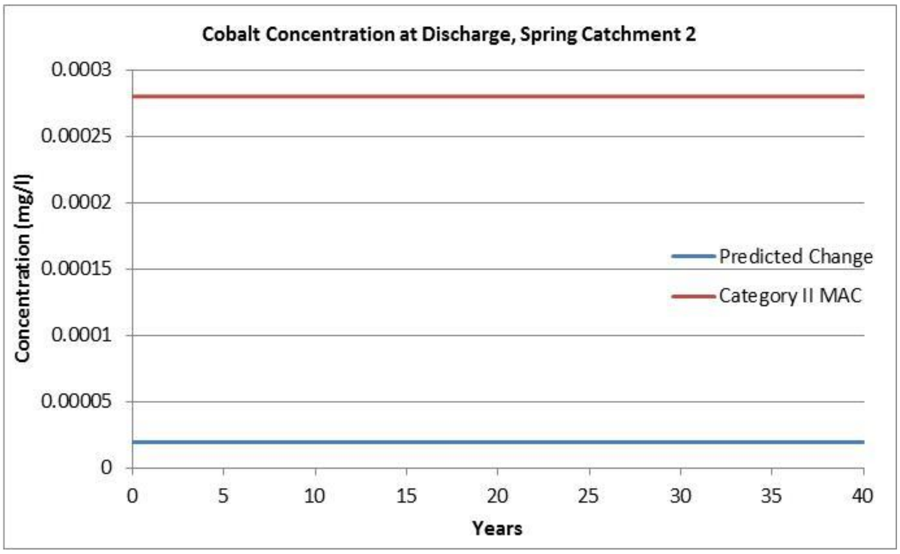
Graphs are presented for change in concentration in groundwater with respect to beryllium, cobalt and nitrate in each catchment. These substances show the greatest magnitude of change and exceed Category II MAC concentrations in some catchments. Calculations are based on direct dilution of pit infiltration in groundwater recharge within the catchment, such that impacts reported are effectively instantaneous. It is considered probable that travel times to the point of discharge to the springs in groundwater will be a number of years, leading to peak impacts occurring later than illustrated.

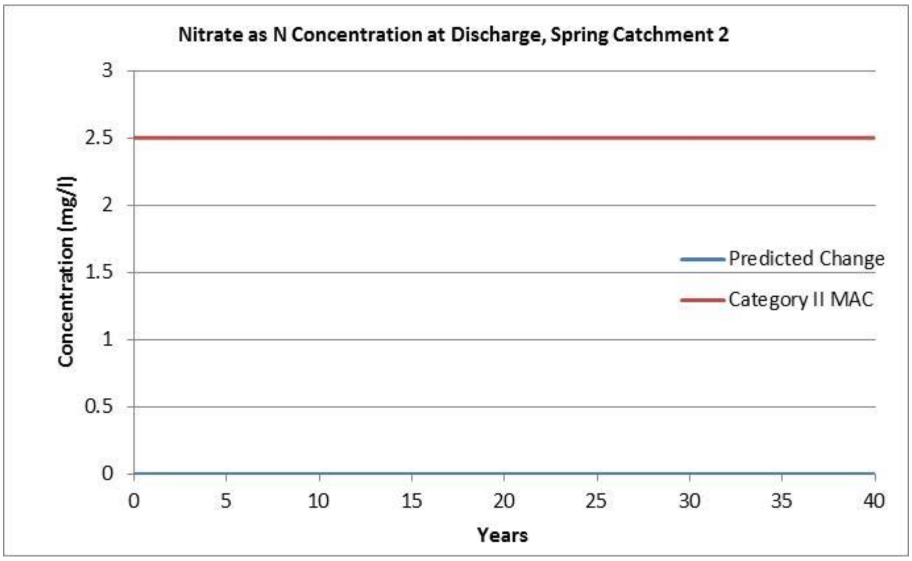


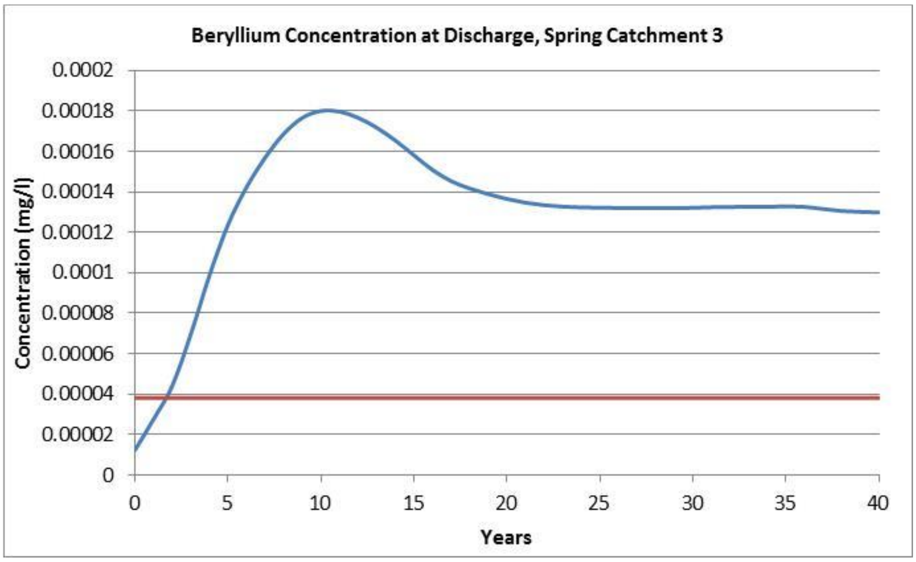


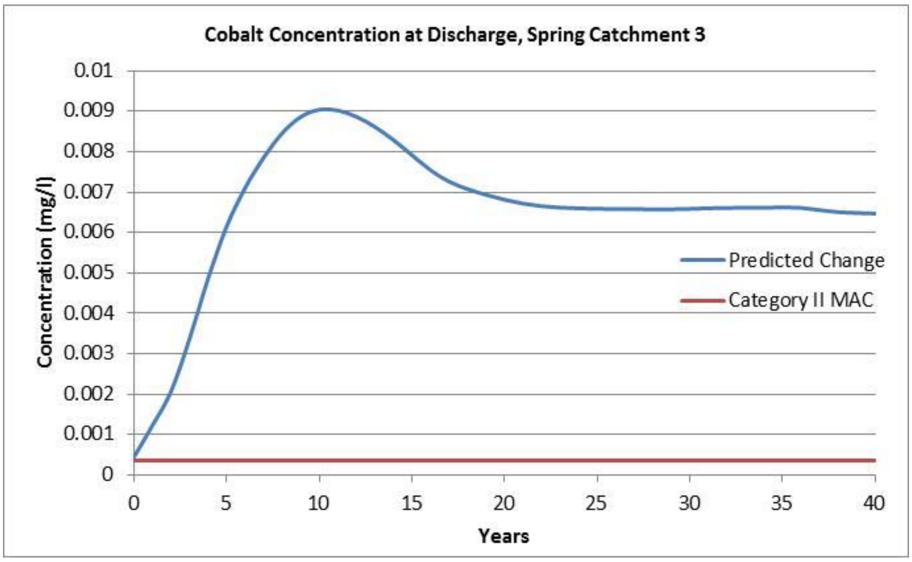

Nitrate as N Concentration at Discharge, Spring Catchment 1
Concentration (mg/l)
3
2.5
2
1.5
1
0.5
0
0
5
10
15
20
25
30
35
40
Years
Predicted Change
Category II MAC

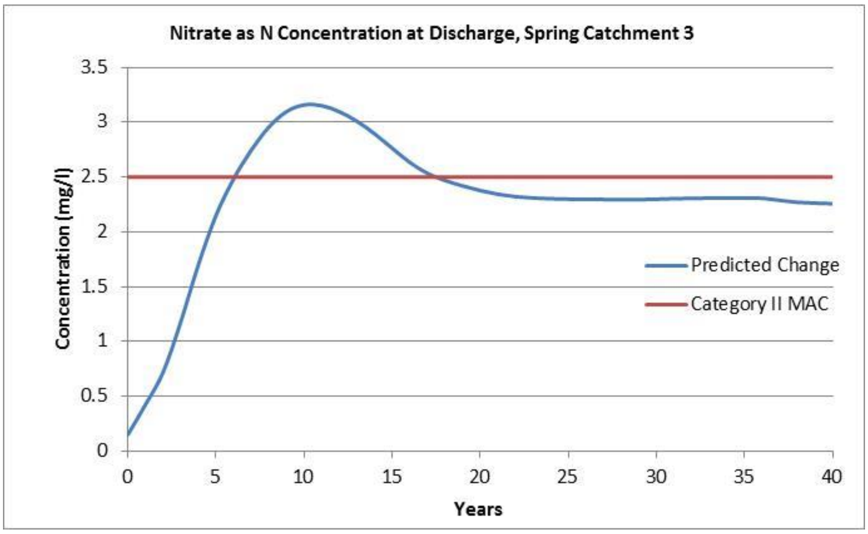

Beryllium Concentration at Discharge, Spring Catchment 2
Concentration (mg/l)
0.00006
0.00005
0.00004
0.00003
0.00002
0.00001
0
0
5
10
15
20
25
30
35
40
Years
Predicted Change
Category II MAC

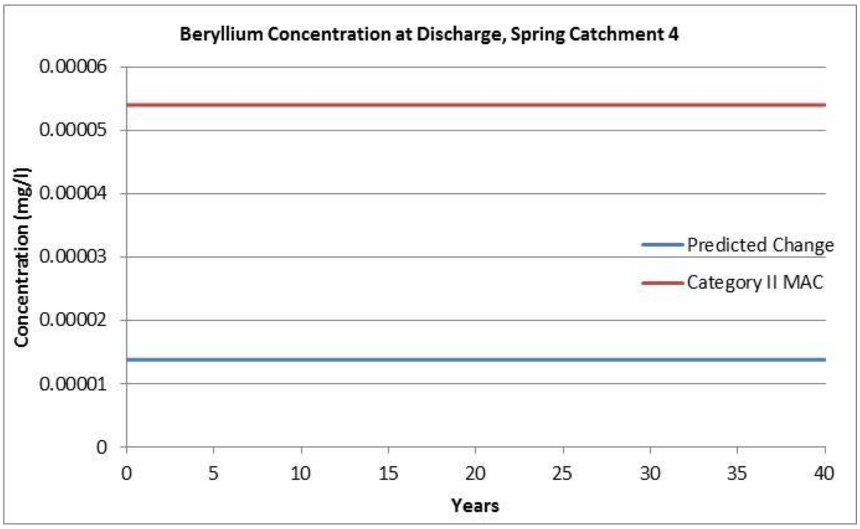

Cobalt Concentration at Discharge, Spring Catchment 2
Concentration (mg/l)
0.0003
0.00025
0.0002
0.00015
0.0001
0.00005
0
0
5
10
15
20
25
30
35
40
Years
Predicted Change
Category II MAC

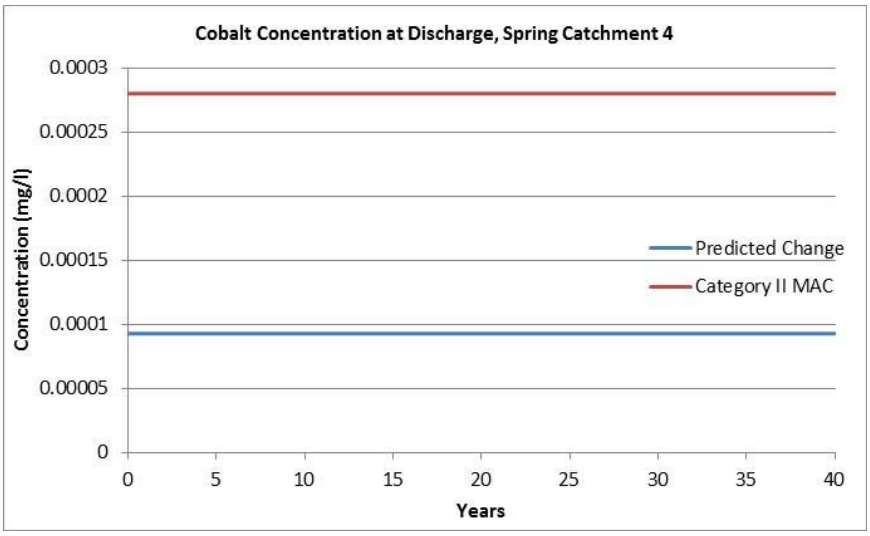

Nitrate as N Concentration at Discharge, Spring Catchment 2
Concentration (mg/l)
3
2.5
2
1.5
1
0.5
0
0
5
10
15
20
25
30
35
40
Years
Predicted Change
Category II MAC

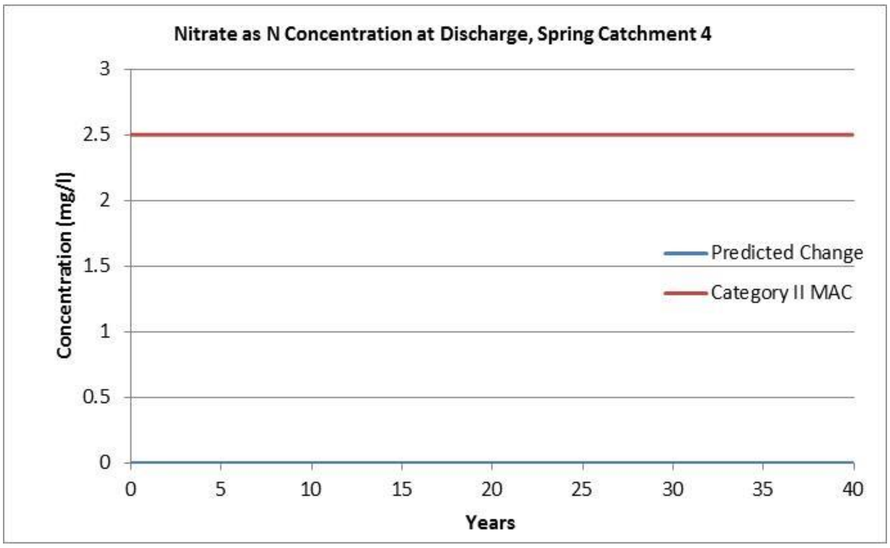

Beryllium Concentration at Discharge, Spring Catchment 3
Concentration (mg/l)
0.0002
0.00018
0.00016
0.00014
0.00012
0.0001
0.00008
0.00006
0.00004
0.00002
0
0
5
10
15
20
25
30
35
40
Years

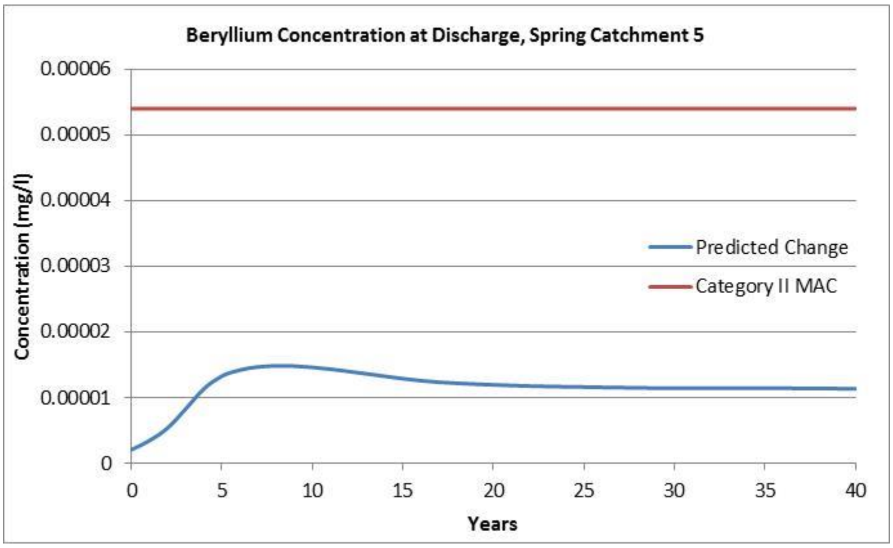

Cobalt Concentration at Discharge, Spring Catchment 3
Concentration (mg/l)
0.01
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
0
5
10
15
20
25
30
35
40
Years
Predicted Change
Category II MAC

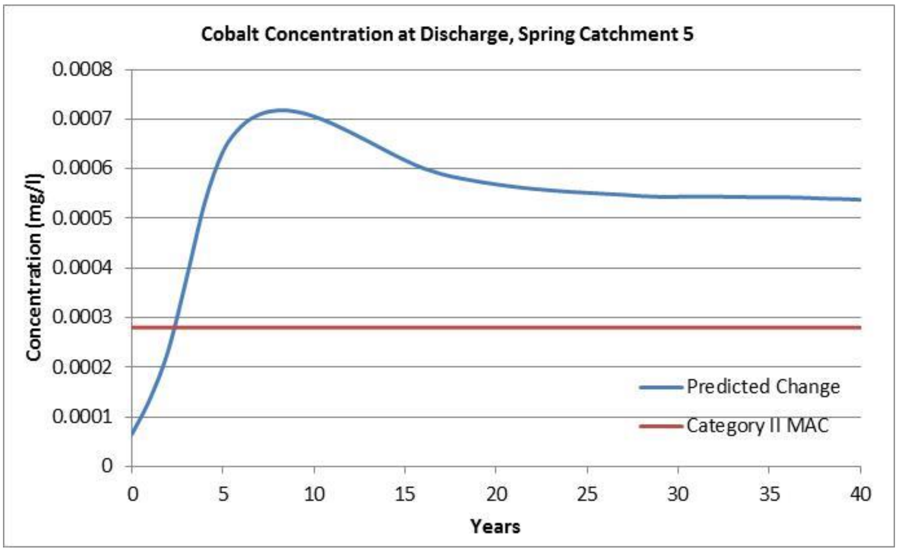

Nitrate as N Concentration at Discharge, Spring Catchment 3
Concentration (mg/l)
3.5
3
2.5
2
1.5
1
0.5
0
0
5
10
15
20
25
30
35
40
Years
Predicted Change
Category II MAC

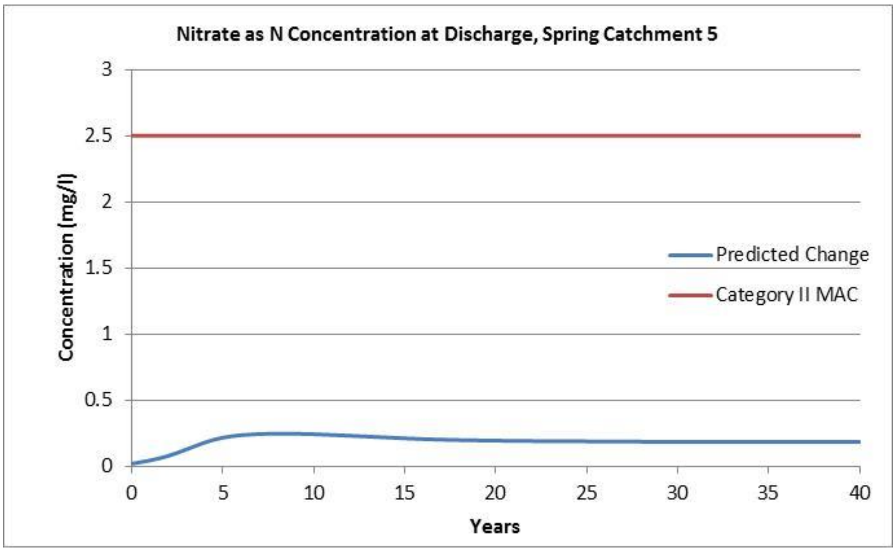

Beryllium Concentration at Discharge, Spring Catchment 4
Concentration (mg/l)
0.00006
0.00005
0.00004
0.00003
0.00002
0.00001
0
0
5
10
15
20
25
30
35
40
Years
Predicted Change
Category II MAC

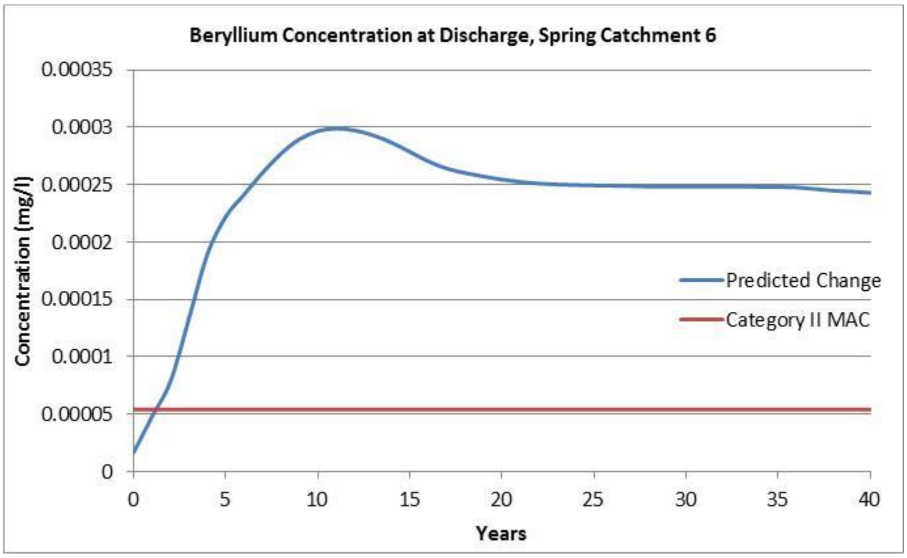

Cobalt Concentration at Discharge, Spring Catchment 4
Concentration (mg/l)
0.0003
0.00025
0.0002
0.00015
0.0001
0.00005
0
0
5
10
15
20
25
30
35
40
Years
Predicted Change
Category II MAC

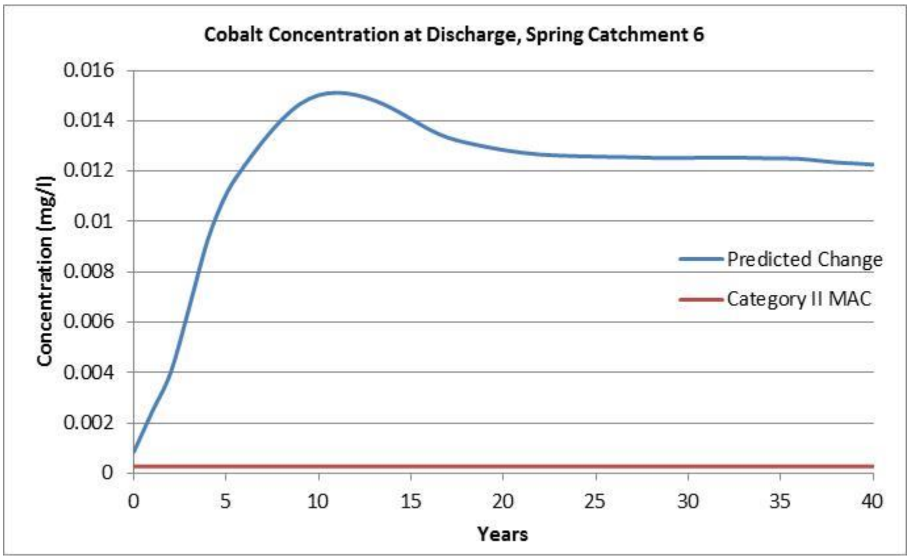

Nitrate as N Concentration at Discharge, Spring Catchment 4
Concentration (mg/l)
Years
Predicted Change
Category II MAC
3
2.5
2
1.5
1
0.5
0
0
5
10
15
20
25
30
35
40

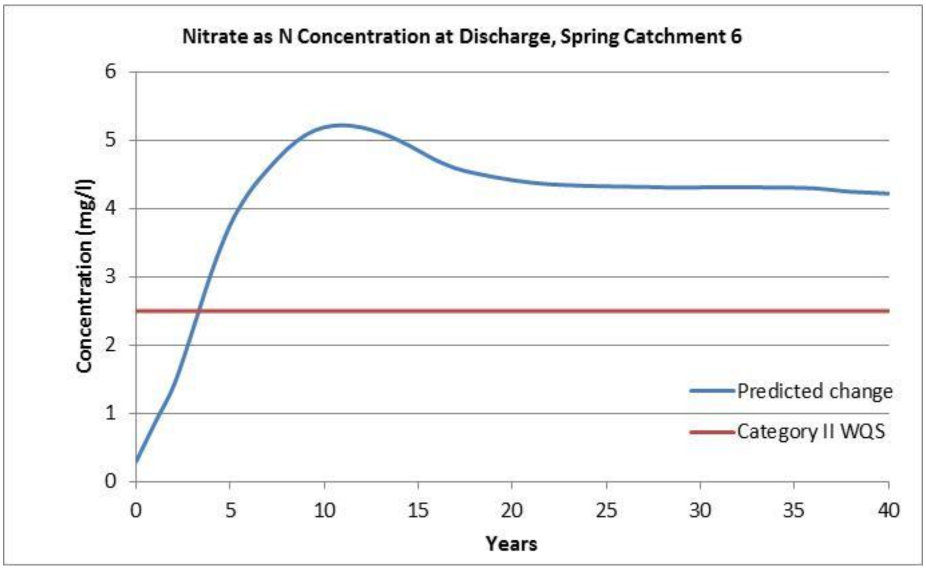

Beryllium Concentration at Discharge, Spring Catchment 5
Concentration (mg/l)
Years
Predicted Change
Category II MAC
0.00006
0.00005
0.00004
0.00003
0.00002
0.00001
0
0
5
10
15
20
25
30
35
40

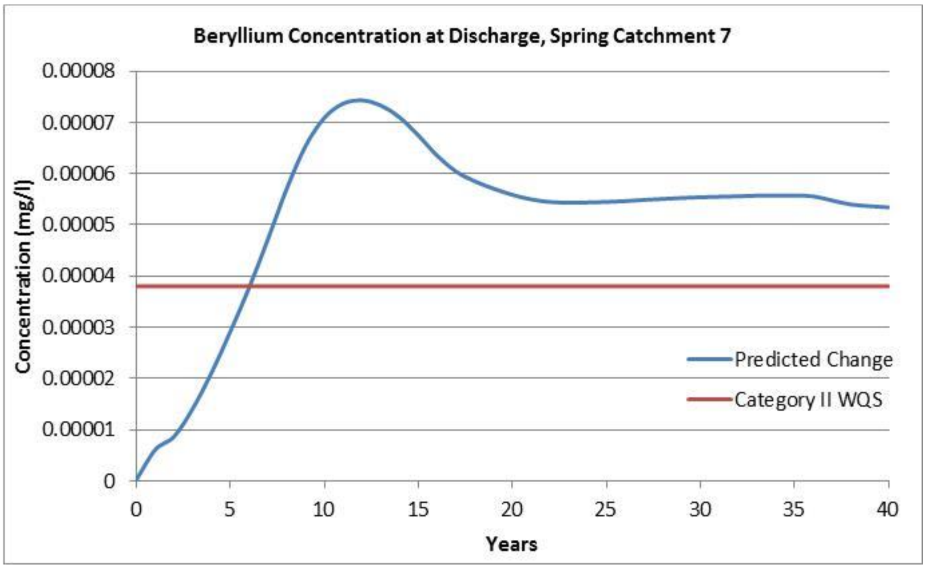

Cobalt Concentration at Discharge, Spring Catchment 5
Concentration (mg/l)
Years
Predicted Change
Category II MAC
0.0008
0.0007
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
0
0
5
10
15
20
25
30
35
40

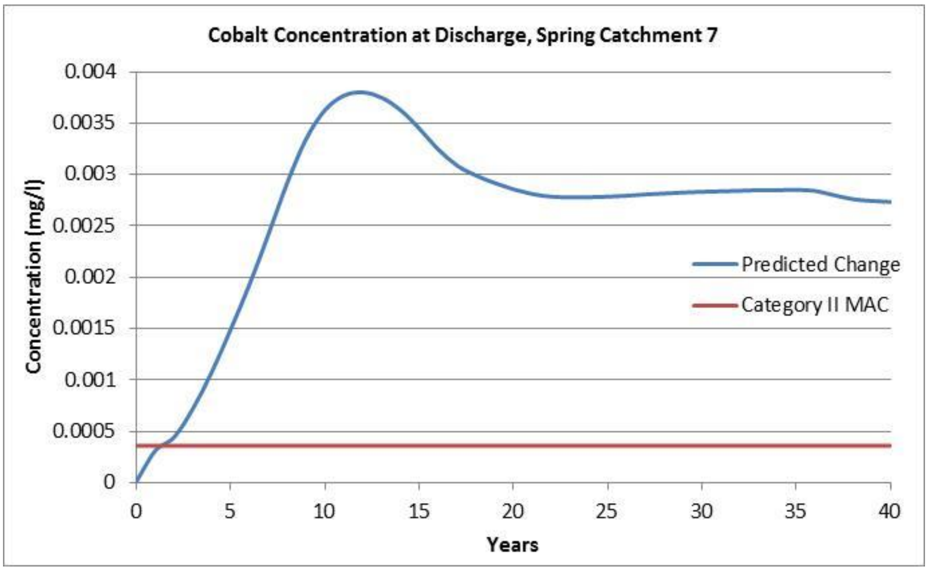

Nitrate as N Concentration at Discharge, Spring Catchment 5
Concentration (mg/l)
Years
Predicted Change
Category II MAC
0
0.5
1
1.5
2
2.5
3
0
5
10
15
20
25
30
35
40

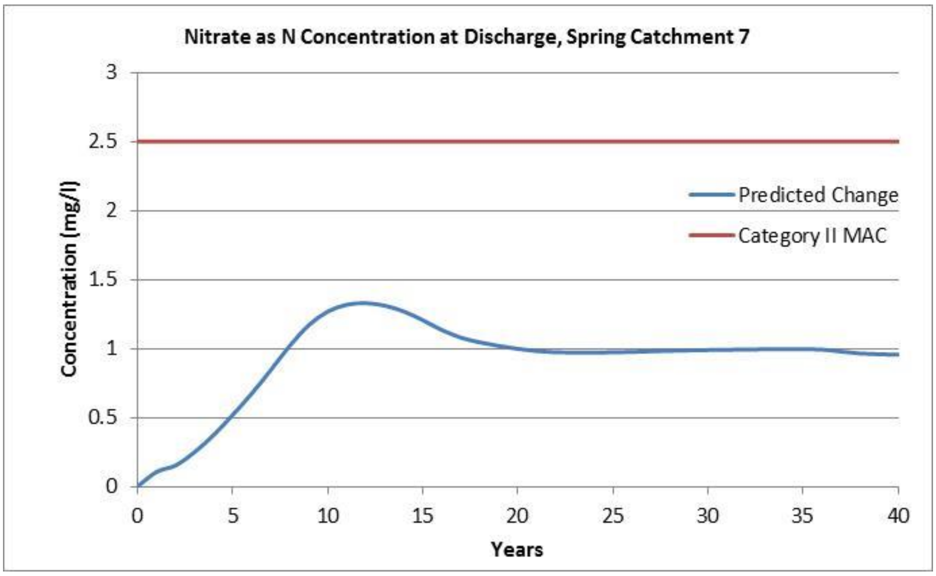

Beryllium Concentration at Discharge, Spring Catchment 6
Concentration (mg/l)
Years
Predicted Change
Category II MAC
0
0.00005
0.0001
0.00015
0.0002
0.00025
0.0003
0.00035
0
5
10
15
20
25
30
35
40


Cobalt Concentration at Discharge, Spring Catchment 6
Concentration (mg/l)
Years
Predicted Change
Category II MAC
0
0.002
0.004
0.006
0.008
0.01
0.012
0.014
0.016
0
5
10
15
20
25
30
35
40


Nitrate as N Concentration at Discharge, Spring Catchment 6
Concentration (mg/l)
Years
Predicted change
Category II WQS
0
1
2
3
4
5
6
0
5
10
15
20
25
30
35
40


Beryllium Concentration at Discharge, Spring Catchment 7
Concentration (mg/l)
Years
Predicted Change
Category II WQS
0
0.00001
0.00002
0.00003
0.00004
0.00005
0.00006
0.00007
0.00008
0
5
10
15
20
25
30
35
40


Cobalt Concentration at Discharge, Spring Catchment 7
Concentration (mg/l)
Years
Predicted Change
Category II MAC
0
0.0005
0.001
0.0015
0.002
0.0025
0.003
0.0035
0.004
0
5
10
15
20
25
30
35
40


Nitrate as N Concentration at Discharge, Spring Catchment 7
Concentration (mg/l)
Years
Predicted Change
Category II MAC
0
0.5
1
1.5
2
2.5
3
0
5
10
15
20
25
30
35
40

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