APPENDIX I

UGW#350010

EAST WASTE ROCK EXTENSION PERMIT MODIFICATION APPLICATION

Rio Tinto

Kennecott Utah Copper
4700 Daybreak Parkway
South Jordan, Utah 84095
801-569-7128 (o)
801-569-7192 (f)

Kelly L. Payne, P.G.
Manager - Environment

September 27, 2012

Mr. Robert Herbert, Section Manager
Groundwater Protection Section
Division of Water Quality
Utah Department of Environmental Quality
195 West 1950 North
P.O. Box 144870
Salt Lake City, Utah 84114-4870

Dear Mr. Herbert:

Subject: **Groundwater Discharge Permit Modification Application**
East Waste Rock Extension Project
Bingham Canyon Mine and Water Collection System, Permit # UGW350010

Kennecott Utah Copper LLC (KUC) has, over the past year, briefed key Division of Water Quality (DWQ) staff regarding the East Waste Rock Extension Project. The project is specific to the water collection system east of the waste rock piles and will entail a major modification to the system in order to accommodate waste rock placement and modification of the existing water collection system. Attached to this letter is the groundwater discharge permit modification application and applicable supplemental documents compiled to support the permit modification as listed:

1. Utah Groundwater Discharge Permit Application
2. Attachment 1, Supplemental Hydrogeological Report
3. Attachment 2, Groundwater Discharge Control Plan
4. Attachment 3, Compliance Monitoring Plan
5. Groundwater Discharge Permit UGW350010 and Statement of Basis (in track changes to capture project modifications)

Not included with the application are modified Contingency and Corrective Action Plan or Closure and Post Closure Plan. These plans currently exist within the existing groundwater discharge permit UGW350010 and remain relevant under the proposed permit modification.

In conjunction with this permit modification application, KUC is submitting a set of construction drawings and specifications for DWQ review and approval.

Should the division have any questions regarding this submittal or require additional information during the review please contact Zeb Kenyon at 801.569.6035.

Sincerely,

Kelly L. Payne, P.G.
Manager – Environment

MAIL TO:
Division of Water Quality
Utah Department of Environmental Quality
Salt Lake City, Utah 84114-4870

Application No.:______________
Date Received:______________
(leave both lines blank)

UTAH GROUNDWATER DISCHARGE PERMIT APPLICATION

Part A - General Facility Information

Please read and follow carefully the instructions on this application form. Please type or print, except for signatures. This application is to be submitted by the owner or operator of a facility having one or more discharges to groundwater. The application must be signed by an official facility representative who is: the owner, sole proprietor for a sole proprietorship, a general partner, an executive officer of at least the level of vice president for a corporation, or an authorized representative of such executive officer having overall responsibility for the operation of the facility.

1. **Administrative Information.** Enter the information requested in the space provided below, including the name, title and telephone number of an agent at the facility who can answer questions regarding this application.

Facility Name: Kennecott Utah Copper LLC Bingham Canyon Mine and Water Collection System

Mail Address: 4700 Daybreak Parkway, South Jordan, Utah 84095
(Number & Street, Box and/or Route, City, State, Zip Code)

Facility Legal Location* See Attachment 1, Figure 1-1 County: Salt Lake

Bingham Canyon Mine and Water Collection System
T. 3 South, R. 2 West, Portions of Sec. 17, 18, 19, 20, 21, 29, 30, 31, 32
T. 3 South, R. 3 West, Portions of Sec. 11, 12, 13, 14, 22, 23, 24, 25, 26, 27, 33, 34, 35, 36
T. 4 South, R. 2 West, Portions of Sec. 6, 7
T. 4 South, R. 3 West, Portions of Sec. 1, 2, 3, 9, 11, 12
East Waste Rock Extension (EWRE)
T. 3 South, R. 2 West, Portion of Sec. 16, 17, 19, 20, 21, 29, 30, 31, 32

*Note: A topographic map or detailed aerial photograph should be used in conjunction with a written description to depict the location of the facility, points of groundwater discharge, and other relevant features/objects.

Contact's Name: Zeb Kenyon Phone No.: (801) 569-6035
Title: Senior Engineer - Environmental

2. **Owner/Operator Information.** Enter the information requested below, including the name, title, and phone number of the official representative signing the application.

Owner

Name: Kennecott Utah Copper LLC Phone No.: (801)204-2000

Mail Address: 4700 Daybreak Parkway, South Jordan, Utah 84095
(Number & Street, Box and/or Route, City, State, Zip Code)

Operator

Name: Same Phone No______________
(If different than Owner's above)
Mail Address:______________
(Number & Street, Box and/or Route, City, State, Zip Code)

Official Representative

Name: Kelly Payne Phone No.: (801) 569-7128
Title: Manager - Environment

3. Facility Classification (check one)

[ ] New Facility
[ ] Existing Facility
[X] Modification of Existing Facility

4. Type of Facility (check one)

[ ] Industrial
[X] Mining
[ ] Municipal
[ ] Agricultural Operation
[ ] Other, please describe:__________

5. SIC/NAICS Codes: NAICS-212234 SIC-1021
Enter Principal 3 Digit Code Numbers Used in Census & Other Government Reports

6. Projected Facility Life: Permanent

7. Identify principal processes used, or services performed by the facility. Include the principal products produced, and raw materials used by the facility:

Open pit mining which primarily involves the extraction of metal bearing ore (Cu, Au, Ag and Mo) and the storage of overburden.

8. List all existing or pending Federal, State, and Local government environmental permits:

	Permit Number
[X] NPDES or UPDES (discharges to surface water)	UT0000051
[ ] CAFO (concentrated animal feeding operation)	
[ ] UIC (underground injection of fluids)	
[X] RCRA (hazardous waste)	UTD000826404
[X] PDS (air emissions from proposed sources)	DAQE-AN0105710028-11
[ ] Construction Permit (wastewater treatment)	
[X] Solid Waste Permit (sanitary landfills, incinerators)	35-0011803
[X] Septic Tank/Drainfield	LUWDS – KUC Bingham Canyon Mine 6190 Area
[X] Other, specify Mining and Reclamation (DOGM)	M/035/0002

9. Name, location (Lat. _____°_____'_____"N, Long. _____°____'____"W) and description of: each well/spring (existing, abandoned, or proposed), water usage(past, present, or future); water bodies; drainages; well-head protection areas; drinking water source protection zones according to UAC 309-600; topography; and man-made structures within one mile radius of the point(s) of discharge site. Provide existing well logs (include total depth and variations in water depths).

Name	Location	Description	Status	Usage

See Attachment 1, Table 2-1 (Features [wells and springs] within one mile of facility)

See Attachment 3, Figure 1-1 (existing monitoring well network)

The above information must be included on a plat map and attached to the application.

Part B - General Discharge Information

Complete the following information for each point of discharge to groundwater. If more than one discharge point exists, photocopy and complete this Part B form for each discharge point.

1. **Location** (if different than Facility Location in Part A): County: Same as facility location
   T.__________, R.__________, Sec.__________, __________1/4 of __________1/4,
   Lat. ______° __________ ' __________"N, Long. ______° ________ ' ________"W

2. **Type of fluid to be Discharged or Potentially Discharged**
   (check as applicable)

   Discharges (fluids discharged to the ground)

   [ ] Sanitary Wastewater: wastewater from restrooms, toilets, showers and the like
   [ ] Cooling Water: non-contact cooling water, non-contact of raw materials, intermediate, final, or waste products
   [ ] Process Wastewater: wastewater used in or generated by an industrial process
   [ ] Mine Water: water from dewatering operations at mines
   [ ] Other, specify:____________________

   Potential Discharges (leachates or other fluids that may discharge to the ground)

   [ ] Solid Waste Leachates: leachates from solid waste impoundments or landfills
   [ ] Milling/Mining Leachates: tailings impoundments, mine leaching operations, etc.
   [X] Storage Pile Leachates: leachates from storage piles of raw materials, product, or wastes
   [ ] Potential Underground Tank Leakage: tanks not regulated by UST or RCRA only
   [ ] Other, specify:____________________

3. **Discharge Volumes**
   For each type of discharge checked in #2 above, list the volumes of wastewater discharged to the ground or groundwater. Volumes of wastewater should be measured or calculated from water usage. If it is necessary to estimate volumes, enclose the number in parentheses. Average daily volume means the average per operating day: ex. For a discharge of 1,000,000 gallons per year from a facility operating 200 days, the average daily volume is 5,000 gallons.

Discharge Type:	Daily Discharge Volume (Average)	all in units of	(Maximum)
None			

4. **Potential Discharge Volumes**
   For each type of potential discharge checked in #2 above, list the maximum volume of fluid that could be discharged to the ground considering such factors as: liner hydraulic conductivity and operating head conditions, leak detection system sensitivity, leachate collection system efficiency, etc. Attach calculation and raw data used to determine said potential discharge. See Attachment 1 (Supplemental Hydrogeology Report, Section 4.3) for seepage calculations.

Discharge Type	Daily Discharge Volume (Average)	All in units of (Maximum)	
Potential seepage of waste rock contact water (WRCW) to bedrock	0.2 *	0.2 *	GPM

* These estimates are likely biased high because (1) conservative assumptions were used in their calculation, and (2) the Eastside Collection System modifications described in Attachment 2 will further reduce formation of WRCW. See section 4.3.2 for details.

5. Means of Discharge or Potential Discharge (check one or more as applicable)

[ ] lagoon, pit, or surface impoundment (fluids)
[ ] land application or land treatment
[ ] discharge to an ephemeral drainage (dry wash, etc.)
[X] storage pile
[ ] landfill (industrial or solid wastes)
[ ] other, specify__________________
[ ] industrial drainfield
[ ] underground storage tank
[ ] percolation/infiltration basin
[ ] mine heap or dump leach
[] mine tailings pond

6. Flows, Sources of Pollution, and Treatment Technologies

Flows. Attach a line drawing showing: 1) water flow through the facility to the groundwater discharge point, and 2) sources of fluids, wastes, or solids which accumulate at the potential groundwater discharge point. Indicate sources of intake materials or water, operations contributing wastes or wastewater to the effluent, and wastewater treatment units. Construct a water balance on the line drawing by showing average flows between intakes, operations, treatment units, and wastewater outfalls. If a water balance cannot be determined, provide a pictorial description of the nature and amount of any sources of water and any collection or treatment measures. See the following example.

TABLE 6-1
Peak Waste Rock Contact Water Flow by Drainage (gallons per minute)

Copper 4	175
Copper 3	58
Copper 2	31
Copper 1	31
Lark	41
Lost Creek	22
Keystone	306
N. Keystone	95
South Crapo	64
Crapo	58
Congor	23
Midas	587

FIGURE 6-1
Waste Rock Contact Water (WRCW) Flow Schematic

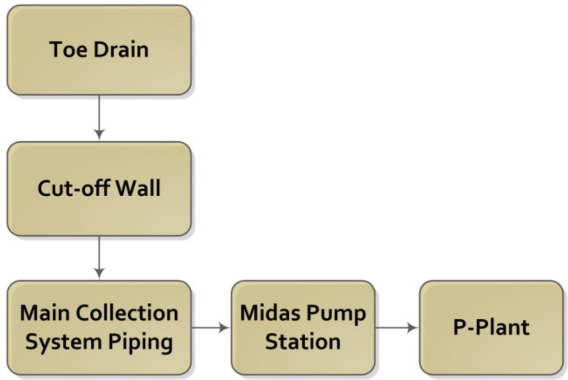
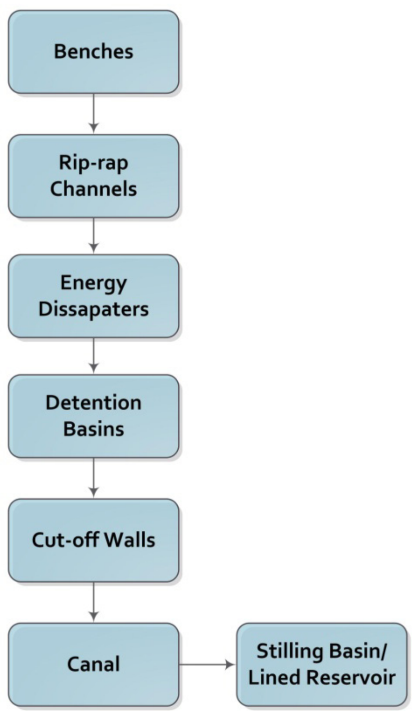


TABLE 6-2
Drainage Basin Flows for the 100-Year, 24-Hour Storm Event by Drainage (gallons per minute)

Copper 4	11,161
Copper 3	3,193
Copper 2	3,753
Copper 1	2,170
Lark	3,206
Lost Creek	4,632
Keystone	8,179
North Keystone	7,206
South Crapo	3,874
Crapo	5,336
Congor	6,197
Midas	17,613

FIGURE 6-2
Storm Water Flow Schematic



7. **Discharge Effluent Characteristics**

Established and Proposed Groundwater Quality Standards - Identify wastewater or leachate characteristics by providing the type, source, chemical, physical, radiological, and toxic characteristics of wastewater or leachate to be discharged or potentially discharged to groundwater (with lab analytical data if possible). This should include the discharge rate or combination of discharges, and the expected concentrations of any pollutant (mg/l). If more than one discharge point is used, information for each point must be provided.

Protection levels and compliance limits have been established for compliance wells at the facility. For more detail see Attachment 3 of the permit application or Appendix B of Groundwater Discharge Permit UGW350010

Hazardous Substances - Review the present hazardous substances found in the Clean Water Act, if applicable. List those substances found or believed present in the discharge or potential discharge.

Sulfuric acid and salts of sulfates and chlorides including cadmium, copper and zinc

Part C – Accompanying Reports and Plans

The following reports and plans should be prepared by or under the direction of a professional engineer or other groundwater professional. Since groundwater permits cover a large variety of discharge activities, the appropriate details and requirements of the following reports and plans will be covered in the pre-design meeting(s). For further instruction refer to the Groundwater Permit Application Guidance Document.

8. **Hydrogeologic Report** (See Attachment 1, Supplemental Hydrogeology Report)

Provide a Geologic Description, with references used, that includes as appropriate:
Structural Geology – regional and local, particularly faults, fractures, joints and bedding plane joints; **Stratigraphy** – geologic formations and thickness, soil types and thickness, depth to bedrock; **Topography** – provide a USGS MAP (7 ½ minute series) which clearly identifies legal site location boundaries, indicated 100 year flood plain area and applicable flood control or drainage barriers and surrounding land uses.

Provide a Hydrologic Description, with references used, that includes:
Groundwater – depths, flow directions and gradients. Well logs should be included if available. Include name of aquifer, saturated thickness, flow directions, porosity, hydraulic conductivity, and other flow characteristics, hydraulic connection with other aquifers or surface sources, recharge information, water in storage, usage, and the projected aerial extent of the aquifer. Should include projected groundwater area of influence affected by the discharge. Provide hydraulic gradient map indicating equal potential head contours and groundwater flow lines. Obtain water elevations of nearby wells at the time of the hydrologic investigation. Collect and analyze groundwater samples from the uppermost aquifer which underlies the discharge point(s). Historic data can be used if the applicant can demonstrate it meets the requirements contained within this section. Collection points should be hydraulically up and down gradient and within a one-mile radius of the discharge point(s). Groundwater analysis should include each element listed in Groundwater Discharge Permit Application, Part B7.

NOTE: Failure to analyze for background concentrations of any contaminant of concern in the discharge or potential discharge may result in the Executive Secretary's presumptive determination that zero concentration exist in the background groundwater quality.

Sample Collection and Analysis Quality Assurance – sample collection and Preservation must meet the requirements of the EPA RCRA Technical Enforcement Guidance Document, OSWER-9959.1, 1986 [UAC R317-6-6.3(I,6)]. Sample analysis must be performed by State of Utah certified laboratories and be certified for each of the parameters of concern. Analytical methods should be selected from the following sources [UAC R317-6-6.3L]: (Standard Methods for the Examination of Water and Wastewater, 20th Ed., 1998; EPA, Methods for Chemical Analysis of Water and Wastes, 1983; Techniques of Water Resources Investigation of the U.S. Geological Survey, 1998, Book 9; EPA Methods published pursuant to 40 CFR Parts 141, 142, 264 (including Appendix IX), and 270. Analytical methods selected should also include minimum detection limits below both the Groundwater Quality Standards and the anticipated groundwater protection levels. Data shall be presented in accordance of accepted hydrogeologic standards and practice.

Provide Agricultural Description, with references used, that includes:
If agricultural crops are grown within legal boundaries of the site the discussion must include: types of crops produced; soil types present; irrigation system; location of livestock confinement areas (existing or abandoned).

Note on Protection Levels:

After the applicant has defined the quality of the fluid to be discharged (Groundwater Discharge Permit Application, Part B), characterized by the local hydrogeologic conditions and determined background groundwater quality (Hydrogeologic Report), the Executive Secretary will determine the applicable groundwater class, based on: 1) the location of the discharge point within an area of formally classified groundwater, or the background value of total dissolved solids. Accordingly, the Executive Secretary will determine applicable protection levels for each pollutant of concern, based on background concentrations and in accordance with UAC R317-6-4.

9. **Groundwater Discharge Control Plan:** (See Attachment 2, Groundwater Discharge Control Plan)

   Select a compliance monitoring method and demonstrate an adequate discharge control system. Listed are some of the Discharge Control Options available.

   No Discharge – prevent any discharge of fluids to the groundwater by lining the discharge point with multiple synthetic and clay liners. Such a system would be designed, constructed, and operated to prevent any release of fluids during both the active life and any post-closure period required.

   Earthen Liner – control the volume and rate of effluent seepage by lining the discharge point with a low permeability earthen liner (e.g. clay). Then demonstrate that the receiving groundwater, at a point as close as practical to the discharge point, does not or will not exceed the applicable class TDS limits and protection levels* set by the Executive Secretary. This demonstration should also be based on numerical or analytical saturated or unsaturated groundwater flow and contaminant transport simulations.

   Effluent Pretreatment – demonstrate that the quality of the raw or treated effluent at the point of discharge or potential discharge does not or will not exceed the applicable groundwater class TDS limits and protection levels* set by the Executive Secretary.

   Contaminant Transport/Attenuation – demonstrate that due to subsurface contaminant transport mechanisms at the site, raw or treated effluent does not or will not cause the receiving groundwater, at a point as close as possible to the discharge point, to exceed the applicable class TDS limits and protection levels* set by the Executive Secretary.

   Other Methods – demonstrate by some other method, acceptable to the Executive Secretary, that the groundwater class TDS limits and protection levels* will be met by the receiving groundwater at a point as close as practical to the discharge point.

   *If the applicant has or will apply for an alternate concentration limit (ACL), the ACL may apply instead of the class TDS limits and protection levels.

   Submit a complete set of engineering plans and specifications relating to the construction, modification, and operation of the discharge point or system. Construction Permits for the following types of facilities will satisfy these requirements. They include: municipal waste lagoons; municipal sludge storage and on-site sludge disposal; land application of wastewater effluent; heap leach facilities; other process wastewater treatment equipment or systems.

   Facilities such as storage piles, surface impoundments and landfills must submit engineering plans and specifications for the initial construction or any modification of the facility. This will include the design data and description of the leachate detection, collection and removal system design and construction. Provide provisions for run on and run-off control.

10. Compliance Monitoring Plan: (See Attachment 3, Compliance Monitoring Plan)

The applicant should demonstrate that the method of compliance monitoring selected meets the following requirements:

Groundwater Monitoring – that the monitoring wells, springs, drains, etc., meet all of the following criteria: is completed exclusively in the same uppermost aquifer that underlies the discharge point(s) and is intercepted by the up gradient background monitoring well; is located hydrologically down gradient of the discharge point(s); designed, constructed, and operated for optimal detection (this will require a hydrogeologic characterization of the area circumscribed by the background sampling point, discharge point and compliance monitoring points); is not located within the radius of influence of any beneficial use public or private water supply; sampling parameters, collection, preservation, and analysis should be the same as background sampling point; groundwater flow direction and gradient, background quality at the site, and the quality of the groundwater at the compliance monitoring point.

Source Monitoring – must provide early warning of a potential violation of groundwater protection levels, and/or class TDS limits and be as or more reliable, effective, and determinate than a viable groundwater monitoring network.

Vadose Zone Monitoring Requirements – Should be: used in conjunction with source monitoring; include sampling for all the parameters required for background groundwater quality monitoring; the application, design, construction, operation, and maintenance of the monitoring system should conform with the guidelines found in: Vadose Zone Monitoring for Hazardous Waste Sites; June 1983, KT-82-018(R).

Leak Detection Monitoring Requirements – Should not allow any leakage to escape undetected that may cause the receiving groundwater to exceed applicable groundwater protection levels during the active life and any required post-closure care period of the discharge point. This demonstration may be accomplished through the use of numeric or analytic, saturated or unsaturated, groundwater flow or contaminant transport simulations, using actual filed data or conservative assumptions. Provide plans for daily observation or continuous monitoring of the observation sump or other monitoring point and for the reporting of any fluid detected and chemical analysis thereof.

Specific Requirements for Other Methods – Demonstrate that: the method is as or more reliable, effective, and determinate than a viable groundwater monitoring well network at detecting any violation of groundwater protection levels or class TDS limits, that may be caused by the discharge or potential discharge; the method will provide early warning of a potential violation of groundwater protection levels or class TDS limits and meets or exceeds the requirements for vadose zone or leak detection monitoring.

Monitoring well construction and groundwater sampling should conform to A Guide to the Selection of Materials for Monitoring Well Construction. Sample collection and preservation, should conform to the EPA RCRA Technical Enforcement Guidance Document, OSWER-9950.1, September, 1986. Sample analysis must be performed by State-certified laboratories by methods outlined in UAC R317-6-6.3L. Analytical methods used should have minimum detection levels which meet or are less than both the groundwater quality standards and the anticipated protection levels.

11. **Closure and Post Closure Plan:** The purpose of this plan is to prevent groundwater contamination after cessation of the discharge or potential discharge and to monitor the discharge or potential discharge point after closure, as necessary. This plan has to include discussion on: liquids or products, soils and sludges; remediation process; the monitoring of the discharge or potential discharge point(s) after closure of the activity.

    (See Appendix D of Groundwater Discharge Permit UGW350010)

12. **Contingency and Corrective Action Plans:** The purpose of this Contingency plan is to outline definitive actions to bring a discharge or potential discharge facility into compliance with the regulations or the permit, should a violation occur. This applies to both new and existing facilities. For existing facilities that may have caused any violations of the Groundwater Quality Standards or class TDS limits as a result of discharges prior to the issuance of the permit, a plan to correct or remedy any contaminated groundwater must be included.

    Contingency Plan – This plan should address: cessation of discharge until the cause of the violation can be repaired or corrected; facility remediation to correct the discharge or violation.

    Corrective Action Plan – for existing facilities that have already violated Groundwater Quality Standards, this plan should include: a characterization of contaminated groundwater; facility remediation proposed or ongoing including timetable for work completion; groundwater remediation.

    (See Appendix C of Groundwater Discharge Permit UGW350010)

Certification

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Kelly Payne, Manager - Environment	(801) 569-7128
NAME & OFFICIAL TITLE (type or print)	PHONE NO. (area code & no.)
Kelly Payne	9/27/12
SIGNATURE	DATE SIGNED

Attachment 1: Supplemental Hydrogeologic Report

East Waste Rock Extension Modification

Groundwater Discharge Permit UGW350010

Prepared for

Kennecott Utah Copper LLC

September 2012

LICENSED PROFESSIONAL GEOLOGIST
MICHAEL
D.
NOVAK
5557386-2250
STATE OF UTAH

CH2MHILL®

215 South State Street, Suite 1000

Salt Lake City, Utah 84111

Contents

TABLES

FIGURES

Illustrations

Drawings/Geological Cross Sections

Appendices

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Acronyms and Abbreviations

°	degree(s)
amsl	above mean sea level
BAT	Best Available Technology
BCM	Bingham Canyon Mine
bgs	below ground surface
Diss. Cd	dissolved cadmium
Diss. Cu	dissolved copper
Diss. ZN	dissolved zinc
DWQ	Division of Water Quality
ECS	Eastside Collection System
EPA	United States Environmental Protection Agency
EWRE	East Waste Rock Extension
ft^3/min	cubic feet per minute
GCMP	Groundwater Characterization and Monitoring Plan
gpm	gallon(s) per minute
KTN	Kennecott True North
KUC	Kennecott Utah Copper, LLC
mg/L	milligram per liter
NOI	Notice of Intent
NR	no recent measurement
NRCS	National Resources Conservation Service
PVC	polyvinyl chloride
SD	standard deviation
SO_4	sulfate
TDS	total dissolved solids
TNW	traditionally navigable waterway
UAC	Utah Administrative Code
UDEQ	Utah Department of Environmental Quality
DWQ	Division of Water Quality
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey
WCS	water collection system
WRCW	waste rock contact water

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1.0 Introduction

1.1 Background

Kennecott Utah Copper LLC (KUC) owns and operates the Bingham Canyon Mine (BCM), which produces copper and other metals from ore extracted from the mine (see Figure 1-1). Open pit operations have been conducted at this site for over 100 years. The waste rock associated with these mining operations has been placed adjacent to the open pit on the slopes of the Oquirrh Mountains. The waste rock disposal areas currently consist of over 5 billion tons of waste rock containing low-grade sulfide mineralization and trace metals from igneous intrusions of limestone and quartzite host rock.

KUC plans to extend operations through year 2028 by expanding the BCM in a project designated as Cornerstone. The Cornerstone mine expansion will significantly increase the amount of ore and waste rock, creating the need for additional waste rock capacity. The plan to place additional waste rock east of the existing dumps is identified as the East Waste Rock Extension (EWRE) (see Figure 1-2).

Under the right conditions, water percolating through waste rock may dissolve sulfur-bearing minerals resulting in low pH pore water which, in turn, dissolves metals. The acidic, metal-bearing water that emerges from the base of the waste rock is called acid rock drainage. The water that emerges from the toe of Bingham Canyon Mine's waste rock dumps varies in pH and dissolved metals concentrations. Water contacting waste rock, regardless of pH or dissolved metals concentrations, will be referred to as waste rock contact water (WRCW).

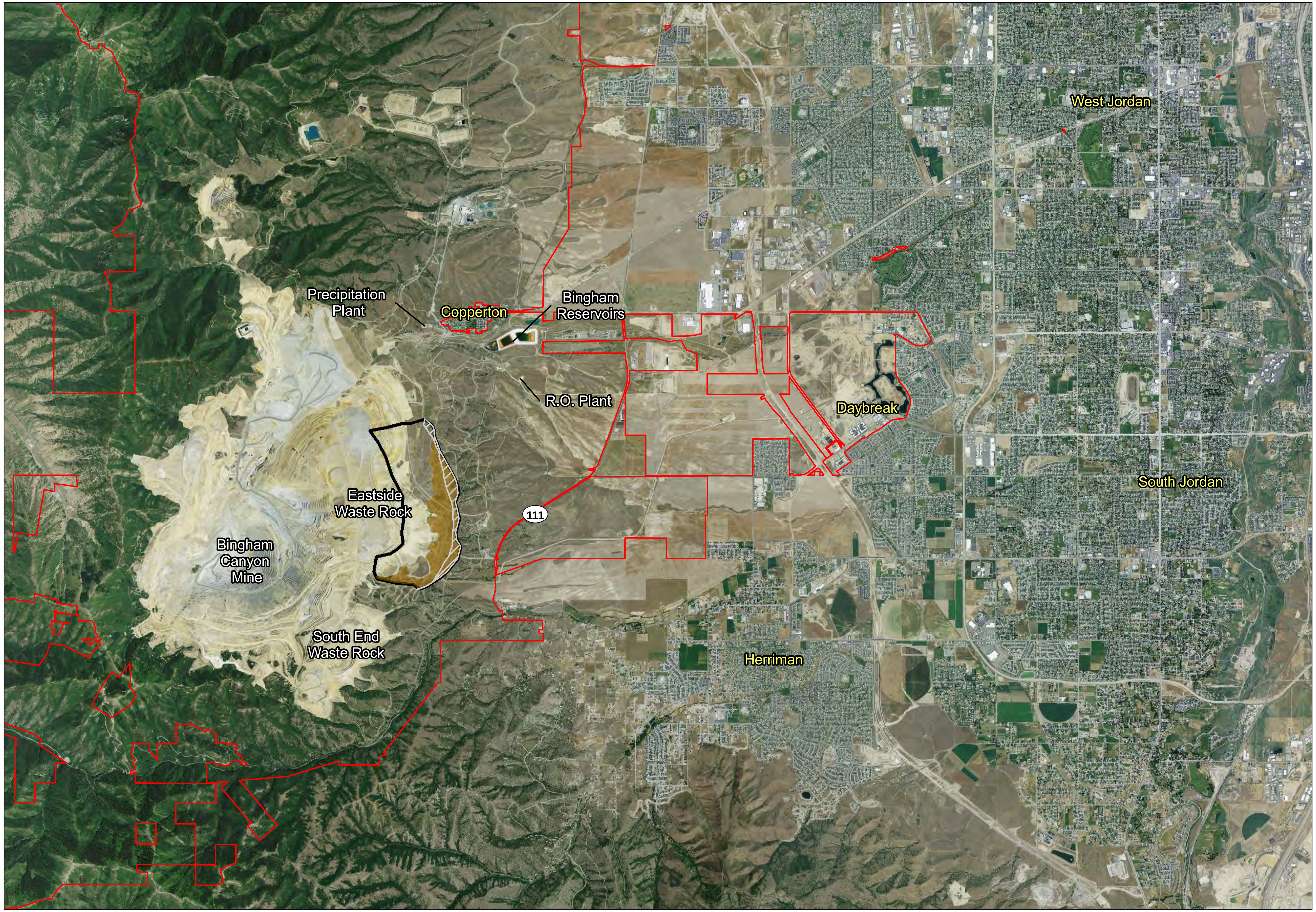
From the late 1920s through 1999, water was actively applied to the top of the waste rock dumps for the purpose of leaching copper. The applied water was collected at the base of the waste rock and processed for copper. The leachate collection was upgraded in 1965 and another major upgrade was completed in the early 1990s. This latest major upgrade, termed the Water Collection System (WCS), included installation of cut-off walls built into bedrock of the natural drainages down gradient of the waste rock dumps to collect WRCW flowing on the surface and though alluvium. This system is also known as the Eastside Collection System (ECS). Maintenance and upgrades to the WCS have been ongoing since its installation.

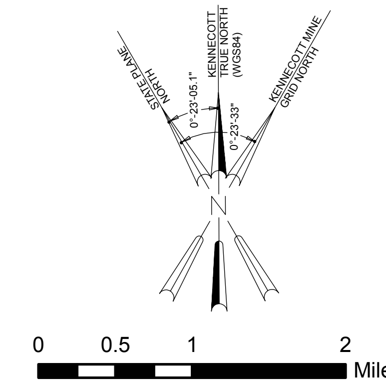
Active leaching, which was in excess of 20,000 gpm, ceased in 2000. Flow records from the WCS indicate that the effects of water actively applied during leaching on cumulative discharge essentially ceased in approximately 2002 to 2003. Since that time, natural precipitation has been the only source of WRCW emerging from the waste rock dumps which is currently less than 1000 gpm.

KUC currently manages WRCW from the existing waste rock dumps under Groundwater Discharge Permit No. UGW350010 (Permit), issued by the Utah Department of Environmental Quality (UDEQ), Division of Water Quality (DWQ) in 1999 and renewed approximately every 5 years thereafter. The most-recent renewal was issued March 15, 2010 (*Groundwater Discharge Permit No. UGW350010 for the Bingham Canyon Mine and Water Collection System, 2010*).

The western boundary of the principal aquifer is located within southwest Salt Lake Basin, close to the waste rock disposal areas to the east of the BCM. In conformance with the Permit, KUC built the WCS (see Figure 1-2) to capture and redirect WRCW and storm water. In addition, a monitoring well network was installed down gradient of the collection system. The existing WCS employs cut-off walls and associated French drains to capture WRCW migrating along surface and alluvial channels. The walls are built into low permeable bedrock. The recovered WRCW is conveyed via gravity in piping to the Precipitation Plant for the recovery of copper. A compliance groundwater monitoring well network is located down gradient of the WCS. More detail regarding the collection system and the compliance monitoring well network can be found in Attachments 2 and 3 of this application.

SLC \\SLCDB\GIS\PROJECTS\KENNECOTT\MAPFILES\437717\GWDISCHARGEPERMITAPP\ATTACH1\BINGHAMCANYON.MXD PMOELLER 9/17/2012 08:04:56





1 inch equals 1.25 miles

LEGEND

- EAST WASTE ROCK EXTENSION FOOTPRINT
- APPROXIMATE EXTENT OF EAST WASTE ROCK EXTENSION OVERLAYING PREVIOUSLY UNDISTURBED LAND (338 ACRES)
- POTENTIAL EXTENT OF WASTE ROCK TOE*
- KENNECOTT PROPERTY BOUNDARY

*MAXIMUM POTENTIAL EXTENT OF WASTE ROCK WILL BE BASED ON ADEQUATE DRAINAGE FROM TOE DRAINS AND BEDROCK TOPOGRAPHY AS DETERMINED DURING CONSTRUCTION

MAP INDEX

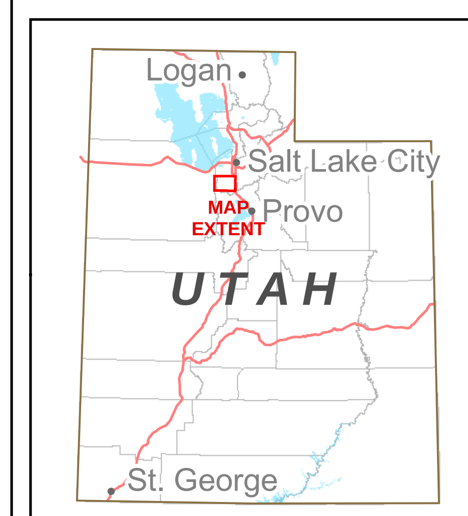


FIGURE 1-1

BINGHAM CANYON MINE SITE OVERVIEW

EAST WASTE ROCK EXTENSION PERMIT MODIFICATION
GROUNDWATER DISCHARGE PERMIT UGW350010
KENNECOTT UTAH COPPER

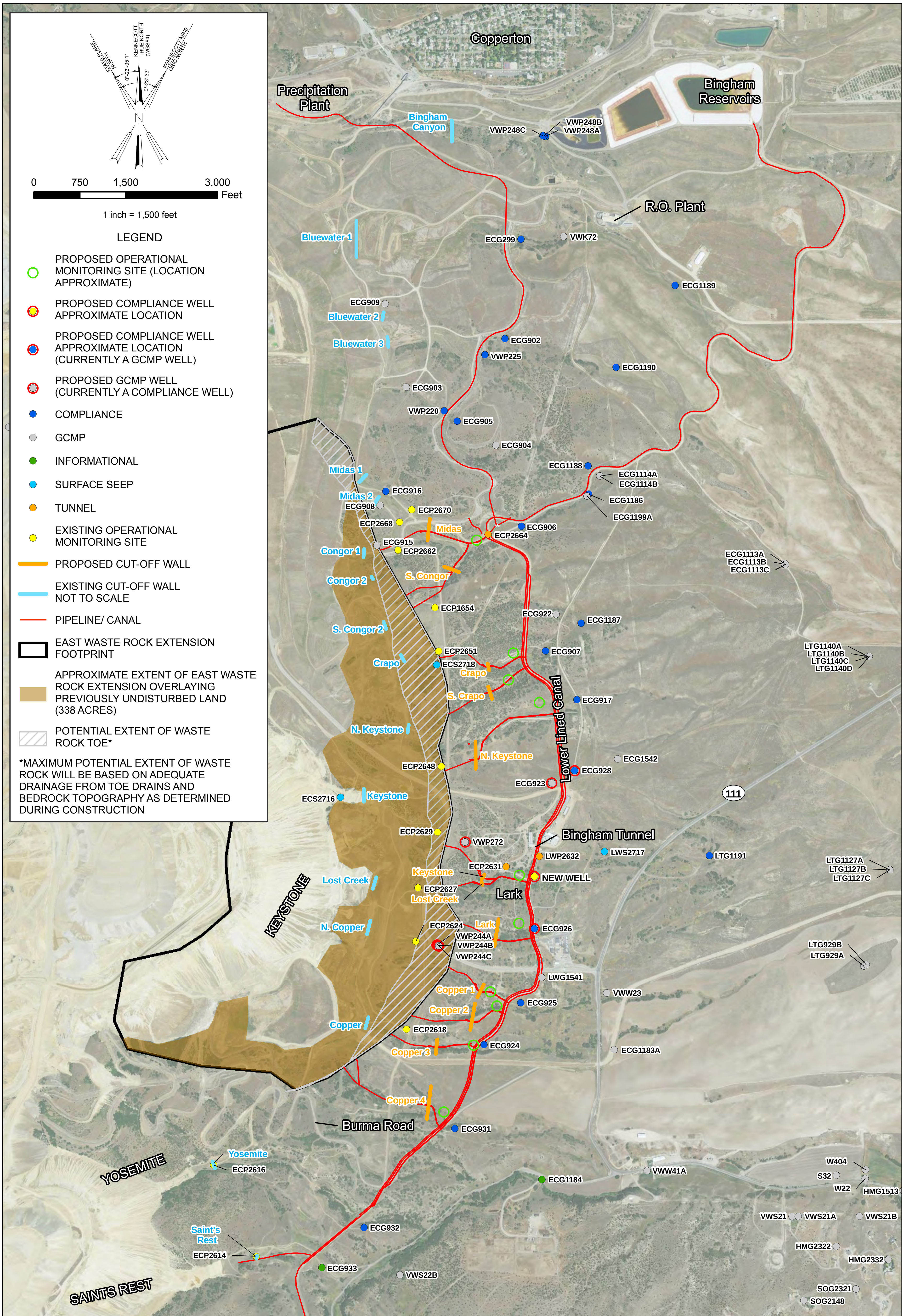


FIGURE 1-2
EAST WASTE ROCK EXTENSION EXISTING AND PLANNED COLLECTION SYSTEMS

EAST WASTE ROCK EXTENSION PERMIT MODIFICATION
GROUNDWATER DISCHARGE PERMIT UGW350010
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The monitoring network consists of compliance monitoring wells located along the down gradient perimeter of the BCM waste rock dumps. Through construction, operation, and monitoring of the existing WCS, KUC has effectively mitigated the release of WRCW from the property.

The proposed EWRE will require relocation of some WCS facilities. KUC will also incorporate engineering advances to the collection system making it as good as, or better than, the existing system. The proposed modifications are detailed in Attachment 2 and include the following:

- Installation of a primary WRCW collection system in the form of a new toe drain system along the relaxed toe of the EWRE
- Replacement of some existing cut-off walls that will be covered by new waste rock in the EWRE area; replacement walls will employ a liner system to protect the concrete and extend the life of the wall
- Installation of new conveyance pipelines to collect and direct WRCW to the existing precipitation plant
- Installation of new pipelines down gradient of the cut-off walls to convey the WRCW will include secondary containment with associated leak detection
- Installation of a new Midas pump station to pump collected WRCW to the Precipitation Plant which will incorporate leak minimization and detection features
- Installation of new compliance monitoring wells and the designation of current Groundwater Characterization and Monitoring Plan (GCMP) wells to compliance monitoring wells in order to fulfill compliance monitoring requirements
- Implementation of a separate storm water management system to collect storm water from the reclaimed dump face and convey it separately from the WRCW to the existing storm water canal via detention basins and associated piping
- Installation of an engineered store-and-release reclamation cover over the top of the waste rock to further minimize infiltration of meteoric water

The new design meets the standard of Best Available Technology (BAT) as described in Attachment 2, Groundwater Discharge Control Plan. The advances listed above will enhance the performance of the WCS, resulting in continued, long-term protection of groundwater resources and compliance with Permit requirements.

1.2 Purpose and Scope

The information in this attachment supports the following sections of the Permit modification application: Part B.3 and B.4 (Discharge Volumes and Potential Discharge Volumes) and Part C.8 (Hydrogeological Report). Table 1-1 summarizes the key information contained in this attachment and its purpose in support of the Permit modification application.

TABLE 1-1
Purpose of Information Contained in Attachment 1

Information	Purpose
Local and regional geological description, including structure, stratigraphy, and topography	Describe the setting in which groundwater resources exist Support discussion of potential WRCW migration, and mitigation of potential migration
Topography and soil description	Supports assessment of gravity drainage and design of the cut-off walls in Attachment 2 Brief description of soil included to validate that site soils are adequate for reclamation
Local and regional hydrology, including surface water hydrology and groundwater hydrogeology	Identify groundwater resources to be protected Support discussion of potential WRCW migration and mitigation of such potential migration
Information on the occurrence and magnitude of WRCW and its potential discharge to the ground	Supports estimation of discharge volumes required in Parts B.3 and B.4 of the Permit application modification
Drainages-specific geological information for drainages comprising the WCS	Supports cut-off wall design (see Attachment 2)
Summary of groundwater monitoring data	Supports the effectiveness of the existing WCS in mitigating WRCW impacts and the conclusion that the proposed, enhanced system will likewise be protective

NOTE:
The information in this Attachment satisfies the requirements of Part B.3 and B.4 (Discharge Volumes and Potential Discharge Volumes) and Part C.8 (Hydrogeological Report) of the Permit application.

2.0 Location, Setting, and Local Land Use

The BCM is located in the Oquirrh Mountains approximately 18 miles southwest of Salt Lake City, Utah. Waste rock from the BCM is placed on the slopes of the Oquirrh Mountains, adjacent to the mine. Approximately 10 miles to the east of the Oquirrh Mountains is the Jordan River, within the southwestern Jordan Valley. This valley is an alluvium-filled basin containing a groundwater resource used as a water supply by some of the cities and residents within the valley. Figure 1-1 presents a site overview of the BCM and surrounding cities.

Most of the southwestern Jordan Valley is used for farming, industry, or suburban residential property. Agricultural development in the valley began in the early 1850s and has continued to the present. Irrigated land and dry farming have been declining in the area, giving way to increased residential use (see Figure 2-1 for land use). Currently, there is a small area of agricultural land use within the KUC property boundaries which include dryland wheat farming and beekeeping for honey production. Agricultural activities do not employ irrigation.

The Bureau of Land Management operates the Wild Horse and Burro Center southeast of the Yosemite drainage (see Figure 2-1). However, this facility is phasing out of operation.

Part A.9 of the Permit application requires identification and descriptions of wells, springs, water bodies, drinking water source protection zones, and human-made structures within a 1-mile radius of the point(s) of discharge site. This information is summarized in Table 2-1.

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TABLE 2-1
Features within One Mile of EWRE

Entity	Identifier	Type	NAD 83 Latitude (decimal degrees)	NAD 83 Longitude (decimal degrees)	Note	EWRE Facilities Within 1 Mile
Drinking Water Source Protection Zones						
Dansie Water Company, System # 18009, Zone-4	18009-001	Dansie Well	40.513604°	-112.090697°	1	Copper 4, Copper 3, Copper 2, Copper 1, Lark, Lost Creek Keystone
Herriman City Municipal Water Department, System # 18157, Zone-4	18157-002	Hamilton Well	40.513410°	-112.085549°	1	Copper 4, Copper 3, Copper 2, Copper 1, Lark, Lost Creek Keystone
Herriman City Municipal Water Department, System # 18157, Zone-4	18157-006	HP Well No.1	40.512830°	-112.082874°	1	Copper 1, Copper 2, Lark
Kennecott - Lark, System # 18152, Zone-4	18152-001	Ltg1139 Well	40.535724°	-112.096283°	1	Copper 1, Lark, Lost Creek, Keystone, North Keystone, South Crapo, Crapo, Congor, Midas
Riverton City Water System, System # 18025, Zone-4	18025-010	Green Well (Suspended)	40.504421°	-112.105839°	1	Yosemite, Copper 4, Copper 3, Copper 2
Wells						
Underground Water Well Kennecott Land Company	59-1271	Well	40.521609°	-112.091064°	--	North Keystone, Keystone, Lost Creek, Lark, Copper 1, Copper 2, Copper 3, Copper 4
Underground Water Well The Last Holdout LLC	59-4118	Well	40.513370°	-112.089309°	--	Lark, Copper 4, Copper 3, Copper 2, Copper 1
Underground Water Well Kennecott Utah Copper LLC	59-93	Well	40.511881°	-112.097720°	--	Copper 4, Copper 3, Copper 2, Copper 1,Yosemite
Underground Water Spring Kennecott Utah Copper LLC	59-3275	Spring	40.509406°	-112.111801°	--	Copper 4, Copper 3, Copper 2, Yosemite
Underground Water Spring Kennecott Utah Copper LLC	59-1819	Spring	40.509406°	-112.111801°	--	Copper 4, Copper 3, Copper 2, Yosemite
Structures						
MPS	--	Structures	40.542342°	-112.098554°	--	Midas, Congor, Crapo, South Crapo, North Keystone
Lark Gate	--	Structures	40.522469°	-112.094682°	--	Yosemite, Copper 4, Copper 3, Copper 2, Copper 1, Lark, Lost Creek, Keystone, North Keystone, South Crapo, Crapo
Lark Truck Shop	--	Structures	40.522739°	-112.095055°	--	Yosemite, Copper 4, Copper 3, Copper 2, Copper 1, Lark, Lost Creek, Keystone, North Keystone, South Crapo, Crapo
Bingham Tunnel*	--	Structures	40.527794°	-112.096654°	--	Midas, Congor, Crapo, South Crapo, North Keystone, Keystone, Lost Creek, Lark, Copper 1, Copper 2, Copper 3, Copper 4
Old Bingham Tunnel	--	Structures	40.541080°	-112.100815°	--	Midas, Congor, Crapo, South Crapo, North Keystone, Keystone
Abandon Hospital & Administration Building	--	Structures	40.528216°	-112.096529°	--	Midas, Congor, Crapo, South Crapo, North Keystone, Keystone, Lost Creek, Lark, Copper 1, Copper 2, Copper 3, Copper 4
Warehouse	--	Structures	40.528372°	-112.095454°	--	Midas, Congor, Crapo, South Crapo, North Keystone, Keystone, Lost Creek, Lark, Copper 1, Copper 2, Copper 3, Copper 4
Electrical Substation	--	Structures	40.528322°	-112.098548°	--	Midas, Congor, Crapo, South Crapo, North Keystone, Keystone, Lost Creek, Lark, Copper 1, Copper 2, Copper 3, Copper 4
Laydown Yard	--	Structures	40.529225°	-112.094777°	--	Midas, Congor, Crapo, South Crapo, North Keystone, Keystone, Lost Creek, Lark, Copper 1, Copper 2, Copper 3, Copper 4
Lower Lined Canal	--	Structures	--	--	--	Midas, Congor, Crapo, South Crapo, North Keystone, Keystone, Lost Creek, Lark, Copper 1, Copper 2, Copper 3, Copper 4, Yosemite
Abandoned Lark Town Site	--	Structures	40.523305°	-112.097986°	--	Midas, Congor, Crapo, South Crapo, North Keystone, Keystone, Lost Creek, Lark, Copper 1, Copper 2, Copper 3, Copper 4, Yosemite
Water Tower	--	Structures	40.527603°	-112.098578°	--	Congor, Crapo, South Crapo, North Keystone, Keystone, Lost Creek, Lark, Copper 1, Copper 2, Copper 3, Copper 4
Streams						
Butterfield	--	Stream	--	--	--	Lark, Copper 4, Copper 3, Copper 2, Copper 1,Yosemite, Lark, Lost Creek, Keystone

NOTE:
Coordinates are for the westernmost portion of the Drinking Water Source Protection Zone.
* Bingham Tunnel Portal labeled with water rights 59-2066, 59-2065, 59-1006, and 59-609

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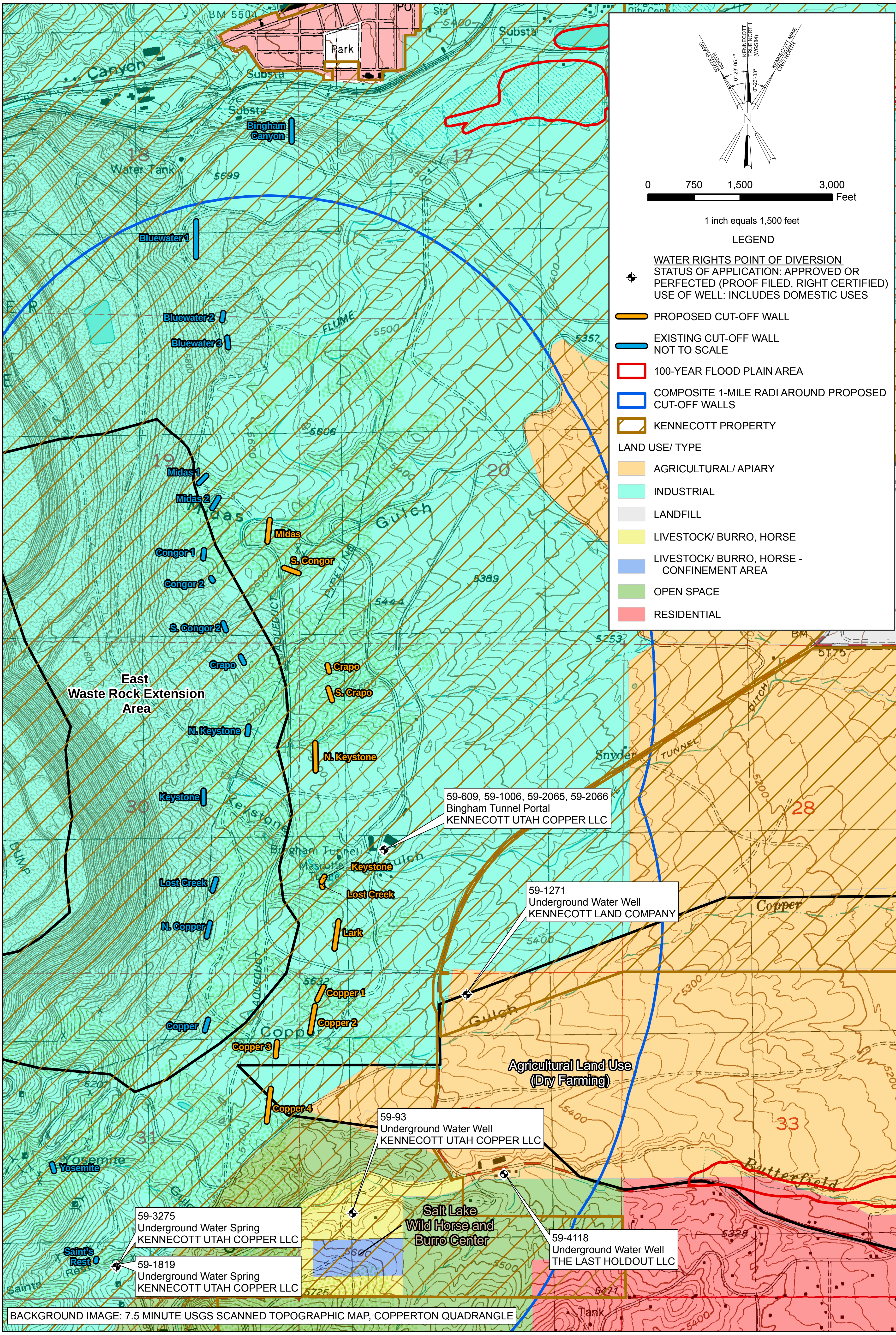

FIGURE 2-1

LOCAL FEATURES

EAST WASTE ROCK EXTENSION PERMIT MODIFICATION
GROUNDWATER DISCHARGE PERMIT UGW350010
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3.0 Geology

This section summarizes the structural geology and stratigraphy in the region and immediate vicinity of the EWRE and describes the surrounding topography, including applicable flood controls. Drainage-specific geological discussions are presented in Section 3.3.

3.1 Regional and Local Structural Geology

The BCM is located in the Oquirrh Mountains in the southwest corner of the Jordan River Valley along the eastern margin of the Basin and Range physiographic province. Surface geology for the EWRE area is shown in Drawing 2, and a site plan is shown in Drawing 1, at the end of this report.

3.1.1 Regional Structural Geology

The Oquirrh Mountains consist of a thick section of complexly folded and faulted upper Paleozoic sedimentary rocks (exhibiting different degrees of metamorphism), Tertiary intrusive and extrusive rocks, and late Tertiary sedimentary rocks (Presnell, 1992). Volcanic rocks contain three well-developed, steeply dipping joint sets, which trend northeast (dominant), northwest, and north-northwest. No significant surface faults are present along the eastern edge of the Oquirrh Mountains, although volcanic flows and dike intrusions appear to be controlled by preexisting (probably Early Tertiary) northeast-trending fractures of regional extent in Paleozoic basement (Smith, 1975).

Although no Late Tertiary reactivation of these structures is apparent, Bouguer gravity data and field observations suggest the presence of regional east-dipping normal faults along the base of the Oquirrh Mountains (Slentz, 1955a, b; Smith, 1961; Zoback, 1983). In Late Tertiary time, Basin and Range faulting produced uplift and erosion of the Oquirrh Mountains; much of the eroded material was deposited in the Jordan Valley, yielding unconsolidated to semiconsolidated basin-fill deposits of clay, silt, sand, gravel, and boulders.

In Late Pleistocene time, inundation of the Jordan Valley by Prehistoric Lake Bonneville produced lacustrine and shoreline deposits in the central valley below 5,200 feet above mean sea level (amsl). The contact between bedrock and alluvial deposits from the eastern edge of the Oquirrh Mountains to the Jordan River is poorly delineated by wells and only approximated by geophysical data.

3.1.2 Local Structural Geology

The EWRE is located at the western edge a late Tertiary structural graben, which has been down-dropped along range-marginal faults at the edge of the Oquirrh Mountains. Angular unconformities exist between the lithologic units in the area. The bedded volcanic units dip eastward into the Jordan Valley at moderate angles (~25 degrees [°]), as does the contact between Paleozoic basement and the volcanics. In the foothills of the Oquirrh Mountains, Plio-Pleistocene fan deposits dip 2° to 4° east to southeast; the dip shallows to less than 1˚ eastward in the main part of the southwestern Jordan Valley. Borehole logging data suggest that the fan deposit-volcanic contact dips 15˚ east near the eastern edge of the Oquirrh Mountains (Stewart, 1978).

There may be a range marginal fault at the eastern edge of the Oquirrh Mountains (Slentz 1955a, b; Crittenden 1964), though no reactivation of this structure is apparent. Numerous small fractures have been found in the volcanic bedrock east of the eastside waste rock dumps (CH2M HILL 2012b).

3.2 Regional and Local Stratigraphy

3.2.1 Regional Stratigraphy

The general stratigraphic sequence of the region is summarized in Table 3-1. The last column in Table 3-1 correlates the regional description with the mapped occurrences of these strata as shown on Drawing 2.

TABLE 3-1
General Stratigraphic Column for EWRE Region

Time Period	Symbols	Description	EWRE Geologic Map
Holocene	Qal	Recent strewn alluvium, colluvium, alluvial fans, and mudflows	Quaternary & Tertiary Alluvial Fan Deposits
	Qfp	Recent abandoned flood plains and stream channels consisting of silt, sand, and gravel	
Pleistocene	Qplb	Provo Formation and younger lake bottom sediments; mainly clays, silts, and sands with local offshore sand bars	
	Qp	Provo Formation and younger shore facies; chiefly sand and gravel in beach deposits, bars, spits, and deltas	
	Qb	Bonneville Formation; mainly shore facies of sand and gravel; includes beach deposits, bars, spits, and deltas	
Pliocene – Pleistocene	TQf	Fanglomerate consisting of unconsolidated and poorly sorted boulders, gravel, sand, and clay; the principal aquifer of the southwestern Jordan Valley	
Lower Oligocene – Upper Miocene	Tj	Salt Lake Formation, Jordan Narrows Unit; marlstone, limestone, sandstone, and tuff; may vary depending on locality NOT EXPOSED IN STUDY AREA	Not Exposed In Study Area
Upper Eocene and Oligocene	Tv	Volcanic rocks consisting of flows, breccias, lahars, tuffs, welded tuffs, stream-deposited pyroclastics, sills, and dikes; volcanics are chiefly latites or latite porphyries (+ hornblende)	Oligocene Volcanic Agglomerate and Latite Breccia Oligocene Latite & Andesite Flows
	Ti	Bingham Stock; intrusive, consisting mainly of quartz monzonite with quartz monzonite porphyry	Oligocene Intrusive Rocks-Mainly Silicic Dikes and Sills
Pennsylvanian – Lower Permian	P – IP	Undifferentiated Pennsylvanian through Lower Permian basin facies sedimentary rocks consisting of quartzites and limestones	Middle Pennsylvanian Butterfield Peaks Formation, Mainly Quartzite and Sandstone with Interbedded Limestone

NOTE:
Map symbols refer to geologic map in KUC (1992) Source: Davis (1983a, b); KUC (1992)

3.2.2 Local Stratigraphy

Drawing 2 presents a surface geological map for the EWRE area, while Drawings 3, 6, 9, 12, 15, 18, and 20 present geologic cross sections, at the end of this report. The geologic cross sections were generated for drainages impacted by the EWRE. Drainages within proximity to one another were consolidated as follows:

- Midas and Congor drainage areas
- North Keystone, South Crapo, and Crapo drainage areas
- Lark, Lost Creek, and Keystone drainage areas
- Copper 1, 2, and 3 drainage areas
- Copper 4 drainage area

Area site plans and details are shown on Drawings 4, 5, 7, 8, 10, 11, 13, 14, 16, 17, and 19. The general stratigraphic sequence near the EWRE is unconsolidated colluvium and alluvium comprised of clayey quartzitic and volcanic gravels overlying more-competent bedrock consisting of andesite, latite porphyry, and agglomerate. The bedrock also contains occasional undifferentiated sills and dikes (Kennecott staff and Swensen, 1991). The alluvial-volcanic contact commonly contains caliche and displays a weathering profile in the underlying volcanic rocks. Angular unconformities exist between the Oligocene volcanics and the Paleozoic units.

Depth to bedrock encountered during the field studies ranged from 0 to 86.5 feet below ground surface (bgs), approximately 300 to 750 feet east or southeast of the anticipated new toe of the waste rock placement area. For the remainder of this Attachment, as well as Attachments 2 and 3 of this submittal, the term bedrock is operationally defined as a native semi-impermeable surface, which may include consolidated rock or the weathered byproduct of the consolidated rock that has sufficient competency to support a concrete water-capture structure.

The following paragraphs describe the major strata evident on the map and cross sections. These descriptions are based on the *Cut-Off Wall Field Investigation and Design Optimization Technical Memorandum* (CH2M HILL, 2012), which documented recent site-specific geologic studies that included the logging of test pits and boreholes at or near proposed cut-off wall locations.

3.2.3 Plio-Pleistocene Alluvial Fan Deposits and Modern Alluvium and Human-Made Fill

The dominant surficial stratigraphic unit near the EWRE consists of Plio-Pleistocene alluvial fan deposits, which extend from the toe of the waste rock disposal area into the southwestern Jordan Valley. These alluvial fan deposits consist of gravels, sands, silts, and clays. The alluvial deposits, which in the vicinity of the EWRE are approximately 10 to 90 feet thick, rest on Tertiary volcanic bedrock and Paleozoic bedrock. The alluvial deposits thicken eastward to form the principal aquifer of the southwestern Jordan Valley.

Holocene alluvium—consisting of cobbles, pebbles, coarse to fine sand, silt, and clay deposits—lies mainly along the valleys of the drainages emerging from the toe of the waste rock disposal area. Alluvium is sparse at the toe of the waste rock disposal areas. Coarse colluvial material consisting of boulders mixed with silt occurs on the steeper slopes at the site and extends beneath the waste rock disposal areas to the west of the site. The thickness of these Holocene deposits generally ranges from 1 to 25 feet.

The human-made fill materials contain locally acquired and re-worked quaternary and tertiary alluvial/colluvial sediment consisting of silty gravels to gravelly silts and silty sand mixtures that can include organic material. The organic materials observed in test pits and borings were consistent with local vegetation.

3.2.4 Tertiary Volcanic Bedrock

Volcanic bedrock underlie the eastern edge of the waste rock disposal area and also crops out along the fringe of the Oquirrh Mountains, which lie to the east of the waste rock dump toe. The Tertiary volcanics are described regionally as a thick (<2,000 feet) section of lithologically complex Oligocene silicic volcanic and shallow intrusive rocks lying with angular unconformity on Paleozoic bedrock. The volcanics consist of laharic breccias, latitic flows, flow breccias, and intrusive rocks, including latite dikes and small monzonitic stocks (Davis, 1983a,b). This sequence acts as "basement" to the Plio-Pleistocene alluvial fan deposits, which are host to the principal aquifer.

Detailed descriptions of the Tertiary volcanics in the vicinity of the EWRE are described in the following paragraphs based on the 2011 and 2012 investigations (CH2M HILL, 2012).

Volcanic Agglomerate. Volcanic agglomerate bedrock was encountered at the Yosemite, South Crapo, Crapo, Congor, and Midas drainages and was observed to range from competent bedrock to well-weathered gravelly clay altered sequences. This material ranged from clayey volcanic gravel to highly altered gravelly clay, depending on the degree of weathering. Drilling in the agglomerate occasionally produced a solid rock core through a 6- to 12-inch competent horizon, revealing heavily weathered material below. Within these weathered portions, there was often increased moisture content and oxidation staining indicating geochemical weathering.

Andesite. Volcanic andesite flow deposits were encountered in several of the test pits and outlier borings in the Copper 4 drainages. This bedrock contact was observed in varying degrees of weathering ranging from low competency, highly altered clay material to highly competent solid rock surfaces. Many of the overburden-andesite contacts were weathered to clay, often with visible standing water located along the weathered bedrock contact in several of the test pits. The relatively high percentage of potassium and other feldspars in the andesite are more susceptible to weathering than quartz and are often altered into low permeability clays. The upper 1 or 2 feet of weathered material often exhibited abundant oxidation staining. A few of the borings located at the Copper 3 and Copper 4 drainages exhibited weathered andesite that was easily advanced into with a rotosonic drill rig and remained moist 10 to 20 feet past the bedrock-overburden contact. There were no observations that suggest the andesite supported fractures that could contribute to extensive groundwater flow. Instead, the andesite seemed to behave as a low-permeability barrier when exposed to moisture and allowed to weather.

Latite Porphyry. Latite porphyry was observed in several test pits and bedrock crops out in the Lark, Lost Creek, and Keystone drainages. This bedrock type was observed to contain numerous fractures and appears to have some resistance to weathering into clay (due to higher percentage of quartz) when compared with the local andesite.

Paleozoic Bedrock. Beneath the Tertiary volcanic bedrock, subcropping below westerly parts of the waste rock dumps are quartzites and limestones of Paleozoic age. Paleozoic bedrock is not exposed near the EWRE but is found adjacent to it on the west and southwest of the BCM. The Paleozoic bedrock is complexly deformed, altered, and intruded by mid-Tertiary silicic igneous rocks (Swenson, 1975; Presnell, 1992). The thickness of Paleozoic bedrock is difficult to estimate because of complex structure (Presnell, 1992); but it probably ranges from 10,000 feet to more than 30,000 feet (Crittenden, 1977; Lund et al., 1990).

3.3 Drainage-Specific Geology

Detailed information on the stratigraphy near the locations of the proposed, re-located cut-off walls was developed during the 2011 to 2012 investigations (CH2M HILL, 2012). Information relevant to the design and performance of the proposed, relocated cutoff walls is summarized below in Table 3-2.

TABLE 3-2
Summary of Drainage Specific Geology

Drainage Name	Alluvium Description	Depth to Bedrock (feet bgs)	Bedrock Description	Site Plan/Cross Section Drawing Numbers
Copper 4	Reclaimed, with gravelly clay, abundant plant, and tree debris (Y1) Clayey quartzitic gravel with sand (Y2 south) grading to inorganic clay (Y2 north)	15 (at proposed C4) 25–33 (Y1 on road) 33–45 (Y2 on road)	Volcanic andesite	1, 16-17/18
Copper 3	Quartzitic gravel with sand, silt, and clay	6–21	Volcanic andesite	1, 13-14/15
Copper 2	Silty quartzitic gravel	6–10	Volcanic andesite	1, 13-14/15
Copper 1	Silty quartzitic gravel	2–20	Volcanic andesite	1, 13-14/15
Lark	Silty gravel and inorganic silty clay	6–20, deepening to south	Latite porphyry	1, 10-11/12
Lost Creek	Minimal over bedrock	0	Latite porphyry	1, 10-11/12
Keystone	Quartzitic gravel with sand, silt, and clay	0–8	Latite porphyry	1, 10-11/12
North Keystone	Clayey, quartzitic gravels	Crops out to north deepening to around 80 feet to the south 80+ (channel center) 56 (on south ridge)	Volcanic andesite and weathered volcanic agglomerate beneath	1, 7-8/9
South Crapo	Minimal	0	Volcanic agglomerate	1, 7-8/9
Crapo	Silty clay with slope-wash gravels	2–19	Latite overlaying volcanic andesite	1, 7-8/9
South Congor	Silty gravel with sand and occasional boulders; tree debris	2–9	Volcanic agglomerate	1, 4-5/6
Midas	Volcanic and quartzitic clayey gravel and gravelly clay	12–57 (west) 22–39 (east)	Volcanic agglomerate, weathered (wet)	1, 4-5/6

3.4 Local Topography and Soils

The EWRE is located on the eastern foothills of the Oquirrh Mountains. The topography slopes to the east toward the southwestern Jordan Valley. Figure 2-1 identifies the EWRE area on a United States Geological Survey (USGS) map, 7½-minute series and identifies KUC's legal site boundaries and indicates the 100-year flood plain areas. For information about the water collection system and storm water control, see Attachment 2, *Groundwater Discharge Control Plan*.

Soils in the EWRE disposal area are derived from Quaternary alluvial, colluvial, and aeolian sediments (Miller 1980; KUC 1992). With the exception of areas affected by human activities, including outwash from mining areas, the area incorporates a complex series of soils ranging from silty to stony loams.

Soils are typically deep to moderately deep (greater than 6 to 5 feet) and well drained. The Natural Resources Conservation Service (NRCS) Custom Soil Resource Report (*http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx*) for the EWRE is included as Appendix B. NRCS reports well-drained, loamy native soils with varying degrees of clay, silt, sand, gravel, and cobbles. The types and volumes of native soil present within the EWRE footprint are adequate for use as a vegetated store-and-release cover to be placed over top the waste rock. The vegetated store-and-release cover is summarized in Attachment 2.

4.0 Hydrology and Hydrogeology

4.1 Surface Water Hydrology

The only naturally flowing perennial stream in the vicinity of the EWRE area is Butterfield Creek. This is a gaining stream in the Oquirrh Mountains, and an intermittent, losing stream in the basin fill of the Jordan Valley (Dames and Moore, 1988). The average flow of Butterfield Creek was about 3 cubic feet per second in 1990 (Salt Lake County, 1991). Typical water quality results for Butterfield Creek are summarized in the Groundwater Assessment Report of the Southwestern Jordan Valley (KUC, 1992).

The nearest major perennial waterway is the Jordan River located approximately 9.5 miles east of the EWRE. Several dry streambeds extend from the toe of the current waste rock dump and trend roughly west to east as illustrated by the topographic map in Figure 2-1. These drainages convey infrequent storm water flow emanating from the surface and below the east face of the existing waste rock dump. Water (surface and subsurface) reaching the cut-off walls is currently collected and delivered to the Precipitation Plant. The new toe drains and cut-off wall collection system will deliver WRCW to the MPS for delivery to the Precipitation Plant; while storm water will gravity drain into a stilling basin for delivery to the wastewater disposal pump station. No mine-impacted water discharges to natural surface water bodies. The systems described in Attachment 2 will continue to prevent surface water and alluvial impacts by eliminating direct discharges to surface water; and by minimizing impacts to the regional alluvial aquifer.

In the spring of 2011, WP Natural Resource Consulting, Inc. (2011) was contracted to delineate potential wetlands and waters of the United States on KUC lands in the vicinity of the EWRE. The investigation area included a number of named and unnamed drainages along the eastern side of the waste rock dumps and areas on south-facing slopes in Butterfield Canyon. Isolated wetlands (i.e., no connectivity or nexus to a Traditional Navigable Waterway [TNW]) were identified along the Low Boy Road, and in Crapo, Keystone (upper and lower sections), Lost Creek, and Copper (upper and lower sections) drainages. Additionally, a number of ephemeral draws with evidence of ordinary high water marks were identified; however, these features were all associated with nearby road storm water runoff. Other hydric features identified in the investigation area are associated with groundwater that has surfaced through the waste rocks dumps at the eastern and southern sides of the EWRE vicinity. The results of the surveys reveal that there are no potential jurisdictional wetlands within the project area, and no waters of the United States as defined by the United States Environmental Protection Agency (EPA) and the United States Army Corps of Engineers (USACE).

Seeps are occasionally observed on the slopes of the existing waste rock dump. Water from these seeps is currently directed into the WCS. Future seeps will be piped to the WRCW collection system using tie-ins as described in Attachment 2.

4.2 Hydrogeology

Regional groundwater occurs in each of the main stratigraphic units described in Section 3.0, Geology. Table 4-1 is a summary of the regional hydrostratigraphic column.

TABLE 4-1
Generalized Hydrostratigraphic Column

Description	Hydrostratigraphic Classification	Estimated Thickness (feet)	At the EWRE (feet bgs)	Associated with Well on Cross Sections*
Holocene alluvium and human-made fill, unconsolidated cobbles, pebbles, coarse to fine sand, silt and clay, mantles entire southwestern Jordan Valley	Matrix containing thin discontinuous zones of perched groundwater	1–25	At surface	N/A
Plio-Pleistocene alluvial fan deposits, generally well-stratified, slightly consolidated sand and gravels, which are relatively rich in carbonate material; constitutes the principal aquifer	Aquifer	300–1,000	788	LTG1140
Oligocene-Miocene Jordan Narrows lake deposits, generally clays and other low-permeability sediments	Aquitard	1,500	Not present	N/A
Tertiary volcanic rocks, mainly latites, breccias, latite flows	Aquifer (fracture flow)	<2,000	1,024	ECG1182
Paleozoic bedrock, generally limestone, quartzite	Aquifer (fracture flow)	~10,000–30,000	2,750	ECG1114A

* See Geological Cross Sections 1 through 18

TABLE 4-2
Details of Wells in the Vicinity of the Eastside Collection System

Site ID	Alias	NAD 83		Easting-KTN (feet)	North-KTN (feet)	Measuring Point Elevation (feet)	Ground Surface Elevation (feet)	Well Type	Casing Material	Screen Type	Screened Interval (feet bgs)	Total Well Depth (feet bgs)	Screened Lithology Type	Screened Lithology Description	Date of Groundwater Measurement	Depth to Water (feet)	Range of depth to Water (feet)
		Longitude	Latitude														
ECG1187		-112.093607	40.537954	18,457	7,539	5,389.40	5,387.65	Compliance Well	PVC	Slotted – Factory	54–164	164.5	Alluvium	Volcanic gravel and clay	2/17/2012	70.95	27.29
ECG1188		-112.0932258	40.545007	18,566.55	10,109.03	5,367.18	5,365.81	Compliance Well	PVC	Slotted – Factory	37.5–117.5	118.0	Alluvium	Volcanic gravel/tuff/ volcanic gravel	2/9/2012	52.30	19.00
ECG1189		-112.088079	40.553089	19,989	13,054	5,381.95	5,380.13	Compliance Well	PVC	Slotted – Factory	205–265	265.5	Alluvium	Volcanic gravel/siltstone	2/9/2012	226.81	21.71
ECG1190		-112.091548	40.549415	19,026	11,715	5,408.39	5,406.63	Compliance Well	PVC	Slotted – Factory	117.5–197.5	198.0	Alluvium	Volcanic gravel	3/2/2012	139.31	17.24
ECG902		-112.098067	40.550695	17,214	12,180	5,517.97	5,516.37	Compliance Well	PVC	Slotted – Factory	223.5–263.1	263.6	Bedrock	Agglomerate	12/1/2011	183.98	31.08
ECG905		-112.100877	40.547016	16,434	10,839	5,584.26	5,582.73	Compliance Well	PVC	Slotted – Factory	251.4–291	291.5	Bedrock	Agglomerate	11/29/2011	207.12	38.42
ECG906		-112.097114	40.542299	17,481	9,121	5,431.98	5,430.38	Compliance Well	PVC	Slotted – Factory	156.7–196.3	196.8	Bedrock	Agglomerate/16 feet latite	12/1/2011	115.50	20.38
ECG907		-112.095702	40.536715	17,875	7,087	5,431.67	5,430.05	Compliance Well	PVC	Slotted – Factory	129.1–168.7	169.2	Bedrock	Andesite/1.5feet of latite	5/14/2012	115.71	23.66
ECG916		-112.105071	40.54387	15,269	9,692	5,608.00	5,606.35	Compliance Well	PVC	Slotted – Factory	235.1–274.7	275.2	Bedrock	Latite	12/20/2011	37.70	39.31
ECG917		-112.093869	40.534523	18,385	6,289	5,466.84	5,465.17	Compliance Well	PVC	Slotted –- Factory	149.9–189.5	190.0	Alluvium	Volcanic gravel	4/27/2012	135.20	27.57
ECG923		-112.09534	40.530805	17,977	4,934	5,513.10	5,511.19	Compliance Well	PVC	Slotted – Factory	116–155.6	156.1	Bedrock	Latite	11/21/2011	103.95	38.99
ECG924		-112.099333	40.519078	16,870	661	5,588.47	5,586.51	Compliance Well	PVC	Slotted – Factory	67.1–106.7	107.2	Bedrock	Andesite	4/27/2012	31.71	8.39
ECG925		-112.097173	40.520949	17,470	1,343	5,555.00	5,553.26	Compliance Well	PVC	Slotted – Factory	67.1–106.7	107.2	Bedrock	Andesite	4/27/2012	33.23	8.69
ECG931		-112.101045	40.515322	16,395	-708	5,619.60	5,618.15	Compliance Well	PVC	Slotted – Factory	105–144.6	145.1	Bedrock	Andesite	2/28/2012	50.55	18.04
ECG932		-112.106375	40.510886	14,914	-2,325	5,714.11	5,712.61	Compliance Well	PVC	Slotted – Factory	145–184.6	185.1	Bedrock	Andesite	11/21/2011	81.95	56.85
LTG1191		-112.086095	40.527547	20,548	3,749	5,331.45	5,329.62	Compliance Well	PVC	Slotted – Factory	20–100	100.5	Alluvium	Volcanic gravel	4/27/2012	22.92	8.92
VWP220	P220	-112.101642	40.547472	16,234	10,999	5,546.11	5,543.00	Compliance Well	Unidentified	Unidentified	100–120	120.0	Bedrock?	Agglomerate??	12/2/2011	72.50	68.17
VWP225	P225	-112.09926	40.549988	16,882.7	11,922.1	Unknown	Unknown	Compliance Well	Unidentified	Unidentified	125–165	Unknown	Bedrock	Volcanic bedrock??	11/29/2011	60.72	87.50
VWP228	P228	-112.109793	40.513177	13,963	-1,491	5,785.21	5,785.21	Compliance Well	Unidentified	Unidentified	Unknown–84?	84.0	Alluvium	Quartz gravel??	2/21/2012	24.65	23.05
VWP244A	P244A	-112.102063	40.523538	16,110.01	2,285.25	5,673.97	5,671.78	Compliance Well	PVC	Slotted – Factory	36.58–46.58	47.6	Alluvium	Quartzite gravel	2/23/2012	43.10	15.58

TABLE 4-2
Details of Wells in the Vicinity of the Eastside Collection System

Site ID	Alias	NAD 83		Easting-KTN (feet)	North-KTN (feet)	Measuring Point Elevation (feet)	Ground Surface Elevation (feet)	Well Type	Casing Material	Screen Type	Screened Interval (feet bgs)	Total Well Depth (feet bgs)	Screened Lithology Type	Screened Lithology Description	Date of Groundwater Measurement	Depth to Water (feet)	Range of depth to Water (feet)
		Longitude	Latitude														
VWP244B	P244B	-112.102014	40.523518	16,123.47	2,278.06	5,673.05	5,671.62	Compliance Well	PVC	Slotted - Factory	62.54–72.54	72.5	Bedrock	Quartzite gravel/rhyolite	10/7/2011	46.30	29.01
VWP244C	P244C	-112.101957	40.523486	16,139.44	2,266.32	5,673.07	5,671.31	Compliance Well	PVC	Slotted - Factory	107.35–127.35	127.4	Bedrock	Agglomerate	10/7/2011	48.28	39.98
VWP272	P272	-112.100426	40.528162	16,571	3,964	5,606.62	5,603.60	Compliance Well	PVC	Slotted - Factory	85–105	105.0	Bedrock	Agglomerate and andesite	12/15/2011	70.88	45.19
ECG1186		-112.093166	40.543737	18,578	9,646	5,368.75	5,367.20	Compliance Well	PVC	Slotted - Factory	36–136	136.5	Alluvium	Volcanic gravel/tuff/ volcanic gravel	2/16/2012	54.92	21.19
ECG1184		-112.095936	40.513043	17,816	-1,537	5,453.30	5,450.69	Informational Well	PVC	Slotted - Factory	60–80	80.50	Alluvium	Quartzite gravel	7/28/2011	32.65	24.86
ECG1113A		-112.081637	40.540606	21,783.1	8,507.9	5,259.61	5,257.85	GCMP	PVC	Slotted - Factory	137.5–177.5	178.0	Alluvium	Volcanic gravel	6/17/2011	99.03	16.72
ECG1113B		-112.081567	40.54055	21,802.6	8,487.6	5,258.45	5,256.67	GCMP	PVC	Slotted - Factory	631–671	671.5	Alluvium	Agglomerate	9/27/2010	133.32	26.88
ECG1113C		-112.081567	40.54055	21,802.6	8,487.6	5,258.28	5,256.67	GCMP	PVC	Slotted - Factory	921.8–961	961.5	Bedrock	Agglomerate	NR	NR	NR
ECG1114A		-112.092469	40.544523	18,771.4	9,932.2	5,364.50	5,362.51	GCMP	PVC	Slotted - Factory	1,216–1,255	1,255.5	Bedrock	Latite porphyry	9/29/2011	48.35	19.92
ECG1114B		-112.092469	40.544523	18,771.4	9,932.2	5,364.49	5,362.51	GCMP	Fiberglass	Slotted - Factory	2,761.5–2,848.5	2,849.0	Bedrock	Paleozoic sandstone and quartzite	9/30/2011	391.72	13.85
ECG1542		-112.091439	40.531853	19,061.25	5,316.53	5,442.65	5,440.65	GCMP	Steel	Unidentified	Unknown–289?	289.00	Unknown	Unknown	NR	NR	NR
ECG903		-112.103815	40.548516	15,617	11,385	5,595.53	5,593.89	GCMP	PVC	Slotted - Factory	156.2–195.8	196.3	Bedrock	Latite porphyry	9/22/2010	139.30	64.44
ECG904		-112.098568	40.545901	17,076	10,433	5,507.40	5,505.88	GCMP	PVC	Slotted - Factory	203.8–243.4	243.9	Bedrock	Agglomerate	4/26/2008	160.71	38.59
ECG908		-112.105367	40.543225	15,187	9,457	5,583.79	5,582.39	GCMP	PVC	Slotted - Factory	204.4–244	244.5	Bedrock	Latite/agglomerate	9/22/2010	4.57	18.73
ECG909		-112.105057	40.55225	15,271	12,745	5,617.40	5,616.08	GCMP	PVC	Slotted - Factory	184.4–224	224.5	Bedrock	Latite breccia/latite flow	9/22/2010	142.51	119.53
ECG915		-112.105555	40.541433	15,135	8,804	5,586.18	5,584.53	GCMP	PVC	Slotted - Factory	135.9–175.5	176.0	Bedrock	Latite/latite flow	11/5/2004	-7.32	30.07
ECG922		-112.095042	40.538334	18,058	7,677	5,435.42	5,433.74	GCMP	PVC	Slotted - Factory	141.6–181.2	183.7	Alluvium	Volcanic gravel/ 9ft andesite	3/30/2012	119.25	10.04
ECG926		-112.09635	40.524259	17,698	2,549	5,545.80	5,544.05	GCMP	PVC	Slotted - Factory	162.2–201.8	202.3	Bedrock	Latite	9/23/2010	37.89	3.77
ECG928		-112.093969	40.531331	183,58	5,126	5,487.06	5,485.23	GCMP	PVC	Slotted - Factory	116.6–156.2	156.7	Bedrock	Latite	9/23/2010	83.77	38.85
VWK72	K72	-112.094565	40.555258	18,189	13841	0.00	5,459.00	GCMP	Steel	Perforated	10–240	240.0	Unknown	Gravel??	4/13/2012	144.40	71.00

TABLE 4-2
Details of Wells in the Vicinity of the Eastside Collection System

Site ID	Alias	NAD 83		Easting-KTN (feet)	North-KTN (feet)	Measuring Point Elevation (feet)	Ground Surface Elevation (feet)	Well Type	Casing Material	Screen Type	Screened Interval (feet bgs)	Total Well Depth (feet bgs)	Screened Lithology Type	Screened Lithology Description	Date of Groundwater Measurement	Depth to Water (feet)	Range of depth to Water (feet)
		Longitude	Latitude														
VWP214A	P214A	-112.091511	40.518879	19,044.87	586.56	5,459.58	5,457.31	GCMP	PVC	Unidentified	262–275	275.0	Alluvium??/ Bedrock??	Gravel??	9/28/2010	40.65	16.49
VWP214B	P214B	-112.091341	40.517832	19,100	200	NR	NR	GCMP	PVC	Unidentified	387–400	400.0	Alluvium?	Volcanic gravel??	9/21/1983	25.80	10.53
VWP218	P218	-112.096686	40.542515	17,600	9,200	5,460.00	5,460.00	GCMP	Unidentified	Unidentified	100–115	115.0	Alluvium?	Volcanic gravel??	8/4/1982	96.25	0.00
VWP221	P221	-112.095962	40.546358	17,800	10,600	NR	NR	GCMP	Unidentified	Unidentified	unknown–40?	40.00	Bedrock?	Agglomerate??	NR	NR	NR
VWP222	P222	-112.096034	40.546289	17,780	10,575	5,395.00	5,395.00	GCMP	Unidentified	Unidentified	35–135	135.00	Bedrock?	Agglomerate??	NR	NR	NR
VWP243	P243	-112.089961	40.535394	19,471	6,607	5,410.90	5,408.29	GCMP	PVC	Slotted - Factory	65–85	85.0	Bedrock	Agglomerate	9/28/2009	83.35	2.16
VWP245	P245	-112.102112	40.545729	16,091	10,370	5,543.34	5,540.91	GCMP	PVC	Slotted - Factory	120–140	140.0	Bedrock	Andesite porphyry	9/22/2010	113.27	49.07
VWP248C	P248C	-112.095914	40.559816	17,828	15,496	5,337.66	5,336.68	GCMP	PVC	Slotted - Factory	175–195	195.0	Bedrock	Andesite agglomerate	NR	NR	NR
VWP270	P270	-112.090113	40.512803	19,438	-1,632	5,406.24	5,402.90	GCMP	PVC	Slotted - Factory	179–199	199.0	Bedrock	Agglomerate	10/1/2010	23.45	184.82
VWP271	P271	-112.091846	40.523442	18,957	2,244	5,483.41	5,480.60	GCMP	PVC	Slotted - Factory	65–85	85.0	Bedrock	Agglomerate	9/27/2010	45.05	403.29
VWW127		-112.086224	40.526999	20,520.64	3,539.77	5,336.75	5,336.75	GCMP	Steel	Open	186–185	186.00	Bedrock	Latite?	NR	NR	NR
VWW23		-112.092130	40.521395	18,877.87	1,498.45	5,480.80	5,484.60	GCMP	Steel	Perforated	365–90	365.00	Unknown	Unknown	NR	NR	NR
VWW41A		-112.089760	40.513437	19,536.2	-1,401.04	NR	5,388.58	GCMP	Steel	Perforated	73–45	190.00	Unknown	Unknown	NR	NR	NR
ECG1182A		-112.100895	40.515292	16,436.81	-712.27	5,619.37	5,617.11	---	PVC	Unidentified	580–600	680.00	Bedrock	Latite autobreccia	1/19/2011	50.44	40.17
ECG1183A		-112.091700	40.518849	18,992.3	578.99	5,462.74	5,460.18	---	PVC	Unidentified	35–65	35.0	Alluvium/ Bedrock	Quartzite gravel/ andesite flow	12/15/2011	42.43	5.15
ECG1199A		-112.093272	40.543654	18,548.44	9,615.71	5,370.26	5,368.48	---	PVC	Unidentified	49.5–169.5	---	Alluvium	Volcanic gravel/ weathered volcanic agglomerate	9/22/2010	52.71	5.36
VWP239	P239	-112.108899	40.520878	14,210	1,315	NR	NR	---	PVC	Unidentified	90–100	---	Alluvium	Quartzite or black sand	9/27/2010	72.60	4.66

NOTES:

?? = Uncertainty, this is often due to a missing log. Geology filled in using neighboring well.

KTN = Kennecott True North

bgs = below ground surface

PVC = polyvinyl chloride

NR = no recent measurements (Period -January 2005 to January 2012).

The principal water-bearing aquifer near the BCM is the Southwestern Jordan Valley Aquifer. Near the EWRE, this aquifer originates in the Plio-Pleistocene alluvial fan and lacustrine sediment deposits. These deposits thicken toward the east and lie above the Tertiary volcanic bedrock and Paleozoic bedrock which form the Oquirrh Mountains. The alluvial sediments are composed of reworked volcanic along with quartzitic alluvial materials. Groundwater primarily enters the alluvial aquifer from the shallow volcanic and deeper Paleozoic bedrock.

The potentiometric surface roughly mirrors topography near the EWRE and the overall flow direction ranges from approximately east to east-northeast (see Figure 4-1). The gradient of the water table is steep in the western portion of the waste rock disposal area (averaging 0.07 foot per foot) as a result of the flow taking place in the relatively low-permeability bedrock making up the Oquirrh Mountains. Bedrock consists of volcanic latites and breccias above and within deeper Paleozoic sedimentary rock. The water table gradient is more gradual (approximately 0.05 foot per foot) farther east from the Oquirrh Mountains in the principal aquifer.

The depths to water measured around the EWRE for monitoring wells installed in alluvium ranged from 23 feet bgs at compliance monitoring well LTG1191, which is a little over 1 mile down gradient (east) of the current toe of the waste rock dump and the current Keystone cut-off wall, to 135 feet bgs at ECG917, which is down gradient of the proposed North Keystone drainage. The depths to water measured around the site in monitoring wells completed in the bedrock ranged from 5 feet bgs at ECG908 down gradient of the current Midas 2 cut-off wall, to 116 feet bgs at ECG907, down gradient of the current Crapo cut-off walls (see Table 4-2).

Water levels in most of the compliance wells peaked in 1998, and in some wells the water levels declined up to 30 feet through 2004. Wells with the largest decline in water levels are located down gradient of the historic leach water application sites. Most of the decline that occurred between 2002 and 2004 eventually returned to pre1998 water levels. Water levels decreased on average from 2006 through 2010. The trend in 2011 was reversed with measured water levels in 32 of 43 wells increasing by an average of 2.71 feet (KUC, 2012). This is largely attributed to an above-average year for precipitation, including a snowpack at approximately 50 percent greater than average.

Hydraulic conductivity describes the ease in which water can move through pore spaces or fractures. Groundwater flow velocities can be estimated from knowledge of the hydraulic conductivity, hydraulic gradient, and the effective porosity at any location. In addition, velocities can be directly evaluated on the rapidity of movement of dissolved, conservative materials through the groundwater system. Table 4-3 summarizes estimates of hydraulic conductivity and groundwater flow velocity based on a number of evaluations (Dames and Moore 1989; Adrian Brown Consultants, Inc. and Adrian Smith Consulting Inc. (ABC/ASCI) 1990; KUC 1992).

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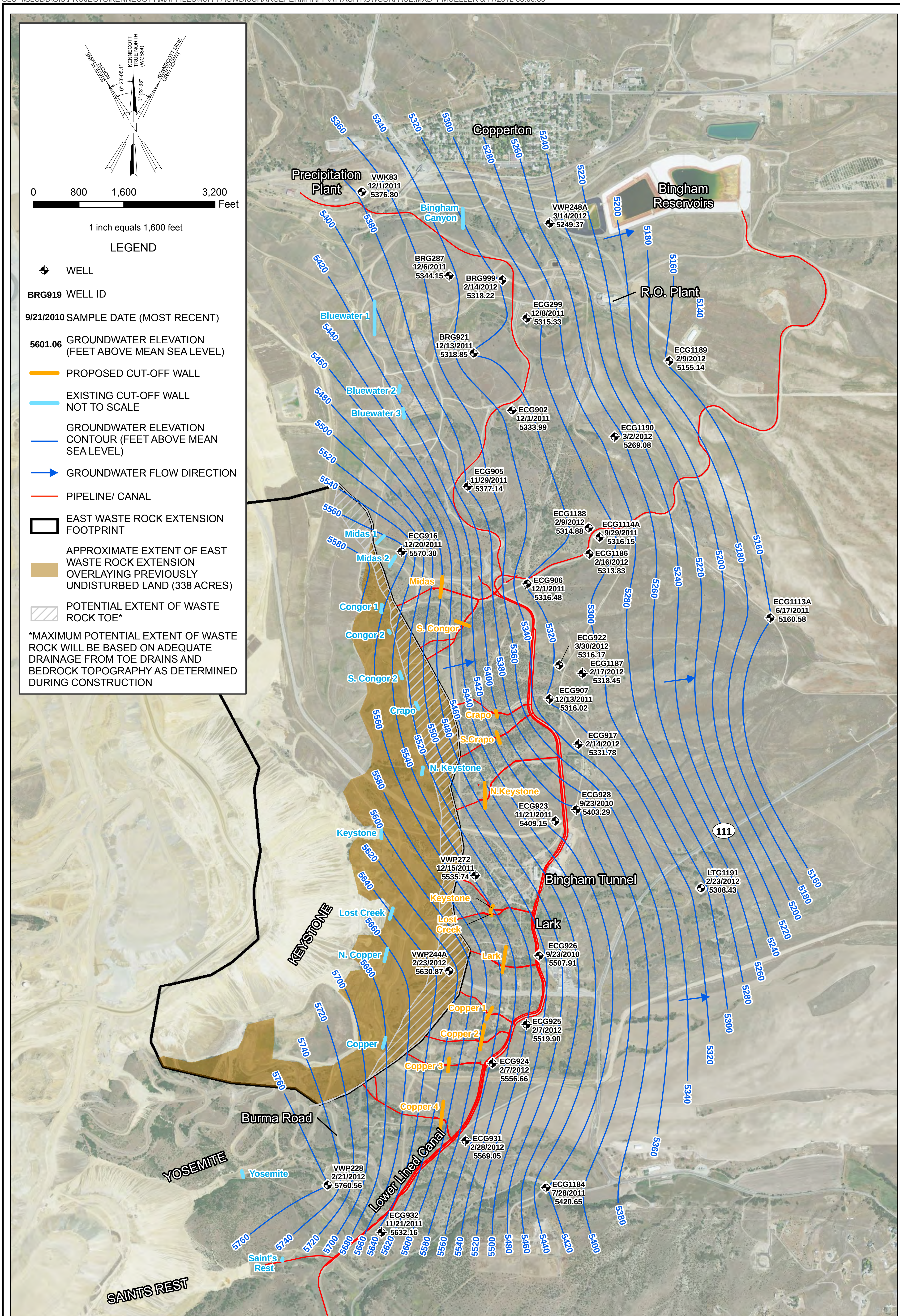


FIGURE 4-1
GROUNDWATER POTENTIOMETRIC SURFACE
EAST WASTE ROCK EXTENSION PERMIT MODIFICATION
GROUNDWATER DISCHARGE PERMIT UGW350010
KENNECOTT UTAH COPPER

TABLE 4-3
Summary of Hydraulic Conductivity and Flow Velocity Estimates

Aquifer	Hydraulic Conductivity (centimeters/second) Min—Max (geometric mean)	Flow Velocity (feet/year) [Range of Estimates)
Plio-Pleistocene alluvium	5×10^{-5} - 3×10^{-3} (3×10^{-3}) [A]	500
Tertiary volcanic bedrock	7×10^{-7} to 5×10^{-2} (5×10^{-5}) [A]	6 to 500
Paleozoic bedrock	$5\ 10^{-6}$ to 5×10^{-4} (5×10^{-5}) [A]	100 to >1000

[A](KUC, 1994)

The mean hydraulic conductivity of the bedrock units is more than two orders of magnitude lower than the alluvium, which results in local perching of groundwater at the alluvium-bedrock contact. This is a key consideration in the WRCW collection system (see Attachment 2), which incorporates toe drains and cut-off walls to capture groundwater at this contact.

4.3 Potential Discharge from EWRE

Part B of the Permit application requires defining the type of fluid to be discharged and the maximum potential volume that could be discharged to the ground. For this Permit modification application, the fluid potentially discharged to the ground is defined as WRCW emanating from the base of the proposed EWRE footprint. The majority of the WRCW will to report to the collection system, while a minor portion of the WRCW will potentially percolate into the underlying bedrock. A brief summary of the EWRE water balance is provided below to introduce the approach taken to estimate potential discharge volume.

Illustration 4-1 shows a schematic representation of a water-balance conceptual model related to the EWRE. The sole inflow to the system is infiltration of rain and snowmelt at the surface of the waste rock dump. Annual precipitation at the BCM ranges from 16 to 30 inches dependent upon elevation. To allow comparison with other flow estimates presented below, the 16 to 30 inch/year linear precipitation estimate was converted to an annual average volumetric flow estimate of 279 gpm to 524 gpm over the 338 acre EWRE footprint overlying previously undisturbed ground.

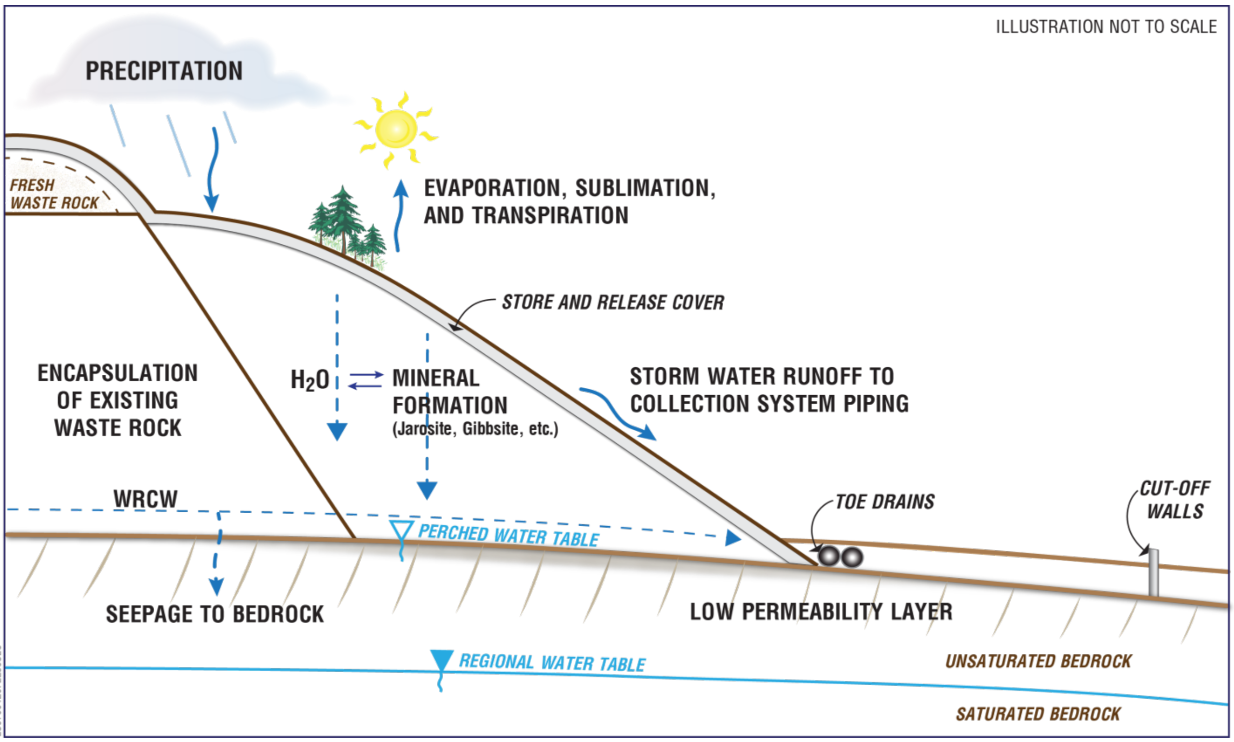
Losses of water from the waste rock will occur via the following processes:

1. Evaporation, sublimation of snow and transpiration by plants will remove water from the top of the system. These processes will be enhanced through the use of an engineered store and release cover system which is explained in more detail in Attachment 2. Engineered covers for similar climates have demonstrated overall reductions in infiltration of precipitation by 85 percent of total precipitation (Warren, et al., 1995).
2. A percentage of precipitation will run-off the reclaimed waste rock slope. The storm water management features associated with the EWRE design will capture and direct rain and snowmelt off of the dump, further reducing the volume of water available for infiltration and deep percolation however there is insufficient information to quantify reduced infiltration by this process. The storm water system is explained in detail in Attachment 2.
3. Water-consuming chemical reactions within the waste rock will result in formation of minerals such as jarosite and gibbsite (Younger, 2002; Chou, et al., 2002; Swayze, et al., 2008). The prevalence of such minerals in the existing waste rock dumps suggests this process is widespread, however there is insufficient information to quantify water losses by this process.

4. Water that percolates deep into the waste rock will reach the contact between the waste rock and bedrock and be collected in the toe drains and cutoff walls. Section 4.3.1 estimates the volume of water reaching bedrock.
5. A small fraction of the WRCW reaching this contact will seep into bedrock. Section 4.3.2 addresses methods for estimating the volume of this seepage, as required by Part B of the Permit application.

WRCW from current operations is captured in the existing WCS. WRCW from the EWRE and existing waste rock dump will be captured in an advanced collection system described in Attachment 2. Furthermore, implementation of the proposed storm water collection system and store-and-release cover will minimize infiltration.

ILLUSTRATION 4-1
EWRE Conceptual Water Balance



4.3.1 Total WRCW Seepage to Bedrock Estimate

This section assesses the potential volume of seepage into bedrock below the EWRE by using a mass-balance approach based partly on current groundwater chemistry data. The data used represent the impacts of existing waste rock dumps and past practices on the principal aquiferbut are used in this section to extrapolate potential future seepage from the EWRE. This is a conservative approach because current groundwater geochemistry likely retains a substantial signature of mass loading from: (1) operations that began in the 1930s and ceased in 2000 including waste-rock leaching and process-water ponding operations and (2) WCRW seepage into bedrock that occurred prior to construction of the WCS.

The maximum volume of WRCW to potentially emanate from the EWRE can be estimated based on current flows captured in the WCS and the assumption that the WRCW discharge rate is proportional to surface area of the waste rock dumps. The area of the proposed EWRE that will overlie currently undisturbed land is approximately 338 acres (see Figure 4-2). This estimate excluded ERWE acreage that will overlie existing previously reclaimed waste rock dump acreage. The existing waste rock dump acreage west of the proposed EWRE is approximately 1,634 acres. Thus, the EWRE area represents approximately 21 percent of the existing waste rock dumps.

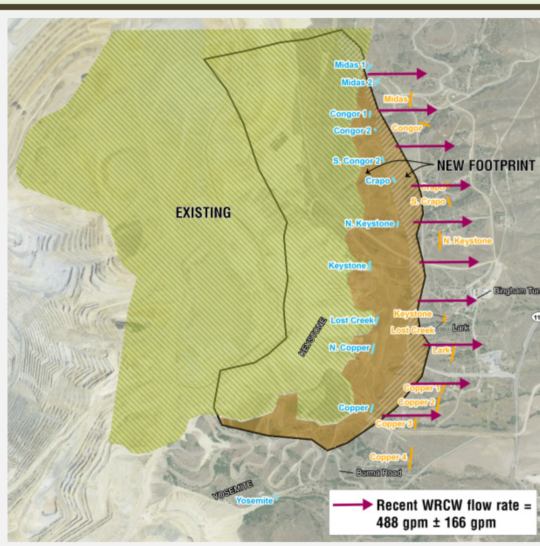
The average flow captured in the WCS since 2003 in drainages downslope from the proposed EWRE is approximately 488 gpm, with a standard deviation of 166 gpm. The following drainages were included in this analysis: Midas 1, Midas 2, Congor 1, Congor 2, South Congor, Crapo, North Keystone, Keystone, Lost Creek, North Copper, and Copper. Year 2003 was selected as the starting point of flow records for this analysis because that is when higher flows associated with leaching operations ceased (based on flow rates from the flumes) and flow from 2003 onward can be assumed to be driven primarily by natural precipitation. Using the 21 percent spatial weighting factor calculated above, total WRCW flow from the EWRE is estimated at 102 gpm ±35 gpm. For reasons noted previously, this should be considered a maximum estimate since planned reclamation and storm water controls are designed to greatly reduce percolation of precipitation and proportionally reduce WRCW formation in both the EWRE and existing waste rock dumps.

Illustration 4-2 provides an overview of the methods and assumption employed in this estimation of WRCW flow from the EWRE.

ILLUSTRATION 4-2
Method of Estimating Waste Rock Contact Water Flow

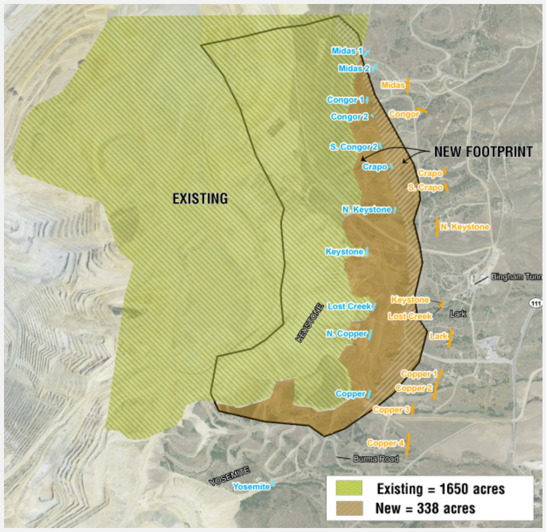
Goal:	Estimate the total volume of WRCW emanating from the base of the proposed EWRE. This estimate is for the total flow of WRCW, not the potential flow percolating into bedrock (see Illustration 4-3).
Method:	The calculation assumed that the flow of WRCW is proportional to the surface areas of the waste rock dumps. Thus, if the EWRE increases the surface area of the waste rock dumps by 21 percent, the increase in total WRCW flow is assumed to be 21 percent of the current flow.

Step 1



Estimate the total average WRCW flow from waste rock dumps west of the proposed EWRE (± one standard deviation). The estimate was based on flume data associated with the ECS for the Midas 1 through Copper drainages. Flume data from 2003 to present was selected to represent the time period in which natural precipitation was the dominant source of percolation in the waste rock and not influenced by historical waste rock leaching operations.

ILLUSTRATION 4-2
Method of Estimating Waste Rock Contact Water Flow

Step 2		Estimate the acreage of existing waste rock dumps east of the proposed EWRE (1634 acres).
Step 3		Estimate the acreage of the proposed EWRE. The EWRE extension will cover (1) existing waste rock dump slopes and (2) currently undisturbed acreage. WRCW flow from existing slopes is accounted for in Step 1. To avoid double counting, only the EWRE acreage for currently undisturbed land was used (338 acres).
Step 4	338 acres ÷ 1,634 acres = 21 percent	Calculate the percentage of surface area expansion resulting from the EWRE.
Step 5	21 percent x 488 gpm = 102 gpm (total) 21 percent x 166 gpm = 35 gpm (standard deviation)	Calculate the potential increased WRCW flow based on Step 1 and Step 4.

SLC \\SLCDB\GIS\PROJECTS\KENNECOTT\MAPFILES\437717\GWDISCHARGEPERMITAPP\ATTACH1\UNDISTURBEDACREAGE.MXD PMOELLER 9/17/2012 08:08:43

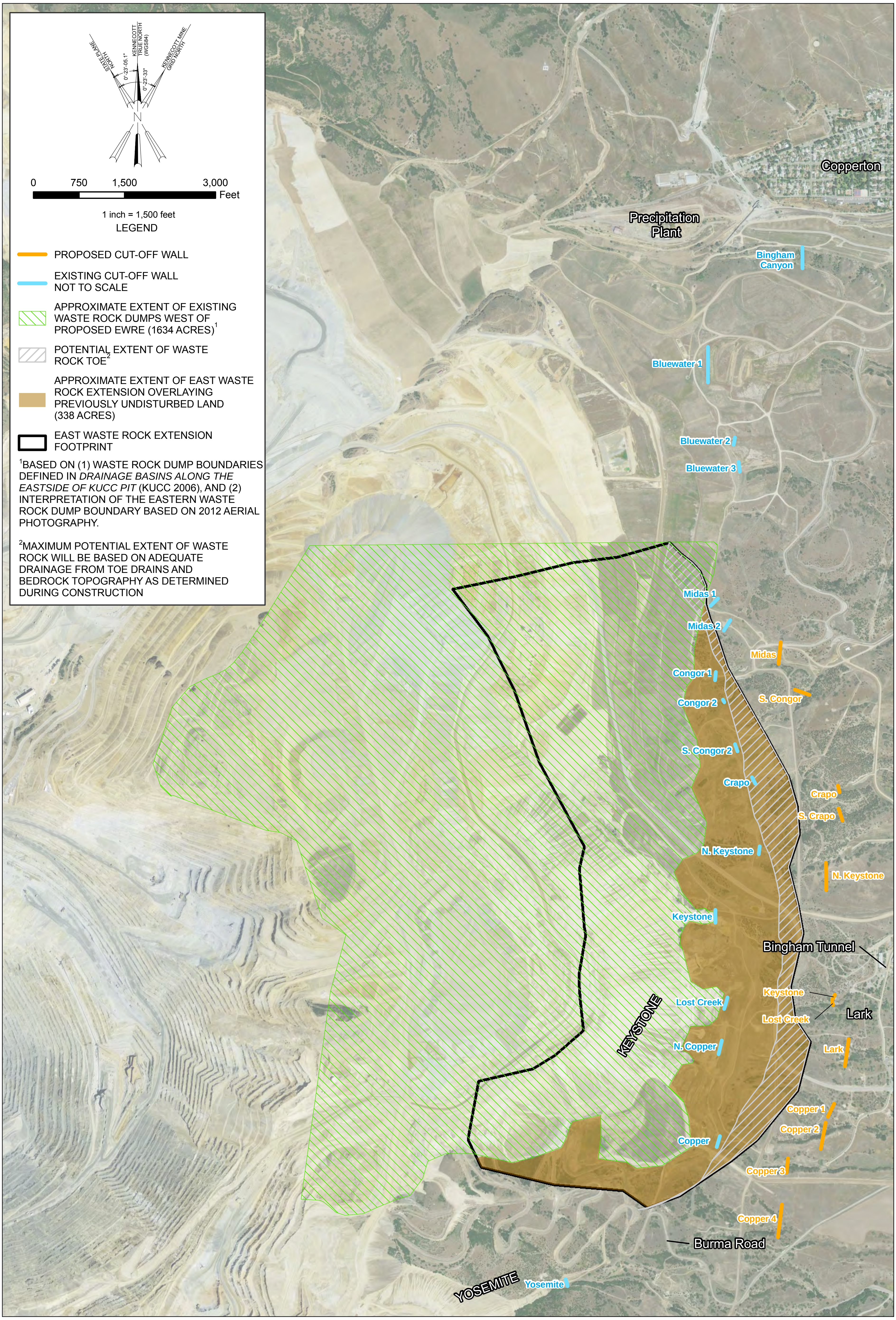


FIGURE 4-2

UNDISTURBED ACREAGE UNDERLYING THE EAST WASTE ROCK EXTENSION

EAST WASTE ROCK EXTENSION PERMIT MODIFICATION

GROUNDWATER DISCHARGE PERMIT UGW350010

KENNECOTT UTAH COPPER

4.3.2 Estimate of Potential Discharge to Bedrock

A small volume of WRCW will migrate vertically into bedrock. This section presents several lines of evidence and reasoning supporting the conclusion that the amount of WRCW potentially migrating into bedrock beneath the EWRE is likely to be a small fraction of the WRCW flow estimated in Section 4.3.1.

This section also presents an evaluation comparing the estimated potential WRCW seepage rate to bedrock with literature-based estimates of leakage from engineered, synthetic liners. This comparison supports the use of naturally-occurring low permeability sediments and rocks in conjunction with components of the BAT as practicable for capturing WRCW potentially generated as part of the EWRE.

The method of estimating potential seepage into bedrock used a simple mixing model based on the conservation of sulfate mass in the WRCW and bedrock aquifer. This model was based on methods included in Section 3.2 of the 1994 Permit Application (KUC, 1994). The mixing model is used to assess the anticipated seepage rate into bedrock based on concentrations observed in the down-gradient monitoring wells. Illustration 4-3 provides an overview of the methods and assumptions employed in this mixing model.

ILLUSTRATION 4-3
Method of Estimating Waste Rock Discharge to Bedrock

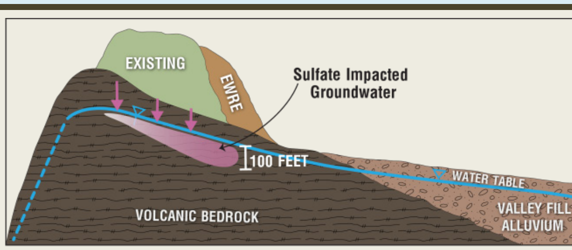
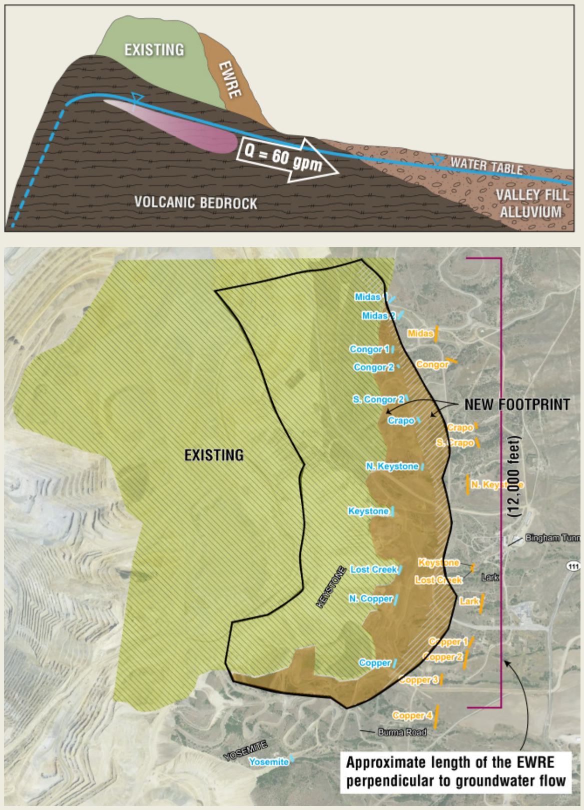
Goal:	Estimate the potential WRCW discharge to the ground.
Method:	The calculation is based on the assumption that the impact to the aquifer from the EWRE would be a proportional increase above existing impacts, specifically, that it would increase based on the acreage of waste rock placed over currently undisturbed acreage. This is a conservative approach to estimating discharge rate and likely results in an over estimate based upon the fact the waste rock dumps are no longer actively leached and WRCW is no longer ponded along the toe of the waste rock dumps. The current WRCW flow to bedrock was calculated using a simple mixing model based on conservation of solute mass and basic hydrogeological principles. The potential future WRCW seepage was then estimated as a fraction of the current flow based on a ratio of surface areas, similar to the calculations shown in Illustration 4-2. This method provides a maximum estimate as it does not account for reductions that will result from new features of the ECS and waste rock reclamation (See Attachment 2).
Step 1	 Estimate the depth of historical WRCW impacts to the bedrock underlying the existing waste rock dumps. This was done using data from bedrock monitoring wells to assess the depth of sulfate impacts above estimated background concentrations. The impacted thickness was estimated to be 100 feet.

ILLUSTRATION 4-3

Method of Estimating Waste Rock Discharge to Bedrock

Step 2



Q = K i A (Darcy's Law)

where: Q = flow rate (volume/time)

K = hydraulic conductivity (length/time)

i = hydraulic gradient (dimensionless)

A = cross sectional area of flow (area)

Estimate the current volumetric flux of sulfate impacted groundwater in bedrock east of the proposed EWRE using Darcy's law (Freeze and Cherry, 1979). Values of hydraulic gradient were estimated from a current potentiometric surface map. Hydraulic conductivity was estimated as the geometric mean of values from permitted compliance monitoring wells in bedrock near the proposed EWRE. The cross sectional area of flow was estimated based on the 100-foot depth (Step 1) and the approximate length of the EWRE perpendicular to groundwater flow (12,000 feet). The estimated flow rate was 60 gpm.

ILLUSTRATION 4-3
Method of Estimating Waste Rock Discharge to Bedrock

Step 3

$C_1 \times Q_1 = C_2 \times Q_2$

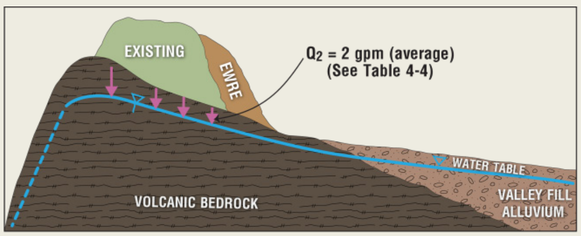
where:

C1 = 663 mg/L = Spatially-weighted/background-adjusted sulfate concentration in bedrock monitoring wells (Table 4-4)

Q1 = Calculated bedrock underflow derived from equation 1 = 60 gpm

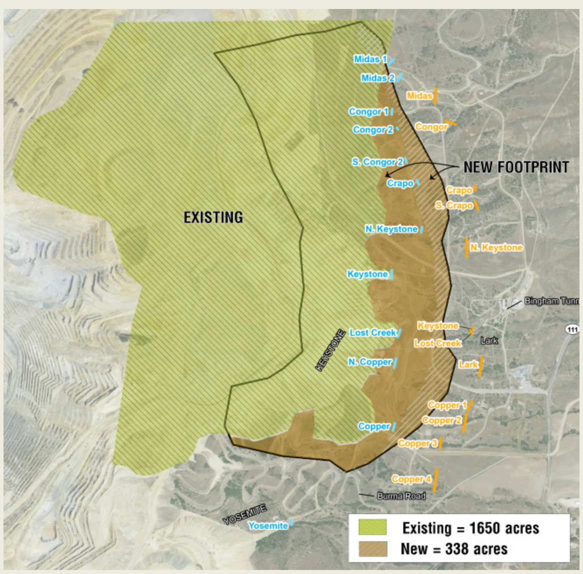
C2 = Concentration of the captured leach water = 42,000 mg/L -the average concentrations of sulfate at the current WRCW collection system (Table 4-4)

Q2 = Flow of the concentrated leach water migrating into bedrock (0.9 gpm)



Use a simple mixing model to solve for the unknown – the flow of water migrating from the current waste rock dumps into the bedrock. The mixing model assumes conservation of sulfate mass where the mass flux of sulfate from the waste rock into the bedrock equals the mass flux of sulfate in the bedrock. The two sulfate concentration values were derived from (1) historical monitoring data in bedrock groundwater monitoring wells, and (2) monitoring data from the eastside collection system.

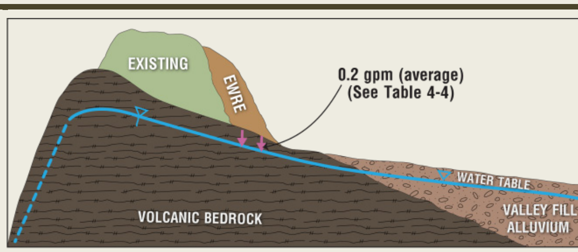
Step 4



338 acres ÷ 1,634 acres = 21 percent

Calculate the percentage of surface area expansion resulting from the EWRE (see Illustration 4-2).

Step 5



21 percent x 0.9 gpm (average) ≈ 0.2 gpm

Calculate the increased WRCW seepage to bedrock due to the EWRE, based on Step 1 and Step 4.

The horizontal underflow in the upper portion of the bedrock can be calculated using groundwater flow principles. The equation used for groundwater flow is Darcy's Law (Freeze and Cherry, 1979):

EQUATION 1

$$Q = K\, i\, A$$

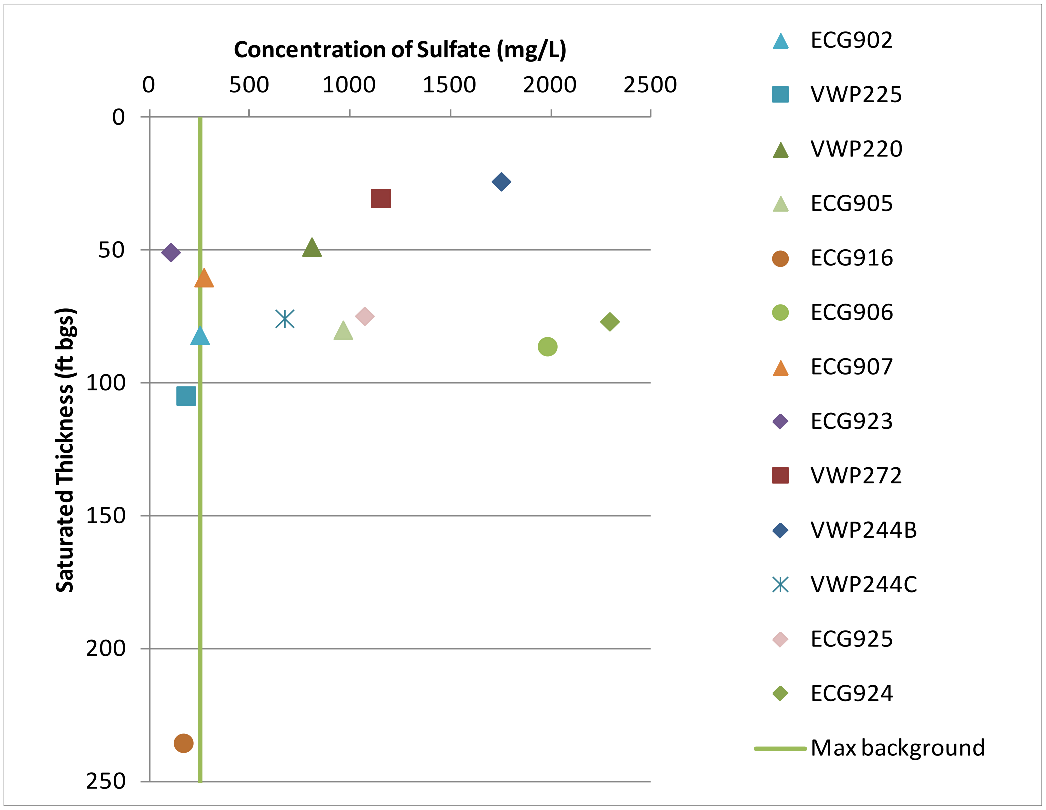
where: Q = flow rate (volume/time)
K = hydraulic conductivity (length/time)
i = hydraulic gradient (dimensionless)
A = cross sectional area of flow (area)

For the Eastside waste rock area, these parameters are as follows:

- **Hydraulic conductivity (K).** As noted in Section 3.3.1, the geometric mean is a good predictor of the effective bulk hydraulic conductivity in rock materials and is used for these calculations. The geometric mean hydraulic conductivity of Paleozoic and volcanic bedrock is 5×10^{-5} centimeters per second (0.14 foot per day).
- **Hydraulic gradient (i).** The horizontal hydraulic gradient to the east of the waste rock dumps is estimated to be 0.07 (dimensionless), based on the groundwater contours presented in Figure 4-1.
- **Cross sectional area (A).** The cross section through which groundwater flows is a vertical plane that runs roughly north to south through the proposed toe of the waste rock extension along the line of the proposed toe drain system. The length of the proposed toe of waste rock is approximately 12,000 feet. The area of the vertical plane equals that length multiplied by the depth of flow of 100 feet, which was estimated from the thickness of sulfate-impacted groundwater.

Water quality (as characterized by sulfate concentration) for the monitoring wells drilled in the bedrock immediately east of the existing waste rock dump was used to estimate the depth of WRCW impacts in the principal aquifer. With the exception of ECG932 having a calculated, saturated thickness of impacted aquifer of 109 feet, all monitoring wells with a saturated thickness greater than approximately 100 feet do not exhibit elevated sulfate concentrations above the maximum background concentration of 250 milligrams per liter (mg/L) (see Table 5-4 in Section 5.2). Based on this analysis, the saturated thickness for the impacted aquifer was conservatively assumed to be approximately 100 feet, shown in Figure 4-3. Using Equation 1 and the previously listed values, the maximum flux ("horizontal underflow") of water through the cross sectional area is approximately 8 cubic feet per minute (ft^3/min), or approximately 60 gpm.

FIGURE 4-3
Sulfate Concentration with Saturated Thickness



The second part of this estimate uses the mixing model and analytical results from water collected at the existing cut-off walls, which are then compared to the chemistry observed at the monitoring wells. The sulfate concentrations used in this equation use the average of a 5-year data set (2007 to 2011) (see Table 4-4).

The calculation was performed using the sulfate data because sulfate concentrations above background are a good indicator of WRCW impacts east of the waste rock dumps. The calculation assumes that sulfate concentrations detected at the monitoring wells above background concentrations originate from the high concentration sulfate impacted WRCW.

The equation for this calculation is as follows:

EQUATION 2

$$C_1 \times Q_1 = C_2 \times Q_2$$

where:

C_1 = Spatially-weighted and background-adjusted sulfate concentration at the monitoring wells = 663 mg/L. See the text below, Figure 4-4 and Table 4-4 for information supporting this calculation.

Q_1 = Calculated bedrock underflow derived from equation 1 = 60 gpm

C_2 = Concentration of the captured leach water = 42,000 mg/L – the average concentrations of sulfate at the ECS

Q_2 = Flow of WRCW potentially seeping into bedrock (gpm)

The spatially-weighted/background-adjusted sulfate concentration was calculated as follows:

1. A north-south line was drawn to the east of the bedrock monitoring wells shown on Figure 4-4 and listed in Table 4-4. This line is also roughly perpendicular to the groundwater flow direction in the principal aquifer.
2. An east-west line was drawn through the approximate mid-points between adjacent wells.
3. The distance between these midpoints (D_{well}) was tabulated (Table 4-4) and assigned to wells that fell between the mid-points. The total distance (D_{total}) was also tabulated.
4. A well-specific weighting factor was calculated by dividing D_{well} by D_{total}.
5. The well-specific weighting factors were then multiplied by the measured sulfate concentration at a well to yield a spatially weighted concentration for each well.
6. The overall spatially-weighted concentration (913 mg/L) was then calculated by summing the values for each well
7. The spatially-weighted/background-adjusted sulfate concentration (663 mg/L) was calculated by subtracting 250 mg/L from the spatially-weighted concentration (913 mg/L). 250 mg/L is the upper end of background sulfate concentration in bedrock based on previous baseline investigations (see Table 5-4). It is appropriate to subtract the background signature as concentrations below this value do not necessarily represent impact from overlying waste rock.

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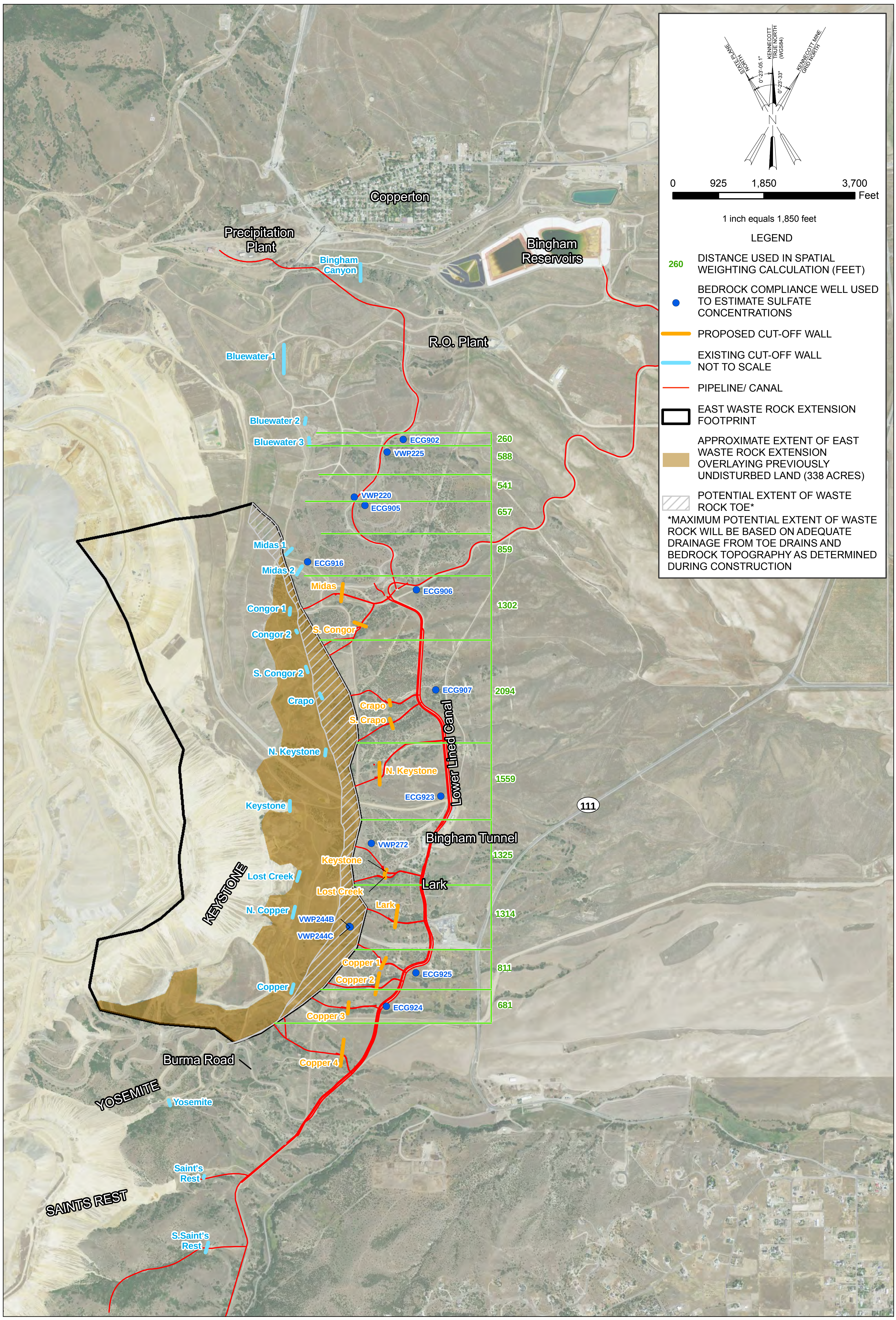

FIGURE 4-4

DISCRETIZATION FOR SPATIAL WEIGHTING

EAST WASTE ROCK EXTENSION PERMIT MODIFICATION
GROUNDWATER DISCHARGE PERMIT UGW350010
KENNECOTT UTAH COPPER

Using Equation 2 and the inputs described above, the resulting seepage from the waste rock to the bedrock for the current waste rock dump configuration is approximately 0.9 gpm. Using the 21 percent spatial weighting factor described previously, the average estimated increase in WRCW seepage from the EWRE is approximately 0.2 gpm. This potential seepage is approximately 0.2 percent of the estimated 102 gpm total WRCW discharge (see above). However, these calculations were based on sulfate concentrations observed in the monitoring wells that may reflect remnant impacts from before construction and operation of the ECS thereby biasing the estimate high.

TABLE 4-4
Spatial Weighting of Sulfate Concentration

Well ID	Length (ft)	Weighting Factor	Sulfate Concentration (mg/L)	Spatially Weighted Concentration (mg/L)
ECG902	260	0.02	250	5.4
VWP225	588	0.05	181	8.87
VWP220	541	0.05	807	36.4
ECG905	657	0.05	963	52.7
ECG916	859	0.07	168	12.0
ECG906	1,302	0.11	1,980	215
ECG907	2,094	0.17	270	47.1
ECG923	1,559	0.13	105	13.6
VWP272	1,325	0.11	1,150	127
VWP244B	1,314	0.11	1,750	192
ECG925	811	0.07	1,070	72.4
ECG924	681	0.06	2,290	130
Total Length (ft):	11,990		Weighted Concentration:	**913**

NOTES:
mg/L = milligram(s) per liter

As part of the effort to identify the BAT for controlling impacts to the regional aquifer, the seepage flux estimates provided above were compared to allowable leakage rates for synthetic liners. A technical memorandum provided as Appendix C evaluates synthetic-liner allowable leakage rates base on studies published by government and industry sources. The 0.2 gpm WRCW seepage rate estimated above is at least two orders of magnitude lower than rates allowed for landfills and waste piles across multiple states in the United States. The estimated EWRE seepage rates also fall within the range described for an idealized “perfect” liner described by the Geosynthetic Institute. When considering liner constructability issues related to the EWRE project area, the leakage rates for a synthetic liner are anticipated to be even higher than those identified for the idealized case. Based on this evaluation, the naturally-occurring, low-permeability surface at the top of bedrock provides much better performance than would be expected from a synthetic liner and is included as part of the BAT for managing WRCW for the EWRE project.

The 0.2 gpm estimated seepage rate based upon the mass-balance/mixing model is a reasonable and conservative approximation for the purpose of completing Part B of the Permit application. This value is likely overestimated since it does not account for: (1) all of the system components described in Attachment 2, such as the surface and subsurface (or alluvial) collection system; (2) losses of precipitation to storm water run-off; and (3) the degree of water-consuming mineralization reactions that will occur in the fresh waste rock with its abundant reaction sites. Considering these factors, the actual seepage of WRCW due to the EWRE is likely to be lower than 0.2 gpm. In addition, the EWRE will reduce WRCW formation and seepage from existing waste rock as the EWRE encapsulates approximately 560 acres of the existing dump where advanced infiltration limiting controls are not currently employed.

5.0 Groundwater Quality

5.1 Recent Compliance Monitoring Results

Compliance groundwater samples for the ECS are currently collected in accordance with the current KUC Groundwater Characterization and Monitoring Plan .This section provides an overview of recent groundwater compliance monitoring results. A total of 43 compliance monitoring wells were sampled and analyzed in 2011 in association with Groundwater Discharge Permit No. UGW350010. Of these, 24 wells are hydraulically down gradient of the EWRE project area. Of the 24 monitoring wells, there are 3 wells that are completed as a nest of wells (VWP244A, B and C). Recent (November 2011 through March 2012) analytical results from these wells are presented in Table 5-1.

Mann-Kendall trend analyses were performed using analytical data from January 1998 to March 2012 for the compliance wells hydraulically down gradient of the proposed EWRE. The Mann-Kendall trend analysis was run at the 95 percent confidence interval and identifies a trend as either increasing or decreasing. If the coefficient of variation is equal to or less than 1, there is no trend and the time series data is labeled “stable.” Water quality data for these wells can be viewed in Table 5-1 and recent results and trends are presented in Figures 5-1 through 5-6.

Time series plots for the compliance wells and other monitoring wells in the vicinity are included as Appendix A to Attachment 1. Applicable permit water quality limits for each well can be found in Table 5-2. Table 5-3 summarizes data analysis of compliance monitoring results including trends and comparisons with compliance limits. Table 5-4 summarizes baseline (i.e., unaffected by historical WRCW) water quality data for the principal aquifer.

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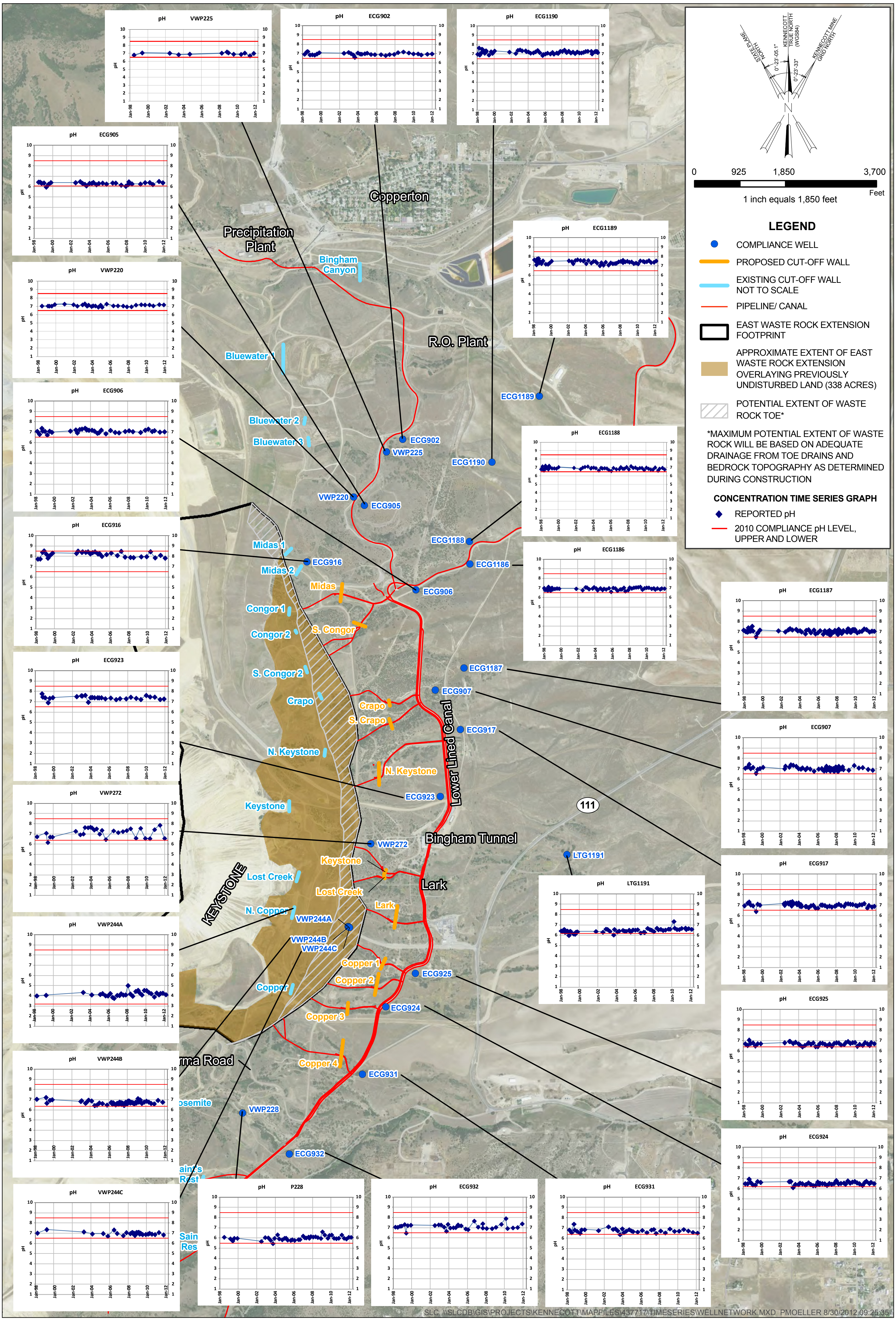
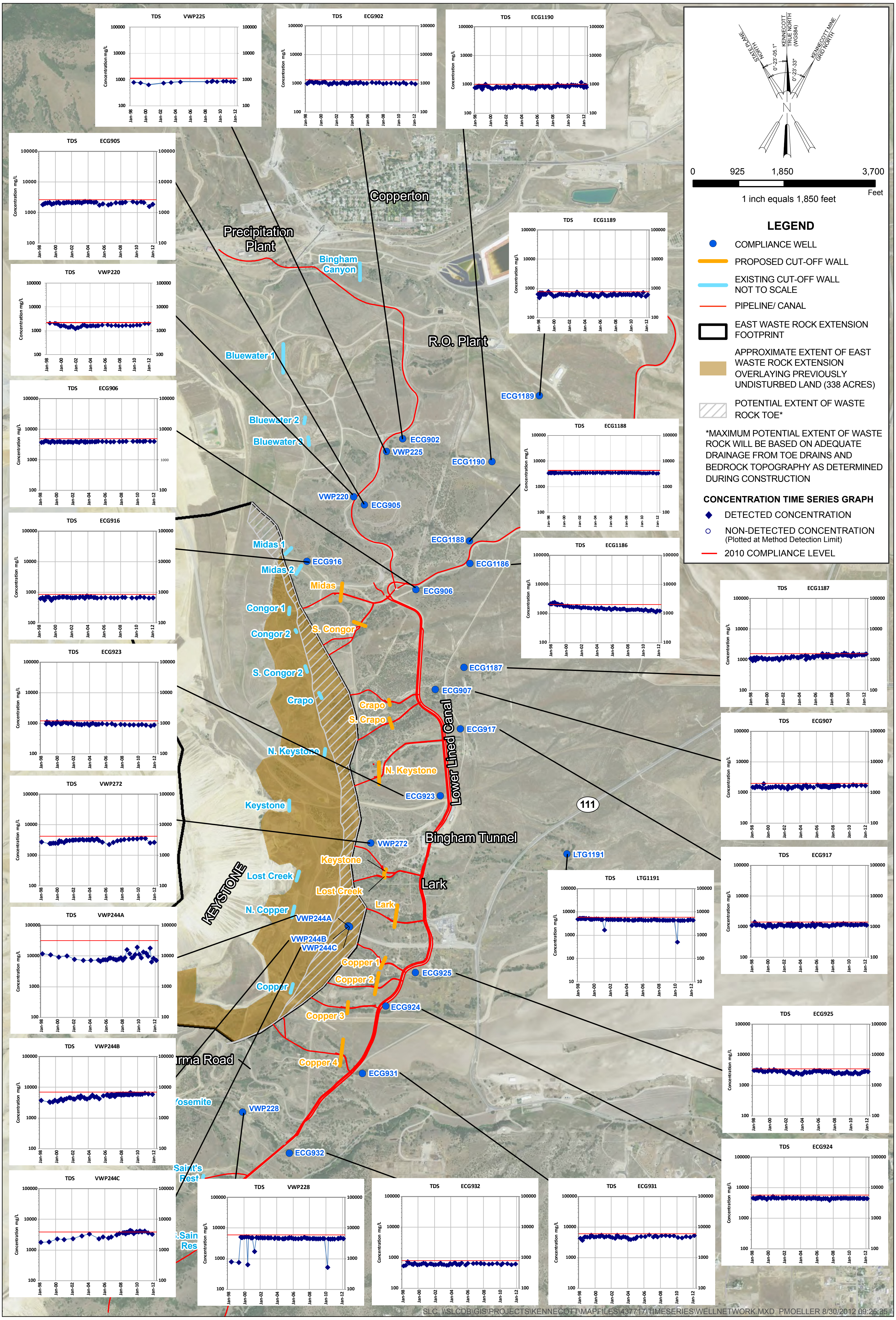


NOTE:

GRID - KENNECOTT TRUE NORTH
pH -

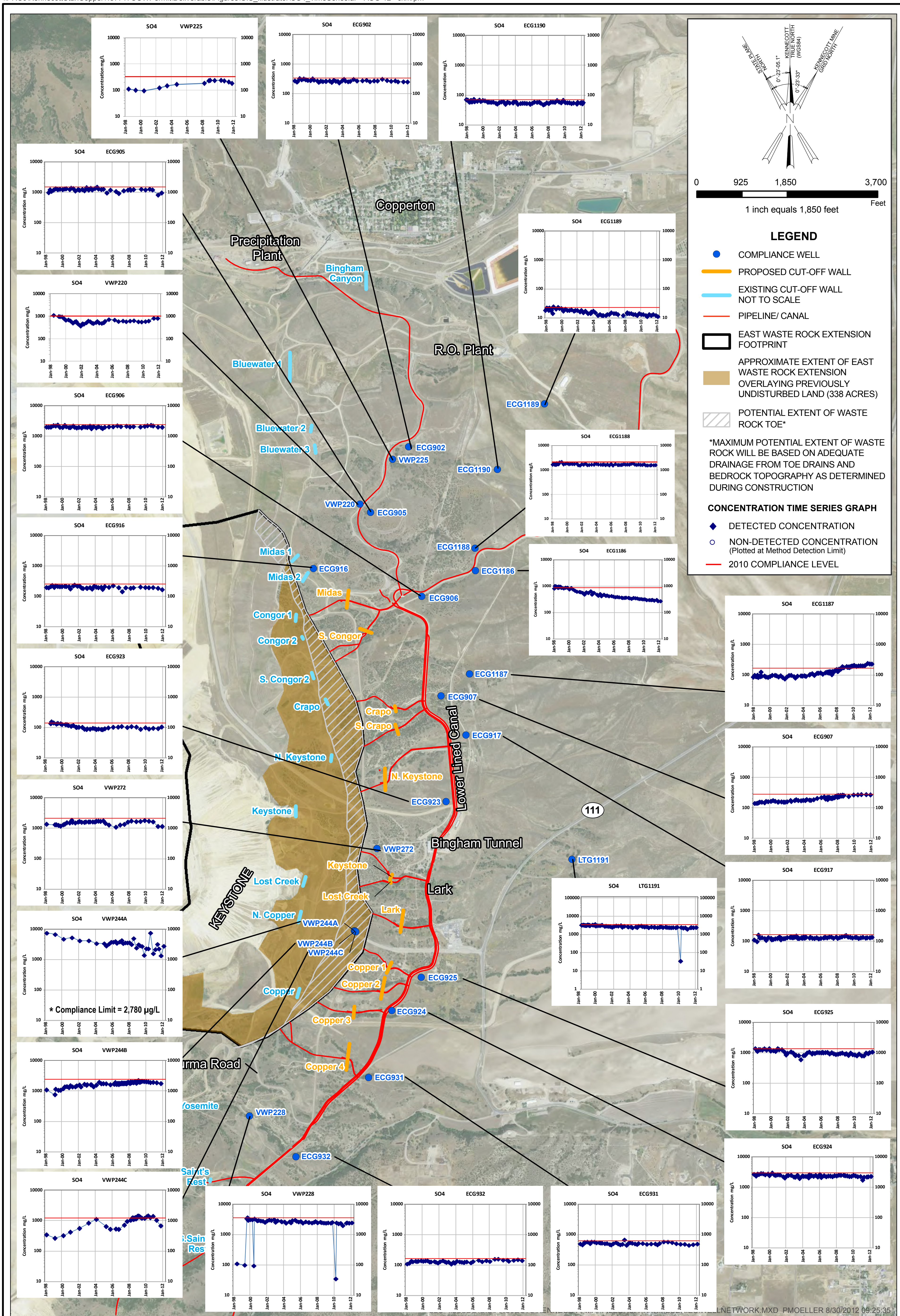
FIGURE 5-1
pH TIME SERIES
EAST WASTE ROCK EXTENSION PERMIT MODIFICATION
GROUNDWATER DISCHARGE PERMIT UGW350010
KENNECOTT UTAH COPPER



NOTE:

GRID - KENNECOTT TRUE NORTH
TDS = TOTAL DISSOLVED SOLIDS

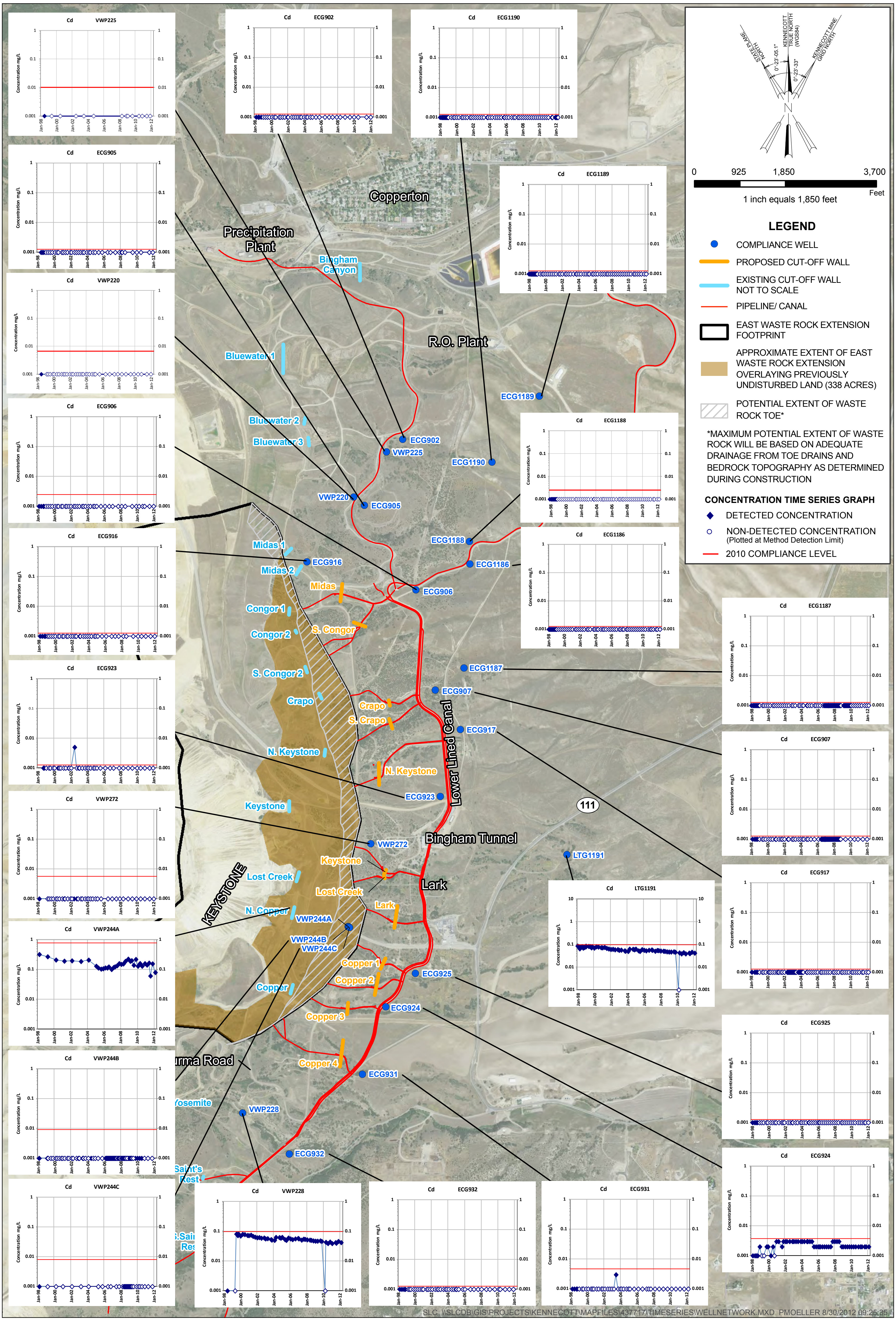
FIGURE 5-2
TOTAL DISSOLVED SOLIDS TIME SERIES
EAST WASTE ROCK EXTENSION PERMIT MODIFICATION
GROUNDWATER DISCHARGE PERMIT UGW350010
KENNECOTT UTAH COPPER



NOTE:

GRID - KENNECOTT TRUE NORTH
SO4 = SULFATE

FIGURE 5-3
SULFATE TIME SERIES
EAST WASTE ROCK EXTENSION PERMIT MODIFICATION
GROUNDWATER DISCHARGE PERMIT UGW350010
KENNECOTT UTAH COPPER

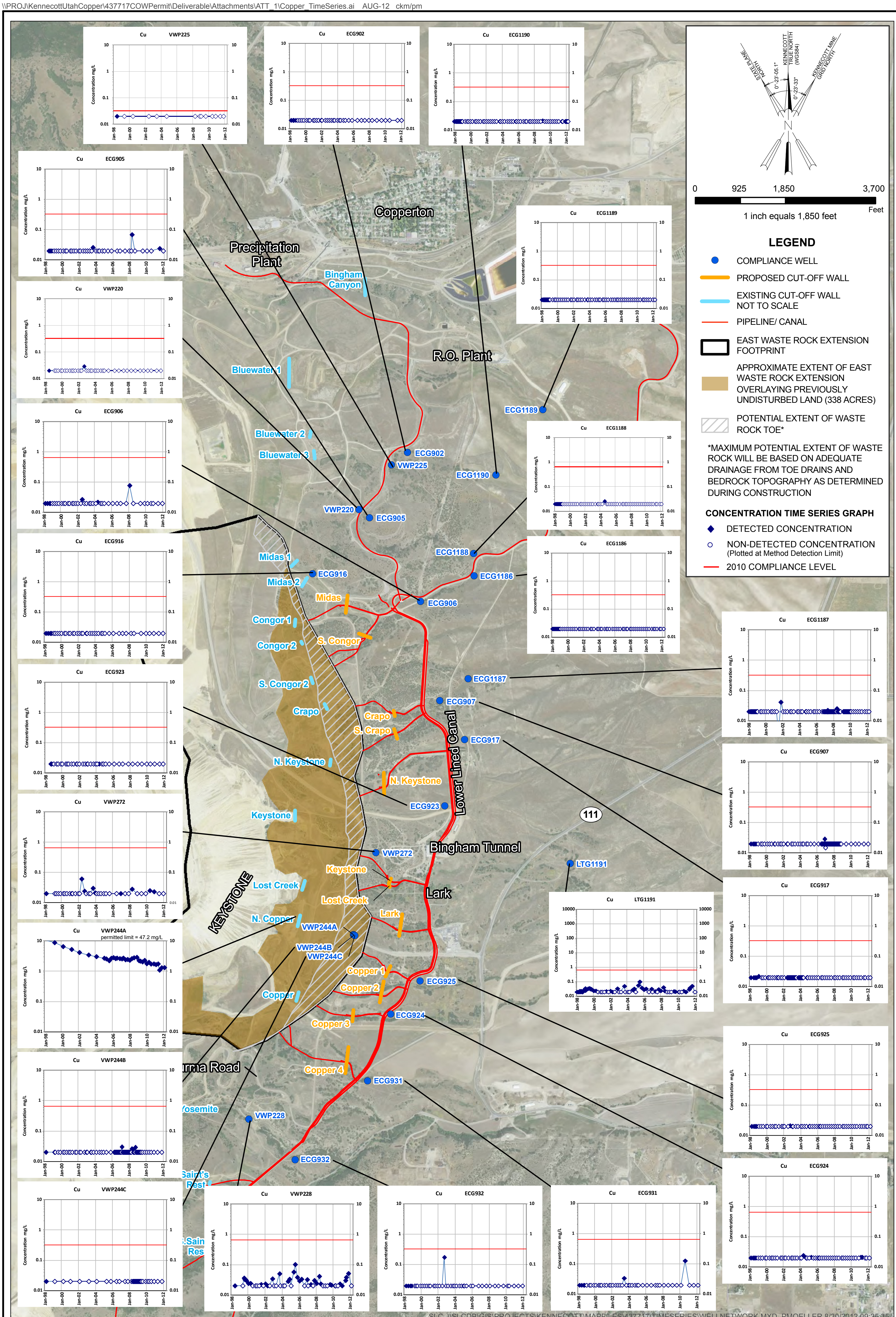


NOTE:

GRID - KENNECOTT TRUE NORTH
Cd = CADMIUM

FIGURE 5-4
CADMIUM TIME SERIES
EAST WASTE ROCK EXTENSION PERMIT MODIFICATION
GROUNDWATER DISCHARGE PERMIT UGW350010
KENNECOTT UTAH COPPER

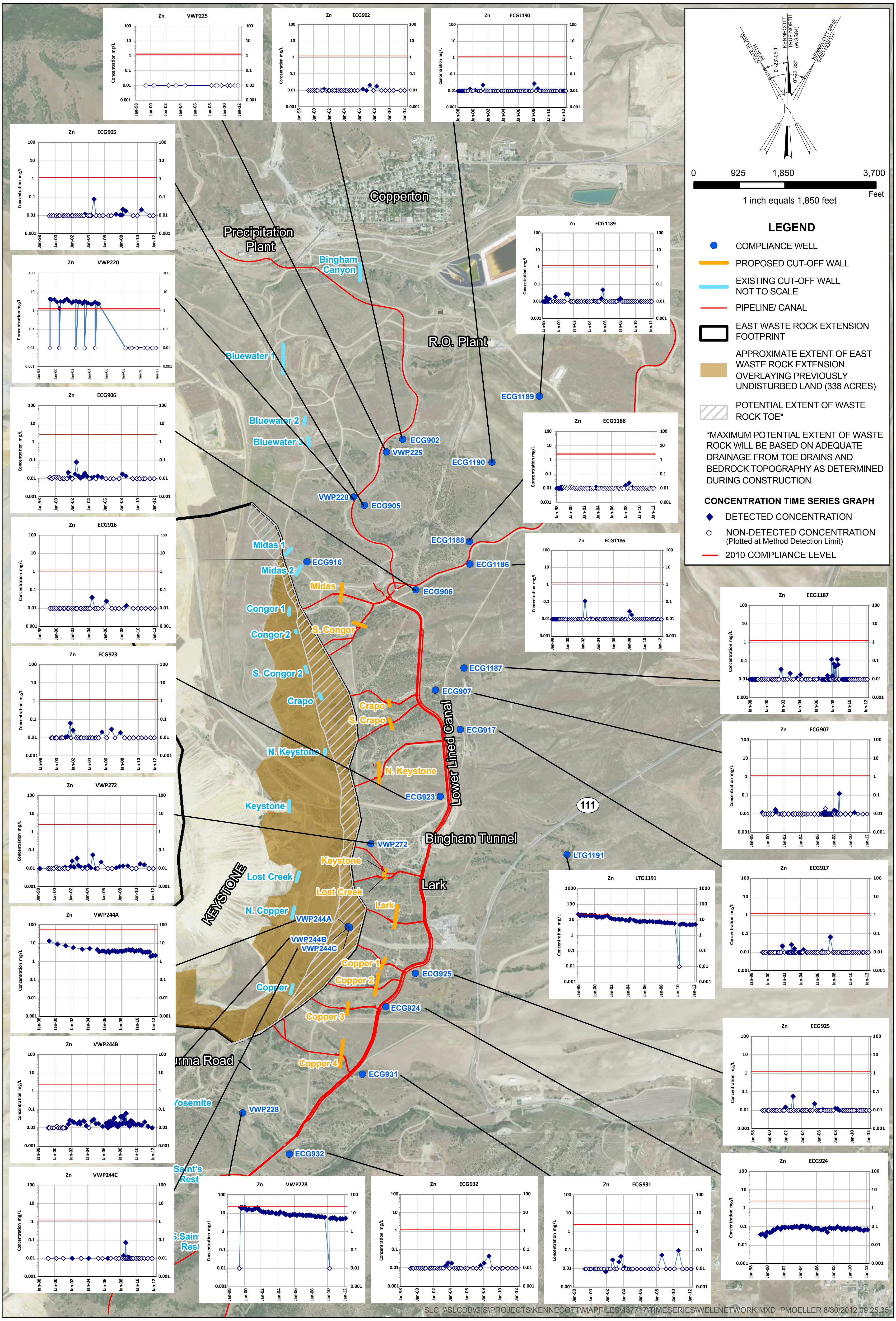
\\PROJ\KennecottUtahCopper\437717COWPermit\Deliverable\Attachments\ATT_1\Copper_TimeSeries.ai AUG-12 ckm/pm



NOTE:

GRID - KENNECOTT TRUE NORTH
Cu = COPPER

FIGURE 5-5
COPPER TIME SERIES
EAST WASTE ROCK EXTENSION PERMIT MODIFICATION
GROUNDWATER DISCHARGE PERMIT UGW350010
KENNECOTT UTAH COPPER



NOTE:

GRID - KENNECOTT TRUE NORTH
Zn = ZINC

FIGURE 5-6
ZINC TIME SERIES
EAST WASTE ROCK EXTENSION PERMIT MODIFICATION
GROUNDWATER DISCHARGE PERMIT UGW 350010
KENNECOTT UTAH COPPER

TABLE 5-1
Compliance Well Water Quality

Station	Date of Last Sample	Total Dissolved Solids (mg/L)	pH	Sulfate (mg/L)	Cadmium (mg/L)	Copper (mg/L)	Zinc (mg/L)	Magnesium (mg/L)	Chloride (mg/L)	Screen Location
ECG1186	2/16/2012	1,250	6.96	273	<0.001	<0.02	<0.01	49	408	Alluvium
ECG1187	2/17/2012	1,550	7.06	228	<0.001	<0.02	<0.01	65	580	Alluvium
ECG1188	2/9/2012	3,340	6.76	1580	<0.001	<0.02	<0.01	122	549	Alluvium
ECG1189	2/9/2012	608	7.53	11	<0.001	<0.02	<0.01	29	224	Alluvium
ECG1190	3/2/2012	802	7.16	56	<0.001	<0.02	<0.01	45	343	Alluvium
ECG902	12/1/2011	960	6.97	250	<0.001	<0.02	<0.01	47	274	Bedrock
ECG905	11/29/2011	1,900	6.39	963	<0.001	<0.02	<0.01	76	130	Bedrock
ECG906	12/1/2011	4,050	7.05	1,980	<0.001	<0.02	<0.01	158	437	Bedrock
ECG907	12/13/2011	1,710	6.88	270	<0.001	<0.02	<0.01	70	592	Bedrock
ECG916	12/20/2011	672	7.84	168	<0.001	<0.02	<0.01	36	154	Bedrock
ECG917	2/14/2012	1,140	6.91	136	<0.001	<0.02	<0.01	49	471	Alluvium
ECG923	11/21/2011	896	7.28	105	<0.001	<0.02	<0.01	17	334	Bedrock
ECG924	2/7/2012	4,450	6.5	2,290	0.002	<0.02	0.07	311	506	Bedrock
ECG925	2/7/2012	2,850	6.71	1070	<0.001	<0.02	<0.01	121	679	Bedrock
ECG931	2/28/2012	5,390	6.53	495	<0.001	<0.02	<0.01	196	2,360	Bedrock
ECG932	11/21/2011	638	7.41	142	<0.001	<0.02	<0.01	49	141	Bedrock
LTG1191	2/23/2012	4,530	6.6	2,460	0.042	<0.02	5.37	358	532	Alluvium
VWP220	12/2/2011	2,020	7.18	807	<0.001	<0.02	<0.01	72	268	Bedrock
VWP225	11/29/2011	828	6.99	181	<0.001	<0.02	<0.01	38	206	Bedrock
VWP228	2/21/2012	6,190	6.09	4,150	0.015	0.11	1.31	816	212	Alluvium
VWP244A	2/23/2012	7,260	4.12	2,780	0.08	1.32	2.17	635	2,090	Alluvium
VWP244B	10/7/2011	5,910	6.77	1,750	<0.001	<0.02	0.01	226	1,510	Bedrock
VWP244C	10/7/2011	3,290	6.85	672	<0.001	<0.02	<0.01	125	924	Bedrock
VWP272	12/15/2011	2,670	6.59	1,150	<0.001	<0.02	<0.01	115	309	Bedrock

NOTES:

mg/L = milligram per liter

TABLE 5-2
Water Quality Standards for Compliance Monitoring Wells

Well ID	Screen Lithology	Sampling Frequency	NAD 83		pH	TDS (mg/L)	SO4 (mg/L)	Diss. Cd (mg/L)	Diss. Cu (mg/L)	Diss. Zn (mg/L)
			Latitude (Decimal Degrees)	Longitude (Decimal Degrees)						
ECG1186	Alluvium	Quarterly	40.5437439	-112.0931764	6.5–8.5	2,002	875	0.001	0.325	1.25
ECG1187	Alluvium	Quarterly	40.5379605	-112.0936179	6.5–8.5	1,589	169	0.001	0.325	1.25
ECG1188	Alluvium	Quarterly	40.5450083	-112.0932055	6.5–8.5	4,360	2,122	0.003	0.650	2.50
ECG1189	Alluvium	Quarterly	40.5530939	-112.0880903	6.5–8.5	763	23	0.001	0.325	1.25
ECG1190	Alluvium	Quarterly	40.5494215	-112.0915596	6.5–8.5	1,030	70	0.001	0.325	1.25
ECG902	Bedrock	Semiannually	40.5507022	-112.0980791	6.5–8.5	1,321	338	0.001	0.325	1.25
ECG905	Bedrock	Semiannually	40.5470216	-112.1008874	6.06–8.5	2,613	1,495	0.001	0.325	1.25
ECG906	Bedrock	Semiannually	40.5423050	-112.0971261	6.5–8.5	4,844	2,434	0.003	0.650	2.50
ECG907	Bedrock	Semiannually	40.5367215	-112.0957122	6.5–8.5	2,004	278	0.001	0.325	1.25
ECG916	Bedrock	Semiannually	40.5438744	-112.1050848	6.5–8.5	862	254	0.001	0.325	1.25
ECG917	Alluvium	Quarterly	40.5345299	-112.0938791	6.5–8.5	1,422	164	0.001	0.325	1.25
ECG923	Bedrock	Semiannually	40.5308104	-112.0953513	6.5–8.5	1,187	141	0.001	0.325	1.25
ECG924	Bedrock	Semiannually	40.5190854	-112.0993430	6.20–8.5	5,739	3,021	0.004	0.650	2.50
ECG925	Bedrock	Semiannually	40.5209548	-112.0971847	6.39–8.5	3,498	1,365	0.001	0.325	1.25
ECG931	Bedrock	Semiannually	40.5153272	-112.1010569	6.39–8.5	6,004	625	0.005	0.650	2.50
ECG932	Bedrock	Semiannually	40.5108910	-112.1063874	6.5–8.5	796	164	0.001	0.325	1.25
LTG1191	Alluvium	Quarterly	40.5275523	-112.0861067	6.17–8.5	5,888	3,525	0.096	0.650	23.33
VWP220	Bedrock	Semiannually	40.5474779	-112.1016540	6.5–8.5	2,205	1,019	0.007	0.325	1.25
VWP225	Bedrock	Semiannually	40.5499882	-112.0992597	6.5–8.5	1,117	331	0.010	0.0325	1.25
VWP228	Alluvium	Quarterly	40.5131827	-112.1098041	5.5–8.5	11,173	7,721	0.064	0.650	4.74
VWP244A	Alluvium	Quarterly	40.5235602	-112.1020939	3.2–8.5	31,790	24,749	0.770	47.2	53.9
VWP244B	Bedrock	Semiannually	40.5235405	-112.1020455	6.34–8.5	6,959	2,389	0.009	0.650	2.50
VWP244C	Bedrock	Semiannually	40.5235083	-112.1019880	6.5–8.5	3,876	1,235	0.008	0.325	1.25
VWP272	Bedrock	Semiannually	40.5281683	-112.1004374	6.37–8.5	4,193	2,144	0.006	0.650	2.50

TABLE 5-2
Water Quality Standards for Compliance Monitoring Wells

NOTES:

All units are mg/L; pH standard units

mg/L = milligrams per liter

TDS = total dissolved solids

SO_4 = sulfate

Diss. Cd = dissolved cadmium

Diss. Cu = dissolved copper

Diss. ZN = dissolved zinc

[1]Compliance Limits are based on 1.25 times the background concentration for TDS for Class II and III groundwater.

[2]For many wells cadmium, copper, and zinc were predominantly nondetects; compliance limits determined from the groundwater quality standard.

[3]Where the background concentrations is less than detection, compliance limits are based on 0.25 times the groundwater quality standard for Class II groundwater and 0.50 times the groundwater quality standard for Class III groundwater for cadmium, copper, and zinc.

[4]If background value exceeds the groundwater quality standard, the Protection Level equals the background value.

[5]The Compliance Limits for IV groundwater are the higher of the groundwater quality standard, the mean times 1.25, or the mean + 2 std. dev.

[6]There is not a groundwater quality standard for sulfate

[7]Compliance limits for sulfate were calculated as the higher of the mean+2 std. dev. or 1.25 times the mean.

[8]Range of pH values for Compliance Limits are based on the higher and lower limit of 6.5-8.5 and/or mean + and -2 std. dev.

[9]Coordinate system in KUC True North south end map drawn in 1927 State Plane Utah Central Zone.

[10]Limits were set using all available data for each individual well through 2008.

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TABLE 5-3A
Compliance Monitoring Data Analysis Summary[1]

Analyte	Count of Compliance Wells by Trend[1]				Well with Increasing Trends[2] within 25% of Current Compliance Limit	Wells with Compliance Limit Exceedances[1,*] (Data set spanning January 1998 to March 2012)
	Insufficient Detections	Decreasing	Stable	Increasing		
Total Dissolved Solid	0	12	5	7	ECG1187 ECG1190 ECG906 ECG907 VWP220	ECG1186 ECG1187 ECG1189 ECG1190 ECG917 VWP244C
Sulfate	0	12	3	9	ECG907 ECG917+ ECG932+	ECG1186 ECG1187* ECT1189 ECG1190 ECG923 ECG925 ECG931 LTG1191 VWP244C
Copper	20	1	2	1	---	---
Zinc	18	3	3	0	---	LTG1191
Cadmium	20	2	2	0	---	ECG923

NOTES:
Compliance limits use the limits established as part of the 2010 Permit renewal (DWQ, 2010).
[1]Based on compliance monitoring data between January 1998 and March 2012.
[2]Based on Mann-Kendall analysis. See text for further discussion.
∗Indicates exceedance in most-recent (November 2011 to March 2012) dataset.
+ The following wells and analytes appear to exhibit stable trends right below the compliance limit despite the Mann-Kendall analysis indicating an upward trend.

TABLE 5-3B
Compliance Monitoring pH Analysis Summary[1]

Analyte	Count of Compliance Wells by Trend[1]: Insufficient Detections	Decreasing H+ ion (Increasing pH)	No Trend	Increasing H+ ion (Decreasing pH)	Wells with Increasing H+ ion Trends[2] within 25% of Current Compliance Limit (Decreasing pH)	Wells with pH out of Compliance Range[1] (Data set spanning January 1998 to March 2012)
pH (analysis based on concentration of hydrogen ion)	0	2	17	5	----	ECG905 ECG916[H] ECG917 ECG924 ECG931 ECG932 LTG1191 VWP228 VWP272

NOTES:

Compliance limits use the limits established as part of the 2010 Permit renewal (DWQ, 2010).

[1]Based on compliance monitoring data between January 1998 and March 2012.

[2]Based on Mann-Kendall analysis. See text for further discussion.

[H] Exceedance on the upper range (high pH).

TABLE 5-4
Baseline Water Quality of Principal Aquifer

Parameter	Range	Typical Value
Arsenic	<0.004–0.03	0.005
Cadmium	<0.001–0.02	0.005
Chromium	<0.002–0.010	0.005
Copper	0.006–0.10	0.02
Lead	0.001–0.015	0.005
Selenium	<0.002–0.010	0.005
Sulfate	10–250	150
TDS	325–1,200	650
pH (units)	7.0–8.1	7.5

NOTES:

All values in mg/L except pH

mg/L = milligrams per liter

TDS = total dissolved solids

Source: KUC, 1992; ABC/ASCI, 1990; Kennecott Environmental Laboratory (KEL), 1993

Key observations for sulfate and TDS are that the majority of compliance wells east of the proposed EWRE exhibit trends as shown in Table 5-5.

TABLE 5-5
Assessment of Water Quality Trends in Compliance Wells

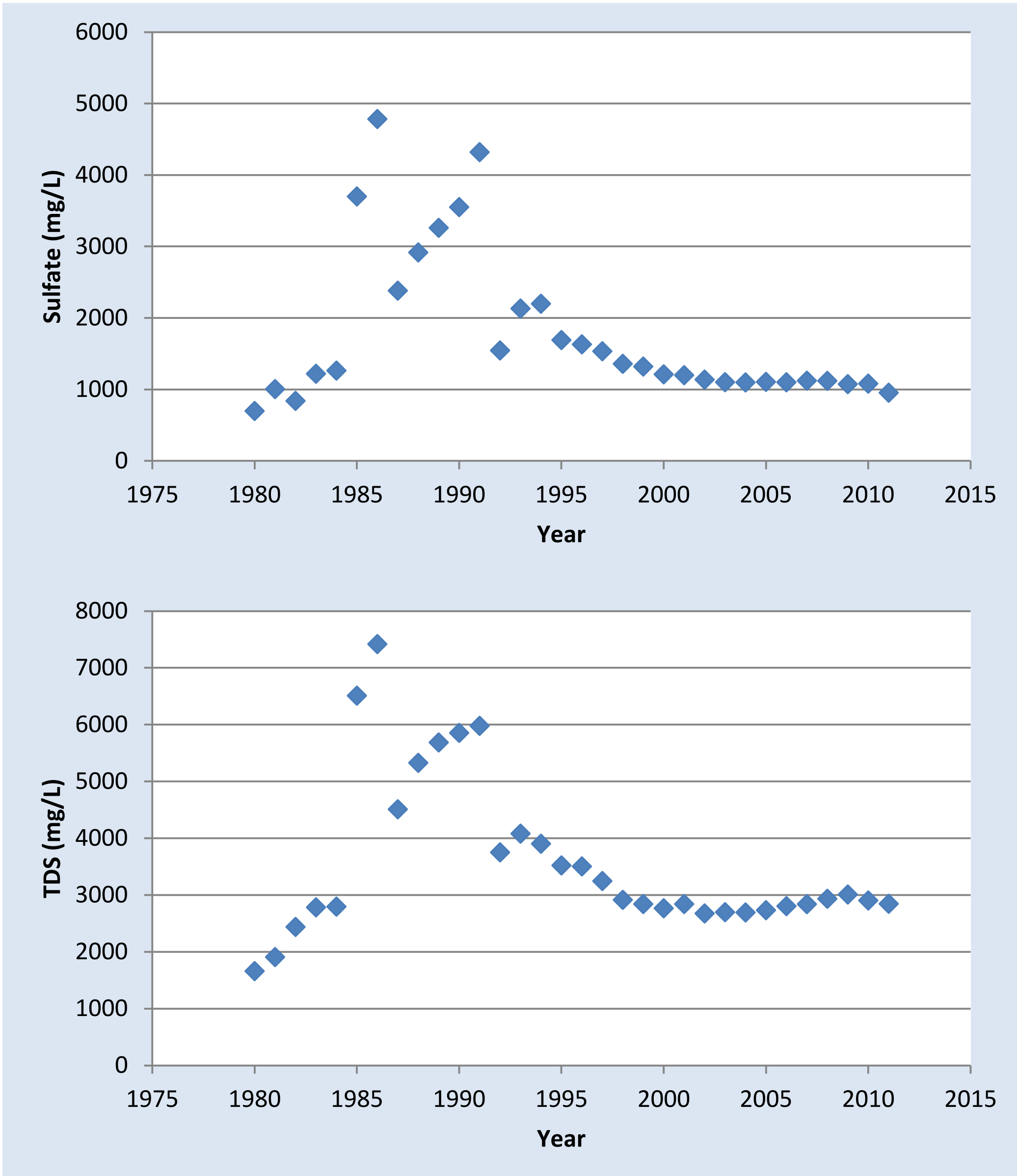
Parameter	Insufficient Detections to Determine Trend	Stable or Decreasing Trends	Concentrations below Current Compliance Limits
Total Dissolved Solids	0%	71%	100%
Sulfate	0%	71%+	96%
Copper	83%	13%	100%
Zinc	75%	25%	100%
Cadmium	83%	17%	100%

+ Includes wells where the Mann-Kendall analysis showing an increasing trend was not confirmed by visual observation of the data

Time-averaged concentrations are below current compliance limits for each of the compliance wells. Sulfate and TDS were considered together because sulfate is a major component of TDS. This analysis uses current compliance limits to simplify the analysis; however, compliance limits have changed over time. This analysis does not assess whether concentrations exceeded compliance limits in effect at the time the data were collected.

Cases with only historical exceedances are of less importance in assessing current WRCW impacts on the regional aquifer. This is because the overall concentration trend when concentrations are averaged across all wells is downward (see Figure 5-7). Therefore, sporadic historical exceedances do not indicate long-term potential for compliance limit exceedances.

FIGURE 5-7
Annual Average Sulfate and TDS in Compliance Wells East of the EWRE



The following discussion focuses on wells with current compliance limit exceedances or with concentration trends suggesting the potential for future exceedances. Wells with only historical exceedances, but not current exceedances or trends approaching compliance limits, are not discussed. However, such wells have been discussed in periodic monitoring reports and related technical documents.

No wells currently exceed their respective TDS compliance limits and only one well (ECG1187) exceeds its compliance limit for sulfate in the most recent dataset. Seven wells (ECG1187, ECG906, ECG907, ECG917, ECG932, ECG1190, and VWP220) exhibit increasing trends within 25 percent of their compliance limit. These seven wells are located down gradient of the Congor 1 and 2, North Keystone, South Crapo, and Crapo cut-off walls. Of these, ECG1187 and ECG907 exhibit upward trends for TDS (Figure 5-3) and sulfate (Figure 5-4). VWP220, which was stable for TDS between December 2002 through October 2010, saw concentrations increase and stabilize below the compliance limit for the sampling rounds in 2011 (Figure 5-3).

Wells ECG917 (sulfate) and ECG932 (TDS) appear to exhibit stable trends right below the compliance limit despite the Mann-Kendall analysis indicating an upward trend.

Compliance wells ECG1190 (TDS), ECG906 (TDS), and ECG932 (sulfate) appear to exhibit stable trends on the log-scale plots (Figures 5-2 and 5-3) but show slight upward trends on the linear scale plots shown in Appendix A of this Attachment, confirming the Mann-Kendall results.

ECG1190 exhibits upward chloride trends of similar magnitude to the TDS, suggesting chloride is the likely major component of increasing TDS. ECG906 exhibits upward TDS, but decreasing sulfate.

KUC and DWQ have been aware of trends in ECG907 and ECG1187 since 2006, and a contaminant source assessment was performed in 2007 to identify and address potential sources of contamination (KUC, 2007a, b). Three potential sulfate sources were found and addressed as a result of this assessment. However, sulfate in the alluvial soils near these drainages will continue to be mobilized by storm water infiltration and instances of higher water table levels for several years. These trends and exceedances reflect remnant effects from the time when leaching operations were occurring and do not reflect WRCW impacts from the period following cessation of leaching and installation of current engineering controls.

The remaining analytes (copper, cadmium, and zinc) exhibit neither recent exceedances nor trends approaching their well-specific compliance limits with the exception of cadmium at ECG923. Examination of the ECG923 data shows only one anomalous detection above the cadmium compliance limit with the remainder of the dataset dominated by nondetect results below the compliance limit. A visual data review does not support the Mann-Kendall results and the data do not indicate a long-term potential for exceedances.

The conclusions from review of the compliance monitoring results are as follows:

- Cessation of leaching operations in 2000 results in dramatic decreases in WRCW impacts on the local aquifer.
- Installation, operation, and maintenance of the WCS is effectively protecting drinking water resources in the principal alluvial aquifer.

The few isolated cases where the analysis suggests potential for long-term compliance limit exceedances (i.e., sulfate at ECG1187 and ECG907) do not reflect impacts from current WRCW discharges and are unlikely to be negatively impacted by the EWRE. It is possible that movement of the South Crapo and Crapo cut-off walls eastward and corresponding reductions in alluvial flow through the use of the an improved toe drain system (see Attachment 2) could reduce the impacts from remnant sulfate in the shallow alluvium, and positively impact conditions at these two compliance wells.

5.2 Baseline Water Quality of the Principal Aquifer

The 1990 baseline water quality of the principal aquifer was described in KUC (1992) and the 1994 permit Notice of Intent (NOI). For the purposes of providing a basis for evaluating the groundwater quality in wells in the vicinity of the WCS, baseline water quality is defined as groundwater quality that would exist in the southwestern Jordan Valley had there been no anthropogenic changes or natural erosion of the Bingham ore body (KUC, 1994). See Table 5-4 for baseline water quality in the principal aquifer.

5.3 Applicable Groundwater Class

The groundwater of the southwestern edge of the Jordan Valley is not classified. However, numerous water quality studies in the area have been conducted by KUC. Based on these analyses, groundwater in the principal aquifer adjacent to the EWRE could be classified as Class II groundwater per Utah Administrative Code (UAC) R317-6-3. DWQ has specified Class II groundwater as drinking water quality. Class II groundwater is characterized by having TDS greater than 400 mg/L and less than 3,000 mg/L, and does not have contaminant concentrations exceeding groundwater quality standards as established in Table 1 of R317-6-2.1.

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Drawings/Geological Cross Sections

Attachment 1

Geological Cross Sections Index

Drawings

1 Site Plan

2 Surface Geology

3 Profile A Geologic Cross Section

4 Midas & S Congor Drainage Areas Site Plan

5 Midas & S Congor Drainage Area Detail Site Plan

6 Midas & S Congor Drainage Area Geologic Cross Sections

7 N Keystone, S Crapo & Crapo Drainage Area Site Plan

8 N Keystone, S Crapo & Crapo Drainage Area Detail Site Plan

9 N Keystone, S Crapo & Crapo Drainage Area Geologic Cross Sections

10 Lark, Lost Creek & Keystone Drainage Area Site Plan

11 Lark, Lost Creek & Keystone Drainage Area Detail Site Plan

12 Lark, Lost Creek & Keystone Drainage Area Geologic Cross Sections

13 Copper 1, 2, & 3 Drainage Area Site Plan

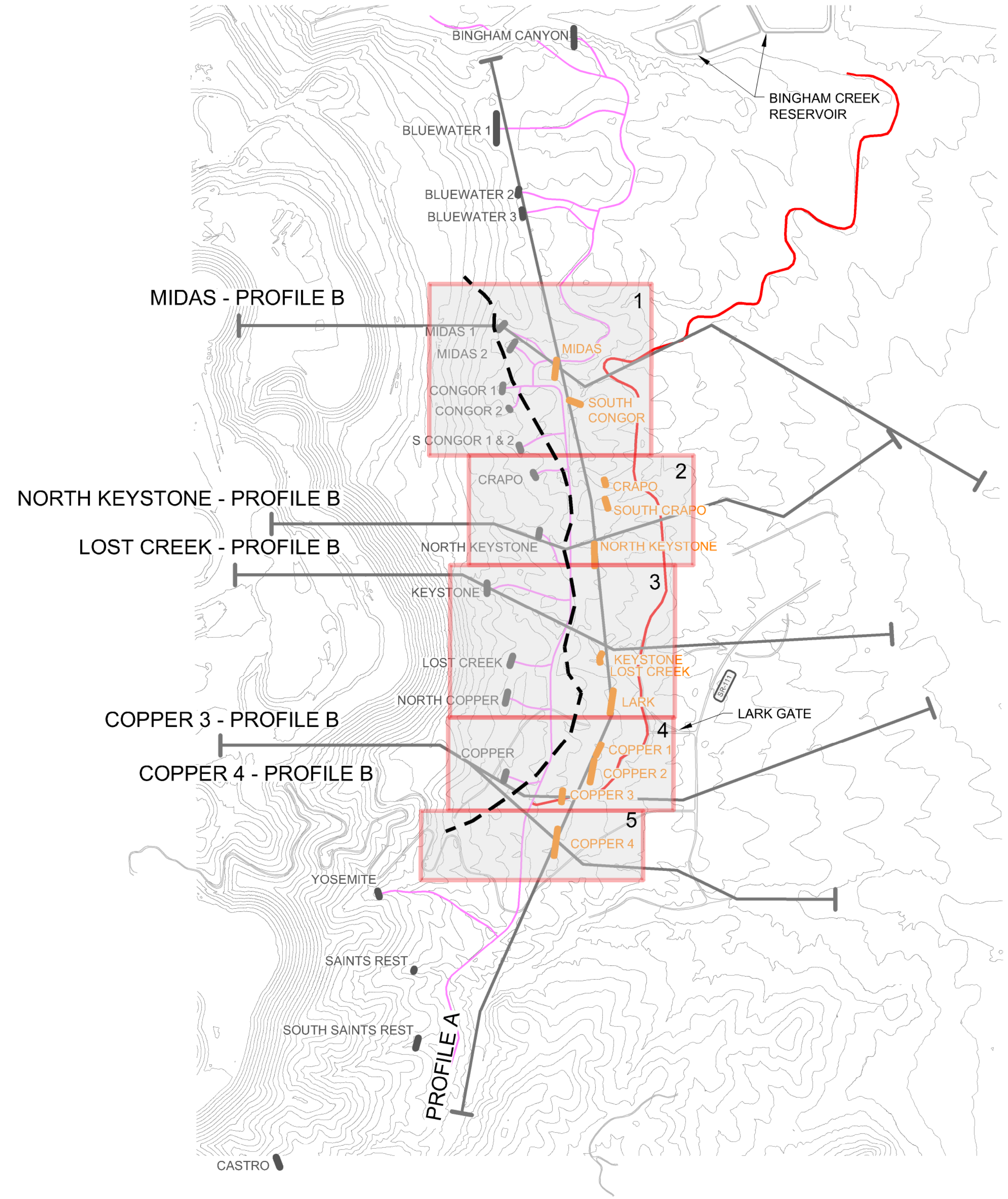
14 Copper 1, 2, & 3 Drainage Area Detail Site Plan

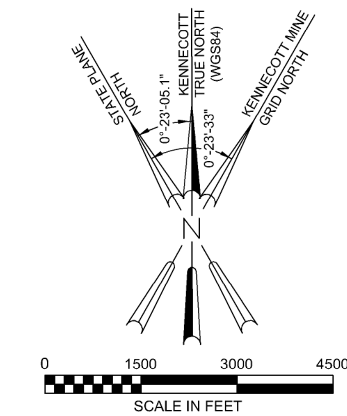
15 Copper 1, 2, & 3 Drainage Area Geologic Cross Sections

16 Copper 4 Drainage Area Site Plan

17 Copper 4 Drainage Area Detail Site Plan

18 Copper 4 Drainage Area Geologic Cross Sections





LEGEND

EXISTING PIPELINE	
NEW PIPELINE	
ACCESS ROAD	
CUTOFF WALL (NEW)	
CUTOFF WALL (EXST)	
APPROXIMATE RELAXED TOE OF WASTE ROCK	
SEE MIDAS & S CONGOR DRAINAGE AREA DETAIL SITE PLAN	1
SEE N KEYSTONE, S CRAPO & CRAPO DRAINAGE AREA DETAIL SITE PLAN	2
SEE LARK, LOST CREEK & KEYSTONE DRAINAGE AREA DETAIL SITE PLAN	3
SEE COPPER 1, 2, & 3 DRAINAGE AREA DETAIL SITE PLAN	4
SEE COPPER 4 DRAINAGE AREA DETAIL SITE PLAN	5

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NO.	DATE	REVISION	BY	CHK	APP	REFERENCE DRAWINGS	NUMBER

CH2MHILL

APPROVAL	DATE	SCALE: AS SHOWN		DATE
		DESIGNED BY	JW FREW	08/12
		DRAWN BY	BJ BUNN	08/12
		CHECKED BY	GA COLGAN	08/12
		PROJECT ENGINEER	M BREWER	08/12
		PROJECT MANAGER	A PARRY	08/12

KENNECOTT
UTAH COPPER

EWRE 2012 EASTSIDE COLLECTION SYSTEM DESIGN
GROUNDWATER DISCHARGE PERMIT

SITE PLAN

Proj. Dwg. No. 1 | KUC Dwg. No. | REV 1

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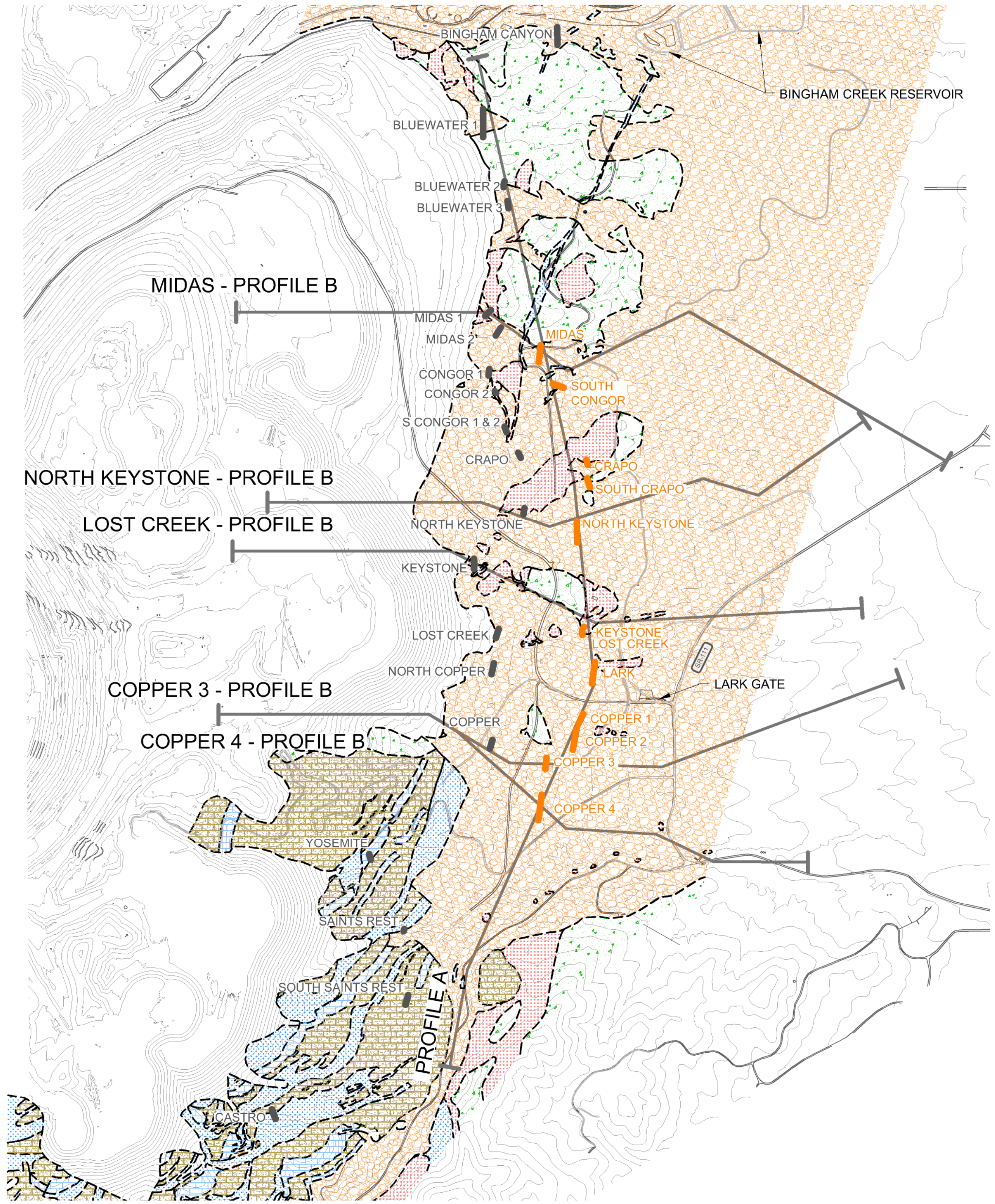

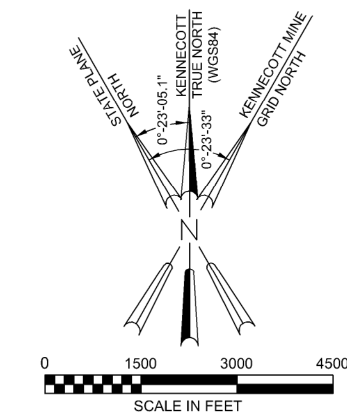

GEOLOGY LEGEND

- ACCESS ROAD
- CUTOFF WALL (NEW)
- CUTOFF WALL (EXST)
- QUATERNARY & TERTIARY ALLUVIAL FAN (PRINCIPAL AQUIFER)
- OLIGOCENE INTRUSIVE ROCKS - MAINLY SILICIC DIKES & SILLS
- OLIGOCENE VOLCANIC AGGLOMERATE & LATITE BRECCIA
- OLIGOCENE LATITE PORPHYRY
- OLIGOCENE LATITE & ANDESITE FLOWS
- MIDDLE PENNSYLVANIAN BUTTERFIELD PEAKS FORMATION, MAINLY QUARTZITE & SANDSTONE WITH INTERBEDDED LIMESTONE

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NO.	DATE	REVISION	BY	CHK	APP	REFERENCE DRAWINGS	NUMBER

CH2MHILL

APPROVAL	DATE			
		SCALE: AS SHOWN		DATE
		DESIGNED BY	JW FREW	08/12
		DRAWN BY	GE ALMSTROM	08/12
		CHECKED BY	GA COLGAN	08/12
		PROJECT ENGINEER	M BREWER	08/12
		PROJECT MANAGER	A PARRY	08/12

KENNECOTT UTAH COPPER

EWRE 2012 EASTSIDE COLLECTION SYSTEM DESIGN
GROUNDWATER DISCHARGE PERMIT

SURFACE GEOLOGY

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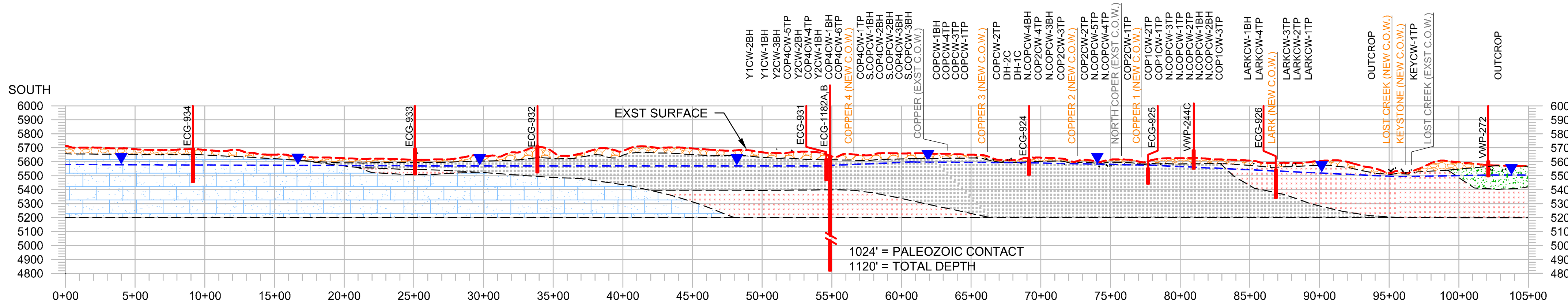
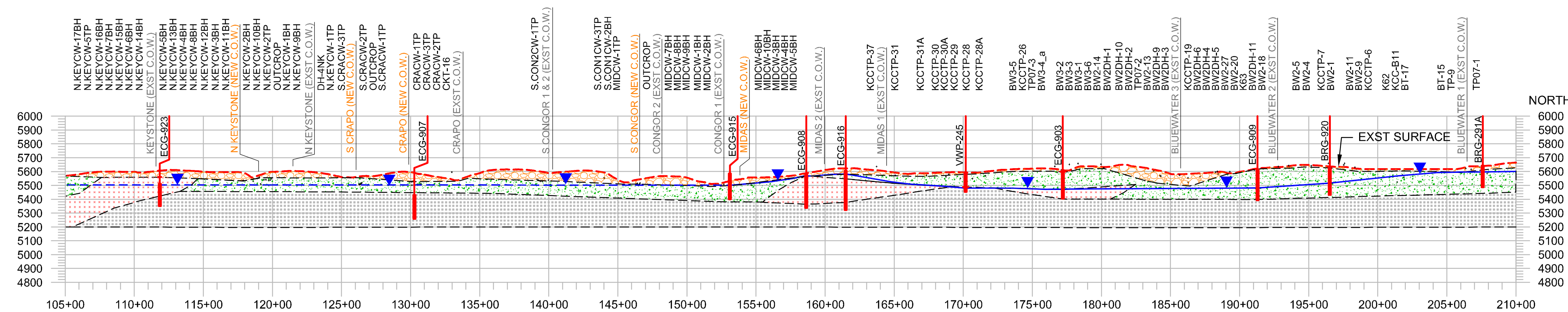


A PROFILE A - STATION 0+00 TO 105+00

2 LOOKING WEST



A PROFILE A - STATION 105+00 TO 210+00

2 LOOKING WEST

MONITOR WELL LOC ID	SCREEN INTERVAL (FT)	TOTAL DEPTH OF BORING (FT)	ELEVATION OF GROUND SURFACE (KUC FT)
BRG-919	116-155	155	5642
BRG-920	159-198	200	5631
ECG-903	158-198	205	5394
ECG-907	131-171	180	5430
ECG-908	207-246	245	5582
ECG-909	186-226	225	5616
ECG-915	138-178	185	5585
ECG-916	268-277	285	5606
ECG-923	119-158	160	5511
ECG-924	69-109	110	5587
ECG-925	69-109	110	5553
ECG-926	165-204	205	5544
ECG-931	107-147	150	5618
ECG-932	147-187	190	5713
ECG-933	142-182	190	5692
ECG-934	187-227	240	5694
ECG-1182A	580-600	1120	5617
ECG-1182B	1080-1100	1120	5617
VWP-244C	114-134	134	5683 (USGS)
VWP-245	120-140	141	5544 (USGS)
VWP-272	85-105	105	5604 (USGS)

0 500 1000 1500

SCALE IN FEET

GEOLOGY LEGEND

- GROUNDWATER MONITORING WELLS
- GROUNDWATER TABLE (DASHED WHERE INFERRED)
- SATURATED ZONE IN WASTE ROCK (DASHED WHERE INFERRED)
- WASTE ROCK DUMP
- QUATERNARY & TERTIARY ALLUVIAL FAN (PRINCIPAL AQUIFER)
- OLIGOCENE INTRUSIVE ROCKS - MAINLY SILICIC DIKES & SILLS
- OLIGOCENE VOLCANIC AGGLOMERATE
- OLIGOCENE LATITE PORPHYRY
- OLIGOCENE LATITE & ANDESITE FLOWS
- MIDDLE PENNSYLVANIAN BUTTERFIELD PEAKS FORMATION, MAINLY QUARTZITE & SANDSTONE

PROFESSIONAL GEOLOGIST JORDAN W. FREW No. 7882425 -2250 STATE OF UTAH

NO.	DATE	REVISION	BY	CHK	APP	REFERENCE DRAWINGS	NUMBER

CH2MHILL

APPROVAL	DATE	SCALE: AS SHOWN	DATE
		DESIGNED BY JW FREW	08/12
		DRAWN BY GE ALMSTROM	08/12
		CHECKED BY GA COLGAN	08/12
		PROJECT ENGINEER M BREWER	08/12
		PROJECT MANAGER A PARRY	08/12

KENNECOTT UTAH COPPER

EWRE 2012 EASTSIDE COLLECTION SYSTEM DESIGN GROUNDWATER DISCHARGE PERMIT

PROFILE A GEOLOGIC CROSS SECTION

Proj. Dwg. No. 3 KUC Dwg. No. REV 1

FILENAME: ProfileA-Master.dwg
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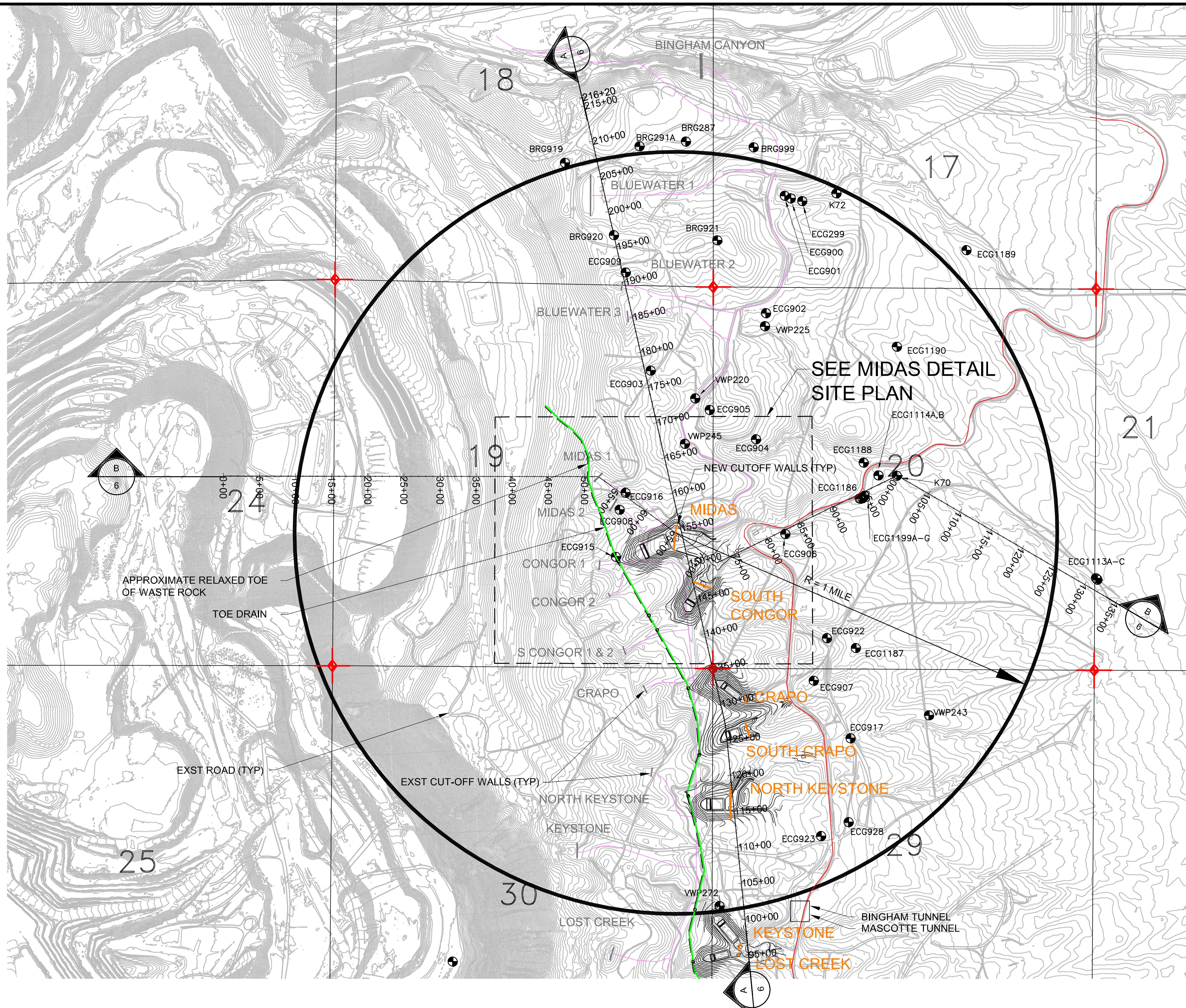
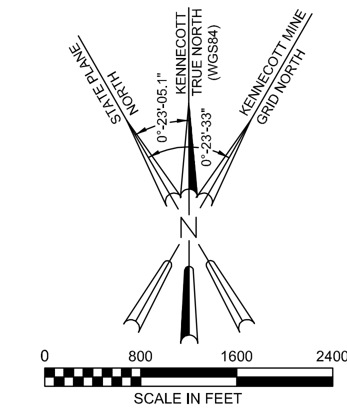




LEGEND

NEW PIPELINE	
ACCESS ROAD	
CUTOFF WALL (NEW)	
CUTOFF WALL (EXST)	
TOE DRAIN (NEW)	
APPROXIMATE RELAXED TOE OF WASTE ROCK	
SECTION CORNER	31 32 / 6 5
MONITORING WELL	
PROPOSED SURFACE GRADING & SURFACE WATER MANAGEMENT STRUCTURES	
TYPICAL	TYP
EXISTING	EXST

LICENSED PROFESSIONAL GEOLOGIST
JORDAN W. FREW
No. 7882425-2250
STATE OF UTAH

NO.	DATE	REVISION	BY	CHK	APP	REFERENCE DRAWINGS	NUMBER

CH2MHILL

APPROVAL	DATE	SCALE: AS SHOWN	DATE
		DESIGNED BY JW FREW	08/12
		DRAWN BY GE ALMSTROM	08/12
		CHECKED BY GA COLGAN	08/12
		PROJECT ENGINEER M BREWER	08/12
		PROJECT MANAGER A PARRY	08/12

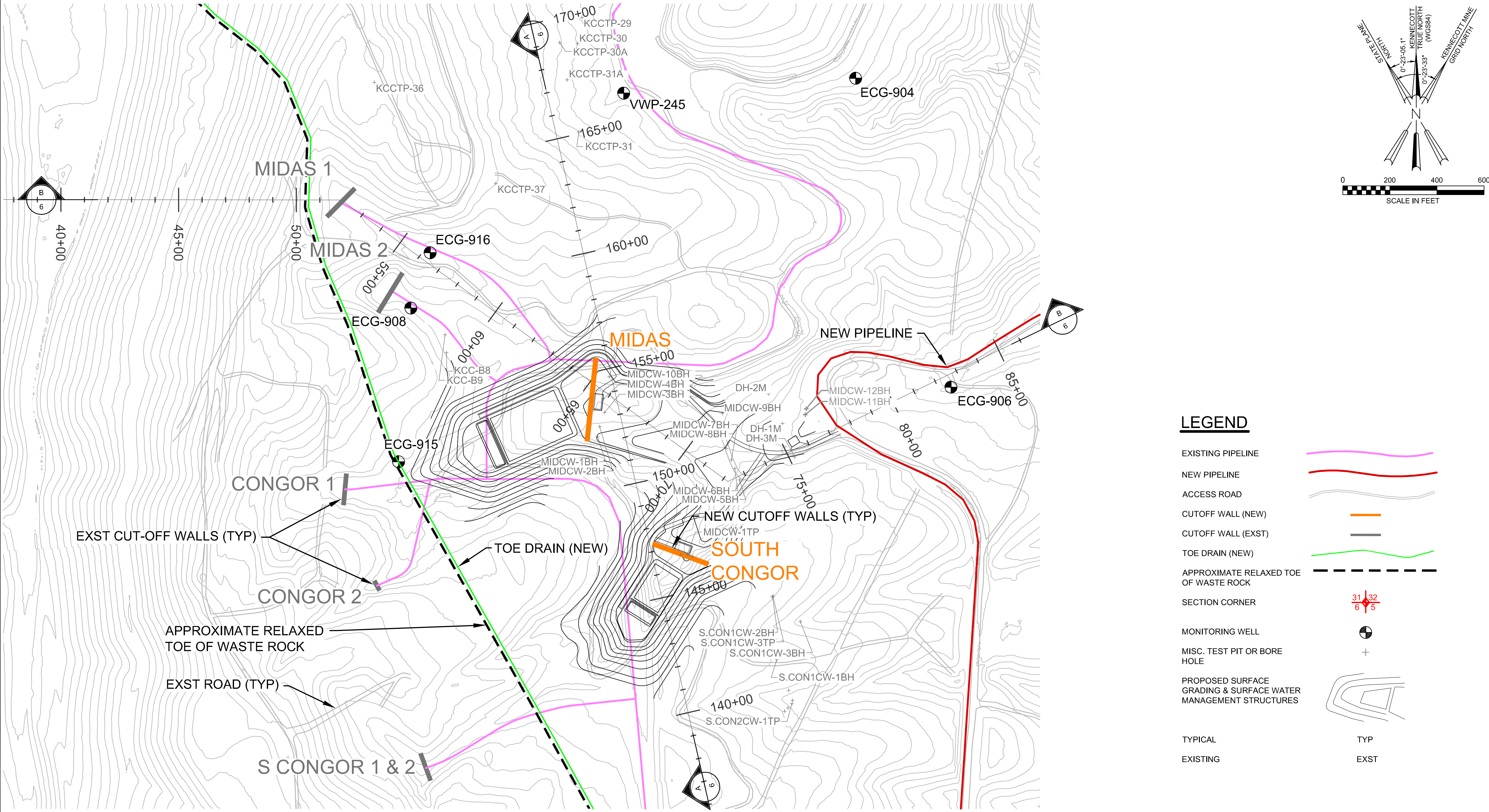
KENNECOTT UTAH COPPER

EWRE 2012 EASTSIDE COLLECTION SYSTEM DESIGN
GROUNDWATER DISCHARGE PERMIT

MIDAS & S CONGOR DRAINAGE AREAS SITE PLAN

Proj. Dwg. No. 4 | KUC Dwg. No. | REV 1

FILENAME: Midas_PLAN.dwg



LICENSED PROFESSIONAL GEOLOGIST
JORDAN W. FREW
No. 7882425-2250
STATE OF UTAH

NO.	DATE	REVISION	BY	CHK	APP	REFERENCE DRAWINGS	NUMBER

CH2MHILL

APPROVAL	DATE			
		SCALE:	AS SHOWN	DATE
		DESIGNED BY	JW FREW	08/12
		DRAWN BY	BJ BUNN	08/12
		CHECKED BY	GA COLGAN	08/12
		PROJECT ENGINEER	M BREWER	08/12
		PROJECT MANAGER	A PARRY	08/12

KENNECOTT UTAH COPPER

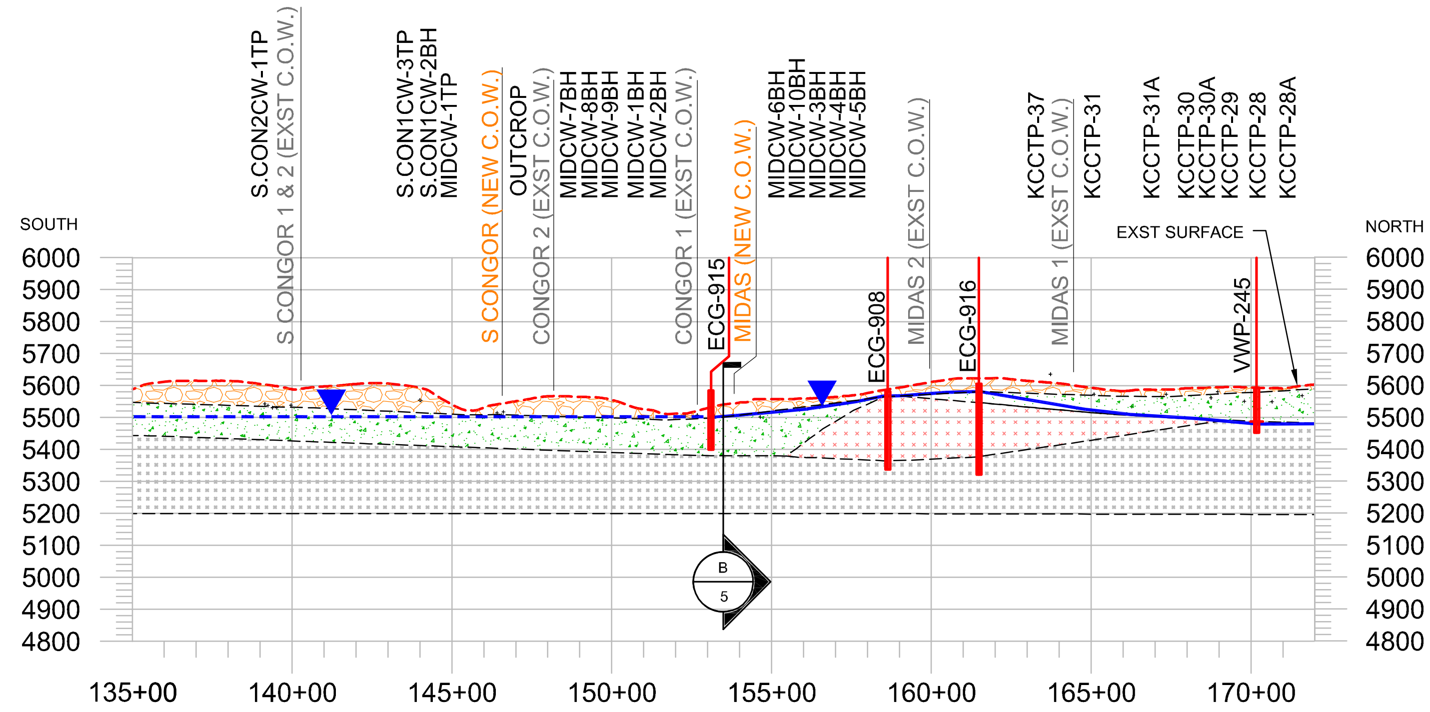
EWRE 2012 EASTSIDE COLLECTION SYSTEM DESIGN
GROUNDWATER DISCHARGE PERMIT

MIDAS & S CONGOR DRAINAGE AREA
DETAIL SITE PLAN

Proj. Dwg. No. 5 | KUC Dwg. No. | REV 1

FILENAME: Midas_DETAIL_PLAN.dwg

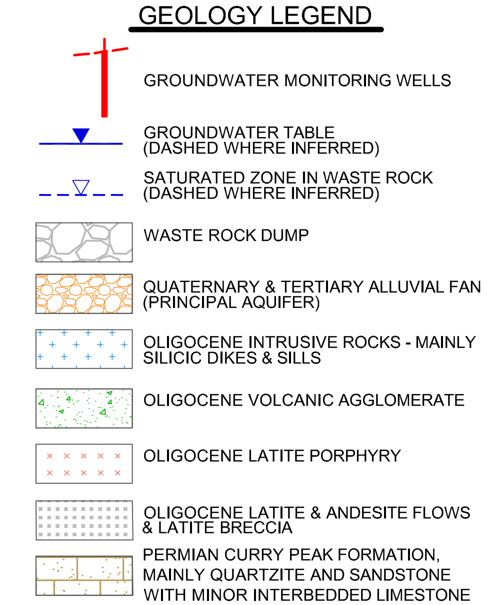
MONITOR WELL LOC ID	SCREEN INTERVAL (FT)	TOTAL DEPTH OF BORING (FT)	ELEVATION OF GROUND SURFACE (KUC FT)
ECG-906	159-199	200	5430
ECG-908	207-246	245	5582
ECG-915	138-178	185	5585
ECG-916	268-277	285	5606
ECG-1113A	138-178	200	5258
ECG-1113B	631-671	980	5257
ECG-1113C	922-961	980	5257
ECG-1114A	1216-1255	3000	5363
ECG-1114B	2762-2791 and 2820-2849	3000	5363
ECG-1186	36-136	175	5367
ECG-1188	38-118	135	5366
ECG-1199A	50-170	176	5368
ECG-1199B	54-56	101	5371
ECG-1199C	74-76	101	5371
ECG-1199D	93-95	101	5371
ECG-1199E	114-116	168	5370
ECG-1199F	134-136	168	5370
ECG-1199G	153-155	168	5370
VWP-245	120-140	141	5544 (USGS)

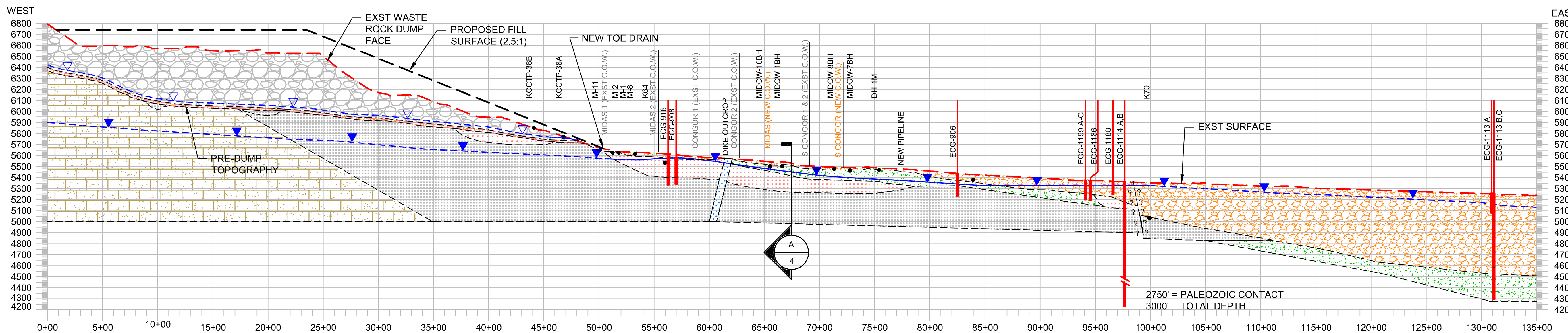


0 300 600 900
SCALE IN FEET

A
5

PROFILE A
LOOKING WEST





0 500 1000 1500
SCALE IN FEET

B
4

PROFILE B
LOOKING NORTH

LICENSED PROFESSIONAL GEOLOGIST
JORDAN W. FREW
No. 7882425-2250
STATE OF UTAH

NO.	DATE	REVISION	BY	CHK	APP	REFERENCE DRAWINGS	NUMBER

CH2MHILL

APPROVAL	DATE	SCALE: AS SHOWN	DATE
		DESIGNED BY JW FREW	08/12
		DRAWN BY GE ALMSTROM	08/12
		CHECKED BY GA COLGAN	08/12
		PROJECT ENGINEER M BREWER	08/12
APPROVED-BY		PROJECT MANAGER A PARRY	08/12

KENNECOTT UTAH COPPER

EWRE 2012 EASTSIDE COLLECTION SYSTEM DESIGN
GROUNDWATER DISCHARGE PERMIT

MIDAS & S CONGOR DRAINAGE AREA
GEOLOGIC CROSS SECTIONS

Proj. Dwg. No. 6 | KUC Dwg. No. | REV 1

FILENAME: Midas_PROF.dwg
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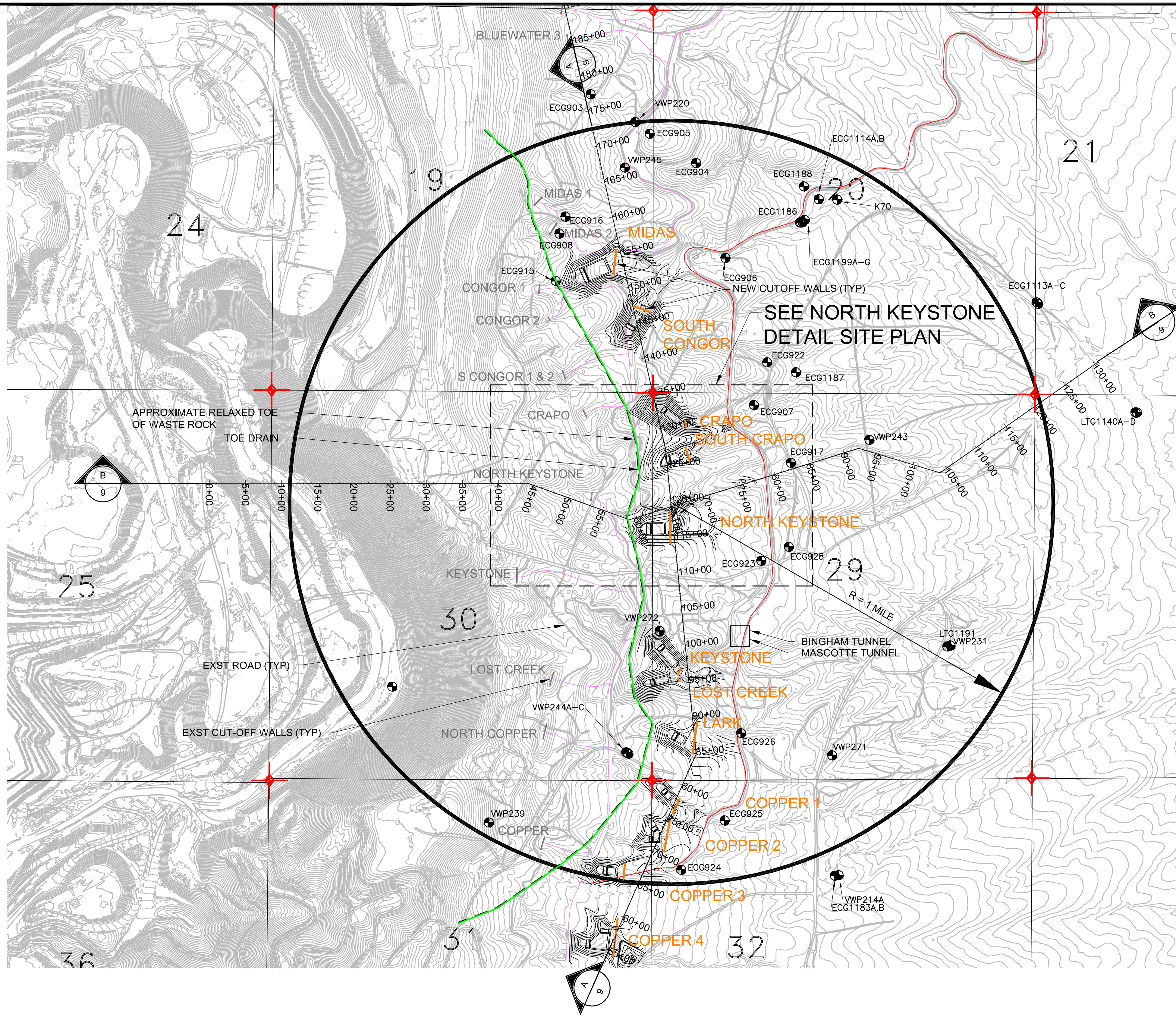
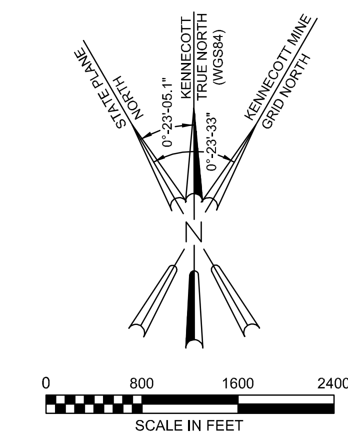




LEGEND

- NEW PIPELINE
- ACCESS ROAD
- CUTOFF WALL (NEW)
- CUTOFF WALL (EXST)
- TOE DRAIN (NEW)
- APPROXIMATE RELAXED TOE OF WASTE ROCK
- SECTION CORNER (31 32 / 6 5)
- MONITORING WELL
- PROPOSED SURFACE GRADING & SURFACE WATER MANAGEMENT STRUCTURES
- TYPICAL — TYP
- EXISTING — EXST

FILENAME: N_Keystone_PLAN.dwg

PROFESSIONAL GEOLOGIST — JORDAN W. FREW — No. 7882425-2250 — LICENSED — STATE OF UTAH

NO.	DATE	REVISION	BY	CHK	APP	REFERENCE DRAWINGS	NUMBER

CH2MHILL

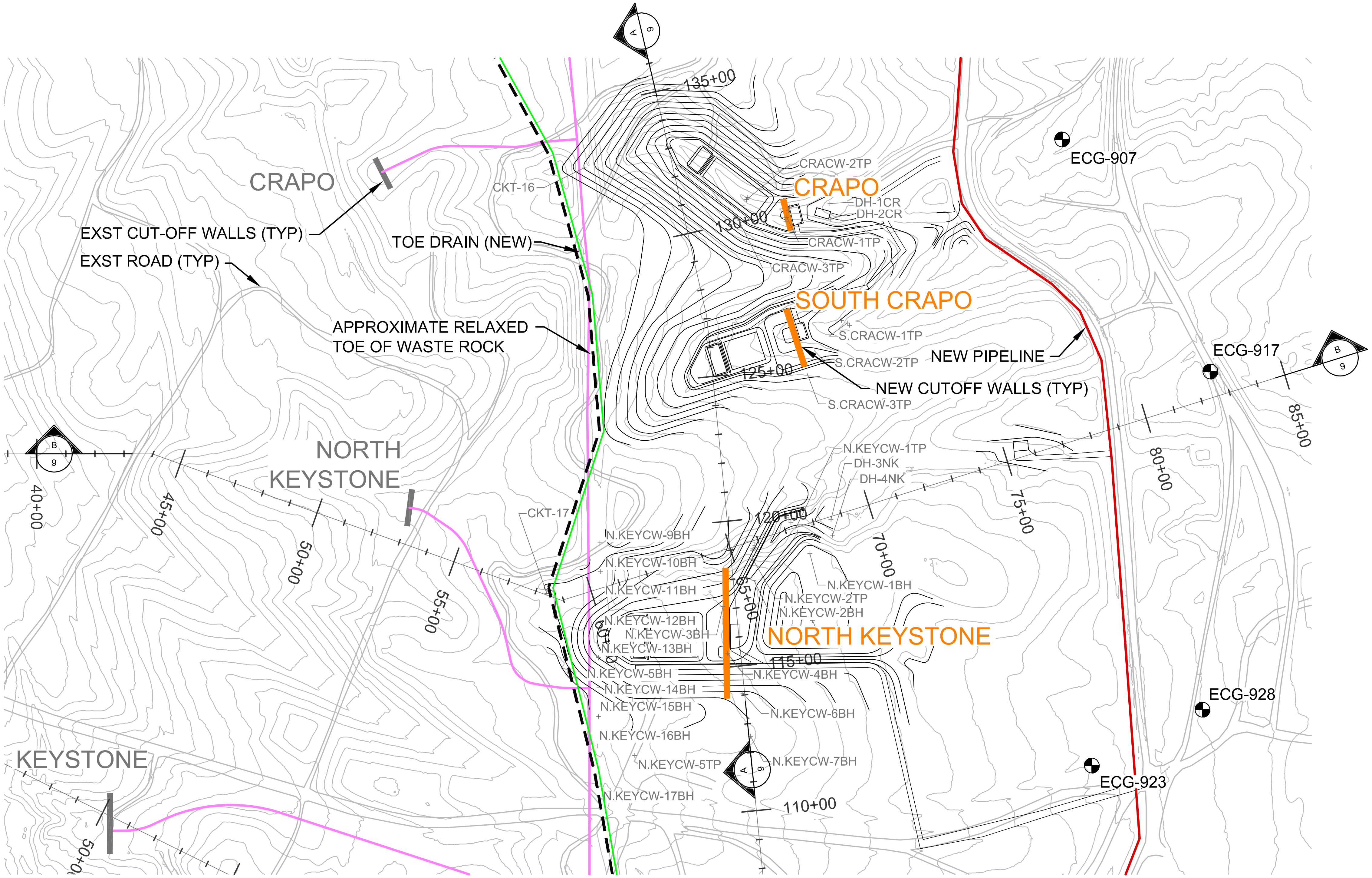
APPROVAL	DATE	SCALE: AS SHOWN	DATE
		DESIGNED BY JW FREW	08/12
		DRAWN BY GE ALMSTROM	08/12
		CHECKED BY GA COLGAN	08/12
		PROJECT ENGINEER M BREWER	08/12
		PROJECT MANAGER A PARRY	08/12

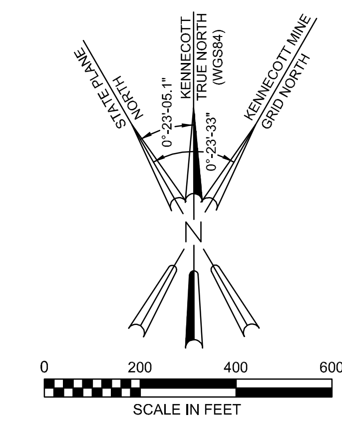
KENNECOTT UTAH COPPER

EWRE 2012 EASTSIDE COLLECTION SYSTEM DESIGN
GROUNDWATER DISCHARGE PERMIT

N KEYSTONE, S CRAPO & CRAPO DRAINAGE AREA SITE PLAN

Proj. Dwg. No. 7 | KUC Dwg. No. | REV 1





LEGEND

EXISTING PIPELINE	
NEW PIPELINE	
ACCESS ROAD	
CUTOFF WALL (NEW)	
CUTOFF WALL (EXST)	
TOE DRAIN (NEW)	
APPROXIMATE RELAXED TOE OF WASTE ROCK	
SECTION CORNER	31 32 / 6 5
MONITORING WELL	
MISC. TEST PIT OR BORE HOLE	+
PROPOSED SURFACE GRADING & SURFACE WATER MANAGEMENT STRUCTURES	
TYPICAL	TYP
EXISTING	EXST

LICENSED PROFESSIONAL GEOLOGIST
JORDAN W. FREW
No. 7882425 -2250
STATE OF UTAH

NO.	DATE	REVISION	BY	CHK	APP	REFERENCE DRAWINGS	NUMBER

CH2MHILL

APPROVAL	DATE	SCALE: AS SHOWN		DATE
		DESIGNED BY	JW FREW	08/12
		DRAWN BY	BJ BUNN	08/12
		CHECKED BY	GA COLGAN	08/12
		PROJECT ENGINEER	M BREWER	08/12
		PROJECT MANAGER	A PARRY	08/12

KENNECOTT UTAH COPPER

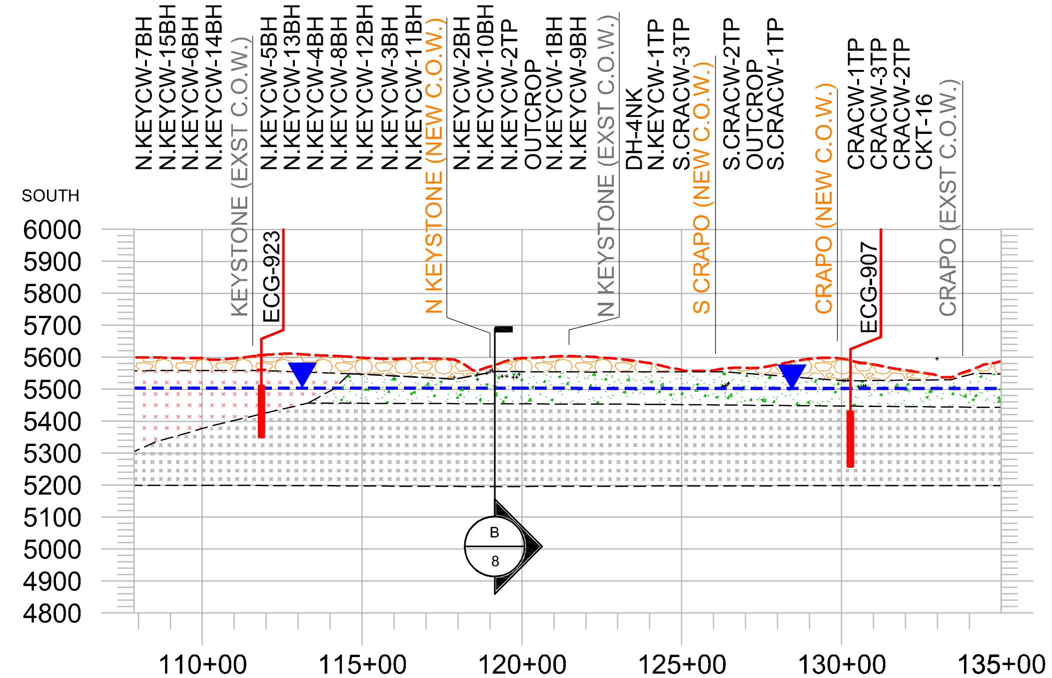
EWRE 2012 EASTSIDE COLLECTION SYSTEM DESIGN
GROUNDWATER DISCHARGE PERMIT

N KEYSTONE, S CRAPO & CRAPO
DRAINAGE AREA DETAIL SITE PLAN

Proj. Dwg. No. 8 | KUC Dwg. No. | REV 1

FILENAME: N_Keystone_DETAIL_PLAN.dwg

MONITOR WELL LOC ID	SCREEN INTERVAL (FT)	TOTAL DEPTH OF BORING (FT)	ELEVATION OF GROUND SURFACE (KUC FT)
ECG-907	131-171	180	5430
ECG-917	152-192	200	5465
LTG-1140A	220-240	370	5205
LTG-1140B	330-350	370	5205
LTG-1140C	610-630	940	5205
LTG-1140D	918-938	940	5205
VWP-243	65-85	87	5412 (USGS)

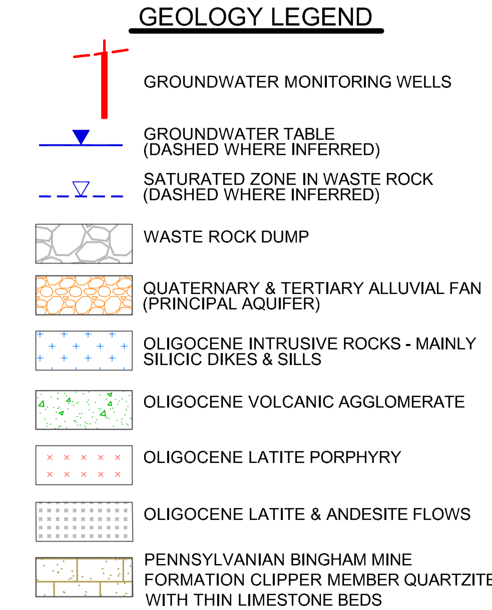


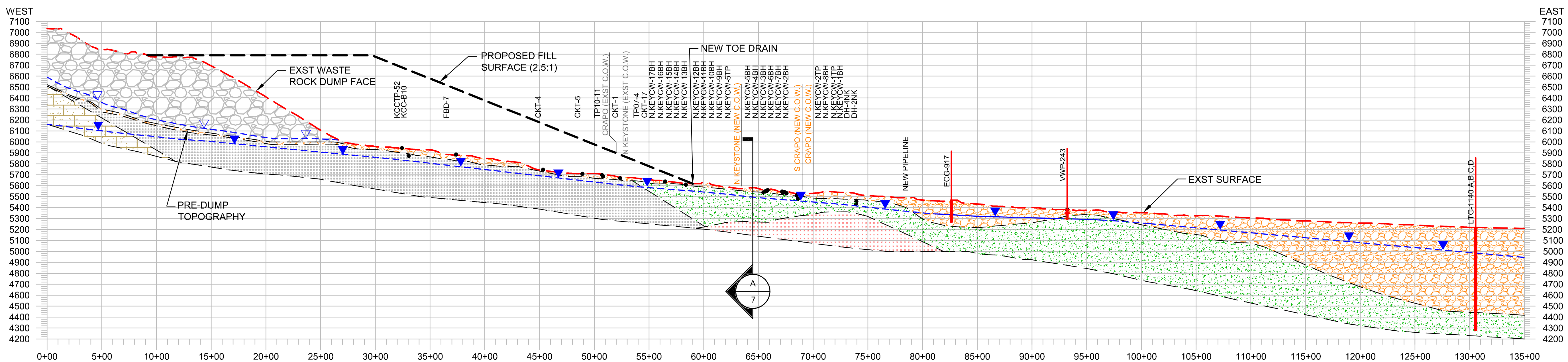
0 300 600 900
SCALE IN FEET

(A) 8

PROFILE A

LOOKING WEST





0 500 1000 1500
SCALE IN FEET

(B) 7

PROFILE B

LOOKING NORTH

PROFESSIONAL GEOLOGIST
LICENSED
JORDAN W. FREW
No. 7882425 -2250
STATE OF UTAH

FILENAME: N_Keystone_PROF.dwg

NO.	DATE	REVISION	BY	CHK	APP	REFERENCE DRAWINGS	NUMBER

CH2MHILL

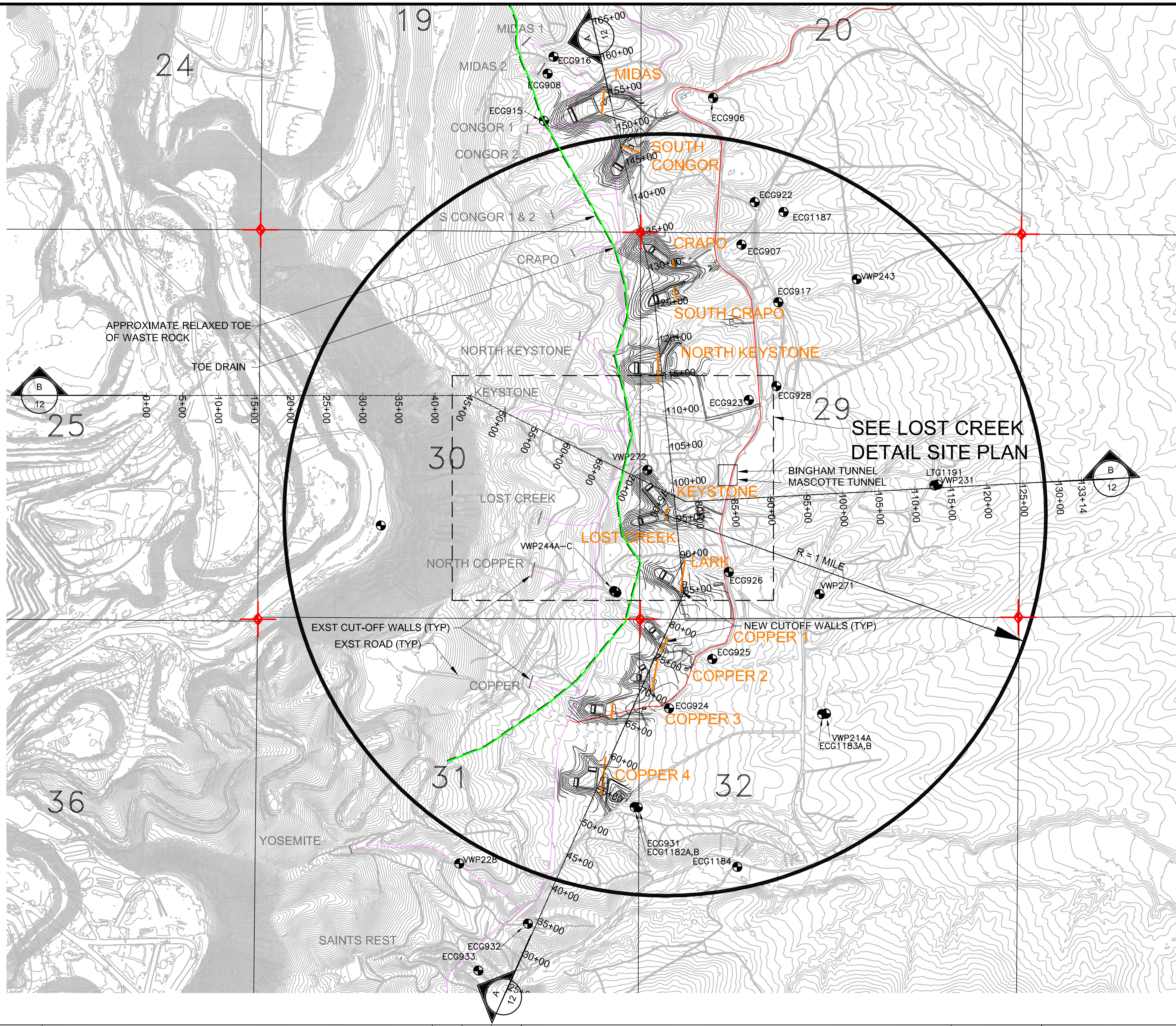
APPROVAL	DATE	SCALE: AS SHOWN	DATE
		DESIGNED BY JW FREW	08/12
		DRAWN BY GE ALMSTROM	08/12
		CHECKED BY GA COLGAN	08/12
		PROJECT ENGINEER M BREWER	08/12
		PROJECT MANAGER A PARRY	08/12

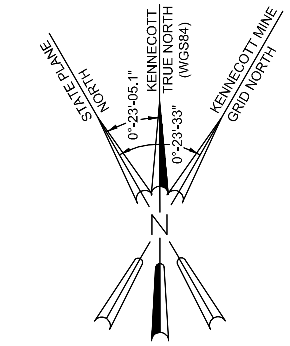
KENNECOTT
UTAH COPPER

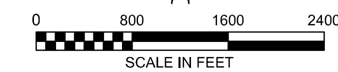
EWRE 2012 EASTSIDE COLLECTION SYSTEM DESIGN
GROUNDWATER DISCHARGE PERMIT

N. KEYSTONE, S CRAPO, CRAPO DRAINAGE AREA GEOLOGIC CROSS SECTIONS

Proj. Dwg. No. 9 | KUC Dwg. No. | REV 1







LEGEND

NEW PIPELINE	
ACCESS ROAD	
CUTOFF WALL (NEW)	
CUTOFF WALL (EXST)	
TOE DRAIN (NEW)	
APPROXIMATE RELAXED TOE OF WASTE ROCK	
SECTION CORNER	31 32 / 6 5
MONITORING WELL	
PROPOSED SURFACE GRADING & SURFACE WATER MANAGEMENT STRUCTURES	
TYPICAL	TYP
EXISTING	EXST

LICENSED PROFESSIONAL GEOLOGIST
JORDAN W. FREW
No. 7882425 -2250
STATE OF UTAH

NO.	DATE	REVISION	BY	CHK	APP	REFERENCE DRAWINGS	NUMBER

CH2MHILL

APPROVAL	DATE	SCALE: AS SHOWN	DATE
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		CHECKED BY GA COLGAN	08/12
		PROJECT ENGINEER M BREWER	08/12
		PROJECT MANAGER A PARRY	08/12

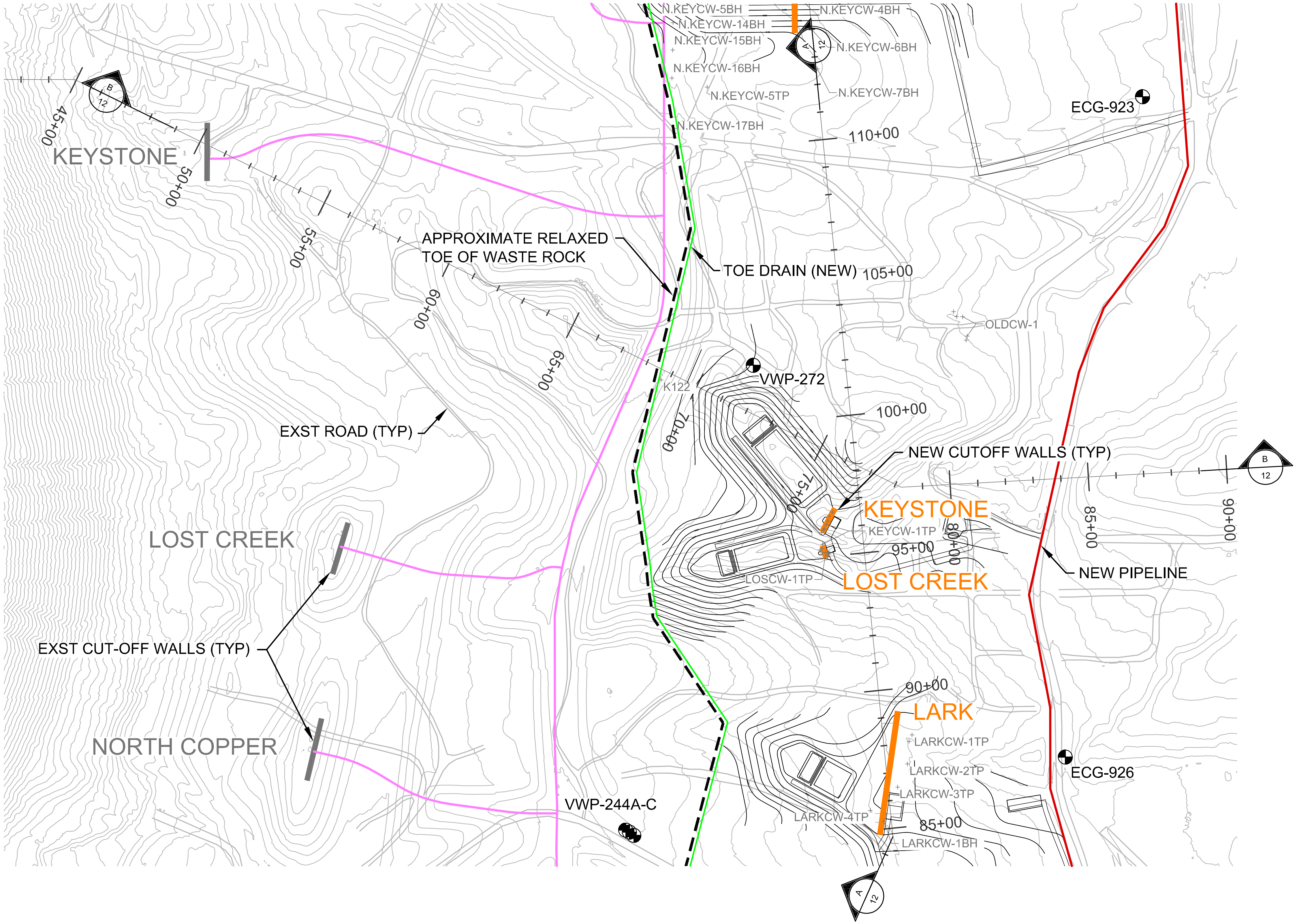
KENNECOTT UTAH COPPER

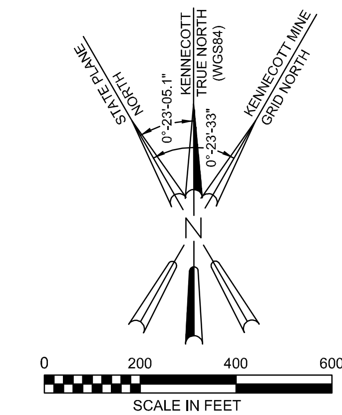
EWRE 2012 EASTSIDE COLLECTION SYSTEM DESIGN
GROUNDWATER DISCHARGE PERMIT

LARK, LOST CREEK & KEYSTONE DRAINAGE AREA SITE PLAN

Proj. Dwg. No. 10 | KUC Dwg. No. | REV 1

FILENAME: Lost Creek_PLAN.dwg





LEGEND

EXISTING PIPELINE	
NEW PIPELINE	
ACCESS ROAD	
CUTOFF WALL (NEW)	
CUTOFF WALL (EXST)	
TOE DRAIN (NEW)	
APPROXIMATE RELAXED TOE OF WASTE ROCK	
SECTION CORNER	31 32 6 5
MONITORING WELL	
MISC. TEST PIT OR BORE HOLE	
PROPOSED SURFACE GRADING & SURFACE WATER MANAGEMENT STRUCTURES	
TYPICAL	TYP
EXISTING	EXST

FILENAME: Lost Creek_DETAIL_PLAN.dwg

LICENSED PROFESSIONAL GEOLOGIST — JORDAN W. FREW — No. 7882425-2250 — STATE OF UTAH

NO.	DATE	REVISION	BY	CHK	APP	REFERENCE DRAWINGS	NUMBER

CH2MHILL

APPROVAL	DATE	SCALE: AS SHOWN		DATE
		DESIGNED BY	JW FREW	08/12
		DRAWN BY	BJ BUNN	08/12
		CHECKED BY	GA COLGAN	08/12
		PROJECT ENGINEER	M BREWER	08/12
		PROJECT MANAGER	A PARRY	08/12

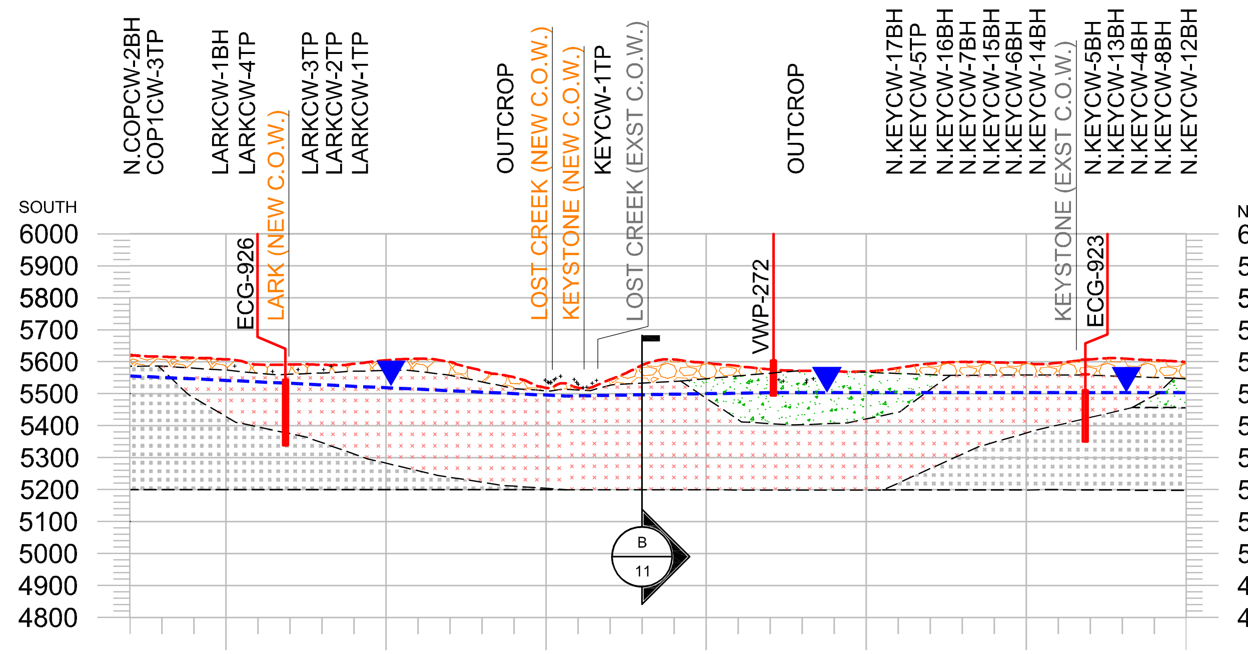
KENNECOTT UTAH COPPER

EWRE 2012 EASTSIDE COLLECTION SYSTEM DESIGN GROUNDWATER DISCHARGE PERMIT

LARK, LOST CREEK & KEYSTONE DRAINAGE AREA DETAIL SITE PLAN

Proj. Dwg. No. 11 | KUC Dwg. No. | REV 1

MONITOR WELL LOC ID	SCREEN INTERVAL (FT)	TOTAL DEPTH OF BORING (FT)	ELEVATION OF GROUND SURFACE (KUC FT)
ECG-923	119-158	160	5511
ECG-926	165-204	205	5544
LTG-1191	20-100	122	5330
VWP-231	UNKNOWN	82	5329
VWP-244C	114-134	134	5683 (USGS)
VWP-271	65-85	85	5481 (USGS)
VWP-272	85-105	105	5604 (USGS)



0 300 600 900
SCALE IN FEET

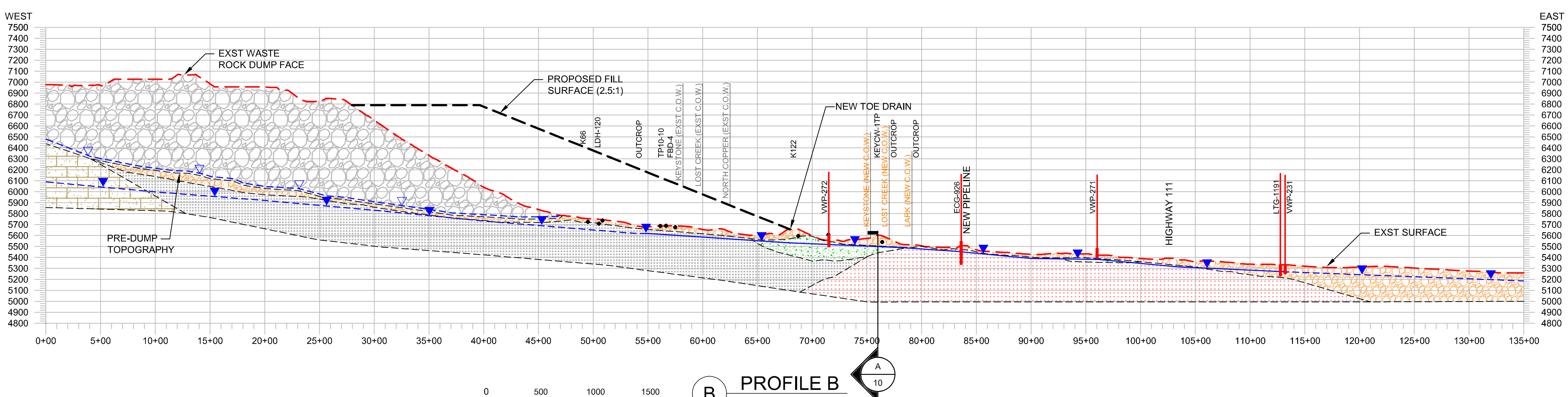
PROFILE A

A
11

LOOKING WEST

GEOLOGY LEGEND

- GROUNDWATER MONITORING WELLS
- GROUNDWATER TABLE (DASHED WHERE INFERRED)
- SATURATED ZONE IN WASTE ROCK (DASHED WHERE INFERRED)
- WASTE ROCK DUMP
- QUATERNARY & TERTIARY ALLUVIAL FAN (PRINCIPAL AQUIFER)
- OLIGOCENE INTRUSIVE ROCKS - MAINLY SILICIC DIKES & SILLS
- OLIGOCENE VOLCANIC AGGLOMERATE
- OLIGOCENE LATITE PORPHYRY
- OLIGOCENE LATITE & ANDESITE FLOWS
- PENNSYLVANIAN BINGHAM MINE FORMATION CLIPPER MEMBER QUARTZITE WITH THIN LIMESTONE BEDS



0 500 1000 1500
SCALE IN FEET

PROFILE B

B
10

LOOKING NORTH

LICENSED PROFESSIONAL GEOLOGIST
JORDAN W. FREW
No. 7882425 -2250
STATE OF UTAH

FILENAME: Lost Creek_PROF.dwg

NO.	DATE	REVISION	BY	CHK	APP	REFERENCE DRAWINGS	NUMBER

CH2MHILL

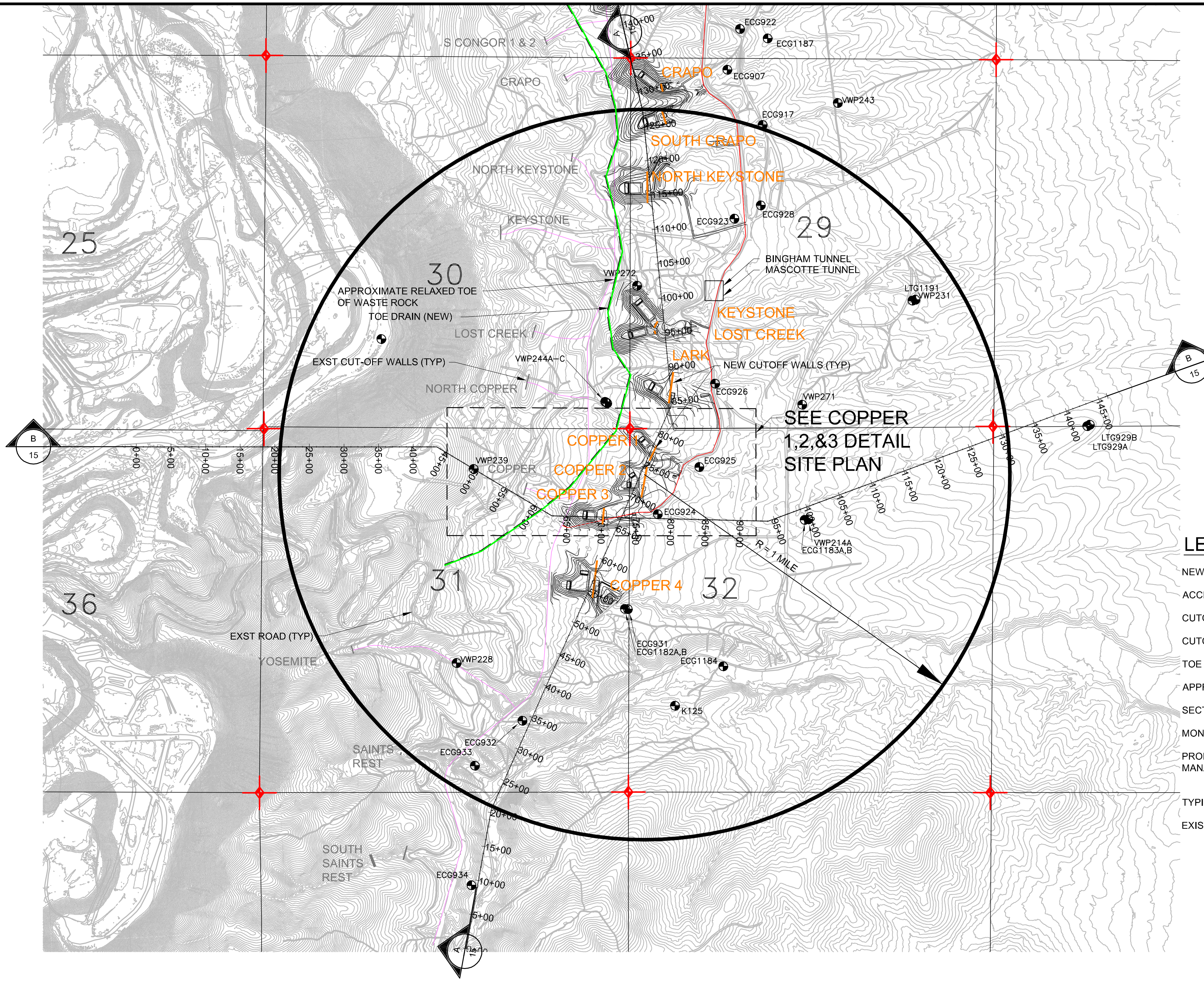
APPROVAL	DATE	SCALE: AS SHOWN	DATE
		DESIGNED BY JW FREW	08/12
		DRAWN BY GE ALMSTROM	08/12
		CHECKED BY GA COLGAN	08/12
		PROJECT ENGINEER M BREWER	08/12
		PROJECT MANAGER A PARRY	08/12

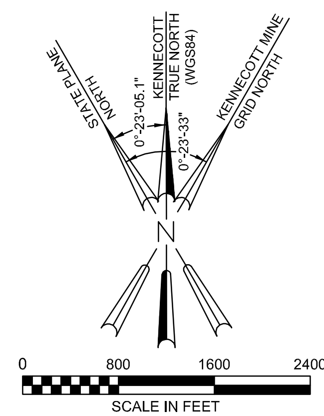
KENNECOTT
UTAH COPPER

EWRE 2012 EASTSIDE COLLECTION SYSTEM DESIGN
GROUNDWATER DISCHARGE PERMIT

LARK, LOST CREEK & KEYSTONE DRAINAGE AREA GEOLOGIC CROSS SECTIONS

Proj. Dwg. No. 12 | KUC Dwg. No. | REV 1





LEGEND

NEW PIPELINE	
ACCESS ROAD	
CUTOFF WALL (NEW)	
CUTOFF WALL (EXST)	
TOE DRAIN (NEW)	
APPROXIMATE RELAXED TOE OF WASTE ROCK	
SECTION CORNER	31 32 / 6 5
MONITORING WELL	
PROPOSED SURFACE GRADING & SURFACE WATER MANAGEMENT STRUCTURES	
TYPICAL	TYP
EXISTING	EXST

LICENSED PROFESSIONAL GEOLOGIST
JORDAN W. FREW
No. 7882425 -2250
STATE OF UTAH

NO.	DATE	REVISION	BY	CHK	APP	REFERENCE DRAWINGS	NUMBER

CH2MHILL

APPROVAL	DATE	SCALE: AS SHOWN	DATE
		DESIGNED BY JW FREW	08/12
		DRAWN BY GE ALMSTROM	08/12
		CHECKED BY GA COLGAN	08/12
		PROJECT ENGINEER M BREWER	08/12
		PROJECT MANAGER A PARRY	08/12

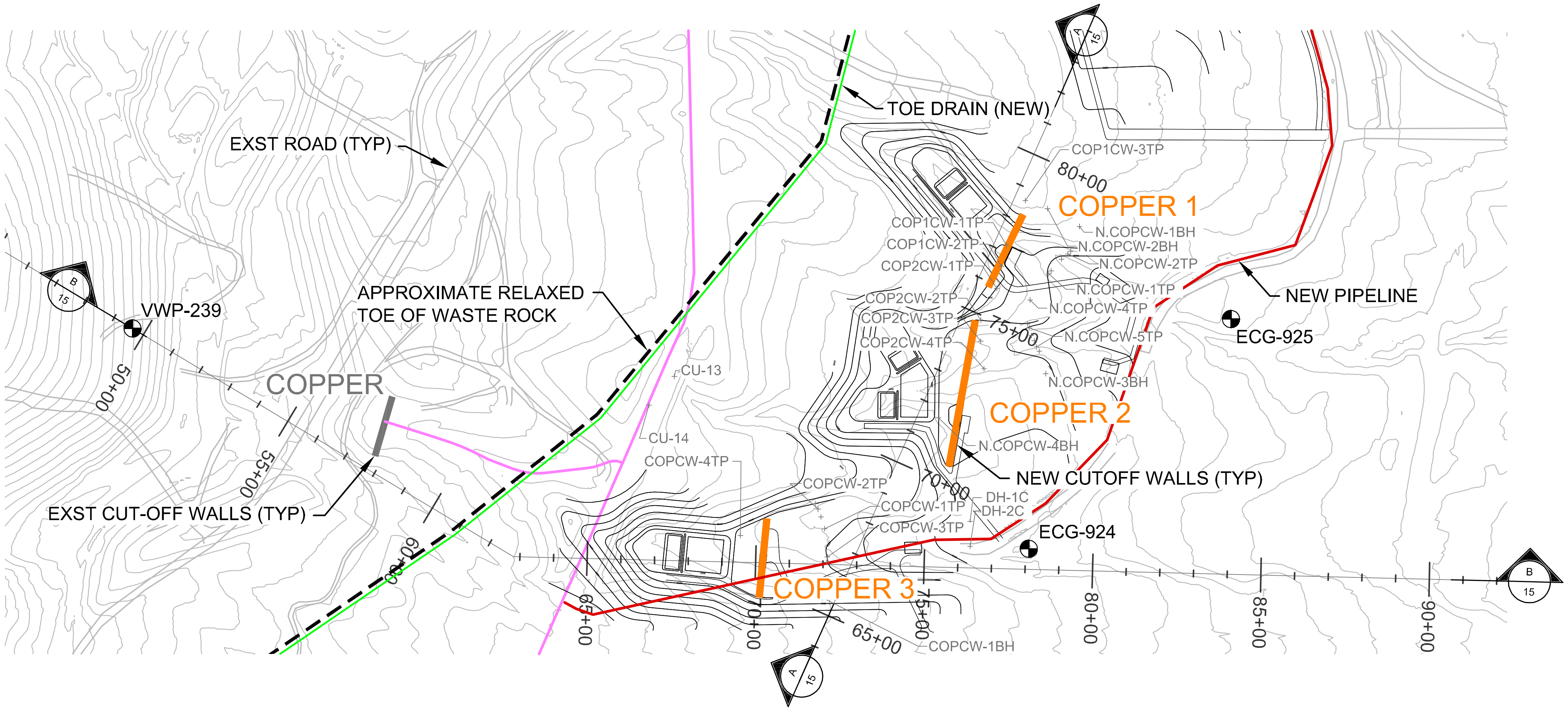
KENNECOTT UTAH COPPER

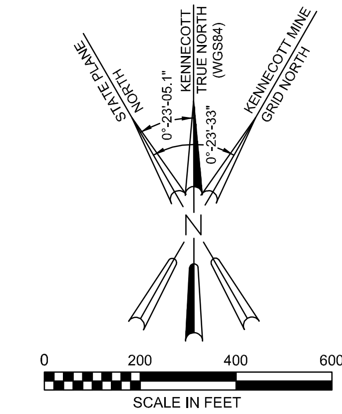
EWRE 2012 EASTSIDE COLLECTION SYSTEM DESIGN
GROUNDWATER DISCHARGE PERMIT

COPPER 1, 2, & 3 DRAINAGE AREA
SITE PLAN

Proj. Dwg. No. 13 | KUC Dwg. No. | REV 1

FILENAME: Copper_3_PLAN.dwg





LEGEND

EXISTING PIPELINE	
NEW PIPELINE	
ACCESS ROAD	
CUTOFF WALL (NEW)	
CUTOFF WALL (EXST)	
TOE DRAIN (NEW)	
APPROXIMATE RELAXED TOE OF WASTE ROCK	
SECTION CORNER	31 32 6 5
MONITORING WELL	
MISC. TEST PIT OR BORE HOLE	+
PROPOSED SURFACE GRADING & SURFACE WATER MANAGEMENT STRUCTURES	
TYPICAL	TYP
EXISTING	EXST

PROFESSIONAL GEOLOGIST
JORDAN W. FREW
No. 7882425 -2250
LICENSED STATE OF UTAH

NO.	DATE	REVISION	BY	CHK	APP	REFERENCE DRAWINGS	NUMBER

CH2MHILL

APPROVAL	DATE	SCALE: AS SHOWN		DATE
		DESIGNED BY	JW FREW	08/12
		DRAWN BY	BJ BUNN	08/12
		CHECKED BY	GA COLGAN	08/12
		PROJECT ENGINEER	M BREWER	08/12
		PROJECT MANAGER	A PARRY	08/12

KENNECOTT
UTAH COPPER

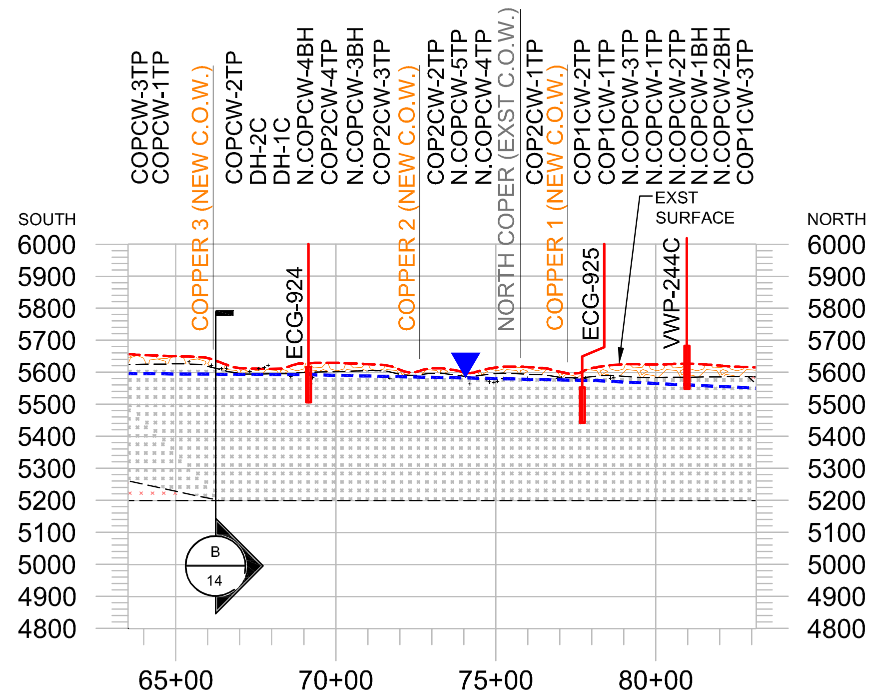
EWRE 2012 EASTSIDE COLLECTION SYSTEM DESIGN
GROUNDWATER DISCHARGE PERMIT

COPPER 1, 2, & 3 DRAINAGE AREA
DETAIL SITE PLAN

Proj. Dwg. No. 14 | KUC Dwg. No. | REV 1

FILENAME: Copper_3_DETAIL_PLAN.dwg

MONITOR WELL LOC ID	SCREEN INTERVAL (FT)	TOTAL DEPTH OF BORING (FT)	ELEVATION OF GROUND SURFACE (KUC FT)
ECG-924	69-109	110	5587
ECG-925	69-109	110	5553
ECG-1183A	35-65	301	5460
ECG-1183B	280-300	301	5460
LTG-929A	122-162	175	5294
LTG-929B	222-262	280	5292
VWP-214	262-275	275	5460 (USGS)



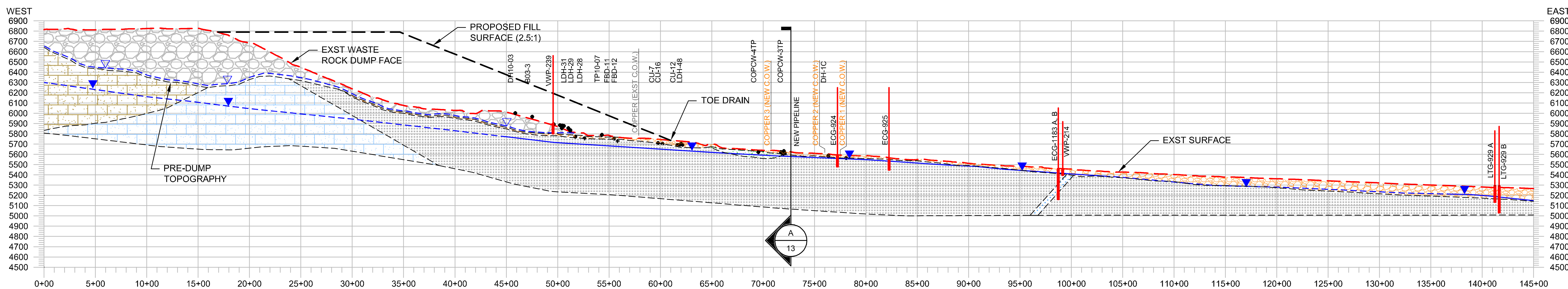
A
14

PROFILE A

LOOKING WEST

GEOLOGY LEGEND

- GROUNDWATER MONITORING WELLS
- GROUNDWATER TABLE (DASHED WHERE INFERRED)
- SATURATED ZONE IN WASTE ROCK (DASHED WHERE INFERRED)
- WASTE ROCK DUMP
- QUATERNARY & TERTIARY ALLUVIAL FAN (PRINCIPAL AQUIFER)
- OLIGOCENE INTRUSIVE ROCKS - MAINLY SILICIC DIKES & SILLS
- OLIGOCENE VOLCANIC AGGLOMERATE
- OLIGOCENE LATITE PORPHYRY
- OLIGOCENE LATITE, ANDESITE, & RHYOLITE FLOWS
- PENNSYLVANIAN BINGHAM MINE FORMATION CLIPPER MEMBER QUARTZITE WITH THIN LIMESTONE BEDS
- MIDDLE PENNSYLVANIAN BUTTERFIELD PEAKS FORMATION, MAINLY QUARTZITE & SANDSTONE



B
13

PROFILE B

LOOKING NORTH

LICENSED PROFESSIONAL GEOLOGIST
JORDAN W. FREW
No. 7882425-2250
STATE OF UTAH

NO.	DATE	REVISION	BY	CHK	APP	REFERENCE DRAWINGS	NUMBER

CH2MHILL

APPROVAL	DATE	SCALE: AS SHOWN	DATE
		DESIGNED BY JW FREW	08/12
		DRAWN BY GE ALMSTROM	08/12
		CHECKED BY GA COLGAN	08/12
		PROJECT ENGINEER M BREWER	08/12
		PROJECT MANAGER A PARRY	08/12

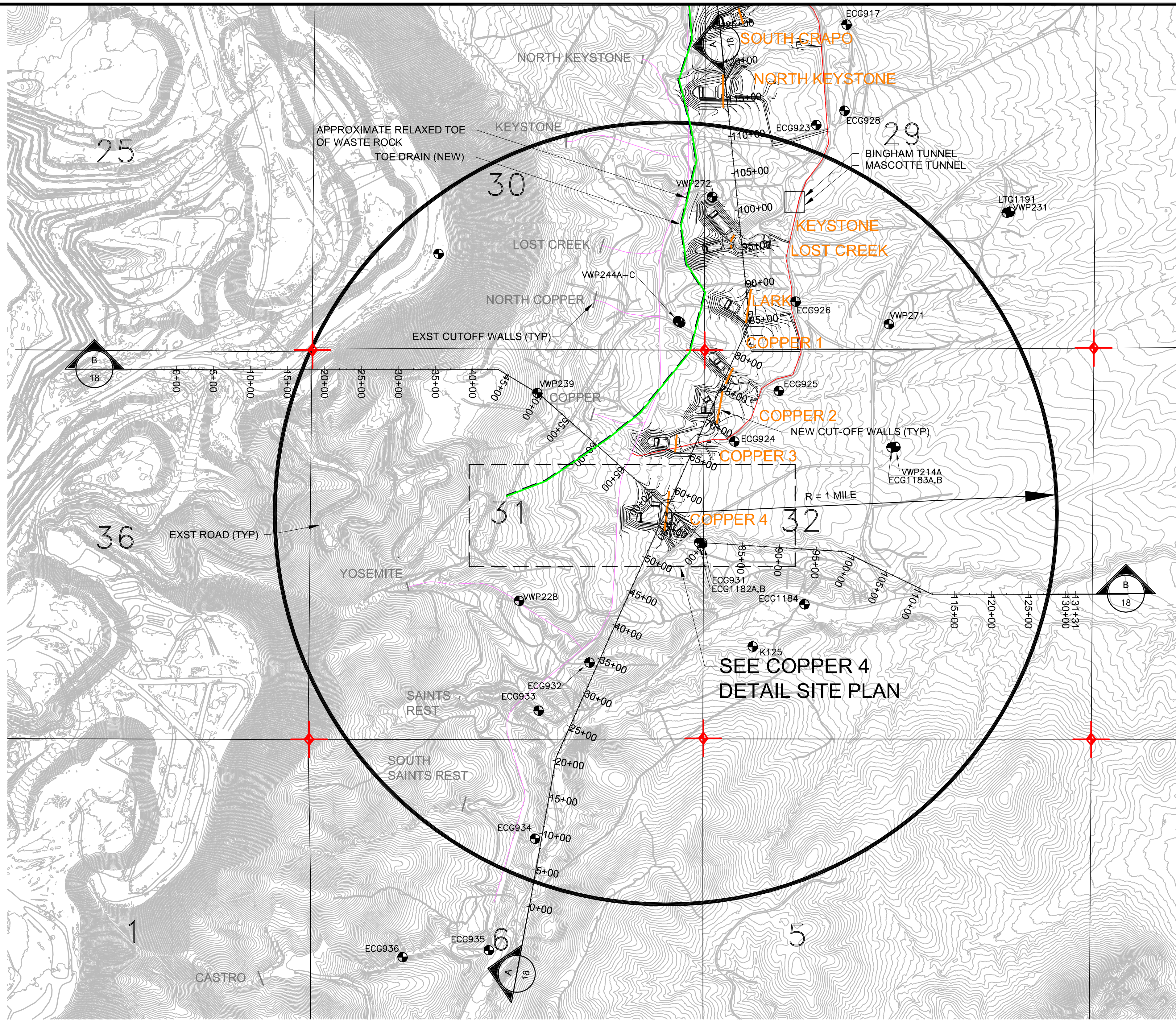
KENNECOTT UTAH COPPER

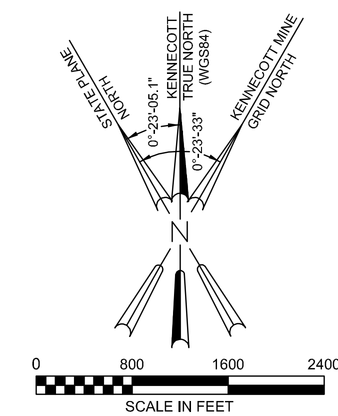
EWRE 2012 EASTSIDE COLLECTION SYSTEM DESIGN
GROUNDWATER DISCHARGE PERMIT

COPPER 1, 2, & 3 DRAINAGE AREA GEOLOGIC CROSS SECTIONS

Proj. Dwg. No. 15 | KUC Dwg. No. | REV 1

FILENAME: Copper_3_PROF.dwg
C:\pw_workdir\ch2mhill_wbg\choggard\d0179660\Copper_3_PROF 8-29-12 10:35am choggard XREFS: KUC-Extopo-ALL:KUC423243_Image:EWREnCOWm:KUC-Extopo-ALL -- 5 FT Interval Contours:451T9051-MOD:Work_Gary:EWRE-DWDnBdr01m:GeologyLegend:ProfileA-Master





LEGEND

- NEW PIPELINE
- ACCESS ROAD
- CUTOFF WALL (NEW)
- CUTOFF WALL (EXST)
- TOE DRAIN (NEW)
- APPROXIMATE RELAXED TOE OF WASTE ROCK
- SECTION CORNER
- MONITORING WELL
- PROPOSED SURFACE GRADING & SURFACE WATER MANAGEMENT STRUCTURES
- TYPICAL — TYP
- EXISTING — EXST

LICENSED PROFESSIONAL GEOLOGIST
JORDAN W. FREW
No. 7882425-2250
STATE OF UTAH

NO.	DATE	REVISION	BY	CHK	APP	REFERENCE DRAWINGS	NUMBER

CH2MHILL

APPROVAL	DATE	SCALE: AS SHOWN	DATE
		DESIGNED BY JW FREW	08/12
		DRAWN BY GE ALMSTROM	08/12
		CHECKED BY GA COLGAN	08/12
		PROJECT ENGINEER M BREWER	08/12
		PROJECT MANAGER A PARRY	08/12

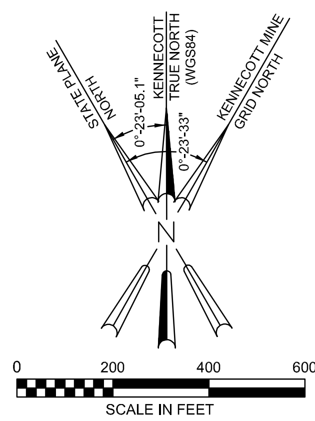
KENNECOTT UTAH COPPER

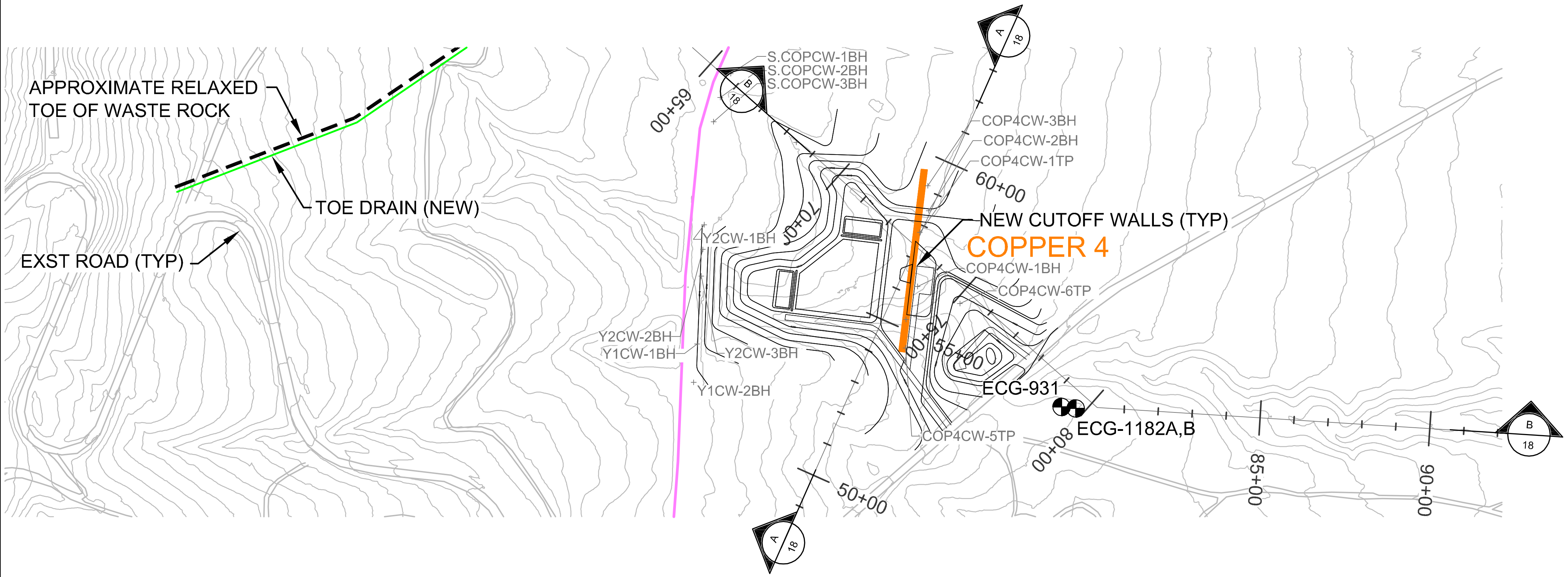
EWRE 2012 EASTSIDE COLLECTION SYSTEM DESIGN
GROUNDWATER DISCHARGE PERMIT

COPPER 4 DRAINAGE AREA SITE PLAN

Proj. Dwg. No. 16 | KUC Dwg. No. | REV 1

FILENAME: Copper_4_PLAN.dwg





LEGEND

- EXISTING PIPELINE
- NEW PIPELINE
- ACCESS ROAD
- CUTOFF WALL (NEW)
- CUTOFF WALL (EXST)
- TOE DRAIN (NEW)
- APPROXIMATE RELAXED TOE OF WASTE ROCK
- SECTION CORNER (31 32 / 6 5)
- MONITORING WELL
- MISC. TEST PIT OR BORE HOLE
- PROPOSED SURFACE GRADING & SURFACE WATER MANAGEMENT STRUCTURES
- TYPICAL — TYP
- EXISTING — EXST

LICENSED PROFESSIONAL GEOLOGIST
JORDAN W. FREW
No. 7882425-2250
STATE OF UTAH

NO.	DATE	REVISION	BY	CHK	APP	REFERENCE DRAWINGS	NUMBER

CH2MHILL

APPROVAL	DATE			DATE
		SCALE:	AS SHOWN	
		DESIGNED BY	JW FREW	08/12
		DRAWN BY	BJ BUNN	08/12
		CHECKED BY	GA COLGAN	08/12
		PROJECT ENGINEER	M BREWER	08/12
		PROJECT MANAGER	A PARRY	08/12

KENNECOTT UTAH COPPER

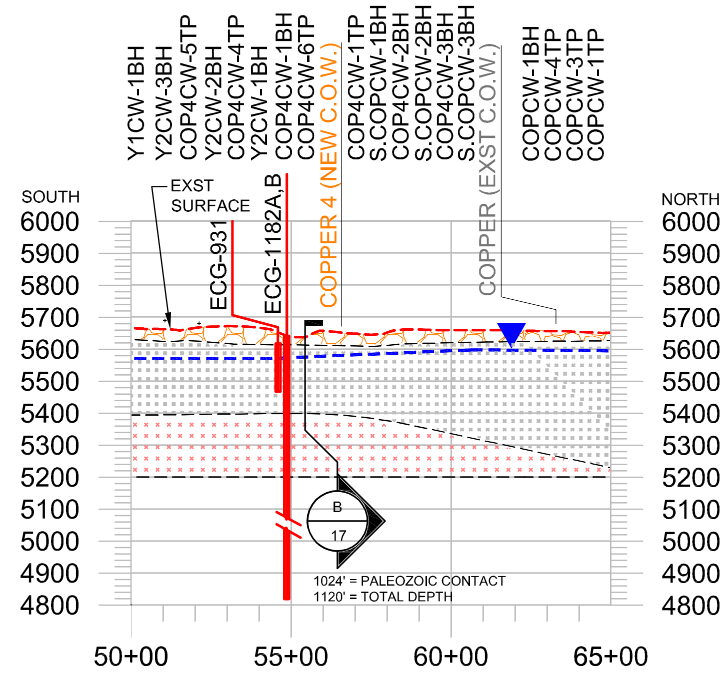
EWRE 2012 EASTSIDE COLLECTION SYSTEM DESIGN
GROUNDWATER DISCHARGE PERMIT

COPPER 4 DRAINAGE AREA
DETAIL SITE PLAN

Proj. Dwg. No. 17 | KUC Dwg. No. | REV 1

FILENAME: COPPER_4_DETAIL_PLAN.dwg

MONITOR WELL LOC ID	SCREEN INTERVAL (FT)	TOTAL DEPTH OF BORING (FT)	ELEVATION OF GROUND SURFACE (KUC FT)
ECG-931	107-147	150	5618
ECG-1182A	580-600	1120	5617
ECG-1182B	1080-1100	1120	5617
ECG-1184	60-80	81	5451
VWP-239	90-100	110	5900 (USGS)
VWP-270	179-199	199	5403 (USGS)

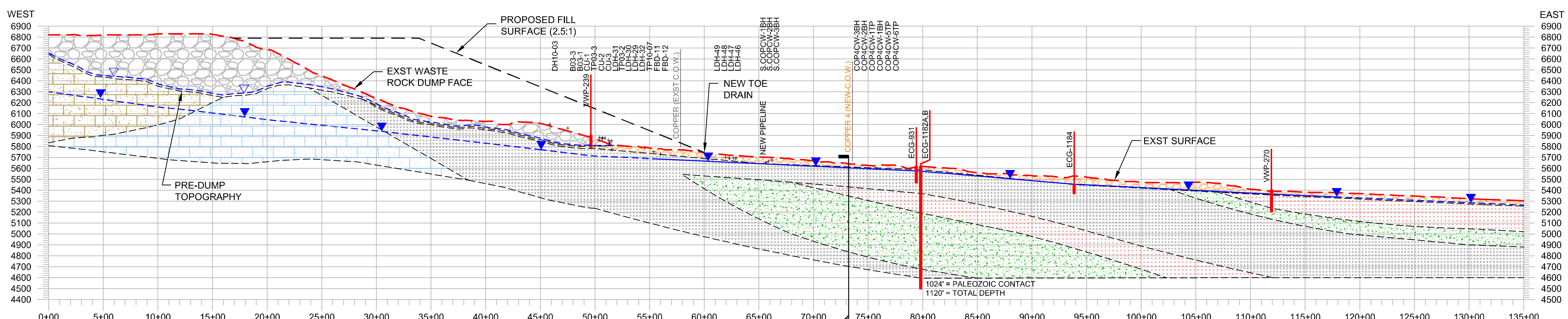


A 17 PROFILE A

LOOKING WEST

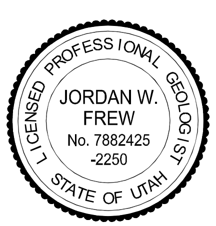
GEOLOGY LEGEND

- GROUNDWATER MONITORING WELLS
- GROUNDWATER TABLE (DASHED WHERE INFERRED)
- SATURATED ZONE IN WASTE ROCK (DASHED WHERE INFERRED)
- WASTE ROCK DUMP
- QUATERNARY & TERTIARY ALLUVIAL FAN (PRINCIPAL AQUIFER)
- OLIGOCENE INTRUSIVE ROCKS - MAINLY SILICIC DIKES & SILLS
- OLIGOCENE VOLCANIC AGGLOMERATE
- OLIGOCENE LATITE PORPHYRY
- OLIGOCENE LATITE, ANDESITE & RHYOLITE FLOWS
- PENNSYLVANIAN BINGHAM MINE FORMATION CLIPPER MEMBER QUARTZITE WITH THIN LIMESTONE BEDS
- MIDDLE PENNSYLVANIAN BUTTERFIELD PEAKS FORMATION, MAINLY QUARTZITE & SANDSTONE



B 16 PROFILE B

LOOKING NORTH



NO.	DATE	REVISION	BY	CHK	APP	REFERENCE DRAWINGS	NUMBER

CH2MHILL

APPROVAL	DATE	SCALE: AS SHOWN	DATE
		DESIGNED BY JW FREW	08/12
		DRAWN BY GE ALMSTROM	08/12
		CHECKED BY GA COLGAN	08/12
		PROJECT ENGINEER M BREWER	08/12
		PROJECT MANAGER A PARRY	08/12

KENNECOTT UTAH COPPER

EWRE 2012 EASTSIDE COLLECTION SYSTEM DESIGN GROUNDWATER DISCHARGE PERMIT

COPPER 4 DRAINAGE AREA GEOLOGIC CROSS SECTIONS

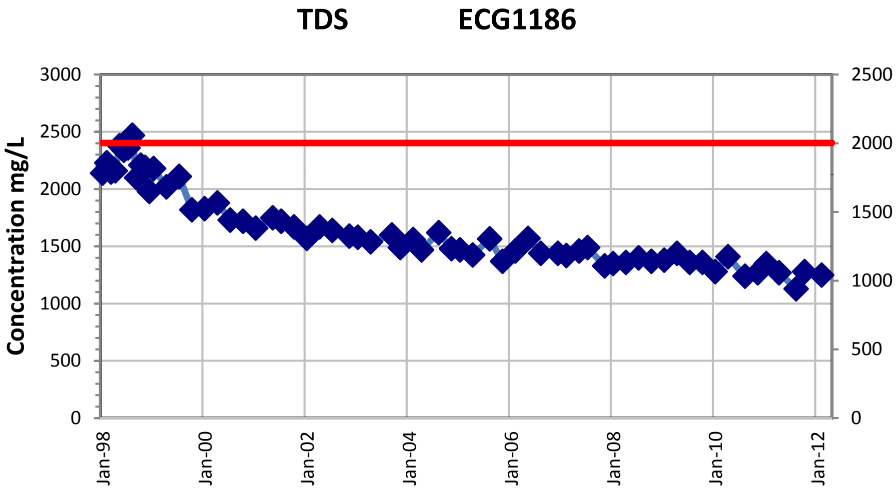
Proj. Dwg. No. 18 | KUC Dwg. No. | REV 1

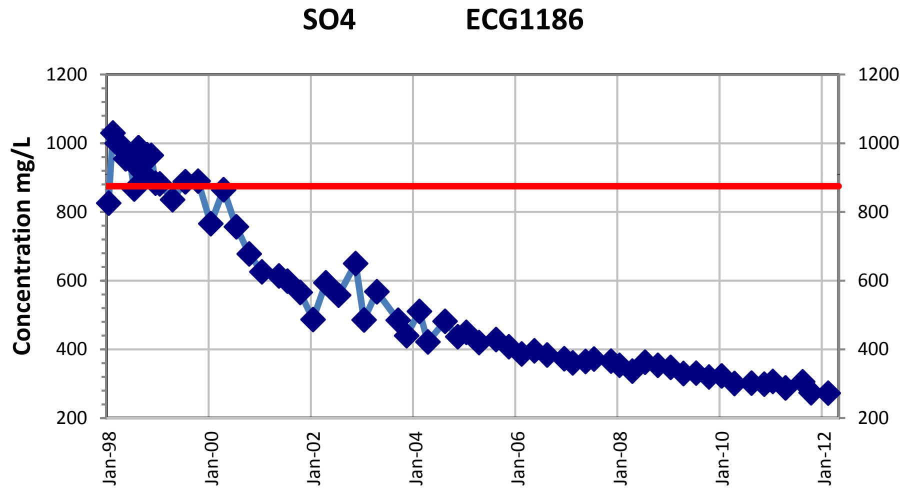
FILENAME: Copper_4_PROF.dwg

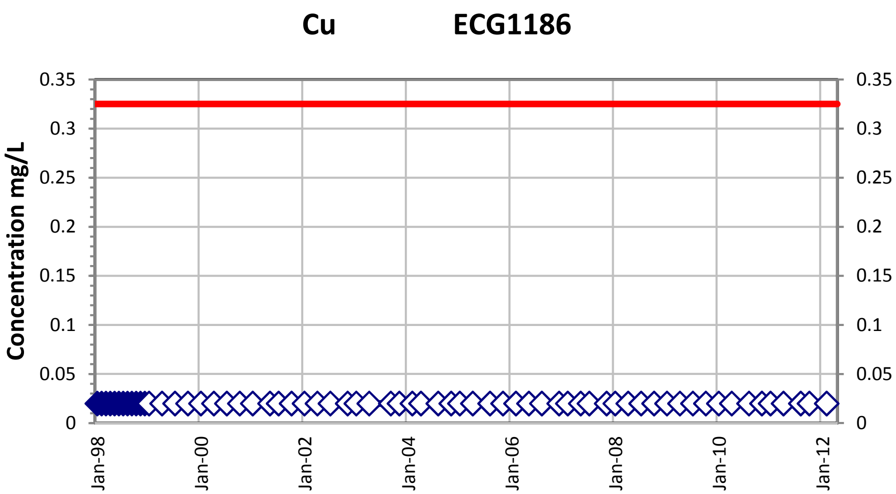
APPENDIX A

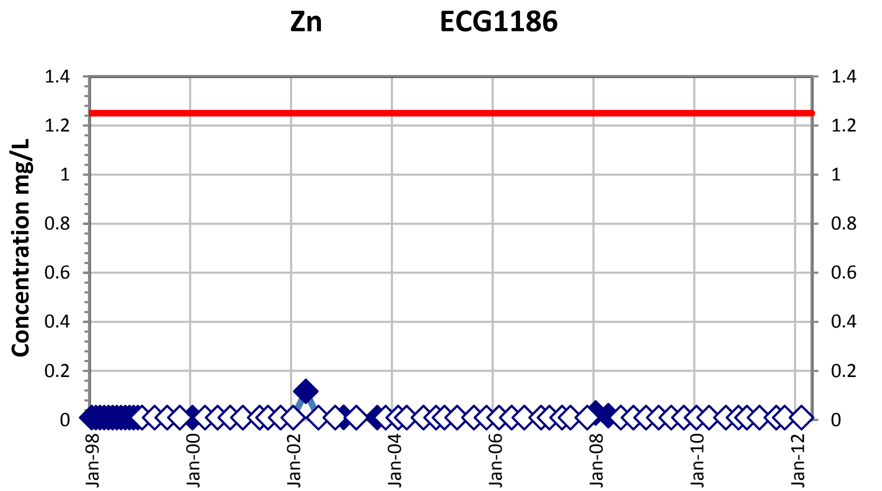
Time Series Plots for Monitoring Wells in the Vicinity of EWRE

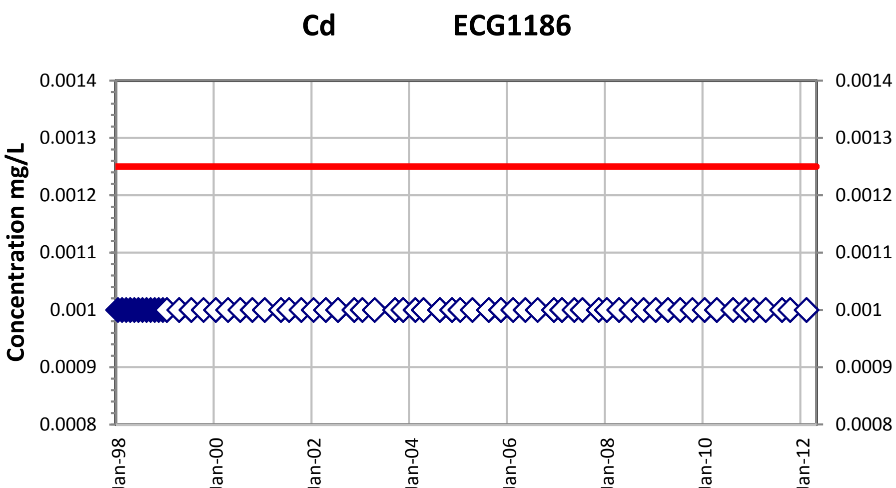
Compliance Wells Chemistry Time Series by Monitoring Well

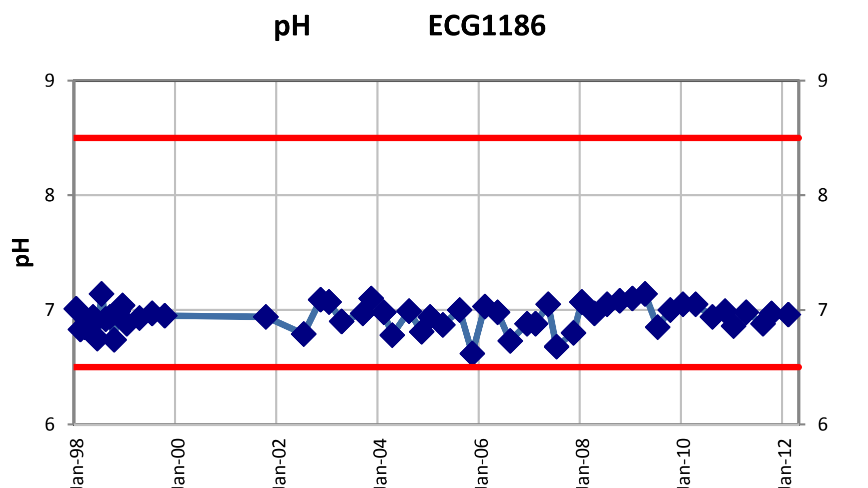

TDS ECG1186
Concentration mg/L
3000
2500
2000
1500
1000
500
0
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12

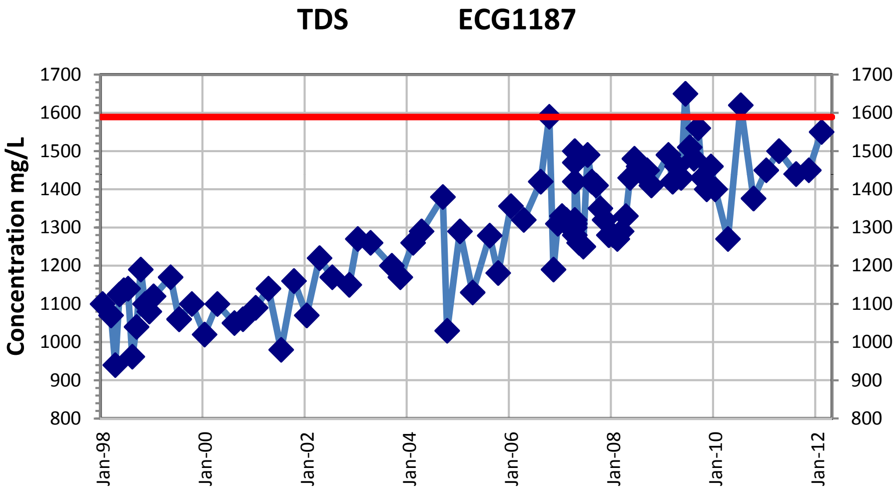

SO4 ECG1186
Concentration mg/L
1200
1000
800
600
400
200
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12

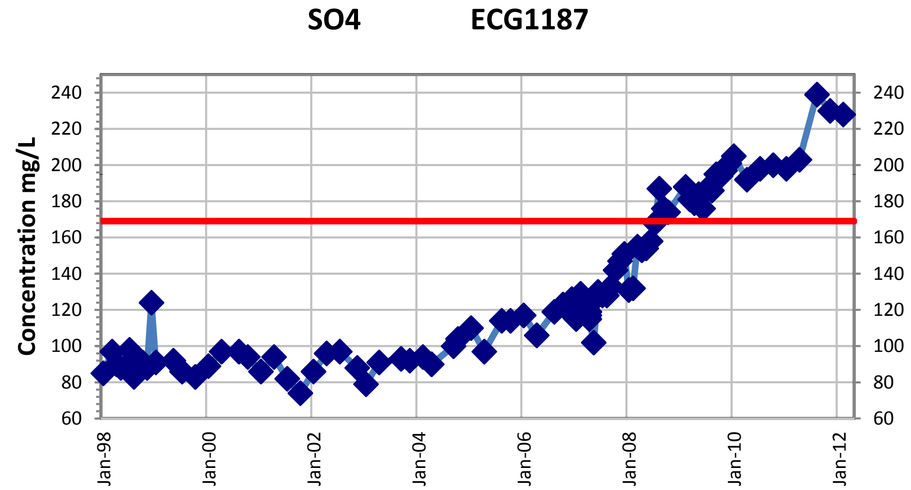

Cu ECG1186
Concentration mg/L
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12

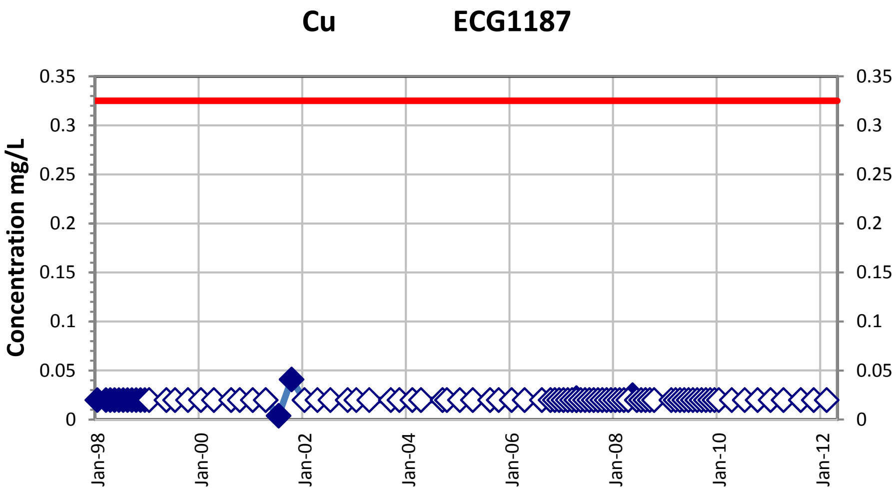

Zn ECG1186
Concentration mg/L
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12

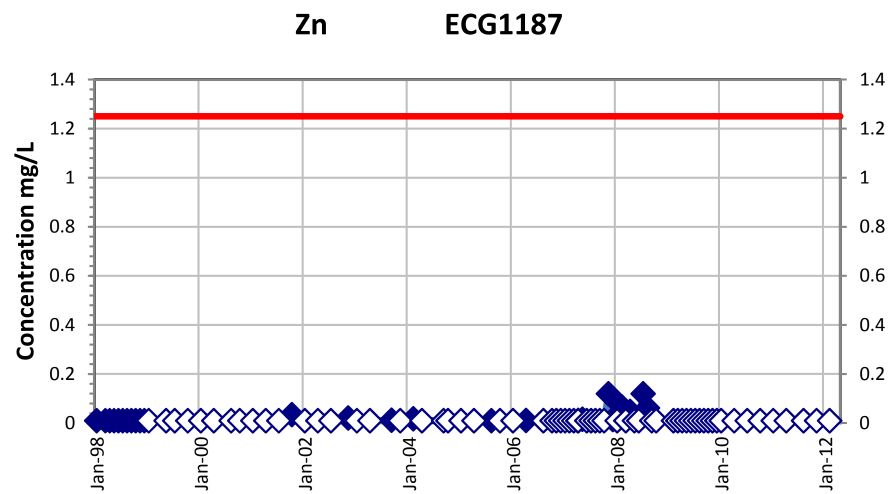

Cd ECG1186
Concentration mg/L
0.0014
0.0013
0.0012
0.0011
0.001
0.0009
0.0008
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12

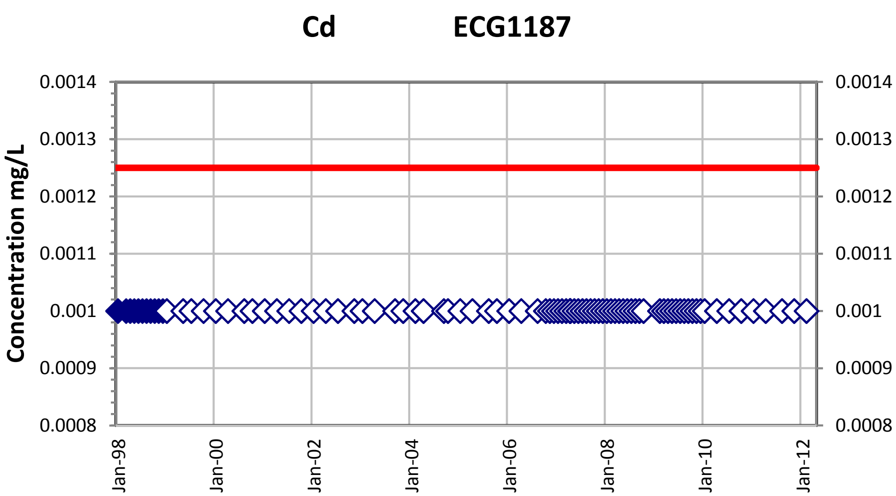

pH ECG1186
pH
9
8
7
6
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12

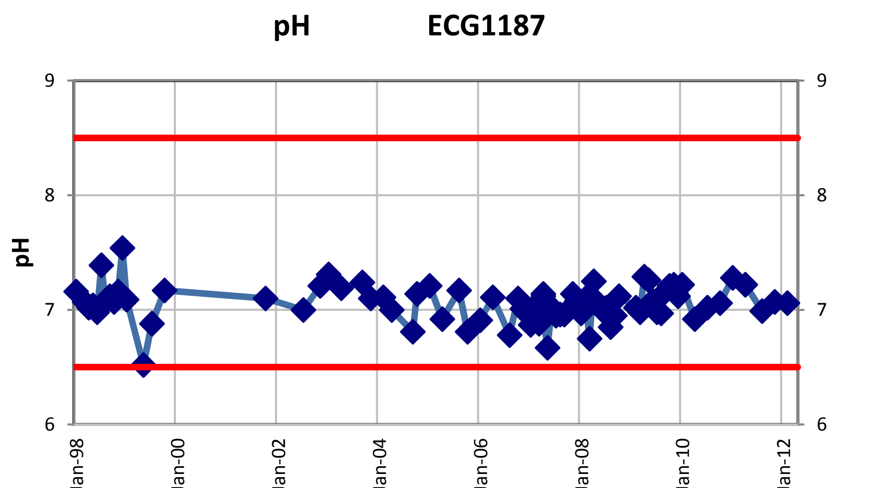

TDS ECG1187
Concentration mg/L
1700
1600
1500
1400
1300
1200
1100
1000
900
800
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12

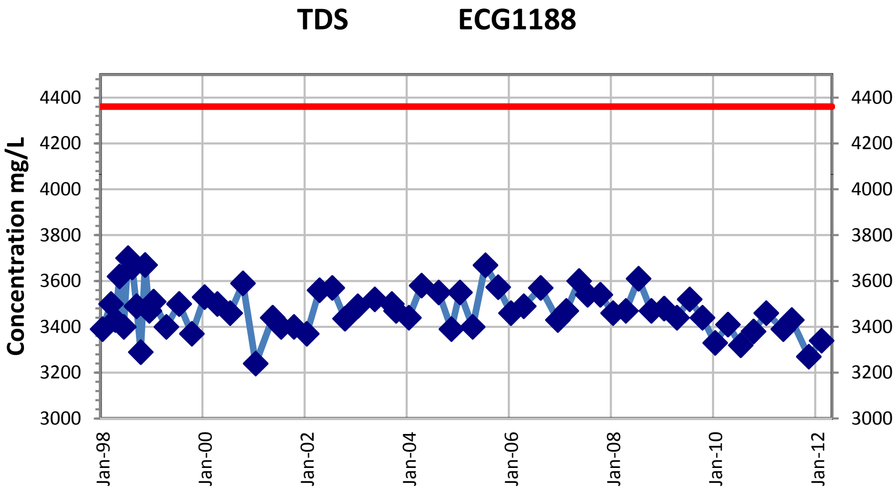

SO4 ECG1187
Concentration mg/L
240
220
200
180
160
140
120
100
80
60
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12

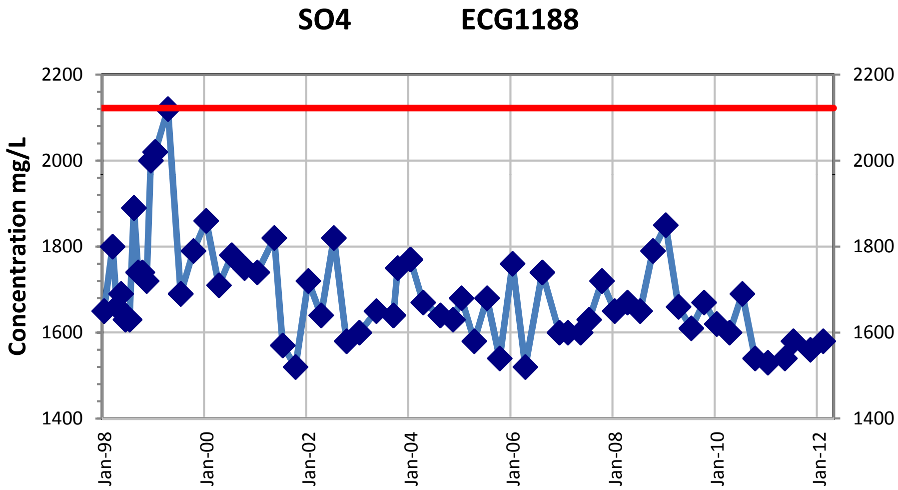

Cu ECG1187
Concentration mg/L
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12

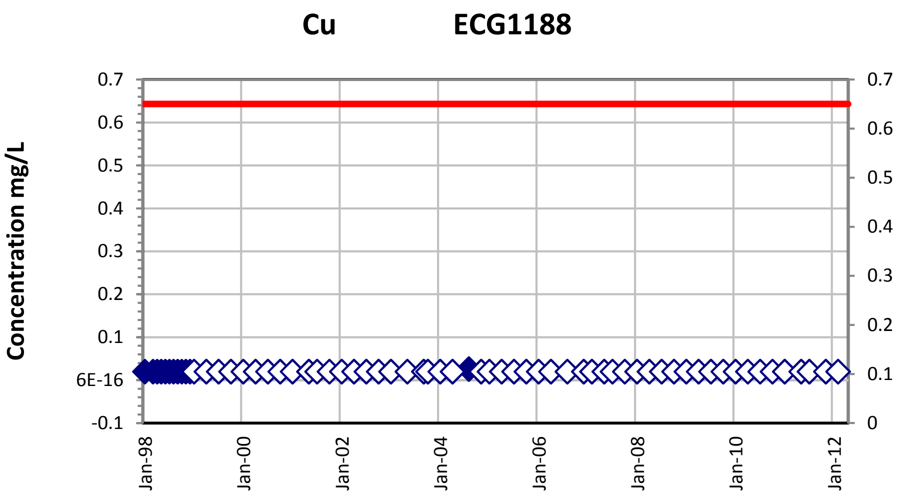

Zn ECG1187
Concentration mg/L
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12

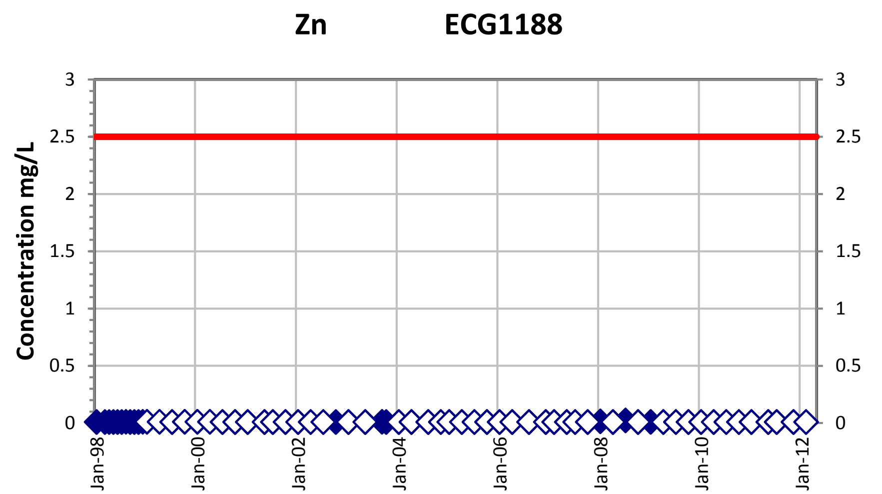

Cd ECG1187
Concentration mg/L
0.0014
0.0013
0.0012
0.0011
0.001
0.0009
0.0008
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12


pH ECG1187
pH
9
8
7
6
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12


TDS ECG1188
Concentration mg/L
4400
4200
4000
3800
3600
3400
3200
3000
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12


SO4 ECG1188
Concentration mg/L
2200
2000
1800
1600
1400
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12


Cu ECG1188
Concentration mg/L
0.7
0.6
0.5
0.4
0.3
0.2
0.1
6E-16
-0.1
0
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12


Zn ECG1188
Concentration mg/L
3
2.5
2
1.5
1
0.5
0
Jan-98
Jan-00
Jan-02
Jan-04
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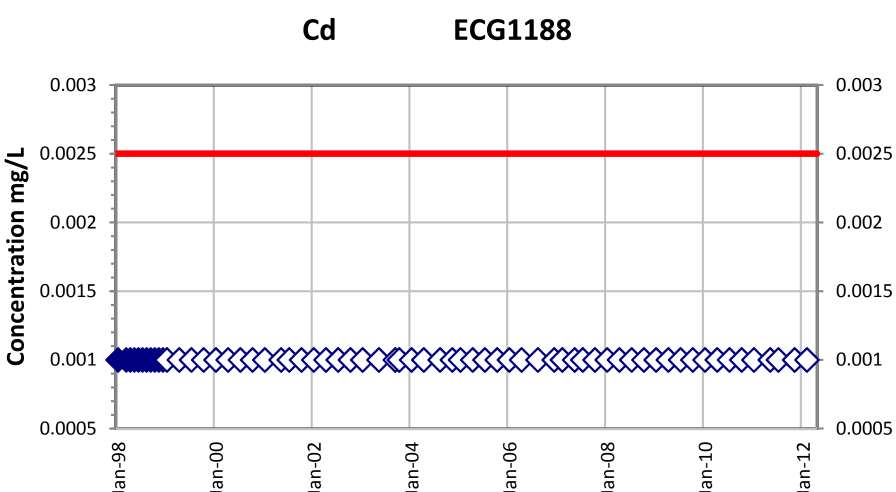
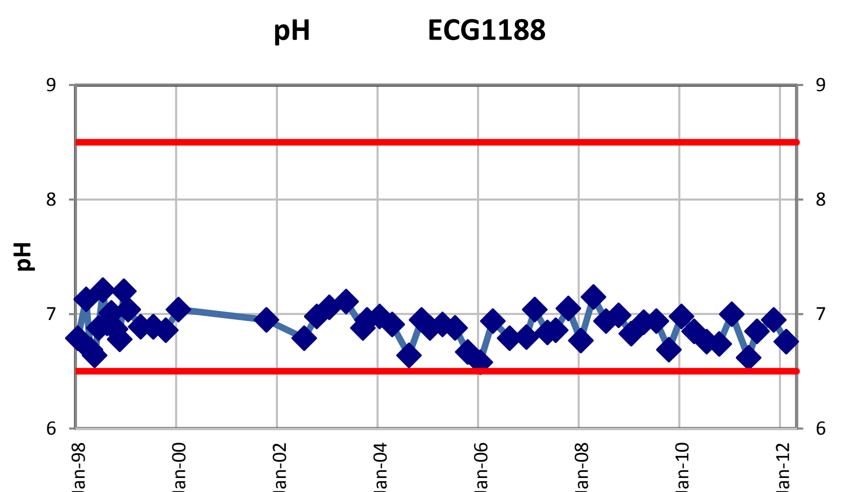
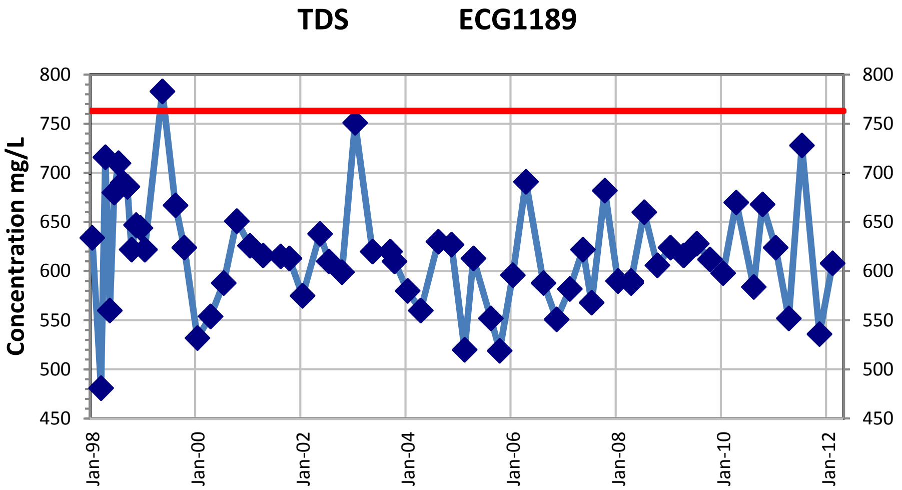
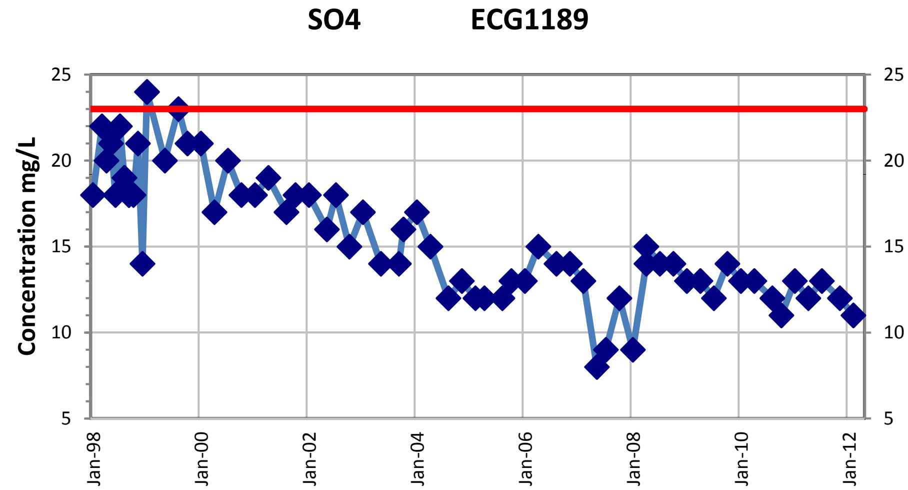
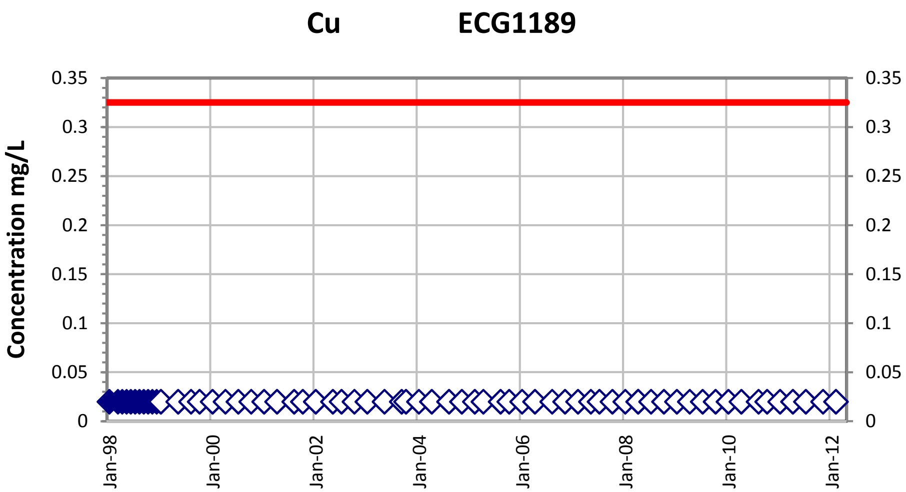
Jan-08
Jan-10
Jan-12

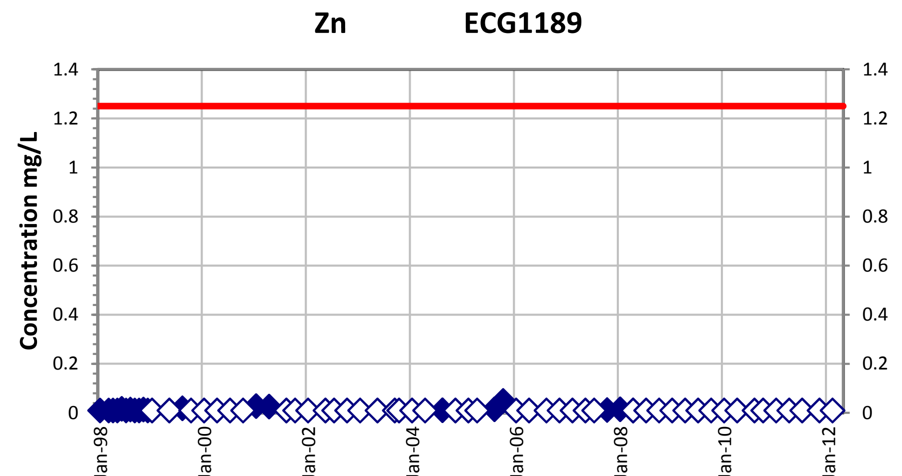

Cd ECG1188
Concentration mg/L
0.003
0.0025
0.002
0.0015
0.001
0.0005
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12

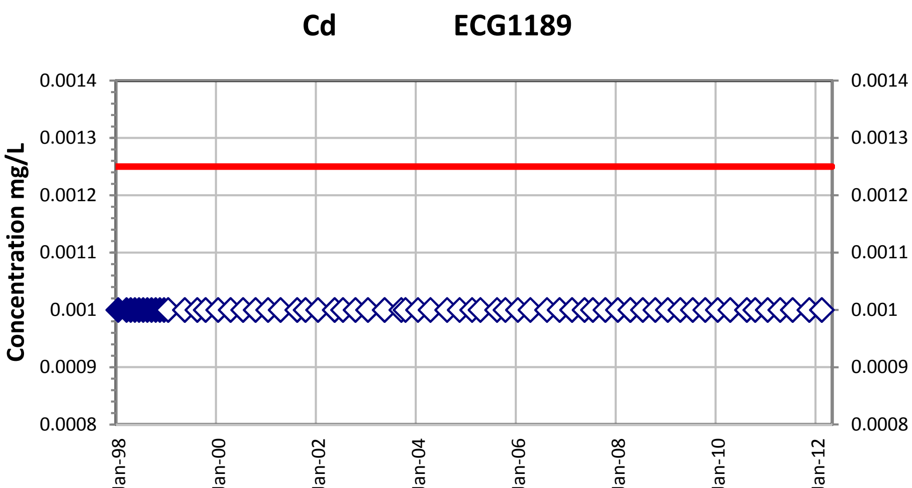

pH ECG1188
pH
9
8
7
6
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12

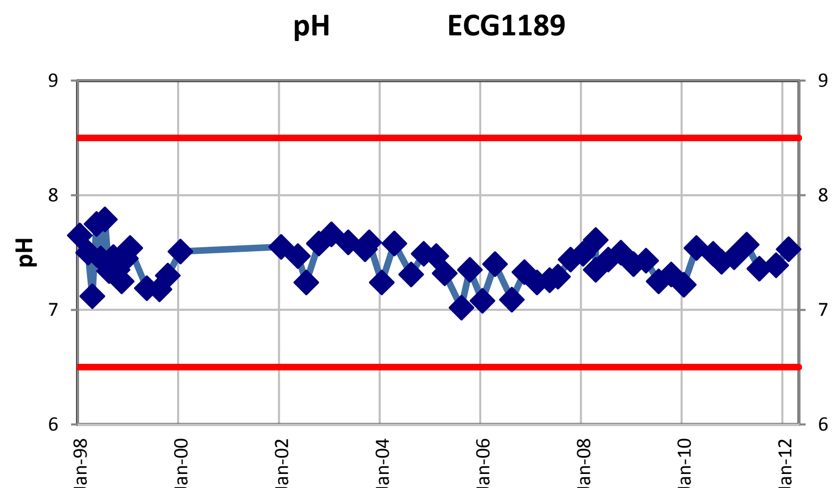

TDS ECG1189
Concentration mg/L
800
750
700
650
600
550
500
450
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12

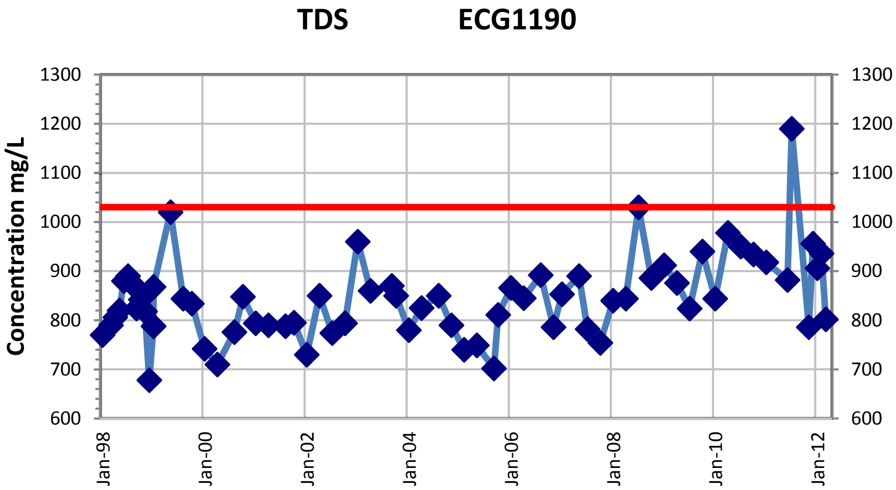

SO4 ECG1189
Concentration mg/L
25
20
15
10
5
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12

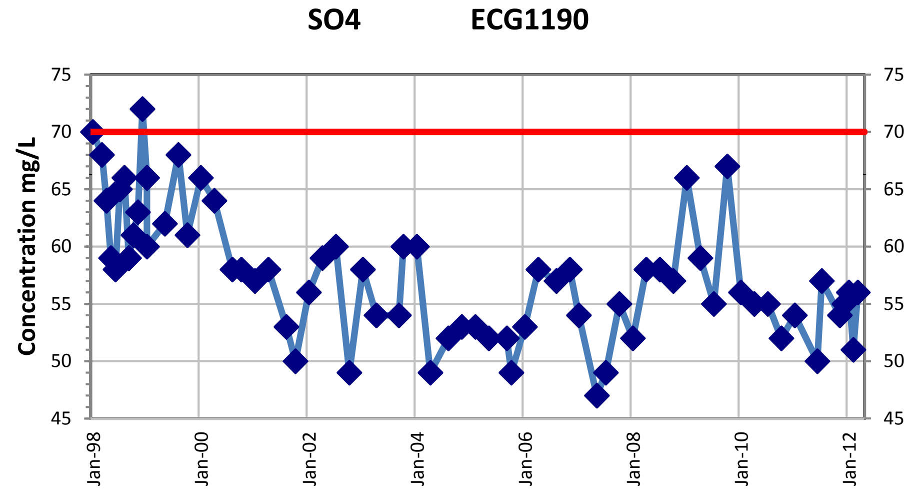

Cu ECG1189
Concentration mg/L
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12

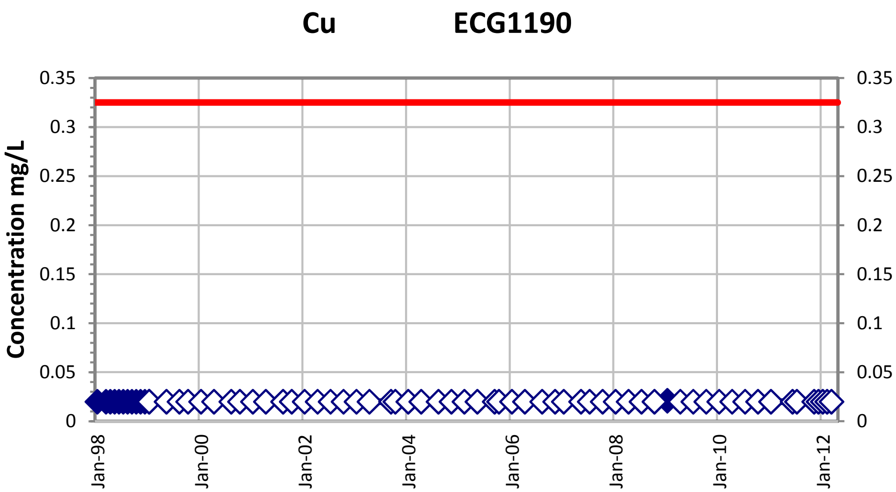

Zn ECG1189
Concentration mg/L
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12


Cd ECG1189
Concentration mg/L
0.0014
0.0013
0.0012
0.0011
0.001
0.0009
0.0008
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12


pH ECG1189
pH
9
8
7
6
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12


TDS ECG1190
Concentration mg/L
1300
1200
1100
1000
900
800
700
600
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12


SO4 ECG1190
Concentration mg/L
75
70
65
60
55
50
45
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12


Cu ECG1190
Concentration mg/L
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Jan-98
Jan-00
Jan-02
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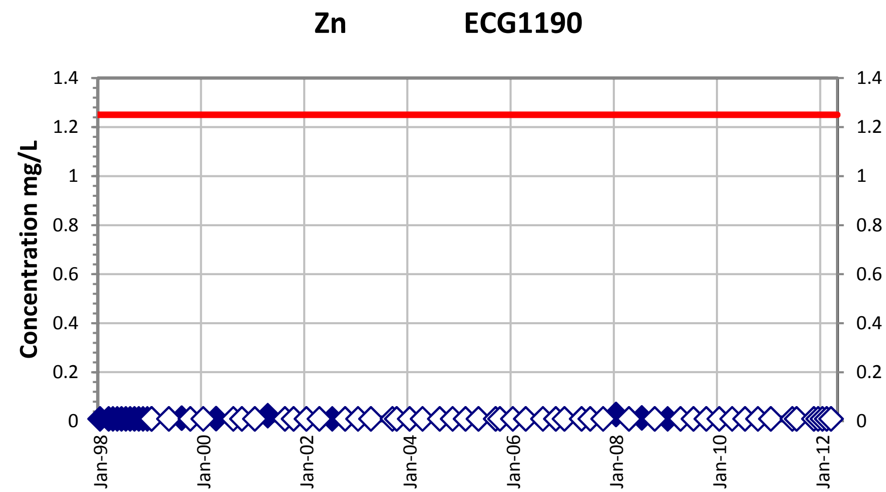
Jan-08
Jan-10
Jan-12


Zn ECG1190
Concentration mg/L
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Jan-98
Jan-00
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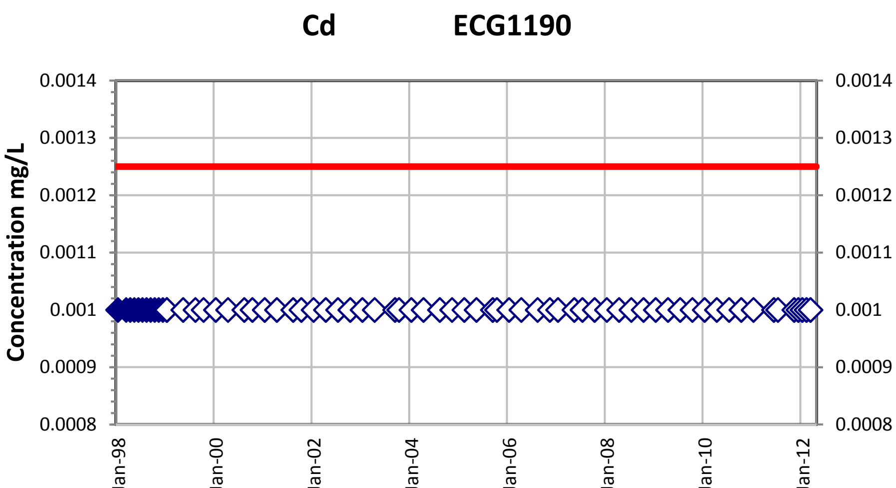
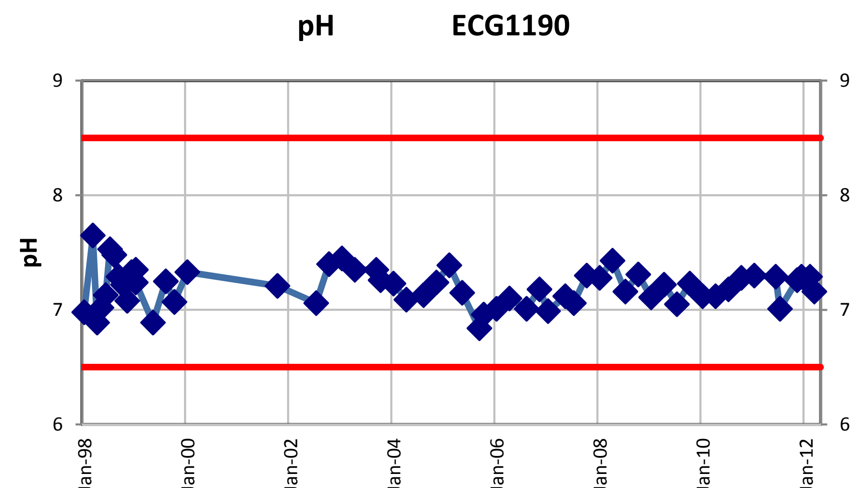
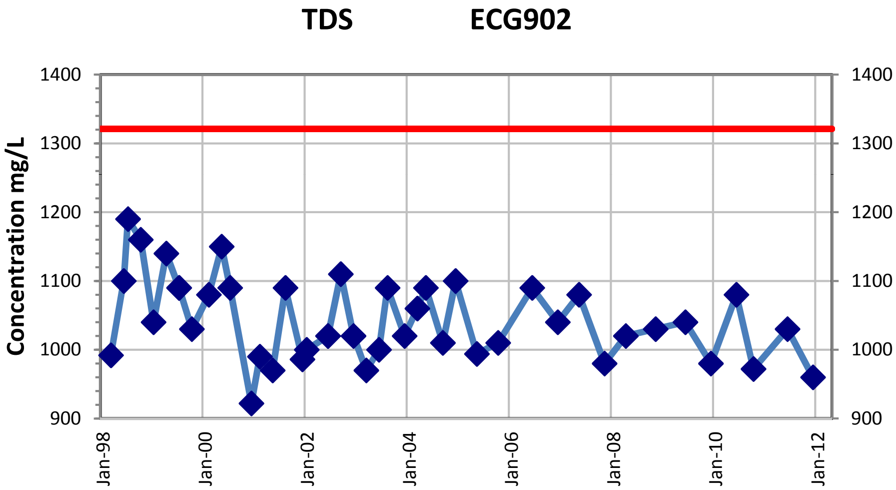
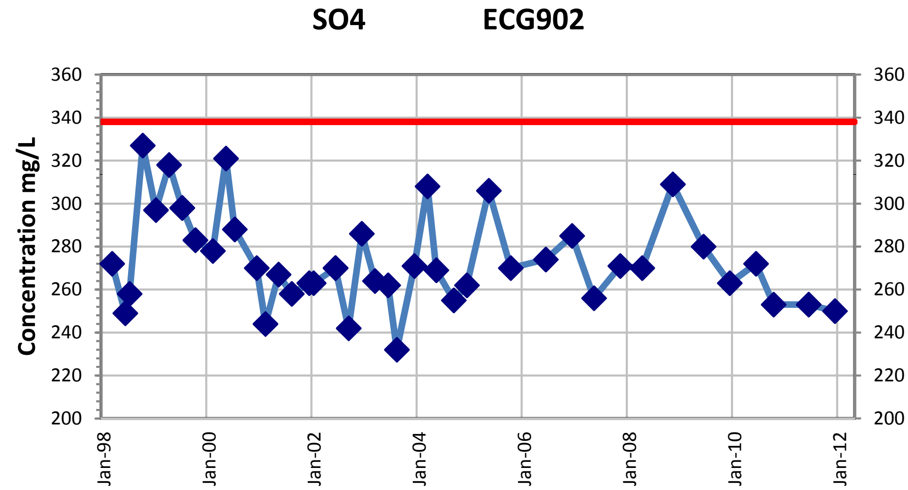
Jan-08
Jan-10
Jan-12


Cd ECG1190
Concentration mg/L
0.0014
0.0013
0.0012
0.0011
0.001
0.0009
0.0008
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12


pH ECG1190
pH
9
8
7
6
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12


TDS ECG902
Concentration mg/L
1400
1300
1200
1100
1000
900
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12


SO4 ECG902
Concentration mg/L
360
340
320
300
280
260
240
220
200
Jan-98
Jan-00
Jan-02
Jan-04
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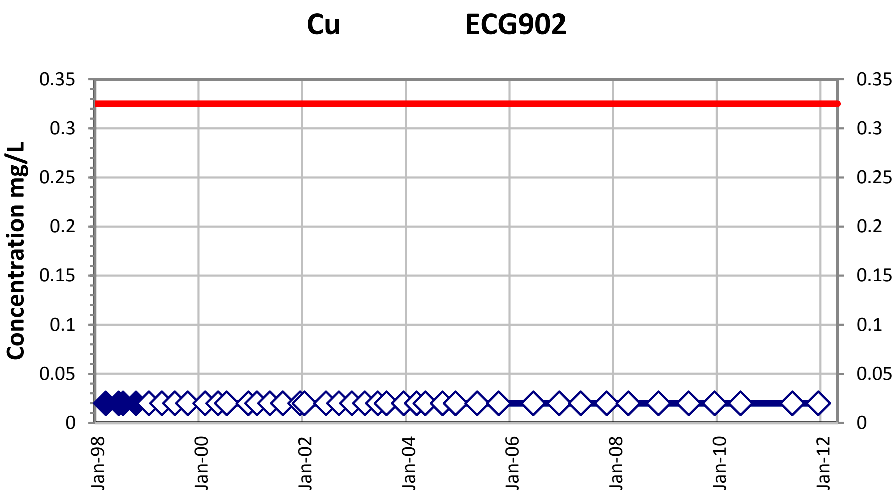
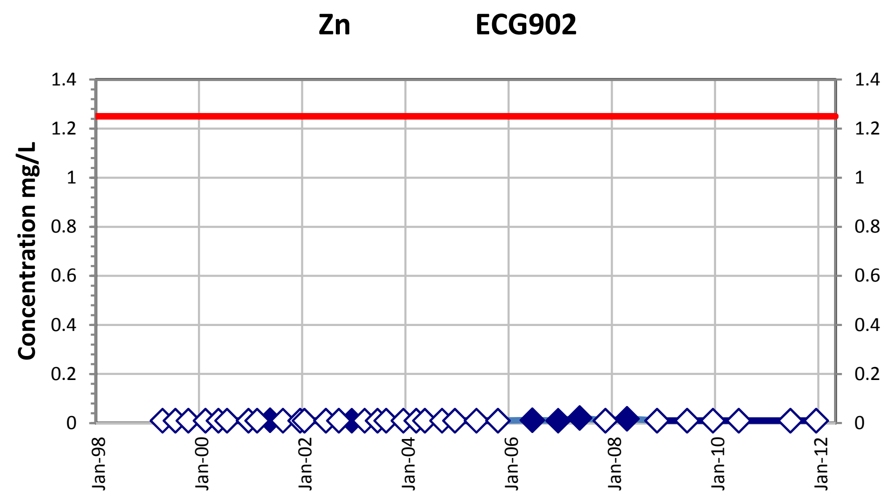
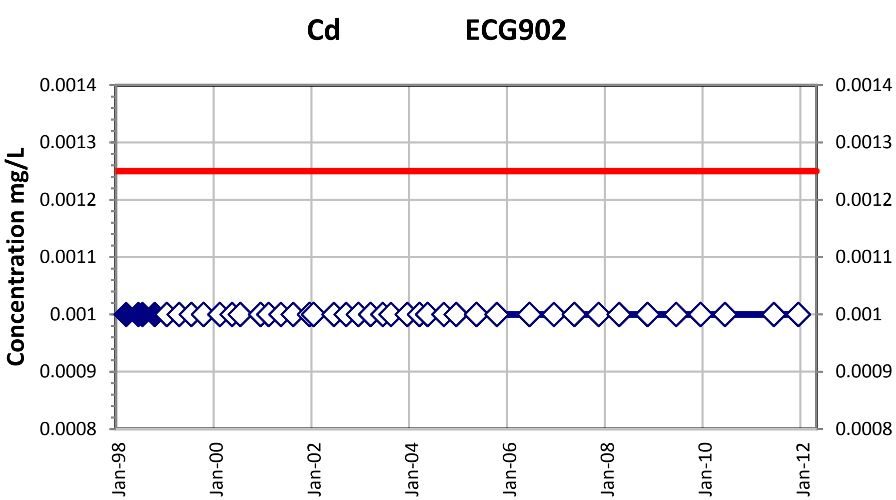
Jan-08
Jan-10
Jan-12


Cu ECG902
Concentration mg/L
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12


Zn ECG902
Concentration mg/L
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12


Cd ECG902
Concentration mg/L
0.0014
0.0013
0.0012
0.0011
0.001
0.0009
0.0008
Jan-98
Jan-00
Jan-02
Jan-04
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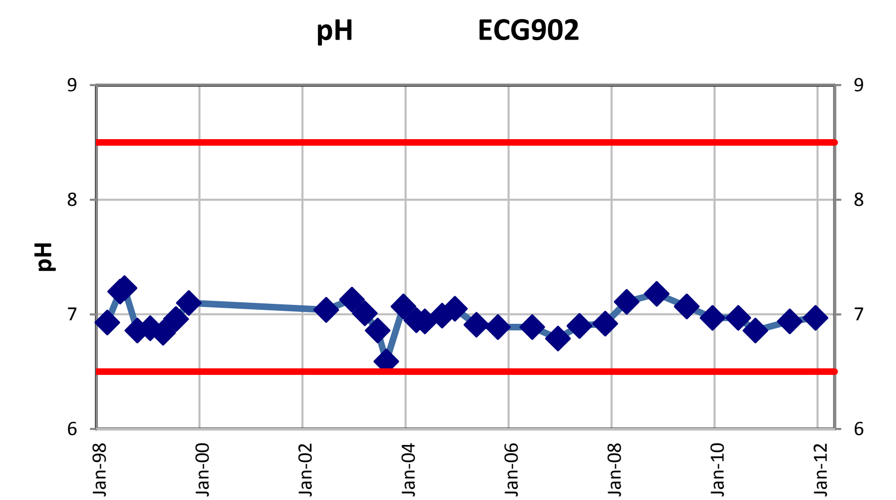
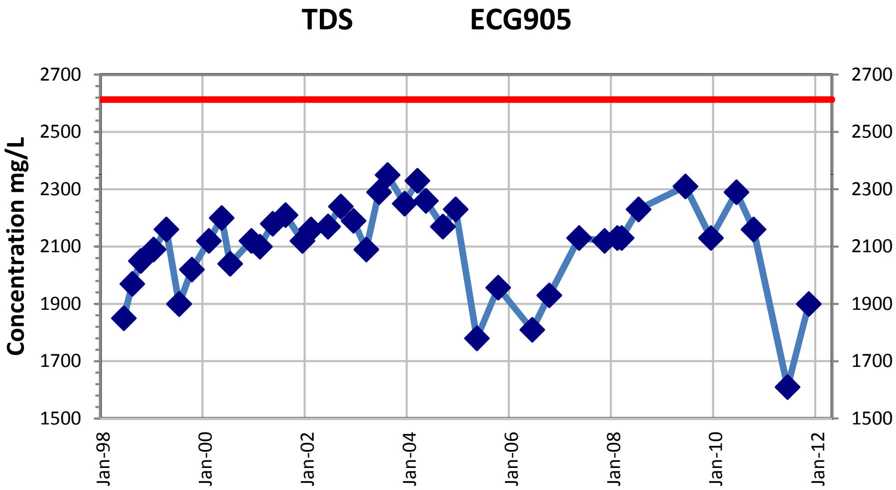
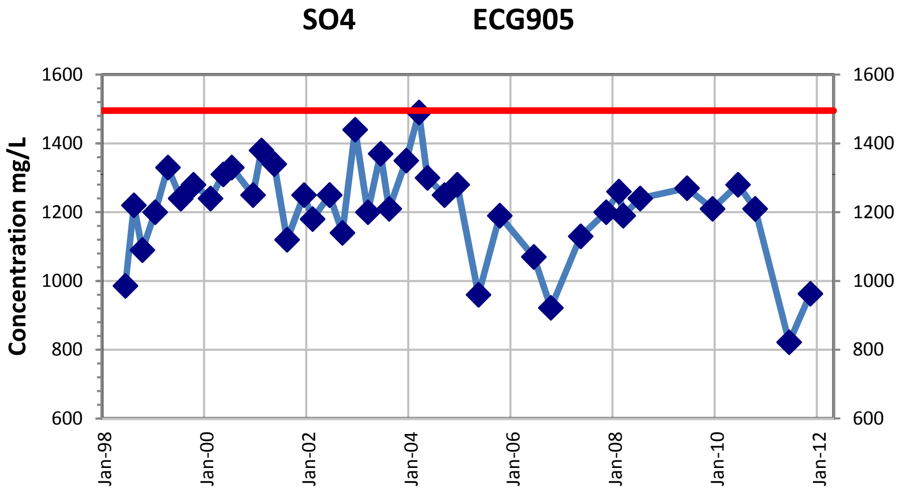
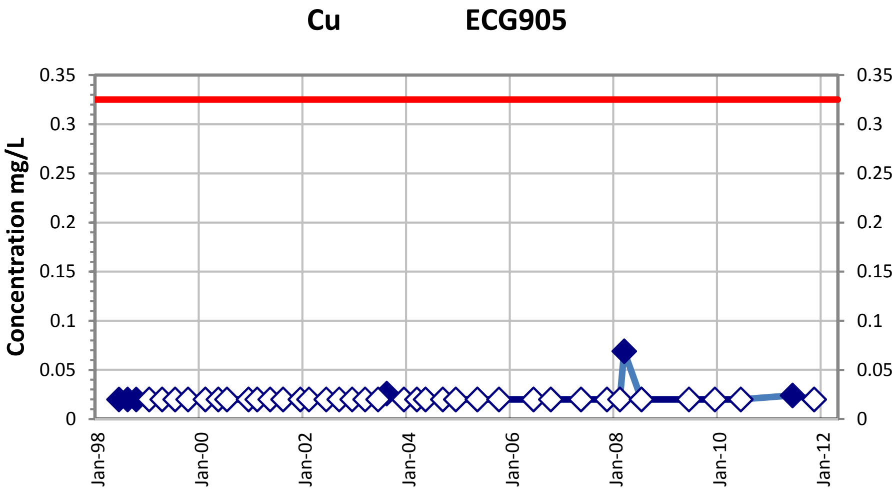
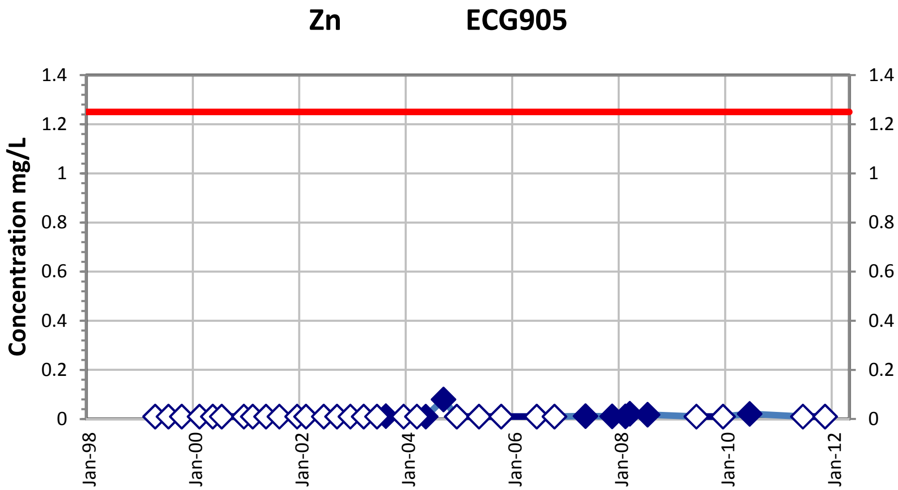
Jan-08
Jan-10
Jan-12

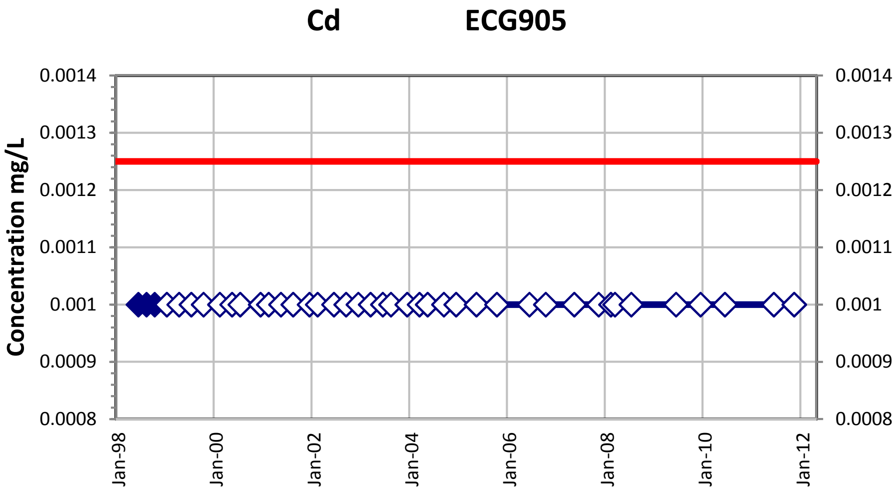

pH ECG902
pH
9
8
7
6
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12

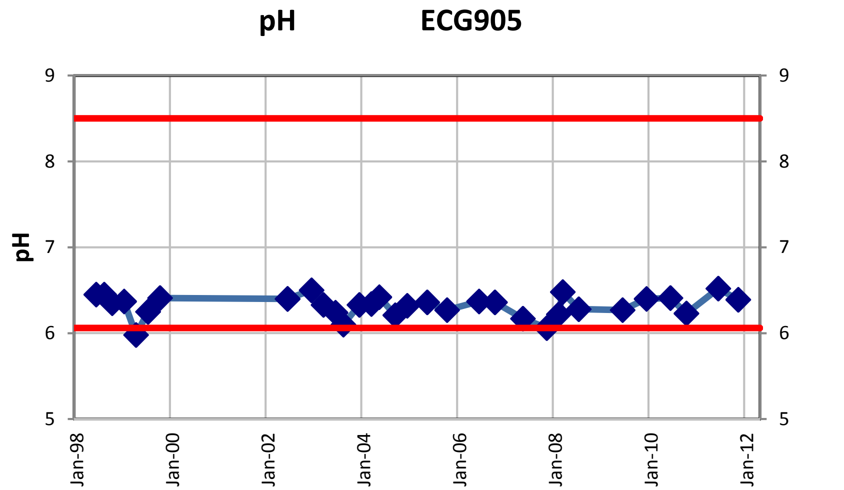

TDS ECG905
Concentration mg/L

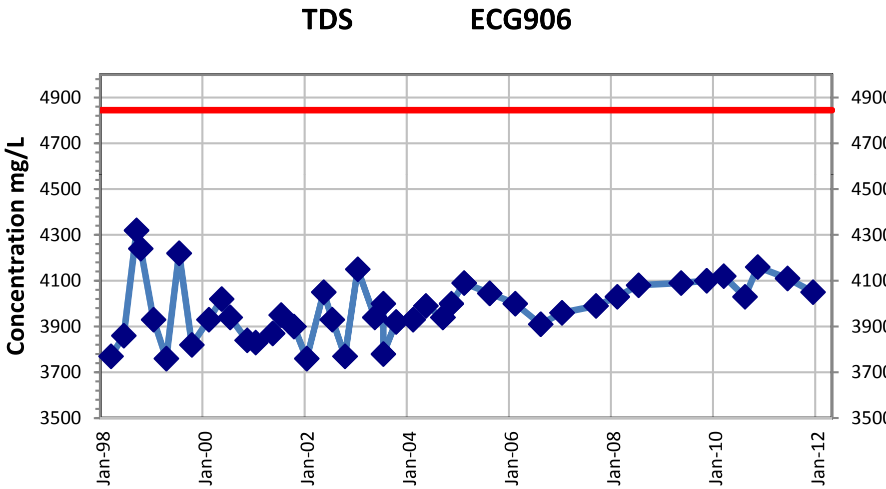

SO4 ECG905
Concentration mg/L

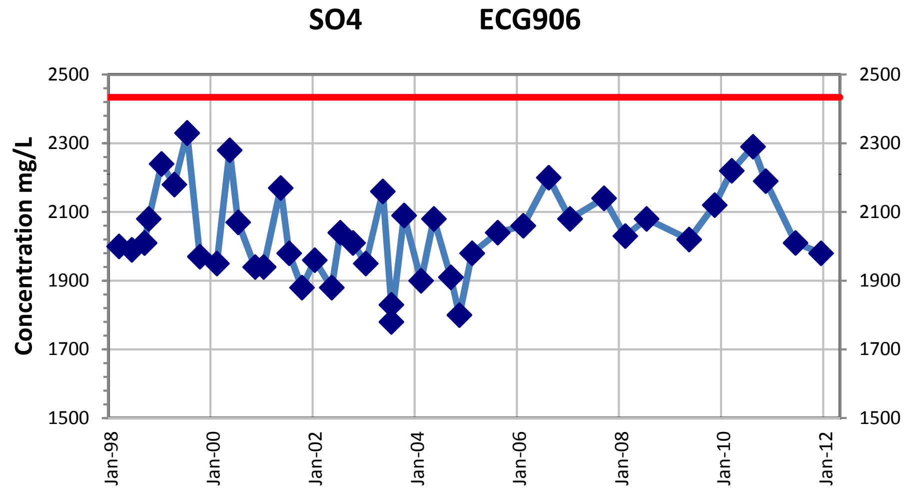

Cu ECG905
Concentration mg/L

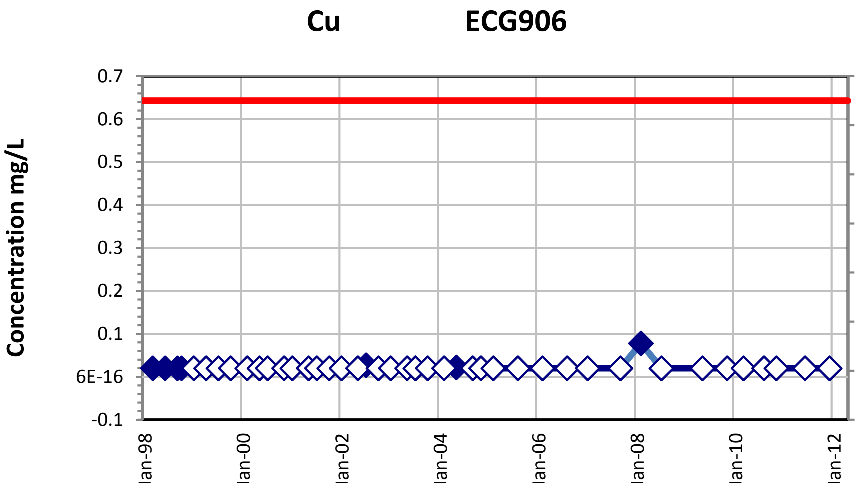

Zn ECG905
Concentration mg/L

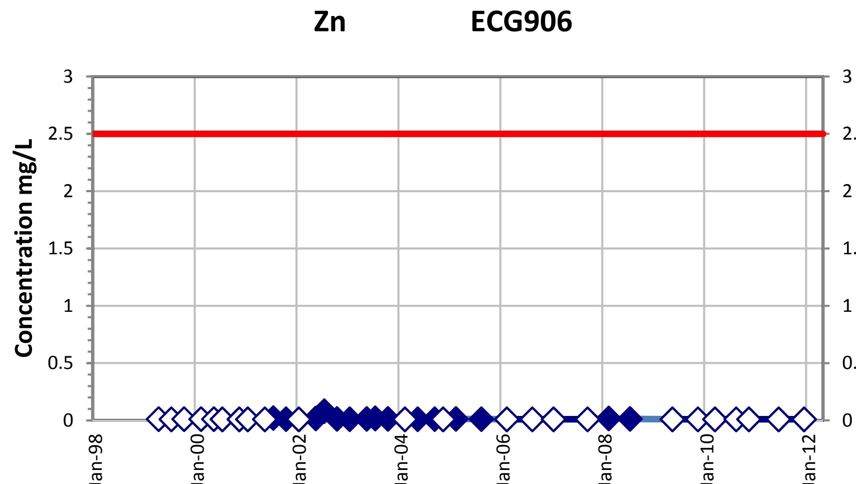

Cd ECG905
Concentration mg/L

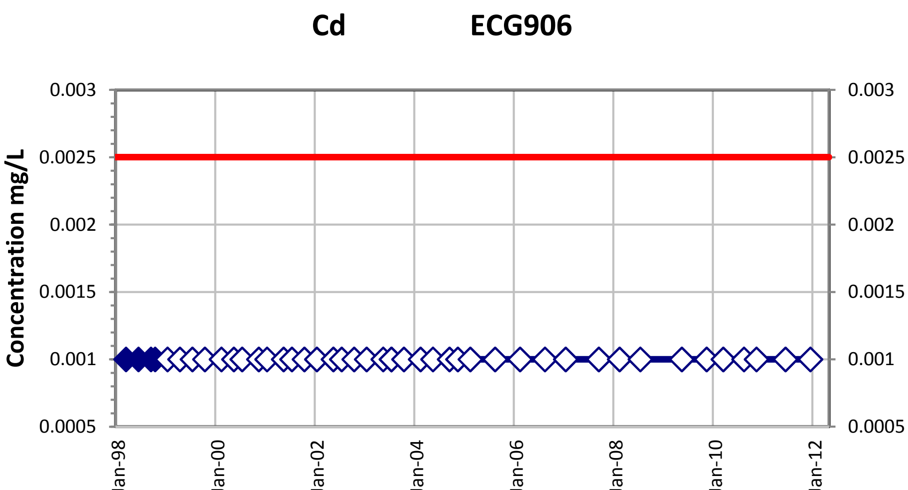

pH ECG905
pH


TDS ECG906
Concentration mg/L
3500
3700
3900
4100
4300
4500
4700
4900
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12


SO4 ECG906
Concentration mg/L
1500
1700
1900
2100
2300
2500
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12


Cu ECG906
Concentration mg/L
-0.1
6E-16
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12


Zn ECG906
Concentration mg/L
0
0.5
1
1.5
2
2.5
3
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12


Cd ECG906
Concentration mg/L
0.0005
0.001
0.0015
0.002
0.0025
0.003
Jan-98
Jan-00
Jan-02
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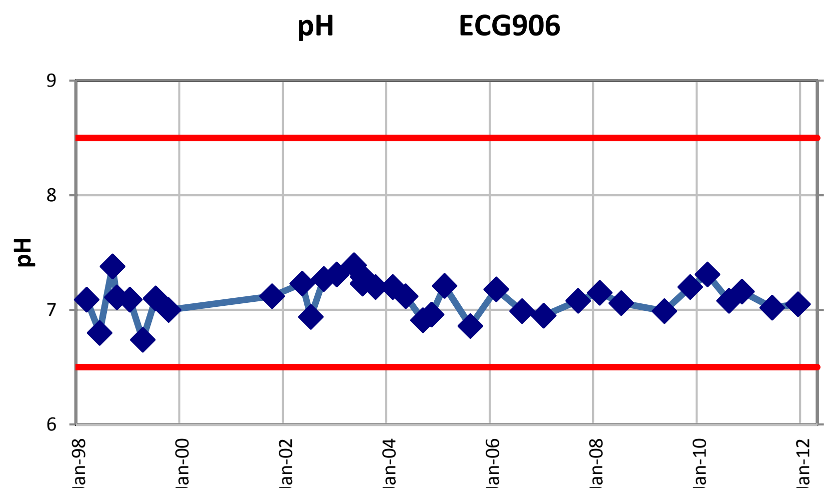
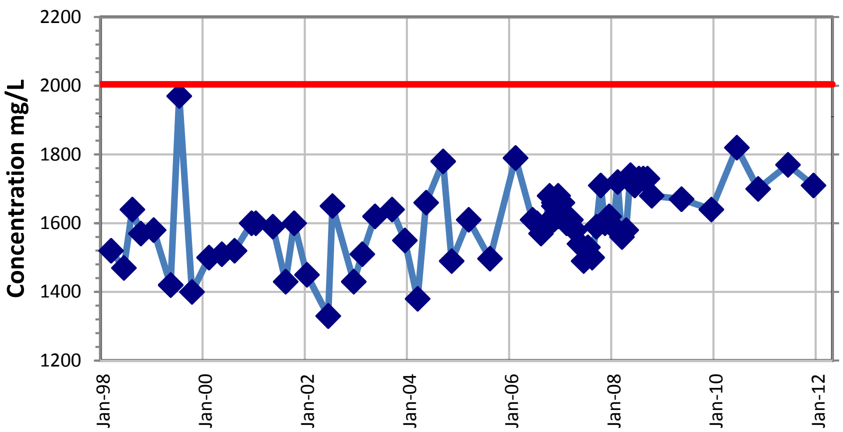
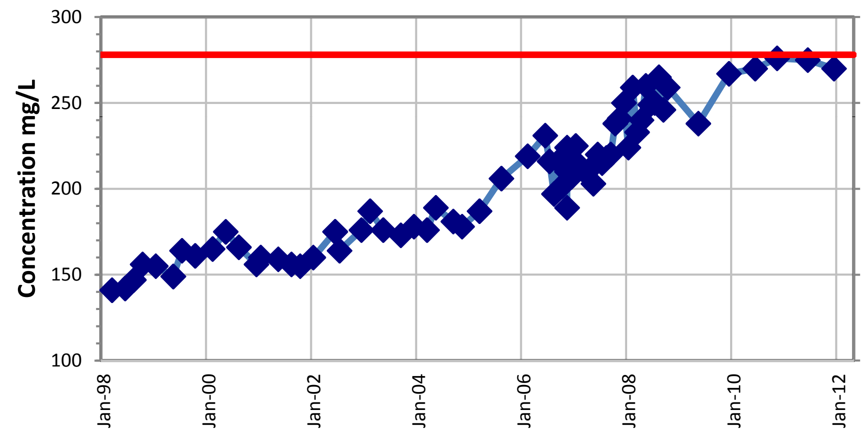
Jan-08
Jan-10
Jan-12


pH ECG906
pH
6
7
8
9
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12

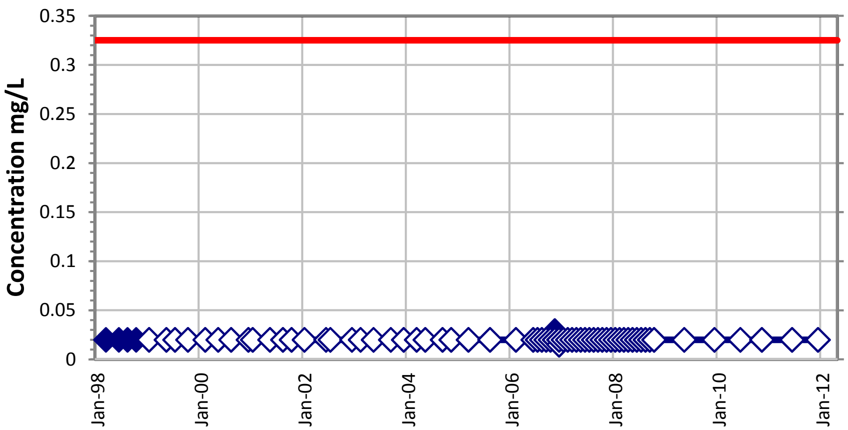
TDS ECG907



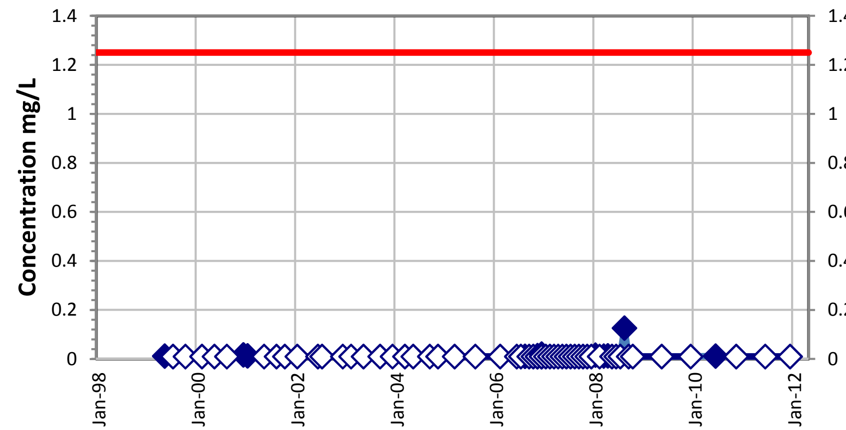
SO4 ECG907



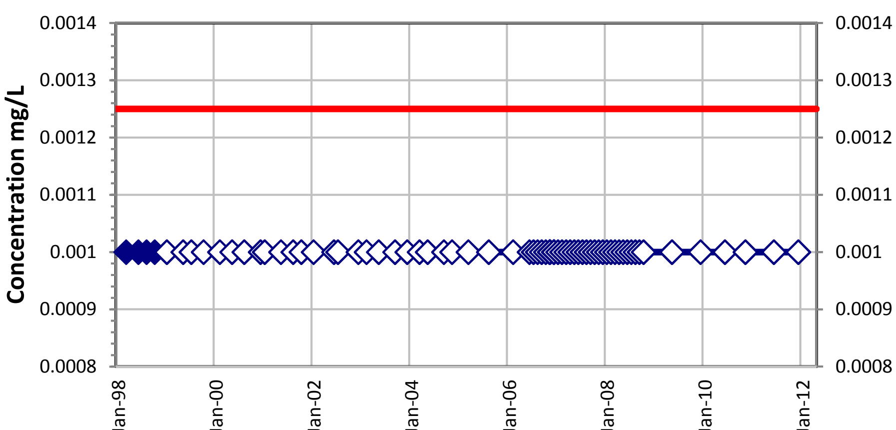
Cu ECG907



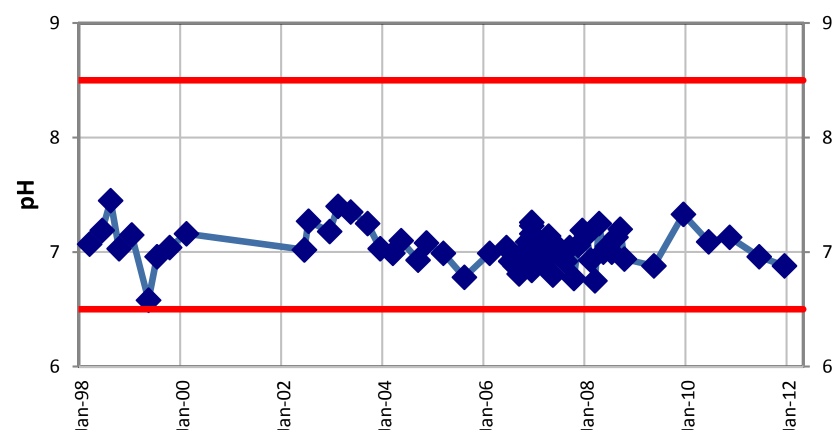
Zn ECG907

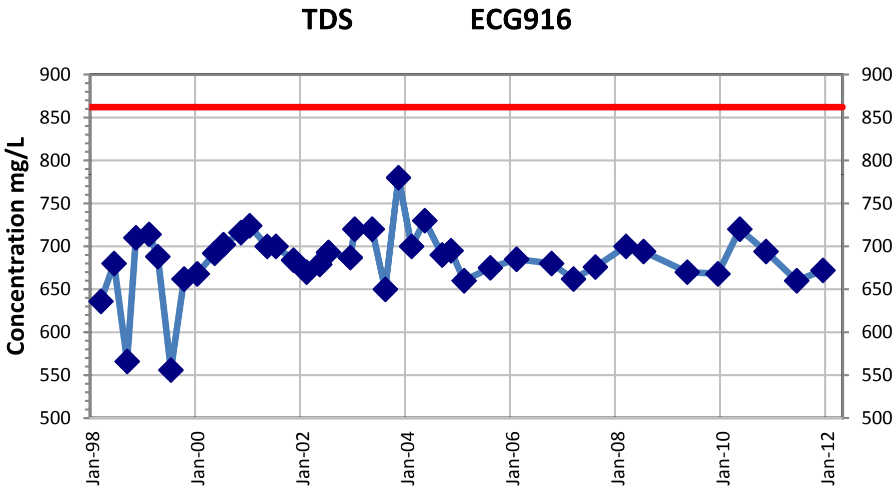


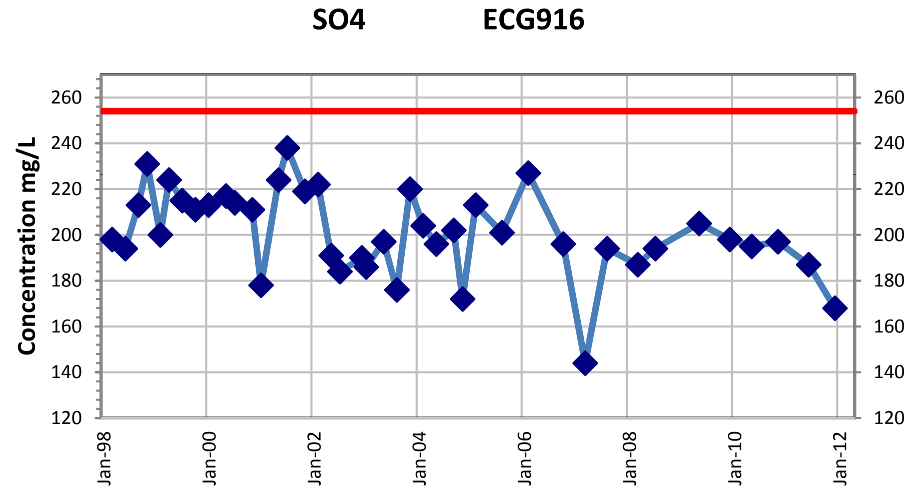
Cd ECG907

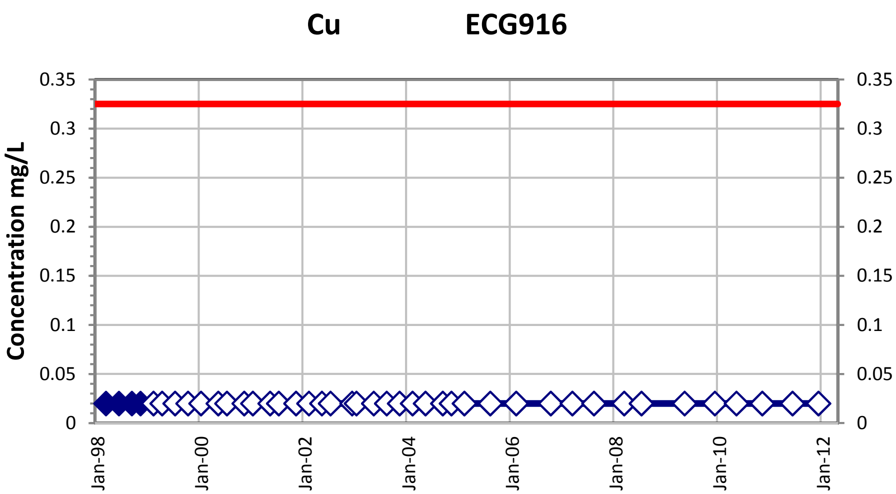


pH ECG907




TDS ECG916
Concentration mg/L
900
850
800
750
700
650
600
550
500
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12


SO4 ECG916
Concentration mg/L
260
240
220
200
180
160
140
120
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12


Cu ECG916
Concentration mg/L
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Jan-98
Jan-00
Jan-02
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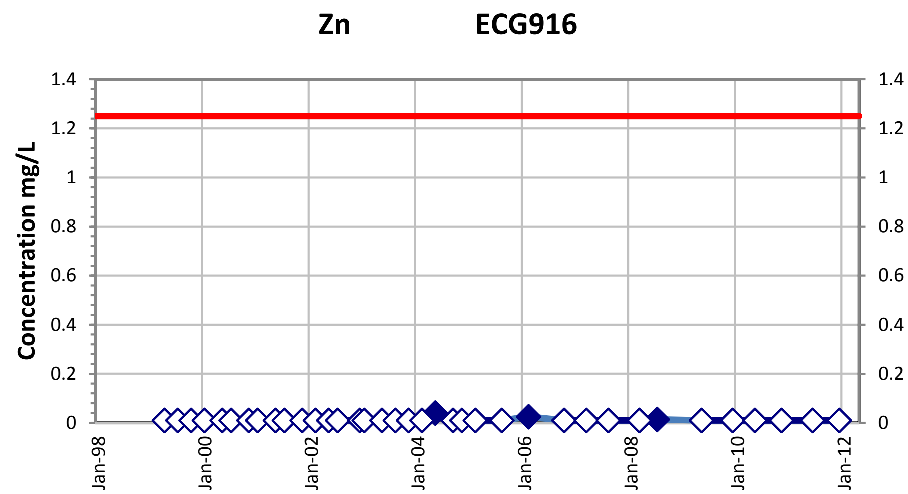
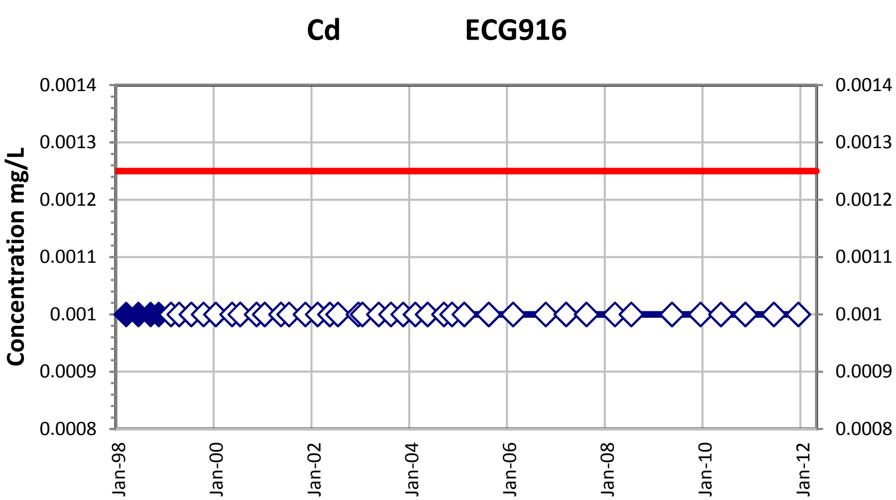
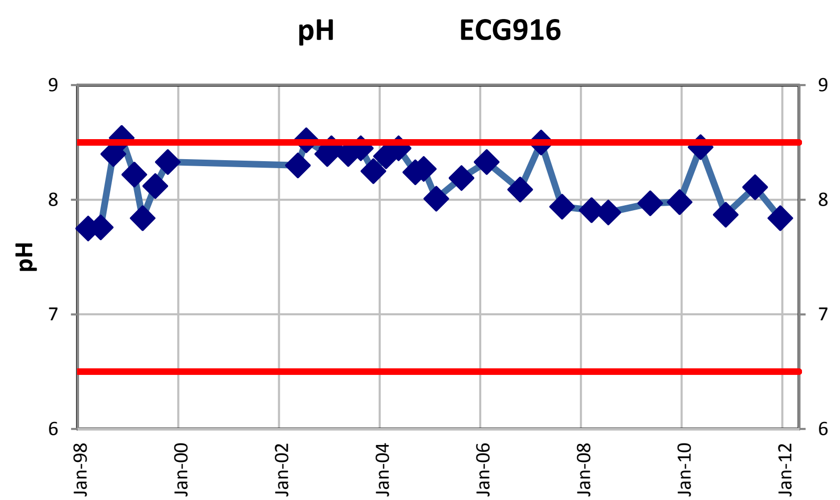
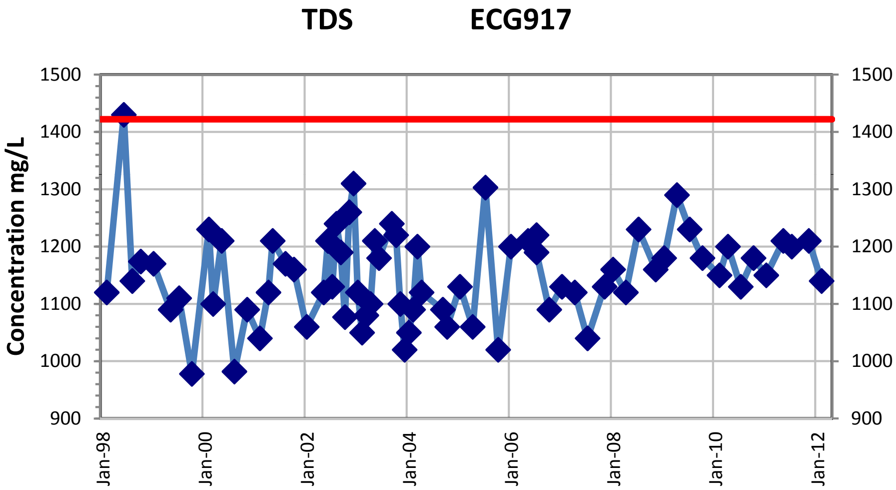
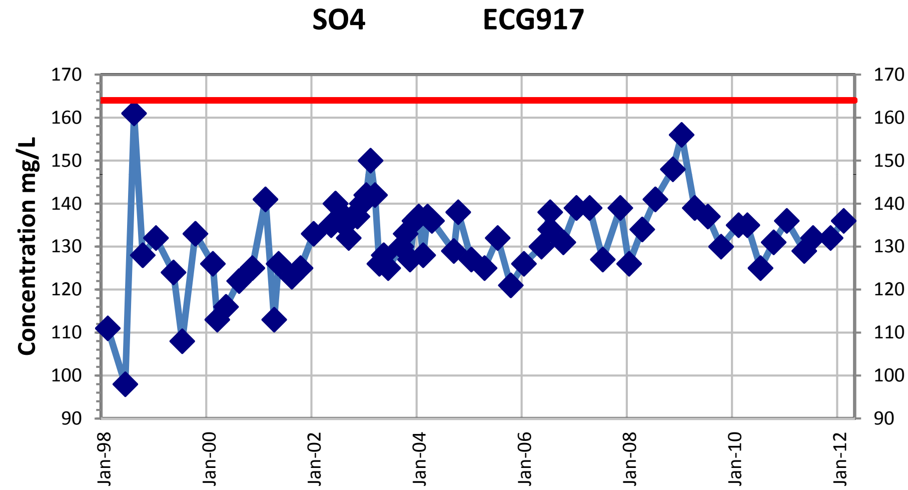
Jan-08
Jan-10
Jan-12

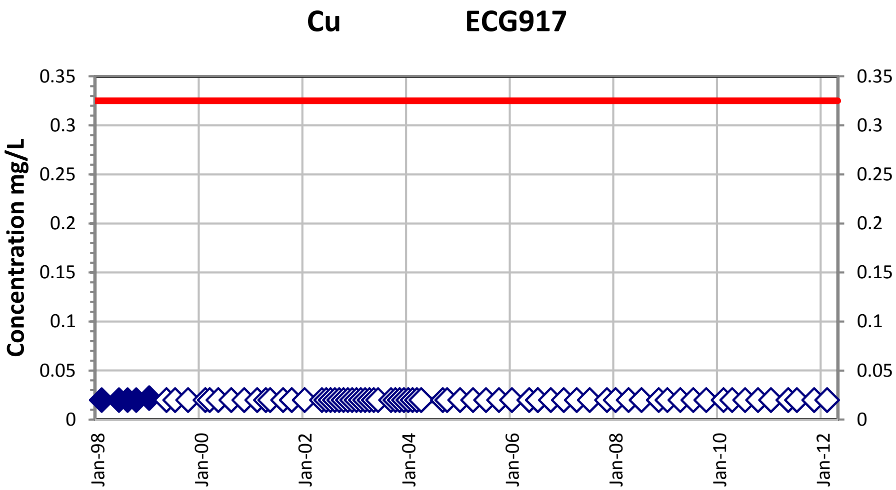

Zn ECG916
Concentration mg/L
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12

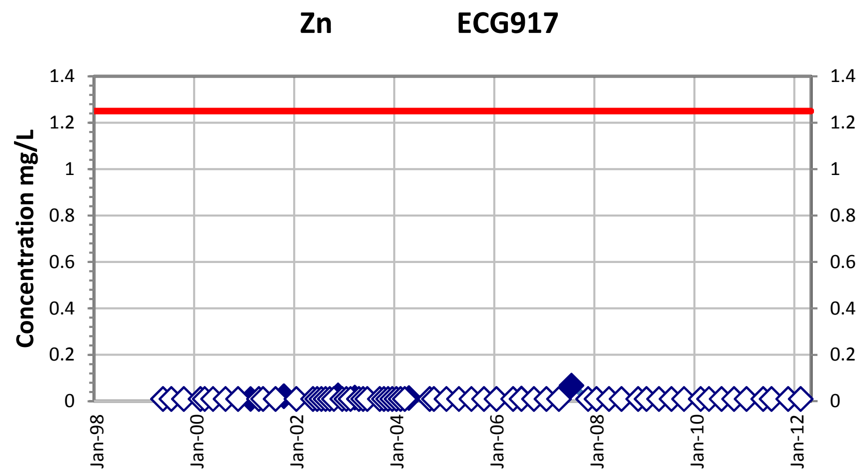

Cd ECG916
Concentration mg/L
0.0014
0.0013
0.0012
0.0011
0.001
0.0009
0.0008
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12

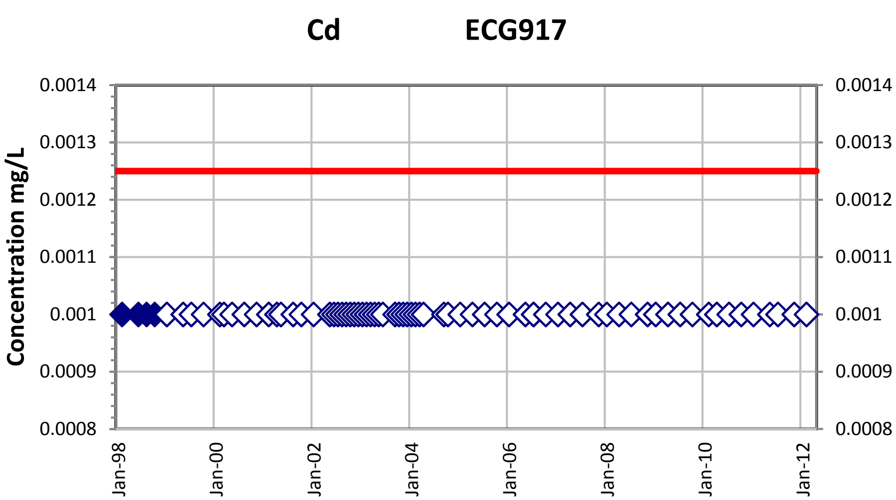

pH ECG916
pH
9
8
7
6
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12

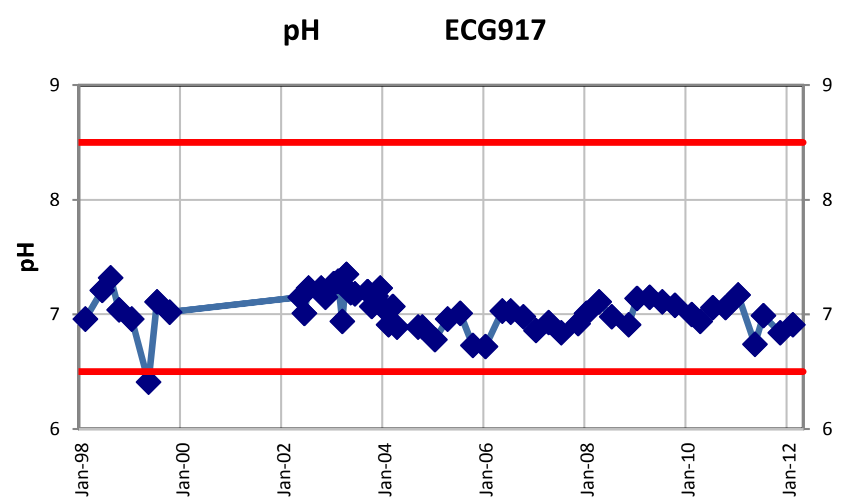

TDS ECG917
Concentration mg/L
1500
1400
1300
1200
1100
1000
900
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12

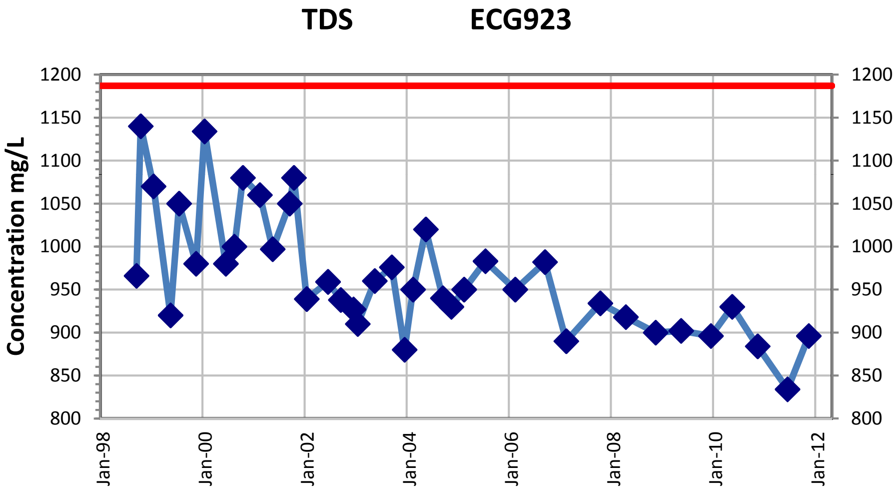

SO4 ECG917
Concentration mg/L
170
160
150
140
130
120
110
100
90
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12


Cu ECG917
Concentration mg/L
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12

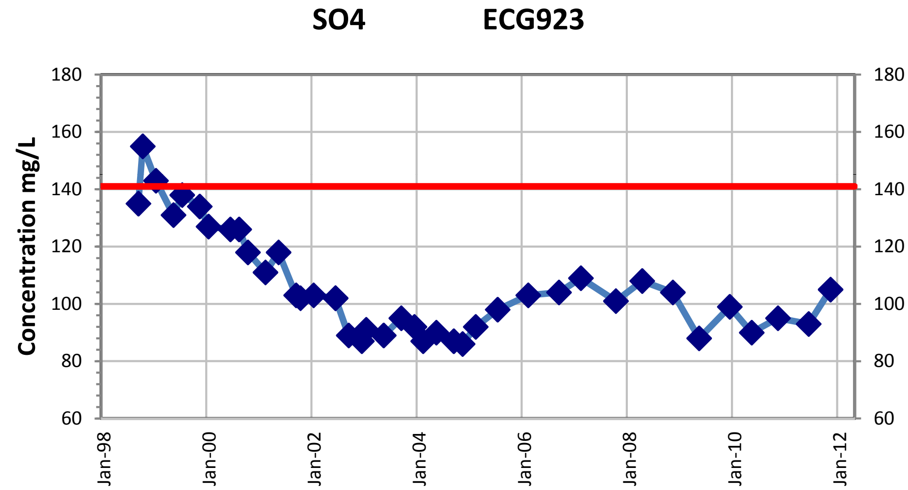

Zn ECG917
Concentration mg/L
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12


Cd ECG917
Concentration mg/L
0.0014
0.0013
0.0012
0.0011
0.001
0.0009
0.0008
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12

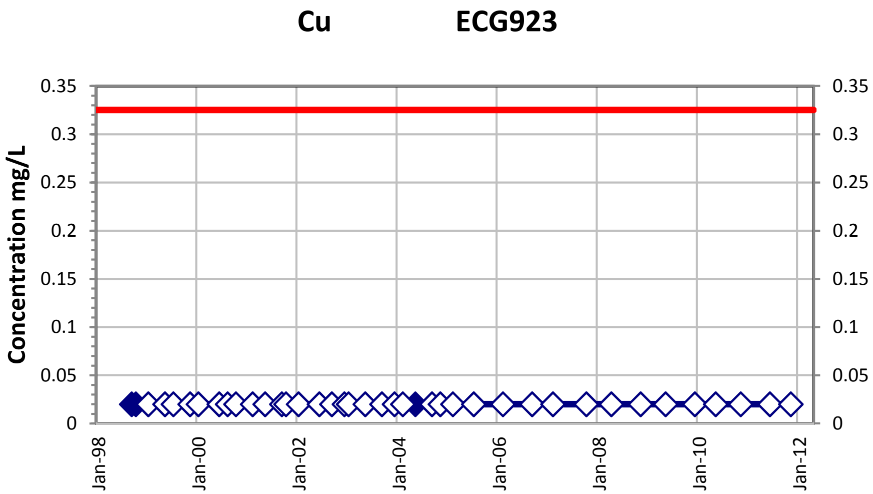

pH ECG917
pH
9
8
7
6
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12



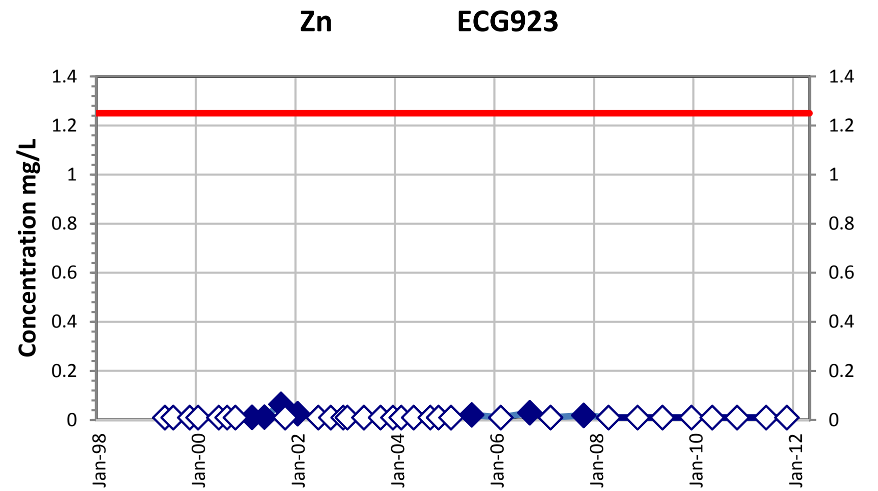
TDS ECG923
Concentration mg/L
1200
1150
1100
1050
1000
950
900
850
800
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12



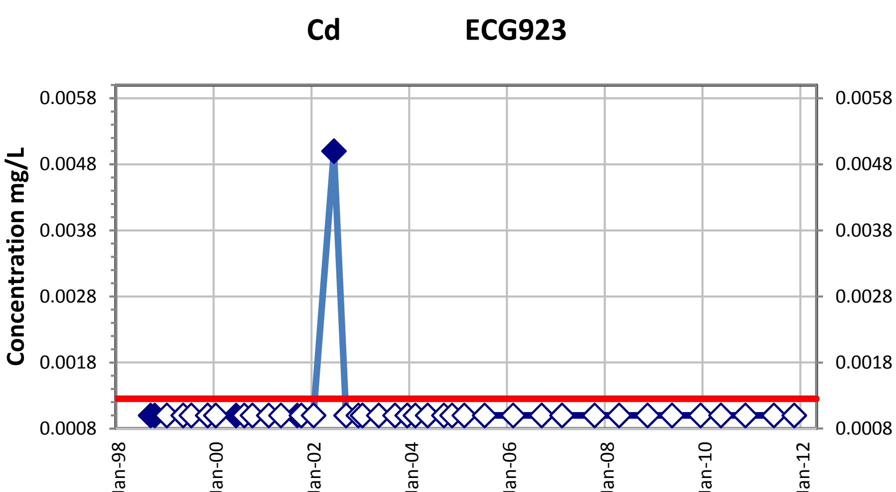
SO4 ECG923
Concentration mg/L
180
160
140
120
100
80
60
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12



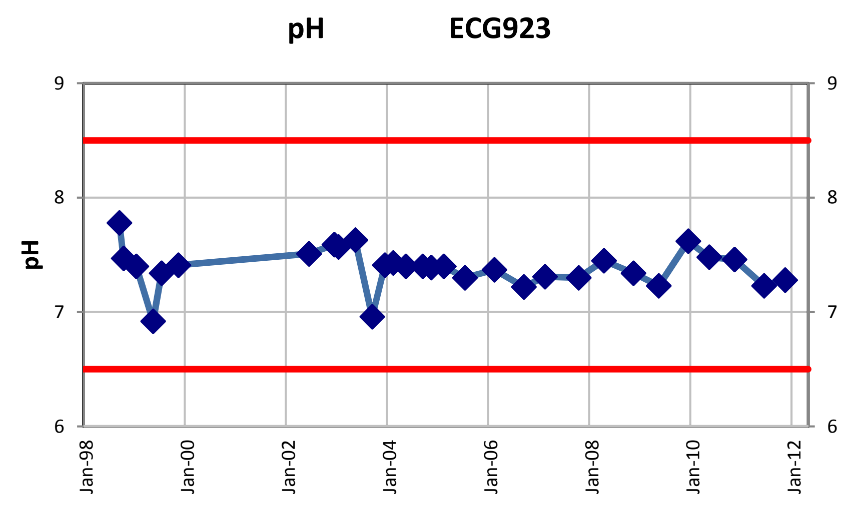
Cu ECG923
Concentration mg/L
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12



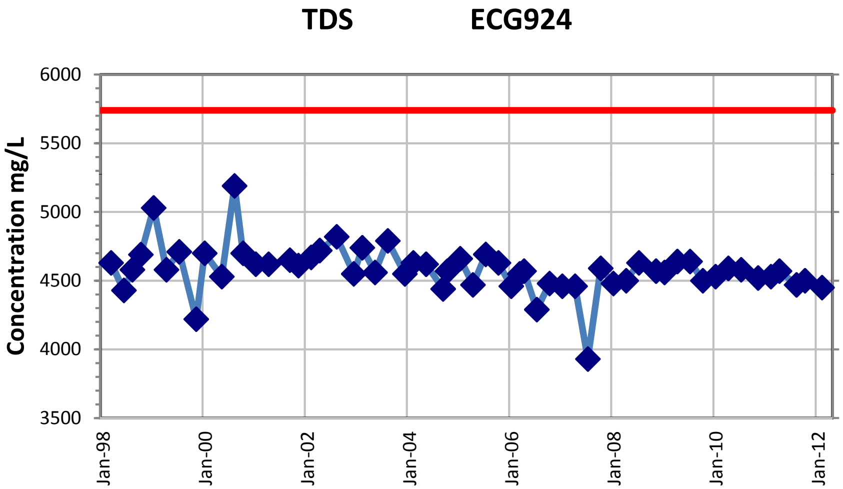
Zn ECG923
Concentration mg/L
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12

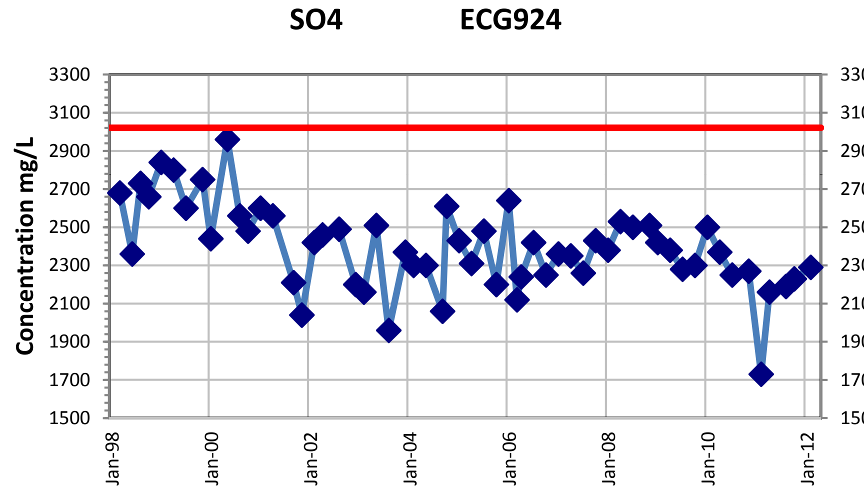


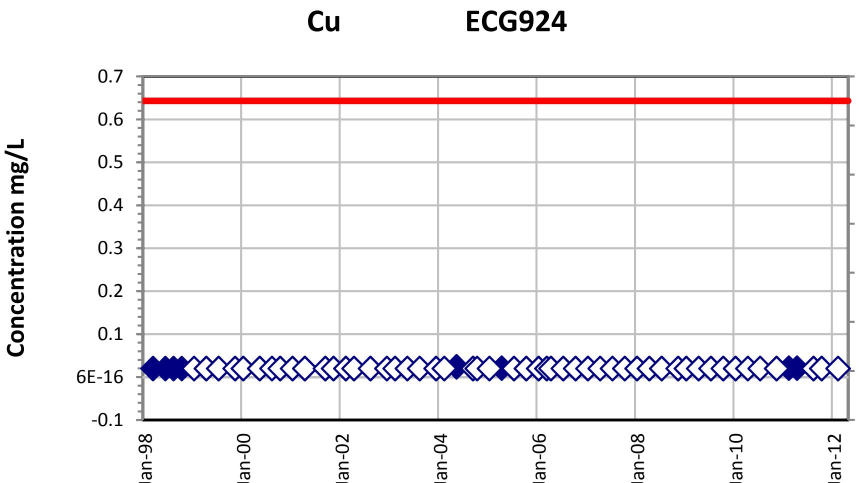
Cd ECG923
Concentration mg/L
0.0058
0.0048
0.0038
0.0028
0.0018
0.0008
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12

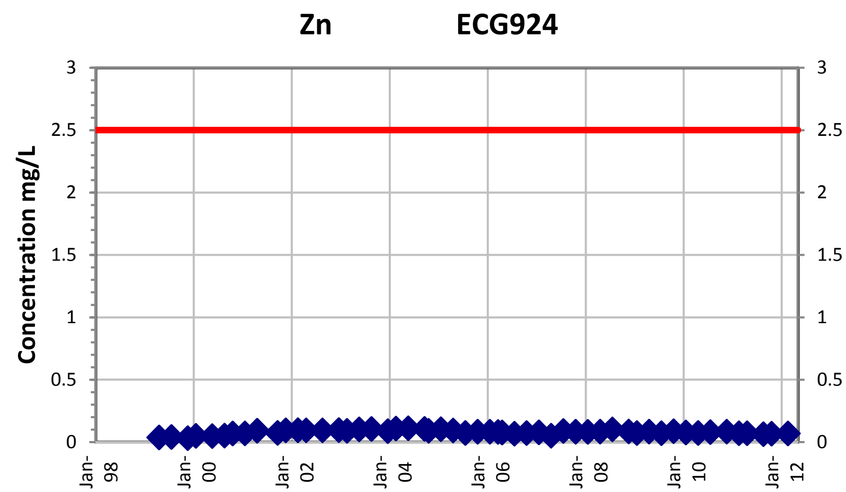


pH ECG923
pH
9
8
7
6
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12


TDS ECG924
Concentration mg/L
6000
5500
5000
4500
4000
3500
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12


SO4 ECG924
Concentration mg/L
3300
3100
2900
2700
2500
2300
2100
1900
1700
1500
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12


Cu ECG924
Concentration mg/L
0.7
0.6
0.5
0.4
0.3
0.2
0.1
6E-16
-0.1
0
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12


Zn ECG924
Concentration mg/L
3
2.5
2
1.5
1
0.5
0
Jan-98
Jan-00
Jan-02
Jan-04
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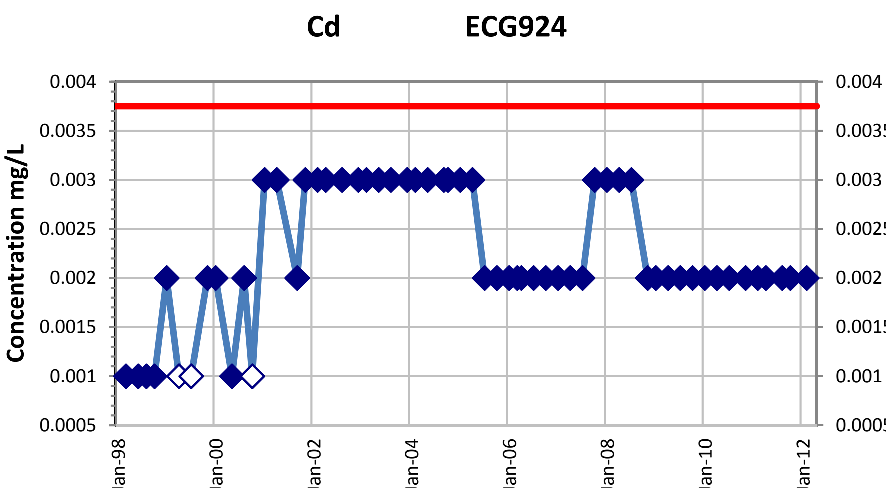
Jan-08
Jan-10
Jan-12


Cd ECG924
Concentration mg/L
0.004
0.0035
0.003
0.0025
0.002
0.0015
0.001
0.0005
Jan-98
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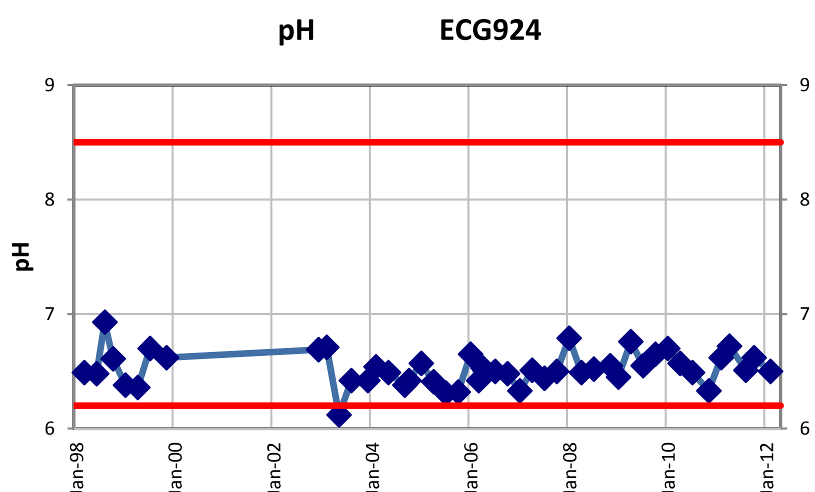
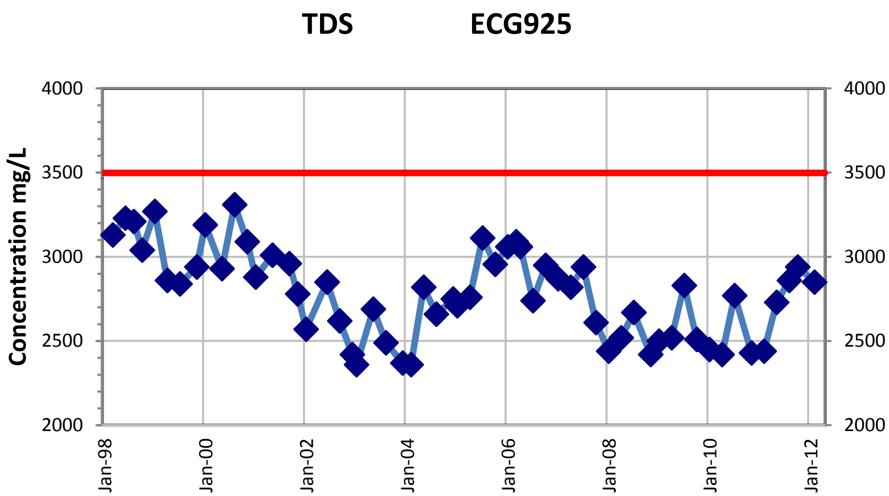
Jan-08
Jan-10
Jan-12


pH ECG924
pH
9
8
7
6
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12


TDS ECG925
Concentration mg/L
4000
3500
3000
2500
2000
Jan-98
Jan-00
Jan-02
Jan-04
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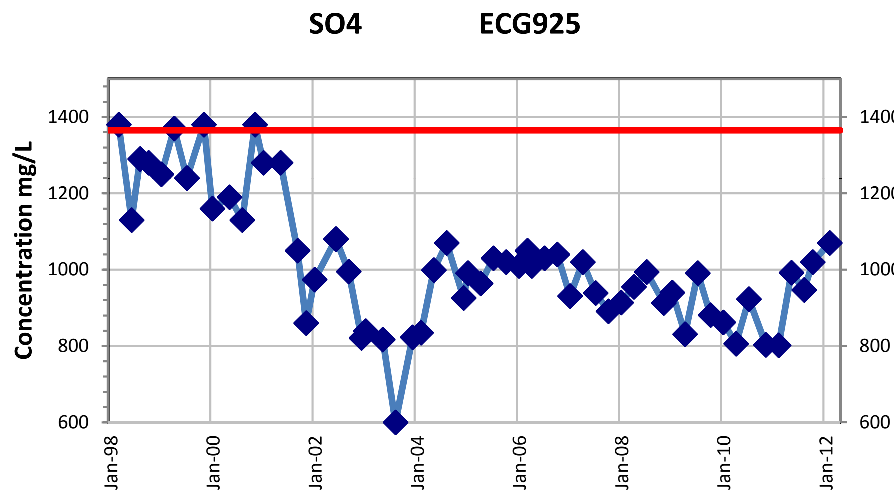
Jan-08
Jan-10
Jan-12


SO4 ECG925
Concentration mg/L
1400
1200
1000
800
600
Jan-98
Jan-00
Jan-02
Jan-04
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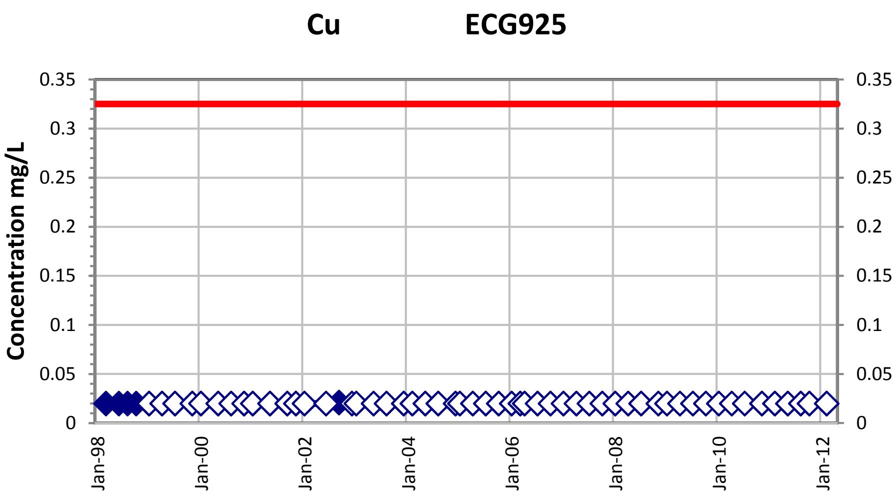
Jan-08
Jan-10
Jan-12


Cu ECG925
Concentration mg/L
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Jan-98
Jan-00
Jan-02
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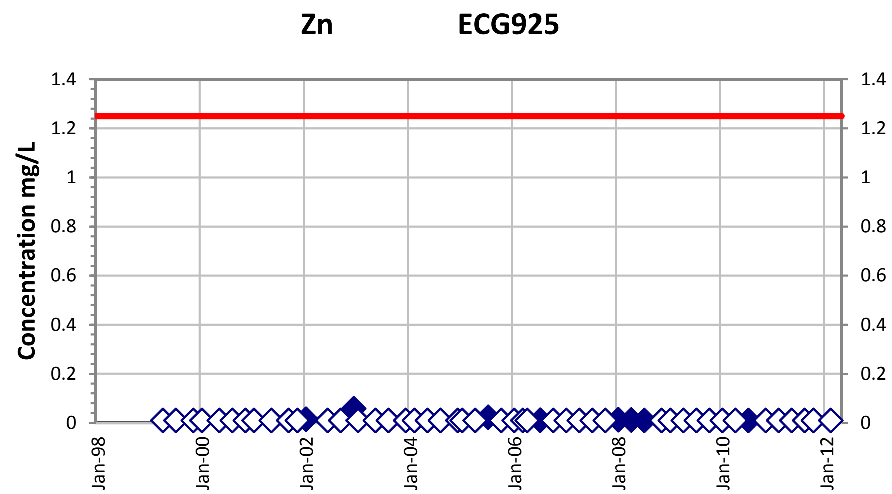
Jan-08
Jan-10
Jan-12


Zn ECG925
Concentration mg/L
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Jan-98
Jan-00
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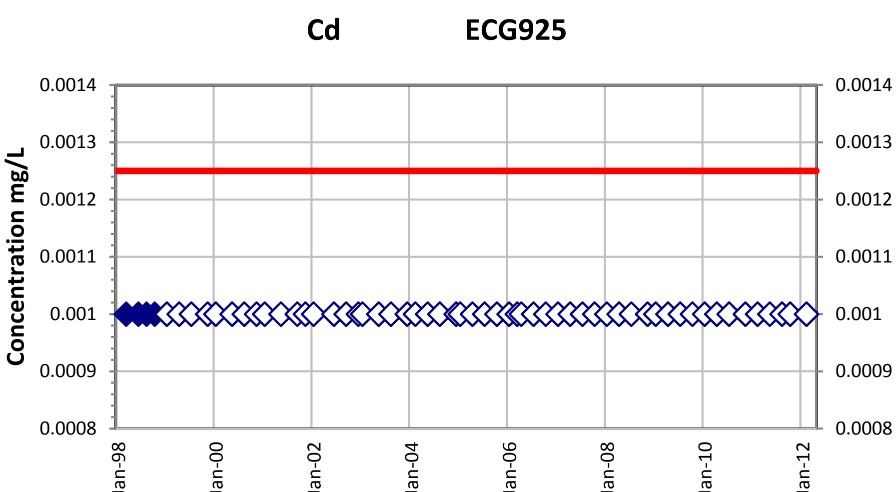
Jan-08
Jan-10
Jan-12


Cd ECG925
Concentration mg/L
0.0014
0.0013
0.0012
0.0011
0.001
0.0009
0.0008
Jan-98
Jan-00
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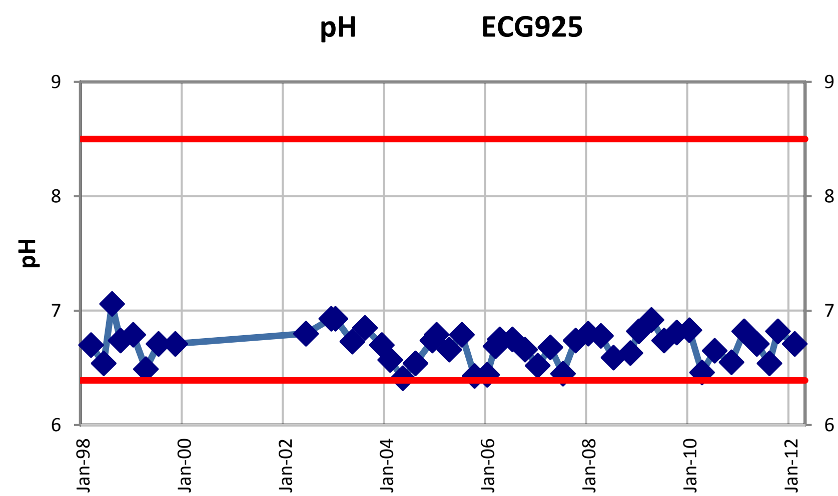
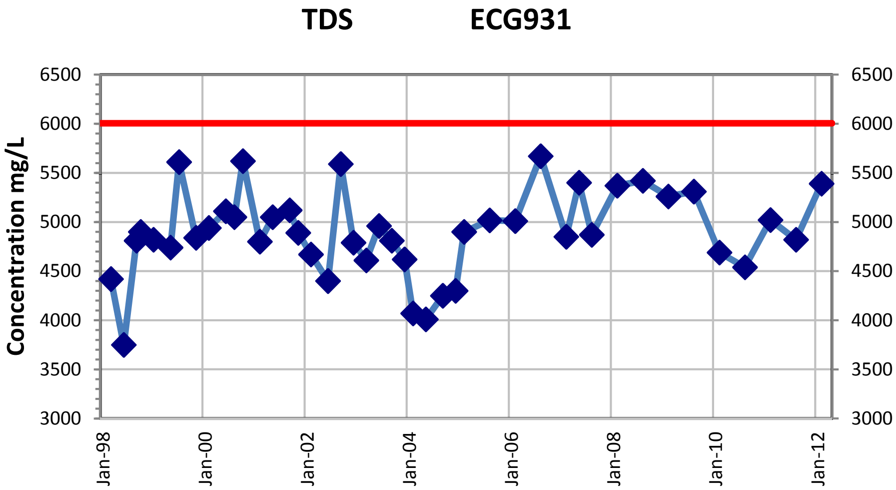
Jan-08
Jan-10
Jan-12


pH ECG925
pH
9
8
7
6
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12


TDS ECG931
Concentration mg/L
6500
6000
5500
5000
4500
4000
3500
3000
Jan-98
Jan-00
Jan-02
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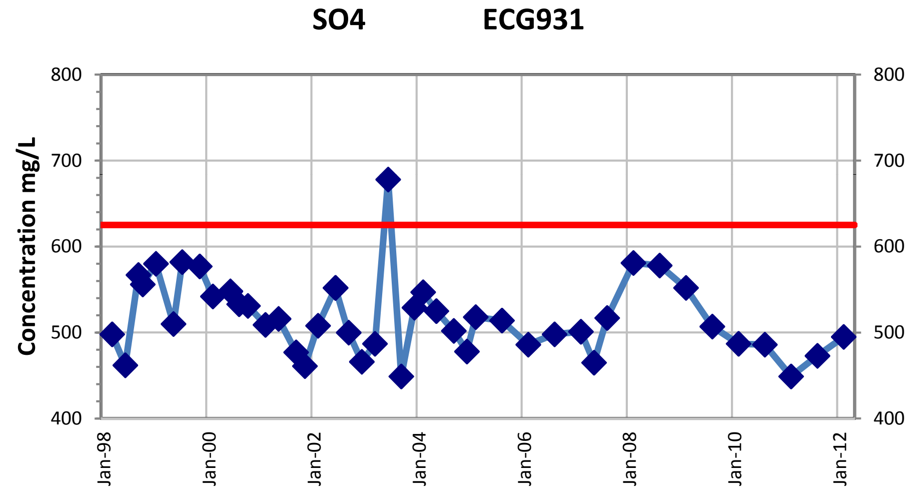
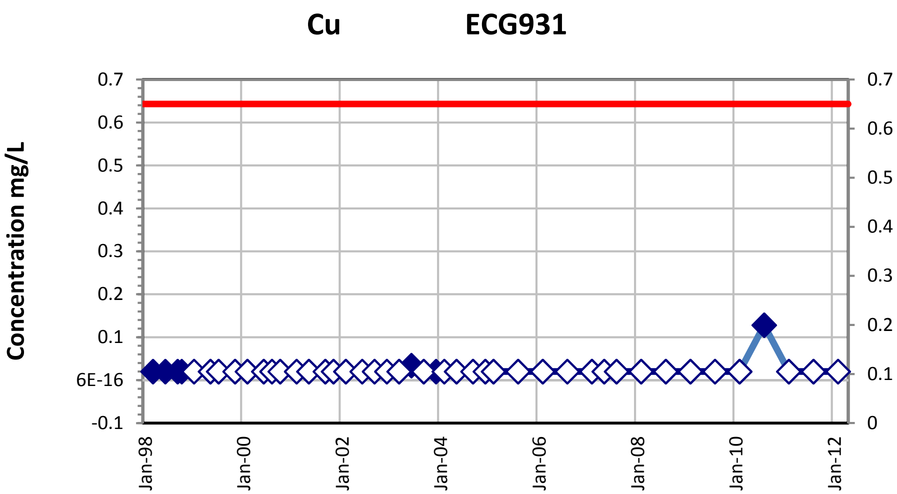
Jan-08
Jan-10
Jan-12


SO4 ECG931
Concentration mg/L
800
700
600
500
400
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12


Cu ECG931
Concentration mg/L
0.7
0.6
0.5
0.4
0.3
0.2
0.1
6E-16
-0.1
0
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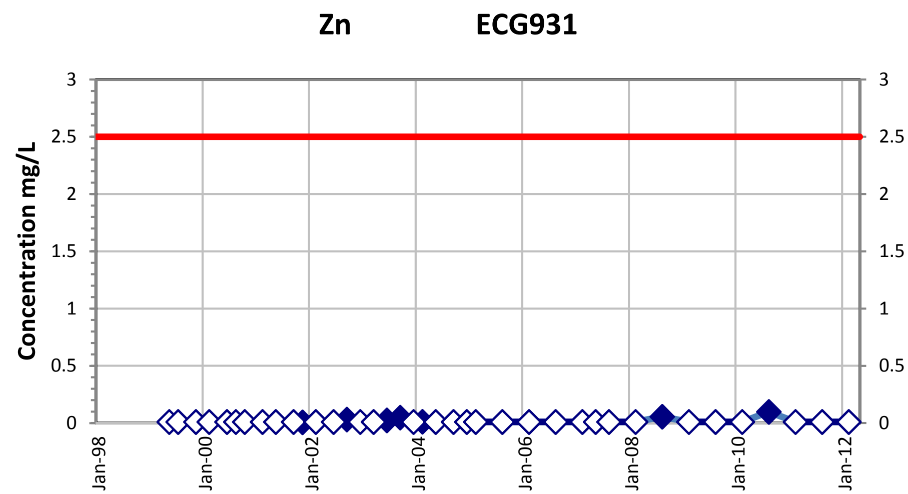
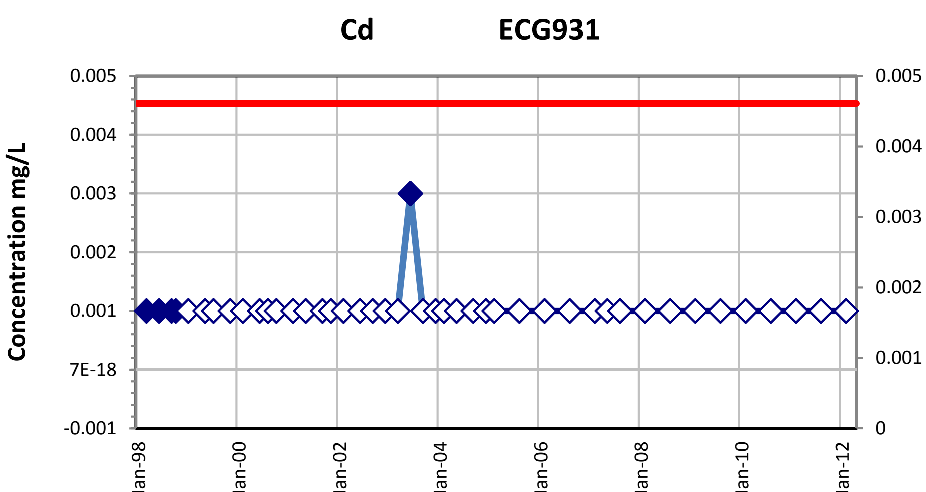
Jan-08
Jan-10
Jan-12


Zn ECG931
Concentration mg/L
3
2.5
2
1.5
1
0.5
0
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12


Cd ECG931
Concentration mg/L
0.005
0.004
0.003
0.002
0.001
7E-18
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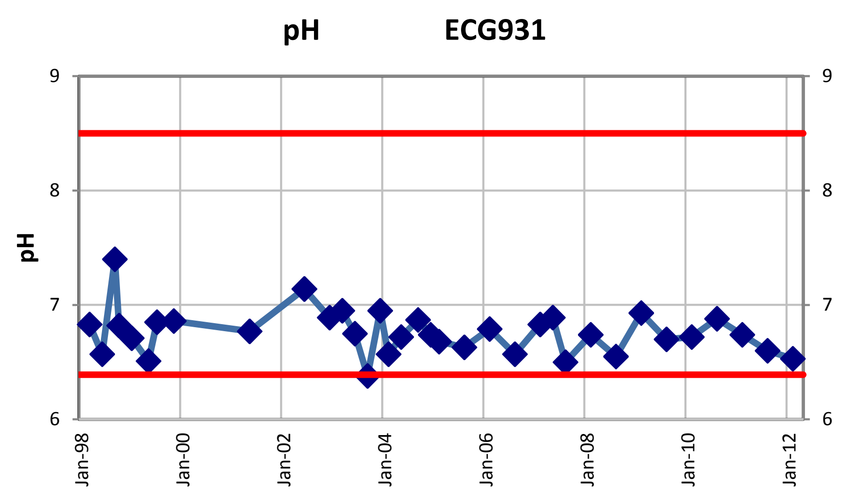
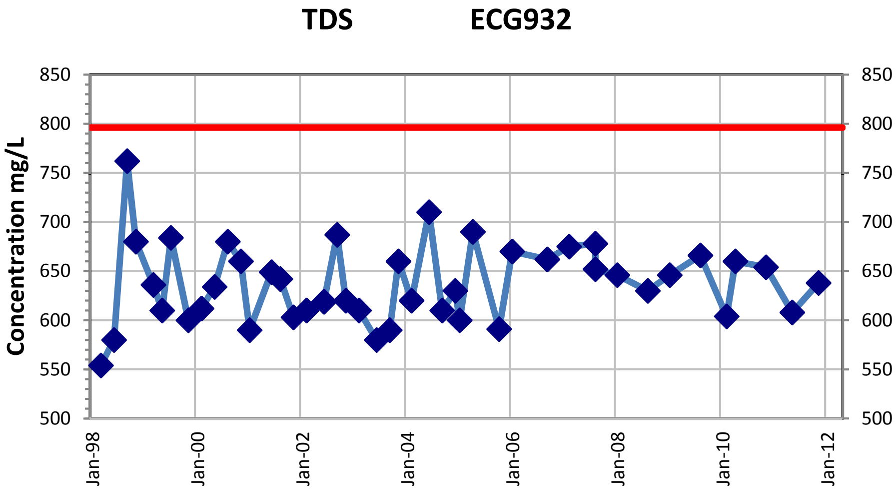
0
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12


pH ECG931
pH
9
8
7
6
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12


TDS ECG932
Concentration mg/L
850
800
750
700
650
600
550
500
Jan-98
Jan-00
Jan-02
Jan-04
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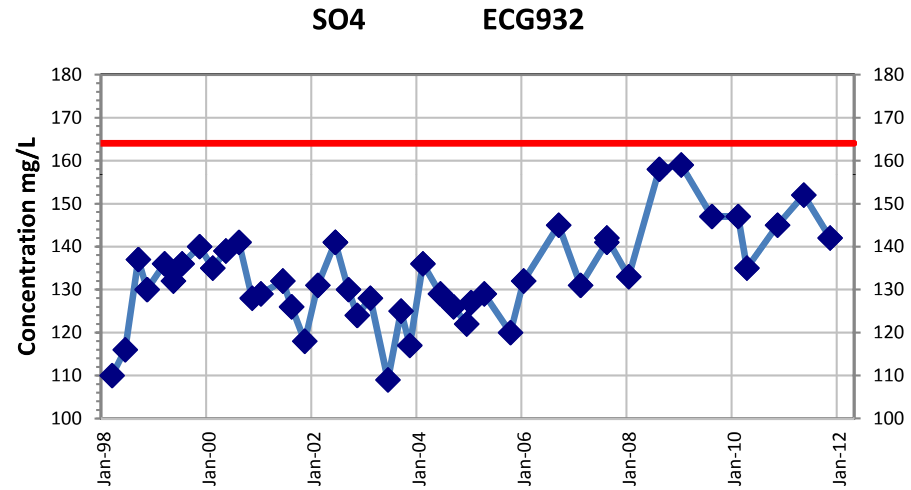
Jan-08
Jan-10
Jan-12


SO4 ECG932
Concentration mg/L
180
170
160
150
140
130
120
110
100
Jan-98
Jan-00
Jan-02
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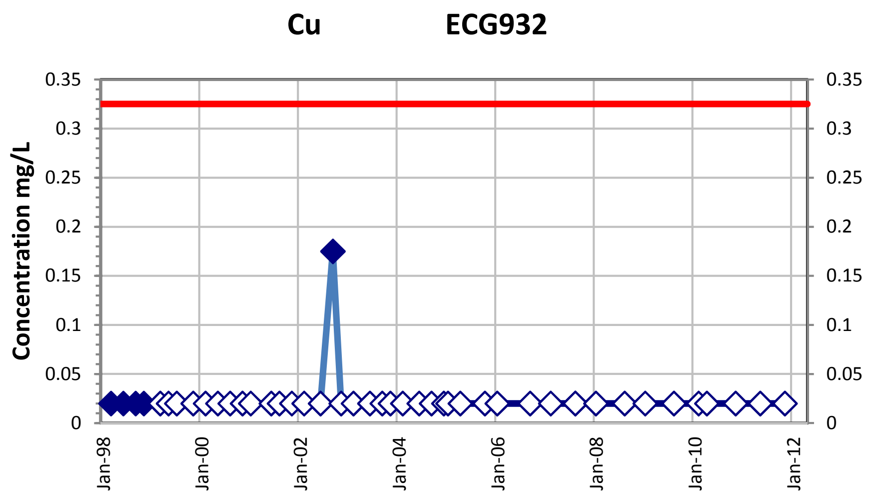
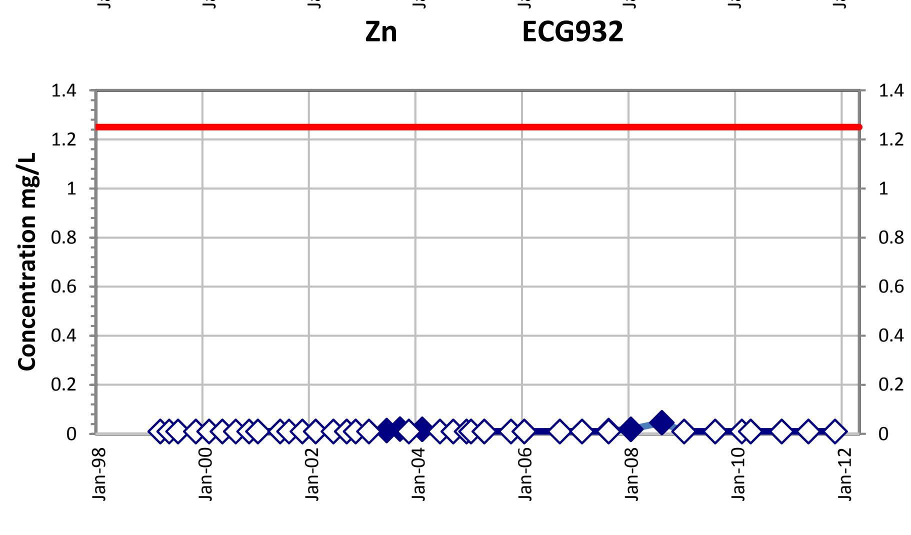
Jan-08
Jan-10
Jan-12


Cu ECG932
Concentration mg/L
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12


Zn ECG932
Concentration mg/L
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Jan-98
Jan-00
Jan-02
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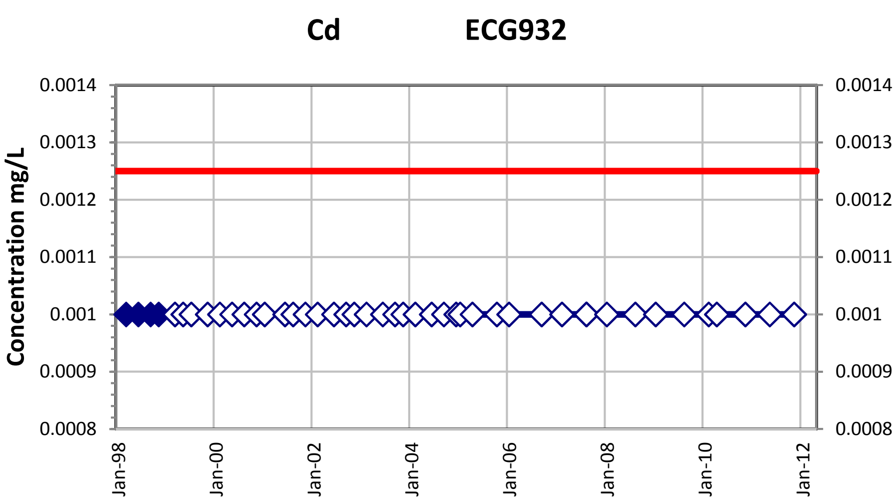
Jan-08
Jan-10
Jan-12


Cd ECG932
Concentration mg/L
0.0014
0.0013
0.0012
0.0011
0.001
0.0009
0.0008
Jan-98
Jan-00
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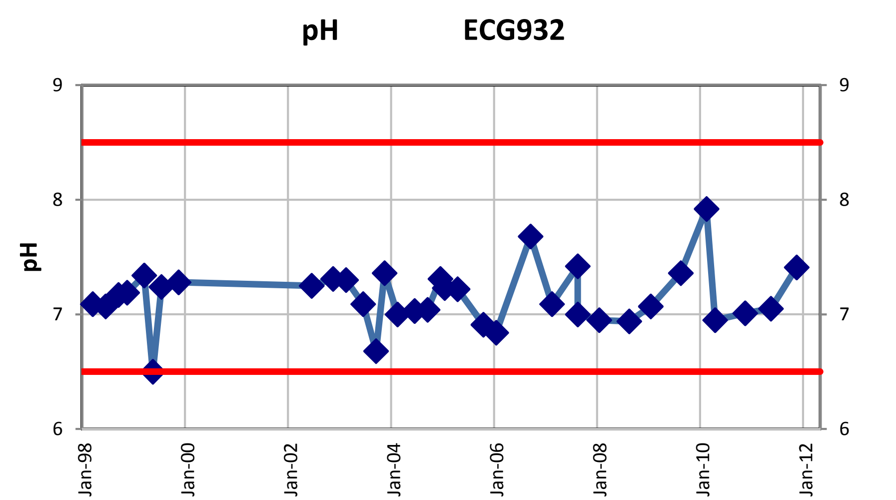
Jan-08
Jan-10
Jan-12


pH ECG932
pH
9
8
7
6
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
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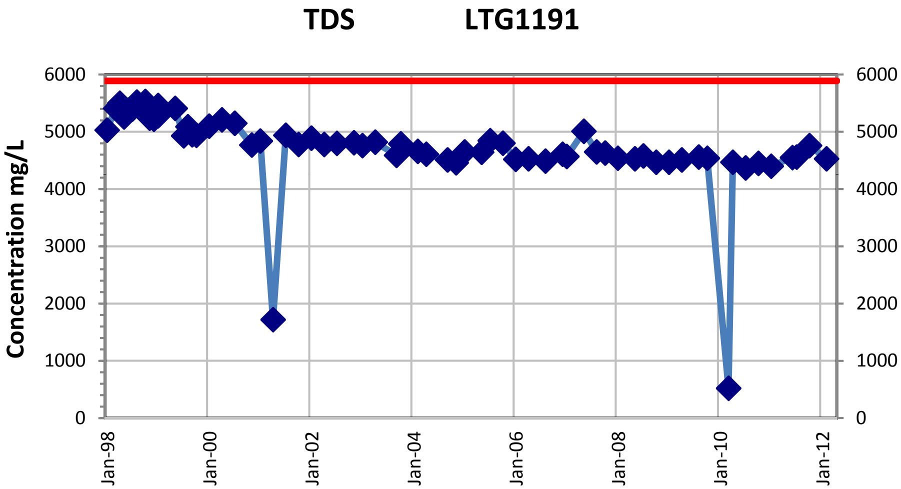
Jan-10
Jan-12


TDS LTG1191
Concentration mg/L
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5000
4000
3000
2000
1000
0
Jan-98
Jan-00
Jan-02
Jan-04
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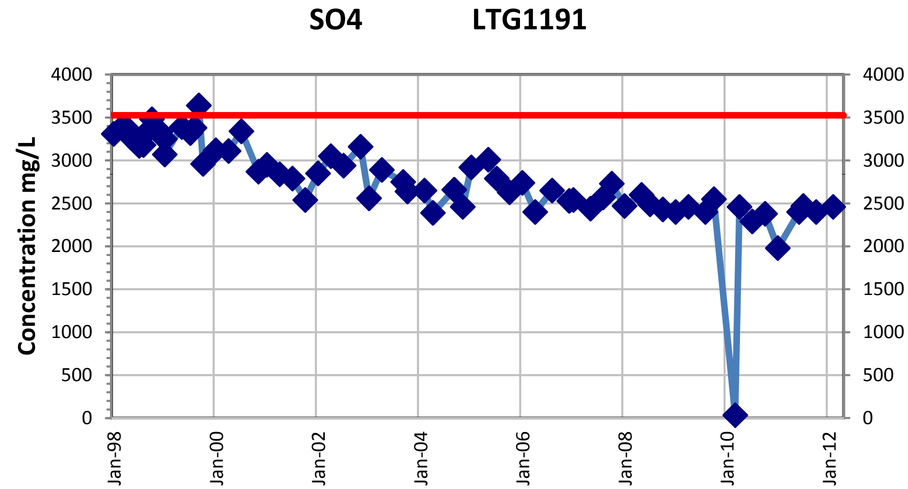
Jan-08
Jan-10
Jan-12


SO4 LTG1191
Concentration mg/L
4000
3500
3000
2500
2000
1500
1000
500
0
Jan-98
Jan-00
Jan-02
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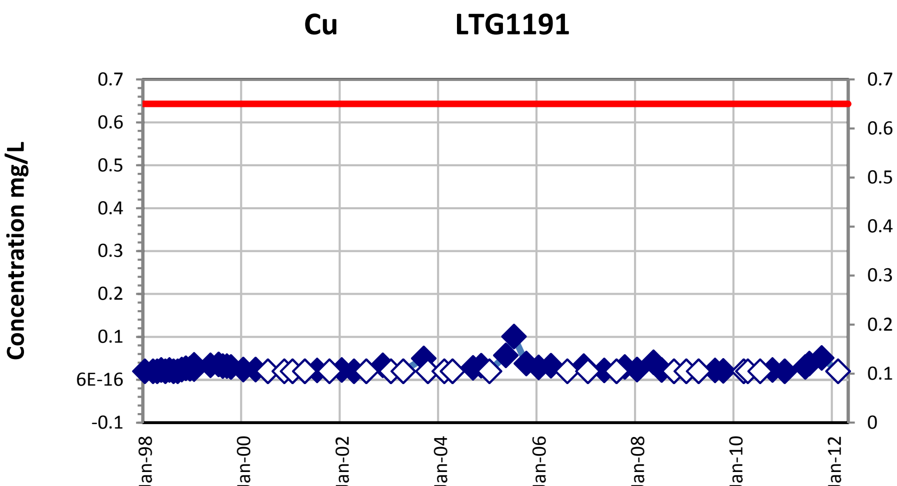
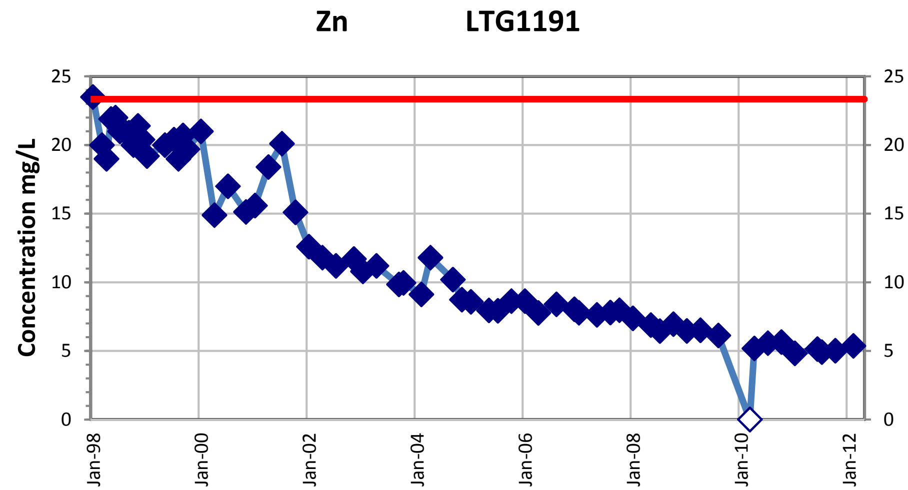
Jan-08
Jan-10
Jan-12


Cu LTG1191
Concentration mg/L
0.7
0.6
0.5
0.4
0.3
0.2
0.1
6E-16
-0.1
0
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12


Zn LTG1191
Concentration mg/L
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20
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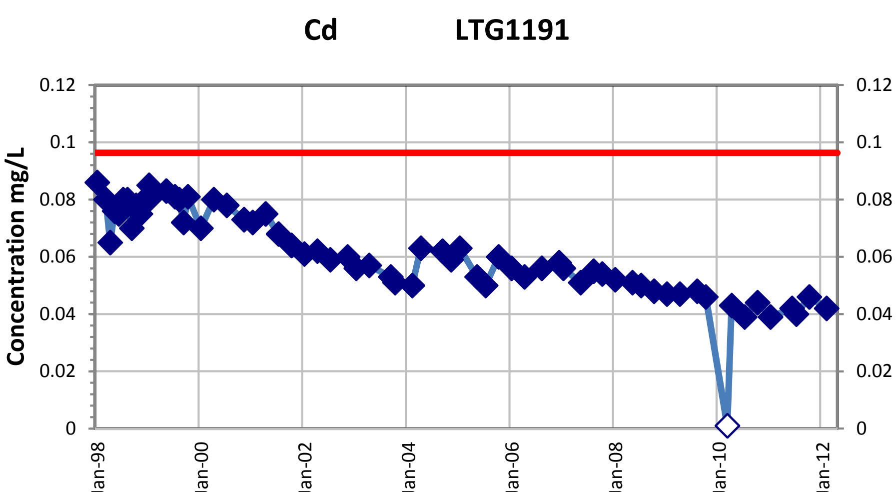
10
5
0
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12


Cd LTG1191
Concentration mg/L
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Jan-98
Jan-00
Jan-02
Jan-04
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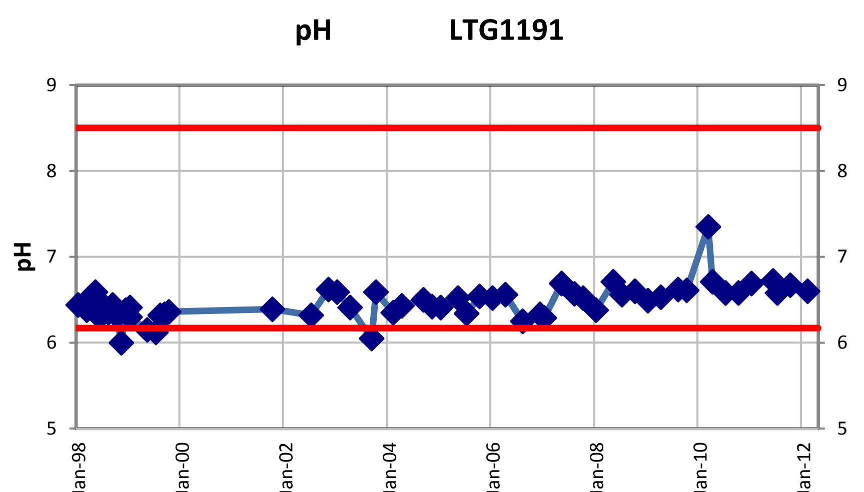
Jan-08
Jan-10
Jan-12


pH LTG1191
pH
9
8
7
6
5
Jan-98
Jan-00
Jan-02
Jan-04
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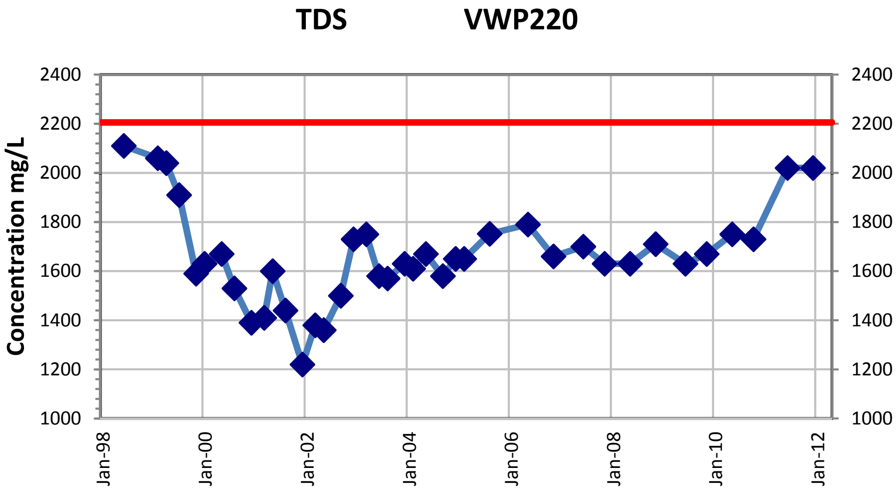
Jan-10
Jan-12


TDS VWP220
Concentration mg/L
2400
2200
2000
1800
1600
1400
1200
1000
Jan-98
Jan-00
Jan-02
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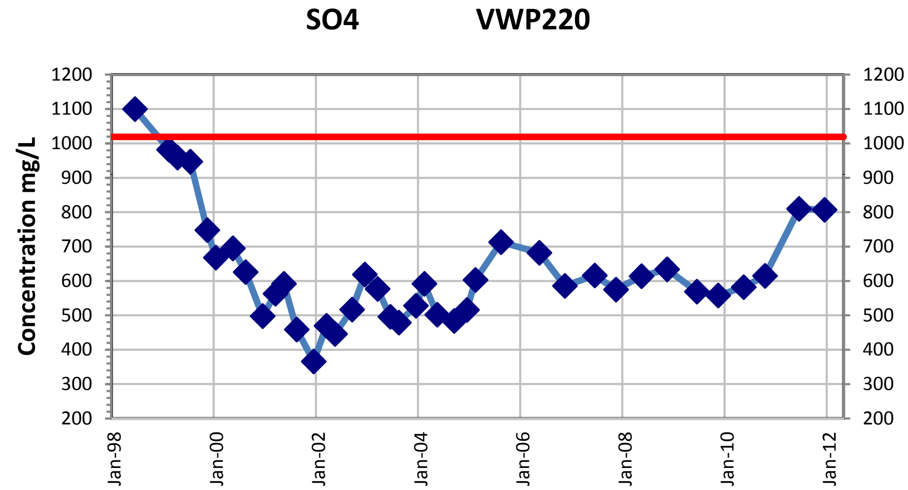
Jan-08
Jan-10
Jan-12


SO4 VWP220
Concentration mg/L
1200
1100
1000
900
800
700
600
500
400
300
200
Jan-98
Jan-00
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Jan-04
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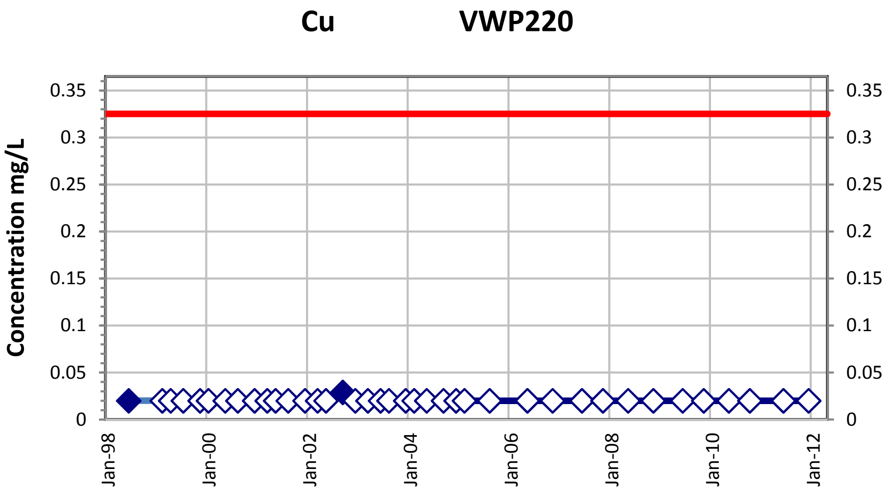
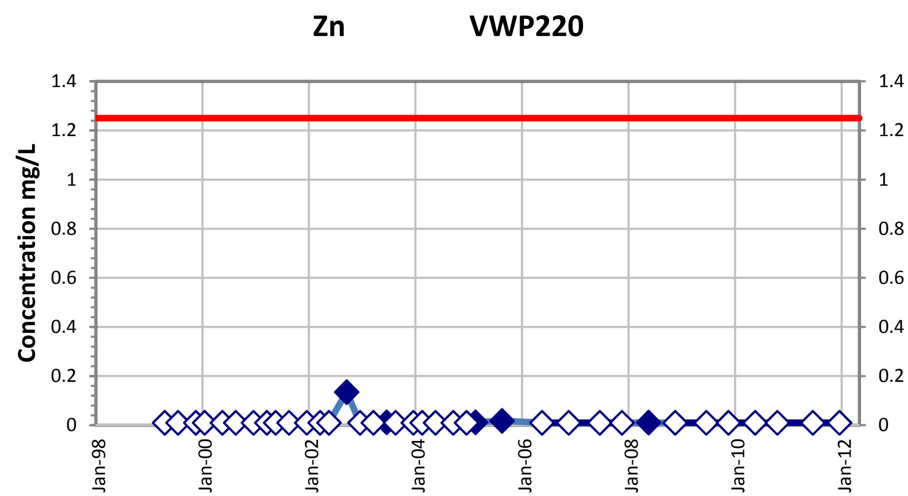
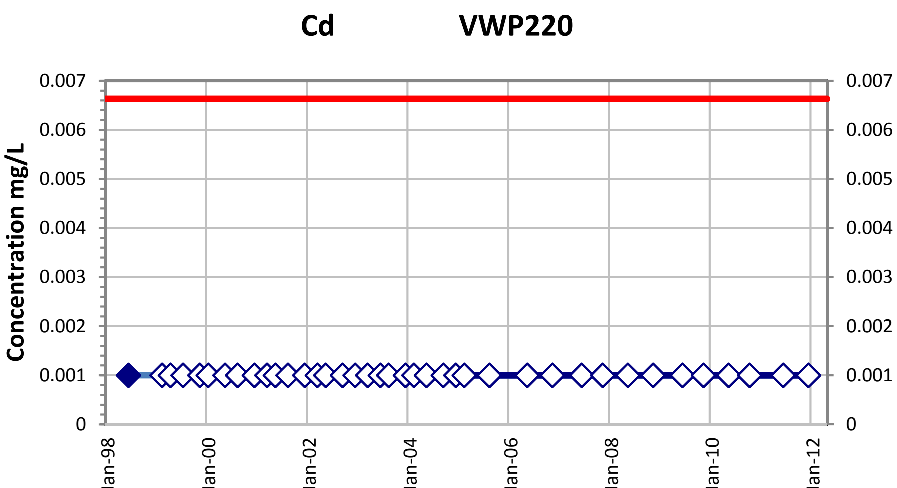
Jan-08
Jan-10
Jan-12


Cu VWP220
Concentration mg/L
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12


Zn VWP220
Concentration mg/L
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12


Cd VWP220
Concentration mg/L
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
Jan-98
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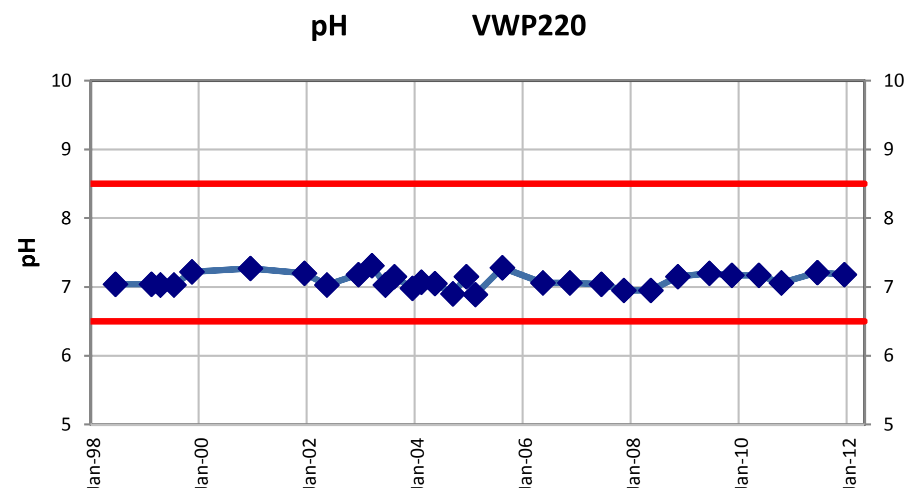
Jan-10
Jan-12


pH VWP220
pH
10
9
8
7
6
5
Jan-98
Jan-00
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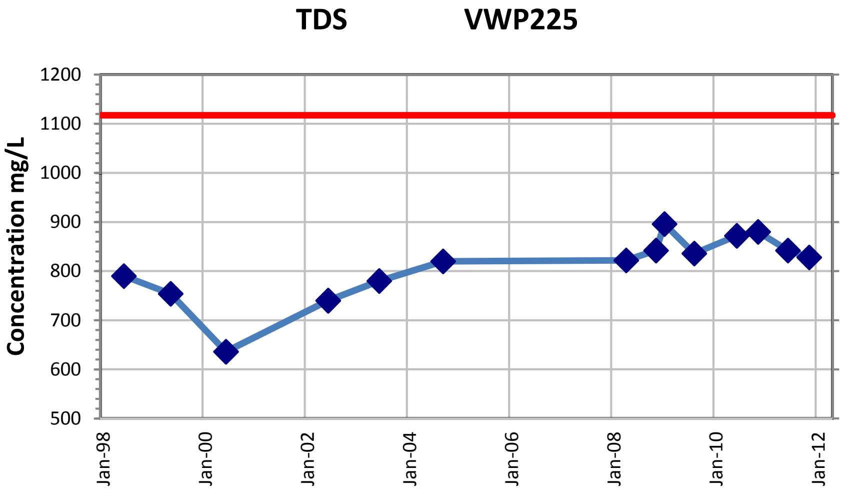
Jan-12


TDS VWP225
Concentration mg/L
1200
1100
1000
900
800
700
600
500
Jan-98
Jan-00
Jan-02
Jan-04
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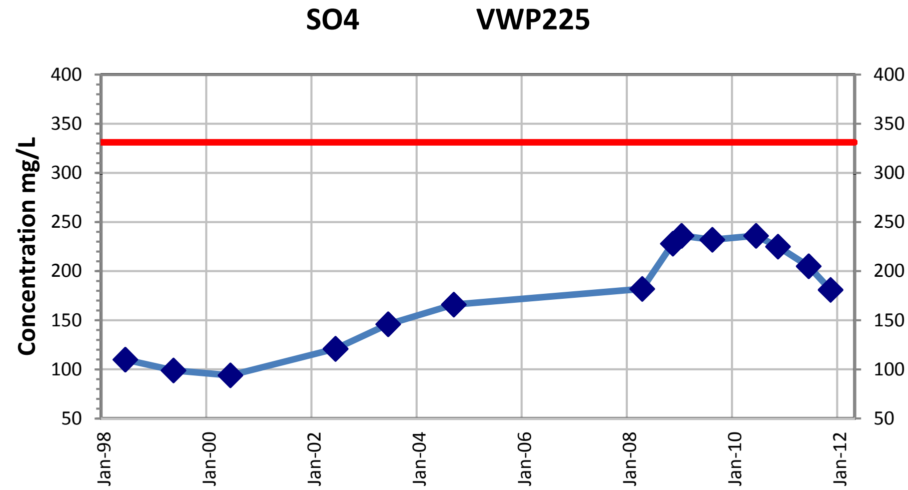
Jan-08
Jan-10
Jan-12


SO4 VWP225
Concentration mg/L
400
350
300
250
200
150
100
50
Jan-98
Jan-00
Jan-02
Jan-04
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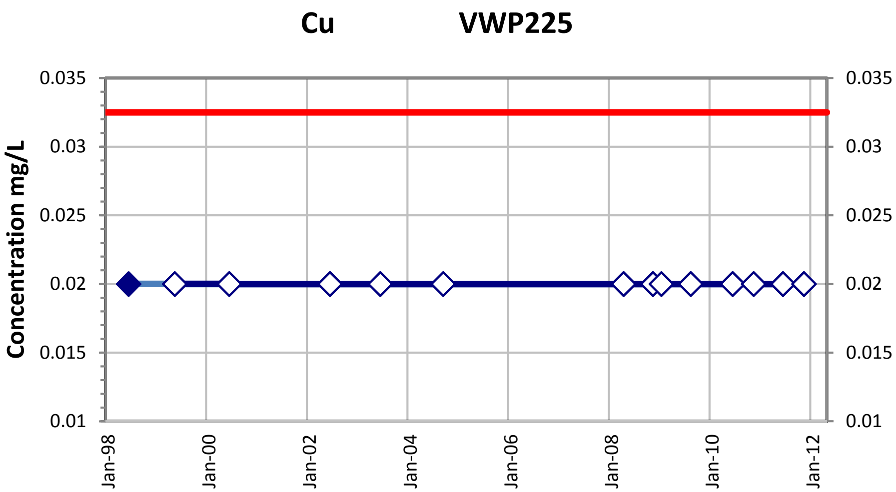
Jan-08
Jan-10
Jan-12


Cu VWP225
Concentration mg/L
0.035
0.03
0.025
0.02
0.015
0.01
Jan-98
Jan-00
Jan-02
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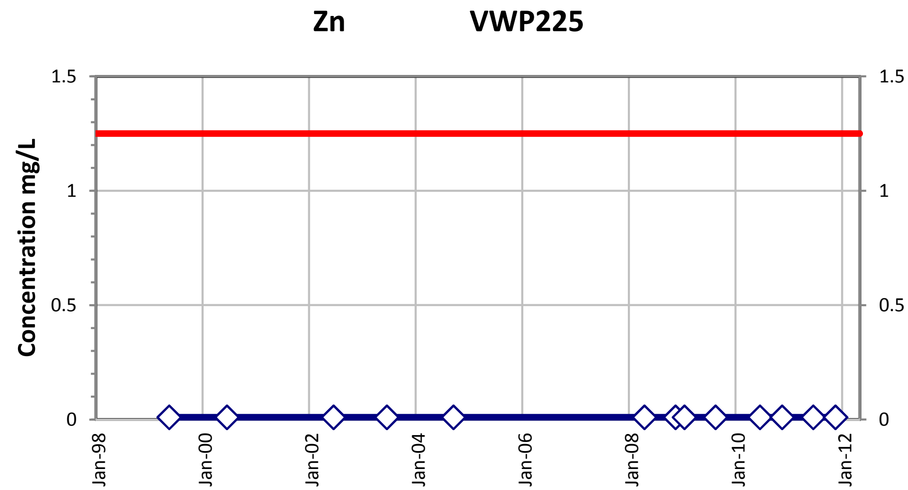
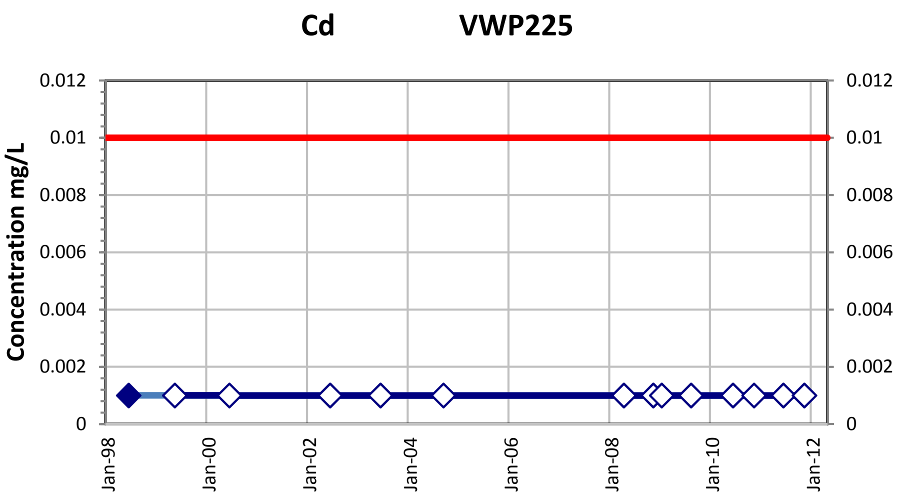
Jan-08
Jan-10
Jan-12


Zn VWP225
Concentration mg/L
1.5
1
0.5
0
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12


Cd VWP225
Concentration mg/L
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0.01
0.008
0.006
0.004
0.002
0
Jan-98
Jan-00
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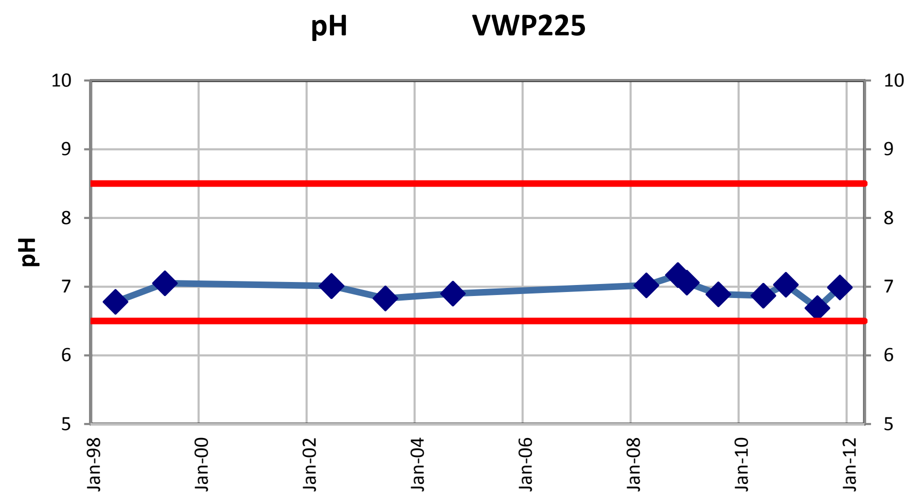
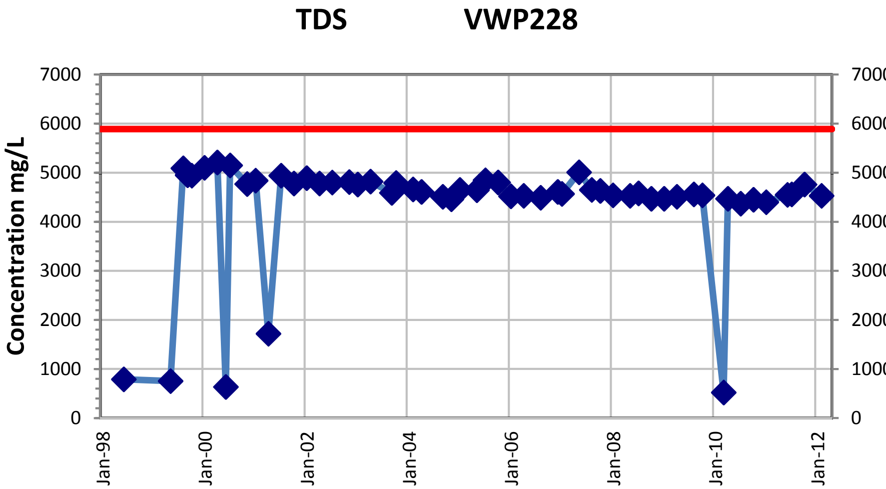
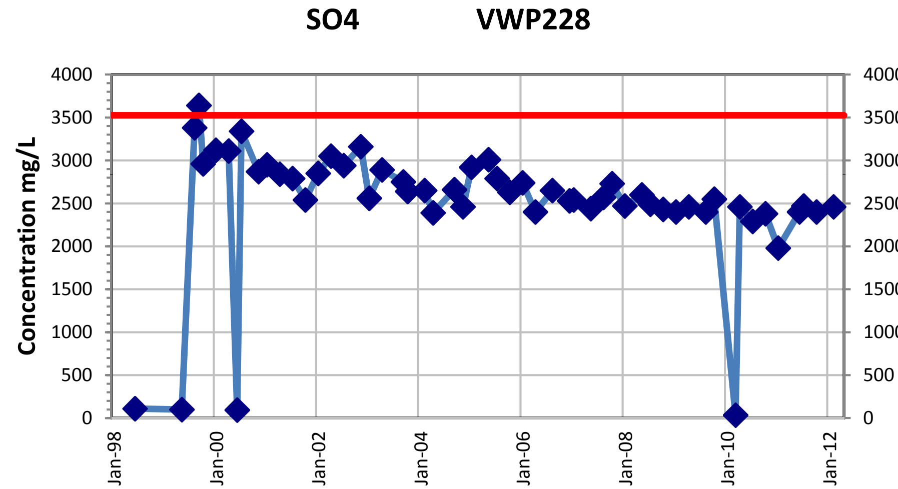
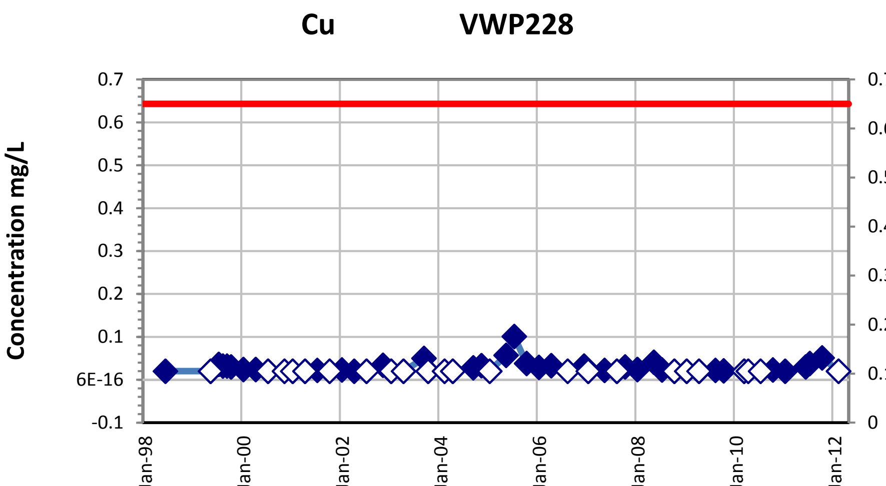
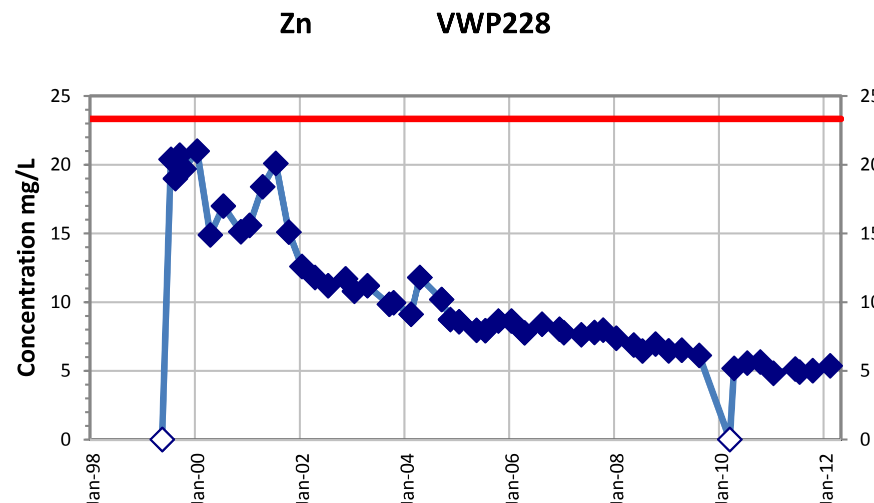
Jan-08
Jan-10
Jan-12

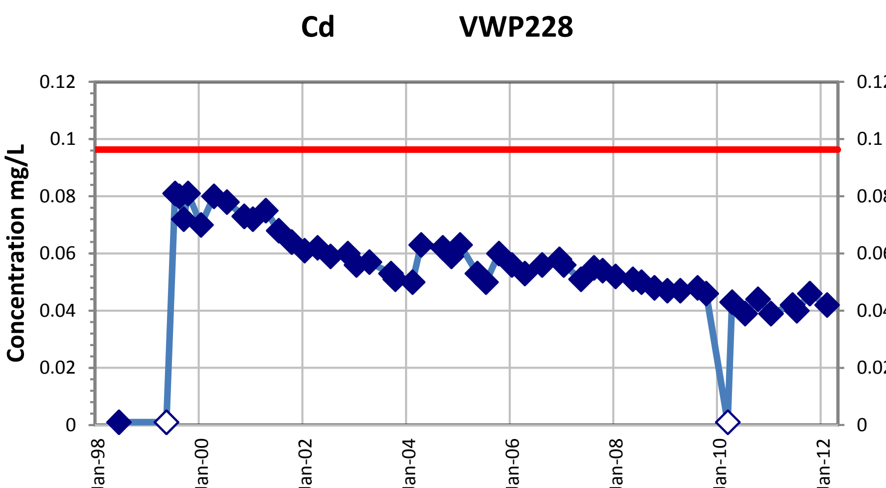

pH VWP225
pH
10
9
8
7
6
5
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12

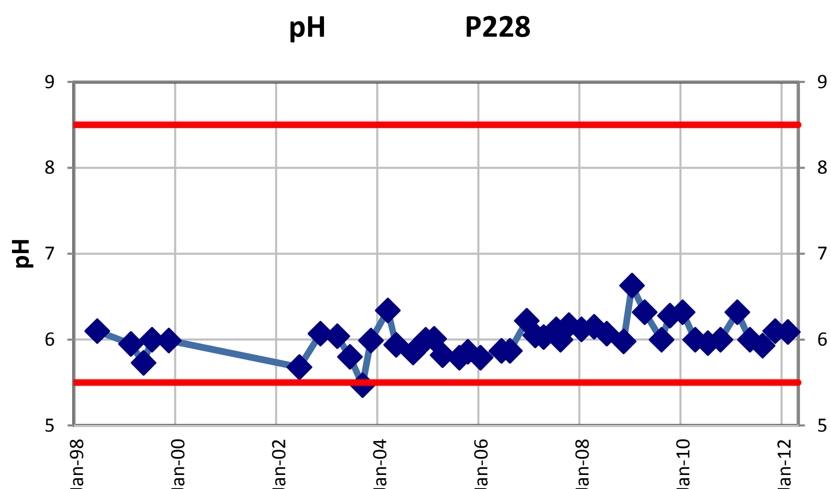

TDS VWP228
Concentration mg/L
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12

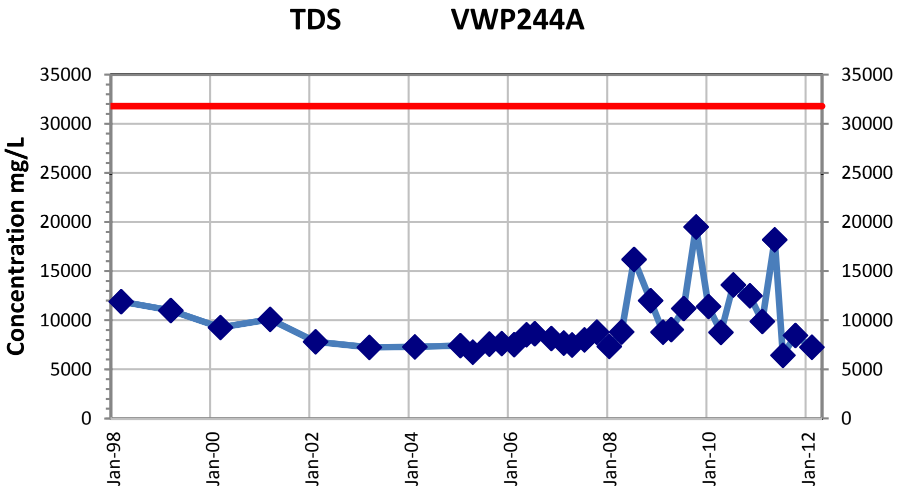

SO4 VWP228
Concentration mg/L
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12

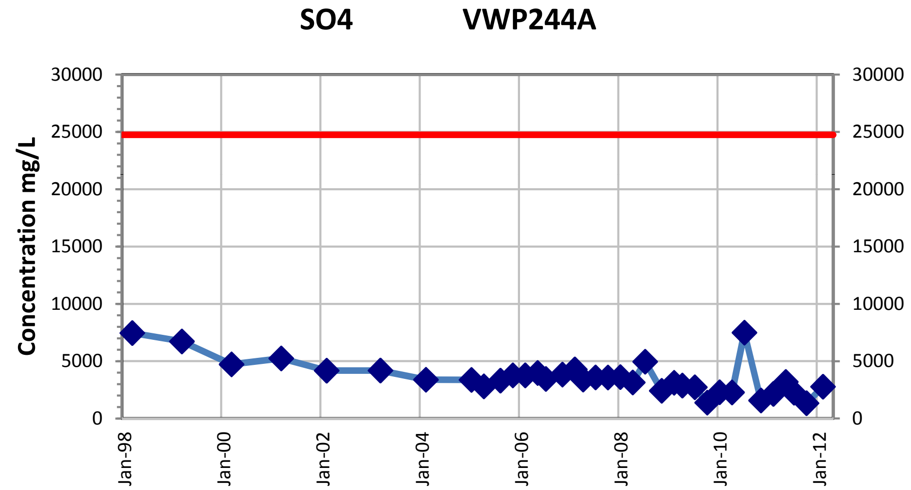

Cu VWP228
Concentration mg/L
6E-16
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12


Zn VWP228
Concentration mg/L
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12


Cd VWP228
Concentration mg/L
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12


pH P228
pH
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12


TDS VWP244A
Concentration mg/L
35000
30000
25000
20000
15000
10000
5000
0
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12


SO4 VWP244A
Concentration mg/L
30000
25000
20000
15000
10000
5000
0
Jan-98
Jan-00
Jan-02
Jan-04
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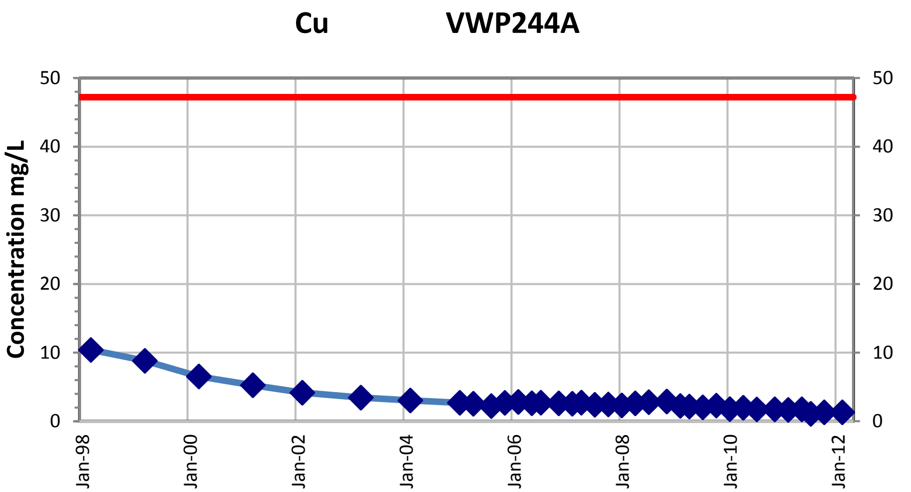
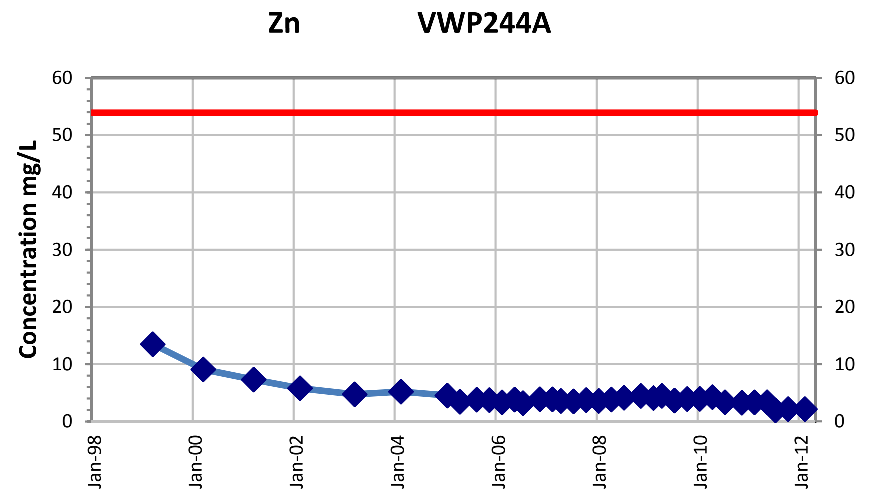
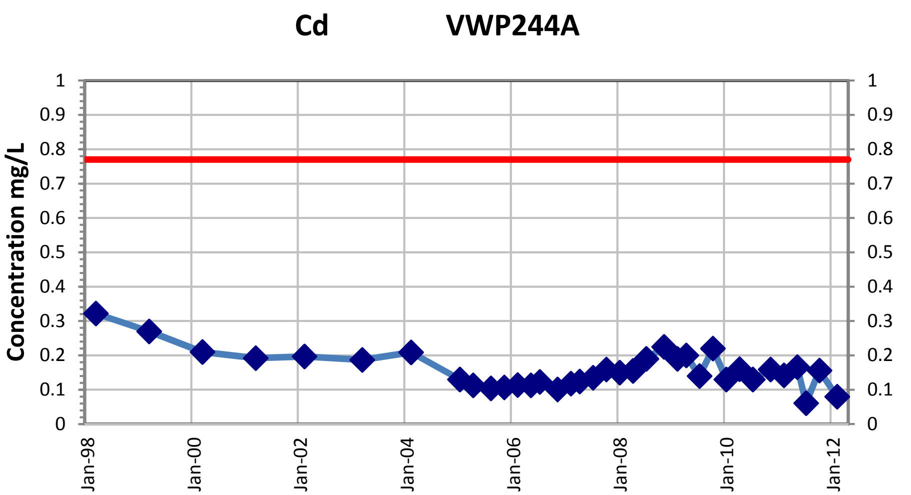
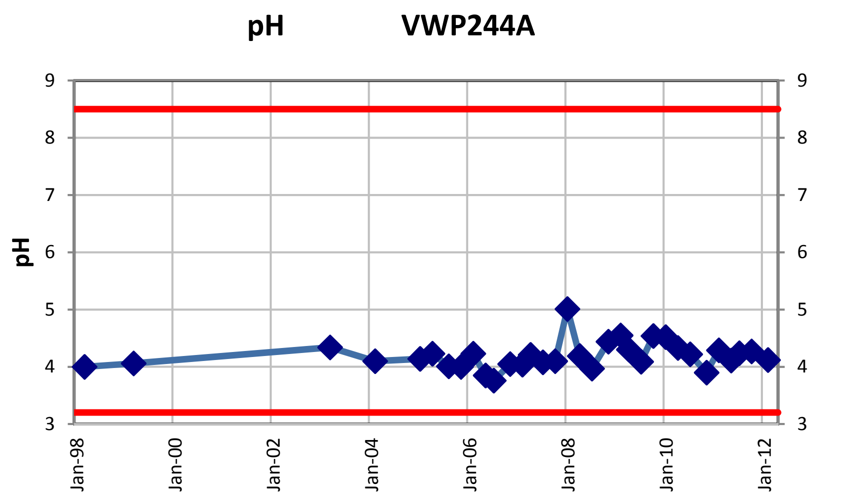
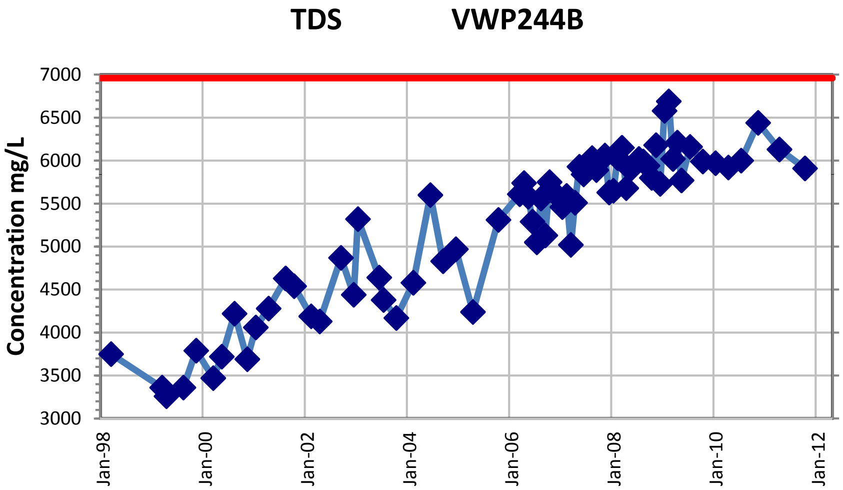
Jan-08
Jan-10
Jan-12


Cu VWP244A
Concentration mg/L
50
40
30
20
10
0
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12


Zn VWP244A
Concentration mg/L
60
50
40
30
20
10
0
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12


Cd VWP244A
Concentration mg/L
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12


pH VWP244A
pH
9
8
7
6
5
4
3
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12


TDS VWP244B
Concentration mg/L
7000
6500
6000
5500
5000
4500
4000
3500
3000
Jan-98
Jan-00
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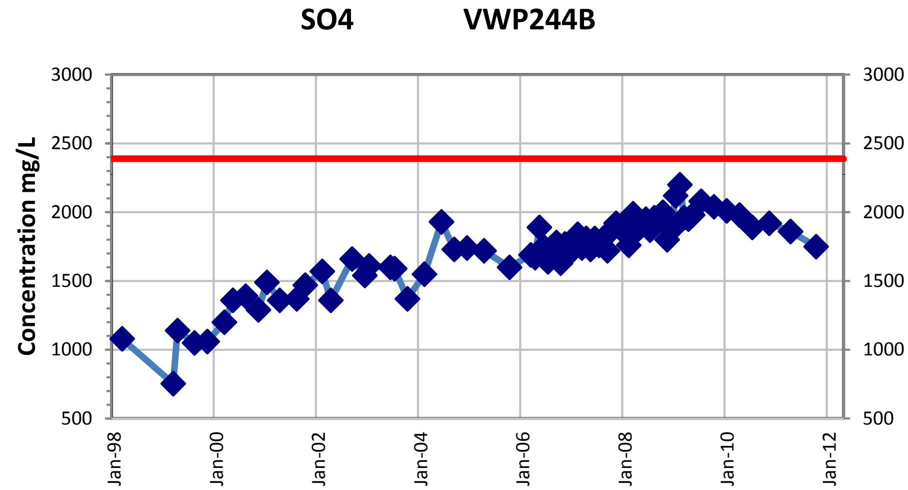
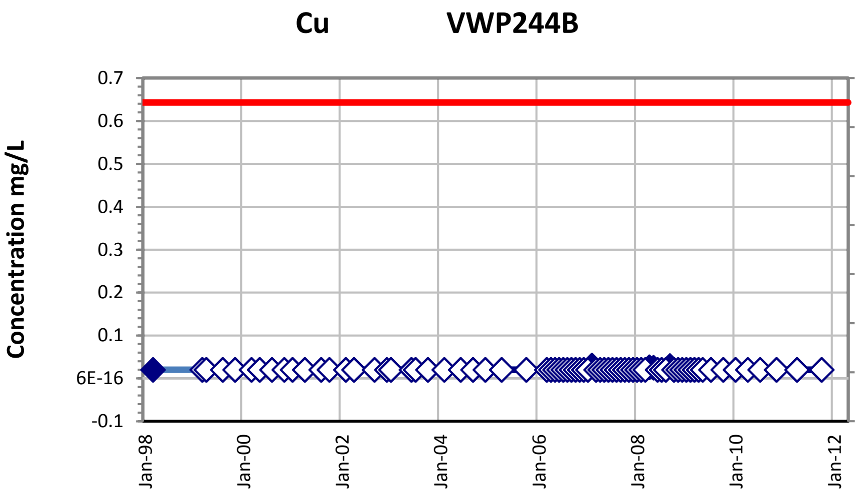
Jan-08
Jan-10
Jan-12


SO4 VWP244B
Concentration mg/L
3000
2500
2000
1500
1000
500
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12


Cu VWP244B
Concentration mg/L
0.7
0.6
0.5
0.4
0.3
0.2
0.1
6E-16
-0.1
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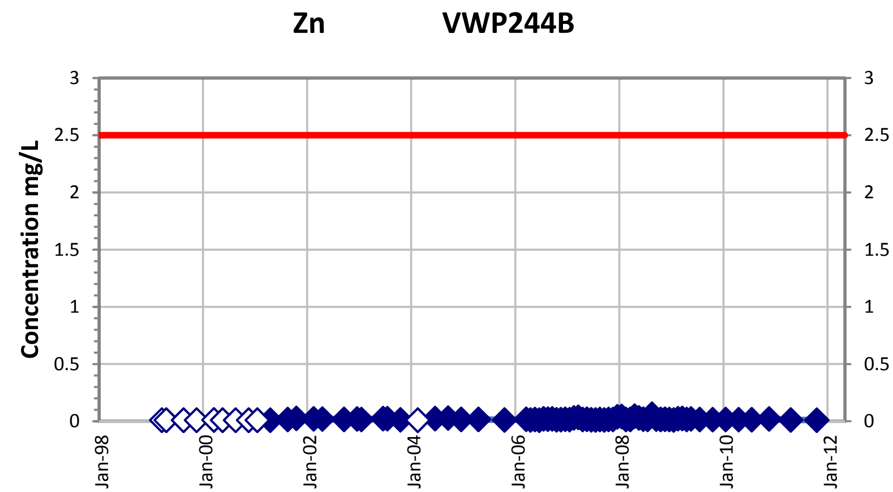
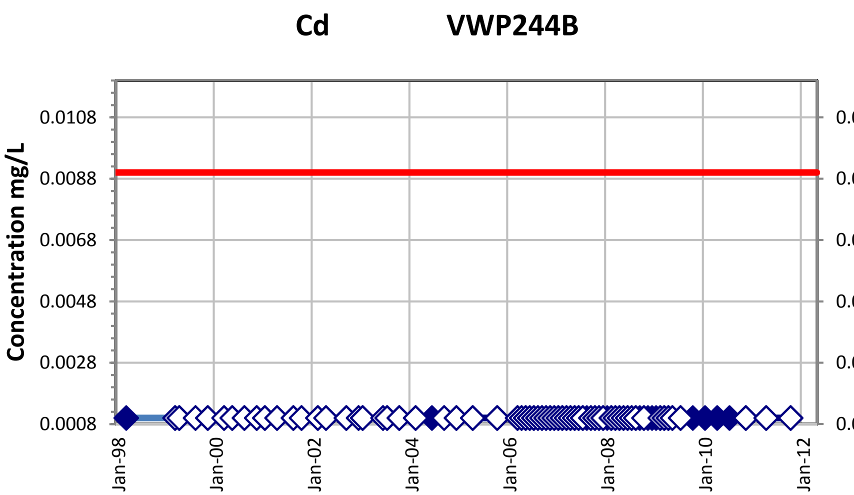
Jan-08
Jan-10
Jan-12


Zn VWP244B
Concentration mg/L
3
2.5
2
1.5
1
0.5
0
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12


Cd VWP244B
Concentration mg/L
0.0108
0.0088
0.0068
0.0048
0.0028
0.0008
Jan-98
Jan-00
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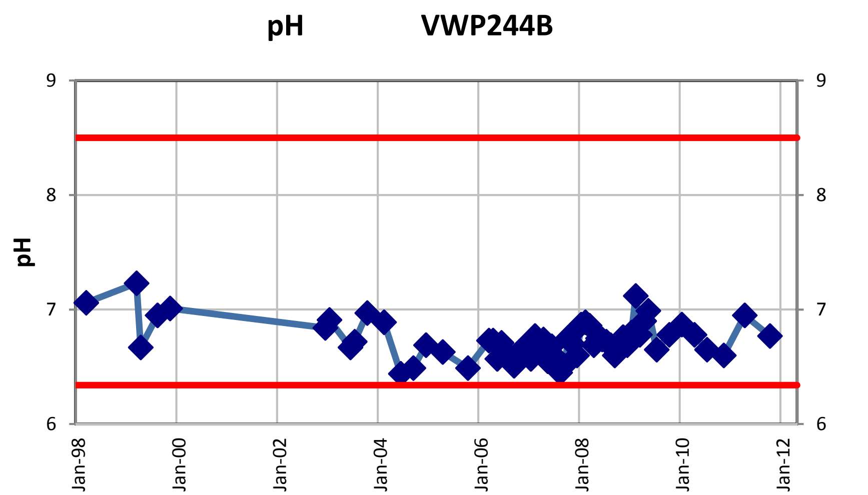
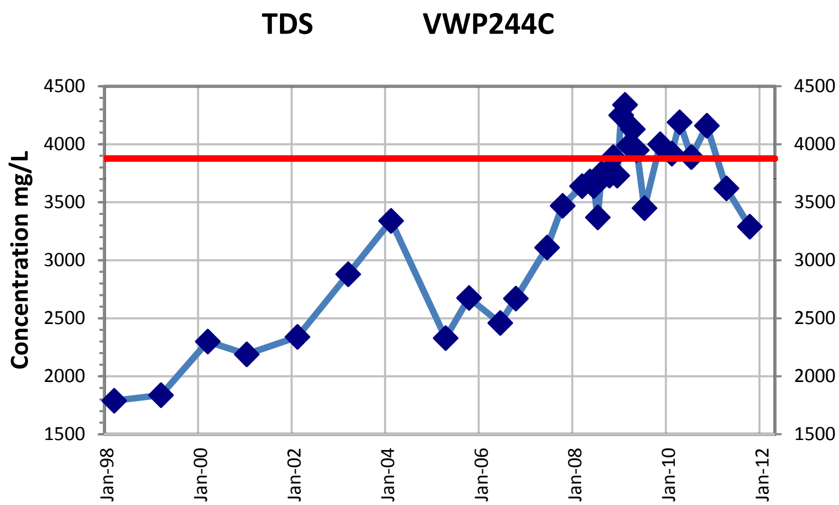
Jan-08
Jan-10
Jan-12


pH VWP244B
pH
9
8
7
6
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12


TDS VWP244C
Concentration mg/L
4500
4000
3500
3000
2500
2000
1500
Jan-98
Jan-00
Jan-02
Jan-04
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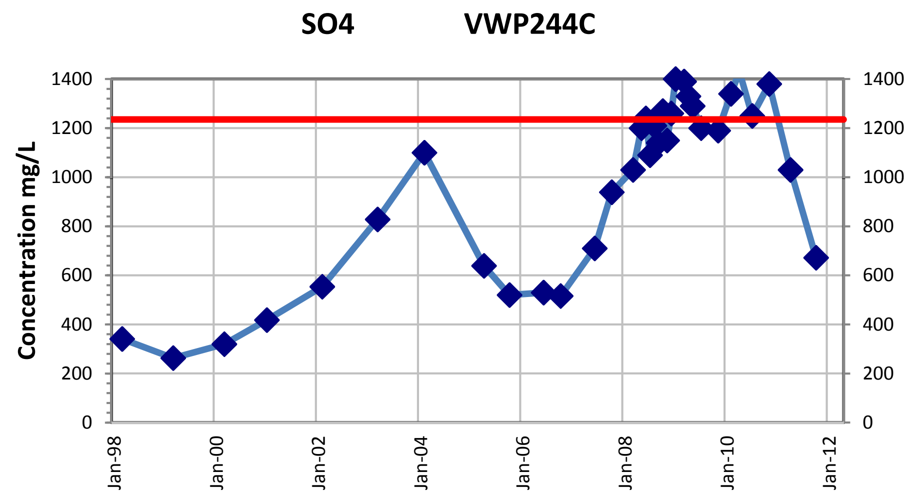
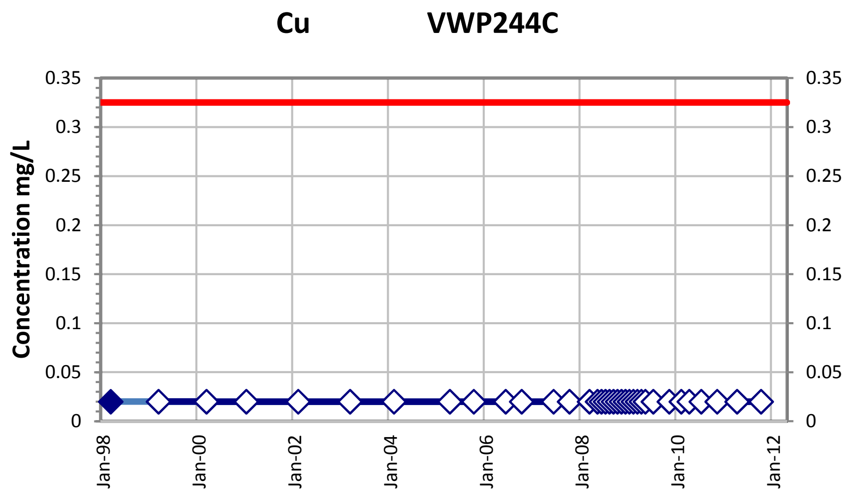
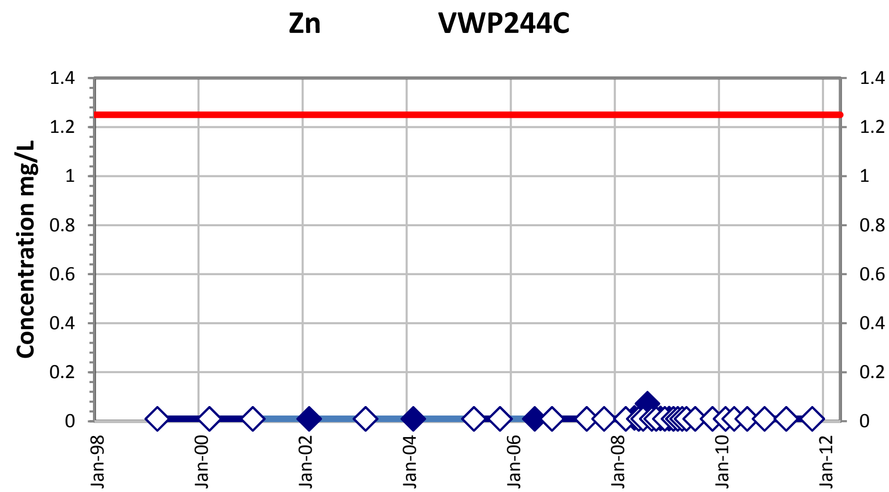
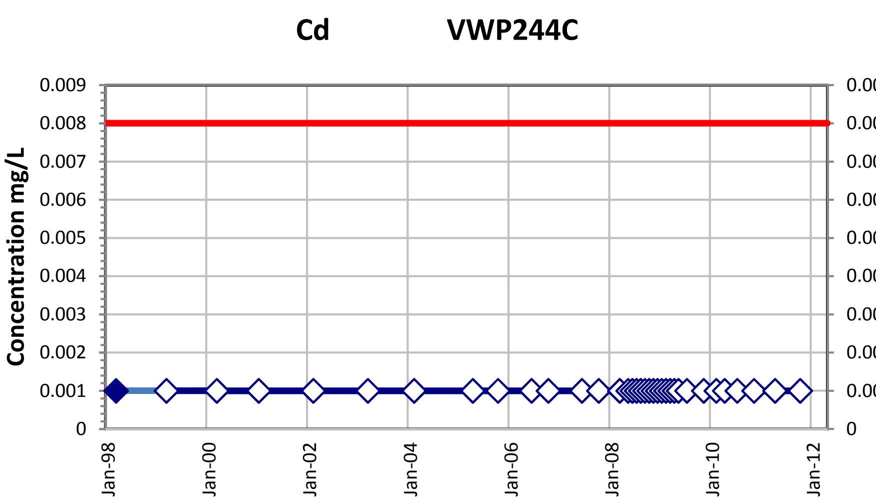
Jan-08
Jan-10
Jan-12


SO4 VWP244C
Concentration mg/L
1400
1200
1000
800
600
400
200
0
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12


Cu VWP244C
Concentration mg/L
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12


Zn VWP244C
Concentration mg/L
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12


Cd VWP244C
Concentration mg/L
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
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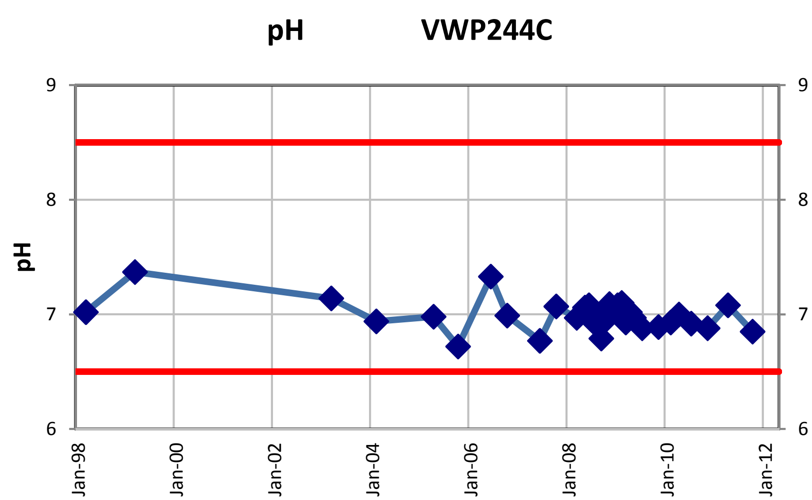
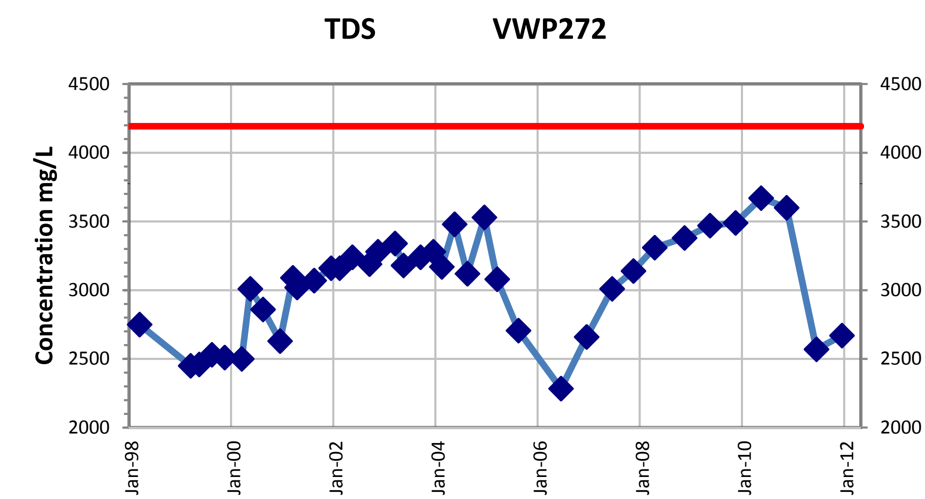
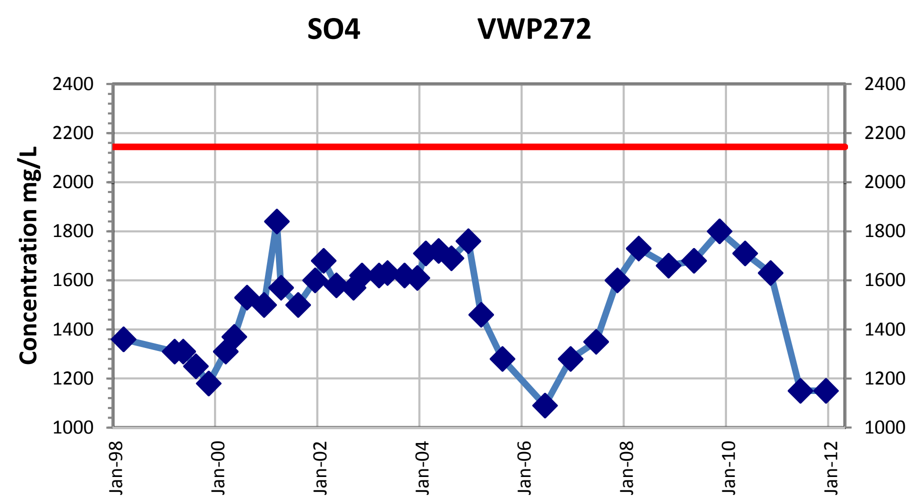
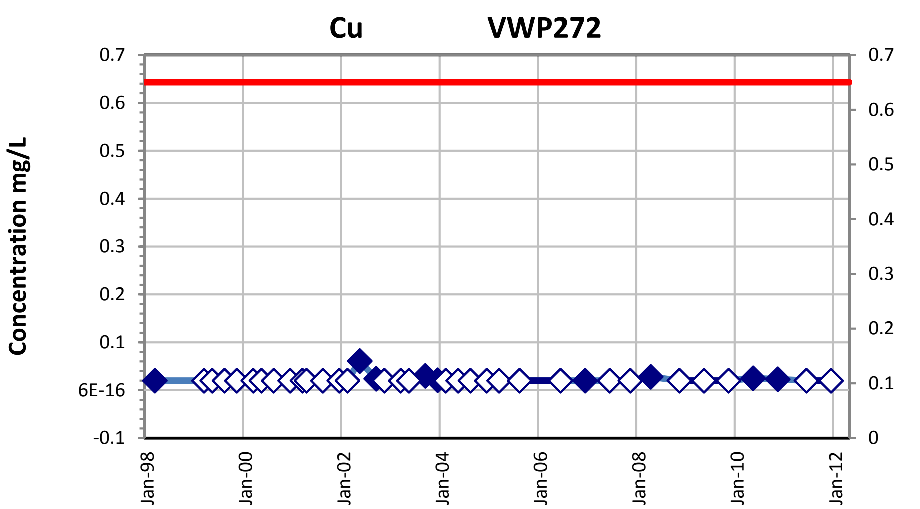
Jan-08
Jan-10
Jan-12


pH VWP244C
pH
9
8
7
6
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12


TDS VWP272
Concentration mg/L
4500
4000
3500
3000
2500
2000
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12


SO4 VWP272
Concentration mg/L
2400
2200
2000
1800
1600
1400
1200
1000
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12


Cu VWP272
Concentration mg/L
0.7
0.6
0.5
0.4
0.3
0.2
0.1
6E-16
-0.1
0
Jan-98
Jan-00
Jan-02
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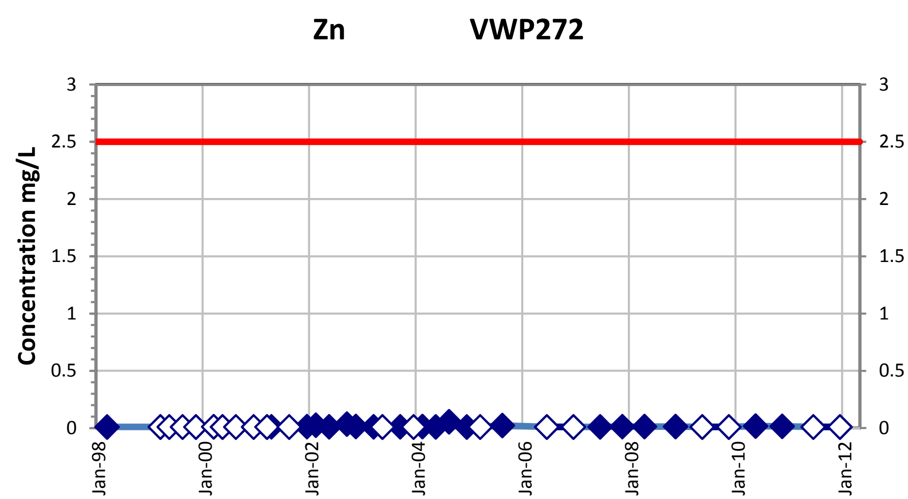
Jan-08
Jan-10
Jan-12


Zn VWP272
Concentration mg/L
3
2.5
2
1.5
1
0.5
0
Jan-98
Jan-00
Jan-02
Jan-04
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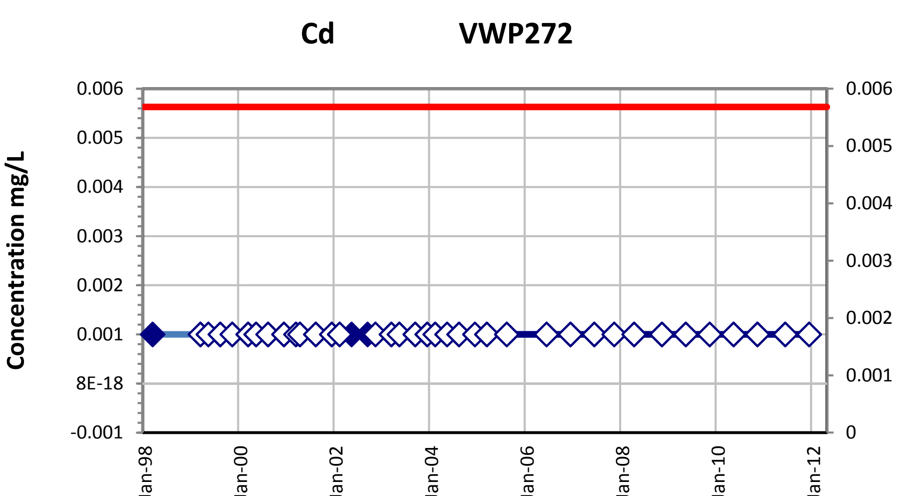
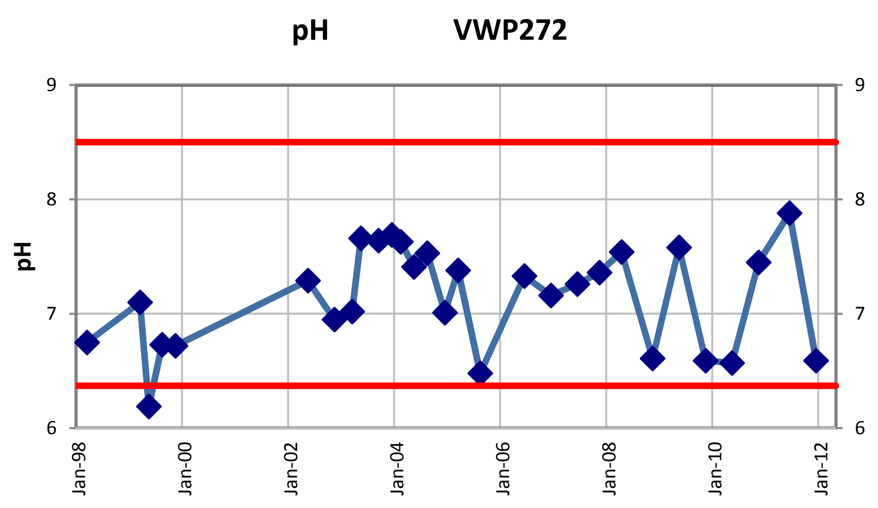
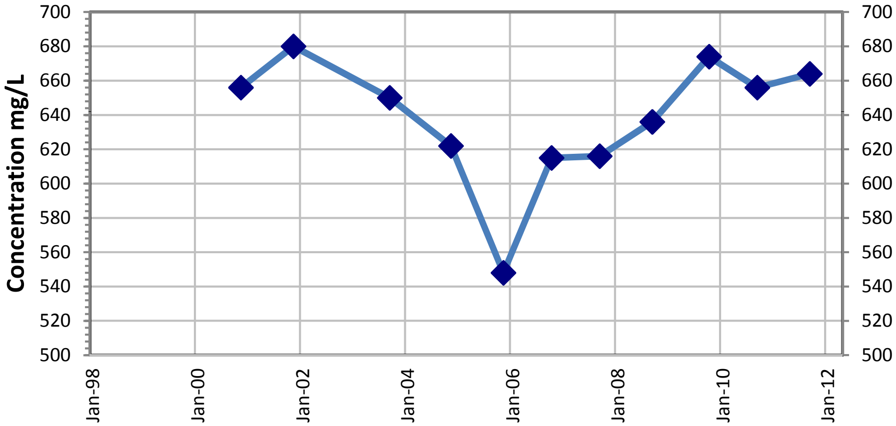
Jan-08
Jan-10
Jan-12


Cd VWP272
Concentration mg/L
0.006
0.005
0.004
0.003
0.002
0.001
8E-18
-0.001
0
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12

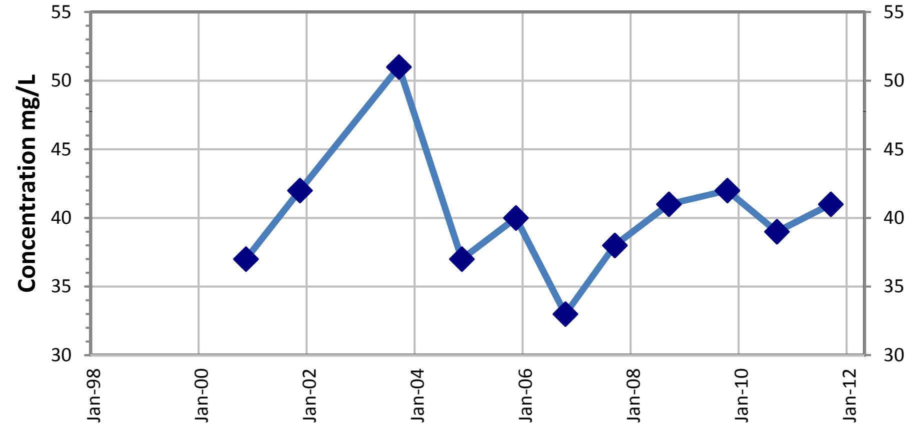

pH VWP272
pH
9
8
7
6
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12

GCMP
&
Informational Well
Chemistry Time Series by
Monitoring Well

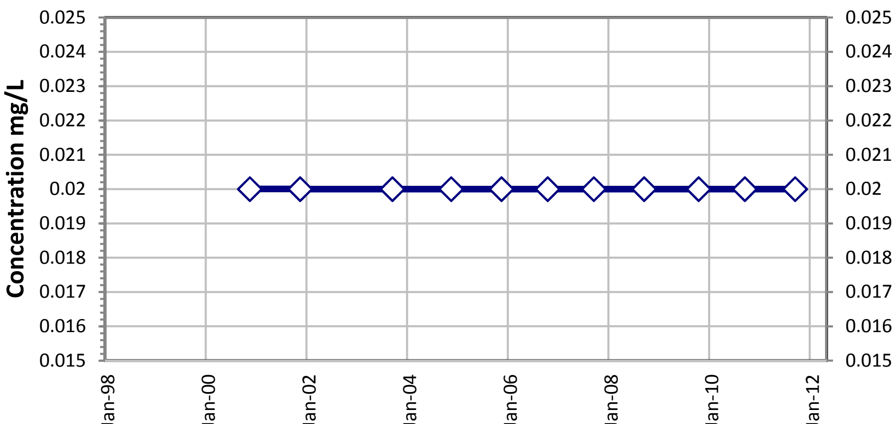
TDS ECG1114A



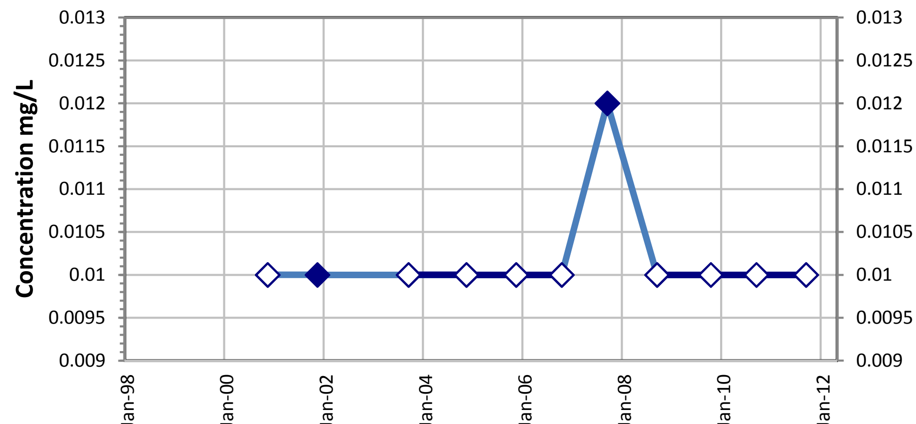
SO4 ECG1114A



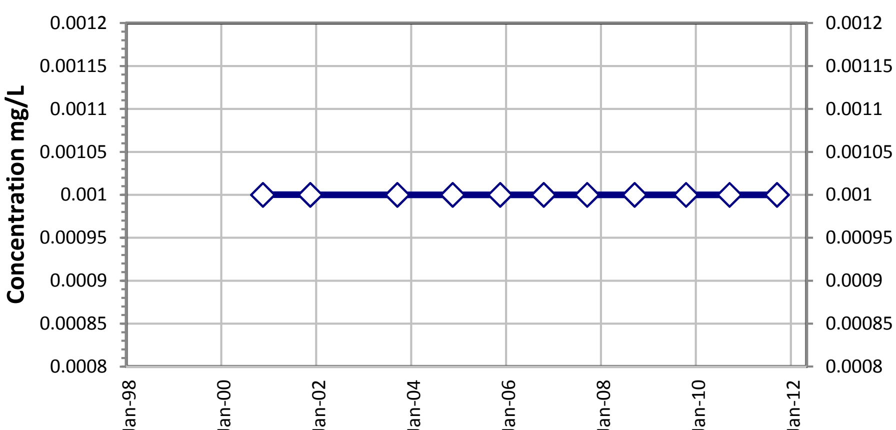
Cu ECG1114A



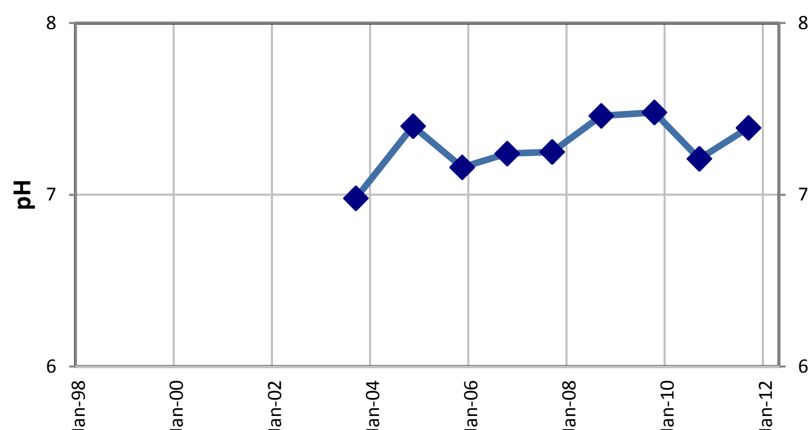
Zn ECG1114A

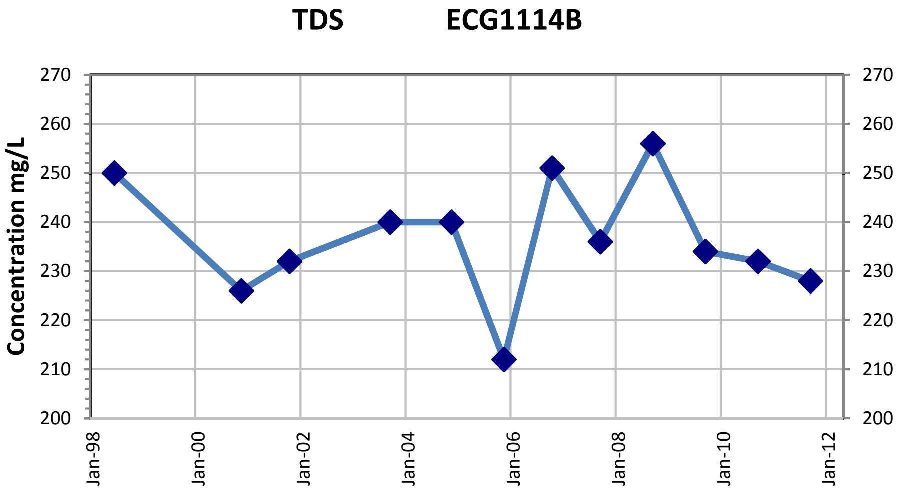


Cd ECG1114A

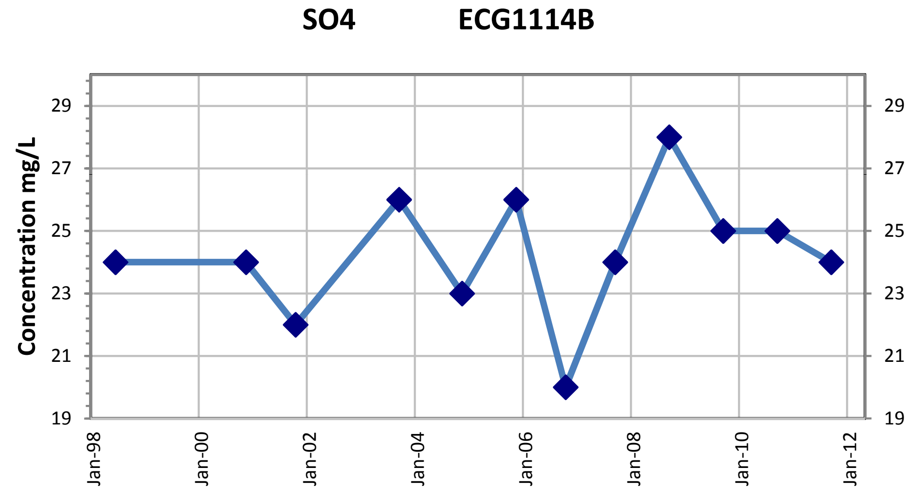


pH ECG1114A

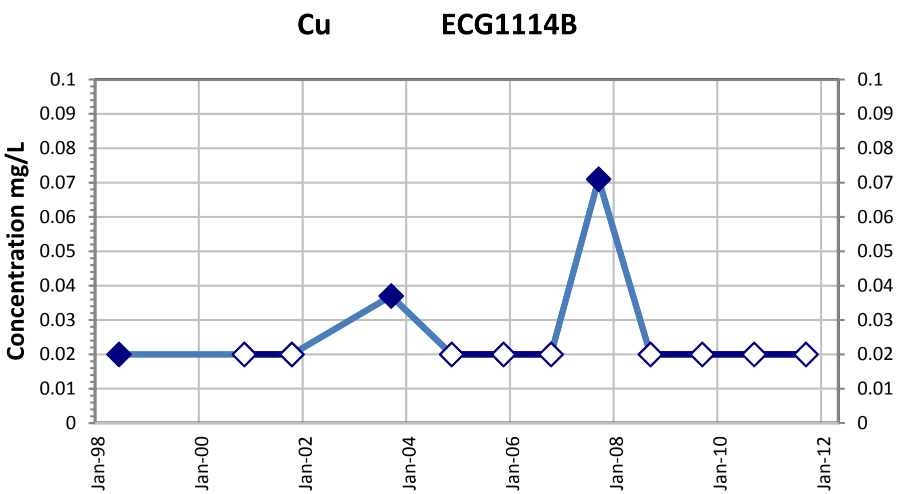




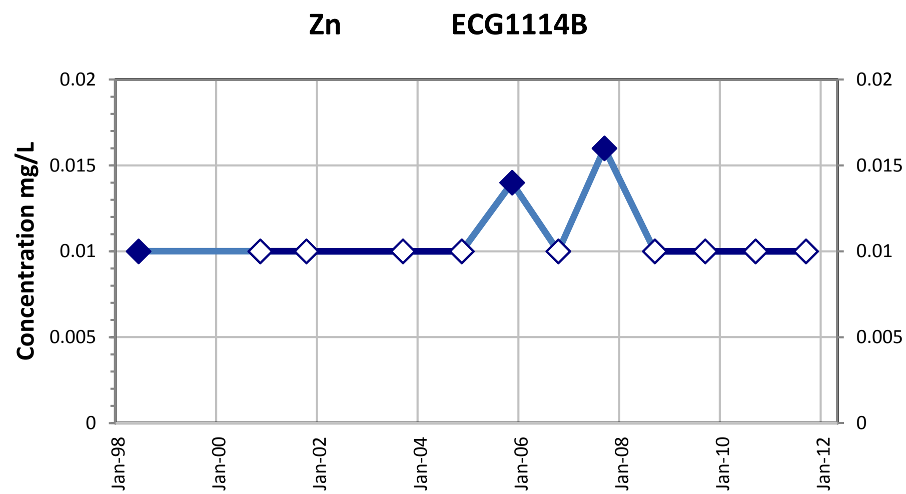
TDS ECG1114B
Concentration mg/L



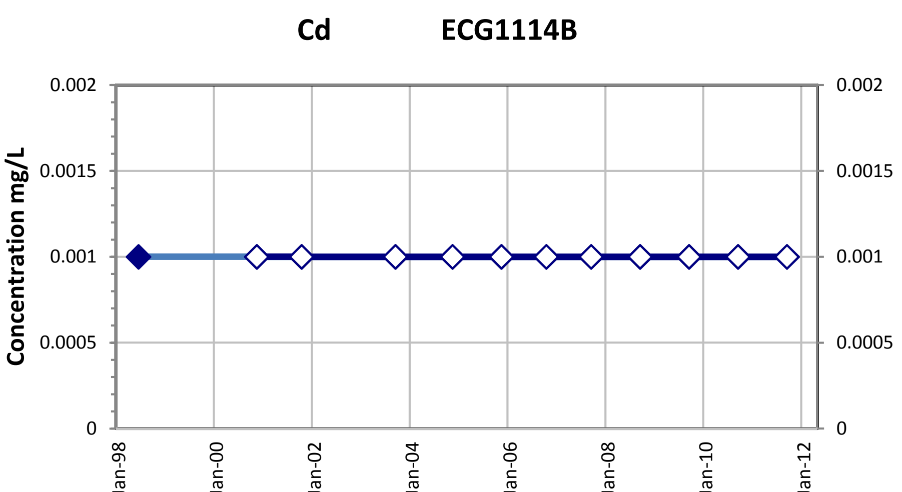
SO4 ECG1114B
Concentration mg/L



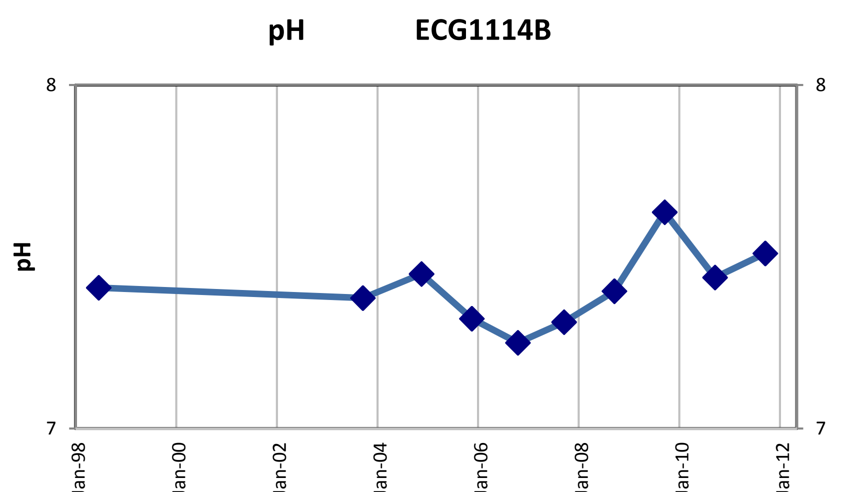
Cu ECG1114B
Concentration mg/L



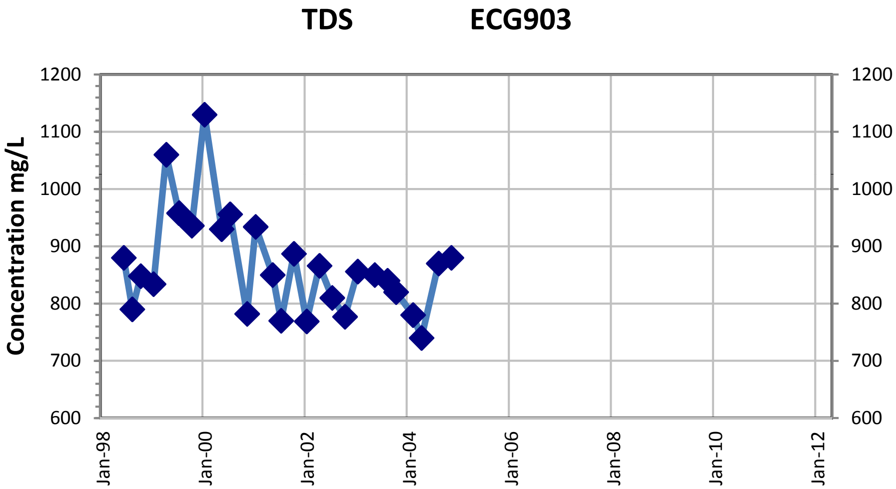
Zn ECG1114B
Concentration mg/L

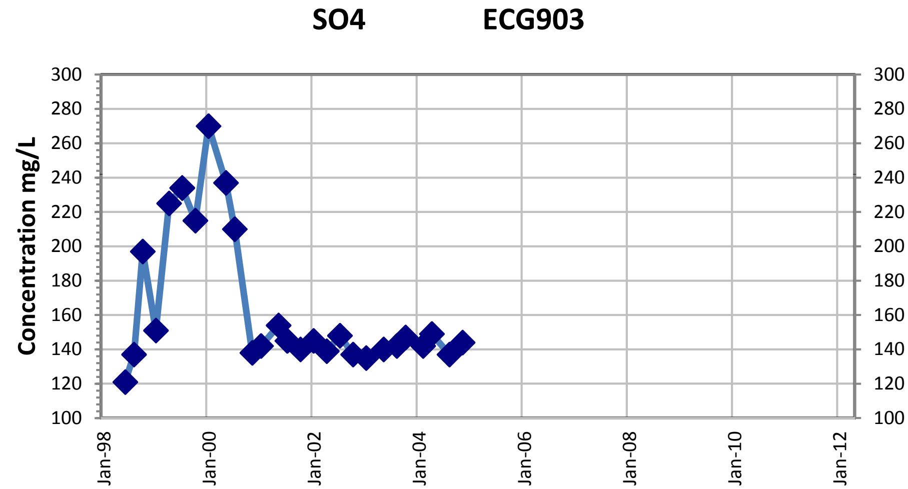


Cd ECG1114B
Concentration mg/L



pH ECG1114B
pH


TDS ECG903
Concentration mg/L
1200
1100
1000
900
800
700
600
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12


SO4 ECG903
Concentration mg/L
300
280
260
240
220
200
180
160
140
120
100
Jan-98
Jan-00
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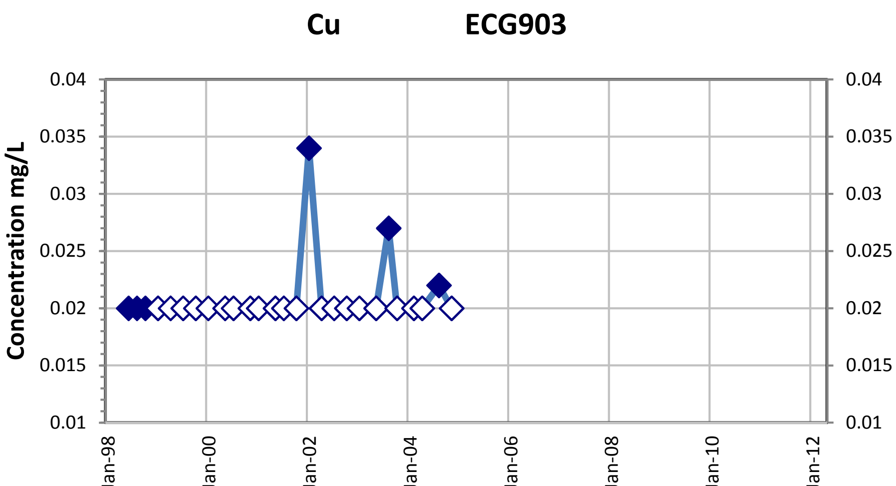
Jan-08
Jan-10
Jan-12


Cu ECG903
Concentration mg/L
0.04
0.035
0.03
0.025
0.02
0.015
0.01
Jan-98
Jan-00
Jan-02
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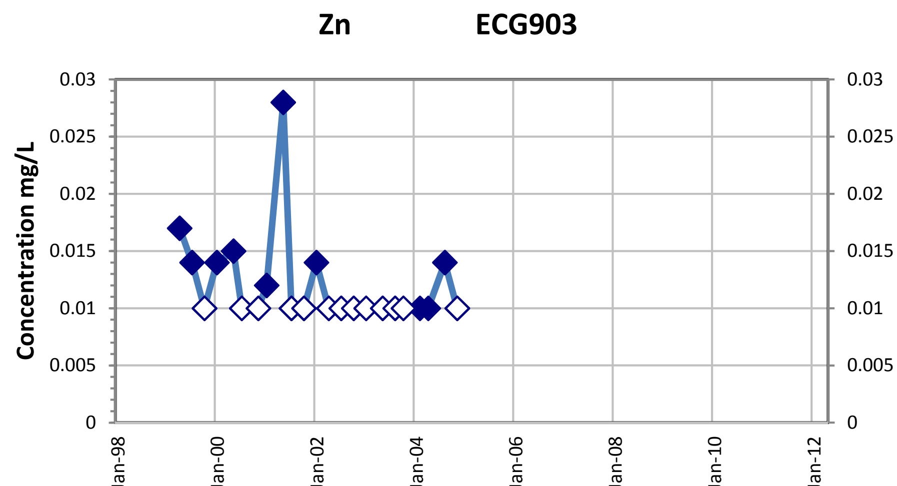
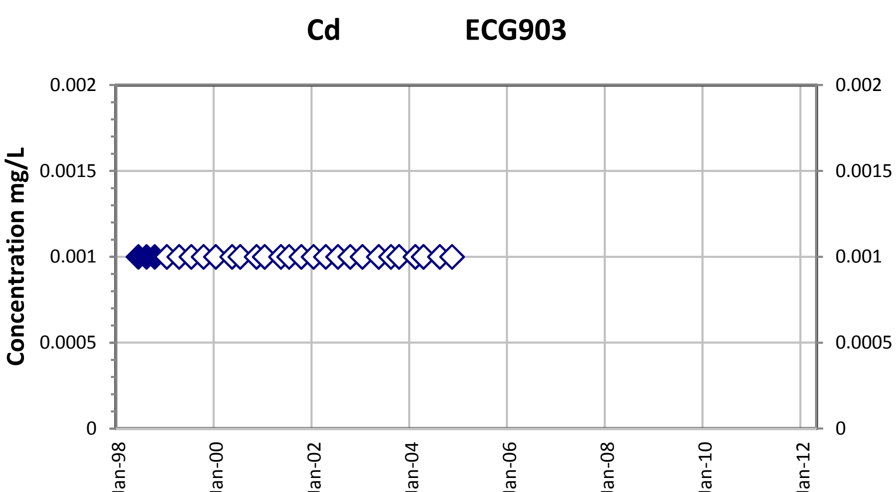
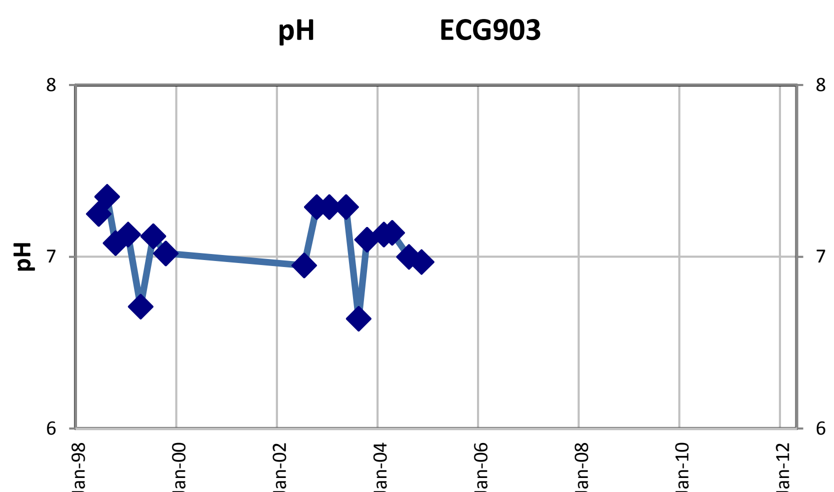
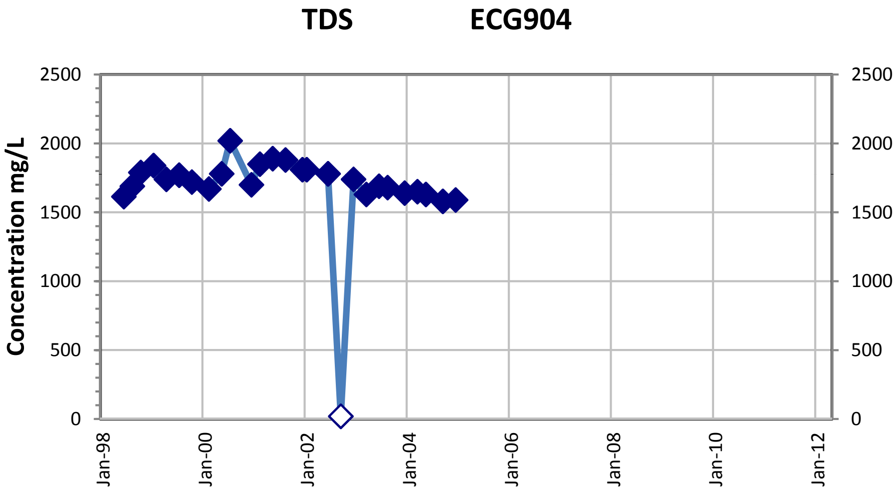
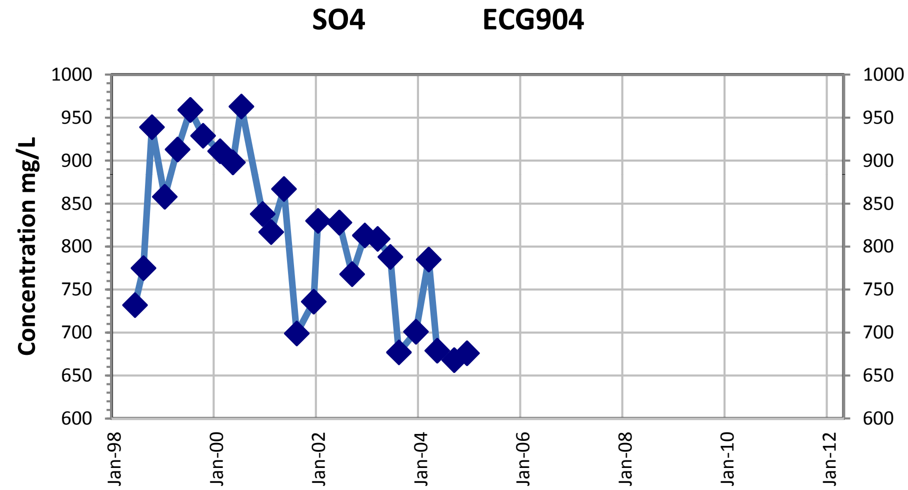
Jan-08
Jan-10
Jan-12

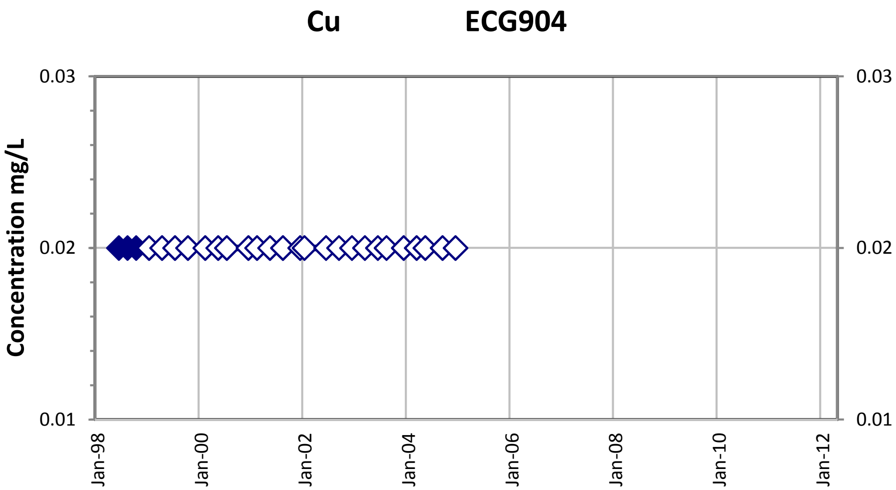

Zn ECG903
Concentration mg/L
0.03
0.025
0.02
0.015
0.01
0.005
0
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12

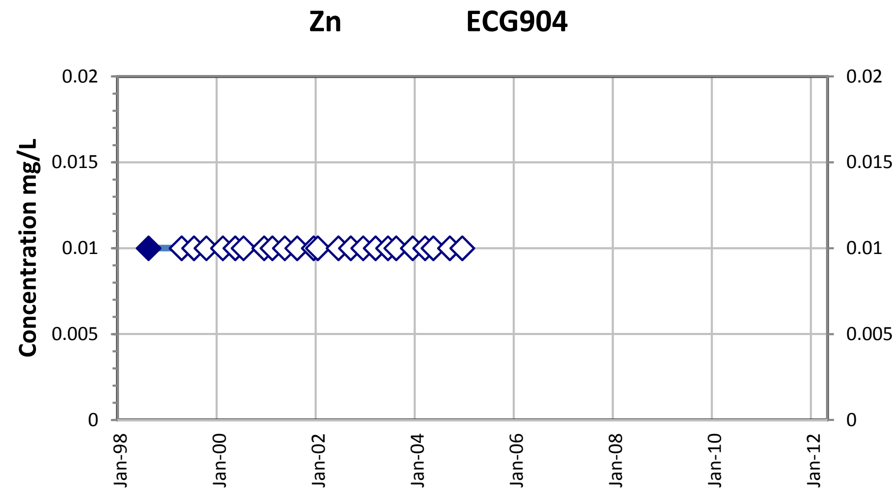

Cd ECG903
Concentration mg/L
0.002
0.0015
0.001
0.0005
0
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12

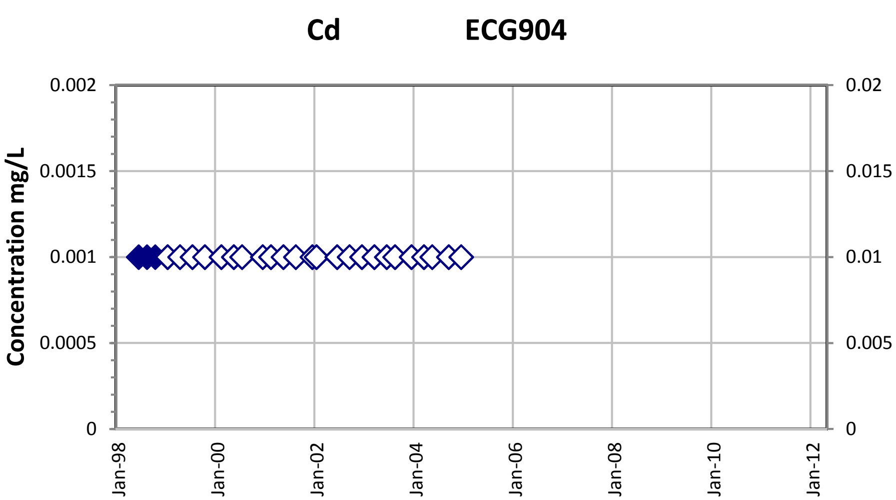

pH ECG903
pH
8
7
6
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12


TDS ECG904
Concentration mg/L
2500
2000
1500
1000
500
0
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12


SO4 ECG904
Concentration mg/L
1000
950
900
850
800
750
700
650
600
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12


Cu ECG904
Concentration mg/L
0.03
0.02
0.01
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12


Zn ECG904
Concentration mg/L
0.02
0.015
0.01
0.005
0
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12


Cd ECG904
Concentration mg/L
0.002
0.0015
0.001
0.0005
0
0.02
0.015
0.01
0.005
0
Jan-98
Jan-00
Jan-02
Jan-04
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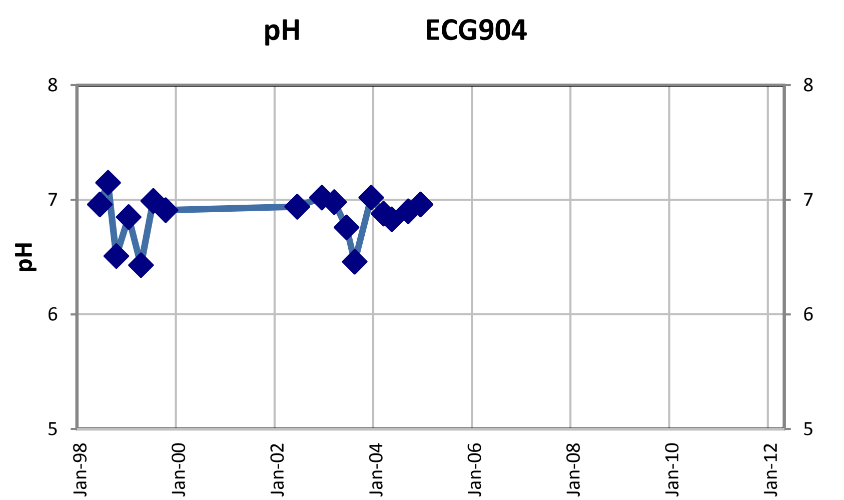
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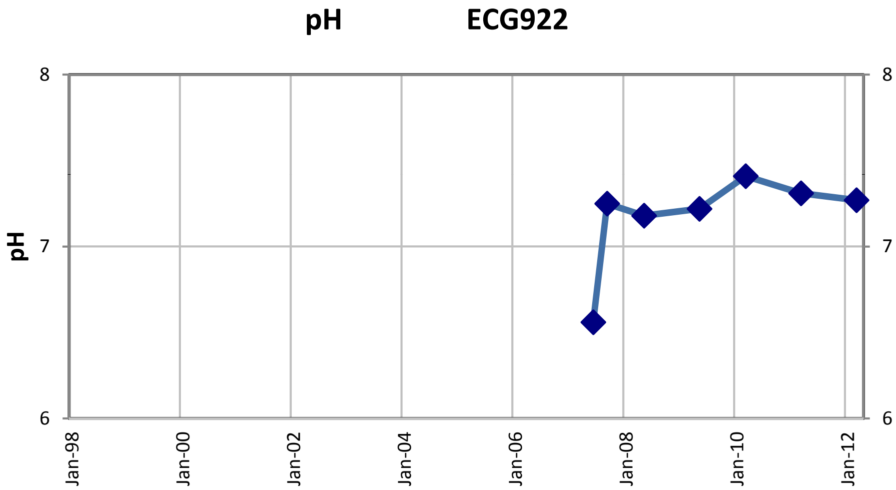

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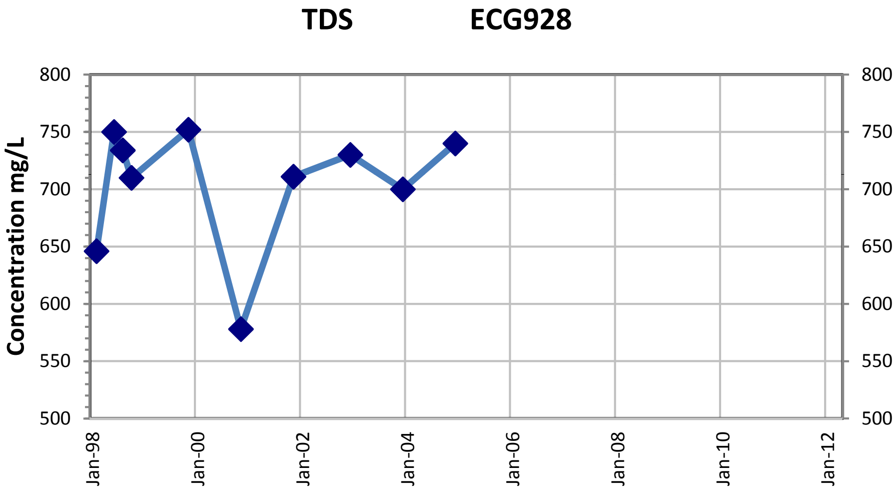
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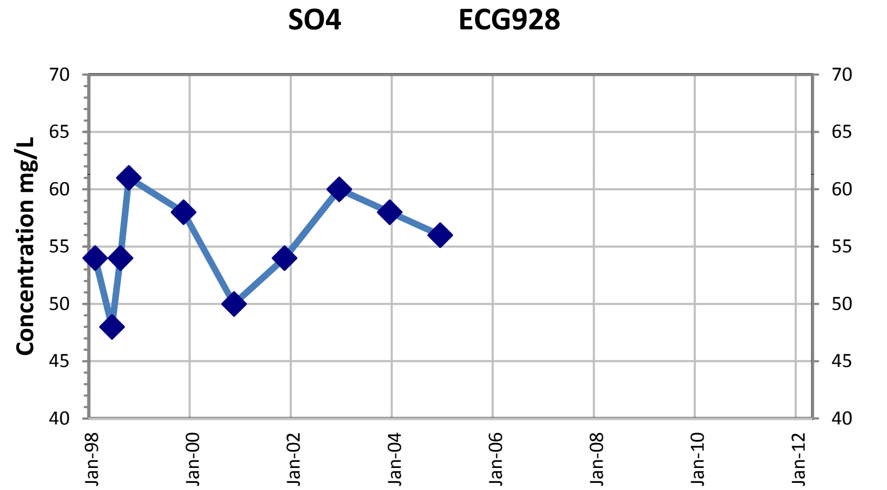
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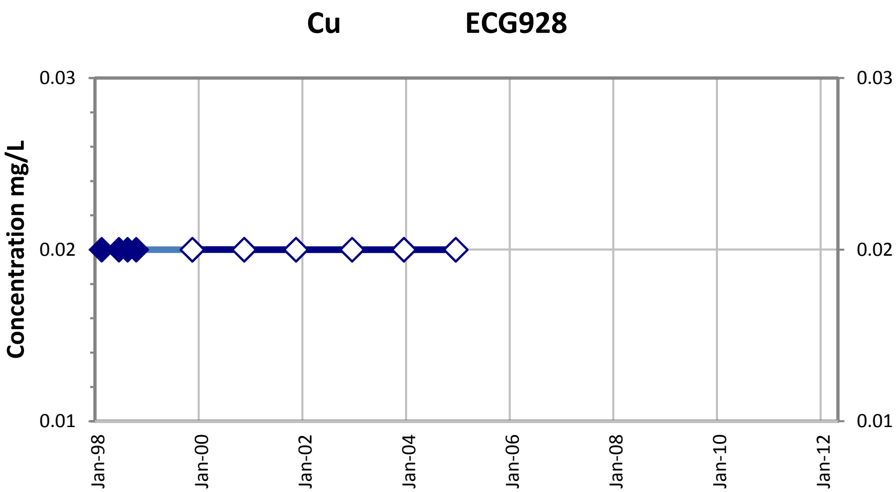
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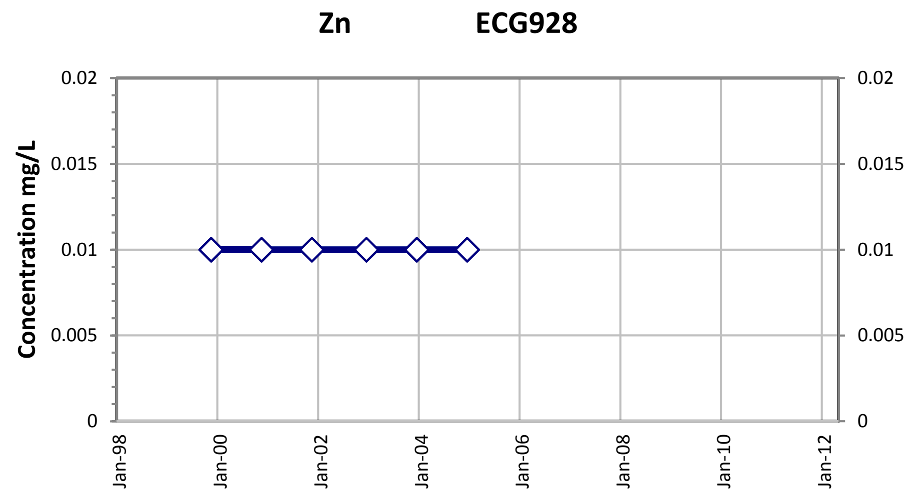
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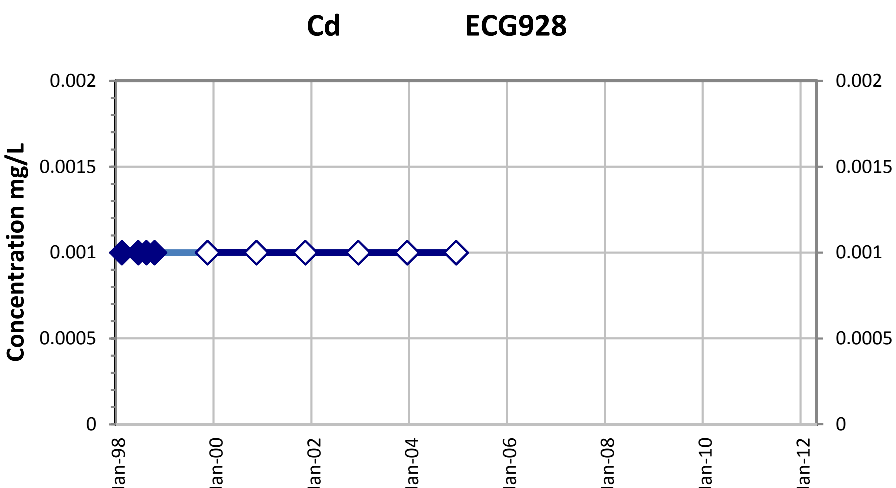
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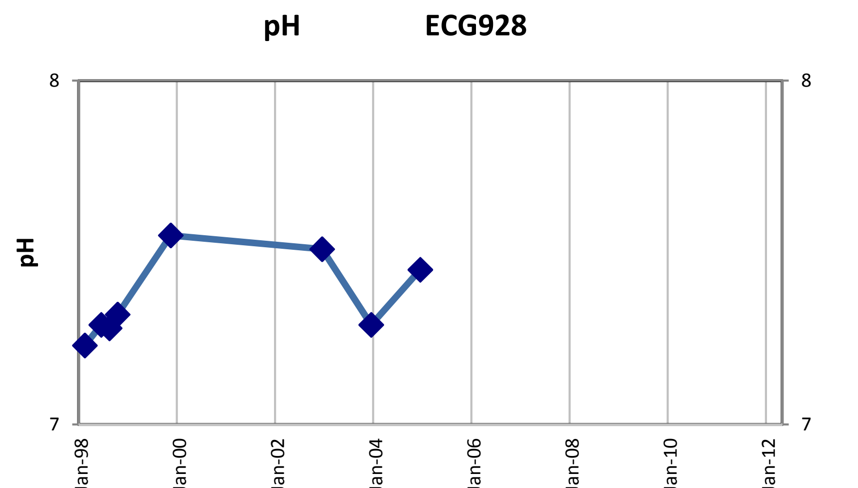
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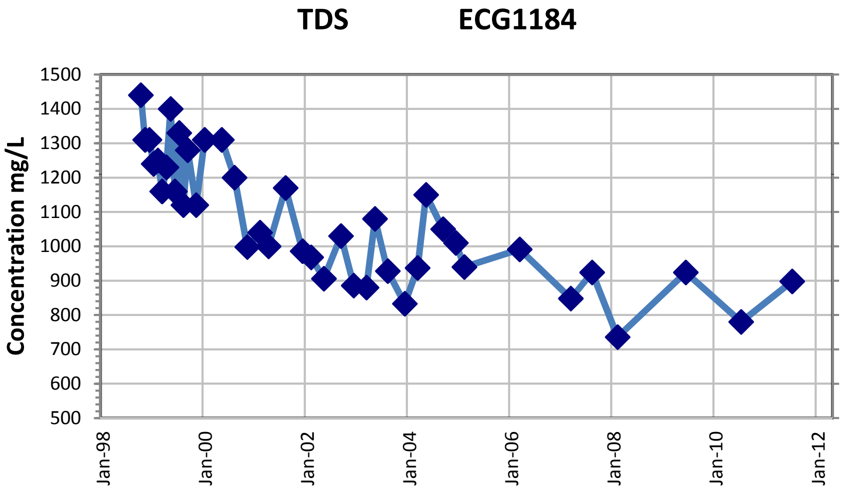
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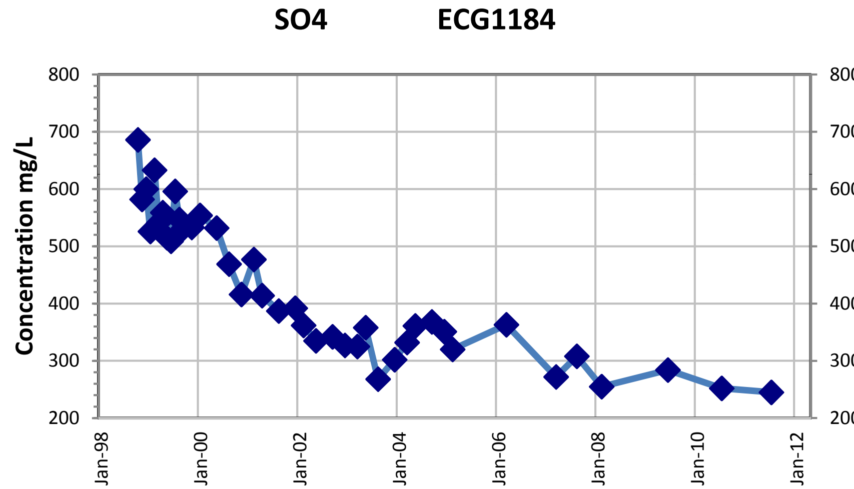
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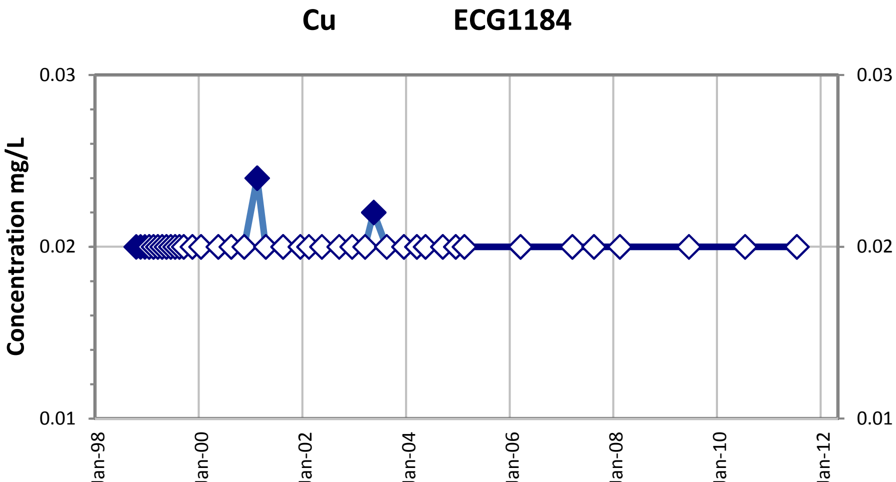
Jan-12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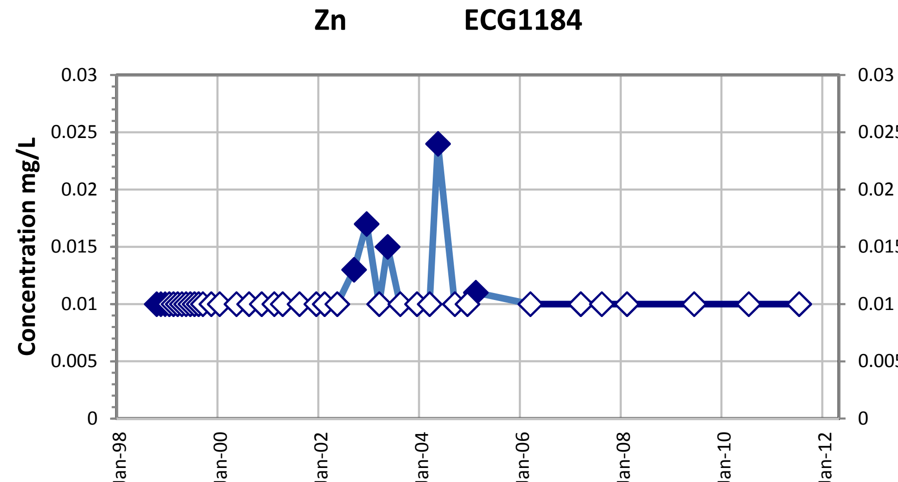
Jan-12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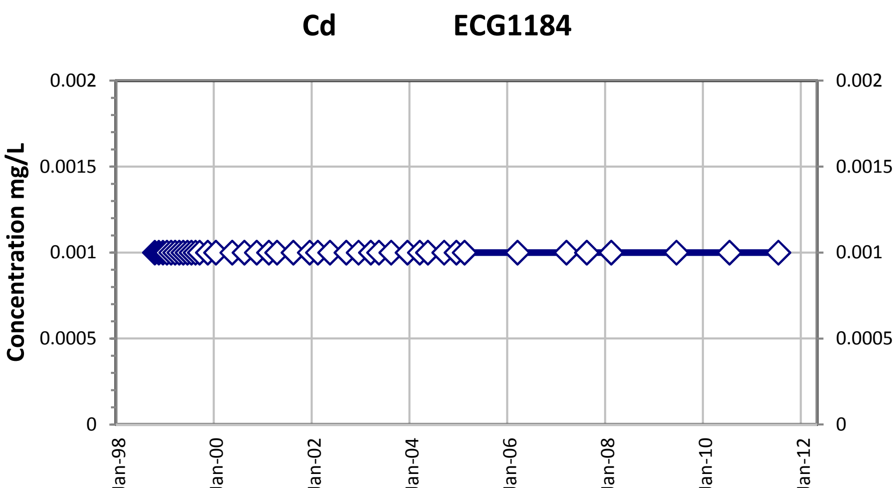
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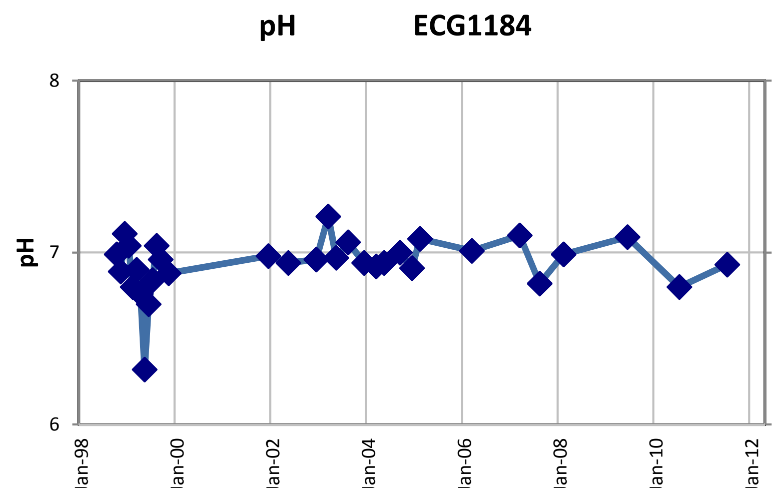
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7
6
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12

APPENDIX B

USDA Natural Resources Conservation Service Custom Soil Report

United States Department of Agriculture

NRCS

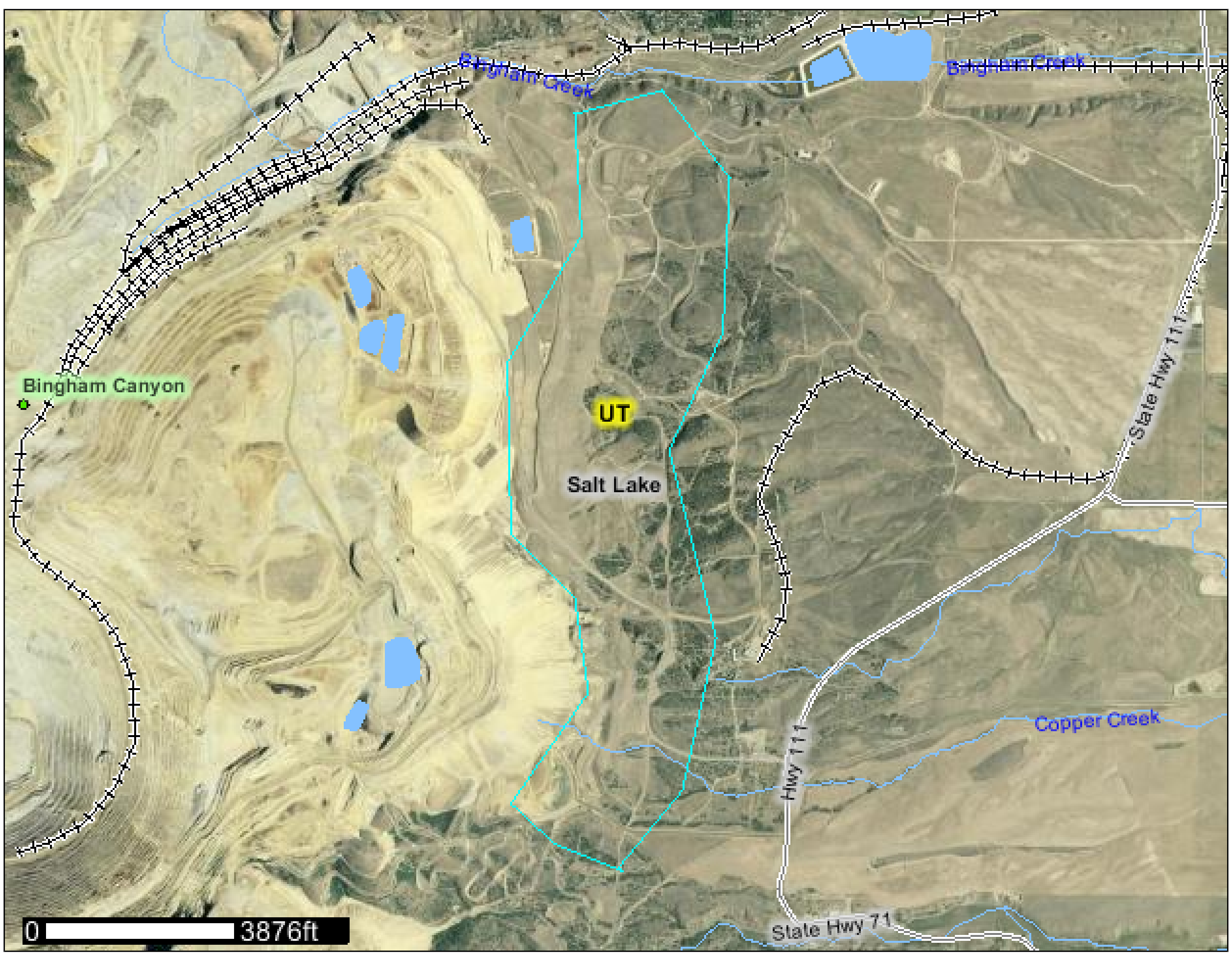
Natural Resources Conservation Service

A product of the National Cooperative Soil Survey, a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local participants

Custom Soil Resource Report for

Salt Lake Area, Utah

EWRE



August 2, 2012

Preface

Soil surveys contain information that affects land use planning in survey areas. They highlight soil limitations that affect various land uses and provide information about the properties of the soils in the survey areas. Soil surveys are designed for many different users, including farmers, ranchers, foresters, agronomists, urban planners, community officials, engineers, developers, builders, and home buyers. Also, conservationists, teachers, students, and specialists in recreation, waste disposal, and pollution control can use the surveys to help them understand, protect, or enhance the environment.

Various land use regulations of Federal, State, and local governments may impose special restrictions on land use or land treatment. Soil surveys identify soil properties that are used in making various land use or land treatment decisions. The information is intended to help the land users identify and reduce the effects of soil limitations on various land uses. The landowner or user is responsible for identifying and complying with existing laws and regulations.

Although soil survey information can be used for general farm, local, and wider area planning, onsite investigation is needed to supplement this information in some cases. Examples include soil quality assessments (http://soils.usda.gov/sqi/) and certain conservation and engineering applications. For more detailed information, contact your local USDA Service Center (http://offices.sc.egov.usda.gov/locator/app?agency=nrcs) or your NRCS State Soil Scientist (http://soils.usda.gov/contact/state_offices/).

Great differences in soil properties can occur within short distances. Some soils are seasonally wet or subject to flooding. Some are too unstable to be used as a foundation for buildings or roads. Clayey or wet soils are poorly suited to use as septic tank absorption fields. A high water table makes a soil poorly suited to basements or underground installations.

The National Cooperative Soil Survey is a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local agencies. The Natural Resources Conservation Service (NRCS) has leadership for the Federal part of the National Cooperative Soil Survey.

Information about soils is updated periodically. Updated information is available through the NRCS Soil Data Mart Web site or the NRCS Web Soil Survey. The Soil Data Mart is the data storage site for the official soil survey information.

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Contents

How Soil Surveys Are Made

Soil surveys are made to provide information about the soils and miscellaneous areas in a specific area. They include a description of the soils and miscellaneous areas and their location on the landscape and tables that show soil properties and limitations affecting various uses. Soil scientists observed the steepness, length, and shape of the slopes; the general pattern of drainage; the kinds of crops and native plants; and the kinds of bedrock. They observed and described many soil profiles. A soil profile is the sequence of natural layers, or horizons, in a soil. The profile extends from the surface down into the unconsolidated material in which the soil formed or from the surface down to bedrock. The unconsolidated material is devoid of roots and other living organisms and has not been changed by other biological activity.

Currently, soils are mapped according to the boundaries of major land resource areas (MLRAs). MLRAs are geographically associated land resource units that share common characteristics related to physiography, geology, climate, water resources, soils, biological resources, and land uses (USDA, 2006). Soil survey areas typically consist of parts of one or more MLRA.

The soils and miscellaneous areas in a survey area occur in an orderly pattern that is related to the geology, landforms, relief, climate, and natural vegetation of the area. Each kind of soil and miscellaneous area is associated with a particular kind of landform or with a segment of the landform. By observing the soils and miscellaneous areas in the survey area and relating their position to specific segments of the landform, a soil scientist develops a concept, or model, of how they were formed. Thus, during mapping, this model enables the soil scientist to predict with a considerable degree of accuracy the kind of soil or miscellaneous area at a specific location on the landscape.

Commonly, individual soils on the landscape merge into one another as their characteristics gradually change. To construct an accurate soil map, however, soil scientists must determine the boundaries between the soils. They can observe only a limited number of soil profiles. Nevertheless, these observations, supplemented by an understanding of the soil-vegetation-landscape relationship, are sufficient to verify predictions of the kinds of soil in an area and to determine the boundaries.

Soil scientists recorded the characteristics of the soil profiles that they studied. They noted soil color, texture, size and shape of soil aggregates, kind and amount of rock fragments, distribution of plant roots, reaction, and other features that enable them to identify soils. After describing the soils in the survey area and determining their properties, the soil scientists assigned the soils to taxonomic classes (units). Taxonomic classes are concepts. Each taxonomic class has a set of soil characteristics with precisely defined limits. The classes are used as a basis for comparison to classify soils systematically. Soil taxonomy, the system of taxonomic classification used in the United States, is based mainly on the kind and character of soil properties and the arrangement of horizons within the profile. After the soil scientists classified and named the soils in the survey area, they compared the individual soils with similar soils in the same taxonomic class in other areas so that they could confirm data and assemble additional data based on experience and research.

The objective of soil mapping is not to delineate pure map unit components; the objective is to separate the landscape into landforms or landform segments that have similar use and management requirements. Each map unit is defined by a unique combination of soil components and/or miscellaneous areas in predictable proportions. Some components may be highly contrasting to the other components of the map unit. The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The delineation of such landforms and landform segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, onsite investigation is needed to define and locate the soils and miscellaneous areas.

Soil scientists make many field observations in the process of producing a soil map. The frequency of observation is dependent upon several factors, including scale of mapping, intensity of mapping, design of map units, complexity of the landscape, and experience of the soil scientist. Observations are made to test and refine the soil-landscape model and predictions and to verify the classification of the soils at specific locations. Once the soil-landscape model is refined, a significantly smaller number of measurements of individual soil properties are made and recorded. These measurements may include field measurements, such as those for color, depth to bedrock, and texture, and laboratory measurements, such as those for content of sand, silt, clay, salt, and other components. Properties of each soil typically vary from one point to another across the landscape.

Observations for map unit components are aggregated to develop ranges of characteristics for the components. The aggregated values are presented. Direct measurements do not exist for every property presented for every map unit component. Values for some properties are estimated from combinations of other properties.

While a soil survey is in progress, samples of some of the soils in the area generally are collected for laboratory analyses and for engineering tests. Soil scientists interpret the data from these analyses and tests as well as the field-observed characteristics and the soil properties to determine the expected behavior of the soils under different uses. Interpretations for all of the soils are field tested through observation of the soils in different uses and under different levels of management. Some interpretations are modified to fit local conditions, and some new interpretations are developed to meet local needs. Data are assembled from other sources, such as research information, production records, and field experience of specialists. For example, data on crop yields under defined levels of management are assembled from farm records and from field or plot experiments on the same kinds of soil.

Predictions about soil behavior are based not only on soil properties but also on such variables as climate and biological activity. Soil conditions are predictable over long periods of time, but they are not predictable from year to year. For example, soil scientists can predict with a fairly high degree of accuracy that a given soil will have a high water table within certain depths in most years, but they cannot predict that a high water table will always be at a specific level in the soil on a specific date.

After soil scientists located and identified the significant natural bodies of soil in the survey area, they drew the boundaries of these bodies on aerial photographs and identified each as a specific map unit. Aerial photographs show trees, buildings, fields, roads, and rivers, all of which help in locating boundaries accurately.

Soil Map

The soil map section includes the soil map for the defined area of interest, a list of soil map units on the map and extent of each map unit, and cartographic symbols displayed on the map. Also presented are various metadata about data used to produce the map, and a description of each soil map unit.

Custom Soil Resource Report
Soil Map

Map Scale: 1:26,000 if printed on A size (8.5" x 11") sheet.

N

Meters
0 250 500 1,000 1,500

Feet
0 1,000 2,000 4,000 6,000

MAP LEGEND

Area of Interest (AOI)

- Area of Interest (AOI)

Soils

- Soil Map Units

Special Point Features

- Blowout
- Borrow Pit
- Clay Spot
- Closed Depression
- Gravel Pit
- Gravelly Spot
- Landfill
- Lava Flow
- Marsh or swamp
- Mine or Quarry
- Miscellaneous Water
- Perennial Water
- Rock Outcrop
- Saline Spot
- Sandy Spot
- Severely Eroded Spot
- Sinkhole
- Slide or Slip
- Sodic Spot
- Spoil Area
- Stony Spot
- Very Stony Spot
- Wet Spot
- Other

Special Line Features

- Gully
- Short Steep Slope
- Other

Political Features

- Cities

Water Features

- Streams and Canals

Transportation

- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

MAP INFORMATION

Map Scale: 1:26,000 if printed on A size (8.5" × 11") sheet.

The soil surveys that comprise your AOI were mapped at 1:20,000.

Please rely on the bar scale on each map sheet for accurate map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: http://websoilsurvey.nrcs.usda.gov
Coordinate System: UTM Zone 12N NAD83

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Salt Lake Area, Utah
Survey Area Data: Version 5, Feb 10, 2010

Date(s) aerial images were photographed: 8/29/2006; 8/10/2006

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend

Salt Lake Area, Utah (UT612)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
DPD	Dry Creek-Copperton association, sloping	43.9	4.1%
DPE	Dry Creek-Copperton association, moderately steep	330.9	30.8%
DRD	Dry Creek soils, 3 to 15 percent slopes	63.1	5.9%
HDF	Harkers-Dry Creek association, moderately steep	262.6	24.5%
HHF	Harkers soils, 6 to 40 percent slopes	15.1	1.4%
PT	Pits, mine	357.0	33.3%
SP	Stony terrace escarpments	0.2	0.0%
Totals for Area of Interest		**1,072.9**	**100.0%**

Map Unit Descriptions

The map units delineated on the detailed soil maps in a soil survey represent the soils or miscellaneous areas in the survey area. The map unit descriptions, along with the maps, can be used to determine the composition and properties of a unit.

A map unit delineation on a soil map represents an area dominated by one or more major kinds of soil or miscellaneous areas. A map unit is identified and named according to the taxonomic classification of the dominant soils. Within a taxonomic class there are precisely defined limits for the properties of the soils. On the landscape, however, the soils are natural phenomena, and they have the characteristic variability of all natural phenomena. Thus, the range of some observed properties may extend beyond the limits defined for a taxonomic class. Areas of soils of a single taxonomic class rarely, if ever, can be mapped without including areas of other taxonomic classes. Consequently, every map unit is made up of the soils or miscellaneous areas for which it is named and some minor components that belong to taxonomic classes other than those of the major soils.

Most minor soils have properties similar to those of the dominant soil or soils in the map unit, and thus they do not affect use and management. These are called noncontrasting, or similar, components. They may or may not be mentioned in a particular map unit description. Other minor components, however, have properties and behavioral characteristics divergent enough to affect use or to require different management. These are called contrasting, or dissimilar, components. They generally are in small areas and could not be mapped separately because of the scale used. Some small areas of strongly contrasting soils or miscellaneous areas are identified by a special symbol on the maps. If included in the database for a given area, the contrasting minor components are identified in the map unit descriptions along with some characteristics of each. A few areas of minor components may not have been observed, and consequently they are not mentioned in the descriptions, especially where the pattern was so complex that it was impractical to make enough observations to identify all the soils and miscellaneous areas on the landscape.

The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The objective of mapping is not to delineate pure taxonomic classes but rather to separate the landscape into landforms or landform segments that have similar use and management requirements. The delineation of such segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, however, onsite investigation is needed to define and locate the soils and miscellaneous areas.

An identifying symbol precedes the map unit name in the map unit descriptions. Each description includes general facts about the unit and gives important soil properties and qualities.

Soils that have profiles that are almost alike make up a *soil series*. Except for differences in texture of the surface layer, all the soils of a series have major horizons that are similar in composition, thickness, and arrangement.

Soils of one series can differ in texture of the surface layer, slope, stoniness, salinity, degree of erosion, and other characteristics that affect their use. On the basis of such differences, a soil series is divided into *soil phases*. Most of the areas shown on the detailed soil maps are phases of soil series. The name of a soil phase commonly indicates a feature that affects use or management. For example, Alpha silt loam, 0 to 2 percent slopes, is a phase of the Alpha series.

Some map units are made up of two or more major soils or miscellaneous areas. These map units are complexes, associations, or undifferentiated groups.

A *complex* consists of two or more soils or miscellaneous areas in such an intricate pattern or in such small areas that they cannot be shown separately on the maps. The pattern and proportion of the soils or miscellaneous areas are somewhat similar in all areas. Alpha-Beta complex, 0 to 6 percent slopes, is an example.

An *association* is made up of two or more geographically associated soils or miscellaneous areas that are shown as one unit on the maps. Because of present or anticipated uses of the map units in the survey area, it was not considered practical or necessary to map the soils or miscellaneous areas separately. The pattern and relative proportion of the soils or miscellaneous areas are somewhat similar. Alpha-Beta association, 0 to 2 percent slopes, is an example.

An *undifferentiated group* is made up of two or more soils or miscellaneous areas that could be mapped individually but are mapped as one unit because similar interpretations can be made for use and management. The pattern and proportion of the soils or miscellaneous areas in a mapped area are not uniform. An area can be made up of only one of the major soils or miscellaneous areas, or it can be made up of all of them. Alpha and Beta soils, 0 to 2 percent slopes, is an example.

Some surveys include *miscellaneous areas*. Such areas have little or no soil material and support little or no vegetation. Rock outcrop is an example.

Salt Lake Area, Utah

DPD—Dry Creek-Copperton association, sloping

Map Unit Setting

Elevation: 4,100 to 6,000 feet
Mean annual precipitation: 17 to 20 inches
Mean annual air temperature: 46 to 48 degrees F
Frost-free period: 120 to 150 days

Map Unit Composition

Copperton and similar soils: 40 percent
Dry creek and similar soils: 30 percent
Dry creek and similar soils: 25 percent
Minor components: 5 percent

Description of Copperton

Setting

Landform: Ridges, drainageways
Down-slope shape: Linear
Across-slope shape: Concave
Parent material: Alluvium derived from limestone, sandstone, and shale

Properties and qualities

Slope: 6 to 40 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.60 to 2.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 60 percent
Maximum salinity: Nonsaline (0.0 to 2.0 mmhos/cm)
Sodium adsorption ratio, maximum: 13.0
Available water capacity: Low (about 5.1 inches)

Interpretive groups

Land capability (nonirrigated): 7s
Ecological site: Upland Gravelly Loam (Bonneville Big Sagebrush) (R028AY306UT)

Typical profile

0 to 6 inches: Very gravelly loam
6 to 13 inches: Very cobbly loam
13 to 19 inches: Very cobbly loam
19 to 42 inches: Very gravelly loam
42 to 60 inches: Extremely cobbly fine sandy loam

Description of Dry Creek

Setting

Landform: Alluvial fans
Down-slope shape: Concave
Across-slope shape: Convex
Parent material: Alluvium derived from limestone, sandstone, and shale

Properties and qualities

Slope: 3 to 15 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.06 to 0.20 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 30 percent
Maximum salinity: Nonsaline (0.0 to 2.0 mmhos/cm)
Sodium adsorption ratio, maximum: 30.0
Available water capacity: High (about 10.2 inches)

Interpretive groups

Land capability (nonirrigated): 3e
Ecological site: Upland Loam (Mountain Big Sagebrush) (R028AY310UT)
Other vegetative classification: Upland Loam (Mountain Big Sagebrush) (028AY310UT)

Typical profile

0 to 6 inches: Silt loam
6 to 11 inches: Silt loam
11 to 15 inches: Silty clay loam
15 to 29 inches: Silty clay
29 to 42 inches: Silty clay loam
42 to 60 inches: Silt loam

Description of Dry Creek

Setting

Landform: Alluvial fans
Down-slope shape: Concave
Across-slope shape: Convex
Parent material: Alluvium derived from limestone, sandstone, and shale

Properties and qualities

Slope: 3 to 15 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.06 to 0.20 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 30 percent
Maximum salinity: Nonsaline (0.0 to 2.0 mmhos/cm)
Sodium adsorption ratio, maximum: 30.0
Available water capacity: Moderate (about 8.1 inches)

Interpretive groups

Land capability (nonirrigated): 3e
Ecological site: Upland Loam (Mountain Big Sagebrush) (R028AY310UT)
Other vegetative classification: Upland Loam (Mountain Big Sagebrush) (028AY310UT)

Typical profile

0 to 6 inches: Gravelly loam
6 to 11 inches: Gravelly loam
11 to 15 inches: Gravelly silty clay loam
15 to 29 inches: Gravelly silty clay
29 to 42 inches: Gravelly silty clay loam
42 to 60 inches: Very gravelly silt loam

Minor Components

Red rock

Percent of map unit: 5 percent

DPE—Dry Creek-Copperton association, moderately steep

Map Unit Setting

Elevation: 4,100 to 6,000 feet
Mean annual precipitation: 17 to 20 inches
Mean annual air temperature: 46 to 48 degrees F
Frost-free period: 120 to 150 days

Map Unit Composition

Dry creek and similar soils: 55 percent
Copperton and similar soils: 35 percent
Minor components: 5 percent

Description of Dry Creek

Setting

Landform: Alluvial fans
Down-slope shape: Concave
Across-slope shape: Convex
Parent material: Alluvium derived from limestone, sandstone, and shale

Properties and qualities

Slope: 15 to 30 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.06 to 0.20 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 30 percent
Maximum salinity: Nonsaline (0.0 to 2.0 mmhos/cm)
Sodium adsorption ratio, maximum: 30.0
Available water capacity: Moderate (about 8.1 inches)

Interpretive groups

Land capability (nonirrigated): 6e
Ecological site: Upland Loam (Mountain Big Sagebrush) (R028AY310UT)
Other vegetative classification: Upland Loam (Mountain Big Sagebrush) (028AY310UT)

Typical profile

0 to 6 inches: Gravelly loam
6 to 11 inches: Gravelly loam
11 to 15 inches: Gravelly silty clay loam
15 to 29 inches: Gravelly silty clay
29 to 42 inches: Gravelly silty clay loam
42 to 60 inches: Very gravelly silt loam

Description of Copperton

Setting

Landform: Breaks on alluvial fans
Down-slope shape: Concave, convex
Across-slope shape: Convex, linear
Parent material: Alluvium derived from limestone, sandstone, and shale

Properties and qualities

Slope: 6 to 40 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.60 to 2.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 60 percent
Maximum salinity: Nonsaline (0.0 to 2.0 mmhos/cm)
Sodium adsorption ratio, maximum: 13.0
Available water capacity: Low (about 5.1 inches)

Interpretive groups

Land capability (nonirrigated): 7s
Ecological site: Upland Gravelly Loam (Bonneville Big Sagebrush) (R028AY306UT)

Typical profile

0 to 6 inches: Very gravelly loam
6 to 13 inches: Very cobbly loam
13 to 19 inches: Very cobbly loam
19 to 42 inches: Very gravelly loam
42 to 60 inches: Extremely cobbly fine sandy loam

Minor Components

Hardpan soils

Percent of map unit: 5 percent

DRD—Dry Creek soils, 3 to 15 percent slopes

Map Unit Setting

Elevation: 4,100 to 6,000 feet
Mean annual precipitation: 17 to 19 inches
Mean annual air temperature: 46 to 48 degrees F
Frost-free period: 130 to 150 days

Map Unit Composition

Dry creek and similar soils: 45 percent
Dry creek and similar soils: 45 percent
Minor components: 10 percent

Description of Dry Creek

Setting

Landform: Alluvial fans
Down-slope shape: Concave
Across-slope shape: Convex
Parent material: Alluvium derived from limestone, sandstone, and shale

Properties and qualities

Slope: 3 to 15 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.06 to 0.20 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 30 percent
Maximum salinity: Nonsaline (0.0 to 2.0 mmhos/cm)
Sodium adsorption ratio, maximum: 30.0
Available water capacity: High (about 10.2 inches)

Interpretive groups

Land capability (nonirrigated): 3e
Ecological site: Upland Loam (Mountain Big Sagebrush) (R028AY310UT)
Other vegetative classification: Upland Loam (Mountain Big Sagebrush) (028AY310UT)

Typical profile

0 to 6 inches: Silt loam
6 to 11 inches: Silt loam
11 to 15 inches: Silty clay loam
15 to 29 inches: Silty clay
29 to 42 inches: Silty clay loam
42 to 60 inches: Silt loam

Description of Dry Creek

Setting

Landform: Alluvial fans
Down-slope shape: Concave
Across-slope shape: Convex
Parent material: Alluvium derived from limestone, sandstone, and shale

Properties and qualities

Slope: 3 to 15 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.06 to 0.20 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 30 percent
Maximum salinity: Nonsaline (0.0 to 2.0 mmhos/cm)
Sodium adsorption ratio, maximum: 30.0
Available water capacity: Moderate (about 8.1 inches)

Interpretive groups

Land capability (nonirrigated): 3e
Ecological site: Upland Loam (Mountain Big Sagebrush) (R028AY310UT)
Other vegetative classification: Upland Loam (Mountain Big Sagebrush) (028AY310UT)

Typical profile

0 to 6 inches: Gravelly loam
6 to 11 inches: Gravelly loam
11 to 15 inches: Gravelly silty clay loam
15 to 29 inches: Gravelly silty clay
29 to 42 inches: Gravelly silty clay loam
42 to 60 inches: Very gravelly silt loam

Minor Components

Copperton

Percent of map unit: 10 percent
Landform: Ridges, terraces
Ecological site: Upland Gravelly Loam (Bonneville Big Sagebrush) (R028AY306UT)

HDF—Harkers-Dry Creek association, moderately steep

Map Unit Setting

Elevation: 4,100 to 7,500 feet
Mean annual precipitation: 17 to 25 inches
Mean annual air temperature: 44 to 48 degrees F

Frost-free period: 80 to 150 days

Map Unit Composition

Harkers and similar soils: 40 percent
Dry creek and similar soils: 25 percent
Copperton and similar soils: 25 percent
Minor components: 10 percent

Description of Harkers

Setting

Landform: Breaks on alluvial fans
Down-slope shape: Concave, convex
Across-slope shape: Convex, linear
Parent material: Colluvium derived from limestone, sandstone, and shale and/or residuum weathered from limestone, sandstone, and shale

Properties and qualities

Slope: 6 to 40 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.06 to 0.20 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Available water capacity: Moderate (about 8.6 inches)

Interpretive groups

Land capability (nonirrigated): 6e
Ecological site: Mountain Loam (Oak) (R047XA432UT)

Typical profile

0 to 14 inches: Loam
14 to 19 inches: Gravelly clay loam
19 to 42 inches: Gravelly clay
42 to 58 inches: Very gravelly clay
58 to 80 inches: Very gravelly clay loam

Description of Copperton

Setting

Landform: Breaks on alluvial fans
Down-slope shape: Concave, convex
Across-slope shape: Convex, linear
Parent material: Alluvium derived from limestone, sandstone, and shale

Properties and qualities

Slope: 6 to 40 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.60 to 2.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 60 percent

Maximum salinity: Nonsaline (0.0 to 2.0 mmhos/cm)
Sodium adsorption ratio, maximum: 13.0
Available water capacity: Low (about 5.1 inches)

Interpretive groups

Land capability (nonirrigated): 7s
Ecological site: Upland Gravelly Loam (Bonneville Big Sagebrush) (R028AY306UT)

Typical profile

0 to 6 inches: Very gravelly loam
6 to 13 inches: Very cobbly loam
13 to 19 inches: Very cobbly loam
19 to 42 inches: Very gravelly loam
42 to 60 inches: Extremely gravelly loamy sand

Description of Dry Creek

Setting

Landform: Drainageways on alluvial fans
Down-slope shape: Linear, concave
Across-slope shape: Concave, convex
Parent material: Alluvium derived from limestone, sandstone, and shale

Properties and qualities

Slope: 15 to 30 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.06 to 0.20 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 30 percent
Maximum salinity: Nonsaline (0.0 to 2.0 mmhos/cm)
Sodium adsorption ratio, maximum: 30.0
Available water capacity: Moderate (about 8.1 inches)

Interpretive groups

Land capability (nonirrigated): 6e
Ecological site: Upland Loam (Mountain Big Sagebrush) (R028AY310UT)
Other vegetative classification: Upland Loam (Mountain Big Sagebrush) (028AY310UT)

Typical profile

0 to 6 inches: Gravelly loam
6 to 11 inches: Gravelly loam
11 to 15 inches: Gravelly silty clay loam
15 to 29 inches: Gravelly silty clay
29 to 42 inches: Gravelly silty clay loam
42 to 60 inches: Very gravelly silt loam

Minor Components

Dry creek

Percent of map unit: 5 percent

Harkers

Percent of map unit: 5 percent

HHF—Harkers soils, 6 to 40 percent slopes

Map Unit Setting

Elevation: 5,500 to 7,500 feet
Mean annual precipitation: 20 to 25 inches
Mean annual air temperature: 44 to 46 degrees F
Frost-free period: 80 to 100 days

Map Unit Composition

Harkers and similar soils: 45 percent
Harkers and similar soils: 45 percent
Minor components: 5 percent

Description of Harkers

Setting

Landform: Alluvial fans, mountain slopes
Down-slope shape: Concave
Across-slope shape: Convex
Parent material: Colluvium derived from limestone, sandstone, and shale and/or residuum weathered from limestone, sandstone, and shale

Properties and qualities

Slope: 10 to 40 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.06 to 0.20 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Available water capacity: Moderate (about 8.6 inches)

Interpretive groups

Land capability (nonirrigated): 6e
Ecological site: Mountain Loam (Oak) (R047XA432UT)

Typical profile

0 to 14 inches: Loam
14 to 19 inches: Gravelly clay loam
19 to 42 inches: Gravelly clay
42 to 58 inches: Very gravelly clay
58 to 80 inches: Very gravelly clay loam

Description of Harkers

Setting

Landform: Alluvial fans, mountain slopes

Down-slope shape: Concave
Across-slope shape: Convex
Parent material: Colluvium derived from limestone, sandstone, and shale and/or residuum weathered from limestone, sandstone, and shale

Properties and qualities

Slope: 6 to 40 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.06 to 0.20 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Available water capacity: Moderate (about 8.2 inches)

Interpretive groups

Land capability (nonirrigated): 6e
Ecological site: Mountain Loam (Oak) (R047XA432UT)

Typical profile

0 to 14 inches: Cobbly loam
14 to 19 inches: Gravelly clay loam
19 to 42 inches: Gravelly clay
42 to 58 inches: Very gravelly clay
58 to 80 inches: Very gravelly clay loam

Minor Components

Wallsburg

Percent of map unit: 5 percent
Landform: Mountain slopes
Ecological site: Mountain Shallow Loam (Mountain Big Sagebrush) (R047XA446UT)

PT—Pits, mine

Map Unit Setting

Elevation: 4,200 to 9,000 feet

Map Unit Composition

Pits, mine: 100 percent

SP—Stony terrace escarpments

Map Unit Setting

Elevation: 4,200 to 5,200 feet
Mean annual precipitation: 14 to 18 inches

Mean annual air temperature: 49 to 56 degrees F
Frost-free period: 130 to 180 days

Map Unit Composition

Stony terrace escarpments: 100 percent

Description of Stony Terrace Escarpments

Setting

Landform: Terraces
Landform position (three-dimensional): Tread
Down-slope shape: Linear
Across-slope shape: Linear

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Glossary

Many of the terms relating to landforms, geology, and geomorphology are defined in more detail in the “National Soil Survey Handbook.”

ABC soil

A soil having an A, a B, and a C horizon.

Ablation till

Loose, relatively permeable earthy material deposited during the downwasting of nearly static glacial ice, either contained within or accumulated on the surface of the glacier.

AC soil

A soil having only an A and a C horizon. Commonly, such soil formed in recent alluvium or on steep, rocky slopes.

Aeration, soil

The exchange of air in soil with air from the atmosphere. The air in a well aerated soil is similar to that in the atmosphere; the air in a poorly aerated soil is considerably higher in carbon dioxide and lower in oxygen.

Aggregate, soil

Many fine particles held in a single mass or cluster. Natural soil aggregates, such as granules, blocks, or prisms, are called peds. Clods are aggregates produced by tillage or logging.

Alkali (sodic) soil

A soil having so high a degree of alkalinity (pH 8.5 or higher) or so high a percentage of exchangeable sodium (15 percent or more of the total exchangeable bases), or both, that plant growth is restricted.

Alluvial cone

A semiconical type of alluvial fan having very steep slopes. It is higher, narrower, and steeper than a fan and is composed of coarser and thicker layers of material deposited by a combination of alluvial episodes and (to a much lesser degree) landslides (debris flow). The coarsest materials tend to be concentrated at the apex of the cone.

Alluvial fan

A low, outspread mass of loose materials and/or rock material, commonly with gentle slopes. It is shaped like an open fan or a segment of a cone. The material was deposited by a stream at the place where it issues from a narrow mountain valley or upland valley or where a tributary stream is near or at its junction with the main stream. The fan is steepest near its apex, which points upstream, and slopes gently and convexly outward (downstream) with a gradual decrease in gradient.

Alluvium

Unconsolidated material, such as gravel, sand, silt, clay, and various mixtures of these, deposited on land by running water.

Alpha,alpha-dipyridyl

A compound that when dissolved in ammonium acetate is used to detect the presence of reduced iron (Fe II) in the soil. A positive reaction implies reducing conditions and the likely presence of redoximorphic features.

Animal unit month (AUM)

The amount of forage required by one mature cow of approximately 1,000 pounds weight, with or without a calf, for 1 month.

Aquic conditions

Current soil wetness characterized by saturation, reduction, and redoximorphic features.

Argillic horizon

A subsoil horizon characterized by an accumulation of illuvial clay.

Arroyo

The flat-floored channel of an ephemeral stream, commonly with very steep to vertical banks cut in unconsolidated material. It is usually dry but can be transformed into a temporary watercourse or short-lived torrent after heavy rain within the watershed.

Aspect

The direction toward which a slope faces. Also called slope aspect.

Association, soil

A group of soils or miscellaneous areas geographically associated in a characteristic repeating pattern and defined and delineated as a single map unit.

Available water capacity (available moisture capacity)

The capacity of soils to hold water available for use by most plants. It is commonly defined as the difference between the amount of soil water at field moisture capacity and the amount at wilting point. It is commonly expressed as inches of water per inch of soil. The capacity, in inches, in a 60-inch profile or to a limiting layer is expressed as:

Very low: 0 to 3
Low: 3 to 6
Moderate: 6 to 9
High: 9 to 12
Very high: More than 12

Backslope

The position that forms the steepest and generally linear, middle portion of a hillslope. In profile, backslopes are commonly bounded by a convex shoulder above and a concave footslope below.

Backswamp

A flood-plain landform. Extensive, marshy or swampy, depressed areas of flood plains between natural levees and valley sides or terraces.

Badland

A landscape that is intricately dissected and characterized by a very fine drainage network with high drainage densities and short, steep slopes and narrow interfluves. Badlands develop on surfaces that have little or no vegetative cover overlying unconsolidated or poorly cemented materials (clays, silts, or sandstones) with, in some cases, soluble minerals, such as gypsum or halite.

Bajada

A broad, gently inclined alluvial piedmont slope extending from the base of a mountain range out into a basin and formed by the lateral coalescence of a series of alluvial fans. Typically, it has a broadly undulating transverse profile, parallel to the mountain front, resulting from the convexities of component fans. The term is generally restricted to constructional slopes of intermontane basins.

Basal area

The area of a cross section of a tree, generally referring to the section at breast height and measured outside the bark. It is a measure of stand density, commonly expressed in square feet.

Base saturation

The degree to which material having cation-exchange properties is saturated with exchangeable bases (sum of Ca, Mg, Na, and K), expressed as a percentage of the total cation-exchange capacity.

Base slope (geomorphology)

A geomorphic component of hills consisting of the concave to linear (perpendicular to the contour) slope that, regardless of the lateral shape, forms an apron or wedge at the bottom of a hillside dominated by colluvium and slope-wash sediments (for example, slope alluvium).

Bedding plane

A planar or nearly planar bedding surface that visibly separates each successive layer of stratified sediment or rock (of the same or different lithology) from the preceding or following layer; a plane of deposition. It commonly marks a change in the circumstances of deposition and may show a parting, a color difference, a change in particle size, or various combinations of these. The term is commonly applied to any bedding surface, even one that is conspicuously bent or deformed by folding.

Bedding system

A drainage system made by plowing, grading, or otherwise shaping the surface of a flat field. It consists of a series of low ridges separated by shallow, parallel dead furrows.

Bedrock

The solid rock that underlies the soil and other unconsolidated material or that is exposed at the surface.

Bedrock-controlled topography

A landscape where the configuration and relief of the landforms are determined or strongly influenced by the underlying bedrock.

Bench terrace

A raised, level or nearly level strip of earth constructed on or nearly on a contour, supported by a barrier of rocks or similar material, and designed to make the soil suitable for tillage and to prevent accelerated erosion.

Bisequum

Two sequences of soil horizons, each of which consists of an illuvial horizon and the overlying eluvial horizons.

Blowout (map symbol)

A saucer-, cup-, or trough-shaped depression formed by wind erosion on a preexisting dune or other sand deposit, especially in an area of shifting sand or loose soil or where protective vegetation is disturbed or destroyed. The adjoining accumulation of sand derived from the depression, where recognizable, is commonly included. Blowouts are commonly small.

Borrow pit (map symbol)

An open excavation from which soil and underlying material have been removed, usually for construction purposes.

Bottom land

An informal term loosely applied to various portions of a flood plain.

Boulders

Rock fragments larger than 2 feet (60 centimeters) in diameter.

Breaks

A landscape or tract of steep, rough or broken land dissected by ravines and gullies and marking a sudden change in topography.

Breast height

An average height of 4.5 feet above the ground surface; the point on a tree where diameter measurements are ordinarily taken.

Brush management

Use of mechanical, chemical, or biological methods to make conditions favorable for reseeding or to reduce or eliminate competition from woody vegetation and thus allow understory grasses and forbs to recover. Brush management increases forage production and thus reduces the hazard of erosion. It can improve the habitat for some species of wildlife.

Butte

An isolated, generally flat-topped hill or mountain with relatively steep slopes and talus or precipitous cliffs and characterized by summit width that is less than the height of bounding escarpments; commonly topped by a caprock of resistant material and representing an erosion remnant carved from flat-lying rocks.

Cable yarding

A method of moving felled trees to a nearby central area for transport to a processing facility. Most cable yarding systems involve use of a drum, a pole, and wire cables in an arrangement similar to that of a rod and reel used for fishing. To reduce friction and soil disturbance, felled trees generally are reeled in while one end is lifted or the entire log is suspended.

Calcareous soil

A soil containing enough calcium carbonate (commonly combined with magnesium carbonate) to effervesce visibly when treated with cold, dilute hydrochloric acid.

Caliche

A general term for a prominent zone of secondary carbonate accumulation in surficial materials in warm, subhumid to arid areas. Caliche is formed by both geologic and pedologic processes. Finely crystalline calcium carbonate forms a nearly continuous surface-coating and void-filling medium in geologic (parent) materials. Cementation ranges from weak in nonindurated forms to very strong in indurated forms. Other minerals (e.g., carbonates, silicate, and sulfate) may occur as accessory cements. Most petrocalcic horizons and some calcic horizons are caliche.

California bearing ratio (CBR)

The load-supporting capacity of a soil as compared to that of standard crushed limestone, expressed as a ratio. First standardized in California. A soil having a CBR of 16 supports 16 percent of the load that would be supported by standard crushed limestone, per unit area, with the same degree of distortion.

Canopy

The leafy crown of trees or shrubs. (See Crown.)

Canyon

A long, deep, narrow valley with high, precipitous walls in an area of high local relief.

Capillary water

Water held as a film around soil particles and in tiny spaces between particles. Surface tension is the adhesive force that holds capillary water in the soil.

Catena

A sequence, or “chain,” of soils on a landscape that formed in similar kinds of parent material and under similar climatic conditions but that have different characteristics as a result of differences in relief and drainage.

Cation

An ion carrying a positive charge of electricity. The common soil cations are calcium, potassium, magnesium, sodium, and hydrogen.

Cation-exchange capacity

The total amount of exchangeable cations that can be held by the soil, expressed in terms of milliequivalents per 100 grams of soil at neutrality (pH 7.0) or at some other stated pH value. The term, as applied to soils, is synonymous with base-exchange capacity but is more precise in meaning.

Catsteps

See Terracettes.

Cement rock

Shaly limestone used in the manufacture of cement.

Channery soil material

Soil material that has, by volume, 15 to 35 percent thin, flat fragments of sandstone, shale, slate, limestone, or schist as much as 6 inches (15 centimeters) along the longest axis. A single piece is called a channer.

Chemical treatment

Control of unwanted vegetation through the use of chemicals.

Chiseling

Tillage with an implement having one or more soil-penetrating points that shatter or loosen hard, compacted layers to a depth below normal plow depth.

Cirque

A steep-walled, semicircular or crescent-shaped, half-bowl-like recess or hollow, commonly situated at the head of a glaciated mountain valley or high on the side of a mountain. It was produced by the erosive activity of a mountain glacier. It commonly contains a small round lake (tarn).

Clay

As a soil separate, the mineral soil particles less than 0.002 millimeter in diameter. As a soil textural class, soil material that is 40 percent or more clay, less than 45 percent sand, and less than 40 percent silt.

Clay depletions

See Redoximorphic features.

Clay film

A thin coating of oriented clay on the surface of a soil aggregate or lining pores or root channels. Synonyms: clay coating, clay skin.

Clay spot (map symbol)

A spot where the surface texture is silty clay or clay in areas where the surface layer of the soils in the surrounding map unit is sandy loam, loam, silt loam, or coarser.

Claypan

A dense, compact subsoil layer that contains much more clay than the overlying materials, from which it is separated by a sharply defined boundary. The layer restricts the downward movement of water through the soil. A claypan is commonly hard when dry and plastic and sticky when wet.

Climax plant community

The stabilized plant community on a particular site. The plant cover reproduces itself and does not change so long as the environment remains the same.

Coarse textured soil

Sand or loamy sand.

Cobble (or cobblestone)

A rounded or partly rounded fragment of rock 3 to 10 inches (7.6 to 25 centimeters) in diameter.

Cobbly soil material

Material that has 15 to 35 percent, by volume, rounded or partially rounded rock fragments 3 to 10 inches (7.6 to 25 centimeters) in diameter. Very cobbly soil material has 35 to 60 percent of these rock fragments, and extremely cobbly soil material has more than 60 percent.

COLE (coefficient of linear extensibility)

See Linear extensibility.

Colluvium

Unconsolidated, unsorted earth material being transported or deposited on side slopes and/or at the base of slopes by mass movement (e.g., direct gravitational action) and by local, unconcentrated runoff.

Complex slope

Irregular or variable slope. Planning or establishing terraces, diversions, and other water-control structures on a complex slope is difficult.

Complex, soil

A map unit of two or more kinds of soil or miscellaneous areas in such an intricate pattern or so small in area that it is not practical to map them separately at the selected scale of mapping. The pattern and proportion of the soils or miscellaneous areas are somewhat similar in all areas.

Concretions

See Redoximorphic features.

Conglomerate

A coarse grained, clastic sedimentary rock composed of rounded or subangular rock fragments more than 2 millimeters in diameter. It commonly has a matrix of sand and finer textured material. Conglomerate is the consolidated equivalent of gravel.

Conservation cropping system

Growing crops in combination with needed cultural and management practices. In a good conservation cropping system, the soil-improving crops and practices more than offset the effects of the soil-depleting crops and practices. Cropping systems are needed on all tilled soils. Soil-improving practices in a conservation cropping system include the use of rotations that contain grasses and legumes and the return of crop residue to the soil. Other practices include the use of green manure crops of grasses and legumes, proper tillage, adequate fertilization, and weed and pest control.

Conservation tillage

A tillage system that does not invert the soil and that leaves a protective amount of crop residue on the surface throughout the year.

Consistence, soil

Refers to the degree of cohesion and adhesion of soil material and its resistance to deformation when ruptured. Consistence includes resistance of soil material to rupture and to penetration; plasticity, toughness, and stickiness of puddled soil material; and the manner in which the soil material behaves when subject to compression. Terms describing consistence are defined in the "Soil Survey Manual."

Contour stripcropping

Growing crops in strips that follow the contour. Strips of grass or close-growing crops are alternated with strips of clean-tilled crops or summer fallow.

Control section

The part of the soil on which classification is based. The thickness varies among different kinds of soil, but for many it is that part of the soil profile between depths of 10 inches and 40 or 80 inches.

Coprogenous earth (sedimentary peat)

A type of limnic layer composed predominantly of fecal material derived from aquatic animals.

Corrosion (geomorphology)

A process of erosion whereby rocks and soil are removed or worn away by natural chemical processes, especially by the solvent action of running water, but also by other reactions, such as hydrolysis, hydration, carbonation, and oxidation.

Corrosion (soil survey interpretations)

Soil-induced electrochemical or chemical action that dissolves or weakens concrete or uncoated steel.

Cover crop

A close-growing crop grown primarily to improve and protect the soil between periods of regular crop production, or a crop grown between trees and vines in orchards and vineyards.

Crop residue management

Returning crop residue to the soil, which helps to maintain soil structure, organic matter content, and fertility and helps to control erosion.

Cropping system

Growing crops according to a planned system of rotation and management practices.

Cross-slope farming

Deliberately conducting farming operations on sloping farmland in such a way that tillage is across the general slope.

Crown

The upper part of a tree or shrub, including the living branches and their foliage.

Cryoturbate

A mass of soil or other unconsolidated earthy material moved or disturbed by frost action. It is typically coarser than the underlying material.

Cuesta

An asymmetric ridge capped by resistant rock layers of slight or moderate dip (commonly less than 15 percent slopes); a type of homocline produced by differential erosion of interbedded resistant and weak rocks. A cuesta has a long, gentle slope on one side (dip slope) that roughly parallels the inclined beds; on the other side, it has a relatively short and steep or clifflike slope (scarp) that cuts through the tilted rocks.

Culmination of the mean annual increment (CMAI)

The average annual increase per acre in the volume of a stand. Computed by dividing the total volume of the stand by its age. As the stand increases in age, the mean annual increment continues to increase until mortality begins to reduce the rate of increase. The point where the stand reaches its maximum annual rate of growth is called the culmination of the mean annual increment.

Cutbanks cave

The walls of excavations tend to cave in or slough.

Decreasers

The most heavily grazed climax range plants. Because they are the most palatable, they are the first to be destroyed by overgrazing.

Deferred grazing

Postponing grazing or resting grazing land for a prescribed period.

Delta

A body of alluvium having a surface that is fan shaped and nearly flat; deposited at or near the mouth of a river or stream where it enters a body of relatively quiet water, generally a sea or lake.

Dense layer

A very firm, massive layer that has a bulk density of more than 1.8 grams per cubic centimeter. Such a layer affects the ease of digging and can affect filling and compacting.

Depression, closed (map symbol)

A shallow, saucer-shaped area that is slightly lower on the landscape than the surrounding area and that does not have a natural outlet for surface drainage.

Depth, soil

Generally, the thickness of the soil over bedrock. Very deep soils are more than 60 inches deep over bedrock; deep soils, 40 to 60 inches; moderately deep, 20 to 40 inches; shallow, 10 to 20 inches; and very shallow, less than 10 inches.

Desert pavement

A natural, residual concentration or layer of wind-polished, closely packed gravel, boulders, and other rock fragments mantling a desert surface. It forms where wind action and sheetwash have removed all smaller particles or where rock fragments have migrated upward through sediments to the surface. It typically protects the finer grained underlying material from further erosion.

Diatomaceous earth

A geologic deposit of fine, grayish siliceous material composed chiefly or entirely of the remains of diatoms.

Dip slope

A slope of the land surface, roughly determined by and approximately conforming to the dip of the underlying bedrock.

Diversion (or diversion terrace)

A ridge of earth, generally a terrace, built to protect downslope areas by diverting runoff from its natural course.

Divided-slope farming

A form of field stripcropping in which crops are grown in a systematic arrangement of two strips, or bands, across the slope to reduce the hazard of water erosion. One strip is in a close-growing crop that provides protection from erosion, and the other strip is in a crop that provides less protection from erosion. This practice is used where slopes are not long enough to permit a full stripcropping pattern to be used.

Drainage class (natural)

Refers to the frequency and duration of wet periods under conditions similar to those under which the soil formed. Alterations of the water regime by human activities, either through drainage or irrigation, are not a consideration unless they have significantly changed the morphology of the soil. Seven classes of natural soil drainage are recognized—*excessively drained, somewhat excessively drained, well drained, moderately well drained, somewhat poorly drained, poorly drained,* and *very poorly drained*. These classes are defined in the "Soil Survey Manual."

Drainage, surface

Runoff, or surface flow of water, from an area.

Drainageway

A general term for a course or channel along which water moves in draining an area. A term restricted to relatively small, linear depressions that at some time move concentrated water and either do not have a defined channel or have only a small defined channel.

Draw

A small stream valley that generally is shallower and more open than a ravine or gulch and that has a broader bottom. The present stream channel may appear inadequate to have cut the drainageway that it occupies.

Drift

A general term applied to all mineral material (clay, silt, sand, gravel, and boulders) transported by a glacier and deposited directly by or from the ice or transported by running water emanating from a glacier. Drift includes unstratified material (till) that forms moraines and stratified deposits that form outwash plains, eskers, kames, varves, and glaciofluvial sediments. The term is generally applied to Pleistocene glacial deposits in areas that no longer contain glaciers.

Drumlin

A low, smooth, elongated oval hill, mound, or ridge of compact till that has a core of bedrock or drift. It commonly has a blunt nose facing the direction from which the ice approached and a gentler slope tapering in the other direction. The longer axis is parallel to the general direction of glacier flow. Drumlins are products of streamline (laminar) flow of glaciers, which molded the subglacial floor through a combination of erosion and deposition.

Duff

A generally firm organic layer on the surface of mineral soils. It consists of fallen plant material that is in the process of decomposition and includes everything from the litter on the surface to underlying pure humus.

Dune

A low mound, ridge, bank, or hill of loose, windblown granular material (generally sand), either barren and capable of movement from place to place or covered and stabilized with vegetation but retaining its characteristic shape.

Earthy fill

See Mine spoil.

Ecological site

An area where climate, soil, and relief are sufficiently uniform to produce a distinct natural plant community. An ecological site is the product of all the environmental factors responsible for its development. It is typified by an association of species that differ from those on other ecological sites in kind and/or proportion of species or in total production.

Eluviation

The movement of material in true solution or colloidal suspension from one place to another within the soil. Soil horizons that have lost material through eluviation are eluvial; those that have received material are illuvial.

Endosaturation

A type of saturation of the soil in which all horizons between the upper boundary of saturation and a depth of 2 meters are saturated.

Eolian deposit

Sand-, silt-, or clay-sized clastic material transported and deposited primarily by wind, commonly in the form of a dune or a sheet of sand or loess.

Ephemeral stream

A stream, or reach of a stream, that flows only in direct response to precipitation. It receives no long-continued supply from melting snow or other source, and its channel is above the water table at all times.

Episaturation

A type of saturation indicating a perched water table in a soil in which saturated layers are underlain by one or more unsaturated layers within 2 meters of the surface.

Erosion

The wearing away of the land surface by water, wind, ice, or other geologic agents and by such processes as gravitational creep.

Erosion (accelerated)

Erosion much more rapid than geologic erosion, mainly as a result of human or animal activities or of a catastrophe in nature, such as a fire, that exposes the surface.

Erosion (geologic)

Erosion caused by geologic processes acting over long geologic periods and resulting in the wearing away of mountains and the building up of such landscape features as flood plains and coastal plains. Synonym: natural erosion.

Erosion pavement

A surficial lag concentration or layer of gravel and other rock fragments that remains on the soil surface after sheet or rill erosion or wind has removed the finer soil particles and that tends to protect the underlying soil from further erosion.

Erosion surface

A land surface shaped by the action of erosion, especially by running water.

Escarpment

A relatively continuous and steep slope or cliff breaking the general continuity of more gently sloping land surfaces and resulting from erosion or faulting. Most commonly applied to cliffs produced by differential erosion. Synonym: scarp.

Escarpment, bedrock (map symbol)

A relatively continuous and steep slope or cliff, produced by erosion or faulting, that breaks the general continuity of more gently sloping land surfaces. Exposed material is hard or soft bedrock.

Escarpment, nonbedrock (map symbol)

A relatively continuous and steep slope or cliff, generally produced by erosion but in some places produced by faulting, that breaks the continuity of more gently sloping land surfaces. Exposed earthy material is nonsoil or very shallow soil.

Esker

A long, narrow, sinuous, steep-sided ridge of stratified sand and gravel deposited as the bed of a stream flowing in an ice tunnel within or below the ice (subglacial) or between ice walls on top of the ice of a wasting glacier and left behind as high ground when the ice melted. Eskers range in length from less than a kilometer to more than 160 kilometers and in height from 3 to 30 meters.

Extrusive rock

Igneous rock derived from deep-seated molten matter (magma) deposited and cooled on the earth’s surface.

Fallow

Cropland left idle in order to restore productivity through accumulation of moisture. Summer fallow is common in regions of limited rainfall where cereal grain is grown.

The soil is tilled for at least one growing season for weed control and decomposition of plant residue.

Fan remnant

A general term for landforms that are the remaining parts of older fan landforms, such as alluvial fans, that have been either dissected or partially buried.

Fertility, soil

The quality that enables a soil to provide plant nutrients, in adequate amounts and in proper balance, for the growth of specified plants when light, moisture, temperature, tilth, and other growth factors are favorable.

Fibric soil material (peat)

The least decomposed of all organic soil material. Peat contains a large amount of well preserved fiber that is readily identifiable according to botanical origin. Peat has the lowest bulk density and the highest water content at saturation of all organic soil material.

Field moisture capacity

The moisture content of a soil, expressed as a percentage of the ovendry weight, after the gravitational, or free, water has drained away; the field moisture content 2 or 3 days after a soaking rain; also called *normal field capacity, normal moisture capacity,* or *capillary capacity*.

Fill slope

A sloping surface consisting of excavated soil material from a road cut. It commonly is on the downhill side of the road.

Fine textured soil

Sandy clay, silty clay, or clay.

Firebreak

An area cleared of flammable material to stop or help control creeping or running fires. It also serves as a line from which to work and to facilitate the movement of firefighters and equipment. Designated roads also serve as firebreaks.

First bottom

An obsolete, informal term loosely applied to the lowest flood-plain steps that are subject to regular flooding.

Flaggy soil material

Material that has, by volume, 15 to 35 percent flagstones. Very flaggy soil material has 35 to 60 percent flagstones, and extremely flaggy soil material has more than 60 percent flagstones.

Flagstone

A thin fragment of sandstone, limestone, slate, shale, or (rarely) schist 6 to 15 inches (15 to 38 centimeters) long.

Flood plain

The nearly level plain that borders a stream and is subject to flooding unless protected artificially.

Flood-plain landforms

A variety of constructional and erosional features produced by stream channel migration and flooding. Examples include backswamps, flood-plain splays, meanders, meander belts, meander scrolls, oxbow lakes, and natural levees.

Flood-plain splay

A fan-shaped deposit or other outspread deposit formed where an overloaded stream breaks through a levee (natural or artificial) and deposits its material (commonly coarse grained) on the flood plain.

Flood-plain step

An essentially flat, terrace-like alluvial surface within a valley that is frequently covered by floodwater from the present stream; any approximately horizontal surface still actively modified by fluvial scour and/or deposition. May occur individually or as a series of steps.

Fluvial

Of or pertaining to rivers or streams; produced by stream or river action.

Foothills

A region of steeply sloping hills that fringes a mountain range or high-plateau escarpment. The hills have relief of as much as 1,000 feet (300 meters).

Footslope

The concave surface at the base of a hillslope. A footslope is a transition zone between upslope sites of erosion and transport (shoulders and backslopes) and downslope sites of deposition (toeslopes).

Forb

Any herbaceous plant not a grass or a sedge.

Forest cover

All trees and other woody plants (underbrush) covering the ground in a forest.

Forest type

A stand of trees similar in composition and development because of given physical and biological factors by which it may be differentiated from other stands.

Fragipan

A loamy, brittle subsurface horizon low in porosity and content of organic matter and low or moderate in clay but high in silt or very fine sand. A fragipan appears cemented and restricts roots. When dry, it is hard or very hard and has a higher bulk density than the horizon or horizons above. When moist, it tends to rupture suddenly under pressure rather than to deform slowly.

Genesis, soil

The mode of origin of the soil. Refers especially to the processes or soil-forming factors responsible for the formation of the solum, or true soil, from the unconsolidated parent material.

Gilgai

Commonly, a succession of microbasins and microknolls in nearly level areas or of microvalleys and microridges parallel with the slope. Typically, the microrelief of clayey soils that shrink and swell considerably with changes in moisture content.

Glaciofluvial deposits

Material moved by glaciers and subsequently sorted and deposited by streams flowing from the melting ice. The deposits are stratified and occur in the form of outwash plains, valley trains, deltas, kames, eskers, and kame terraces.

Glaciolacustrine deposits

Material ranging from fine clay to sand derived from glaciers and deposited in glacial lakes mainly by glacial meltwater. Many deposits are bedded or laminated.

Gleyed soil

Soil that formed under poor drainage, resulting in the reduction of iron and other elements in the profile and in gray colors.

Graded stripcropping

Growing crops in strips that grade toward a protected waterway.

Grassed waterway

A natural or constructed waterway, typically broad and shallow, seeded to grass as protection against erosion. Conducts surface water away from cropland.

Gravel

Rounded or angular fragments of rock as much as 3 inches (2 millimeters to 7.6 centimeters) in diameter. An individual piece is a pebble.

Gravel pit (map symbol)

An open excavation from which soil and underlying material have been removed and used, without crushing, as a source of sand or gravel.

Gravelly soil material

Material that has 15 to 35 percent, by volume, rounded or angular rock fragments, not prominently flattened, as much as 3 inches (7.6 centimeters) in diameter.

Gravelly spot (map symbol)

A spot where the surface layer has more than 35 percent, by volume, rock fragments that are mostly less than 3 inches in diameter in an area that has less than 15 percent rock fragments.

Green manure crop (agronomy)

A soil-improving crop grown to be plowed under in an early stage of maturity or soon after maturity.

Ground water

Water filling all the unblocked pores of the material below the water table.

Gully (map symbol)

A small, steep-sided channel caused by erosion and cut in unconsolidated materials by concentrated but intermittent flow of water. The distinction between a gully and a rill is one of depth. A gully generally is an obstacle to farm machinery and is too deep to be obliterated by ordinary tillage whereas a rill is of lesser depth and can be smoothed over by ordinary tillage.

Hard bedrock

Bedrock that cannot be excavated except by blasting or by the use of special equipment that is not commonly used in construction.

Hard to reclaim

Reclamation is difficult after the removal of soil for construction and other uses. Revegetation and erosion control are extremely difficult.

Hardpan

A hardened or cemented soil horizon, or layer. The soil material is sandy, loamy, or clayey and is cemented by iron oxide, silica, calcium carbonate, or other substance.

Head slope (geomorphology)

A geomorphic component of hills consisting of a laterally concave area of a hillside, especially at the head of a drainageway. The overland waterflow is converging.

Hemic soil material (mucky peat)

Organic soil material intermediate in degree of decomposition between the less decomposed fibric material and the more decomposed sapric material.

High-residue crops

Such crops as small grain and corn used for grain. If properly managed, residue from these crops can be used to control erosion until the next crop in the rotation is established. These crops return large amounts of organic matter to the soil.

Hill

A generic term for an elevated area of the land surface, rising as much as 1,000 feet above surrounding lowlands, commonly of limited summit area and having a well defined outline. Slopes are generally more than 15 percent. The distinction between a hill and a mountain is arbitrary and may depend on local usage.

Hillslope

A generic term for the steeper part of a hill between its summit and the drainage line, valley flat, or depression floor at the base of a hill.

Horizon, soil

A layer of soil, approximately parallel to the surface, having distinct characteristics produced by soil-forming processes. In the identification of soil horizons, an uppercase letter represents the major horizons. Numbers or lowercase letters that follow represent subdivisions of the major horizons. An explanation of the subdivisions is given in the “Soil Survey Manual.” The major horizons of mineral soil are as follows:

O horizon: An organic layer of fresh and decaying plant residue.

L horizon: A layer of organic and mineral limnic materials, including coprogenous earth (sedimentary peat), diatomaceous earth, and marl.

A horizon: The mineral horizon at or near the surface in which an accumulation of humified organic matter is mixed with the mineral material. Also, a plowed surface horizon, most of which was originally part of a B horizon.

E horizon: The mineral horizon in which the main feature is loss of silicate clay, iron, aluminum, or some combination of these.

B horizon: The mineral horizon below an A horizon. The B horizon is in part a layer of transition from the overlying A to the underlying C horizon. The B horizon also has distinctive characteristics, such as (1) accumulation of clay, sesquioxides, humus, or a combination of these; (2) prismatic or blocky structure; (3) redder or browner colors than those in the A horizon; or (4) a combination of these.

C horizon: The mineral horizon or layer, excluding indurated bedrock, that is little affected by soil-forming processes and does not have the properties typical of the overlying soil material. The material of a C horizon may be either like or unlike that in which the solum formed. If the material is known to differ from that in the solum, an Arabic numeral, commonly a 2, precedes the letter C.

Cr horizon: Soft, consolidated bedrock beneath the soil.

R layer: Consolidated bedrock beneath the soil. The bedrock commonly underlies a C horizon, but it can be directly below an A or a B horizon.

M layer: A root-limiting subsoil layer consisting of nearly continuous, horizontally oriented, human-manufactured materials.

W layer: A layer of water within or beneath the soil.

Humus

The well decomposed, more or less stable part of the organic matter in mineral soils.

Hydrologic soil groups

Refers to soils grouped according to their runoff potential. The soil properties that influence this potential are those that affect the minimum rate of water infiltration on a bare soil during periods after prolonged wetting when the soil is not frozen. These properties include depth to a seasonal high water table, the infiltration rate, and depth to a layer that significantly restricts the downward movement of water. The slope and the kind of plant cover are not considered but are separate factors in predicting runoff.

Igneous rock

Rock that was formed by cooling and solidification of magma and that has not been changed appreciably by weathering since its formation. Major varieties include plutonic and volcanic rock (e.g., andesite, basalt, and granite).

Illuviation

The movement of soil material from one horizon to another in the soil profile. Generally, material is removed from an upper horizon and deposited in a lower horizon.

Impervious soil

A soil through which water, air, or roots penetrate slowly or not at all. No soil is absolutely impervious to air and water all the time.

Increasers

Species in the climax vegetation that increase in amount as the more desirable plants are reduced by close grazing. Increasers commonly are the shorter plants and the less palatable to livestock.

Infiltration

The downward entry of water into the immediate surface of soil or other material, as contrasted with percolation, which is movement of water through soil layers or material.

Infiltration capacity

The maximum rate at which water can infiltrate into a soil under a given set of conditions.

Infiltration rate

The rate at which water penetrates the surface of the soil at any given instant, usually expressed in inches per hour. The rate can be limited by the infiltration capacity of the soil or the rate at which water is applied at the surface.

Intake rate

The average rate of water entering the soil under irrigation. Most soils have a fast initial rate; the rate decreases with application time. Therefore, intake rate for design purposes is not a constant but is a variable depending on the net irrigation application. The rate of water intake, in inches per hour, is expressed as follows:

Very low: Less than 0.2
Low: 0.2 to 0.4
Moderately low: 0.4 to 0.75
Moderate: 0.75 to 1.25
Moderately high: 1.25 to 1.75
High: 1.75 to 2.5
Very high: More than 2.5

Interfluve

A landform composed of the relatively undissected upland or ridge between two adjacent valleys containing streams flowing in the same general direction. An elevated area between two drainageways that sheds water to those drainageways.

Interfluve (geomorphology)

A geomorphic component of hills consisting of the uppermost, comparatively level or gently sloping area of a hill; shoulders of backwearing hillslopes can narrow the upland or can merge, resulting in a strongly convex shape.

Intermittent stream

A stream, or reach of a stream, that does not flow year-round but that is commonly dry for 3 or more months out of 12 and whose channel is generally below the local water table. It flows only during wet periods or when it receives ground-water discharge or long, continued contributions from melting snow or other surface and shallow subsurface sources.

Invaders

On range, plants that encroach into an area and grow after the climax vegetation has been reduced by grazing. Generally, plants invade following disturbance of the surface.

Iron depletions

See Redoximorphic features.

Irrigation

Application of water to soils to assist in production of crops. Methods of irrigation are:

Basin: Water is applied rapidly to nearly level plains surrounded by levees or dikes.

Border: Water is applied at the upper end of a strip in which the lateral flow of water is controlled by small earth ridges called border dikes, or borders.

Controlled flooding: Water is released at intervals from closely spaced field ditches and distributed uniformly over the field.

Corrugation: Water is applied to small, closely spaced furrows or ditches in fields of close-growing crops or in orchards so that it flows in only one direction.

Drip (or trickle): Water is applied slowly and under low pressure to the surface of the soil or into the soil through such applicators as emitters, porous tubing, or perforated pipe.

Furrow: Water is applied in small ditches made by cultivation implements. Furrows are used for tree and row crops.

Sprinkler: Water is sprayed over the soil surface through pipes or nozzles from a pressure system.

Subirrigation: Water is applied in open ditches or tile lines until the water table is raised enough to wet the soil.

Wild flooding: Water, released at high points, is allowed to flow onto an area without controlled distribution.

Kame

A low mound, knob, hummock, or short irregular ridge composed of stratified sand and gravel deposited by a subglacial stream as a fan or delta at the margin of a melting glacier; by a supraglacial stream in a low place or hole on the surface of the glacier; or as a ponded deposit on the surface or at the margin of stagnant ice.

Karst (topography)

A kind of topography that formed in limestone, gypsum, or other soluble rocks by dissolution and that is characterized by closed depressions, sinkholes, caves, and underground drainage.

Knoll

A small, low, rounded hill rising above adjacent landforms.

Ksat

See Saturated hydraulic conductivity.

Lacustrine deposit

Material deposited in lake water and exposed when the water level is lowered or the elevation of the land is raised.

Lake plain

A nearly level surface marking the floor of an extinct lake filled by well sorted, generally fine textured, stratified deposits, commonly containing varves.

Lake terrace

A narrow shelf, partly cut and partly built, produced along a lakeshore in front of a scarp line of low cliffs and later exposed when the water level falls.

Landfill (map symbol)

An area of accumulated waste products of human habitation, either above or below natural ground level.

Landslide

A general, encompassing term for most types of mass movement landforms and processes involving the downslope transport and outward deposition of soil and rock materials caused by gravitational forces; the movement may or may not involve saturated materials. The speed and distance of movement, as well as the amount of soil and rock material, vary greatly.

Large stones

Rock fragments 3 inches (7.6 centimeters) or more across. Large stones adversely affect the specified use of the soil.

Lava flow (map symbol)

A solidified, commonly lobate body of rock formed through lateral, surface outpouring of molten lava from a vent or fissure.

Leaching

The removal of soluble material from soil or other material by percolating water.

Levee (map symbol)

An embankment that confines or controls water, especially one built along the banks of a river to prevent overflow onto lowlands.

Linear extensibility

Refers to the change in length of an unconfined clod as moisture content is decreased from a moist to a dry state. Linear extensibility is used to determine the shrink-swell potential of soils. It is an expression of the volume change between the water content of the clod at $^{1}/_{3}$- or $^{1}/_{10}$-bar tension (33kPa or 10kPa tension) and oven dryness. Volume change is influenced by the amount and type of clay minerals in the soil. The volume change is the percent change for the whole soil. If it is expressed as a fraction, the resulting value is COLE, coefficient of linear extensibility.

Liquid limit

The moisture content at which the soil passes from a plastic to a liquid state.

Loam

Soil material that is 7 to 27 percent clay particles, 28 to 50 percent silt particles, and less than 52 percent sand particles.

Loess

Material transported and deposited by wind and consisting dominantly of silt-sized particles.

Low strength

The soil is not strong enough to support loads.

Low-residue crops

Such crops as corn used for silage, peas, beans, and potatoes. Residue from these crops is not adequate to control erosion until the next crop in the rotation is established. These crops return little organic matter to the soil.

Marl

An earthy, unconsolidated deposit consisting chiefly of calcium carbonate mixed with clay in approximately equal proportions; formed primarily under freshwater lacustrine conditions but also formed in more saline environments.

Marsh or swamp (map symbol)

A water-saturated, very poorly drained area that is intermittently or permanently covered by water. Sedges, cattails, and rushes are the dominant vegetation in marshes, and trees or shrubs are the dominant vegetation in swamps. Not used in map units where the named soils are poorly drained or very poorly drained.

Mass movement

A generic term for the dislodgment and downslope transport of soil and rock material as a unit under direct gravitational stress.

Masses

See Redoximorphic features.

Meander belt

The zone within which migration of a meandering channel occurs; the flood-plain area included between two imaginary lines drawn tangential to the outer bends of active channel loops.

Meander scar

A crescent-shaped, concave or linear mark on the face of a bluff or valley wall, produced by the lateral erosion of a meandering stream that impinged upon and undercut the bluff.

Meander scroll

One of a series of long, parallel, close-fitting, crescent-shaped ridges and troughs formed along the inner bank of a stream meander as the channel migrated laterally down-valley and toward the outer bank.

Mechanical treatment

Use of mechanical equipment for seeding, brush management, and other management practices.

Medium textured soil

Very fine sandy loam, loam, silt loam, or silt.

Mesa

A broad, nearly flat topped and commonly isolated landmass bounded by steep slopes or precipitous cliffs and capped by layers of resistant, nearly horizontal rocky material. The summit width is characteristically greater than the height of the bounding escarpments.

Metamorphic rock

Rock of any origin altered in mineralogical composition, chemical composition, or structure by heat, pressure, and movement at depth in the earth’s crust. Nearly all such rocks are crystalline.

Mine or quarry (map symbol)

An open excavation from which soil and underlying material have been removed and in which bedrock is exposed. Also denotes surface openings to underground mines.

Mine spoil

An accumulation of displaced earthy material, rock, or other waste material removed during mining or excavation. Also called earthy fill.

Mineral soil

Soil that is mainly mineral material and low in organic material. Its bulk density is more than that of organic soil.

Minimum tillage

Only the tillage essential to crop production and prevention of soil damage.

Miscellaneous area

A kind of map unit that has little or no natural soil and supports little or no vegetation.

Miscellaneous water (map symbol)

Small, constructed bodies of water that are used for industrial, sanitary, or mining applications and that contain water most of the year.

Moderately coarse textured soil

Coarse sandy loam, sandy loam, or fine sandy loam.

Moderately fine textured soil

Clay loam, sandy clay loam, or silty clay loam.

Mollic epipedon

A thick, dark, humus-rich surface horizon (or horizons) that has high base saturation and pedogenic soil structure. It may include the upper part of the subsoil.

Moraine

In terms of glacial geology, a mound, ridge, or other topographically distinct accumulation of unsorted, unstratified drift, predominantly till, deposited primarily by the direct action of glacial ice in a variety of landforms. Also, a general term for a landform composed mainly of till (except for kame moraines, which are composed mainly of stratified outwash) that has been deposited by a glacier. Some types of moraines are disintegration, end, ground, kame, lateral, recessional, and terminal.

Morphology, soil

The physical makeup of the soil, including the texture, structure, porosity, consistence, color, and other physical, mineral, and biological properties of the various horizons, and the thickness and arrangement of those horizons in the soil profile.

Mottling, soil

Irregular spots of different colors that vary in number and size. Descriptive terms are as follows: abundance—*few, common,* and *many;* size—*fine, medium,* and *coarse;* and contrast—*faint, distinct,* and *prominent*. The size measurements are of the diameter along the greatest dimension. *Fine* indicates less than 5 millimeters (about 0.2 inch); *medium,* from 5 to 15 millimeters (about 0.2 to 0.6 inch); and *coarse,* more than 15 millimeters (about 0.6 inch).

Mountain

A generic term for an elevated area of the land surface, rising more than 1,000 feet (300 meters) above surrounding lowlands, commonly of restricted summit area (relative to a plateau) and generally having steep sides. A mountain can occur as a single, isolated mass or in a group forming a chain or range. Mountains are formed primarily by tectonic activity and/or volcanic action but can also be formed by differential erosion.

Muck

Dark, finely divided, well decomposed organic soil material. (See Sapric soil material.)

Mucky peat

See Hemic soil material.

Mudstone

A blocky or massive, fine grained sedimentary rock in which the proportions of clay and silt are approximately equal. Also, a general term for such material as clay, silt, claystone, siltstone, shale, and argillite and that should be used only when the amounts of clay and silt are not known or cannot be precisely identified.

Munsell notation

A designation of color by degrees of three simple variables—hue, value, and chroma. For example, a notation of 10YR 6/4 is a color with hue of 10YR, value of 6, and chroma of 4.

Natric horizon

A special kind of argillic horizon that contains enough exchangeable sodium to have an adverse effect on the physical condition of the subsoil.

Neutral soil

A soil having a pH value of 6.6 to 7.3. (See Reaction, soil.)

Nodules

See Redoximorphic features.

Nose slope (geomorphology)

A geomorphic component of hills consisting of the projecting end (laterally convex area) of a hillside. The overland waterflow is predominantly divergent. Nose slopes consist dominantly of colluvium and slope-wash sediments (for example, slope alluvium).

Nutrient, plant

Any element taken in by a plant essential to its growth. Plant nutrients are mainly nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, iron, manganese, copper, boron, and zinc obtained from the soil and carbon, hydrogen, and oxygen obtained from the air and water.

Organic matter

Plant and animal residue in the soil in various stages of decomposition. The content of organic matter in the surface layer is described as follows:

Very low: Less than 0.5 percent
Low: 0.5 to 1.0 percent
Moderately low: 1.0 to 2.0 percent
Moderate: 2.0 to 4.0 percent
High: 4.0 to 8.0 percent
Very high: More than 8.0 percent

Outwash

Stratified and sorted sediments (chiefly sand and gravel) removed or “washed out” from a glacier by meltwater streams and deposited in front of or beyond the end moraine or the margin of a glacier. The coarser material is deposited nearer to the ice.

Outwash plain

An extensive lowland area of coarse textured glaciofluvial material. An outwash plain is commonly smooth; where pitted, it generally is low in relief.

Paleoterrace

An erosional remnant of a terrace that retains the surface form and alluvial deposits of its origin but was not emplaced by, and commonly does not grade to, a present-day stream or drainage network.

Pan

A compact, dense layer in a soil that impedes the movement of water and the growth of roots. For example, *hardpan, fragipan, claypan, plowpan,* and *traffic pan*.

Parent material

The unconsolidated organic and mineral material in which soil forms.

Peat

Unconsolidated material, largely undecomposed organic matter, that has accumulated under excess moisture. (See Fibric soil material.)

Ped

An individual natural soil aggregate, such as a granule, a prism, or a block.

Pedisediment

A layer of sediment, eroded from the shoulder and backslope of an erosional slope, that lies on and is being (or was) transported across a gently sloping erosional surface at the foot of a receding hill or mountain slope.

Pedon

The smallest volume that can be called “a soil.” A pedon is three dimensional and large enough to permit study of all horizons. Its area ranges from about 10 to 100 square feet (1 square meter to 10 square meters), depending on the variability of the soil.

Percolation

The movement of water through the soil.

Perennial water (map symbol)

Small, natural or constructed lakes, ponds, or pits that contain water most of the year.

Permafrost

Ground, soil, or rock that remains at or below 0 degrees C for at least 2 years. It is defined on the basis of temperature and is not necessarily frozen.

pH value

A numerical designation of acidity and alkalinity in soil. (See Reaction, soil.)

Phase, soil

A subdivision of a soil series based on features that affect its use and management, such as slope, stoniness, and flooding.

Piping

Formation of subsurface tunnels or pipelike cavities by water moving through the soil.

Pitting

Pits caused by melting around ice. They form on the soil after plant cover is removed.

Plastic limit

The moisture content at which a soil changes from semisolid to plastic.

Plasticity index

The numerical difference between the liquid limit and the plastic limit; the range of moisture content within which the soil remains plastic.

Plateau (geomorphology)

A comparatively flat area of great extent and elevation; specifically, an extensive land region that is considerably elevated (more than 100 meters) above the adjacent lower lying terrain, is commonly limited on at least one side by an abrupt descent, and has a flat or nearly level surface. A comparatively large part of a plateau surface is near summit level.

Playa

The generally dry and nearly level lake plain that occupies the lowest parts of closed depressions, such as those on intermontane basin floors. Temporary flooding occurs primarily in response to precipitation and runoff. Playa deposits are fine grained and may or may not have a high water table and saline conditions.

Plinthite

The sesquioxide-rich, humus-poor, highly weathered mixture of clay with quartz and other diluents. It commonly appears as red mottles, usually in platy, polygonal, or reticulate patterns. Plinthite changes irreversibly to an ironstone hardpan or to irregular aggregates on repeated wetting and drying, especially if it is exposed also to heat from the sun. In a moist soil, plinthite can be cut with a spade. It is a form of laterite.

Plowpan

A compacted layer formed in the soil directly below the plowed layer.

Ponding

Standing water on soils in closed depressions. Unless the soils are artificially drained, the water can be removed only by percolation or evapotranspiration.

Poorly graded

Refers to a coarse grained soil or soil material consisting mainly of particles of nearly the same size. Because there is little difference in size of the particles, density can be increased only slightly by compaction.

Pore linings

See Redoximorphic features.

Potential native plant community

See Climax plant community.

Potential rooting depth (effective rooting depth)

Depth to which roots could penetrate if the content of moisture in the soil were adequate. The soil has no properties restricting the penetration of roots to this depth.

Prescribed burning

Deliberately burning an area for specific management purposes, under the appropriate conditions of weather and soil moisture and at the proper time of day.

Productivity, soil

The capability of a soil for producing a specified plant or sequence of plants under specific management.

Profile, soil

A vertical section of the soil extending through all its horizons and into the parent material.

Proper grazing use

Grazing at an intensity that maintains enough cover to protect the soil and maintain or improve the quantity and quality of the desirable vegetation. This practice increases the vigor and reproduction capacity of the key plants and promotes the accumulation of litter and mulch necessary to conserve soil and water.

Rangeland

Land on which the potential natural vegetation is predominantly grasses, grasslike plants, forbs, or shrubs suitable for grazing or browsing. It includes natural grasslands, savannas, many wetlands, some deserts, tundras, and areas that support certain forb and shrub communities.

Reaction, soil

A measure of acidity or alkalinity of a soil, expressed as pH values. A soil that tests to pH 7.0 is described as precisely neutral in reaction because it is neither acid nor alkaline. The degrees of acidity or alkalinity, expressed as pH values, are:

Ultra acid: Less than 3.5
Extremely acid: 3.5 to 4.4
Very strongly acid: 4.5 to 5.0
Strongly acid: 5.1 to 5.5
Moderately acid: 5.6 to 6.0
Slightly acid: 6.1 to 6.5
Neutral: 6.6 to 7.3
Slightly alkaline: 7.4 to 7.8
Moderately alkaline: 7.9 to 8.4
Strongly alkaline: 8.5 to 9.0
Very strongly alkaline: 9.1 and higher

Red beds

Sedimentary strata that are mainly red and are made up largely of sandstone and shale.

Redoximorphic concentrations

See Redoximorphic features.

Redoximorphic depletions

See Redoximorphic features.

Redoximorphic features

Redoximorphic features are associated with wetness and result from alternating periods of reduction and oxidation of iron and manganese compounds in the soil. Reduction occurs during saturation with water, and oxidation occurs when the soil is not saturated. Characteristic color patterns are created by these processes. The reduced iron and manganese ions may be removed from a soil if vertical or lateral fluxes of water occur, in which case there is no iron or manganese precipitation in that soil. Wherever the iron and manganese are oxidized and precipitated, they form either soft masses or hard concretions or nodules. Movement of iron and manganese as a result of redoximorphic processes in a soil may result in redoximorphic features that are defined as follows:

1. Redoximorphic concentrations.—These are zones of apparent accumulation of iron-manganese oxides, including:
   - A. Nodules and concretions, which are cemented bodies that can be removed from the soil intact. Concretions are distinguished from nodules on the basis of internal organization. A concretion typically has concentric layers that are visible to the naked eye. Nodules do not have visible organized internal structure; *and*
   - B. Masses, which are noncemented concentrations of substances within the soil matrix; *and*
   - C. Pore linings, i.e., zones of accumulation along pores that may be either coatings on pore surfaces or impregnations from the matrix adjacent to the pores.
2. Redoximorphic depletions.—These are zones of low chroma (chromas less than those in the matrix) where either iron-manganese oxides alone or both iron-manganese oxides and clay have been stripped out, including:
   - A. Iron depletions, i.e., zones that contain low amounts of iron and manganese oxides but have a clay content similar to that of the adjacent matrix; *and*
   - B. Clay depletions, i.e., zones that contain low amounts of iron, manganese, and clay (often referred to as silt coatings or skeletans).
3. Reduced matrix.—This is a soil matrix that has low chroma *in situ* but undergoes a change in hue or chroma within 30 minutes after the soil material has been exposed to air.

Reduced matrix

See Redoximorphic features.

Regolith

All unconsolidated earth materials above the solid bedrock. It includes material weathered in place from all kinds of bedrock and alluvial, glacial, eolian, lacustrine, and pyroclastic deposits.

Relief

The relative difference in elevation between the upland summits and the lowlands or valleys of a given region.

Residuum (residual soil material)

Unconsolidated, weathered or partly weathered mineral material that accumulated as bedrock disintegrated in place.

Rill

A very small, steep-sided channel resulting from erosion and cut in unconsolidated materials by concentrated but intermittent flow of water. A rill generally is not an obstacle to wheeled vehicles and is shallow enough to be smoothed over by ordinary tillage.

Riser

The vertical or steep side slope (e.g., escarpment) of terraces, flood-plain steps, or other stepped landforms; commonly a recurring part of a series of natural, steplike landforms, such as successive stream terraces.

Road cut

A sloping surface produced by mechanical means during road construction. It is commonly on the uphill side of the road.

Rock fragments

Rock or mineral fragments having a diameter of 2 millimeters or more; for example, pebbles, cobbles, stones, and boulders.

Rock outcrop (map symbol)

An exposure of bedrock at the surface of the earth. Not used where the named soils of the surrounding map unit are shallow over bedrock or where "Rock outcrop" is a named component of the map unit.

Root zone

The part of the soil that can be penetrated by plant roots.

Runoff

The precipitation discharged into stream channels from an area. The water that flows off the surface of the land without sinking into the soil is called surface runoff. Water that enters the soil before reaching surface streams is called ground-water runoff or seepage flow from ground water.

Saline soil

A soil containing soluble salts in an amount that impairs growth of plants. A saline soil does not contain excess exchangeable sodium.

Saline spot (map symbol)

An area where the surface layer has an electrical conductivity of 8 mmhos/cm more than the surface layer of the named soils in the surrounding map unit. The surface layer of the surrounding soils has an electrical conductivity of 2 mmhos/cm or less.

Sand

As a soil separate, individual rock or mineral fragments from 0.05 millimeter to 2.0 millimeters in diameter. Most sand grains consist of quartz. As a soil textural class, a soil that is 85 percent or more sand and not more than 10 percent clay.

Sandstone

Sedimentary rock containing dominantly sand-sized particles.

Sandy spot (map symbol)

A spot where the surface layer is loamy fine sand or coarser in areas where the surface layer of the named soils in the surrounding map unit is very fine sandy loam or finer.

Sapric soil material (muck)

The most highly decomposed of all organic soil material. Muck has the least amount of plant fiber, the highest bulk density, and the lowest water content at saturation of all organic soil material.

Saturated hydraulic conductivity (Ksat)

The ease with which pores of a saturated soil transmit water. Formally, the proportionality coefficient that expresses the relationship of the rate of water movement to hydraulic gradient in Darcy's Law, a law that describes the rate of water movement through porous media. Commonly abbreviated as "Ksat." Terms describing saturated hydraulic conductivity are:

Very high: 100 or more micrometers per second (14.17 or more inches per hour)

High: 10 to 100 micrometers per second (1.417 to 14.17 inches per hour)

Moderately high: 1 to 10 micrometers per second (0.1417 inch to 1.417 inches per hour)

Moderately low: 0.1 to 1 micrometer per second (0.01417 to 0.1417 inch per hour)

Low: 0.01 to 0.1 micrometer per second (0.001417 to 0.01417 inch per hour)

Very low: Less than 0.01 micrometer per second (less than 0.001417 inch per hour).

To convert inches per hour to micrometers per second, multiply inches per hour by 7.0572. To convert micrometers per second to inches per hour, multiply micrometers per second by 0.1417.

Saturation

Wetness characterized by zero or positive pressure of the soil water. Under conditions of saturation, the water will flow from the soil matrix into an unlined auger hole.

Scarification

The act of abrading, scratching, loosening, crushing, or modifying the surface to increase water absorption or to provide a more tillable soil.

Sedimentary rock

A consolidated deposit of clastic particles, chemical precipitates, or organic remains accumulated at or near the surface of the earth under normal low temperature and pressure conditions. Sedimentary rocks include consolidated equivalents of alluvium, colluvium, drift, and eolian, lacustrine, and marine deposits. Examples are sandstone, siltstone, mudstone, claystone, shale, conglomerate, limestone, dolomite, and coal.

Sequum

A sequence consisting of an illuvial horizon and the overlying eluvial horizon. (See Eluviation.)

Series, soil

A group of soils that have profiles that are almost alike, except for differences in texture of the surface layer. All the soils of a series have horizons that are similar in composition, thickness, and arrangement.

Severely eroded spot (map symbol)

An area where, on the average, 75 percent or more of the original surface layer has been lost because of accelerated erosion. Not used in map units in which “severely eroded,”“very severely eroded,” or “gullied” is part of the map unit name.

Shale

Sedimentary rock that formed by the hardening of a deposit of clay, silty clay, or silty clay loam and that has a tendency to split into thin layers.

Sheet erosion

The removal of a fairly uniform layer of soil material from the land surface by the action of rainfall and surface runoff.

Short, steep slope (map symbol)

A narrow area of soil having slopes that are at least two slope classes steeper than the slope class of the surrounding map unit.

Shoulder

The convex, erosional surface near the top of a hillslope. A shoulder is a transition from summit to backslope.

Shrink-swell

The shrinking of soil when dry and the swelling when wet. Shrinking and swelling can damage roads, dams, building foundations, and other structures. It can also damage plant roots.

Shrub-coppice dune

A small, streamlined dune that forms around brush and clump vegetation.

Side slope (geomorphology)

A geomorphic component of hills consisting of a laterally planar area of a hillside. The overland waterflow is predominantly parallel. Side slopes are dominantly colluvium and slope-wash sediments.

Silica

A combination of silicon and oxygen. The mineral form is called quartz.

Silica-sesquioxide ratio

The ratio of the number of molecules of silica to the number of molecules of alumina and iron oxide. The more highly weathered soils or their clay fractions in warm-temperate, humid regions, and especially those in the tropics, generally have a low ratio.

Silt

As a soil separate, individual mineral particles that range in diameter from the upper limit of clay (0.002 millimeter) to the lower limit of very fine sand (0.05 millimeter). As a soil textural class, soil that is 80 percent or more silt and less than 12 percent clay.

Siltstone

An indurated silt having the texture and composition of shale but lacking its fine lamination or fissility; a massive mudstone in which silt predominates over clay.

Similar soils

Soils that share limits of diagnostic criteria, behave and perform in a similar manner, and have similar conservation needs or management requirements for the major land uses in the survey area.

Sinkhole (map symbol)

A closed, circular or elliptical depression, commonly funnel shaped, characterized by subsurface drainage and formed either by dissolution of the surface of underlying bedrock (e.g., limestone, gypsum, or salt) or by collapse of underlying caves within bedrock. Complexes of sinkholes in carbonate-rock terrain are the main components of karst topography.

Site index

A designation of the quality of a forest site based on the height of the dominant stand at an arbitrarily chosen age. For example, if the average height attained by dominant and codominant trees in a fully stocked stand at the age of 50 years is 75 feet, the site index is 75.

Slickensides (pedogenic)

Grooved, striated, and/or glossy (shiny) slip faces on structural peds, such as wedges; produced by shrink-swell processes, most commonly in soils that have a high content of expansive clays.

Slide or slip (map symbol)

A prominent landform scar or ridge caused by fairly recent mass movement or descent of earthy material resulting from failure of earth or rock under shear stress along one or several surfaces.

Slope

The inclination of the land surface from the horizontal. Percentage of slope is the vertical distance divided by horizontal distance, then multiplied by 100. Thus, a slope of 20 percent is a drop of 20 feet in 100 feet of horizontal distance.

Slope alluvium

Sediment gradually transported down the slopes of mountains or hills primarily by nonchannel alluvial processes (i.e., slope-wash processes) and characterized by particle sorting. Lateral particle sorting is evident on long slopes. In a profile sequence, sediments may be distinguished by differences in size and/or specific gravity of rock fragments and may be separated by stone lines. Burnished peds and sorting of rounded or subrounded pebbles or cobbles distinguish these materials from unsorted colluvial deposits.

Slow refill

The slow filling of ponds, resulting from restricted water transmission in the soil.

Slow water movement

Restricted downward movement of water through the soil. See Saturated hydraulic conductivity.

Sodic (alkali) soil

A soil having so high a degree of alkalinity (pH 8.5 or higher) or so high a percentage of exchangeable sodium (15 percent or more of the total exchangeable bases), or both, that plant growth is restricted.

Sodic spot (map symbol)

An area where the surface layer has a sodium adsorption ratio that is at least 10 more than that of the surface layer of the named soils in the surrounding map unit. The surface layer of the surrounding soils has a sodium adsorption ratio of 5 or less.

Sodicity

The degree to which a soil is affected by exchangeable sodium. Sodicity is expressed as a sodium adsorption ratio (SAR) of a saturation extract, or the ratio of Na^{+} to Ca^{++} + Mg^{++}. The degrees of sodicity and their respective ratios are:

Slight: Less than 13:1

Moderate: 13-30:1

Strong: More than 30:1

Sodium adsorption ratio (SAR)

A measure of the amount of sodium (Na) relative to calcium (Ca) and magnesium (Mg) in the water extract from saturated soil paste. It is the ratio of the Na concentration divided by the square root of one-half of the Ca + Mg concentration.

Soft bedrock

Bedrock that can be excavated with trenching machines, backhoes, small rippers, and other equipment commonly used in construction.

Soil

A natural, three-dimensional body at the earth's surface. It is capable of supporting plants and has properties resulting from the integrated effect of climate and living matter acting on earthy parent material, as conditioned by relief and by the passage of time.

Soil separates

Mineral particles less than 2 millimeters in equivalent diameter and ranging between specified size limits. The names and sizes, in millimeters, of separates recognized in the United States are as follows:

Very coarse sand: 2.0 to 1.0
Coarse sand: 1.0 to 0.5
Medium sand: 0.5 to 0.25
Fine sand: 0.25 to 0.10
Very fine sand: 0.10 to 0.05
Silt: 0.05 to 0.002
Clay: Less than 0.002

Solum

The upper part of a soil profile, above the C horizon, in which the processes of soil formation are active. The solum in soil consists of the A, E, and B horizons. Generally, the characteristics of the material in these horizons are unlike those of the material below the solum. The living roots and plant and animal activities are largely confined to the solum.

Spoil area (map symbol)

A pile of earthy materials, either smoothed or uneven, resulting from human activity.

Stone line

In a vertical cross section, a line formed by scattered fragments or a discrete layer of angular and subangular rock fragments (commonly a gravel- or cobble-sized lag concentration) that formerly was draped across a topographic surface and was later buried by additional sediments. A stone line generally caps material that was subject to weathering, soil formation, and erosion before burial. Many stone lines seem to be buried erosion pavements, originally formed by sheet and rill erosion across the land surface.

Stones

Rock fragments 10 to 24 inches (25 to 60 centimeters) in diameter if rounded or 15 to 24 inches (38 to 60 centimeters) in length if flat.

Stony

Refers to a soil containing stones in numbers that interfere with or prevent tillage.

Stony spot (map symbol)

A spot where 0.01 to 0.1 percent of the soil surface is covered by rock fragments that are more than 10 inches in diameter in areas where the surrounding soil has no surface stones.

Strath terrace

A type of stream terrace; formed as an erosional surface cut on bedrock and thinly mantled with stream deposits (alluvium).

Stream terrace

One of a series of platforms in a stream valley, flanking and more or less parallel to the stream channel, originally formed near the level of the stream; represents the remnants of an abandoned flood plain, stream bed, or valley floor produced during a former state of fluvial erosion or deposition.

Stripcropping

Growing crops in a systematic arrangement of strips or bands that provide vegetative barriers to wind erosion and water erosion.

Structure, soil

The arrangement of primary soil particles into compound particles or aggregates. The principal forms of soil structure are:

Platy: Flat and laminated
Prismatic: Vertically elongated and having flat tops
Columnar: Vertically elongated and having rounded tops
Angular blocky: Having faces that intersect at sharp angles (planes)
Subangular blocky: Having subrounded and planar faces (no sharp angles)
Granular: Small structural units with curved or very irregular faces

Structureless soil horizons are defined as follows:

Single grained: Entirely noncoherent (each grain by itself), as in loose sand
Massive: Occurring as a coherent mass

Stubble mulch

Stubble or other crop residue left on the soil or partly worked into the soil. It protects the soil from wind erosion and water erosion after harvest, during preparation of a seedbed for the next crop, and during the early growing period of the new crop.

Subsoil

Technically, the B horizon; roughly, the part of the solum below plow depth.

Subsoiling

Tilling a soil below normal plow depth, ordinarily to shatter a hardpan or claypan.

Substratum

The part of the soil below the solum.

Subsurface layer

Any surface soil horizon (A, E, AB, or EB) below the surface layer.

Summer fallow

The tillage of uncropped land during the summer to control weeds and allow storage of moisture in the soil for the growth of a later crop. A practice common in semiarid regions, where annual precipitation is not enough to produce a crop every year. Summer fallow is frequently practiced before planting winter grain.

Summit

The topographically highest position of a hillslope. It has a nearly level (planar or only slightly convex) surface.

Surface layer

The soil ordinarily moved in tillage, or its equivalent in uncultivated soil, ranging in depth from 4 to 10 inches (10 to 25 centimeters). Frequently designated as the “plow layer,” or the “Ap horizon.”

Surface soil

The A, E, AB, and EB horizons, considered collectively. It includes all subdivisions of these horizons.

Talus

Rock fragments of any size or shape (commonly coarse and angular) derived from and lying at the base of a cliff or very steep rock slope. The accumulated mass of such loose broken rock formed chiefly by falling, rolling, or sliding.

Taxadjuncts

Soils that cannot be classified in a series recognized in the classification system. Such soils are named for a series they strongly resemble and are designated as taxadjuncts to that series because they differ in ways too small to be of consequence in interpreting their use and behavior. Soils are recognized as taxadjuncts only when one or more of their characteristics are slightly outside the range defined for the family of the series for which the soils are named.

Terminal moraine

An end moraine that marks the farthest advance of a glacier. It typically has the form of a massive arcuate or concentric ridge, or complex of ridges, and is underlain by till and other types of drift.

Terrace (conservation)

An embankment, or ridge, constructed across sloping soils on the contour or at a slight angle to the contour. The terrace intercepts surface runoff so that water soaks into the soil or flows slowly to a prepared outlet. A terrace in a field generally is built so that the field can be farmed. A terrace intended mainly for drainage has a deep channel that is maintained in permanent sod.

Terrace (geomorphology)

A steplike surface, bordering a valley floor or shoreline, that represents the former position of a flood plain, lake, or seashore. The term is usually applied both to the relatively flat summit surface (tread) that was cut or built by stream or wave action and to the steeper descending slope (scarp or riser) that has graded to a lower base level of erosion.

Terracettes

Small, irregular steplike forms on steep hillslopes, especially in pasture, formed by creep or erosion of surficial materials that may be induced or enhanced by trampling of livestock, such as sheep or cattle.

Texture, soil

The relative proportions of sand, silt, and clay particles in a mass of soil. The basic textural classes, in order of increasing proportion of fine particles, are *sand, loamy sand, sandy loam, loam, silt loam, silt, sandy clay loam, clay loam, silty clay loam, sandy clay, silty clay,* and *clay*. The sand, loamy sand, and sandy loam classes may be further divided by specifying “coarse,”“fine,” or “very fine.”

Thin layer

Otherwise suitable soil material that is too thin for the specified use.

Till

Dominantly unsorted and nonstratified drift, generally unconsolidated and deposited directly by a glacier without subsequent reworking by meltwater, and consisting of a heterogeneous mixture of clay, silt, sand, gravel, stones, and boulders; rock fragments of various lithologies are embedded within a finer matrix that can range from clay to sandy loam.

Till plain

An extensive area of level to gently undulating soils underlain predominantly by till and bounded at the distal end by subordinate recessional or end moraines.

Tilth, soil

The physical condition of the soil as related to tillage, seedbed preparation, seedling emergence, and root penetration.

Toeslope

The gently inclined surface at the base of a hillslope. Toeslopes in profile are commonly gentle and linear and are constructional surfaces forming the lower part of a hillslope continuum that grades to valley or closed-depression floors.

Topsoil

The upper part of the soil, which is the most favorable material for plant growth. It is ordinarily rich in organic matter and is used to topdress roadbanks, lawns, and land affected by mining.

Trace elements

Chemical elements, for example, zinc, cobalt, manganese, copper, and iron, in soils in extremely small amounts. They are essential to plant growth.

Tread

The flat to gently sloping, topmost, laterally extensive slope of terraces, flood-plain steps, or other stepped landforms; commonly a recurring part of a series of natural steplike landforms, such as successive stream terraces.

Tuff

A generic term for any consolidated or cemented deposit that is 50 percent or more volcanic ash.

Upland

An informal, general term for the higher ground of a region, in contrast with a low-lying adjacent area, such as a valley or plain, or for land at a higher elevation than the flood plain or low stream terrace; land above the footslope zone of the hillslope continuum.

Valley fill

The unconsolidated sediment deposited by any agent (water, wind, ice, or mass wasting) so as to fill or partly fill a valley.

Variegation

Refers to patterns of contrasting colors assumed to be inherited from the parent material rather than to be the result of poor drainage.

Varve

A sedimentary layer or a lamina or sequence of laminae deposited in a body of still water within a year. Specifically, a thin pair of graded glaciolacustrine layers seasonally deposited, usually by meltwater streams, in a glacial lake or other body of still water in front of a glacier.

Very stony spot (map symbol)

A spot where 0.1 to 3.0 percent of the soil surface is covered by rock fragments that are more than 10 inches in diameter in areas where the surface of the surrounding soil is covered by less than 0.01 percent stones.

Water bars

Smooth, shallow ditches or depressional areas that are excavated at an angle across a sloping road. They are used to reduce the downward velocity of water and divert it off and away from the road surface. Water bars can easily be driven over if constructed properly.

Weathering

All physical disintegration, chemical decomposition, and biologically induced changes in rocks or other deposits at or near the earth's surface by atmospheric or biologic agents or by circulating surface waters but involving essentially no transport of the altered material.

Well graded

Refers to soil material consisting of coarse grained particles that are well distributed over a wide range in size or diameter. Such soil normally can be easily increased in density and bearing properties by compaction. Contrasts with poorly graded soil.

Wet spot (map symbol)

A somewhat poorly drained to very poorly drained area that is at least two drainage classes wetter than the named soils in the surrounding map unit.

Wilting point (or permanent wilting point)

The moisture content of soil, on an ovendry basis, at which a plant (specifically a sunflower) wilts so much that it does not recover when placed in a humid, dark chamber.

Windthrow

The uprooting and tipping over of trees by the wind.

APPENDIX C

Synthetic Liner Evaluation Technical Memorandum

East Waste Rock Extension HDPE Liner System Evaluation

PREPARED FOR: Zeb Kenyon/KUC

PREPARED BY: CH2M HILL

DATE: September 19, 2012

Introduction

In August 2010, Kennecott Utah Copper (KUC) announced that it had begun evaluating the potential to extend the life of the Bingham Canyon Mine and operations to 2028. The extension, named the Cornerstone Project, would allow the mine to continue operation at current levels of copper production. The project involves pushing back the south wall of the mine about 1,000 feet and deepening the mine by about 300 feet to access additional ore resources. The Cornerstone Project will generate additional waste rock as part of the mining process. The East Waste Rock Extension (EWRE) consists of placing waste rock further east of the existing Keystone waste rock dumps.

One perceived benefit of the EWRE project is the opportunity to reclaim the historic, eastside dumps. These dumps will be reclaimed by grading the waste rock and covering it with an engineered cover. Subsequently, the reclaimed slopes will be re-vegetated. The cover will limit the infiltration of precipitation and oxygen to waste rock which may lead to the formation of low pH water with elevated concentrations of dissolved metals. KUC is investigating options to control the *de minimus* amount of seepage anticipated from waste rock that may seep into bedrock. As part of evaluating best available technologies for managing this water, this Technical Memorandum provides an evaluation of using an HDPE liner to capture any infiltration before it reaches the bedrock.

Objectives

The objectives of this technical memorandum are as follows:

1. Evaluate regulatory based action leakage rates associated with high-density polyethylene (HDPE) liners for permitted facilities throughout the United States;
2. Evaluate the feasibility of using an HDPE liner at the bedrock/waste rock interface for the EWRE to reduce or prevent infiltration; and
3. Estimate order-of-magnitude construction costs for installing an HDPE liner under the EWRE footprint (+100/-50 percent accuracy).

Liner Performance Comparison

Papers published by the United States Environmental Protection Agency (EPA) and the Geosynthetic Institute (GSI) are referenced in this comparison. Both the EPA and GSI have reviewed known facility performance and associated variables for water and leachate containment structures using HDPE liners to provide guidance regarding appropriate leakage rates. Although few examples of waste rock storage facilities or mining related facilities exist, a comparison can be drawn from the industry accepted action leakage rates (ALRs) for landfills, waste rock, and the few regulated facilities associated with mining related leach water applications. Table 1 presents a comparison of ALR values and respective gpm flows relative to the 338 acres associated with the EWRE.

TABLE 1
Comparison of ALR for Lined Facilities

Facility Description/Type	Source	Action Leakage Rate (gal/acres-day)	Calculated EWRE ALR (gpm)
Landfills	EPA, 1993	100	25
Waste piles	EPA, 1992	100	25
In situ leach mines—General	Koerner & Koerner	1700	399
Metal laden seepage water—Alaska	Koerner & Koerner	480	112
In situ leach mines—South Dakota	Koerner & Koerner	1700	399
Leach collection systems—Utah EPA	Koerner & Koerner	200	46
“de minimum” leakage—Perfect liner	Koerner & Koerner	0.02 - 2.0	0.005 - 0.469

A review of the ALRs indicates a wide range of acceptable leakage rates for similar type and size facilities ranging from 25 to 399 gpm with respect to the 338 acres of the EWRE. The GSI review concluded that a liner that functions in a “perfect” manner leaks at a rate of 0.02 to 2.0 gallons/acre-day or 0.005 to 0.469 gpm when related to the EWRE footprint.

EPA guidance organizes landfills and waste rock into the same category. EPA review of the performance of these facilities concluded that a leakage rate below 100 gallons/acre-day, or approximately 25 gpm when related to the EWRE, is acceptable.

HDPE Liner Feasibility Evaluation

Conceptual Design

A basic conceptual liner system for the EWRE using HDPE to capture leachate (or WRCW) from waste rock material would consist of a gravel drainage system on top of the liner material. The liner would be supported by a clay layer and a subgrade foundation materials on top of the exposed bedrock. A gravel drainage system comprised of a minimum 1-foot-thick (minimum) pea-gravel layer would serve as an adequate drain conduit for a WRCW collection system. The gravel drainage layer would serve a secondary purpose of providing protection to the HDPE liner from the placement of the waste rock material. Due to the anticipated loading from the waste rock, a minimum 2.0-millimeter HDPE liner would be required.

Geosynthetic membranes would be required on top and below the drain rock layer. The membrane placed on top of the HDPE liner would provide protection during drain rock placement, and a second membrane placed on top of the drain rock would assist in maintaining the integrity of the drain rock layer during placement of waste rock.

Significant quantities of engineered fill composed of clay and foundation rock will be required to provide a smooth and stable bedding surface. This is needed to ensure proper WRCW drainage given the expected surface variability throughout the 338 acres of the EWRE. It is anticipated that an average thickness of at least 2 feet of engineered fill between the bedrock contact and the liner will be required to support the liner while providing clear drain paths for the WRCW to the collection system.

Performance Analysis

As displayed in Table 1, the projected rate of leakage for the best possible performing HDPE system covering the 338 acres of the EWRE ranges from 0.005 to 0.469 gpm. Typical construction procedures that would result in the best possible liner involves an HDPE liner installed on a level surface with construction quality assurance oversight to ensure proper welding. Such conditions would be required to minimize the number of holes contributing to leakage. However, due to the variability of the topography, size of area and the high loading on the HDPE liner from waste rock placement, the leakage rate has the potential to be much greater than that expected for a perfect landfill liner.

There are several challenges to consider when discussing the use of an HDPE liner over the EWRE foot print to prevent WRCW leakage from the lined facility:

- The variable topography will require extensive site preparation and large quantities of bedding material to minimize damage to the liner and promote adequate WRCW flow to a drainage collection system.
- Sloping areas on hillsides have the potential to create high “shear” zones in the liner that will likely result in significant liner tears.
- As HDPE liners age, they are subject to “stress cracking” and “brittle fractures,” even under ideal conditions. Given the high loads born by the HDPE liner from waste rock and the necessary sloping of the liner to facilitate WRCW drainage, the rates of “stress cracking” and “brittle fractures” will be amplified.
- The placement of waste rock and the manner in which it would be placed will place a significant load on the HDPE liner and will likely result in tears, punctures, and breaks in the welding.
- Anticipated WRCW seepage may become trapped beneath the liner and bypass the liner collection system. Concentrated flow will have a greater likelihood of percolating to bedrock.
- Rips and/or tears in the liner system cannot be detected or repaired once the waste rock has been placed.
- The liner would likely create a slip plane or unstable surface below the waste rock that would be subject to movement and a greater potential for dump failure.

In summary, there are multiple technical challenges to consider when installing an HDPE liner over the 338 acres of the EWRE that will require extensive engineering and construction quality assurance. It is likely that under the conditions listed above, the HDPE liner will eventually develop enough breaks, cracks, fractures, punctures, and tears leading to leakage rates exceeding most, if not all of the ALRs provided in Table 1 and above the seepage rate calculated for EWRE foundation materials.

Order-Of-Magnitude Construction Cost Estimate

Rough order-of-magnitude construction costs associated with installing the HDPE liner are estimated to be approximately $120 million. Due to the large area, the highly variable nature of the topography, and the need to “smooth” out the receiving surface to ensure WRCW drainage, significant volumes of engineered fill will be required during the construction. The costs of installing the engineered fill exceed 50 percent of the overall cost.

The topography of the EWRE is variable and is assumed to similarly represent the underlying bedrock. Without fully understanding the nature of the underlying bedrock, the cost estimate represents a rough order-of-magnitude cost estimate assuming the bedrock surface matches similarly that of the surface topography. Irregular surfaces and steep slopes may require additional earthwork and geomembranes that will further add to construction costs.

Conclusions

In conclusion, the HDPE liner installation has failure risks as detailed above that would most likely result in seepage rates greater than those ALRs displayed in Table 1. In addition, the hydraulic conductivity of the underlying bedrock provides a low permeability barrier that will perform as good or better than an engineered liner to prevent infiltration of WRCW into the underlying bedrock. The natural bedrock topography also provides a surface contact ideal for directing WRCW towards the collection system. Last, the benefits of limiting infiltration through the use of an engineered store and release cover, as described in Attachment 2, Groundwater Discharge Control Plan, far exceed those of installing an HDPE liner below the EWRE footprint. Therefore, the installation of an HDPE liner is not recommended for the EWRE project.

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Attachment 2: Groundwater Discharge Control Plan

East Waste Rock Extension Permit Modification

Groundwater Discharge Permit UGW350010

Prepared for

Kennecott Utah Copper LLC

September 2012

CH2MHILL®

215 South State Street, Suite 1000

Salt Lake City, Utah 84111

Contents

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Acronyms and Abbreviations

ARD	acid rock drainage
BAT	Best Available Technology
BCM	Brigham Canyon Mine
CL	volcanic gravely clay
cm/s	centimeter(s) per second
ECS	Eastside Collection System
EWRE	East Waste Rock Extension
GC	clayey quartzitic and/or volcanic gravel
GM	silty quartzitic gravel
HDPE	high-density polyethylene
KUC	Kennecott Utah Copper LLC
mm	millimeter(s)
MPS	Midas Pump Station
PSD	particle size distribution
psi	pound(s) per square inch
TDS	total dissolved solids
UDOGM	Utah Division of Oil, Gas and Mining
UDWQ	Utah Department of Environmental Quality, Division of Water Quality
WCS	Water Collection System
WRCW	waste rock contact water
WWDPS	Wastewater Disposal Pump Station

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1.0 Introduction

The Bingham Canyon Mine (BCM) operations are located in the Oquirrh Mountains approximately 18 miles southwest of Salt Lake City, Utah. This mine produces copper and other metals that are currently extracted using an open-pit method of mining. Open-pit operations have been conducted at this site for over 100 years.

The mine facility and water collection system (WCS) currently operate under Groundwater Discharge Permit UGW350010, issued by the Utah Department of Environmental Quality, Division of Water Quality (UDWQ). The permit was first issued in June 1994 and has been renewed on a regular basis approximately every 5 years. The most-recent renewal was March 23, 2010 (UDWQ, 2010).

The waste rock associated with this mining operation has been placed adjacent to the open pit on the slopes of the Oquirrh Mountains. The waste rock disposal areas consist of over 5 billion tons of waste rock. The waste rock consists of low concentrations of sulfide mineralization and trace metals in an intrusive host rock, limestone, and quartzite.

The permitted facilities associated with this plan include the WCS designed to capture waste rock contact water (WRCW) emanating from the toe of the waste rock that prevents the contact water from potentially entering the groundwater aquifer. The WCS is also referred to as the Eastside Collection System (ECS).

This permit modification is applicable to the primarily east facing waste rock dumps between the Copper drainage (south end) to the Midas drainage (north end). KUC is applying for a permit modification to address the East Waste Rock Extension (EWRE) project. This Groundwater Discharge Control Plan has been prepared to fulfill Part C, Section 9, of the permit modification application. The plan describes discharge control technologies that will be implemented to either maintain Best Available Technology (BAT) at current standards, or where opportunity exists, refine BAT through the following:

1) Improved waste rock cover design
2) Improved storm water controls
3) Improved cut-off walls and collection system

The remainder of this plan is organized as follows:

- Section 2.0—Existing and Planned Systems
- Section 3.0—Monitoring and Inspection Methods
- Section 4.0—Summary of Controls

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2.0 Existing and Planned System

Between the years of 1994 and 1996, a collection system was installed to collect mine leach water reporting to the toe of the waste rock dumps at the Bingham Canyon Mine. Upon the cessation of active leaching in 2000, the system remained in place to capture WRCW that results from infiltration of precipitation through the waste rock. The WRCW capture system is currently comprised of a series of concrete cut-off walls, french drains and associated piping and canals. Cut-off walls are concrete structures built into bedrock and located in the drainage bottoms down gradient of the waste rock piles. The purpose of the walls and french drains is to capture WRCW and prevent it from entering the aquifer. Monitoring wells are installed down gradient of the capture system to demonstrate the effectiveness of the system to capture WRCW through compliance with the Utah Groundwater Quality Protection Program. Figure 2-1 shows the existing capture system and monitoring wells.

The current collection system has demonstrated satisfactory performance from 1998 to the present time, as demonstrated by the compliance monitoring well network. Collection system performance and water quality data are reported to UDWQ quarterly through compliance monitoring reports and, more-extensively, in annual reports. Figure 2-2 presents average sulfate concentrations in down gradient monitoring wells in the EWRE area from 1980 to 2011. The figure displays how average sulfate concentrations have decreased dramatically since the installation of the collection system. Figure 2-3 shows concentrations of total dissolved solids (TDS) have also decreased during the same time period. A more-detailed discussion of monitoring well sampling results is included in Attachment 1, Supplemental Hydrogeologic Report.

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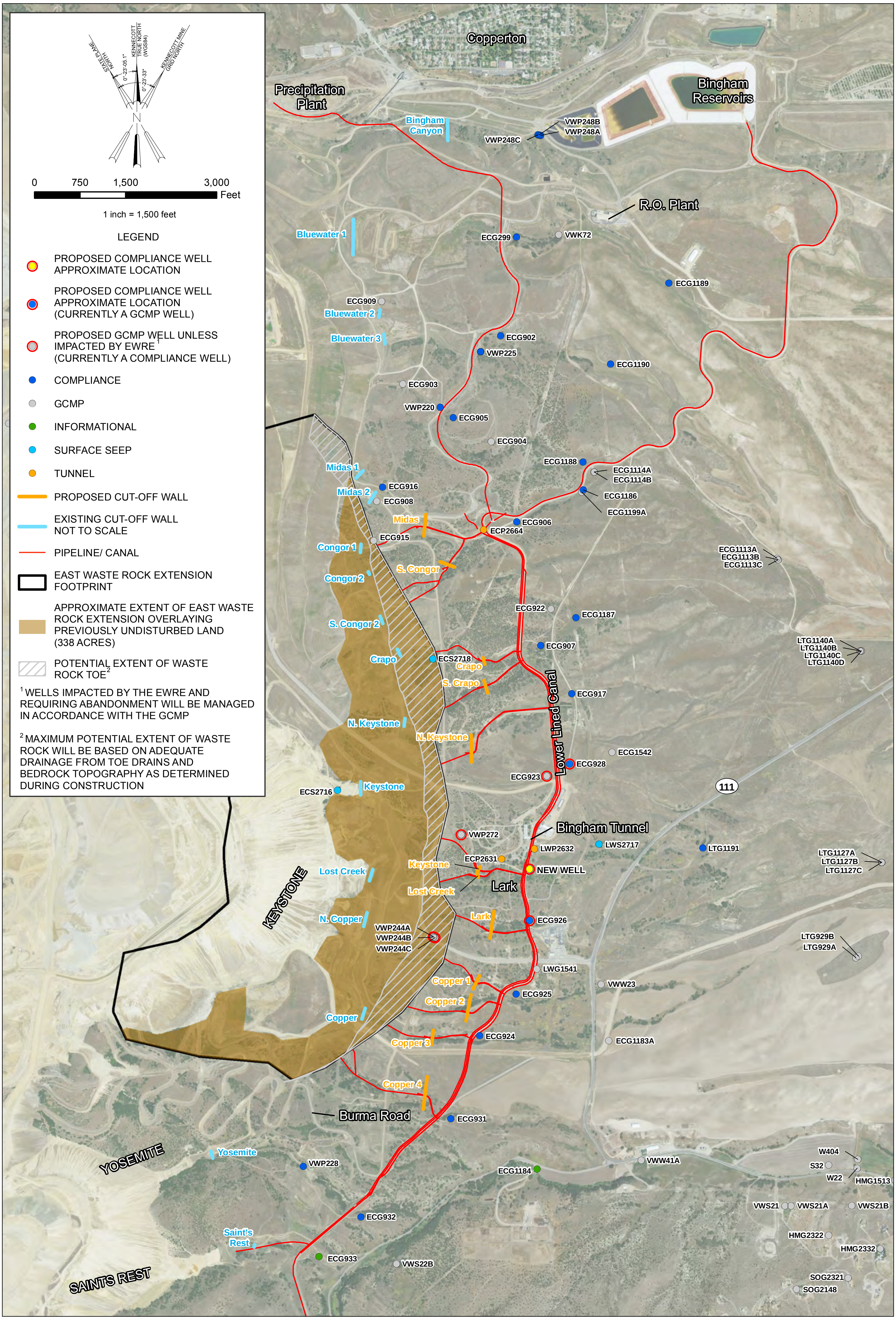


FIGURE 2-1

EAST WASTE ROCK EXTENSION EXISTING AND PLANNED COLLECTION SYSTEMS

EAST WASTE ROCK EXTENSION PERMIT MODIFICATION
GROUNDWATER DISCHARGE PERMIT UGW350010
KENNECOTT UTAH COPPER

FIGURE 2-2
Average Sulfate Concentrations in EWRE Area

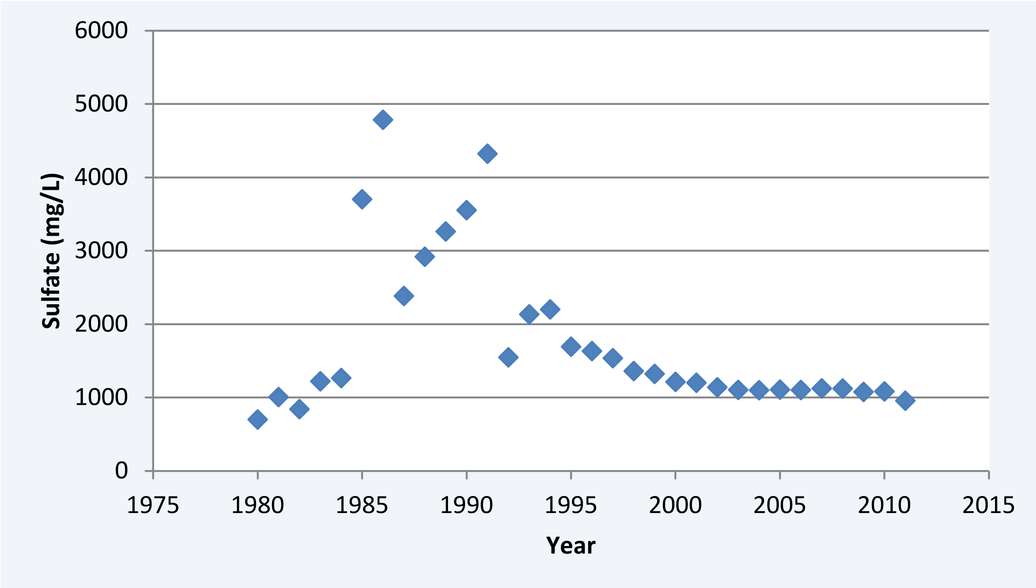
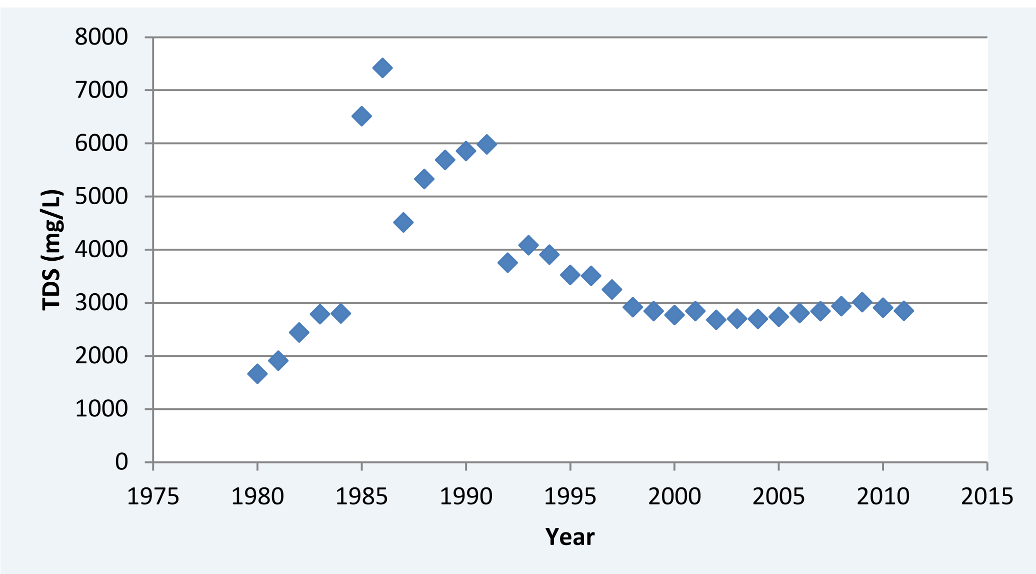


FIGURE 2-3
Average Concentrations of TDS in the EWRE Area



2.1 Existing System

The WRCW from the existing waste rock is currently captured by a system of French drains, sumps, pipes, and cut-off walls located near the toe of the waste rock in each drainage basin. The water is then gravity fed to a collection system consisting of an upper and lower pipeline and secondary containment system. The water from the system flows to an existing Precipitation Plant where dissolved copper is extracted. Details of the current system are described in the following paragraphs. The cut-off walls and conveyance piping for the existing collection system are shown in Figure 2-1.

Precipitation up gradient of the cut-off walls, and the WRCW emerging from the toe of the waste rock dumps is collected in a series of collector pipes, french drains and cut-off wall installations, with one wall located in each of the principal drainages down gradient from the toe of the waste rock. These installations intercept the surface water flowing in the stream channels, as well as sub-surface water flowing in the alluvium. A typical dual WRCW and storm water collection system installation contains the following elements:

- Earthen sediment collection basins, where practical, collect storm water immediately down gradient from the toe of the waste rock and capture sediment before entering the pipelines.
- Piping, where practical, captures mine-impacted water close to the dump toe and conveys it to the cut-off wall.
- A concrete containment wall, or cut-off wall, installed into the underlying, low permeability bedrock directs the flow of storm water and WRCW from the basin into the collection system. Perforated pipes and gravel parallel to the cut-off wall direct subsurface waters to the collection system piping. In most cases, the cut-off wall has a spillway to pass surface water flows greater than the estimated 10-year, 24-hour design storm event.
- Seepage collection trenches, or French drains, extend to the top of the local drainage catchment in either direction. These trenches are excavated to bedrock and lined with clay. A perforated collector pipe is placed in a filter-cloth-enclosed gravel drain on top of the clay. The trenches are backfilled with coarse gravel. Water within the pipe is directed to the cut-off wall. .

High-density polyethylene (HDPE) pipe conveys WRCW and storm water by gravity from each of the drainages to the main collection system pipe. Currently, the main pipe runs adjacent from the Queen drainage to the Midas drainage below-ground. From the Midas drainage to the Bluewater 1 drainage the pipe runs above-ground adjacent to a concrete-lined canal that can capture WRCW in the event of a pipe failure. From the Bluewater 1 drainage the WRCW is pumped to the Precipitation Plant for copper recovery, or can gravity drain to the Large Reservoir. A lower lined canal exists to capture water as the result of a process upset or large storm event and conveys water to the Large Reservoir. The Bingham Canyon Large Reservoir facility is managed under Groundwater Discharge Permit UGW350006.

2.2 Proposed System

The existing waste rock dumps have non-vegetated angle-of-repose slopes that pose significant challenges if reclaimed in their current state without careful planning. Placing waste rock to the east of the existing dumps will allow for relaxed slopes that can be reclaimed, and will also allow for the addition of storm water management systems. Where waste rock is placed to the east, the existing cut-off wall system will need to be replaced between the Copper and Midas drainages where the new footprint will cover or disrupt the existing collection system. Waste rock placement to the east of the existing dumps will allow for the opportunity to implement the following changes:

- Reclaimed waste rock slopes at a ratio of 2.5 horizontal feet to 1 vertical foot
- An engineered, vegetated waste rock cover designed to minimize erosion, sustain vegetation, and reduce infiltration and subsequent water degradation
- Surface water management systems to direct and control storm water flows off the catch benches and reclaimed dump faces, reducing infiltration and the potential for erosion
- A new collection system design consisting of the following:

  - Detention basins up gradient of, or adjacent to, the cut-off walls, designed for a 100-year, 24-hour storm event
  - A toe drain system that will provide primary capture of WRCW immediately down gradient of the waste rock dump; the cut-off walls will act as a secondary capture system
  - New cut-off walls
  - Separate WRCW and storm water conveyance to minimize precipitation, scaling, and potential for system failure
  - Dual containment of WRCW piping down gradient of the cut-off walls to reduce the risk of release to the environment
  - Liners that provide dual containment of WRCW at the cut-off walls, flumes and wet well at the new Midas Pump Station (MPS) to reduce the risk of a release to the environment

The aforementioned design upgrades are discussed in more detail in this permit modification attachment.

Before waste rock is placed within the project area, native areas containing previously undisturbed vegetation will be excavated to bedrock while areas containing reclaimed slopes over waste rock will have growth media salvaged for reuse. Excavating to bedrock in the native vegetated areas will allow for the following:

- Placement of coarse drain rock beneath the dump in drainage bottoms from the current toe to the new toe drain to provide a preferential flow path to the new toe drains along the bedrock contact
- Maximization of WRCW capture through optimal placement of toe drains at the bedrock contact near the relaxed toe of the waste rock

The new toe drain system will overlap the existing collection system at the Midas drainage. The system as a whole will work similarly to the current system in that WRCW and storm water flows will gravity drain and require no pumping. The WRCW flow will gravity drain from the toe drains to the new MPS. At the MPS, the WRCW water will be pumped to the existing Precipitation Plant for copper recovery, with the option to gravity drain the water to the Wastewater Disposal Pump Station (WWDPS) adjacent to the Large Reservoir. Secondary containment and leak detection capability will be provided at the flumes, WRCW conveyance piping, and for the wet-well at the new MPS.

2.2.1 Waste Rock Store-and-Release Cover Design

The reclamation approach for the EWRE includes placing an engineered cover, referred to as a "store-and-release cover", atop the waste rock. A store-and-release cover is an engineered, vegetated soil cap designed to minimize infiltration of meteoric precipitation to the underlying waste rock based upon site specific climatic conditions and characteristics of available cover material(s). The cover is important to the groundwater discharge permit in that by minimizing meteoric water from entering the waste rock, minimization of WRCW reporting at the toe of the dump can also be achieved.

Store-and-release covers hold incoming precipitation until a given percentage of the water is removed by evapotranspiration. Additional meteoric water is removed through the processes of evaporation, sublimation, and surface run-off. The remaining water that moves through the cover to the underlying waste rock is referred to as net percolation (O'Kane, 2012).

The engineered cover is designed to provide the following benefits:

- Reduce infiltration into waste rock surfaces by enhancing evapotranspiration thereby reducing the amount of contact water moving through the dumps
- Inhibit oxygen transport through the dumps, lowering the amount of oxygen available to react with sulfide minerals present in the waste rock, and limiting acid rock drainage (ARD) generation, also known as WRCW
- Enhance slope stability and limit surface water flow and erosion
- Create a healthy and sustainable vegetated community of native species, that will resemble adjacent native topography and provide wildlife habitat

A phased approach is being used to determine and design the appropriate store-and-release cover for the site. The approach takes into consideration site-specific available cover materials, site-specific climate and vegetation, as well as topographic constraints and constructability. The steps are summarized as follows:

- Characterization of cover materials. Site investigations for the EWRE included many boreholes, of which representative samples of the site soils were selected for laboratory analysis.
  - The dominant soil classes at the site were a silty quartzitic gravel (GM); volcanic gravely clay (CL); and clayey quartzitic and/or volcanic gravel (GC).
  - Laboratory analyses were performed on the various soil types to understand the material properties. The testing included particle size distribution (PSD), Atterberg limits, hydrometer, compaction, specific gravity, permeability, and moisture retention curves. Agronomic test work was also completed on the soil material to understand the need for future soil amendments when placed back on the slopes.
  - Soil volumes for each soil class were estimated based upon borehole and test pit information from the CH2M HILL field investigations in 2011 and 2012 (CH2M HILL, 2012a).
- Characterization of vegetation. Vegetation performance at Bingham Canyon has been studied for over 20 years. Recently, reclamation seed mix performance has been studied in more detail and compared against native species' growing season, health, and rooting depth.
- Climate data inputs. A 50-year climate database was developed using historical data from the Salt Lake City Airport, Dry Fork (U.S. Department of Agriculture) and multiple weather stations located throughout the mine. Data sets from these stations included air temperature, relative humidity, rainfall, wind speed, and net radiation.
- Various cover scenarios were selected and modeled to predict performance. The model VADOSE/W (GEO-SLOPE International Ltd., 2007) was used. The modeling exercise incorporates the inputs listed previously to provide an indication of how a cover will perform with the ultimate goal of minimizing net percolation weighed against logistics (i.e., some cover designs perform better than others but would be exceptionally difficult to build in the field). Several cover alternatives were selected and performance was weighed against each alternative. Constructability was also a large factor in selection. Once a cover style was selected, further modeling was performed to optimize the cover thickness. Varying cover thicknesses will allow for more water-holding capacity and optimal vegetation performance.

The store-and-release cover is one component of the larger reclamation process. A brief and simplified description of the reclamation sequence is provided as follows:

- Strip and stockpile growth media from the footprint of the dump extension area. Where the footprint is over native and relatively undisturbed ground, the media will be stripped to bedrock while segregating the GM (primarily associated with topsoil and containing a seed bank of native vegetation) from the GC and CL units, which will be essentially homogenized through the salvage, stockpile, and final placement process. Where the footprint is over reclaimed slopes atop historic waste rock, only the material that will support vegetation will be salvaged.
- Place waste rock in 200- to 250-foot angle of repose lifts with appropriate step backs so that each lift may be relaxed to a 2.5:1 slope. The slope will be cross-ripped parallel to the toe and crest to provide a surface that will anchor the cover to the underlying waste rock.
- Place cover material along the crest or top of the relaxed slope, doze material to desired thickness, and cross rip parallel to the toe and crest. Cross-ripping of the slope will be executed to limit erosion potential on slopes by minimizing the potential for concentrated flow paths and bring fine material to the surface resulting in microhabitats to encourage plant establishment. The cross-rips provide water catchment and storage for vegetation.
- Apply soil amendments as needed and plant with species of seed mix and seedlings approved by the Utah Division of Oil, Gas and Mining (UDOGM).

2.2.2 Storm Water Control on Dump Face

After reclamation of the waste rock and installation of cover materials, a storm water management system will be installed to control and direct storm water from the benches of the reclaimed slopes. The storm water will be directed from the benches to storm water detention basins located up gradient of the cut-off walls. This is important to the groundwater discharge permit because a robust storm water and sediment collection system will minimize infiltration into waste rock and subsequent potential generation of contaminated water. The storm water management system will also limit sediment from entering the WRCW collection system, minimizing the chance of sediment and or scale buildup plugging the lines.

The storm water design will essentially eliminate meteoric water from coming into contact with the waste rock. Energy dissipation structures at the toe of the reclaimed waste rock slopes will de-energize the high-velocity flows and prevent damage to downstream structures.

The primary design objectives are to capture and direct surface water runoff and to prevent erosion of surface soils, minimizing subsequent sediment delivery to the collection system. Slope length and grade are factors in erosion potential and determine the velocity of the surface water runoff (runoff). Long, continuous slopes allow runoff to build up momentum with resulting high-velocity flows that concentrate to produce rills and gullies. Since the predominant erosion process is the transportation of soil particles by flowing water, diversion benches, and riprap-lined channels (downdrain channels) have been designed to create velocity breaks and counteract erosional effects of unarmored surfaces.

Diversion Benches

To prevent erosive velocities from occurring on the long dump slopes, the slopes will be bisected with diversion benches at regular intervals. The bench heights will be approximately 200 vertical feet. The benches will reduce the velocity of runoff flowing down the slope by shortening the distance that runoff can flow directly downhill. In addition to slowing runoff velocity and concentrating flow, the diversion benches will also:

- Provide a place for small amounts of sediment to settle out.
- Be back-sloped at 2 percent toward the dump face; and
- Have channels constructed at the bench-slope interface to convey storm water to the riprap-lined downdrains.

These channels will be lined with a mixture of bentonite and benign waste rock blended to form a low-permeability barrier for storm water, thus reducing the potential for surface water infiltration and the subsequent formation of WRCW. To prevent erosion, the diversion bench channels will also be armored with coarse, angular rock.

Differential settlement along the benches is anticipated, causing low points in the diversion bench channel and possible ponding of water. To prevent overtopping of the diversion bench and erosion of the slope below, a berm will be constructed along the outside edge of the diversion bench. Flow collected by the diversion benches and conveyed in the diversion bench channels will be directed to downdrains.

Downdrain Channels

Riprap-lined downdrain channels have been designed to carry concentrated runoff collected by the diversion benches down the waste rock slopes without causing erosion. These channels will deliver runoff to the storm drain collection system and are intended to serve as permanent waterways that have been designed, shaped, and lined to provide for safe conveyance of runoff.

Flow velocity will be minimized by lining the channels with rip-rap. The riprap-lined channels will be wide enough so that runoff flows will be fully contained. The channels have sufficient capacity to pass the peak flow from a 100-year frequency storm. The rip-rap has been sized to be stable and resistant to erosion at the design peak flow. Well-graded rip-rap forms a dense, flexible, self-healing cover that will adapt well to uneven surfaces.

At locations where the flow transitions from the diversion bench channel into the downdrain, it is critical to prevent erosion of the downdrain channel, diversion bench channel, and diversion bench berm. To prevent the potential for flows to bypass around the rip-rap on the benches, a continuous, reinforced, flexible surface will be provided through this critical transition area.

To prevent scour at the outlet of rip-rap-lined channels, flow transition structures are provided to dissipate the flow’s high energy and reduce the flow velocity. Flow transition structures include rip-rap aprons and rip-rap energy dissipation basins.

2.2.3 Storm Water Detention Basins

The storm water detention basin design includes detention basins associated with all EWRE drainages. The size of each detention basin was determined based on the estimated peak flow rates from storm water modeling based on a 100-year, 24-hour storm event and the planned, reclaimed site topography. At a minimum, the storage provided in each detention basin will be sufficient to contain the estimated peak storm volume. Modeling details are described as follows.

A model capable of both hydrologic and hydraulic modeling was selected to simulate storm water flows from the EWRE. The model XPSWMM (XP Software, Inc., 2011) was selected to predict and evaluate the storm water flow rates, as well as the hydraulics of the conveyance systems for both storm water and WRCW flows. This software is a comprehensive model for dynamic modeling of storm water, sanitary, and river systems. It can be used to simulate natural rainfall-runoff processes and the performance of engineered systems used to convey those flows. This program was selected because it seamlessly incorporates hydrologic inputs to the hydraulic model and avoids the extra step of importing hydrologic results from different modeling software to the hydraulic model.

Several parameters were required for the hydrologic piece of the model. They include the 100-year, 24-hour storm curve data and the basin information such as area, time of concentration, and elevation data for each of the sub-basins identified. All model runs used a curve number of 60. This information is shown in Table 2-1. The "A" entries in the table refer to the reclaimed dump face portion of the drainage basin and the "B" refers to the area down gradient of the reclaimed toe.

TABLE 2-1
Summary of Drainage Basin Inputs and Results for the 100-Year, 24-Hour Design Event

Basin Names		Area (acres)	Length of Watercourse (feet)	Ave Slope (meters/minute)	Model Input Tc (minutes)	Peak Runoff (cubic feet/ second)
Copper 4	A	70	1,995	39%	16.4	13.9
	B	58	1,620	8%	24.8	8.8
Copper 3	A	24	1,960	40%	16	4.8
	B	17	1,150	11%	17.1	3.3
Copper 2	A	30	2,075	39%	16.9	5.8
	B	18	1,450	10%	21.4	3
Copper 1	A	27	2,210	39%	17.7	5.1
	B	11	1,265	7%	21.7	1.8
Lark	A	28	2,210	39%	17.6	5.3
	B	15	1,200	9%	19.4	2.7
Lost Creek	A	17	2,030	46%	15.6	10.7
	B	7	1,050	7%	19.4	4.3
Keystone	A	36	2,030	46%	15.6	10.7
	B	17	1,050	7%	19.4	4.3
N. Keystone	A	57	1,865	47%	14.5	12.3
	B	21	820	12%	13.2	4.8
South Crapo	A	27	1,635	53%	12.7	6.2
	B	19	1,300	11%	19.1	3.4
Crapo	A	32	1,455	60%	11.2	8
	B	26	1,555	11%	21.6	4.3
Congor	A	26	1,465	61%	11.1	6.5
	B	22	1,340	10%	20	3.8
Midas	A	72	1,885	51%	14.3	15.8
	B	48	945	7%	17.8	8.9

Results of the model were used to size detention basins designed to contain the peak storm volume. Table 2-2 shows contributing acreages and peak storm volumes used to size the storm water detention basins.

TABLE 2-2
Estimated Peak Storm Volumes

Basin	Contributing Watershed Area (acres)	Estimated Peak Storm Volume (acre-feet)
Copper4	203	3.84
Copper3	54	0.97
Copper2	68	1.04
Copper1	38	0.59
Lark	58	0.88
Lost creek	71	1.35
Keystone	133	2.40
N. Keystone	112	2.03
S. Crapo	68	1.12
Crapo	99	1.63
Congor	109	1.88
Midas	282	5.41
Total	1,403	25.06

As shown in Figures 2-4 and 2-5, the detention basins include an engineered topographic low point for water detention and a pervious rock berm followed by an additional water detention area and an embankment of less than 6 feet. The primary overflow structure is at a height of 4 feet and includes a pipe penetration at the bottom of the basin elevation sized to entirely drain the detention basin within 24 hours. The detention basin embankment is provided with an emergency overflow at 5 feet. The primary structure directs the storm water through a pipeline to the cut-off wall storm water collection box.

The detention basins are sized to accommodate the peak storm volumes to attenuate the peak flows. The detention basins are all well below the size required for Utah Dam Safety Review (20 acre-feet) and will not constitute a threat to human life or property if they fail. The detention basins are slightly oversized to accommodate sediment buildup. However, they will be cleaned periodically to maintain the desired storage volume. The drain pipes from the bottom of the detention basins into the primary overflow structure are sized to provide drainage of the basins within 24 hours. Piping between the cut-off walls and the storm water canal has been sized to accept the entire peak flow from the design storm.

Storm water detention basins will be located below the toe of the waste rock and above the cut-off walls unless field conditions during construction indicate modifications to the configuration is required. General bedrock topography related to cut-off wall placement is well mapped (site geology is described in detail in Attachment 1 of this permit application). Clarity of final cut-off wall placement will better exist when bedrock is exposed during construction. During construction, priority will be given to optimize the recovery of WRCW using a robust toe drain system, followed by optimization of cut-off wall locations. If optimizing a cut-off wall location requires placing it to close to the dump toe to adequately accommodate the appropriately sized detention basin, the associated basin will be located adjacent to or down gradient of the cut-off wall.

FIGURE 2-4
Detention Basin Detail

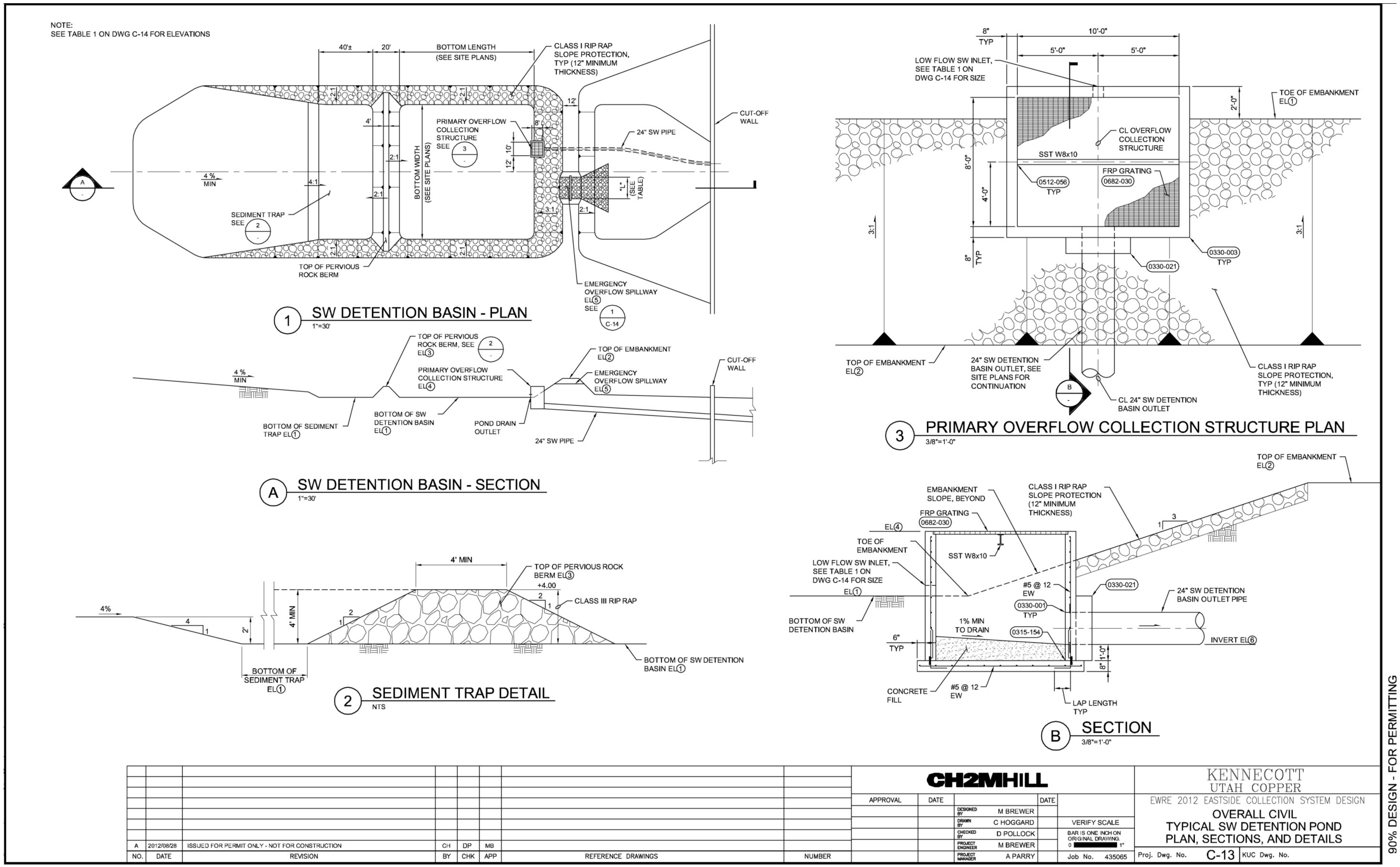
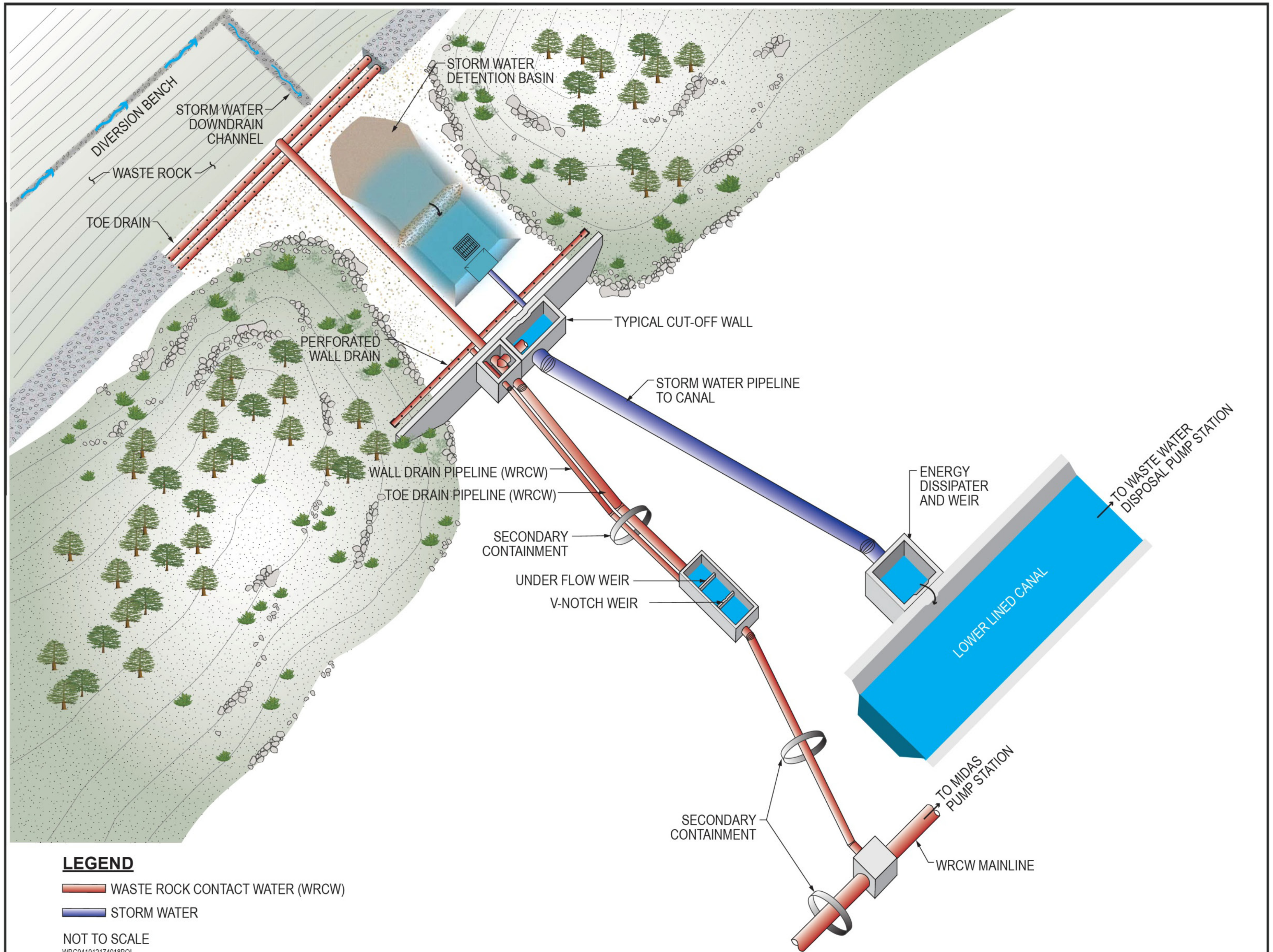


FIGURE 2-5
Conceptual East Waste Rock Collection System



2.2.4 Canal

Storm water flows will be accommodated by the existing and realigned and/or rebuilt sections of the lower lined canal, which will direct flows to the WWDPS. The existing lower lined canal originates at the Copper drainage, or named Copper 3 with respect to the EWRE design modification. Flows from the canal go to the WWDPS with overflow to the existing lined reservoirs. A pipeline will convey storm water collected from drainages south of Copper 3 where there is currently no canal.

The existing canal has been determined to be of adequate size with respect to the storm water design criteria listed in section 2.2.3, therefore dimensions will remain unchanged. The existing canal dimensions are approximately:

- Upstream of the MPS the canal has a 4-foot-wide base width with 1:1 slopes and 3-foot walls.
- Downstream of the MPS the canal has a 10-foot base with 1:1 slopes and 3.5-foot-high walls.

2.2.5 Water Collection System

The new system improves upon the existing system through more-efficient capture of WRCW by placing toe drains on top of low-permeability bedrock at the toe of the relaxed waste rock. Other advances include separation of WRCW and storm water, as well as robust linings and secondary containment structures to minimize the potential for a release of WRCW to the environment. An illustration of the proposed new collection system is provided in Figure 2-5. Detailed descriptions regarding specific design advances are found in the subparts of this section.

Key design criteria for the modified water collection system include the following:

- The system will be designed to capture surface and alluvial water up gradient of the cut-off walls; WRCW arriving at the toe of the waste rock will be collected in subsurface toe drains and conveyed in a system separate from surface water.
- Storm water will be conveyed to the existing WWDPS in the lower lined canal; WRCW from the toe drains and all water from drainages south of Copper 4 will be transported to the MPS and then to the existing Precipitation Plant.
- The cut-off wall locations will accommodate gravity flows from the cut-off walls to the down gradient collection system piping.
- The system is designed to accommodate a 24-hour, 100-year storm event.
- New walls will be located up gradient from significant increases in alluvial thickness or where bedrock dips steeply to the east.
- Cut-off walls will be located on low-permeable volcanic bedrock.

The primary WRCW collection system employs the use of toe drains running parallel and located adjacent to the relaxed and reclaimed toe of the waste rock; the secondary capture system is the cut-off walls. Figure 2-5 illustrates the conceptual design of the separate WRCW and storm water capture systems. More detail on the capture systems is included in later sections of this document.

Construction Sequencing

Construction sequencing will be coordinated to continue WRCW capture with the existing system while the new system is built and commissioned. The main collection system piping and MPS will be built first. Construction sequencing will generally be conducted in the following manner:

1. The WRCW main collection header to the MPS will be built from south to north; this includes construction of the piping from the WRCW mainline to the individual flumes within the drainage basins. The canal will also be refurbished from south to north. The hard piping from the cut-off wall to the junction with the future toe drains will also be constructed and will be adjusted as needed while the toe drains are constructed.
2. The cut-off walls will be constructed in each of the major drainages to intercept alluvial flows and will be built into the low permeability bedrock as indicated by field conditions.
3. The connections will be made between the WRCW piping and the canal to the cut-off walls.
4. The toe drain will be constructed beginning with low points in the collection system where flows are expected to be greatest and will be built with a minimum 1 percent slope to facilitate collection of WRCW within each drainage; toe drains will be connected between drainages after the lower elevation toe drains are installed and could be finalized concurrent with construction of the cover material. The waste rock toe will be modified as needed to accommodate the toe drain construction.
5. Following construction of the toe drain, the toe drain and hard piping will be connected.
6. Cut-off walls to be covered by the EWRE will be breached and old pipes will be sealed or flanged to prevent unwanted flow, if not removed.

The cut-off walls will be constructed in the order in which they will be impacted by waste rock placement. The current plan for waste rock placement starts at Copper 4 and moves north toward Midas.

The exact location of the toe drains and cut-off walls will be determined in the field based on depth to bedrock and the ability to maintain gravity flows to the cut-off walls. Extensive field investigations have been conducted to establish the location of the cut-off walls. However, the actual bedrock topography may differ from what is currently shown on the design drawings. Figure 2-1 illustrates the potential extent of waste rock coverage based on the field installation of the toe drains. Cut-off wall locations and dimensions shown in Figure 2-1 and in the design drawings will be subject to “field fit” based on actual bedrock topography as refined at the time of installation.

The current design drawings show all storm water detention basins up gradient of the cut-off walls. However, if required, the storm water detention basins may be located adjacent to or down gradient of the cut-off walls. This scenario would occur if cut-off walls were moved closer to the toe drain in order to achieve a shallower depth to bedrock (≤40 feet), to minimize earth moving efforts. This caveat is not considered problematic because WRCW and storm water are managed separately under the new design.

Primary Collection System: Toe Drains

The toe drains are designed to intercept WRCW moving along the bedrock contact as it reports directly from the toe of the waste rock. Field investigations conducted in the project area have determined that low permeability bedrock is present at the base of the alluvium beneath the proposed waste rock placement. The hydraulic conductivity of coarse grained unconsolidated waste rock is several orders of magnitude higher than the underlying Paleozoic and volcanic bedrocks which have geometric mean hydraulic conductivities of 5×10^{-5} centimeters per second (cm/s) (KUC, 1994). Additional hydrogeological information is located in Attachment 1, Supplemental Hydrogeological Report.

The toe drains are composed of two perforated, parallel, 12-inch-diameter pipes placed along the lower permeability layer at the bedrock contact. To increase the toe drain’s effectiveness in selected locations, the trench wall down gradient of the waste rock will consist of engineered fill consisting of a low-permeability clay (hydraulic conductivity of 1×10^{-5} cm/s or less) to direct water into the toe drain collection system. The toe drains are designed to minimize infiltration of surface water. Toe drains may be etched into bedrock in places to maintain the 1 percent minimum slope required for adequate drainage.

There will be two types of toe drains. Type 1 is a more robust design to be used at low points in the collection system where flow reporting from the waste rock is anticipated to be greatest. Type 2 will be used at the high points in the collection system and where flow from waste rock will be small. Cross sections of the toe drain designs are provided in Figure 2-6. In the drainage bottoms where the vast majority of WRCW is currently flowing, and is anticipated to continue to flow based upon hydrologic principles, the toe drain will be include a thicker clay unit.

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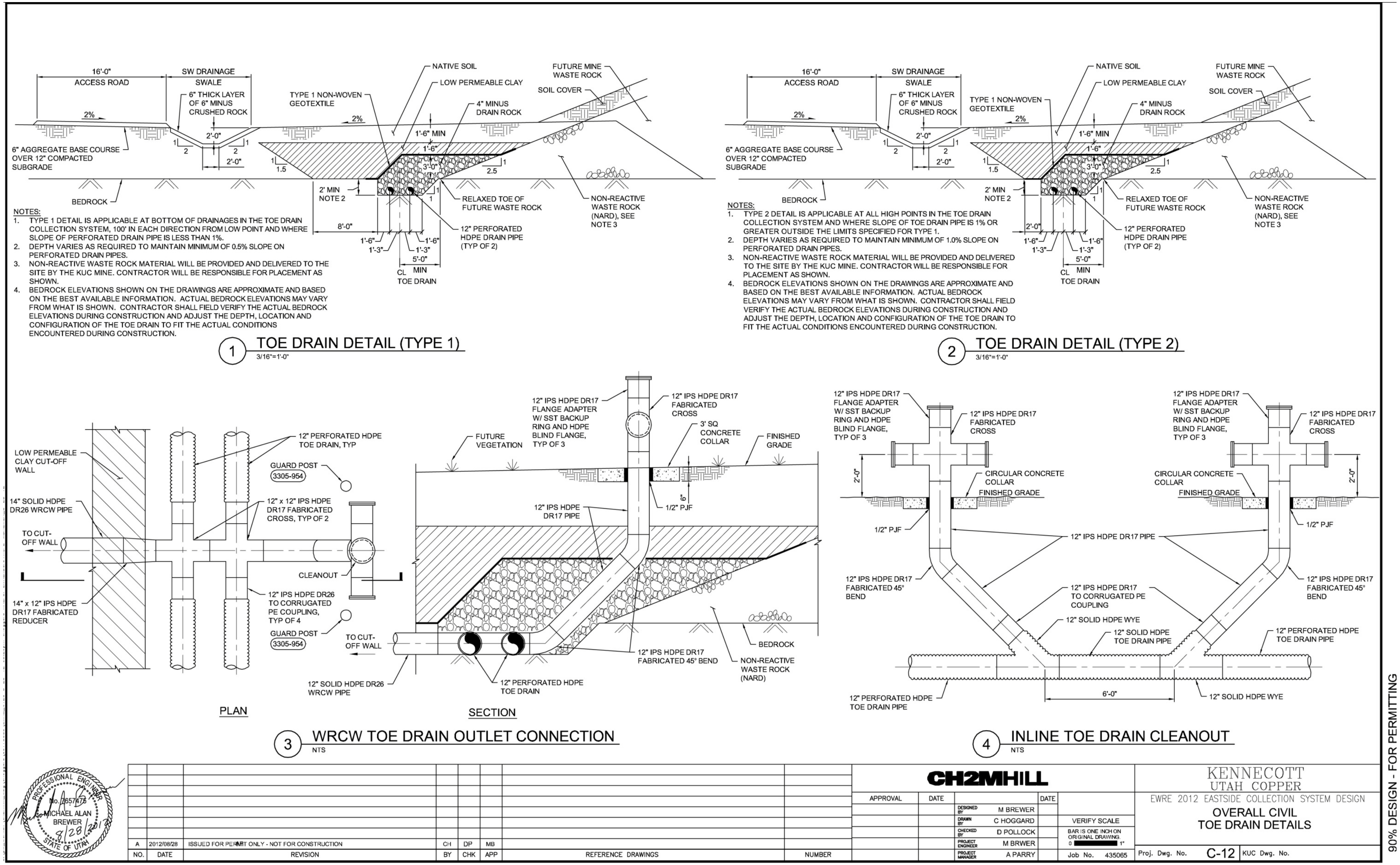
FIGURE 2-6
Overall Civil Toe Drain Details



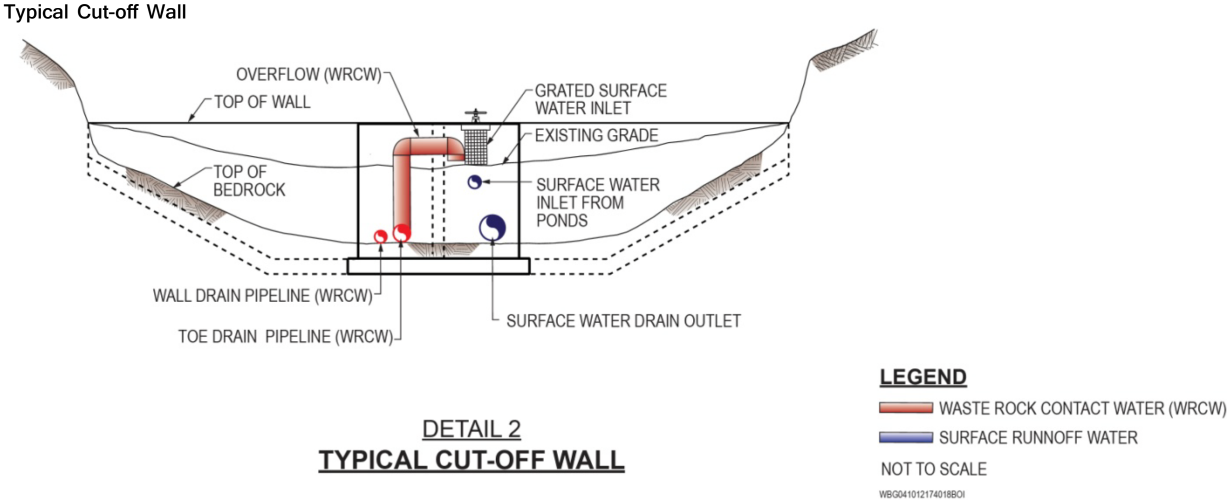
Within each drainage basin, the toe drains will connect up to a solid wall conveyance pipeline. This piping will extend down gradient from the toe drain to the cut-off wall and subsequent collection system. At the cut-off wall, the toe drain water will be transported via gravity to the MPS and then pumped to the main header feeding the Precipitation Plant.

The existing waste rock contains a few minor seeps that do not always coincide with drainage bottoms or waste rock toes. Tie-ins with the toe drain will be provided with the clean-outs approximately every 500 feet to capture potential future seeps that may emanate from unanticipated locations. The tie-ins will allow the seep water to be piped into the collection system rather than run over the surface to be collected at the cut-off wall.

Secondary Collection System: Cut-off Walls

The cut-off walls are designed as a secondary capture system for alluvial groundwater, with the toe drains functioning as the primary capture system. Similar to the existing system, cut-off walls will be located in each of the major drainages and installed into bedrock for structural support and to enhance capture effectiveness. A French drain will run parallel to the base of each cut-off wall along the surface of the bedrock to capture any WRCW moving down the channel that has not been intercepted by the toe drains. Figure 2-1 shows the approximate locations of the cut-off walls, and Figure 2-7 shows a typical cut-off wall in cross section.

FIGURE 2-7
Typical Cut-off Wall



Based on bedrock topography, some new walls will replace multiple existing walls while, in other cases, multiple new walls will be required to replace single existing walls. Table 2-3 shows the existing and proposed new cut-off walls.

TABLE 2-3
Existing and New Cut-off Walls

Existing Cut-off Wall	New Cut-off Wall (relocated)
Copper	Copper 4 Copper 3 Copper 2
North Copper	Copper 1 Lark
Lost Creek	Lost Creek
Keystone	Keystone
North Keystone	North Keystone South Crapo
Crapo	Crapo
South Congor 1 South Congor 2	South Congor
Congor 1 Congor 2 Midas 1 (will be left in place) Midas 2 (will be left in place)	Midas

Field investigations to site the new cut-off wall locations were conducted in August 2011 and again in July/August 2012. The investigations consisting of test pit excavations, sonic drilling, and site surveys to determine the depth to bedrock at the proposed cut-off wall locations. Field logs are included in the Cut-off Wall Field Investigation and Design Optimization, Technical Memorandum (CH2M HILL, 2012b).

Storm water from the detention basins will pass through the cut-off wall into the canal where it will be conveyed to the WWDPS. WRCW collected in the toe drain collection system and perforated pipe on the upslope side of the cut-off wall will be piped to the main WRCW water conveyance pipeline, where it will be conveyed to the new MPS. WRCW can be diverted, if needed, into the storm water system in the event of an upset condition, or during maintenance, by diverting the flow at the cut-off walls.

The estimated size of each wall was determined based on bedrock and surface topography and will be modified during construction based on field conditions. Approximate cut-off wall dimensions are shown in Table 2-4.

TABLE 2-4
Approximate Cut-off Wall Dimensions

Proposed Cut-off Wall (relocated)	Approximate Dimensions (feet) (Maximum Depth × Overall Length)
Copper 4	13×370
Copper 3	28×270
Copper 2	16×440
Copper 1	13×105
Lark	29×450
Lost Creek	12×45
Keystone	20×90
North Keystone	29×225
South Crapo	12×152
Crapo	12×90
South Congor	21×130
Midas	23×356

Cut-off walls will be constructed with concrete and standard rebar. In addition, cut-off walls will have an HDPE liner installed on the up gradient face. The liner will be anchored at the top with stainless-steel batten bars and will otherwise be held in place by the soil backfill. The liner is anchored at the bottom by extending into the bedrock, batten bars will be used on the sides. The HDPE liner will have a minimum thickness of 40 mil (1 millimeter [mm]). Additionally, a geocomposite liner will be installed on the outside face of the HDPE liner to provide protection from damage to the HDPE liner during installation of backfill and to provide a drainage path for groundwater to be conveyed down to the perforated collection piping at the base of the wall.

Water Conveyance Piping

The collection system down gradient of the cut-off walls includes a pipeline to receive WRCW from the new system and the flows from the existing system south of Copper 4. The new WRCW piping will include a secondary containment HDPE pipe that will gravity drain from each cut-off wall to the main WRCW pipe where it will be conveyed to the MPS. WRCW pumped from the MPS to the Precipitation Plant will incorporate the existing piping and secondary containment. The WRCW piping overflows to the storm water canal, and the WWDPS overflows to the lined reservoirs.

Modeling was performed using the XPSWMM model (XP Software, Inc., 2011) to verify gravity drainage, pipe sizes, required area of the canal, flow rates, and corresponding velocities meeting the design criteria. Hydrologic inputs to the model included the 100-year, 24-hour storm curve data and the basin information, such as area, time of concentration, curve number, and elevation data for each of the drainage areas.

The same model used to predict storm water flow rates, XPSWMM, was used to model flows in the WRCW collection system piping and flow in the canal. The hydraulic inputs for the model were extensive.

A partial list of the hydraulic model inputs is as follows:

- Ground surface and invert elevations of structures and pipes as they connect to each other

- Storage capacities for cut-off wall detention basins modeled as storage nodes with an overflow weir and an outlet pipe sized to allow the ponds to empty within 24 hours of the 100-year, 24-hour storm event
- Stilling basin (flume) and weir elevations, storage, and configuration data with overflow to the canal
- Channel configuration for flows routed from the waste rock to the cut-off wall detention basins; Manning's n was assumed at 0.35 for a 50 to 100 feet wide vegetated swale
- Canal cross section data and Manning's n (assumed at 0.24 for a concrete lined channel)
- Pipe lengths, slopes and Manning's n (assumed at 0.13 for all HDPE pipe)
- Pipe inside diameters were used assuming HDPE IPS DR 26 pipe (rated for a pressure of 65 pounds per square inch [psi])

An alignment adjacent to the existing canal will be excavated to accommodate the WRCW piping. All main WRCW collection system piping will have secondary containment with manual leak detection and cleanouts approximately every 1,000 feet. In addition, automatic leak detection will be provided in up to eight separate locations near cut-off wall piping connections with the main collection system piping as described in Section 3.

2.2.6 Secondary Containment

Secondary containment of the WRCW conveyance system will reduce the risk of release to the environment. Dual containment of WRCW flow is provided at the following locations:

- WRCW piping between the cut-off walls and the main collection system piping
- Flumes associated with WRCW flows and the wet well at the MPS
- Main WRCW collection system piping from junctions with the cut-off walls to the MPS and from the MPS to the upper collection system
- Pressurized discharge WRCW piping from the MPS to the Precipitation Plant collection system

Concrete structures that are located along the WRCW conveyance system, including stilling basins and the MPS, will be lined with a cast-in-place HDPE liner with a minimum thickness of 120 mil (3 mm). The liner will be anchored to the concrete with cast-in-place anchors that are bonded to the back of the liner. The interstitial space between the liner and the concrete is unbonded between anchors and will include leak detection monitoring, with the concrete structure providing secondary containment. Spark and vacuum testing will be used by the manufacturer to ensure the integrity of the liner before it is placed into service.

3.0 Monitoring and Inspection Methods

Monitoring is described in detail in the Compliance Monitoring Plan (Attachment 3). Compliance wells are currently sampled to determine the compliance of the cut-off wall system. No changes in approach to the compliance monitoring strategy are proposed as part of this permit modification.

3.1 Operational Monitoring Sites

Operational monitoring sites will be replaced in kind with the existing sites as outlined in Table 3-1 and depicted in Figure 3-1. No changes are proposed to the tunnels shown on Table 3-1. Water from existing seeps covered by the new waste rock footprint will be collected by the new toe drain system. Seeps outside of the EWRE footprint and down gradient of the lower lined canal will remain unchanged, specifically the Lower Keystone Seep, LWS2717. New seeps will be accommodated by tie-ins located approximately every 500 feet along the toe drains.

New operational monitoring sites will have formatted names and numbers in accordance with the current KUC Groundwater Characterization Monitoring Plan.

TABLE 3-1
Operational Monitoring Sites

	NAD 83			
Sample ID	Latitude (decimal degrees))	Longitude (decimal degrees)	Existing Cut-off Wall	New Cut-off Wall (relocated)
ECP2618	40.519778	-112.103875	Copper	Copper 4 Copper 3 Copper 2
ECP2624	40.523714	-112.103322	North Copper	Copper 1 Lark
ECP2627	40.526113	-112.103205	Lost Creek	Lost Creek
ECP2629	40.528593	-112.102059	Keystone	Keystone
ECP2648	40.531550	-112.101822	North Keystone	North Keystone South Crapo
ECP2651	40.536710	-112.101976	Crapo	Crapo
ECP1654	40.538653	-112.102194	South Congor 1 and South Congor 2	South Congor
ECP2662	40.541237	-112.104358	Congor 1, Congor 2	Midas
ECP2668	40.542489	-112.104263	Midas 2 Effluent	No change
ECP2670	40.543043	-112.103551	Midas 1 Effluent	No change
ECP2664	40.541940	-112.099068	Old Bingham Tunnel Effluent	No change
ECP2631	40.527060	-112.098030	Tunnel (Mascotte) below the Lost Creek/Keystone Confluence	No change

TABLE 3-1
Operational Monitoring Sites

	NAD 83			
Sample ID	Latitude (decimal degrees))	Longitude (decimal degrees)	Existing Cut-off Wall	New Cut-off Wall (relocated)
ECS2716	40.530166	-112.107741	Upper Keystone Seep	Will be accommodated as needed in the new design
ECS2718	40.536092	-112.102091	Crapo Seep	Will be accommodated as needed in the new design
LWP2632	40.527517	-112.096077	Bingham Tunnel at Weir	No change
LWS2717	40.527726	-112.092249	Lower Keystone Seep	Will be accommodated as needed in the new design

Compliance monitoring wells scheduled for replacement due to either waste rock placement or construction related conflicts are described in detail in Attachment 3, Compliance Monitoring Plan.

3.2 Operational Reporting and Inspections

Monitoring data for operational sites including cut-off walls, seeps, and informational wells will be submitted to UDWQ in an annual report provided by March 31 of each year, consistent with the existing groundwater discharge permit.

Quarterly documented inspections are currently performed on the collection system to verify proper operation and to confirm the system continues to operate as designed. The quarterly inspections will continue for the new system with the following changes:

- A flow meter will be installed to measure the total WRCW flow from the MPS to the Precipitation Plant.
- The main WRCW pipeline will include automatic sensors installed at low points associated with the secondary containment system. Automatic leak detection will be installed near the junction of cut-off wall piping with the main collection system piping in key drainages, including Copper 4, Copper 3, Copper 1/Copper 2, Lark, Lost Creek/Keystone, North Keystone, South Crapo/Crapo, and South Congor/Midas. Manholes to allow for manual leak detection will be provided approximately every 1,000 feet along the entire length of the main pipeline from Copper 4 to the MPS.

In addition, the entire system will continue to receive regularly scheduled maintenance and repair. Quarterly inspections of the collection system including the detention basins, cut-off walls, flumes, pipelines, and MPS will continue to be performed. In the event of a failure, the following scenarios apply as shown in Table 3-2. Repairs and regular maintenance will be maintained to keep the system’s robust design fully operational.

TABLE 3-2
Failure Scenarios

Failure scenario	Result
Failure of toe drain	Redundant (second slotted pipe) will continue to capture WRCW.
Failure of both toe drain pipes	Cut-off wall will collect WRCW.
Failure of piping from toe drain to cut-off wall	Cut-off wall will collect WRCW.
Cut-off wall or pipe failure	Monitor wells will detect failures
Failure of WRCW piping down gradient of the cut-off walls	Dual containment will prevent a release to the environment; leak detection capability will provide notice of a breach.
Storm event exceeds capacity of WRCW piping	Overflow of WRCW goes to the storm water canal.
Exceptional storm event (greater than 100-year, 24hour) exceeds capacity of the WWDPS	Overflow will go to the lined reservoirs.
Failure of pumping systems at the MPS due to power outage or equipment failure	WRCW will gravity drain through the storm water canal to the WWDPS.

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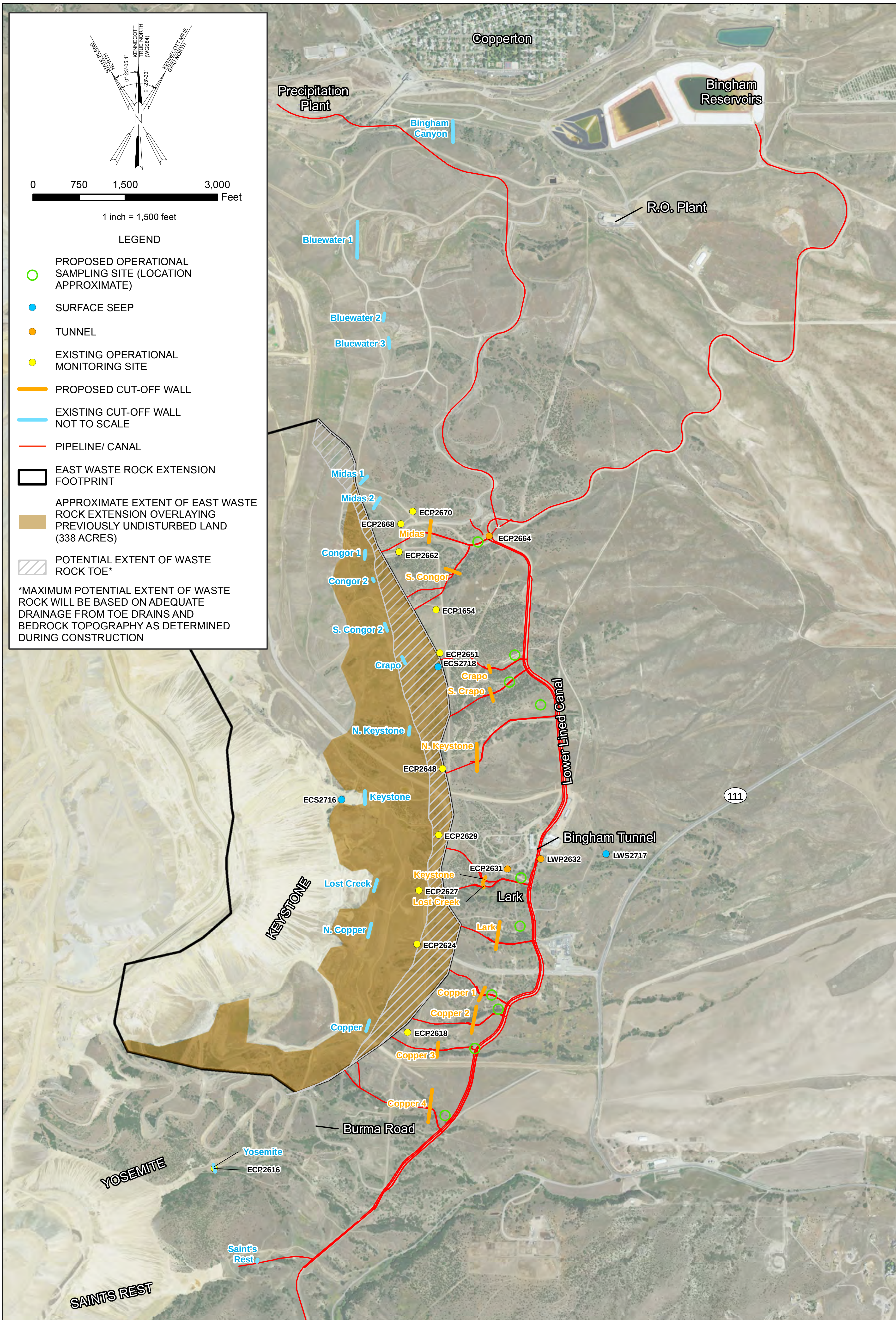

FIGURE 3-1

OPERATIONAL MONITORING SITES

EAST WASTE ROCK EXTENSION PERMIT MODIFICATION
GROUNDWATER DISCHARGE PERMIT UGW350010
KENNECOTT UTAH COPPER

4.0 Summary of Controls

The 1994 permit application (KUC, 1994) summarized potential losses of WRCW to the environment. The system advances described earlier in this document will further minimize potential losses by employing the following:

- Reduction of net percolation and resulting reduction in drainage through the waste rock as a result of the store-and-release cover
- Primary and secondary capture systems for WRCW (redundant toe drains and cut-off wall systems)
- Linings and secondary containment for flumes and the wet well at the new MPS
- Secondary containment for the WRCW pipelines down gradient of the cut-off walls
- Storm water and drainage management
- Reclaimed waste rock slopes

Routine operations and maintenance will continue to be performed in order to best maintain the system. Compliance groundwater monitoring wells will be sampled in order to continue monitoring water quality in each of the drainages.

The entire water collection system has been designed with redundancy and secondary containment, as applicable, to minimize the potential for release of WRCW to the environment.

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5.0 References

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Attachment 3: Compliance Monitoring Plan

East Waste Rock Extension Permit Modification

Groundwater Discharge Permit UGW350010

Prepared for

Kennecott Utah Copper LLC

September 2012

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Contents

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Acronyms and Abbreviations

BAT	Best Available Technology
BCM	Bingham Canyon Mine
Cd	cadmium
Cu	copper
ECS	Eastside Collection System
EPA	United States Environmental Protection Agency
EWRE	East Waste Rock Extension
GCMP	*Groundwater Characterization and Monitoring Plan*
gpm	gallon(s) per minute
KUC	Kennecott Utah Copper LLC
mg/L	milligram(s) per liter
NA	not applicable
SO_4	Sulfate
TBD	to be determined
TDS	total dissolved solids
UDWQ	Utah Department of Environmental Quality, Division of Water Quality
Zn	zinc
WCS	water collection system
WRCW	waste rock contact water

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1.0 Introduction

The permitted facility includes the Water Collection System (WCS) associated with waste rock at the Kennecott Utah Copper LLC (KUC) Bingham Canyon Mine (BCM). This system is also known as the Eastside Collection System (ECS). The BCM operations are located in the Oquirrh Mountains approximately 18 miles southwest of Salt Lake City, Utah. This mine produces copper and other metals that are currently extracted using an open-pit method of mining. Open-pit operations have been conducted at this site for over 100 years.

The WCS currently operates under Groundwater Discharge Permit UGW350010, issued by the Utah Department of Environmental Quality, Division of Water Quality (UDWQ). The permit was first issued in June 1994 and has been renewed on a regular basis approximately every 5 years. The most-recent renewal was March 23, 2010 (UDWQ, 2010).

The waste rock associated with this mining operation has been placed adjacent to the open pit on the slopes of the Oquirrh Mountains. The waste rock disposal areas consist of over 5 billion tons of waste rock. The waste rock consists of low concentrations of sulfide mineralization and trace metals in an intrusive host rock, limestone, and quartzite.

This permit modification is applicable to the easterly facing waste rock dumps between the Copper drainage (south end) to the Midas drainage (north end). KUC is applying for a permit modification to address the East Waste Rock Extension (EWRE) project.

1.1 Purpose

In accordance with Utah Administrative Code R317-6-6.3, a Compliance Monitoring Plan is required to demonstrate that the Best Available Technology (BAT) used is functioning adequately to protect area groundwater quality. The plan will demonstrate how compliance with groundwater protection limits for the WCS will be achieved. This plan is consistent with Appendix A of the *Groundwater Discharge Permit No. UGW350010* (UDWQ, 2010) and will address changes to the existing monitoring system as a result of modifications to the cut-off wall and collection system to accommodate an expanded waste rock footprint. For more details regarding the proposed WCS modifications, see Attachment 2 of the EWRE Groundwater Discharge Permit Modification Application.

1.2 Context

Proposed changes to the Compliance Monitoring Plan are specific to the EWRE project area. The EWRE area includes all drainages from the Copper drainage at the south of the project area, to the Midas drainage at the northern boundary. Drainages outside of this area and their associated compliance monitoring locations will not be impacted by the EWRE and will be maintained as required to comply with the existing permit. The EWRE project area is illustrated in Figure 1-1.

Elements of the EWRE pertaining to site hydrogeology, hydro-geochemistry, and water quality are discussed in Attachment 1 of the EWRE Groundwater Discharge Permit Modification Application. In addition, KUC has an existing Groundwater Monitoring Plan that is described in the current *Groundwater Characterization and Monitoring Plan* (GCMP). The GCMP outlines the procedures and methods for collecting, analyzing, and reporting groundwater monitoring data.

This Compliance Monitoring Plan for the WCS includes the following:

- Monitoring strategy

- Description of the operational monitoring program
- Description of the compliance monitoring program

The plan outlines the groundwater and operational monitoring associated with the permit and the protection of the principal aquifer of the southwestern Jordan Valley.

1.3 Monitoring Strategy Overview

The inspection, maintenance, operational monitoring, and groundwater compliance monitoring will be performed as specified in the existing groundwater discharge permit for the WCS. Compliance monitoring is divided into two categories—operational monitoring and groundwater compliance monitoring. Operational monitoring consists of inspections to verify the collection system is operating as designed and that it continues to be properly maintained. In addition, operational monitoring sites associated with the collection system will continue to be evaluated. Groundwater compliance monitoring consists of sampling a network of compliance monitoring wells down gradient of the WCS to verify the collection system is operating as designed and that waste rock contact water (WRCW) is being managed in accordance with the groundwater discharge permit. The locations of the operational monitoring sites and groundwater compliance wells are provided in Figure 1-1.

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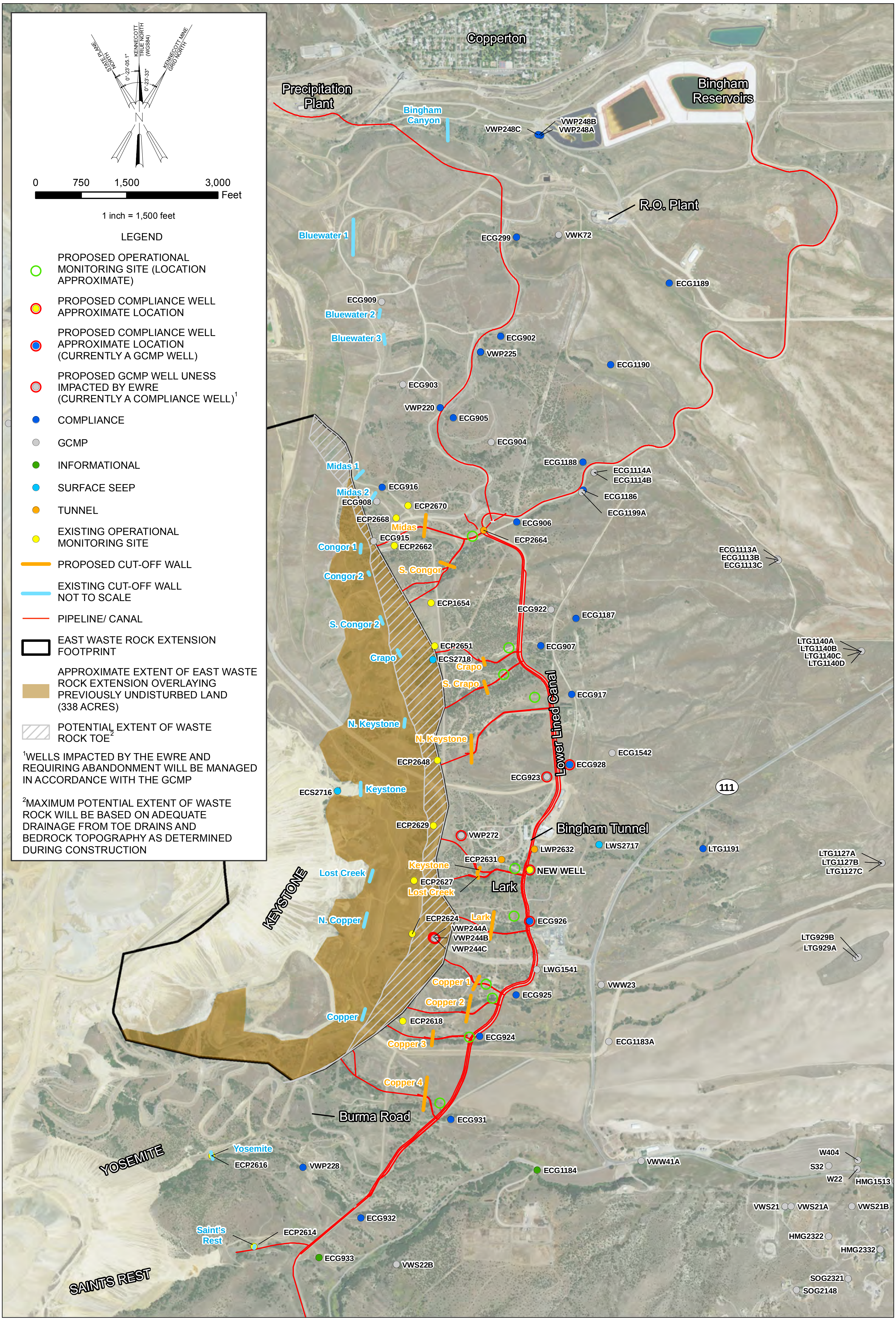

FIGURE 1-1
EAST WASTE ROCK EXTENSION COMPLIANCE MONITORING NETWORK
EAST WASTE ROCK EXTENSION PERMIT MODIFICATION
GROUNDWATER DISCHARGE PERMIT UGW350010
KENNECOTT UTAH COPPER

2.0 Operational Monitoring

Operational monitoring is intended to provide pertinent information regarding the proper functionality of the WCS as described in Attachment 2 of the EWRE Groundwater Discharge Permit Modification Application to document compliance with permit requirements, and to identify potential impacts to groundwater. Operational monitoring of informational wells, seeps, tunnels, and flows reporting to the cut-off walls serve as an early warning for the compliance well network. Actions that will be conducted to ensure that the system is functional and compliant with operational and regulatory criteria include the following:

- Inspecting and maintaining detention basins and associated stormwater and sediment control structures
- Inspecting and maintaining cut-off walls and associated ditches, pipelines, flumes, and flow monitoring equipment
- Monitoring flows and water quality parameters associated with each of the drainages
- Monitoring seeps and tunnels, including flow and water quality, and making system adjustments to capture seep flow as necessary
- Inspecting and maintaining the main WRCW collection pipeline through leak detection and visual inspection of secondary containment

An integral part of maintaining BAT is preventive maintenance, which includes routine scheduled inspection and maintenance of the water collection system, documentation, and adequate employee training.

2.1 Source Monitoring

Source monitoring is conducted at various locations that correlate with the water collection system and provides a characterization of water emanating from the toe of the waste rock dump reporting to the various cut-off walls and flumes. These sites are referred to as Operational Monitoring Sites and are listed under the existing permit in Table E-1 of Appendix E. The sites are sampled semiannually for water quality and volumetric flow.

Table 2-1 lists the operational monitoring sites impacted by the EWRE with replacement "in kind" sampling and associated new cut-off walls. Figure 2-1 illustrates the existing and new operational monitoring site locations. Numbering of the new operational monitoring locations will be established through the GCMP protocols upon permit modification approval.

TABLE 2-1
Operational Monitoring Sites

Sample ID	NAD 83 Latitude (decimal degrees)	NAD 83 Longitude (decimal degrees)	Existing Cut-off Wall	Proposed Cut-off Wall (relocated)
ECP2618	40.519778	-112.103875	Copper	Copper 4 Copper 3 Copper 2
ECP2624	40.523714	-112.103322	North Copper	Copper 1 Lark
ECP2627	40.526113	-112.103205	Lost Creek	Lost Creek
ECP2629	40.528593	-112.102059	Keystone	Keystone
ECP2648	40.531550	-112.101822	North Keystone	North Keystone South Crapo
ECP2651	40.536710	-112.101976	Crapo	Crapo
ECP1654	40.538653	-112.102194	South Congor 1 and South Congor 2	South Congor
ECP2662	40.541237	-112.104358	Congor 1, Congor 2	Midas
ECP2668	40.542489	-112.104263	Midas 2 Effluent	Will remain unchanged
ECP2670	40.543043	-112.103551	Midas 1 Effluent	Will remain unchanged

Note: New sample identification numbers will be generated in accordance with the current GCMP.

2.1.1 Tunnels

Three tunnels exist within close proximity of the EWRE project area. Water draining from the tunnels is sampled semiannually for quality and measured quarterly for flow. No changes to the tunnels are planned as part of the proposed modification. Tunnel information is included in Table 2-2.

TABLE 2-2
Tunnels within the EWRE Project Area

Source ID	Description	NAD 83 Latitude (decimal degrees)	NAD 83 Longitude (decimal degrees)	Status After Modification
LWP2632	Bingham Tunnel at Weir	40.527517	-112.096077	No change
ECP2631	Mascotte Tunnel below the Lost Creek/Keystone Confluence	40.52706	-112.098027	No change
ECP2664	Old Bingham Tunnel	40.541941	-112.099068	No change

2.1.2 Seeps

Currently, three seeps occur along the BCM East Waste Rock area. The location, water quality, and flow rates of seeps may change as a result of the EWRE. KUC will continue to assess the collection system area for seeps on a quarterly basis. Seeps above the water collection system will be connected to the WRCW collection system as described in Attachment 2 of the EWRE Groundwater Discharge Permit Modification Application, thereby minimizing the release of potentially impacted water to the principal aquifer. Water samples will continue to be collected and analyzed for pH and conductivity for seeps down gradient of the water collection system. Any seep that has a measured pH less than 4.5 and conductivity greater than 5,000 micro-ohms per centimeter will be managed according to Appendix A of the *Groundwater Discharge Permit No. UGW350010* (UDWQ, 2010). Seeps associated with the project are listed in Table 2-3.

TABLE 2-3
Seeps Near the EWRE Project Area

		NAD 83		
Source ID	**Description**	**Latitude (decimal degrees)**	**Longitude (decimal degrees)**	**Status After Modification**
ECS2716	Seep up gradient of existing Keystone cut-off wall	40.530125	-112.107750	This seep will be buried by the proposed EWRE footprint and will no longer be present after the modification.
ECS2718	Seep down gradient of the existing Crapo cut-off wall	40.536053	-112.102103	This seep is located within the potential extent of the EWRE footprint and will continue to be monitored as required by the existing permit, unless buried.
LWS2717	Lower Keystone Seep down gradient of the proposed collection system	40.527686	-112.092261	This seep is located down gradient of the proposed collection system, is not impacted by the new footprint and will continue to be monitored as required by the existing permit.

2.1.3 Vadose Zone Monitoring

As described in Attachment 2, Groundwater Discharge Control Plan, the toe drains and cut-off walls intersect potential contact of WRCW with the vadose zone in the EWRE area therefore, no vadose zone monitoring is planned.

2.1.4 Leak Detection Monitoring

All WRCW collection system conveyance pipelines down gradient of the cut-off walls associated with this modification will be enclosed in secondary containment. An electronic optical sensor leak detection system will be installed at up to eight locations near the junction of cut-off wall piping with the WRCW mainline. This system will provide visual indication when a leak is detected. The optical sensor will be placed in designed low spots associated with the secondary containment. KUC personnel will maintain the electronic leak detection system according to the manufacturer’s recommendation. In addition, visual inspection ports will be provided along the WRCW mainline approximately every 1,000 feet and quarterly visual inspections of the pipelines and canal can be performed.

2.1.5 Inspections

Inspections of the newly proposed Operational Monitoring Sites associated with the water collection system will be performed consistent with Appendix A of *Groundwater Discharge Permit No. UGW350010* (UDWQ, 2010).

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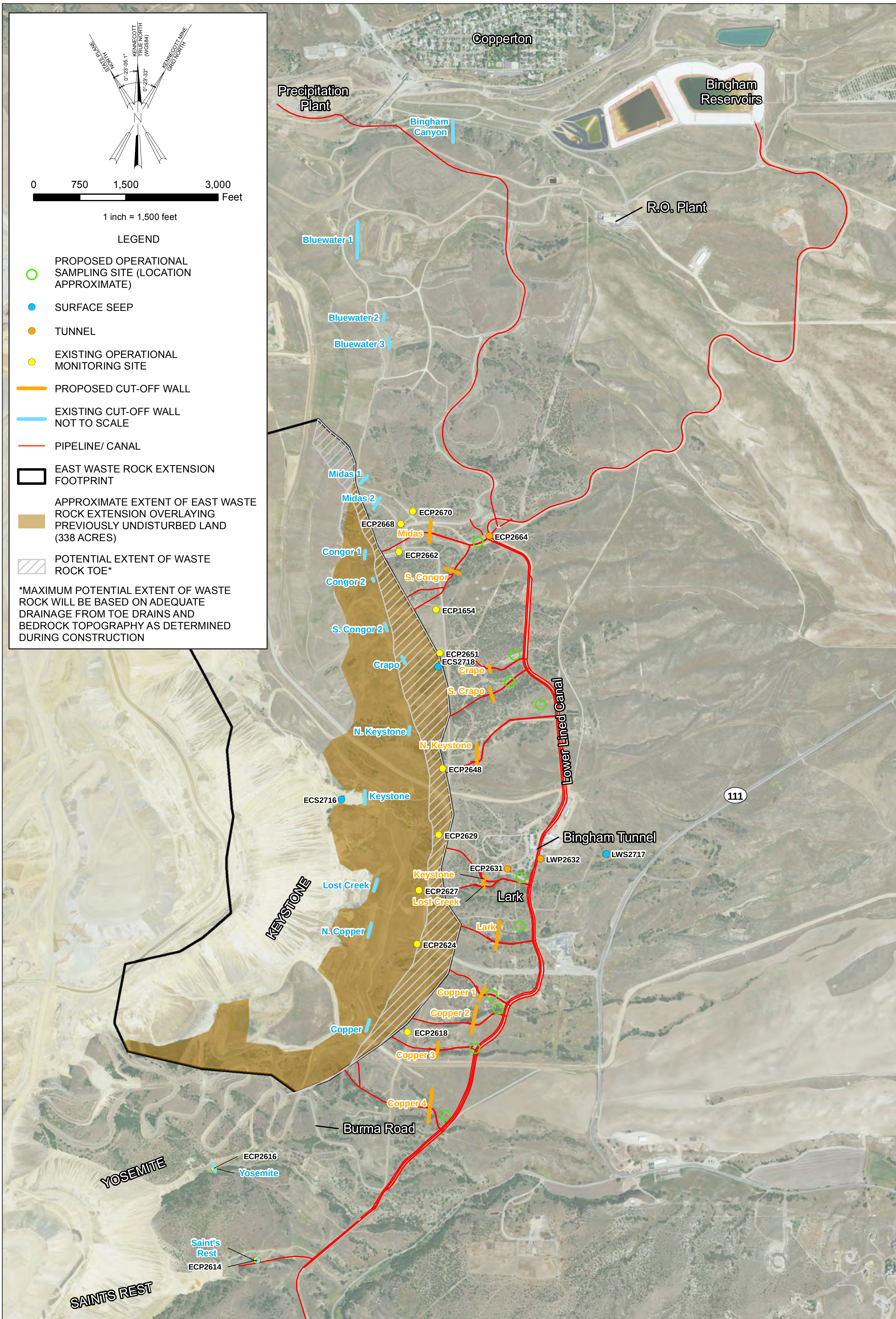

FIGURE 2-1
OPERATIONAL MONITORING POINTS
EAST WASTE ROCK EXTENSION PERMIT MODIFICATION
GROUNDWATER DISCHARGE PERMIT UGW350010
KENNECOTT UTAH COPPER

3.0 Groundwater Monitoring Program

A monitoring well network of 43 wells is used for compliance monitoring of the WCS. Twenty-four of the 43 compliance wells are located hydraulically down gradient of the drainages impacted by the EWRE project area as shown in Figure 3-1, at the end of this section. The compliance monitoring well network will continue to provide monitoring in each of the major drainages and are intended to provide detection of a subsurface release along flow paths down gradient of the EWRE area.

The EWRE footprint and subsequent WCS modifications will impact several of the existing groundwater monitoring wells. Table 3-1 summarizes the wells impacted and the fate of those wells. There are two types of monitoring wells potentially impacted by the EWRE project:

1) Compliance, and
2) Informational wells also referred as GCMP wells.

Up to four compliance wells will no longer meet the compliance monitoring criteria for one of the following reasons:

1) The well is within the EWRE footprint and will be buried by waste rock,
2) The modified WCS is down gradient of the well so the well will no longer be appropriately located to monitor potential impacts, or
3) The realignment of the mine access road conflicts with the well location.

One informational well may be impacted by waste rock placement. This well will be appropriately abandoned and then buried as a result of waste rock placement.

TABLE 3-1
Groundwater Monitoring Wells Impacted by EWRE

Well ID	Well Type	EWRE Impact	Well Fate
VWP244A, B & C	Compliance	Covered by waste rock	Abandon
VWP272	Compliance	WCS moved down gradient of well	Maintain as GCMP
ECG915	Informational	Covered by waste rock	Abandon
ECG923	Compliance	WCS moved down gradient of well	Maintain as GCMP
ECG906	Compliance	Potential access road conflict	Abandon

In cases where wells are buried by waste rock, the well will be properly abandoned prior to waste rock placement, in accordance with the KUC GCMP. In cases where wells are required to be replaced due to modifications to the collection system, and the wells are not impacted by waste rock or other construction activity, the well will remain as an informational well and will be sampled periodically under the KUC GCMP plan. Replacing these compliance monitoring wells “in kind” is discussed in more detail later in this section.

It should be noted that the maximum potential extent of the waste rock toe was considered for this discussion. If the final waste rock toe is further to the west than the maximum extent shown on Figure 3-1, wells VWP244A, B and C, and ECG915 may remain in their current state. It should also be noted that well ECG906 may or may not be impacted by the mine access road re-alignment.

The existing compliance monitoring wells in the EWRE project area and their status after the proposed modification are listed in Appendix A and illustrated in Figure 3-1. Screened intervals and lithologies for all wells in the EWRE area are also shown in Figure 3-1. Proposed replacement well information is provided in Table 3-2.

KUC is proposing to drill two new wells to replace the wells impacted by the EWRE footprint and collection system; the first well will replace VWP272 and the second well will replace ECG906 should it be impacted by the new mine access road. KUC is also proposing to use two existing wells to replace two compliance monitoring wells that no longer meet the compliance well criteria outlined in the original groundwater discharge permit application submitted in 1994. The wells to be replaced “in kind” are ECG923 and the VWP244A, B and C series. These wells will be replaced with ECG928 and ECG926, respectively. Well statistics comparing existing wells with replacement wells are included in Appendix B of Attachment 3.

Compliance wells will be relocated to replace, “in kind,” the wells that are impacted or no longer meet the criteria outlined in the original permit application. Wells located under the proposed footprint will be abandoned in accordance with the existing groundwater discharge permit requirements. Monitoring well placement is generally described in Sections 1.3 and 1.4 of the *Eastside Collection Monitoring System Ground Water Discharge Revision 1* (KUC, 1994) as follows:

- “The basic monitoring concept is to install a line of compliance monitoring wells at the edge of the principal aquifer of the southwest Jordan Valley. These wells will be located to monitor the quality of groundwater which moves away from the Bingham Canyon mine. The compliance monitoring wells will be located directly down gradient from each of the active leach collection facilities to monitor possible releases from the leach collection system to the principal aquifer.”
- “Each compliance monitoring well will be completed on the edge of the saturated portion of the principal aquifer, and each will monitor the upper most 100 feet of saturated aquifer or its total vertical extent, whichever is less.”

The key rationale for monitoring well placement described in the aforementioned permit application is summarized as follows:

- Wells are located at the first point down gradient of the eastside collection system to directly monitor the aquifer.
- Monitoring wells are down gradient from all the WRCW generation, transport, and protection systems, including the cut-off walls, canal, pipes, and the stormwater collection system. Thus the compliance monitoring wells provide monitoring of potential releases of WRCW from the system controls designed to protect the principal aquifer.
- The location of the compliance monitoring wells down gradient of the WSC provides the opportunity for remedial responses in the event of an exceedance of the standards set for the compliance monitoring wells, prior to impacted water reaching the southwest Jordan Valley principal aquifer.

The original cut-off wall and collection system was designed to capture water from active leaching with water applied at flow rates over 20,000 gallons per minute (gpm). Active leaching ceased in 2000. The current collection system manages waste rock impacted storm water that infiltrates through, or runs off of the dumps.

A more-specific list of monitoring well citing criteria can be found in Sections 3.4.1 and 3.4.2 of the *Eastside Collection Monitoring System Ground Water Discharge Revision 1* and are summarized as follows:

- Incorporate long screen intervals (up to 100 feet) to guarantee the well intersects any contaminated water that passes through bedrock.
- The screened interval is intended to cover the entire depth of the saturated aquifer from the water table to close to the bedrock at a chosen location.
- One well per drainage will be provided as a compliance monitoring well.
- Reasonable all-weather access to the location will be maintained.

TABLE 3-2
Proposed New Compliance Monitoring Wells

Well ID	Location	Screen length, feet	Screen interval is in saturated aquifer	Located down gradient of mine impacted waters and collection system?	Reasonable all weather access
ECG926	Lark drainage	39.6	Yes	Yes	Yes
ECG928	Between N. Keystone and Keystone	50.0	Yes	Yes	Yes
VWP272 Replacement	Keystone/Lost Creek drainage	95[1]	Yes	Yes	Yes
ECG906 Replacement	Approximately 500 feet down gradient of existing ECG906	100[1]	Yes	Yes	Yes

NOTES:
[1]Estimated based upon known information of neighboring wells.

A side-by-side comparison, including construction, lithology, and associated water quality of the proposed compliance wells and the wells being replaced, is provided in Appendix B.

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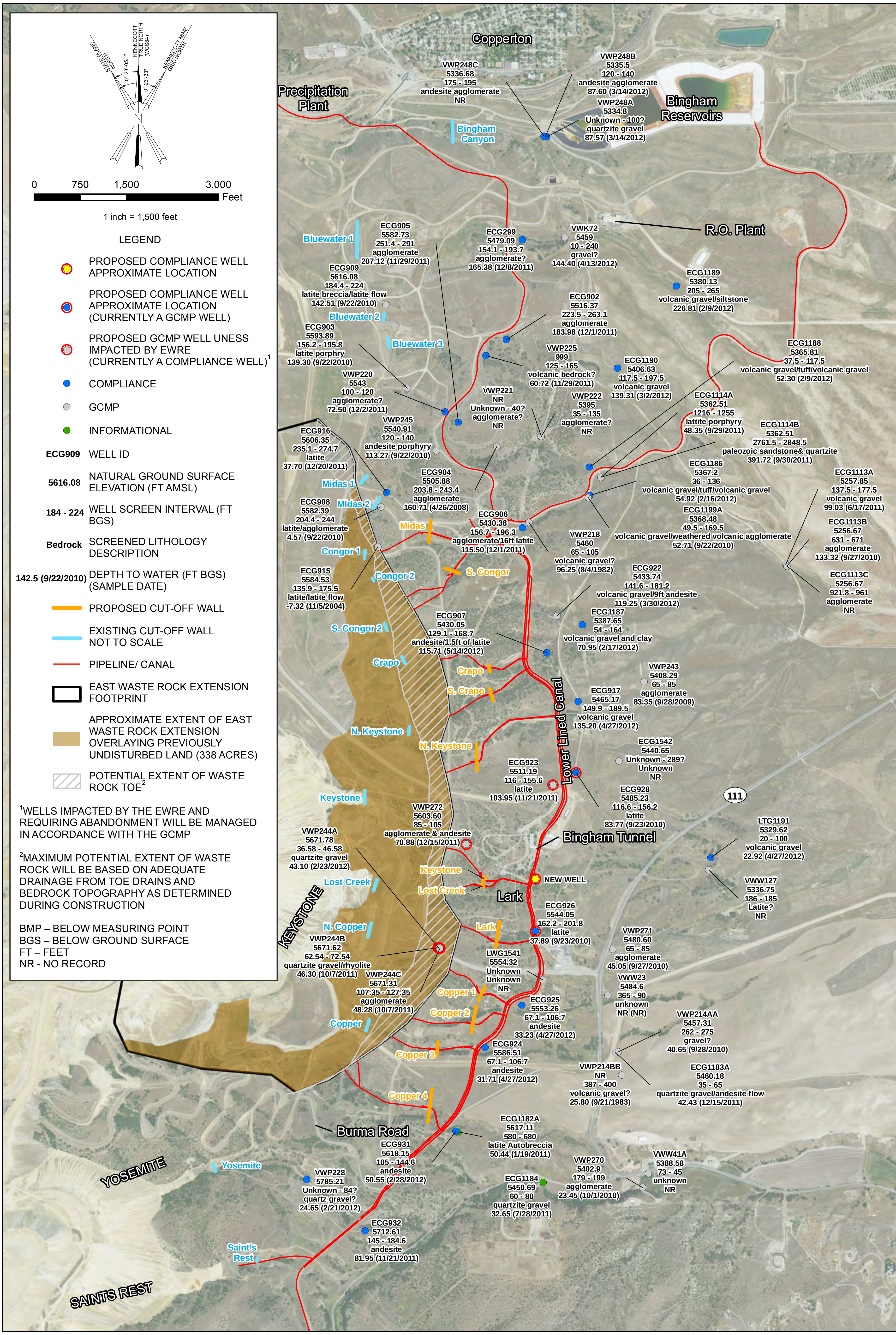

FIGURE 3-1

MONITORING WELL SCREENED INTERVAL AND LITHOLOGY

EAST WASTE ROCK EXTENSION PERMIT MODIFICATION
GROUNDWATER DISCHARGE PERMIT UGW350010
KENNECOTT UTAH COPPER

4.0 Other Specific Requirements

Water sampling and monitoring will be done using the methods for sampling, analyses, and quality control specified in the KUC GCMP. Permit limits for new compliance monitoring wells are provided in Table 4-1 where data are available. Where data are not available, wells will undergo accelerated monitoring until sufficient data are available to calculate compliance limits, as outlined in the current KUC GCMP. Compliance limits for wells down gradient of the EWRE area are shown in Appendix C.

New wells will be constructed using guidance approved in the United States Environmental Protection Agency (EPA) *Resource Conservation and Recovery Act Groundwater Monitoring Technical Enforcement Guidance Document* (1986). Lithologic logs and well construction data for the new monitoring wells will be provided in accordance with permit requirements. Any violations of permit requirements will be managed according to Part 1, Sections G and H, of *Groundwater Discharge Permit No. UGW350010* (UDWQ, 2010). Corrective actions will follow the procedures outlined in Appendix C of *Groundwater Discharge Permit No. UGW350010* (UDWQ, 2010), titled Contingency and Correction Action Plan.

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TABLE 4-1
EWRE Compliance Well Permit Limits (units of mg/L and pH standard units)

Well ID	Location	NAD 83 Longitude (decimal degrees)	NAD 83 Latitude (decimal degrees)	Completion Lithology	Monitoring Frequency	pH	TDS	SO_4	Dissolved Cd	Dissolved Cu	Dissolved Zn
ECG928	Between N. Keystone and Keystone	-112.094013	40.531358	bedrock	semiannual	TBD	TBD	TBD	TBD	TBD	TBD
ECG926	Lark drainage	-112.096384	40.524285	bedrock	semiannual	TBD	TBD	TBD	TBD	TBD	TBD
VWP272 Replacement	Keystone/Lost Creek drainage	-112.096381 (approximate)	40.526596 (approximate)	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
ECG906 Replacement	Down gradient of the Midas Pump Station	-112.095857 (approximate)	40.542143 (approximate)	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD

NOTES:

Cd = Cadmium

Cu = Copper

mg/L = milligram(s) per liter

SO_4 = Sulfate

TBD = To Be Determined

TDS = Total Dissolved Solids

Zn = Zinc

ECG928, ECG926, and the proposed new well do not have permitted compliance limits. Limits are proposed for the wells where data are available using the criteria listed in the following notes. In the event that the wells exceed the protection levels, KUC will follow Part 1, Section G, of the existing permit and develop a source assessment and compliance plan to achieve compliance.

TDS compliance limits are calculated as 1.25 times the background concentration for Class II and Class III groundwater.

For many wells Cd, Cu, and Zn were predominantly nondetects; compliance limits are therefore determined from the groundwater quality standard.

Where the background concentrations is < detection, compliance limits are based on 0.25 times the groundwater quality standard for Class II groundwater and 0.50 times the groundwater quality standard for Class III groundwater for Cd, Cu, and Zn.

If background value exceeds the groundwater quality standard, the Protection Level equals the background value.

The Compliance Limits for Class IV groundwater are the higher of the groundwater quality standard, the mean *1.25, or the mean+2 std. dev.

There is not a groundwater quality standard for SO_4; compliance limits for sulfate were calculated as the higher of the mean+2 std. dev. or 1.25 times the mean.

Range of pH values for compliance limits are based on the higher and lower limit of 6.5 to 8.5 and/or mean + and - 2 std. dev.

Limits were set using all available data for each individual well through 2011.

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5.0 References

Kennecott Utah Copper (KUC). 1994. *Eastside Collection Monitoring System Ground Water Discharge Revision 1*. June.

United States Environmental Protection Agency (EPA). 1986. *Resource Conservation and Recovery Act Groundwater Monitoring Technical Enforcement Guidance Document*.

Utah Department of Environmental Quality, Division of Water Quality (UDWQ). 2010. *Ground Water Discharge Permit No. UGW350010*. March.

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Appendix A
Existing EWRE Compliance Monitoring Wells and Status after the Proposed Modification

APPENDIX A
Existing EWRE Compliance Monitoring Wells and Status After the Permit Modification

		NAD 83				
Well ID	**Location**	**Longitude (decimal degrees)**	**Latitude (decimal degrees)**	**Completion Lithology**	**Monitoring Frequency**	**Status After Modification***
VWP220	Bluewater 3 drainage	-112.101642	40.547472	Bedrock	Semiannual	A
VWP225	Bluewater drainage	-112.099260	40.549988	Bedrock	Semiannual	A
VWP228	Yosemite drainage	-112.109804	40.513183	Alluvium	Quarterly	A
VWP244A	North Copper drainage	-112.102094	40.523560	Alluvium	Quarterly	C
VWP244B	North Copper drainage	-112.102045	40.523541	Alluvium	Quarterly	C
VWP244C	North Copper drainage	-112.101988	40.523508	Bedrock	Semiannual	C
VWP272	Keystone drainage	-112.100437	40.528168	Alluvium	Quarterly	B
ECG902	Bluewater drainage	-112.098079	40.550702	Bedrock	Semiannual	A
ECG905	Bluewater drainage	-112.100887	40.547022	Bedrock	Semiannual	A
ECG906 (Replacement)	Midas drainage	-112.095857 (approximate)	40.542143 (approximate)	Bedrock	Semiannual	D
ECG907	Crapo drainage	-112.095712	40.536721	Bedrock	Semiannual	A
ECG916	Midas 1 drainage	-112.105085	40.543874	Bedrock	Semiannual	A
ECG917	North Keystone drainage	-112.093879	40.534530	Alluvium	Quarterly	A
ECG923	Between Keystone and N. Keystone drainages	-112.095351	40.530810	Bedrock	Semiannual	B
ECG924	Copper drainage	-112.099343	40.519085	Bedrock	Semiannual	A
ECG925	North Copper drainage	-112.097185	40.520955	Bedrock	Semiannual	A
ECG926	Lark drainage	-112.096384	40.524285	Bedrock	Semiannual	E
ECG928	Between N. Keystone and Keystone	-112.094013	40.531358	Bedrock	Semiannual	E
ECG931	South Copper drainage	-112.101057	40.515327	Bedrock	Semiannual	A
ECG932	Yosemite drainage	-112.106387	40.510891	Bedrock	Semiannual	A
ECG1186	Midas drainage	-112.093176	40.543744	Alluvium	Quarterly	A
ECG1187	Crapo drainage	-112.093618	40.537960	Alluvium	Quarterly	A
ECG1188	Midas drainage	-112.093205	40.545008	Alluvium	Quarterly	A
ECG1189	Bluewater drainage	-112.088090	40.553094	Alluvium	Quarterly	A
ECG1190	Bluewater drainage	-112.091560	40.549422	Alluvium	Quarterly	A
LTG1191	Keystone drainage	-112.086107	40.527552	Alluvium	Quarterly	A

APPENDIX A
Existing EWRE Compliance Monitoring Wells and Status After the Permit Modification

		NAD 83				
Well ID	Location	Longitude (decimal degrees)	Latitude (decimal degrees)	Completion Lithology	Monitoring Frequency	Status After Modification*
VWP272 (Replacement)	Keystone/Lost Creek drainage	-112.096381 (approximate)	40.526596 (approximate)	TBD	TBD	D

NOTES:

Only compliance wells associated with the EWRE modification area are included in this table.

EWRE = East Waste Rock Extension

TBD = to be determined

* STATUS:

(A) No change; monitoring well is not affected by either the dump footprint or collection system modification.

(B) *Groundwater Characterization and Monitoring Plan* (GCMP); well will not be covered by EWRE footprint but is up gradient of new collection system alignment and will be incorporated into the GCMP monitoring well network and no longer associated with the groundwater discharge permit.

(C) Well may fall into either B category or may be abandoned if covered by EWRE footprint, depending upon final dump toe configuration.

(D) New well

(E) Currently a GCMP well; will be converted to a compliance monitoring well.

Appendix B
Replacement Well Statistics

APPENDIX B
VWP272 Replacement Well Statistics

Well ID	VWP272	VWP272 Replacement
Current Status	Compliance	Proposed[1]
Status after EWRE	GCMP	Compliance
General Location	Down gradient of Keystone and Lost Creek Cut-off Walls	Down gradient of new Lost Creek and Keystone Cut-off Walls
Coordinates (NAD 83 lat., long. [decimal degrees])	40.528168, -112.100437	40.526596, -112.096381 (approximate)
Year Installed	1986	TBD
Surface Elevation	5,603.6	~5,465
Casing Elevation	5,606.14	~5,468
Total Depth (feet)	105	150
Screen Interval (feet)	85–105	50–145
Screen Length (feet)	20	95
Screen Lithology	Agglomerate	Latite Porphyry
Background Water Quality		
Date	1986	TBD
Mean Depth to Water (feet)	63.48	TBD
pH	7.03	TBD
Conductivity (micromhos/centimeter)	2950	TBD
TDS (mg/L)	2,795	TBD
Sulfate (mg/L)	1390	TBD
Copper (mg/L)	0.05	TBD
Cadmium (mg/L)	0.005	TBD
Zinc (mg/L)	0.05	TBD
Current Water Quality		
Date of Sample	June 2012	TBD
Mean Depth to Water (feet)	74.34	TBD
pH	7.31	TBD
TDS (mg/L)	3,090	TBD
Sulfate (mg/L)	1410	TBD
Copper (mg/L)	<0.02	TBD
Cadmium (mg/L)	<0.001	TBD
Zinc (mg/L)	0.015	TBD

NOTES:
[1] The proposed well-specific conditions are estimated based upon known information of neighboring wells. Actual well parameters will be determined during well installation.
EWRE = East Waste Rock Extension
GCMP = Groundwater Characterization and Monitoring Plan
mg/L = milligram(s) per liter
TDS = total dissolved solids
mg/L = milligrams per liter
TBD = to be determined

APPENDIX B
ECG923 Replacement Well Statistics

Well ID	ECG923	ECG928
Current Status	Compliance	GCMP
Status after EWRE	GCMP	Compliance
General Location	Between Keystone and N. Keystone drainages	Between Keystone and N. Keystone drainages
Coordinates (NAD 83 lat., long. [decimal degrees])	40.530810, -112.095351	40.531358, -112.094013
Year Installed	1992	1992
Surface Elevation	5,511.19	5,485.23
Casing Elevation	5,513.59	5,487.88
Total Depth (feet)	156.1	156.7
Screen Interval (feet)	116–115.6	116.6–156.2
Screen Lithology	Latite	Latite
Background Water Quality		
Date	1992	2004
Mean Depth to Water (feet)	105.19	70.06
pH	7.51	4.45
Conductivity (micromhos/centimeter)	1,250	1,097
TDS (mg/L)	838	740
Sulfate (mg/L)	66	56
Copper (mg/L)	16	<0.02
Cadmium (mg/L)	0.001	<0.001
Zinc (mg/L)	37	<0.01
Current Water Quality		
Date	November 2011	NA
Mean Depth to Water (feet)	98.72	NA
pH	7.28	NA
Conductivity (micromhos/centimeter)	896	NA
TDS (mg/L)	896	NA
Sulfate (mg/L)	105	NA
Copper (mg/L)	<0.02	NA
Cadmium (mg/L)	<0.001	NA

NOTES:

[1] The proposed well specific conditions are estimated based upon known information of neighboring wells. Actual well parameters will be determined during well installation.
EWRE = East Waste Rock Extension
GCMP = Groundwater Characterization and Monitoring Plan
mg/L = milligram(s) per liter
NA = not applicable
TDS = total dissolved solids

APPENDIX B
VWP244A, B and C Replacement Well Statistics

Well ID	VWP244A	VWP244B	VWP244C	ECG926[1]
Current Status	Compliance	Compliance	Compliance	GCMP
Status after EWRE	GCMP or abandon[2]	GCMP or abandon[2]	GCMP or abandon[2]	Compliance
General Location	Approximately 1,100 feet down gradient of N. Copper cut-off wall	Approximately 1,100 feet down gradient of N. Copper cut-off wall	Approximately 1,100 feet down gradient of N. Copper cut-off wall	1,500 feet down gradient of VWP244A, B, and C
Coordinates (NAD 83 lat., long. [decimal degrees])	40.523560, -112.102094	40.523541, -112.102045	40.523508, -112.101988	40.524285, -112.096384
Year Installed	1985	1985	1985	1992
Surface Elevation	5,680.74	5,682.36	5,683.48	5,544
Casing Elevation	5,683.33	5,685	5,685.94	5,632.79
Total Depth (feet)	57	82	134	204.6
Screen Interval (feet)	45–55	70–80	113.5–133.5	164.5–204.1
Screen Length (feet)	10	10	20	39.6
Screen Lithology	Gravels & Rhyolite	Rhyolite	Agglomerate	Latite Porphyry
Background Water Quality				
Date	1985	1985	1985	1992
Mean Depth to Water (feet)	47.8	49.3	48.7	36.1
pH	4.46	6.05	6.6	7.99
Conductivity (micromhos/cm)	14,000	3,000	2,600	1,550
TDS (mg/L)	17,997	1,590	1,414	1,060
Sulfate (mg/L)	10,600	241	194	101
Copper (mg/L)	3.4	0.01	0.01	0.011
Cadmium (mg/L)	1	0.01	0.01	0.003
Zinc (mg/L)	28	0.05	0.05	0.179
Current Water Quality				
Date of Sample	June 2012	June 2012	June 2012	2004
Mean Depth to Water (feet)	43.65	48.15	52	38.42
pH	4.2	6.58	6.89	7.37
TDS (mg/L)	7,770	6,620	3,810	980
Sulfate (mg/L)	2,750	1,800	1,000	142

APPENDIX B
VWP244A, B and C Replacement Well Statistics

Well ID	VWP244A	VWP244B	VWP244C	ECG926[1]
Copper (mg/L)	1.377	<0.02	<0.02	<0.02
Cadmium (mg/L)	0.114	0.001	<0.001	<0.001
Zinc (mg/L)	2.371	<0.01	<0.01	0.03

NOTES:

[1] ECG926 is proposed to replace the VWP244 series.

[2] Final status of well based upon final EWRE footprint.

EWRE = East Waste Rock Extension
GCMP = Groundwater Characterization and Monitoring Plan
mg/L = milligrams per liter
TDS = total dissolved solids

APPENDIX B
ECG906 Replacement Well Statistics

Well ID	ECG906	ECG906 Replacement
Current Status	Compliance	Proposed[1]
Status after EWRE	Abandoned	Compliance
General Location	Down gradient of Midas Pump Station approximately 200-feet	Down gradient of Midas Pump Station approximately 700-feet
Coordinates (NAD 83 lat., long. [decimal degrees])	40.542305, -112.097126	40.542143, -112.095857 (approximate)
Year Installed	1992	TBD
Surface Elevation	5,430.38	~5,400
Casing Elevation	5,432.67	~5,403
Total Depth (feet)	39.6	100
Screen Interval (feet)	158.9–198.5	100–200
Screen Length (feet)	39.6	100
Screen Lithology	Andesite-Latite Flow	Agglomerate-Latite/Andesite Flow
Background Water Quality		
Date	1992	TBD
Mean Depth to Water (feet)	36.10	TBD
pH	7.99	TBD
Conductivity (microohms/centimeter)	1,550	TBD
TDS (mg/L)	1,060	TBD
Sulfate (mg/L)	101	TBD
Copper (mg/L)	0.011	TBD
Cadmium (mg/L)	0.003	TBD
Zinc (mg/L)	0.179	TBD
Current Water Quality		
Date of Sample	June 2012	TBD
Mean Depth to Water (feet)	52	TBD
pH	6.89	TBD
TDS (mg/L)	3,810	TBD
Sulfate (mg/L)	1000	TBD
Copper (mg/L)	<0.02	TBD
Cadmium (mg/L)	<0.001	TBD
Zinc (mg/L)	<0.01	TBD

NOTES:

[1] The proposed well specific conditions are estimated based upon known information of neighboring wells. Actual well parameters will be determined during well installation.

EWRE = East Waste Rock Extension
mg/L = milligrams per liter
TBD = to be determined
TDS = total dissolved solids

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Appendix C
EWRE Compliance Well Permit Limits

APPENDIX C
EWRE Compliance Well Permit Limits (units of mg/L and pH standard units)

		NAD 83									
Well ID	Location	Longitude (decimal degrees)	Latitude (decimal degrees)	Completion Lithology	Monitoring Frequency	pH	TDS	SO_4	Dissolved Cd	Dissolved Cu	Dissolved Zn
VWP220	Bluewater 3 drainage	-112.101642	40.547472	Bedrock	Semiannual	6.5–8.5	2,205	1,019	0.007	0.325	1.25
VWP225	Bluewater drainage	-112.099260	40.549988	Bedrock	Semiannual	6.5–8.5	1,117	331	0.010	0.325	1.25
VWP228	Yosemite drainage	-112.109804	40.513183	Alluvium	Quarterly	5.5–8.5	11,173	7,721	0.064	0.65	4.74
ECG926	Lark drainage	-112.096384	40.524285	Bedrock	Semiannual	TBD	TBD	TBD	TBD	TBD	TBD
VWK272 Replacement	Keystone/Lost Creek drainage	-112.096381 (approximate)	40.526596 (approximate)	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
ECG902	Bluewater drainage	-112.098079	40.550702	Bedrock	Semiannual	6.5–8.5	1,321	338	0.001	0.325	1.25
ECG905	Bluewater drainage	-112.100887	40.547022	Bedrock	Semiannual	6.06–8.5	2,613	1,495	0.001	0.325	1.25
ECG906	Midas drainage	-112.097126	40.542305	Bedrock	Semiannual	6.5–8.5	4,844	2,434	0.003	0.65	2.5
ECG906 Replacement	Midas drainage	-112.095857 (approximate)	40.542143 (approximate)	Bedrock	Semiannual	TBD	TBD	TBD	TBD	TBD	TBD
ECG907	Crapo drainages	-112.095712	40.536721	Bedrock	Semiannual	6.5–8.5	2,004	278	0.001	0.325	1.25
ECG916	Midas 1 drainage	-112.105085	40.543874	Bedrock	Semiannual	6.5–8.5	862	254	0.001	0.325	1.25
ECG917	North Keystone drainage	-112.093879	40.534530	Alluvium	Quarterly	6.5–8.5	1,422	164	0.001	0.325	1.25
ECG928	Between Keystone and N. Keystone drainages	-112.094013	40.531358	Bedrock	TBD	TBD	TBD	TBD	TBD	TBD	TBD
ECG924	Copper 3 Drainage	-112.099343	40.519085	Bedrock	Semiannual	6.20–8.5	5,739	3,021	0.004	0.65	2.5
ECG925	Copper 1 and 2 drainages	-112.097185	40.520955	Bedrock	Semiannual	6.39–8.5	3,498	1,365	0.001	0.325	1.25

APPENDIX C
EWRE Compliance Well Permit Limits (units of mg/L and pH standard units)

		NAD 83									
Well ID	Location	Longitude (decimal degrees)	Latitude (decimal degrees)	Completion Lithology	Monitoring Frequency	pH	TDS	SO_4	Dissolved Cd	Dissolved Cu	Dissolved Zn
ECG932	Yosemite drainage	-112.106387	40.510891	Bedrock	Semiannual	6.5–8.5	796	164	0.001	0.325	1.25
ECG931	Copper 4 Drainage	-112.101057	40.515327	Bedrock	Semiannual	6.39–8.5	6,004	625	0.005	0.65	2.5
ECG1186	Midas drainage	-112.093176	40.543744	Alluvium	Quarterly	6.5–8.5	2,002	875	0.001	0.325	1.25
ECG1187	Crapo drainages	-112.093618	40.537960	Alluvium	Quarterly	6.5–8.5	1,589	169	0.001	0.325	1.25
ECG1188	Midas drainage	-112.093205	40.545008	Alluvium	Quarterly	6.5–8.5	4,360	2,122	0.003	0.65	2.5
ECG1189	Bluewater drainage	-112.088090	40.553094	Alluvium	Quarterly	6.5–8.5	763	23	0.001	0.325	1.25
ECG1190	Bluewater drainage	-112.091560	40.549422	Alluvium	Quarterly	6.5–8.5	1,030	70	0.001	0.325	1.25
LTG1191	Keystone drainage	-112.086107	40.527552	Alluvium	Quarterly	6.17–8.5	5,888	3,525	0.096	0.65	23.33

NOTES:

- ECG928, ECG926, and the proposed new wells do not have permitted compliance limits. Limits are proposed for the wells where data are available using the criteria listed in the following notes. In the event the wells exceed the protection levels, Kennecott Utah Copper LLC will follow Part 1, Section G, of the existing permit and develop a source assessment and compliance plan to achieve compliance.
- TDS compliance limits are calculated as 1.25 times the background concentration for Class II and Class III groundwater.
- For many wells, Cd, Cu, and Zn were predominantly nondetects; compliance limits are therefore determined from the groundwater quality standard.
- Where the background concentrations is < detection, compliance limits are based on 0.25 times the ground water quality standard for Class II groundwater and 0.50 times the groundwater quality standard for Class III groundwater for Cd, Cu, and Zn.
- If background value exceeds the groundwater quality standard, the Protection Level equals the background value.
- The Compliance Limits for Class IV groundwater are the higher of the groundwater quality standard, the mean *1.25, or the mean+2 std. dev.
- There is not a groundwater quality standard for SO_4; compliance limits for sulfate were calculated as the higher of the mean+2 std. dev. or 1.25 times the mean.
- Range of pH values for compliance limits are based on the higher and lower limit of 6.5 to 8.5 and/or mean + and - 2 std. dev.
- Limits were set using all available data for each individual well through 2011.

APPENDIX C
EWRE Compliance Well Permit Limits (units of mg/L and pH standard units)

		NAD 83									
Well ID	Location	Longitude (decimal degrees)	Latitude (decimal degrees)	Completion Lithology	Monitoring Frequency	pH	TDS	SO_4	Dissolved Cd	Dissolved Cu	Dissolved Zn

NOTES: (cont.)

Cd = cadmium

Cu = copper

SO_4 = sulfate

TBD = to be determined

TDS = total dissolved solids

Zn = zinc

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