CR KENDALL MINE
AMENDED CLOSURE PLAN
WATER MANAGEMENT

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CR KENDALL MINE
AMENDED CLOSURE PLAN
WATER MANAGEMENT

1.0 INTRODUCTION

On April 30, 2012, CR Kendall Corporation (CR Kendall) and the Montana Department of Environmental Quality (MDEQ) entered into an Agreement under which CR Kendall would submit a Request for Amendment to Mine Operating Permit #00122 and defining the terms under which MDEQ would conduct an Environmental Analysis. As part of the agreement CR Kendall agreed to submit a revised final reclamation plan to address the remaining reclamation items at the site, namely final capping and reseeding of the former process pads, final design and installation of water treatment facilities, and long-term reclamation monitoring and maintenance. Capping of the process pads is discussed in detail in CR Kendall's Application for Minor Permit Amendment #11-001 which was approved by MDEQ in October 2011 and is discussed in detail herein. This document describes the proposed Closure Water Management plan which includes water treatment, discussion of facilities to be retained, and a discussion of long-term maintenance and monitoring of the system.

The Kendall Mine is located in the North Moccasin Mountains in Fergus County, Montana, approximately 8 miles west of Hilger, Montana and 25 miles north of Lewistown, Montana (Figure 1-1).

All of the components of this Closure Water Management plan (watershed flow augmentation, groundwater capture, zeolite water treatment, discharge of treated water to the Kendall Pit) have been employed at the Kendall Mine since approximately 1998 and have been proven to be effective under a variety of conditions. A number of alternative water management methods, in particular water treatment options, have also been evaluated since

FIGURE 1-1. LOCATION MAP, KENDALL MINE

1996, but none were found to perform as well or as reliably as the currently operating and proposed system.

1.1 PURPOSE AND SCOPE

The purpose of this Final Closure Water Management Plan is to modify the existing reclamation plan to allow for long-term management of water from spent ore process pads and waste rock repositories including:

1. Capture and temporary storage of process pad and waste rock drainage;
2. Long-term treatment of process pad and waste rock drainage by zeolites to remove thallium;
3. Disposal of spent zeolites in Pond 7;
4. Discharge of treated water to groundwater in the Kendall pit;
5. Maintenance of ponds, buildings, pipelines and other infrastructure needed to support the water management/treatment system;
6. Monitoring and mitigation plans for water management facilities; and
7. Augmentation of stream flows to supply down-gradient water users.

Although the final capping of the process pads is part of the approved reclamation plan and is not modified by this Closure Water Management Plan, performance of the pad cover system is an important component of the water management system and thus is described in this plan. Similarly, the watershed flow augmentation system is approved/required by an existing Administrative Order and is not modified by this plan but is described as part of the overall long-term water management plan.

1.2 SUMMARY OF MINE OPERATIONAL HISTORY

The Kendall Mine area is an historic mining area that has been mined intermittently since approximately 1880, initially with placer operations and later with hard rock mining and cyanide mills from approximately 1900 to 1941. The current CR Kendall Mine is an open pit/heap process gold mine permitted and operated under Hard Rock Mining Permit #00122.

Modern cyanide heap process operations were initiated by Triad Resources in 1981 and continued by Greyhall Resources through 1986. Canyon Resources Corporation voluntarily took over the management of the site to prevent uncontrolled discharges of cyanide process solution during the bankruptcy of Greyhall Resources in 1987. Canyon Resources Corporation formed a joint venture with Addwest Gold Corporation called Kendall Venture and resumed mining in 1988. In 1990, Canyon Resources Corporation took over sole management of the property through its subsidiary CR Kendall Corporation (CR Kendall). Mining ceased in February 1995. Gold recovery by CR Kendall continued through the fall of 1997.

1.3 SUMMARY OF MINE RECLAMATION HISTORY

The reclamation status of facilities and land areas at the Kendall Mine is shown on Exhibit 1. With the exception of process pads 3 and 4 and facilities that will be retained for use in the water management system, all major disturbed areas at Kendall have been reclaimed. Montana Department of Environmental Quality (MDEQ) approval for reclamation of process pads 3 and 4, including the proposed pad capping system, has been granted by MDEQ (Revision #11-001 to Permit #00122), but the cap is only partially installed. The process pad capping system is scheduled to be completed during the 2012 field season. CR Kendall has posted additional bond to cover the eventuality that the proposed pad cover system does not meet reclamation objectives and must be removed or modified.

The following mine facilities are fully reclaimed and no further reclamation activities other than monitoring and maintenance are proposed:

1. Horseshoe Pit and Horseshoe Waste Repository;
2. Muleshoe Pit, North Muleshoe Pit and Muleshoe Waste Repository;
3. Barnes-King Pit;
4. Haul Road Pit; and
5. Kendall Pit and Kendall Waste Repository.

The following mine facilities are components of the long-term water management system and will be retained in an operational state:

1. Groundwater capture/pump back facilities (wells, pumps and piping);
2. Ponds 2B, 3B, 7 and 8;
3. Storm water control structures;
4. Water treatment and maintenance facilities;
5. Support facilities (roads, power distribution, pipelines, etc.); and
6. Land application area for contingency water treatment and discharge.

1.4 SUMMARY OF PROPOSED FINAL WATER MANAGEMENT PLAN

The proposed water management plan will ensure public safety and protect water resources by maintaining flow to downstream water users, minimizing contact of water with spent ore on the process pads, capturing and treating mine water and groundwater that does not meet groundwater standards and returning the treated water to the groundwater system. Since concentrations of thallium, cyanide, nitrate and other parameters in mine water are decreasing (improving), water treatment is not expected to be needed beyond approximately 10 to 40 years. Water treatment will cease once water quality standards and or background levels are met. Treatment in perpetuity is not proposed. The location of water management plan components are shown on Exhibit 2.

1.4.1 Water Management Goals

The overall goal of the water management plan is to ensure public safety and protect water resources in accordance with the Metal Mine Reclamation Act:

> "(10) The reclamation plan must provide sufficient measures to ensure public safety and to prevent the pollution of air or water and the degradation of adjacent lands. (11) A reclamation plan must be approved by the department if it adequately provides for the accomplishment of the requirements and standards set forth in this section. (12) The reclamation plan must provide for permanent landscaping and contouring to minimize the amount of precipitation that infiltrates into disturbed areas that are to be

graded, covered, or vegetated, including but not limited to tailings impoundments and waste rock repositories. The plan must also provide measures to prevent objectionable post-mining groundwater discharges." (MCA 82-4-336)

A supplemental goal is to attain conditions such that no active water treatment is required. Since concentrations of thallium, cyanide, nitrate and other parameters in mine water are decreasing (improving), water treatment is not expected to be needed beyond approximately 10 to 40 years.

1.4.2 Flow Augmentation

Kendall augments surface water flows in the Little Dog Creek and South Fork of Last Chance Creek drainages pursuant to an Administrative Order (FID 151) which was issued in May of 2000. Kendall must deliver water to these drainages from April 15th to August 30th, and the amount of water must equal or exceed the entire amount of water collected and pumped out of the drainages the previous year. Typically, Kendall greatly exceeds the amount of water required to be augmented in both drainages, averaging 162% of the required amount in Little Dog Creek and 123% of the required amount in South Fork Last Chance Creek. Kendall also typically delivers water to these drainages for a greater time period than the April to August time frame.

The sources of the augmentation water are as follows:

- Little Dog Creek
    - Spring water from the Little Dog Creek Spring above the mine site.
    - Groundwater from Water Wells 6 and/or 7.
- South Fork Last Chance Creek
    - Spring water from the Mason Canyon Spring above the mine site.
    - Ground water from Water Well 6.

Spring water is the primary source of augmentation water to both drainages. Ground water from wells is only used to make up the differential should the springs not produce enough

water to meet required volumes. Kendall maintains totalizing flow meters on all sources of augmentation water, and flows and volumes are reported monthly to MDEQ, and yearly to the DNRC.

1.4.3 Process Pad Drainage

Process pads 3 and 4 are currently in a partially capped state. MDEQ-approved Revision #11-001 to Permit #00122 provides for placement of 17 inches of topsoil and lining of drainage ditches to minimize infiltration and pad drainage and to provide effective re-vegetation. The proposed final cover will consist of a subsoil/bentonite-amended subsoil basal layer (currently in place) with topsoil cap and geosynthetic-lined drainage ditches that will reduce long-term infiltration and drainage from the process pads to an estimated annual average of less than five gallons per minute (gpm).

Under the proposed Closure Water Management Plan, drainage from the process pads will continue to flow to the existing Ponds 7 and 8 for temporary storage prior to pumping to a central water treatment system at the former processing plant. At the treatment facility, the water will be temporarily stored and then treated to remove thallium via zeolite adsorption. During storage and treatment, pad drainage will be co-mingled with groundwater and waste rock drainage from the waste rock groundwater capture systems. Treated mine water will meet all groundwater quality standards and will be discharged to groundwater via the Kendall Pit. Spent zeolites from the water treatment system will be stored in Pond 7.

1.4.4 Groundwater Capture Systems

Groundwater capture systems have been used to control seepage from the waste rock repositories, pads and historic tailings since 1998. Operation of the existing capture systems will continue for long-term water management. These systems will capture alluvial groundwater in the South Fork Last Chance Creek, Mason Canyon (Process Valley), Barnes-King Gulch, and Little Dog Creek drainages via groundwater capture wells. Captured groundwater will then be pumped to storage ponds and then to the water treatment site for treatment to remove thallium via zeolites. During storage and treatment, captured

groundwater will be co-mingled with process pad drainage. Treated mine water will meet all groundwater quality standards and will be discharged to groundwater via the Kendall Pit.

1.4.5 Water Quality Parameters of Concern

The primary parameter of concern in mine water (groundwater capture/pumpback system and process pad drainage flows) is thallium. Thallium concentrations routinely exceed applicable water quality standards in all mine water sources, and therefore thallium concentrations must be reduced by zeolite water treatment prior to release of mine water to groundwater. Cyanide, nitrate, antimony, arsenic, and selenium are secondary parameters of concern. Concentrations of these secondary parameters of concern may exceed water quality standards in one or more mine water sources at some times. Management of water storage to achieve a thorough blending of mine waters is required to reduce the concentrations of these parameters to better than applicable standards prior to release of mine water to groundwater. Other trace metals (e.g., cadmium, chromium, copper, lead, silver, strontium, uranium, zinc) do not routinely occur in mine water at concentrations of environmental concern. Thallium, cyanide, nitrate, antimony, arsenic, and selenium are therefore the primary focus of this water management plan.

1.4.6 Water Storage, Treatment and Discharge

All process pad drainage and captured groundwater is pumped through a series of storage ponds prior to treatment and discharge. Water from all sources initially is pumped to Pond 7 (5.47 Mgal) where initial mixing and primary storage of mine water occurs. Pond 7 is connected via overflow line to Pond 8 (13.3 Mgal), which is used for storage during high inflow periods of the year. Water in Pond 7 is pumped to Ponds 2B and 3B prior to treatment at the zeolite treatment system located at the existing process plant/mine office building.

The proposed closure water treatment system is a slightly modified version of the zeolite adsorption system that Kendall has used to effectively treat mine water for removal of thallium since 1998. The system has been proven to be highly effective and reliably removes thallium to levels that are lower than local background concentrations and lower than the MT

groundwater standard (2 ppb). The existing treatment system will be modified slightly to 1) provide for the use of zeolites with a higher adsorption capacity; and 2) provide pre-treatment filtration to remove suspended solids prior to zeolite treatment. Water treatment wastes (spent zeolites and filtered solids (sediment and algae)) will be non-hazardous and will be disposed in Pond 7. Since concentrations of thallium, cyanide, nitrate and other parameters in mine water are decreasing (improving), water treatment is not expected to be needed beyond approximately 10 to 40 years. Water treatment will cease once water quality standards and/or background levels are met. Treatment in perpetuity is not proposed.

Treated water will be discharged to groundwater at the Kendall Pit using existing pipelines. Treated water will be tested monthly to confirm treatment effectiveness.

The mine has a permitted land application area that has been used effectively for treatment and discharge of mine water. The land application area is fully reclaimed and revegetated. Although use of the land application is not anticipated, it will be retained as a contingency component of the water management system. If unforeseen conditions arise, the land application area could be used as a supplemental water treatment method for removal of nitrogen compounds (nitrate, nitrite, ammonia, cyanide) by vegetative uptake.

1.4.7 Stormwater

No changes to the approved stormwater management plan are proposed. Stormwater management will continue in accordance with the existing Stormwater General Permit (Permit #300026) and approved Stormwater Pollution Prevention Plan (SWPPP).

2.0 PROCESS PADS CAPPING AND FINAL RECLAMATION

As described above, the overall goal of Kendall Mine reclamation is to achieve comparable stability and utility as the surrounding environment in terms of vegetative cover, soil stability, water and safety. An additional goal for the process pads is to minimize drainage from the pads in order to reduce water treatment needs. The planned and recently approved pad cap (modified water balance cover) will reduce pad drainage flows to rates that can be effectively and efficiently handled by the zeolite water treatment system.

2.1 DESCRIPTION OF COVER ALTERNATIVES

The planned pad cap was selected after evaluation of many capping alternatives. The following section summarizes the alternatives evaluated and describes why the currently planned cap is believed to be the optimal system for pad capping at the Kendall Mine.

2.1.1 Barrier Covers

Barrier covers were considered by Kendall but are not proposed due to concerns about the geotechnical stability of the covers on the 3:1 slopes of the pads, poorer vegetation growth compared to soil/water balance caps, cost, and insignificant reduction in pad drainage flow compared to water balance covers. MDEQ/CDM (2004) also considered a variety of barrier covers that incorporate low-permeability synthetic liners (e.g., PVC), clay layers, and geocomposite liners (GCLs, a combination of synthetic materials with natural clay materials). The covers considered by MDEQ consisted of:

- 16 to 24 inches of topsoil;
- 18 inches of subsoil;
- A gravel or geosynthetic drain layer; and
- A clay, synthetic or GCL low-permeability layer.

Barrier covers were evaluated for effectiveness of excluding water from the pad (CDM, 2004) as part of the EIS process, but a detailed evaluation of technical issues such as slope

stability was not conducted. The EIS evaluation predicted that at best, barrier covers could reduce pad drainage flows by a few gallons per minute (gpm). Since the currently operating and proposed final water treatment system is designed to handle up to 100 gpm, the potential flow reduction is not significant, and the disadvantages of barrier covers do not justify the potential reduction in flows of a few gpm.

2.1.2 Reduced Permeability Layer Cover

The originally approved and permitted capping plan was to construct a "reduced permeability layer" (RPL) cap consisting of (from top down):

- 10- to 14-inch topsoil layer;
- 18-inch subsoil layer;
- 12 inches of coarse rock drainage layer (limestone); and
- 12 inches of on-site clayey materials placed on top of the processed ore.

Limitations and disadvantages of the RPL cap were:

1. The materials available to construct the coarse rock drainage layer appear to leach thallium (CDM, 2004; Womack and Associates, 2005) and it is likely that water draining from this layer would need to be treated. Therefore, the RPL cap would not function to reduce the amount of water requiring treatment.
2. The on-site clayey materials (mined from mudstones and siltstones of the Kibbey Formation) do not appear to contain as much clay and are not as low in permeability as originally estimated (CDM, 2004). Therefore, the cap would not function to reduce infiltration and drainage from the pad to the extent originally estimated.

2.1.3 Water Balance Soil Cover

The second approved and permitted cover system was a "water balance soil cover." This cover system, proposed by Kendall in 1999 and approved by MDEQ in 2000, consisted of the following layers:

- 17 inches of topsoil; over
- 19 inches of subsoil.

The water balance cover was evaluated by MDEQ in 2001 in a draft Environmental Assessment (EA) (MDEQ, 2001). The Draft EA concluded that the water balance cover would provide a suitable growth media for vegetation and the water balance cover was selected by MDEQ as the preferred alternative in the Draft EA. However, the Final EA concluded that an EIS was warranted based on public comment. The water balance cover was further evaluated for MDEQ in 2004 (CDM, 2004) as part of the EIS process. In the summer of 2004, Kendall initiated process pad reclamation beginning with re-grading the process pads to their final reclamation slopes; lining the area between process pads 3 and 4; and installing the final, approved reclamation cap over this area.

2.1.4 Modified Water Balance Cover – Proposed Final Pad Cap

Kendall's currently approved cover is a modified water balance cover composed of the following:

- 17 inches of topsoil; over
- 6 inches of subsoil basal layer material amended with 5 to 8 percent sodium bentonite; over
- 12 inches of subsoil basal layer material.

This cover is similar to the previously proposed and evaluated water balance cover with the exception of sodium bentonite amendment of the upper part of the basal layer and a slight reduction in basal layer thickness from 19 to 18 inches. Addition of bentonite clay to the basal layer reduces the subsoil permeability and enhances evapotranspiration, thus decreasing infiltration and subsequent drainage from the pad. As described in Section 2.2 below, the addition of sodium bentonite to the basal layer more than compensates for the slight reduction in basal layer thickness.

In November of 2005, Kendall submitted a Request for Minor Permit Revision, which changed the nature of the capping system's basal layer from 19 inches of subsoil to 6 inches of minus 1.25-inch screened subsoil amended with sodium bentonite at 5 to 8 percent by volume over 12 inches of minus 6-inch screened subsoil. MDEQ approved this change in May of 2006 as Minor Permit Revision #05-001 and Kendall placed the basal layer on process pads 3 and 4 during the 2006 and 2008 field seasons. In July 2011, Kendall submitted a Request for Minor Permit Revision to allow placement of the 17-inch topsoil layer on top of the previously approved and placed 18-inch modified subsoil basal layer. This Permit Revision was approved by MDEQ in October 2011. The topsoil layer is scheduled to be constructed during the 2012 field season.

2.2 PROPOSED FINAL PAD CAP CONSTRUCTION

Construction of the modified water balance cover pad capping system is described in the Request for Permit Revision #11-001 (CR Kendall, 2011) and is summarized as follows:

- The soil cover cap will be constructed using materials that have been previously stockpiled at various locations on site.
- Prior to placement of the topsoil layer, any erosion-caused rills or gullies in the subsoil layer will be repaired. Straw wattles which were placed on the basal layer to reduce erosion, will be removed and any basal layer material collected behind them will be spread to restore positive drainage.
- All slopes to receive topsoil will have a roughened surface; if necessary, the surface will be scarified parallel to the slope contour taking care not to penetrate the bentonite-enhanced layer. After the topsoil has been spread, large clods and hard lumps will be broken up before seeding. Documentation of soil placement depths will be conducted on a nominal 100-foot by 100-foot grid over the surface and slopes of the process pads.
- The contour drainages, which have already been lined with the 18-inch basal layer as described above, will be lined with a geomembrane liner system consisting of a 30-mil LLDPE (linear low density polyethylene) membrane underlain by 16-ounce non-

woven geotextile. The contour drainages will be armored with geotechnically and geochemically appropriate 12-inch riprap.

PROPOSED FINAL PAD CAP HYDRAULIC PERFORMANCE

Estimates of the performance of the proposed final cap in reducing pad drainage flows can be derived in part from empirical evidence of flow reductions prior to, and after, placement of the partial cap and from simulation of pad drainage with numeric hydrologic models.

2.2.1 Observed Precipitation

Precipitation and other climate data have been collected at the mine site since 1993. Total annual precipitation and average monthly precipitation for the period of record are shown in Figures 2-1 and 2-2. Average annual precipitation for the period of 1993 to 2010 is 24.55 inches.

FIGURE 2-1. ANNUAL PRECIPITATION 1993 - 2010

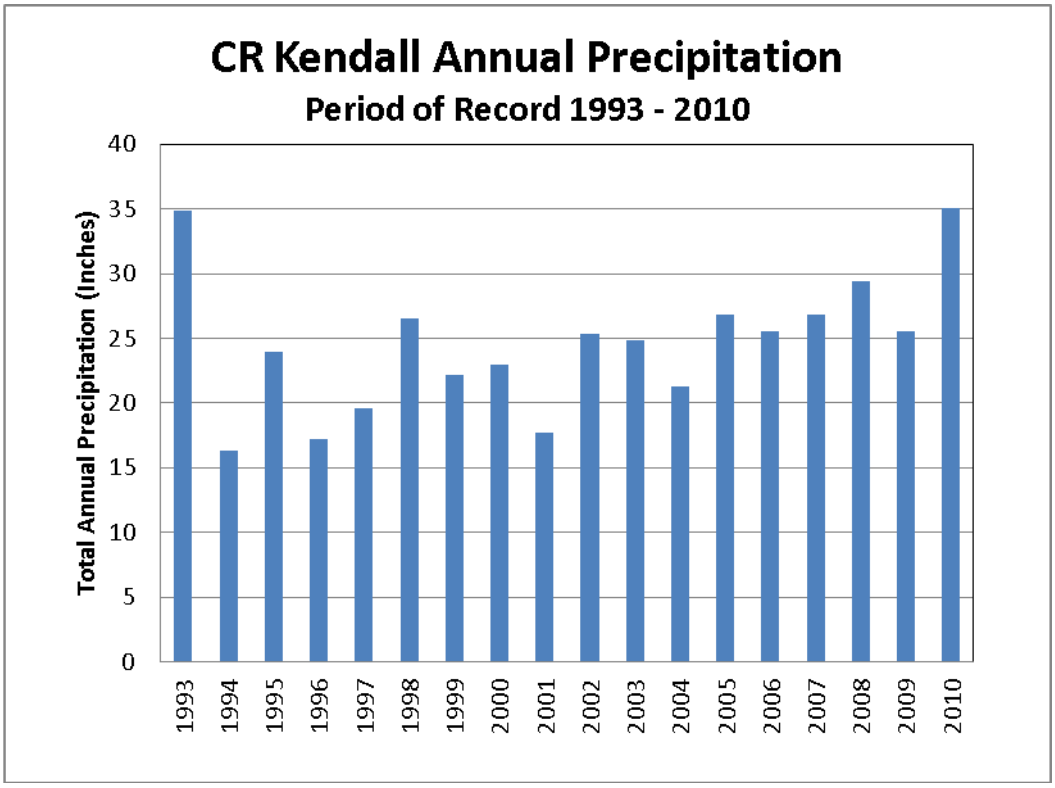
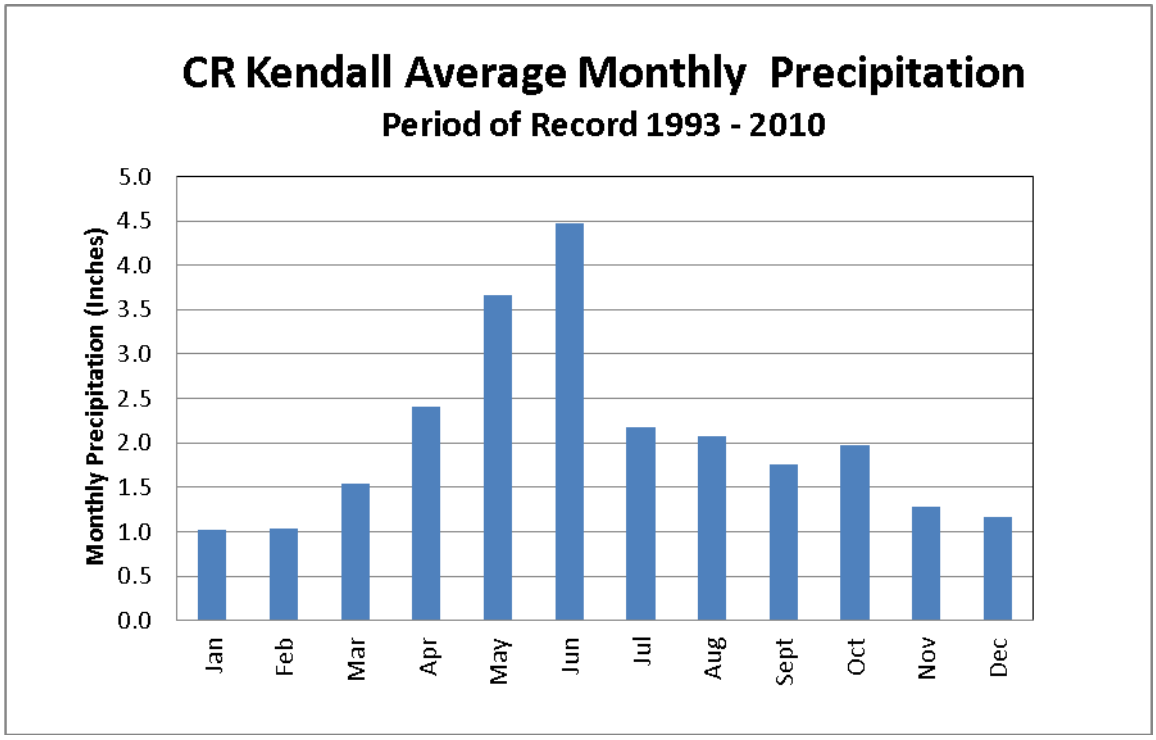


FIGURE 2-2. AVERAGE MONTHLY PRECIPITATION



2.2.2 Observed Constructed Partial Cap Drainage

Construction of a partial cap consisting of the 18-inch subsoil basal layer was completed in 2008. A comparison of precipitation and pad drainage flows prior to, and after, partial pad construction is shown in Figure 2-3. Prior to partial capping, pad drainage flows averaged 32 gpm annually. After partial capping, pad drainage flows declined to an annual average of 11.5 gpm representing a 64 percent decrease in flow. This decrease in flow occurred in spite of increased precipitation after partial cap placement.

Another, perhaps better way to compare flows before and after partial capping is to normalize or correct for the difference in precipitation by expressing drainage flows as a percentage of the precipitation falling on the 56.4 acre pads as shown on Figure 2-4. Prior to partial capping, drainage flows represented 45 percent of the precipitation falling on the pads. After partial capping, drainage flows decreased to 13 percent of incident precipitation.

FIGURE 2-3. LEACH PAD DRAINAGE FLOW 2000 THROUGH 2010

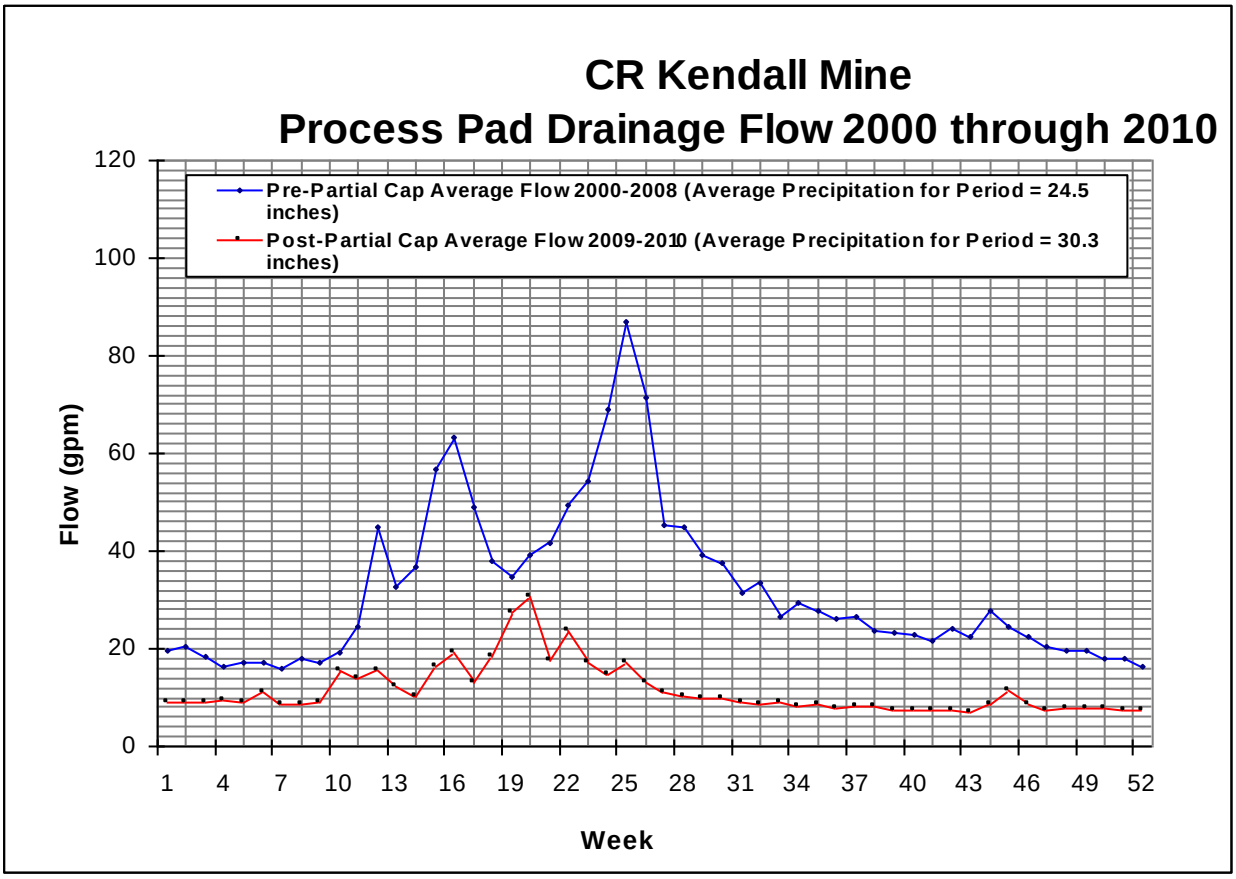
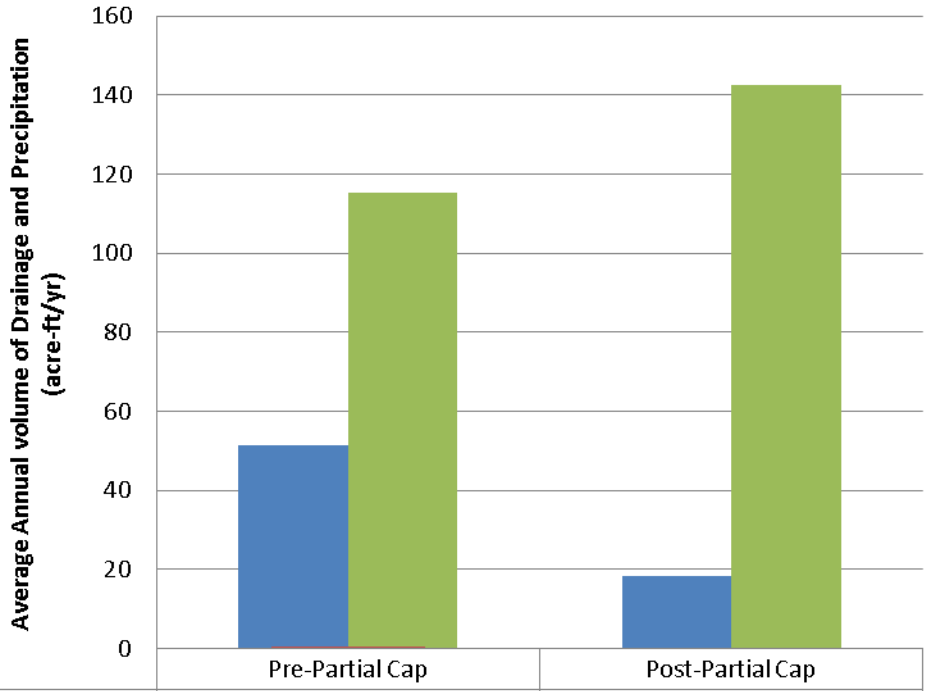


FIGURE 2-4. PROCESS PAD DRAINAGE VOLUME AS PERCENT OF PRECIPITATION



	Pre-Partial Cap	Post-Partial Cap
Total Annual Drainage Volume (acre-ft)	52	18
Total Annual Precipitation Volume (acre-ft)	115	142
Total Annual Drainage (percent of precipitation)	45%	13%

2.2.3 Predicted Complete Cap Drainage

Hydraulic performance of the modified water balance cover was evaluated with the HELP (Hydrologic Evaluation of Landfill Performance) Model (Version 3.07, USEPA, 1994) as described in this section. Output from the HELP model simulations is included in Appendix A.

Input parameters for the model simulations are summarized in Tables 2-1 and 2-2. The water balance cover previously proposed by Kendall in 1999 and approved by MDEQ in 2000 was

evaluated with the HELP Model by CDM (2004) as part of the MDEQ EIS process. For modeling the final modified water balance cover, soil input parameters matched those used by CDM (2004) with the following exceptions:

- Subsoil thickness was reduced from 19 to 18 inches to match the final cap design.
- Characteristics of the subsoil basal layer material were updated to reflect the material that was actually placed on the pads. This material was characterized through test pits, borings, and geotechnical and geochemical analysis by Womack and Associates (2005).
- The top 6 inches of the basal subsoil layer was assumed to contain 5 sodium percent bentonite, therefore hydraulic conductivity (k_{sat}) and other parameters of the soil were adjusted to reflect the addition of sodium bentonite to the subsoil.
- Model simulations were run for a 100-year period to allow attainment of steady-state moisture conditions.

TABLE 2-1. HELP MODEL SOIL INPUT PARAMETERS

Parameter Input	**Input & Units**
Topsoil porosity	0.4 (unitless)
Topsoil texture	Loam
Topsoil field capacity	0.232 (unitless)
Topsoil wilting point	0.116 (unitless)
Topsoil Ksat	3.7 x 10-4 cm/sec
Topsoil thickness	17 inches
Subsoil porosity	0.4 (unitless)
Subsoil texture	Sandy clay loam
Subsoil field capacity	0.34 (unitless)
Subsoil wilting point	0.24 (unitless)
Subsoil Ksat	1.14 x 10-4 cm/sec
Subsoil thickness	18 inches
5% Bentonite soil porosity	0.427 (unitless)
5% Bentonite soil ksat	7.0 x 10-7 cm/sec
5% Bentonite soil thickness	6 inches
Spent ore porosity	0.397 (unitless)
Spent ore field capacity	.032 (unitless)
Spent ore wilting point	.013 (unitless)

Spent ore Ksat	0.3 cm/sec
Spent ore thickness	600 inches

TABLE 2-2. HELP MODEL CLIMATE INPUT PARAMETERS

Parameter	**Input & Units**
Curve Number	79.8 Pad Top, 86.0 Pad Slope
Area	16.4 ac. Pad Top, 40 ac. Pad Slope
Evaporative Zone Depth	17 in. Pad Top, 12 in. Pad Slope
Station Latitude	47.04 Degrees
Max Leaf Area Index	1.5 Pad Top, 1.0 Pad Slope
Start of Growing Season	24-Mar
End of Growing Season	14-Sep
Average Annual Wind Speed	10.6 mph
Avg. 1st Quarter RH	69%
Avg. 2nd Quarter RH	57%
Avg. 3rd Quarter RH	49%
Avg. 4th Quarter RH	66%
Average Annual Precipitation for 100 year simulation	23.29 inches
Average Annual Precipitation for years 35 – 100 of simulation	24.35 inches

Precipitation simulated by the HELP model agreed very well with precipitation data measured at the mine site since 1992. Average measured annual precipitation for the period of 1993 to 2010 is 24.55 inches, which compares favorably with the simulated average annual precipitation of 24.35 inches for years 35 to 100 years of the model simulation (the period of the model in which steady-state conditions were attained). Although the HELP model calculates and estimates initial moisture conditions in the pad materials and cover to be nearly steady-state values, model results demonstrated that steady-state conditions were not attained until approximately year 35 of the simulation. Prior to year 35 of the simulation, the moisture content of the spent ore material is drier than steady-state conditions, and during this period, seepage from the overlying cover is retained by the spent ore rather than freely drained. Thus, drainage from simulation years 0 to 35 underestimates long-term drainage from the pad.

Results for Years 35 to 100 (the steady-state portion) of the HELP simulation are summarized in Table 2-3 and Figures 2-5 through 2-7. Based on HELP model simulation, pad drainage is expected to be reduced to less than 5 gpm with the modified water balance cover.

TABLE 2-3. SUMMARY OF HELP MODEL PREDICTION OF PAD DRAINAGE WITH MODIFIED WATER BALANCE COVER

Parameter	Annual Average HELP Model Result for Simulation Years 35 – 100	Annual Maximum HELP Model Result for Simulation Years 35 – 100
Precipitation (ft^3/yr)	4,985,627	7,611,935
Runoff (ft^3/yr)	640,931	2,184554
Evapotranspiration (ft^3/yr)	4,096,734	5,934,762
Percolation through cover (ft^3/yr)	240,667	313,572
Pad Drainage (ft^3/yr)	237,259	310,004
Pad Drainage (% of Precipitation)	4.76	4.07
Pad Drainage (gpm)	3.38	4.41

FIGURE 2-5. HELP MODEL RESULTS FOR MODIFIED WATER BALANCE COVER (VOLUME/YEAR)

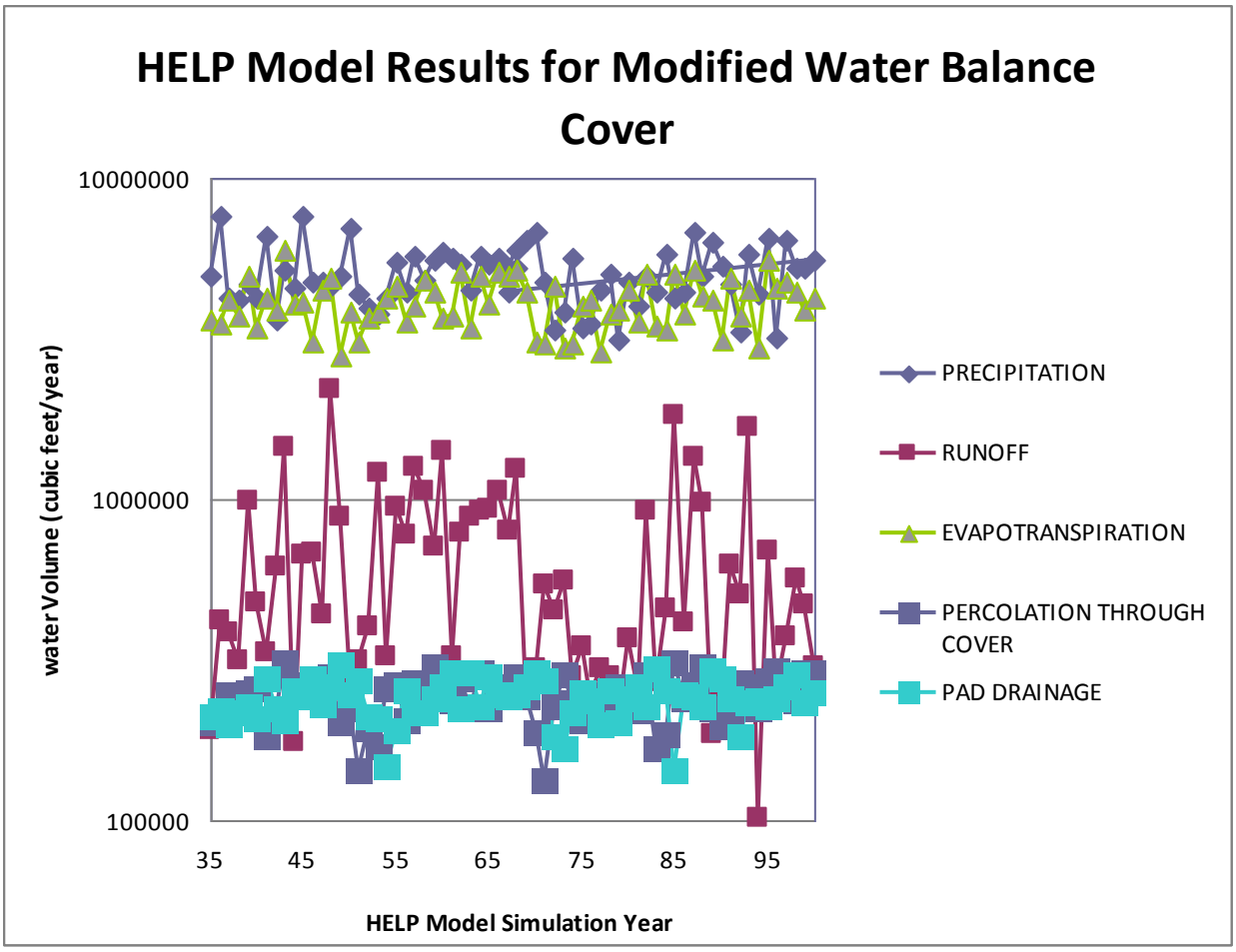


FIGURE 2-6. HELP MODEL RESULTS FOR MODIFIED WATER BALANCE COVER – PERCENT OF PRECIPITATION

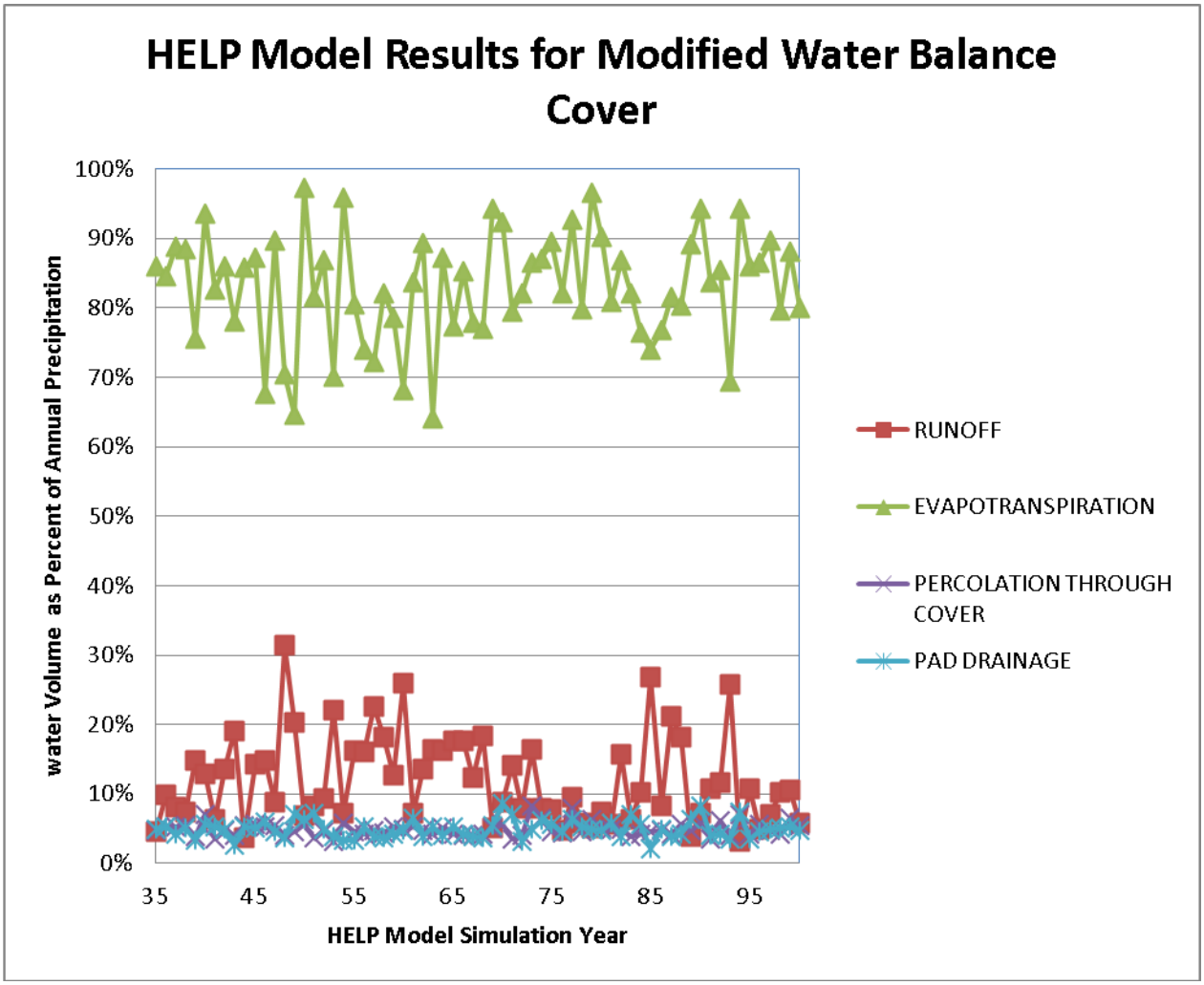
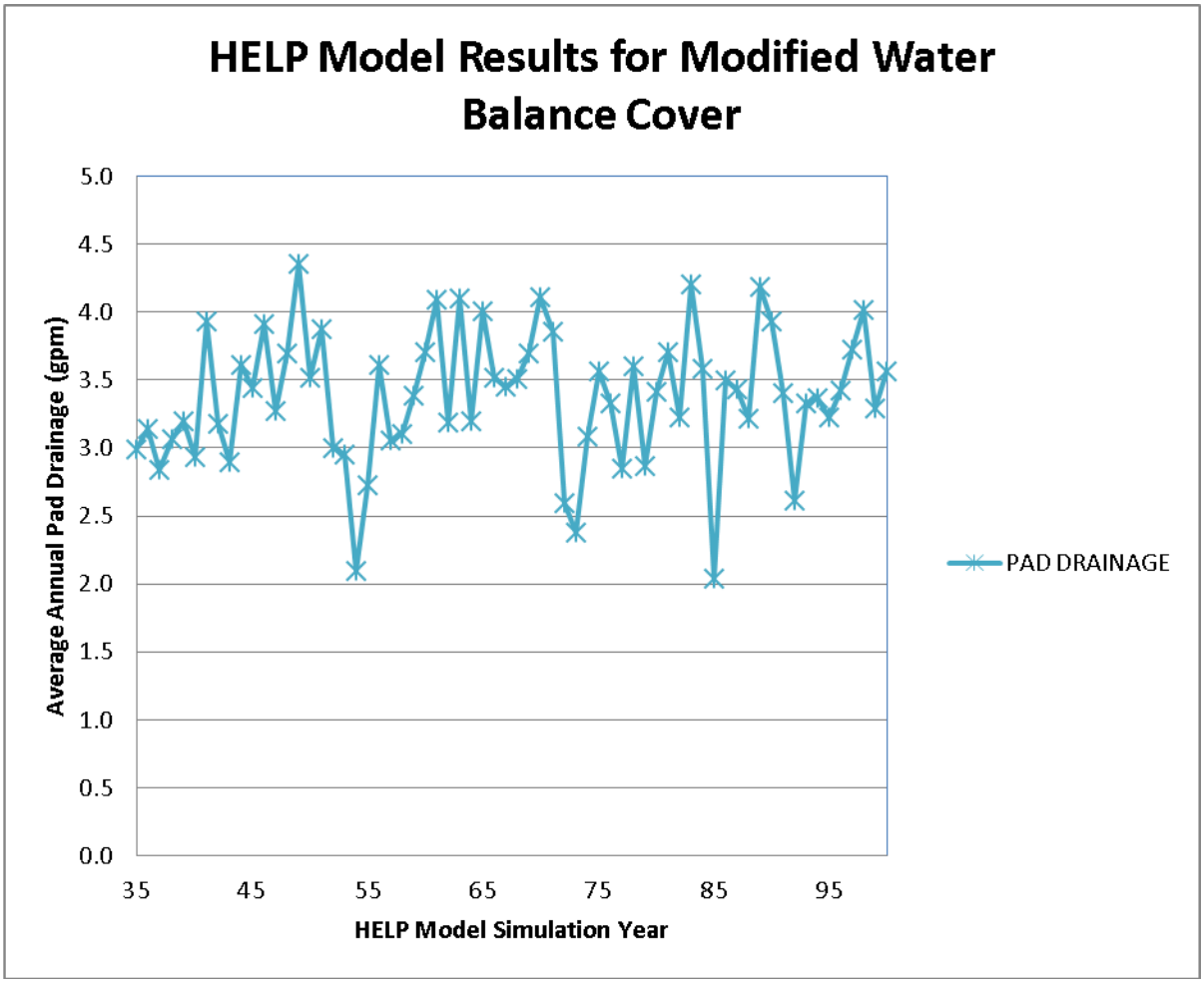


FIGURE 2-7. HELP MODEL RESULTS FOR MODIFIED WATER BALANCE COVER – PAD DRAINAGE (GPM)



2.3 PAD DRAINAGE WATER QUALITY

Application of process solutions to the process pad ceased in 1997 and gold recovery from the pads ceased in fall 1997. Partial capping of the pads did not begin until summer 2006, and thus natural precipitation was allowed to infiltrate and rinse the spent ore on the pads for approximately nine years. Over this nine-year rinsing period, it is estimated (based on average pad drainage over the period) that approximately 160 million gallons of rainwater and snowmelt infiltrated and rinsed the spent ore on the pads.

A statistical summary of all available water quality data for pad drainage is provided in Appendix B. Graphs showing thallium, cyanide and other chemical parameter concentrations in pad drainage over time and trend analysis estimates of future concentrations are provided in Appendix C. Table 2-4 summarizes current concentrations and trends for parameters of interest for pad drainage.

The cessation of cyanide leaching and rinsing of the spent ore with rain has resulted in a steady improvement in pad drainage water quality over time. Total cyanide concentrations decreased from nearly 300 mg/L in 1991 to less than 10 mg/L in 1997 when gold recovery ceased. From 2009 through August 2011, total cyanide concentrations varied between approximately 0.6 to 0.2 mg/L, equal to or slightly higher than the Montana groundwater quality standard and federal drinking water standard (maximum contaminant limit or MCL) of 0.2 mg/L. Based on projections of the observed cyanide trend (Appendix C) it is estimated that average total cyanide concentrations should drop below the groundwater quality standard within the next few years (based on linear projection) to a decade (based on exponential projection). This extrapolation assumes that the observed trends, which have occurred during a period of partial pad capping, will continue in the future after the pad cap is completed.

The concentrations of other parameters of concern have also decreased as described in Table 2-4 and are expected to meet water quality standards (MDEQ-7 numeric criteria for groundwater or background concentrations) within the next 5 to 40 years. The Montana Water Quality Act (MCA 75-5-306) provides that it is not necessary to treat water to purer than background concentrations. Background concentrations were estimated by MDEQ (MDEQ, 1999) and Water Management Consultants (WMC, 2003) based on metal concentrations in a variety of water, soil, rock, and historic mining waste materials in the Mason Canyon area.

Nitrate concentrations in pad drainage decreased from a peak of nearly 200 mg/L in 1998 to an average of approximately 40 mg/L currently. Based on projections of the observed nitrate trend it is estimated that average nitrate concentrations should drop below the groundwater

TABLE 2-4. SUMMARY OF PROCESS PAD DRAINAGE WATER QUALITY

Parameter	Period of Record for Average and Maximum Concentrations	Process Pad Drainage			Predicted Years to Meet Water Quality Standards or Background Concentrations *		Water Quality Standards		
		Average Concentration (mg/L)	Maximum Concentration (mg/L)	Observed Trend (2005 - 2011)	Linear Extrapolation	Exponential or Polynomial Extrapolation	Groundwater Quality Standard in MDEQ-7 (mg/L)	Estimated Background Concentration in Mason Canyon	
								MDEQ ((1999) (mg/L)	Water Management Consultants (2003) (mg/L)
Total Cyanide	2011	0.321	0.51	Decreasing	5 or longer	5 or longer	0.2		
Nitrate + Nitrite	2011	49.93	61.4	Decreasing	5 or longer	20 or longer	10		
Antimony	2005-2011	0.02	0.024	Steady	15 or longer	30 or longer	0.006		
Arsenic	2010-2011	0.148	0.158	Decreasing	15 or longer	40 or longer	0.01	0.05	0.05
Selenium	2010-2011	0.06	0.078	Decreasing	5 or longer	5 or longer	0.05	0.01	0.05
Thallium	2010-2011	0.734	0.931	Decreasing	40 or longer	15 or longer	0.002	0.05	0.1

Notes:

* Predicted years assuming continuation of current trends.

quality standard of 10 mg/L within the next five (based on linear projection) to twenty years (based on exponential projection).

Antimony concentrations in pad drainage have decreased from approximately 0.033 mg/L in 1998 to less than 0.02 mg/L currently. Based on projections of the observed antimony trend (Appendix C) it is estimated that average antimony concentration should drop below the groundwater quality standard of 0.006 mg/L within the next fifteen (based on linear projection) to thirty years (based on exponential projection).

Arsenic concentrations in pad drainage decreased from approximately 0.3 mg/L in 1998 to approximately 0.15 mg/L currently. Based on projections of the observed arsenic trend (Appendix C) it is estimated that average arsenic concentrations should drop below the groundwater quality standard of 0.01 mg/L within the next fifteen (based on linear projection) to forty years (based on exponential projection).

Selenium concentrations in pad drainage decreased from approximately 0.2 mg/L in 1998 to approximately 0.08 mg/L currently. Based on projections of the observed selenium trend it is estimated that average selenium concentrations should drop below the groundwater quality standard of 0.05 mg/L within the next few years (based on linear and exponential projections).

Thallium concentrations in pad drainage decreased from a peak of around 1 mg/L in 1998 to an average of approximately 0.7 mg/L currently. Based on projections of the observed thallium trend (Appendix C) it is estimated that average thallium concentration should drop below the groundwater quality standard of 0.002 mg/L within the next fifteen (based on polynomial projection) to forty years (based on exponential projection).

3.0 GROUNDWATER CAPTURE SYSTEM FLOWS AND WATER QUALITY

Flow rate varies between the individual pumpback systems and also varies with annual and seasonal fluctuations in precipitation. In addition, several chemical parameters such as nitrate and thallium exhibit long-term declining concentration trends. Flow rates and water quality of each groundwater capture/pumpback system are described in this section. Current and expected future water quality and flows to be treated by the water treatment plant (i.e., mixed or combined site-wide flows) are described in Section 4.0.

3.1 CAPTURE SYSTEM FLOWS

Flows captured by the groundwater capture systems are seasonally variable and individually range from approximately 5 to 70 gallons per minute (gpm) (Figure 3-1). Cumulative flow from all systems ranges from approximately 20 to 200 gpm. Peak flows occur in the period from approximately April through July and coincide with, or somewhat lag behind, spring snowmelt and the peak rainfall months of May and June (see Figure 2-2, Section 2.0).

3.2 CAPTURE SYSTEM WATER QUALITY

A statistical summary of water quality in the groundwater capture/pump back systems is provided in Appendix B. Graphs showing thallium and other chemical parameter concentrations over time and trend analysis estimates of future concentrations are provided in Appendix C.

3.2.1 Muleshoe Branch of Little Dog Creek (KVPB-6 Pumpback System)

Portions of the Muleshoe Pit, Muleshoe Waste Repository and Horseshoe Waste Repository are located in the Muleshoe Branch of Little Dog Creek. Shallow groundwater in the area is captured by the KVPB-6 pumpback system, located at the toe of the Muleshoe repository.

FIGURE 3-1. AVERAGE WEEKLY PUMP BACK FLOWS 1999 – 2010

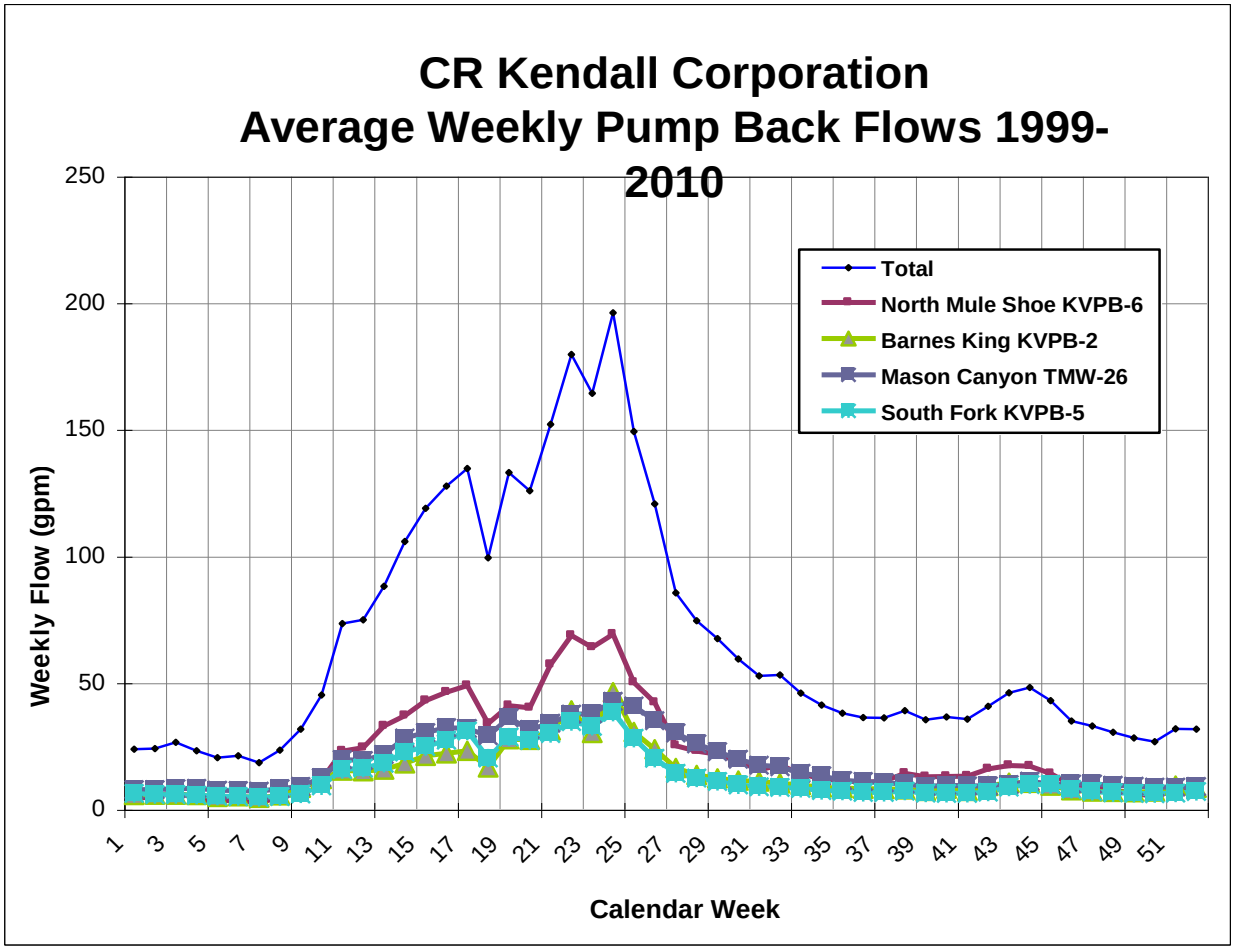


Table 3-1 summarizes current concentrations and trends for parameters of interest for KVPB-6. The concentrations of all parameters except thallium currently meet water quality standards. Thallium concentrations in KVPB-6 have exhibited strong declining trends and are projected to meet estimated background concentrations within the next 5 to 40 years. Concentrations of nitrate + nitrite and selenium meet water quality standards but continue to exhibit decreasing trends also.

3.2.2 Barnes-King Gulch (KVPB-2 Pumpback System)

Portions of the Muleshoe Pit, North Muleshoe Pit and Muleshoe Waste Repository are located in Barnes-King Gulch. Barnes-King Gulch was the site of the historic Barnes-King Mill (circa 1901 – 1923) which deposited tailings throughout the drainage both on the CR Kendall mine site and downstream of the mine site for a distance of several miles. Alluvial groundwater in the drainage is captured by groundwater capture and pumpback system KVPB-2. Several pilot-scale water treatment systems have been built in Barnes-King Gulch to treat KVPB-2 water as described in Section 5.0.

Table 3-2 summarizes current concentrations and trends for parameters of interest for KVPB-2. The concentrations of all parameters except thallium currently meet water quality standards. Thallium concentrations in KVPB-2 have exhibited strong declining trends and are projected to meet estimated background concentrations within the next 10 to 40 years. Concentrations of nitrate + nitrite and arsenic meet water quality standards but continue to exhibit decreasing trends also.

3.2.3 Mason Canyon (TMW-26 Pumpback System)

Process pads 3 and 4; Ponds 7, 8, 2B and 3B; and the water treatment (former processing and mine support) facilities are located in Mason Canyon, also known as the Process Valley. Process pads 3 and 4 are partially capped with a cover consisting of 18 inches of subsoil amended with 5 percent bentonite. Stormwater runoff from the pads is routed to the natural drainage near the downstream boundary of the mine site. Drainage from the pads flows to Pond 7.

TABLE 3-1. SUMMARY OF KVPB-6 (MULESHOE BRANCH LITTLE DOG CREEK) WATER QUALITY

Parameter	Period of Record for Average and Maximum Concentrations	KVPB-6 (Muleshoe Branch Little Dog Creek)			Predicted Years to Meet Water Quality Standards or Background Concentrations *		Water Quality Standards		
		Average Concentration (mg/L)	Maximum Concentration (mg/L)	Observed Trend (2005 - 2011)	Linear Extrapolation	Exponential or Polynomial Extrapolation	Groundwater Quality Standard in MDEQ-7	Estimated Background Concentration in Muleshoe Branch Little Dog Creek: MDEQ (1999)	Estimated Background Concentration in Muleshoe Branch Little Dog Creek: Water Management Consultants (2003)
Total Cyanide	2011	0	0	Steady	Meets Currently	Meets Currently	0.2	Not estimated	Not estimated
Nitrate + Nitrite	2011	2.68	3.17	Decreasing	Meets Currently	Meets Currently	10	Not estimated	Not estimated
Antimony	2005-2011	0.0013	0.002	Steady	Meets Currently	Meets Currently	0.006	Not estimated	Not estimated
Arsenic	2010-2011	0.01	0.011	Steady	Meets Currently	Meets Currently	0.01	Not estimated	0.025
Selenium	2010-2011	0.05	0.059	Decreasing	Meets Currently	Meets Currently	0.05	0.01	0.05
Thallium	2010-2011	0.356	0.46	Decreasing	10 to 15	20 to 40	0.002	0.01	0.02

TABLE 3-2. SUMMARY OF KVPB-2 BARNES-KING GULCH WATER QUALITY

Parameter	Period of Record for Average and Maximum Concentrations	KVPB-2 (Barnes-King Gulch)			Predicted Years to Meet Water Quality Standards or Background Concentrations		Water Quality Standards (mg/L)		
		Average Concentration (mg/L)	Maximum Concentration (mg/L)	Observed Trend (2005 - 2011)	Linear Extrapolation	Exponential or Polynomial Extrapolation	Groundwater Quality Standard in MDEQ-7	Estimated Background Concentration in Barnes-King Gulch: MDEQ (1999)	Estimated Background Concentration in Barnes-King Gulch: Water Management Consultants (2003)
Total Cyanide	2011	0	0	Steady	Meets Currently	Meets Currently	0.2	Not estimated	Not estimated
Nitrate + Nitrite	2011	2.07	2.4	Decreasing	Meets Currently	Meets Currently	10	Not estimated	Not estimated
Antimony	2005-2011	0.005	0.008	Steady	Meets Currently	Meets Currently	0.006	0.015	Not estimated
Arsenic	2010-2011	0.0073	0.009	Decreasing	Meets Currently	Meets Currently	0.01	0.05	0.05
Selenium	2010-2011	0.022	0.03	Steady	Meets Currently	Meets Currently	0.05	0.01	0.05
Thallium	2010-2011	1.26	1.8	Decreasing	10 to 15	20 to 40	0.002	0.05	0.1

Mason Canyon is the former site of the historic Kendall Mill (circa 1901-1912) and has been used for cyanide processing of ore since approximately 1900. Tailings from the historic milling operations were deposited in Mason Canyon and remain in the drainage beneath the current pads 3 and 4. Portions of the historic tailings were incorporated into the process pad underliner. Alluvial groundwater in the drainage is impacted by the contact with historic mine tailings and process water. Migration of the alluvial groundwater off-site is controlled with pumpback system TMW-26.

Table 3-3 summarizes current concentrations and trends for parameters of interest for pumpback system TMW-26. The concentrations of all parameters except thallium currently meet water quality standards. Thallium concentrations in TMW-26 have exhibited strong declining trends and are projected to meet estimated background concentrations within the next 10 to 40 years. Concentrations of nitrate + nitrite meet water quality standards but continue to exhibit decreasing trends also.

3.2.4 South Fork of Last Chance Creek (KVPB-5 Pumpback System)

The Kendall Waste Rock Repository is located in the South Fork of Last Chance Creek. The Kendall Repository is fully reclaimed and re-vegetated and no further reclamation or disturbance of this facility is proposed. Drainage from the waste repository is controlled with pump back system KVPB-5. Under this proposed water management plan, treated mine water would be discharged to groundwater in the Kendall Pit. The Kendall Pit is located in the headwaters of Mason Canyon close to the surface water divide with South Fork of Last Chance Creek. Since groundwater divides do not always exactly match surface water divides, it is possible that current and future flows from the Kendall Pit may flow beneath the South Fork of Last Chance Creek watershed in addition to the Mason Canyon watershed.

Table 3-4 summarizes current concentrations and trends for parameters of interest for pumpback system KVPB-5. The concentrations of all parameters except thallium currently meet water quality standards. Thallium concentrations in KVPB-5 have exhibited declining trends and are projected to meet estimated background concentrations within the next 5 to 10 years. Concentrations of nitrate + nitrite and selenium meet water quality standards but continue to exhibit decreasing trends also.

TABLE 3-3. SUMMARY OF PUMPBACK TMW-26 (MASON CANYON) WATER QUALITY

Parameter	Period of Record for Average and Maximum Concentrations	TMW-26 (Mason Canyon)			Predicted Years to Meet Water Quality Standards or Background Concentrations		Water Quality Standards (mg/L)		
		Average Concentration (mg/L)	Maximum Concentration (mg/L)	Observed Trend (2005 - 2011)	Linear Extrapolation	Exponential or Polynomial Extrapolation	Groundwater Quality Standard in MDEQ-7	Estimated Background Concentration in Mason Canyon	
								MDEQ (1999)	Water Management Consultants (2003)
Total Cyanide	2011	0	0	Steady	Meets Currently	Meets Currently	0.2		
Nitrate + Nitrite	2011	2.36	2.95	Decreasing	Meets Currently	Meets Currently	10		
Antimony	2005-2011	0.00139	0.0015	Steady	Meets Currently	Meets Currently	0.006		
Arsenic	2010-2011	0.0031	0.005	Steady	Meets Currently	Meets Currently	0.01	0.05	0.05
Selenium	2010-2011	0.013	0.02	Steady	Meets Currently	Meets Currently	0.05	0.01	0.05
Thallium	2010-2011	0.038	0.067	Steady	Occasionally Meets	Occasionally Meets	0.002	0.05	0.1

TABLE 3-4. SUMMARY OF PUMPBACK KVPB-5 (SOUTH FORK LAST CHANCE CREEK) WATER QUALITY

Parameter	Period of Record for Average and Maximum Concentrations	KVPB-5 (South Fork Last Chance Creek)			Predicted Years to Meet Water Quality Standards or Background Concentrations		Water Quality Standards (mg/L)		
		Average Concentration (mg/L)	Maximum Concentration (mg/L)	Observed Trend (2005 - 2011)	Linear Extrapolation	Exponential or Polynomial Extrapolation	Groundwater Quality Standard in MDEQ-7	Estimated Background Concentration in Mason Canyon	
								MDEQ (1999)	Water Management Consultants (2003)
Total Cyanide	2011	0	0	Steady	Meets Currently	Meets Currently	0.2		
Nitrate + Nitrite	2011	2.39	2.98	Decreasing	Meets Currently	Meets Currently	10		
Antimony	2005-2011	0.00125	0.0015	Steady	Meets Currently	Meets Currently	0.006		
Arsenic	2010-2011	0.0034	0.005	Steady	Meets Currently	Meets Currently	0.01		0.05
Selenium	2010-2011	0.016	0.022	Decreasing	Meets Currently	Meets Currently	0.05		0.02
Thallium	2010-2011	0.024	0.037	Decreasing	5 to 10	5 to 10	0.002	0.01	0.02

4.0 INFLOW TO WATER TREATMENT SYSTEM

This section describes the estimation of the range of future water treatment plant inflow rates and chemical concentrations that are expected based on observed and predicted pumpback and pad drainage conditions. The estimation is made using mixing equations (i.e., a spreadsheet-based mathematical mixing model) that are based on the site conceptual model.

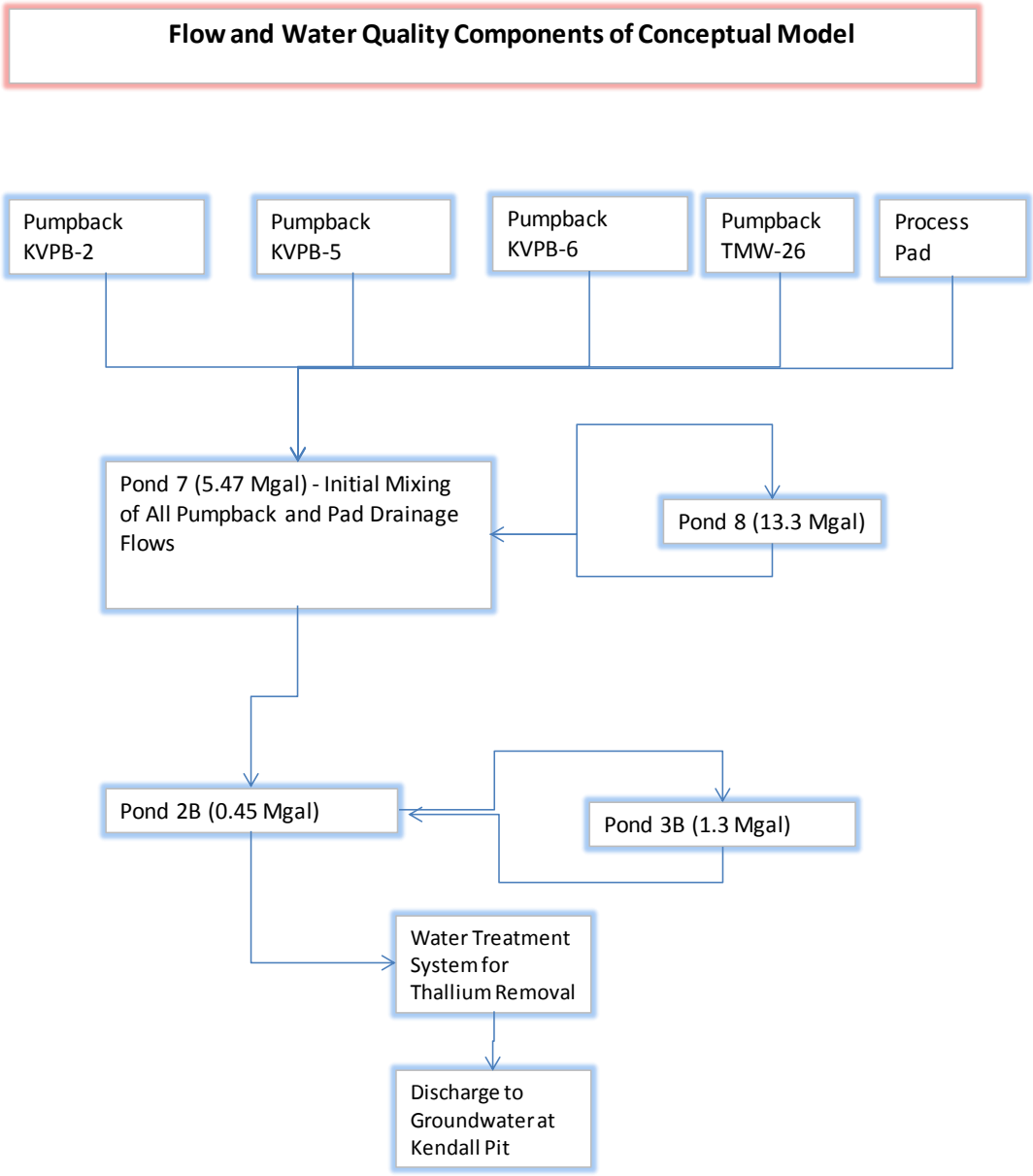
Inflow to the water treatment system is comprised of water from the groundwater capture/pumpback systems combined with pad drainage flows. These flows are routed through, and mixed in, a series of storage ponds (2B, 3B, 7 and 8) before water treatment. As described in Sections 2.0 and 3.0, flow rates of individual pumpback systems and pad drainage varies with annual and seasonal fluctuations in precipitation. Chemical concentrations are also variable, and some chemical parameters such as cyanide, nitrate, arsenic, selenium and thallium exhibit long-term declining concentration trends in both pumpback and pad drainage flows. In addition, the retention time in the storage ponds affects the interval over which inflows are mixed and as a result, the water quality of pond outflow/water treatment plant inflow is dependent on the active storage volume of the ponds. Thus, the flow rate and chemical concentration of inflow to the treatment plant is a function of several variables that must be considered in the site conceptual model and in the mathematical mixing model.

4.1 CONCEPTUAL MODEL

The site conceptual model for water treatment plant inflow reflects the existing and proposed future management system for water from the pumpback systems and pad drainage. The conceptual model is illustrated in Figure 4-1 and is described as follows:

1. The sources of water for treatment include the four pumpback systems and pad drainage, each with unique flow hydrographs and water chemistries. Water flows and chemical concentrations are variable and cyanide, nitrate, arsenic, selenium and thallium concentrations exhibit long-term declining concentration trends.

FIGURE 4-1. FLOW AND WATER QUALITY COMPONENTS OF CONCEPTUAL MODEL

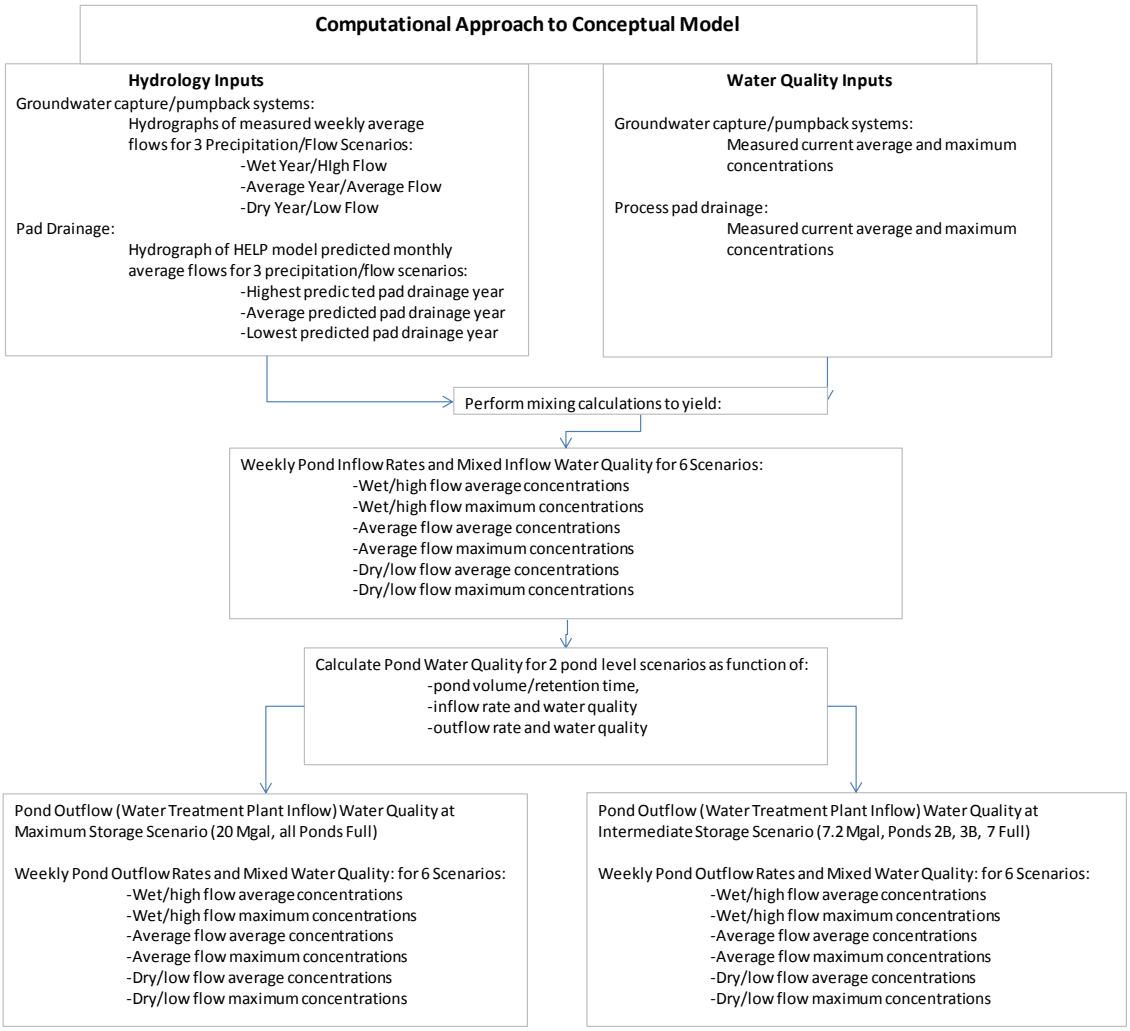


2. Water from all sources initially flows or is pumped to Pond 7 where the water becomes mixed and is stored.
3. Pond 7 has an overflow line that conveys water to Pond 8 when Pond 7 is full and inflow exceeds outflow (to Pond 2B and treatment). Pond 8 is typically operated as an overflow pond with no outflow except a return line to Pond 7.
4. From Pond 7, water is pumped to Pond 2B which functions as the feed water pond for the water treatment plant.
5. Pond 3B is connected to Pond 2B via overflow line and Pond 3B functions as a surge pond to help buffer (balance) Pond 2B inflows with water treatment plant withdrawals.
6. Water is pumped from Pond 2B to the treatment plant for thallium removal.
7. Treated water is discharged to groundwater in the Kendall Pit.

The computational approach to representing the conceptual model is described in Figure 4-2 and is summarized as follows:

1. Inputs to the model consist of:
    a. Measured weekly pumpback flows for three precipitation/flow conditions (wet, average, dry).
    b. Predicted monthly pad drainage flows (from the HELP Model as described in Section 2.4).
    c. Measured average and maximum chemical concentrations for the pumpback and pad drainage flows.
    d. Combination of the three flow and two water quality scenarios yields six sets of input conditions:
        i. wet year average concentration;
        ii. wet year maximum concentration;
        iii. average year average concentration;
        iv. average year maximum concentration;
        v. dry year average concentration; and
        vi. dry year maximum concentration.

FIGURE 4-2. COMPUTATIONAL APPROACH TO MIXING MODEL



2. For each of the six flow and water quality conditions, weekly average inflow to Pond 7 is calculated via mixing equations based on the rate and water quality of flow from each water source. These mixing calculations thus yield six arrays of predicted weekly pond inflow concentrations covering the range of flows and water quality.
3. Pond and pond outflow water qualities differ from short-term inflow water quality due to the large capacity of the ponds relative to inflow rates and the mixing that occurs in the pond over the long retention times. The larger the active storage volume of the ponds, the longer the retention and mixing time of the ponds and the less pond water quality is affected by short term fluctuations in inflow rate and water quality (i.e., the more closely pond water quality reflects long-term average inflow rate and quality). Conversely, the smaller the active storage volume of the ponds, the more closely pond water quality reflects short-term variations in inflow water quality. The final step in the estimation of pond outflow/water treatment plant inflow water quality is to calculate pond outflow water quality for the six flow and water quality conditions for two different pond active storage area conditions:
    a. Maximum storage available (20.5 Mgal), all ponds utilized, such as might occur during an extreme wet/high flow period.
    b. Intermediate storage (7.2 Mgal), only Ponds 2B, 3B, and 7 utilized, such as might occur during dry or average periods.
4. Final output of the mixing calculation are twelve sets of weekly predicted pond outflow chemical concentrations that cover the range of expected flow, water quality, and storage conditions:
    a. Six predicted pond outflow concentrations for intermediate pond storage condition.
    b. Six predicted pond outflow concentrations for a maximum pond storage conditions.

4.2 UNCERTAINTIES AND LIMITATIONS OF THE MIXING MODEL

As for any model or prediction of future events, the mixing model has uncertainties and limitations. The purpose of identifying these limitations is twofold: 1) understanding these uncertainties and limitations aids in the interpretation of model predictions; and 2)

identifying the uncertainties guides the development of contingency actions that could be implemented if future conditions differ from model assumptions or predictions (see Section 7.0). In spite of these identified uncertainties and limitations, the mixing model is an appropriate tool for evaluating the proposed water management system.

The identified limitations or uncertainties of the mixing model are:

- Future precipitation conditions;
- HELP predictions of pad drainage flow;
- Timing of flows;
- Assumption of full mixing in ponds;
- Combination of maximum concentrations; and
- Concentration trends will continue.

The mixing model assumes that future precipitation conditions will be similar to past conditions measured at the site and similar to those predicted by the HELP model synthetic climate record. If future precipitation were to be wetter or drier than historic measurements and HELP model predictions, then pumpback and pad drainage flows could be higher or lower than evaluated in the mixing model. If this were to occur, the chemical concentrations of mixed water treatment inflow could vary from those predicted by the mixing model. The mixing model evaluates the most extreme conditions previously observed at the site, thus it is unlikely that future conditions will greatly exceed mixing model conditions and therefore, chemical concentrations predicted by the mixing model are not likely to be exceeded by future conditions.

The mixing model incorporates pad drainage flow predictions of the HELP model. The HELP model has inherent uncertainties and actual future flows could differ somewhat from predictions. However, the ultimate driver for pad flows is precipitation and the consideration of extreme precipitation years in the mixing model provides a conservative basis for the HELP predictions. Moreover, the HELP model predicted timing of pad flows (i.e., flow hydrograph) is out of phase with pumpback flow hydrographs. This hydrograph prediction is

subject to some uncertainty, but this also represents a conservative case as it results in higher predicted mixed water concentrations.

The mixing model considers maximum measured concentrations for pumpback and pad drainage water and evaluates the case where all of the maximum concentrations occur simultaneously at one time. Since there are a finite number of measured concentrations, there is a small statistical probability that higher concentrations could occur in the future. However, evaluating maximum measured concentrations is believed to be conservative for two reasons: 1) Concentrations for most parameters exhibit strong declining trends which makes it less likely that the observed maximums will be exceeded in the future; and 2) it is unlikely that maximum concentrations would occur in all water sources at the same time, thus the mixing model tends to overestimate potential maximum mixed water concentrations. Although it is theoretically possible that the declining concentration trends could reverse it is not believed to be likely, in particular for chemicals that do not occur naturally in the native rock material to any significant extent but rather are present as the result of mining or ore processing (i.e., cyanide from ore processing; nitrate + nitrite from blasting residues and/or cyanide degradation). The combination of a finite and ever-decreasing amount of cyanide and nitrogen compounds in waste rock and spent ore with the observed, ongoing decreases in mine water concentrations of cyanide and nitrogen compounds in mine water; make it highly unlikely that cyanide and nitrogen concentrations in mine water will increase in the future.

The pond water quality portion of the mixing model assumes that full mixing occurs in the storage ponds. In theory, this assumption is never completely true, but given the large pond volumes, long retention time, and multiple pond layout this is a fair approximation for the purpose of this mixing analysis.

4.3 POND INFLOW RATES

Pond inflows consist of the groundwater capture/pumpback system flows and pad drainage. Monitoring of actual pumpback system and pad drainage flows and HELP model predictions of future pad drainage flows demonstrate the strong correlation between precipitation on the site and pumpback and pad drainage flows (see Sections 2.3 and 3.1). To evaluate the

expected range of pond inflow rates arising from observed and future expected precipitation conditions, the mixing model incorporates pumpback and pad drainage flows for three precipitation scenarios (wet, average, and dry) represented by the following conditions:

- The driest year measured at the mine site (2001, 17.72 inches of rainfall);
- Average annual precipitation (24.53 inches of rainfall); and
- The wettest year measured at the mine site (2010, 35.05 inches of rainfall).

For the pumpback systems, the weekly flow rates used in the mixing model are the actual measured flows from years 2001, 2010, and the average for the period of 1999-2010 as shown in Figure 4-3. Pad drainage flows are predicted to decline after the completion of the pad cover system (as described in Section 2.4) and therefore future flows are expected to be substantially less than currently or previously measured. For pad drainage flows, HELP model predicted monthly average flows for model simulation years with similar precipitation to the observed dry, average, and wet years were used (i.e., model years 40, 47, and 48 with annual precipitation of 17.81, 24.39, and 37.18 inches, respectively) as shown in Figure 4-4.

A comparison of Figures 4-3 and 4-4 reveals that the HELP model predicts a future pad drainage flow hydrograph that is the inverse of the currently observed pumpback and pad drainage flow hydrographs. The currently observed pumpback and pad drainage flow hydrographs generally mimic, with a short time lag, precipitation and snowmelt with highest flows in the spring and early summer. However, the HELP model predicts a longer time lag between precipitation/snowmelt inputs and pad drainage flows, such that highest future pad drainage is predicted to occur during fall and winter. In other words, the HELP model predicts that the pad cover will not only reduce the amount of water infiltrating the pad, but also slow down the movement of water through the cover such that there is a delayed response of pad drainage to precipitation inputs. The effect of the non-synchronicity of future pumpback and pad flow hydrographs is that inflows are predicted to have a higher proportion of pad drainage flows during the winter.

FIGURE 4-3. PUMPBACK SYSTEM FLOW SCENARIOS IN MIXING MODEL

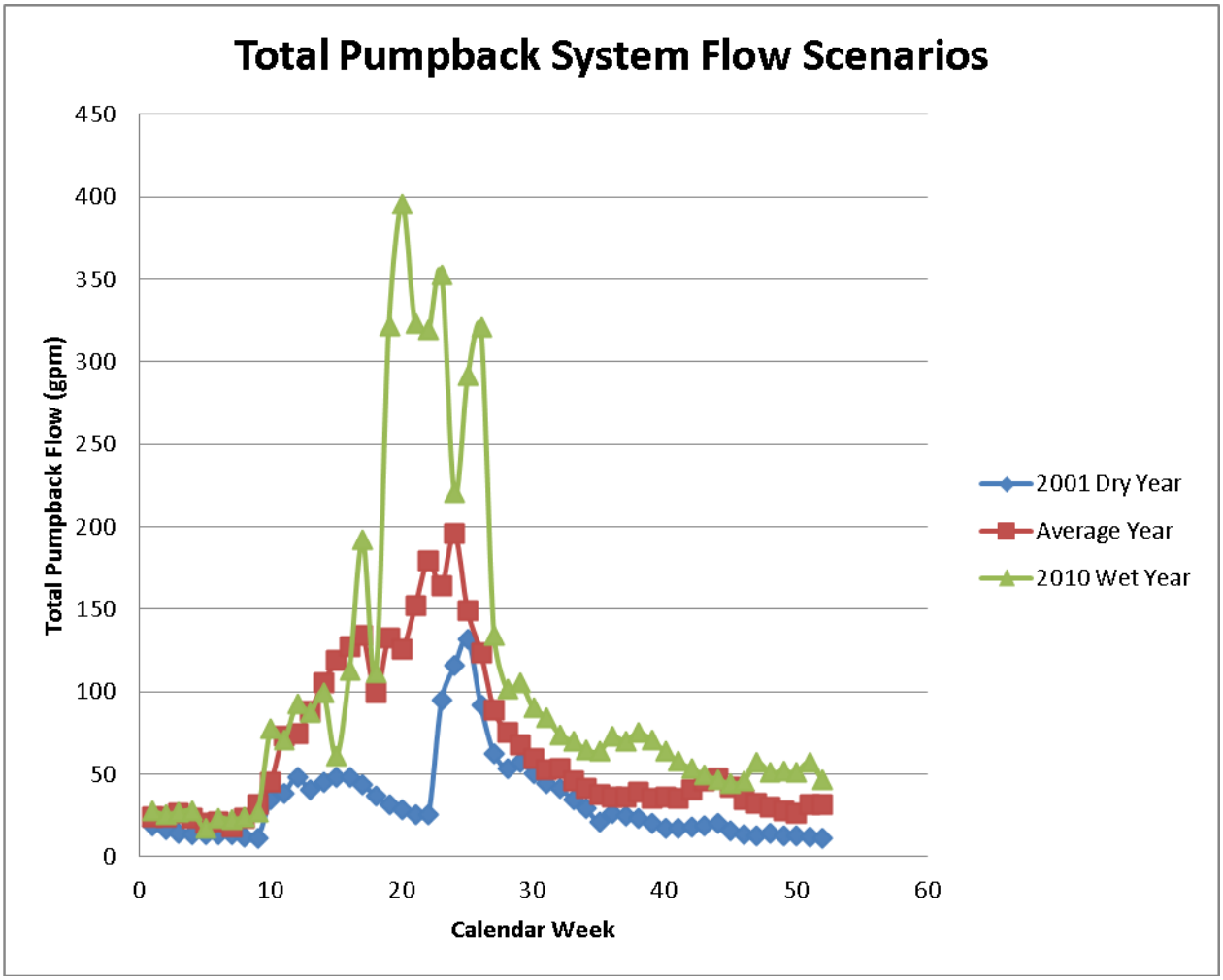
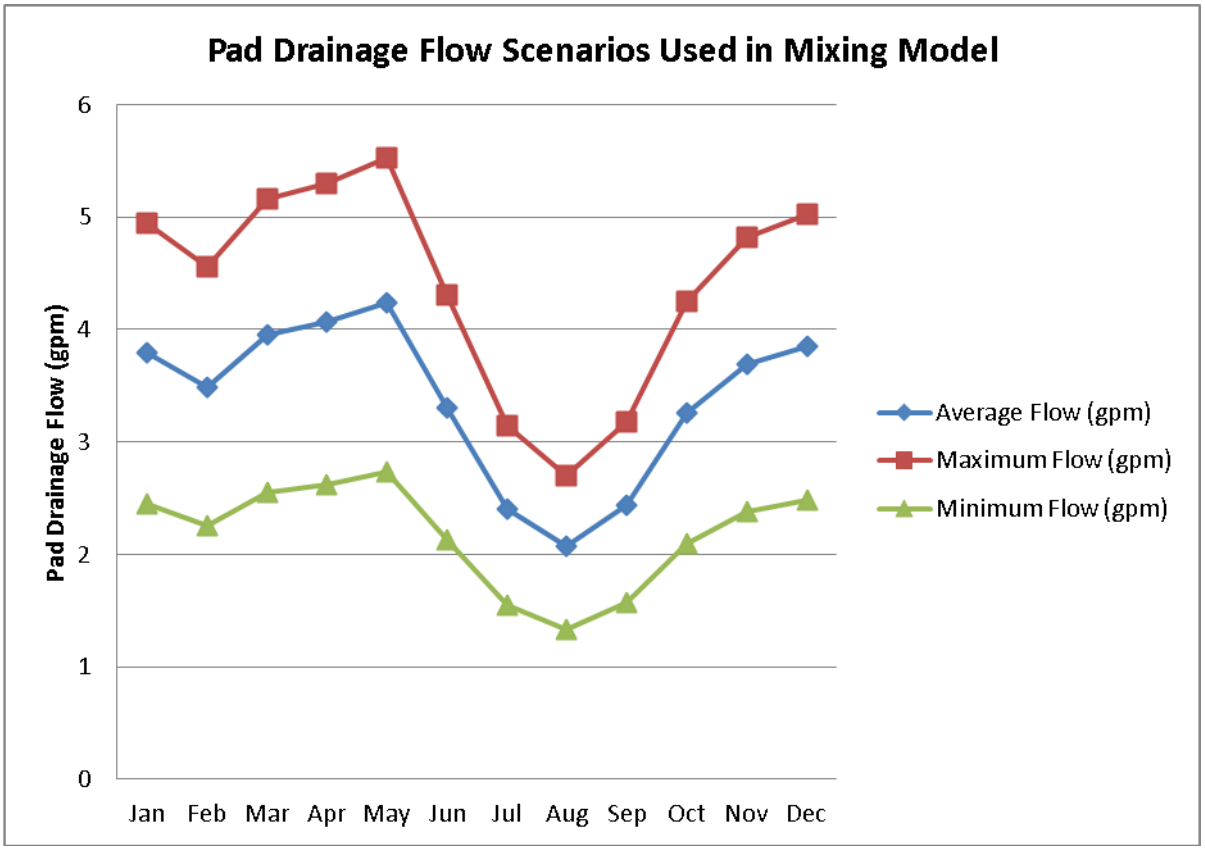


FIGURE 4-4. PAD DRAINAGE FLOW SCENARIOS IN MIXING MODEL



4.4 POND INFLOW CHEMISTRY

Pond inflow chemistry is dependent on the future water quality of the various inflow sources. Water quality of the various sources is variable over time. Therefore, the mixing model incorporates estimates of likely future typical and potential extreme water quality conditions to account for this variability. In the model, typical conditions are represented by measured average chemical concentrations while extreme conditions are represented by measured maximum concentrations. Nearly all parameters exhibit declining trends reflecting the general site-wide water quality improvement that has occurred. Therefore, the more recent water quality data is more representative of likely future water quality conditions than older data. The selected data period of record, average and maximum concentration, and current observed trends for parameters of interest for each inflow water source used in the mixing model are summarized in Table 2-1 (Section 2.4) and Tables 3-1 through 3-4 (Section 3.2).

The mixing model calculates the combined inflow water quality for each week according to the equation:

$$C_{Inflow} = ((Q_{KVPB2}C_{KVPB2})+(Q_{KVPB5}C_{KVPB5})+(Q_{KVPB6}C_{KVPB6})+(Q_{TMW26}C_{TMW26})+(Q_{PAD}C_{PAD}))/(\text{Total Flow})$$

Where: Q_{KVPB2} = flow rate of water source;

C_{KVPB2} = chemical concentration of water source; and

Total Flow = sum of all flows ($Q_{KVPB2}+Q_{KVPB5}+Q_{KVPB6}+Q_{TMW26}+Q_{PAD}$)

Mixing model predicted weekly nitrate + nitrite concentrations of pond inflow for the six precipitation/chemical concentration scenarios are shown in Figure 4-5. The model predicts that nitrate + nitrite concentrations flowing into Pond 7 will vary from approximately 3 to 6 mg/L during the summer months to 8 to 16 mg/L during the winter months. These predicted seasonal cycles reflect the difference in timing of high and low pumpback flows compared to pad drainage flows and the much higher nitrate + nitrite concentration of pad drainage flows.

4.5 STORAGE POND CHEMICAL CONCENTRATIONS

Water quality in the pond is a function of pond retention time (length of time that water is retained in the pond), pond inflow rates and water quality, and pond outflow rates and water quality. The mixing model calculates the pond water quality for each week according to the equation:

$$C_{Pond\ Week\ t} = ((V_{Inflow}C_{Inflow})+(V_{Pond}C_{Pond}) - (V_{Outflow}C_{Outflow}))/(V_{Pond})$$

Where V_{Pond} = Volume or active storage capacity of pond available for mixing;

V_{Inflow} = Volume of water flowing into pond each week;

$V_{Outflow}$ = Volume of water flowing out of pond each week (assumed to equal V_{Inflow} to maintain steady pond volume);

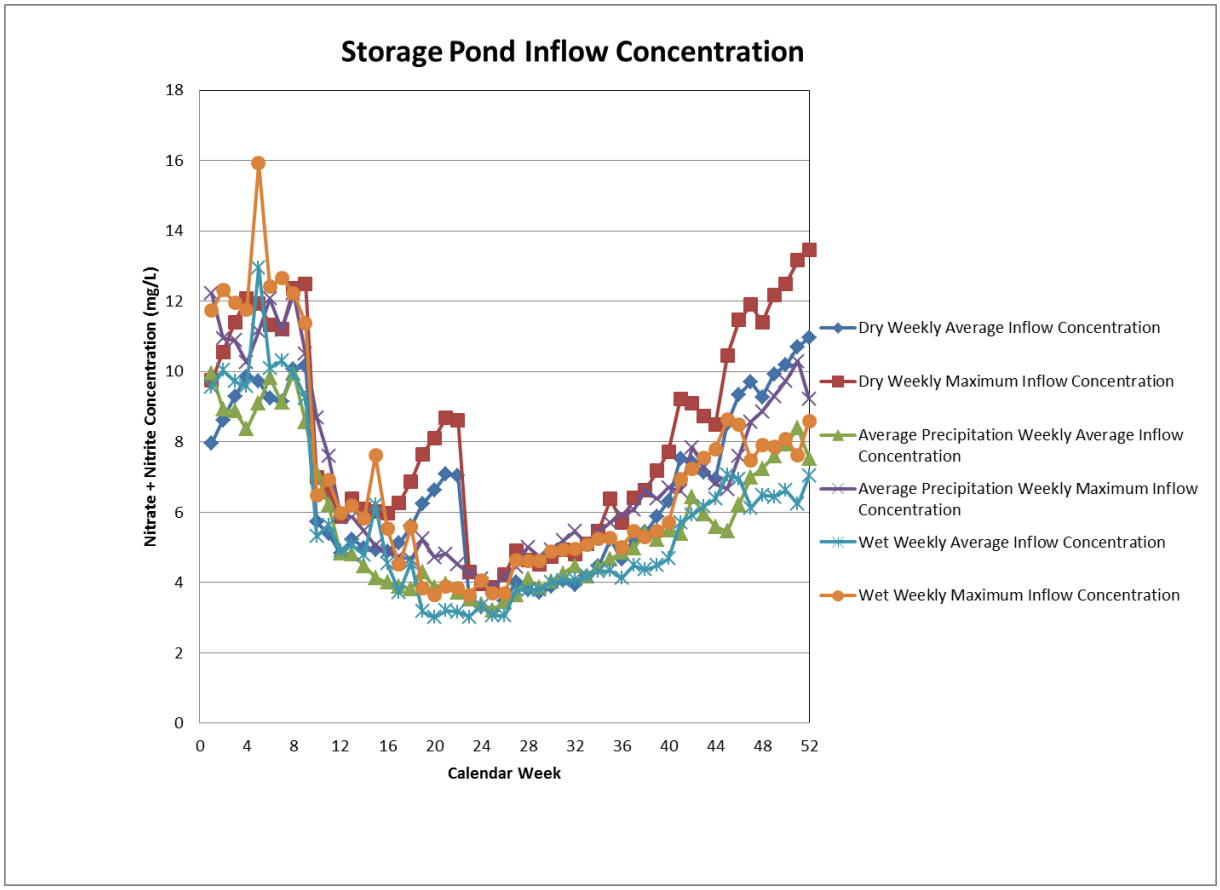
C_{Inflow} = chemical concentration in mixed inflow water;

$C_{Pond\ Week\ t}$ = chemical concentration in pond for week t; and

$C_{Outflow}$ = chemical concentration flowing out of pond for week t (assumed to

equal pond concentration for the previous week ($C_{Pond\ Week\ t-1}$)).

FIGURE 4-5. PREDICTED NITRATE CONCENTRATION OF STORAGE POND INFLOW



This calculation approach assumes that the ponds are completely mixed so that pond outflow concentrations equal bulk pond concentrations. In theory, this assumption is never completely true, but given the large pond volume, long retention time, and multiple pond layout this is a fair approximation for the purpose of this mixing analysis. Moreover, if this assumption is not borne out, there are relatively simple operational changes that could be implemented to correct the problem with the existing pond system (i.e., monitoring, segregation, storage and controlled blending of waters as described in Section 7.0).

Mixing model predicted weekly nitrate + nitrite concentrations of pond and pond outflow for the six precipitation/chemical concentration scenarios and two pond active storage area

conditions are shown in Figure 4-6. Model predicted weekly concentrations of cyanide, antimony, arsenic, selenium, and thallium in the pond and pond outflow are included in Appendix D. The model predicts that the variability in nitrate+nitrite concentrations in the ponds will be reduced compared to the variability of pond inflow concentrations. Pond and pond outflow concentrations are predicted to range from approximately 3 to 6 mg/L during the summer months to 5 to 9 mg/L during the winter months.

4.6 TREATMENT PLANT INFLOW CONCENTRATIONS

Water stored in the ponds will be pumped to the water treatment plant for thallium removal. The average and maximum predicted concentrations in treatment plant influent for the twelve mixing model scenarios are given in Table 4-1 along with relevant Montana groundwater quality standards. With the exception of thallium, influent concentrations of all parameters are lower (better than) water quality standards or background groundwater concentrations in the area of the Kendall Pit (Mason Canyon and South Fork of Last Chance Creek), for all scenarios. The Kendall Pit is located in the headwaters of Mason Canyon close to the surface water divide with South Fork of Last Chance Creek. Since groundwater divides do not always exactly match surface water divides, it is possible that current and future flows from the Kendall Pit may flow beneath Mason Canyon and/or the South Fork of Last Chance Creek watersheds. Background concentrations were estimated by MDEQ (1999) and Water Management Consultants (WMC, 2003) based on metal concentrations in a variety of water, soil, rock, and historic mining waste materials in the area.

FIGURE 4-6. PREDICTED NITRATE + NITRITE CONCENTRATION IN STORAGE POND AND POND OUTFLOW

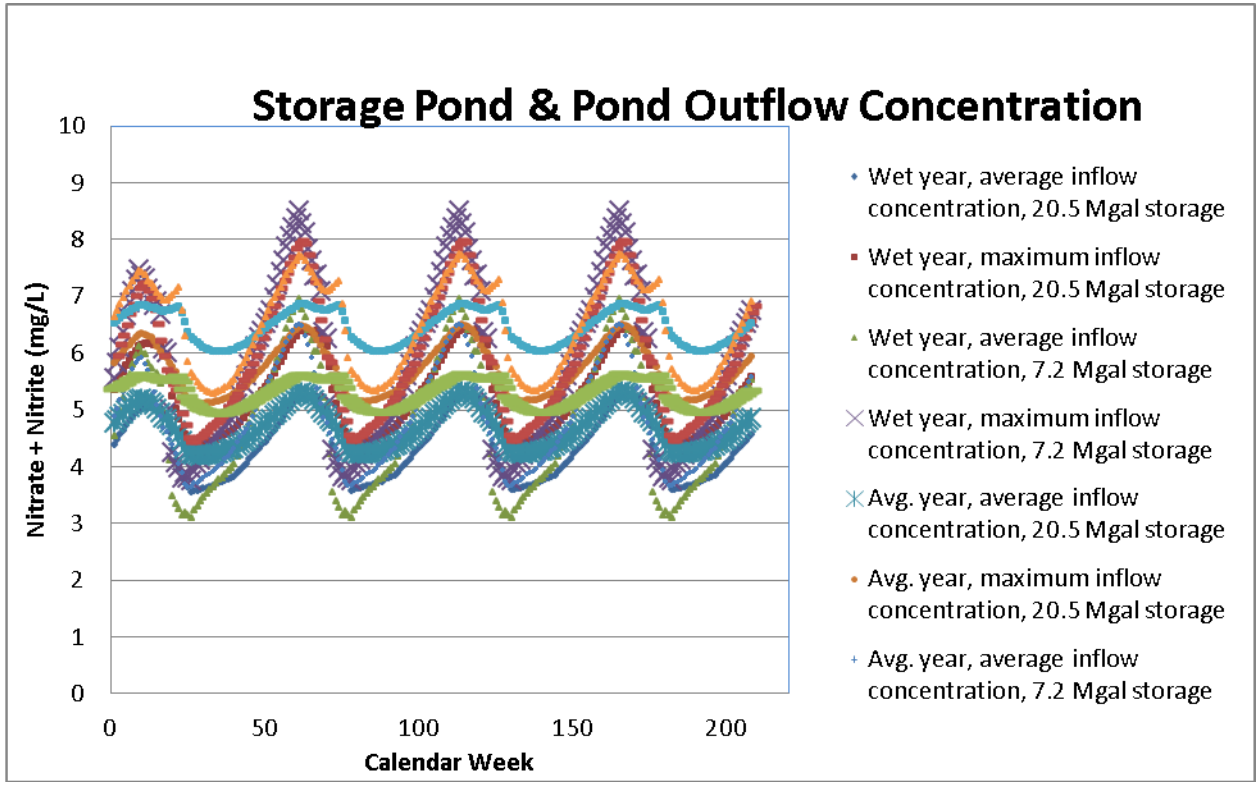


TABLE 4-1. PREDICTED WATER TREATMENT PLANT INFLUENT CONCENTRATIONS

Parameter	Pond Storage Scenario	Concentration Statistic	Flow and Concentration Scenarios						Montana Groundwater Quality Standard (MDEQ-7) (mg/L)
			Low Flow Average Concentration (mg/L)	Low Flow Maximum Concentration	Average Flow Average Concentration (mg/L)	Average Flow Maximum Concentration (mg/L)	Maximum Flow Average Concentration (mg/L)	Maximum Flow Maximum Concentration (mg/L)	
Cyanide	20.5 Mgal	Annual Average	0.02	0.03	0.02	0.02	0.01	0.02	0.200
		Weekly Maximum	0.02	0.03	0.02	0.03	0.02	0.03	
	7.2 Mgal	Annual Average	0.02	0.03	0.02	0.03	0.02	0.02	
		Weekly Maximum	0.03	0.04	0.03	0.04	0.03	0.03	
Nitrate + Nitrite	20.5 Mgal	Annual Average	5.28	6.46	4.68	5.71	4.34	5.28	10
		Weekly Maximum	5.62	6.88	5.34	6.52	5.27	6.43	
	7.2 Mgal	Annual Average	5.29	6.47	4.84	5.90	4.73	5.77	
		Weekly Maximum	6.34	7.76	6.51	7.97	6.96	8.52	
Antimony	20.5 Mgal	Annual Average	0.003	0.004	0.003	0.004	0.003	0.004	0.006
		Weekly Maximum	0.003	0.004	0.003	0.004	0.003	0.004	
	7.2 Mgal	Annual Average	0.003	0.004	0.003	0.004	0.003	0.004	
		Weekly Maximum	0.004	0.004	0.004	0.005	0.004	0.005	

TABLE 4-1. PREDICTED WATER TREATMENT PLANT INFLUENT CONCENTRATIONS (continued)

Parameter	Pond Storage Scenario	Concentration Statistic	Flow and Concentration Scenarios						Water Quality Standards				
			Low Flow Average Concentration (mg/L)	Low Flow Maximum Concentration	Average Flow Average Concentration (mg/L)	Average Flow Maximum Concentration (mg/L)	Maximum Flow Average Concentration (mg/L)	Maximum Flow Maximum Concentration (mg/L)	Montana Groundwater Quality Standard (MDEQ-7) (mg/L)	Estimated Background South Fork Last Chance Creek- MDEQ (1999) (mg/L)	Estimated Background South Fork Last chance Creek – (WMC, 2003) (mg/L)	Estimated Background Mason Canyon-MDEQ (1999) (mg/L)	Estimated Background Mason Canyon-(WMC, 2003) (mg/L)
Arsenic	20.5 Mgal	Annual Average	0.015	0.017	0.013	0.015	0.012	0.014	0.010	0.050		0.05	0.05
		Weekly Maximum	0.016	0.018	0.015	0.017	0.015	0.017					
	7.2 Mgal	Annual Average	0.015	0.017	0.014	0.015	0.013	0.015					
		Weekly Maximum	0.018	0.020	0.018	0.021	0.020	0.022					
Selenium	20.5 Mgal	Annual Average	0.030	0.038	0.029	0.037	0.029	0.037	0.050				
		Weekly Maximum	0.030	0.039	0.029	0.037	0.030	0.038					
	7.2 Mgal	Annual Average	0.030	0.038	0.029	0.037	0.029	0.037					
		Weekly Maximum	0.031	0.039	0.030	0.038	0.031	0.039					
Thallium	20.5 Mgal	Annual Average	0.301	0.386	0.329	0.426	0.355	0.462	0.002	0.010	0.020	0.05	0.1
		Weekly Maximum	0.306	0.393	0.337	0.436	0.362	0.471					
	7.2 Mgal	Annual Average	0.301	0.387	0.331	0.428	0.355	0.461					
		Weekly Maximum	0.316	0.405	0.349	0.450	0.389	0.510					

5.0 WATER TREATMENT ALTERNATIVES

The proposed water treatment for long-term water management is thallium removal via zeolite adsorption as detailed in the following Section 6.0. A variety of treatment options have been evaluated and tested at Kendall. Most recently (2010-2011), two long-term pilot scale tests have been conducted with the zeolite treatment system. This section summarizes water treatment alternatives that have been tested and describes the results of the long-term zeolite pilot tests.

5.1 ALTERNATIVES EVALUATED AND NOT SELECTED

A thorough summary of early water treatment studies conducted at CR Kendall is provided in a report by Golder (2006). Water treatment methods that have been considered include a variety of biological systems and sulfide precipitation.

5.1.1 Reverse Osmosis

A full-scale reverse osmosis (RO) system was operated at Kendal during mine closure. This system was able to treat cyanide and nitrate but was only partially effective in thallium removal. The zeolite system was initially tested and installed as a polishing step to supplement the RO system. Reverse osmosis treatment was discontinued due to the better performance of the zeolite system.

5.1.2 Biological Treatment

Biological treatment has been considered and evaluated at Kendall for many years as summarized in Table 5-1.

TABLE 5-1. BIOLOGICAL PASSIVE TREATMENT STUDIES

Study	Company	Date	Results	Interpretation
Bench-Scale Treatability Tests (Part I)	Hydrometrics, Inc.	Dec. 1995-July 1996	Lime addition to pH 11 plus permanganate was the only successful treatment to remove Tl to levels below 0.003 mg/L.	Provides hope that MnO_2 formation could remove Tl, because MnO_2 is the product of permanganate reduction.
Bench-Scale Treatability Tests (Part II)	Hydrometrics, Inc.	July-Oct. 1996	Columns removed Tl to below the 0.002 mg/L standard, but removed little else.	Sulfate was significantly reduced and residence times could have been decreased to less than 24 hrs. A small amount of iron helped with Tl removal.
Passive Treatment System (Horizontal Flow)	Environmental & Petroleum Consulting	March 1998-Oct. 2000	EP&C modified a biocell designed by Hydrometrics to improve hydraulic conductivity. Tl, Se, Zn and NO_3 were sufficiently removed; However, Fe, Mn and As were released into the water.	Aeration channel was significantly undersized for Fe, Mn and As removal. KVPB-6 water contained too much NO_3 at the residence time used. Not enough organic material was used.
In Situ Reactive Zone Treatment	Arcadis	March 2005-May 2006	Lab-scale testing had good Tl removal, but Zn and Mn were not analyzed. Was only a semi-passive system, with nutrient addition required.	Iron sulfides were added, in the belief they could aid co-precipitation.
Nutrient Reducing Bioreactor	Golder and Associates	2007 - 2010	Good thallium removal but Fe, As, and occasionally Se were released into the water.	Aerobic cell undersized, active aeration/oxidation required.

The most recent test of a biological system was a pilot scale, passive biological treatment system which was operated from 2007 until 2010 (Golder, 2010). The system consisted of a sulfate-reducing reactor and aerobic polishing cell. The system effectively removed thallium (from about 1300 ug/L to less than 2 ug/L) and other heavy metals, but produced elevated levels of ammonia, hydrogen sulfide, total organic carbon and some metals. Although

effective for thallium removal, this system produced a poor overall effluent quality that would require a large active aeration/oxidation system to remedy.

5.1.3 Sulfide Precipitation

Sodium sulfide addition was evaluated in bench tests in the 1990s, with mixed results (Hydrometrics, 1996). Thallium was effectively removed, probably through coprecipitation, when concentrations of iron, zinc or manganese were relatively high. Sulfide precipitation was viewed as a possible pretreatment step, to reduce thallium concentrations prior to "polishing" with zeolites or biological treatment. It may be possible to improve the efficiency of sulfide precipitation through modifications such as pH adjustment, longer residence times or use of sodium hydrosulfide in place of sodium sulfide. However, based on the simplicity and effectiveness of zeolite treatment, sulfide precipitation was not pursued further.

5.2 ZEOLITE PILOT TEST RESULTS

Zeolites have been proven to very effective in removing thallium from mine water through bench- and pilot-scale testing, and through operating a 100 gpm, full-scale treatment system at the Kendall Mine for over 10 years. This zeolite treatment system is advantageous in that it is effective, simple to operate and generates an innocuous, non-hazardous waste product (spent zeolites). TCLP testing indicates that the thallium is effectively sequestered on the zeolites, with less than one percent of the thallium being mobile.

Although the current full-scale operating system is very effective, a review of previous bench-scale testing, current operational results, and discussions with zeolite providers suggested that higher loading capacities might be achievable with different zeolite mineral species. Previous zeolite systems at Kendall have employed the zeolite chabazite. To evaluate performance of the zeolite clinoptilolite, several sets of bench tests were run using clinoptilolite of different size gradations and from different suppliers in 2010. The bench test results were promising and led Kendall personnel to operate two pilot tests on-site as described in the following subsections.

5.2.1 Steelhead Clinoptilolite

The first pilot test using 14x40 mesh clinoptilolite (zeolite) from Steelhead Specialty Minerals was operated at the Kendall site from November 29, 2010 until February 2, 2011 (65 days). Operation and results of the pilot test are described in Appendix E and are summarized as follows:

- Five small columns (24-inch diameter, each containing approximately 8 cubic feet or 400 lbs of zeolite material) were operated in series using gravity flow at a constant flow rate.
- Influent concentration was 0.6 mg/L thallium, which is very representative of anticipated site conditions.
- The test was terminated after thallium breakthrough above the minimum detection limit of 0.0002 mg/L was consistently measured in final column effluent.
- Nearly 500,000 gallons of North End pumpback water were treated successfully during the test.
- A higher thallium adsorption capacity (delayed breakthrough) was noted at a lower flow rate.
- Water quality parameters other than thallium were not affected by zeolite treatment.
- Clinoptilolite in the first column achieved a thallium loading of 0.376 percent.
- Spent zeolite material was tested by TCLP and the adsorbed thallium was found to be essentially non-leachable as less than 1 percent of the thallium was liberated.

Overall, the pilot test was highly successful as mine water was treated for over 65 days with no thallium detected in the effluent and no operational difficulties.

5.2.2 St. Cloud Clinoptilolite

The second pilot test using 16x50 mesh St. Cloud clinoptilolite was operated immediately after the first test, from February 7, 2011 until June 6, 2011 (120 days). Operation and results of the pilot test are described in Appendix F and are summarized as follows:

- The same five small columns used in the first test were operated in series using gravity flow and constant flow rate.
- The average influent thallium concentration of 0.379 mg/L in this test was somewhat lower than the first test but is still within anticipated future mixed mine water quality as described in Section 4.0.
- The test was terminated after a thallium concentration above the minimum detection limit of 0.0002 mg/L ("breakthrough") was consistently measured in Column 5 effluent. Approximately 869,000 gallons of North End pumpback water were treated during the St. Cloud Clinoptilolite test.
- A low flow rate of 5 gpm was used throughout the test because a higher thallium adsorption capacity (delayed breakthrough) was noted at this low flow rate in Test #1.
- Water quality parameters other than thallium were again unaffected by zeolite treatment.
- Clinoptilolite in the first column achieved a thallium loading of 0.32 percent.
- Spent zeolite material was tested by TCLP and the adsorbed thallium was found to be essentially non-leachable as less than 1 percent of the thallium was liberated.

Overall, the pilot test was highly successful as mine water was treated for 120 days with no thallium detected in the effluent. It was noted in this test that some clogging of the media occurred due to suspended solids (primarily algae) in the influent water. The solids were effectively removed by pre-filtration and as the result of this experience; the long-term water treatment system incorporates media-filtration prior to zeolite treatment.

6.0 PROPOSED WATER TREATMENT SYSTEM

The selected method for long-term removal of thallium from mine waters is zeolite adsorption. The proposed water treatment system (Figure 6-1) consists of the following steps/elements:

- Primary water storage will be provided by Pond 7 with supplemental storage by Pond 8.
- The treatment system will be located at the existing water treatment building.
- Existing storage Pond 2B will serve as a feed water pond with surge capacity provided by existing Pond 3B.
- Media filtration will be provided to remove suspended solids prior to zeolite treatment.
- Zeolite treatment will occur in the existing zeolite columns using primarily clinoptilolite zeolite. Chabazite zeolite may also be used.
- Effluent will be monitored as needed to ensure proper operation and thallium removal prior to discharge to the Kendall Pit.
- Water treatment residuals (spent zeolites and suspended solids) will be placed in Pond 7.

6.1 DESIGN CRITERIA

The design criteria for the zeolite treatment system are:

1. Inflow rates to storage ponds will be seasonally variable and similar to previously observed pumpback system flow rates and HELP model predicted pad drainage rates as described in Sections 3.0 and 4.0. Total average annual flow is expected to be approximately 65 gpm (61 gpm pumpback flows and 4 gpm pad drainage).
2. Typical treatment flow rates average 80 gpm but could range from 60 to 100 gpm. If inflow rates do not provide sufficient water to meet minimum treatment system flows, continuous treatment will be temporarily suspended until sufficient water is available (i.e., treatment plant will run in batch mode).

FIGURE 6-1. WATER TREATMENT SYSTEM SCHEMATIC

3. Influent water quality initially will be similar to the range of concentrations predicted by the mixing model (summarized in Table 4-1) and will be treated to remove thallium as necessary to meet water quality standards.
4. Future influent thallium concentrations will decrease due to diminishing mine water concentrations.
5. Influent and effluent water quality will be monitored routinely to ensure compliance with water quality standards. In the event effluent water quality does not meet discharge limits, contingency actions will be taken to prevent release to groundwater. Contingency actions are described in Section 7.0 and would include storage and blending of water, return of treated water to storage ponds, or land application of water to reduce nitrate or cyanide concentrations.

6.2 STORAGE OF WATERS BEFORE TREATMENT

Prior to treatment, water will be stored in a series of four ponds with a total capacity of approximately 20.5 million gallons (see Figure 4-1, Section 4.0). Typical operation of the ponds is as follows:

1. Water from all sources initially flows or is pumped to Pond 7 (5.47 Mgal) where the water becomes mixed and is stored.
2. Pond 7 has an overflow line that conveys water to Pond 8 (13.3 Mgal) when Pond 7 is full and inflow exceeds outflow to Pond 2B and treatment. Pond 8 is typically operated as an overflow pond with no outflow except a return line to Pond 7.
3. From Pond 7, water is pumped to Pond 2B (0.45 Mgal) which functions as the feed water pond for the water treatment plant.
4. Pond 3B (1.32 Mgal) is connected to Pond 2B via overflow line and Pond 3B functions as a surge pond to help buffer Pond 2B inflows with water treatment plant withdrawals.
5. Water is pumped from Pond 2B to the treatment plant for thallium removal.

Other water routing options are possible with the existing pond layout and alternative operating approaches could be used for pond maintenance or for other contingency purposes.

6.3 SUSPENDED SOLIDS REMOVAL

To date, the zeolite columns at Kendall have operated effectively without any pre-treatment for solids removal. However, the pilot tests identified the potential for clogging of zeolite media with suspended solids, and therefore the long-term water management plan provides pre-treatment for removal of total suspended solids (TSS) with a multimedia filter to ensure continued long-term operation of the system. These filters typically have several layers of gravel support media, with the actual filtration media above the gravel. Operation is downflow during filtration and upflow during backwashing. A typical multimedia filter composition is shown in Table 6-1, with media listed from top to bottom (lightest to densest).

TABLE 6-1. MULTIMEDIA FILTER COMPOSITION

Media	Size	Depth (in.)
Anthracite	0.85 – 0.95 mm	12
Silica sand	0.44 – 0.55 mm	12
Garnet	40 – 50 mesh	12
Fine gravel	¼ - 1/2”	3
Coarse gravel	½ - 3/4”	6

The proposed multimedia filtration system will be located within the existing water treatment building and will be comprised of two filters in parallel, a feed pump, a backwash (clean water) tank and backwash pump. Filtered water will be used for backwashing the filters. The described system will have a capacity of 100 gpm, with two 36-inch-diameter filters and a side shell height of 56 inches.

6.4 THALLIUM REMOVAL

Thallium will be removed from influent water by using the existing zeolite column system, using clinoptilolite in place of the current chabazite (zeolite) media. Approximately 4,000 pounds of clinoptilolite will be loaded into each column, with a typical average flow rate of 80 gpm and a typical maximum treatment capacity of 100 gpm. Higher flow rates may be

accommodated with the system but would generally be avoided as higher flow rates would result in lower thallium loadings and greater zeolite consumption.

Pilot testing showed that thallium adsorption was enhanced at lower flow rates, but full-scale experience demonstrates this enhancement occurs only up to a point. In the full-scale system, treatment efficiency is reduced at very low flow rates due to lack of fluidization of the zeolite media. Therefore, the typical minimum flow rate to the system will be 60 gpm. If flows to the treatment plant are too low to maintain a consistent flow of 60 gpm or greater, the system will be operated in batch mode (i.e., cycled on and off as needed). Since thallium adsorption to zeolites is a physical/chemical process, this operation at "non-steady state" will not compromise treatment efficiency.

Pilot testing and previous full-scale operations have shown that zeolites will adsorb more thallium when exposed to higher concentrations, as is typical with adsorbents. To maximize thallium loading on the zeolite material, zeolite in each column will be transferred backward (upstream) periodically, with fresh material being loaded into Column 5 (the effluent, or downstream end of the system) and material from Column 1 (the beginning or influent end of the system) being discarded. It is anticipated that zeolite will be transferred by slurrying it with treated water, and pumping it from one column to another. In addition, influent concentrations may be managed by adjusting source flows (i.e., pumpback systems and pad drainage flows) to increase removal efficiency.

The design of the proposed treatment system is primarily, but not exclusively, based on the use of clinoptilolite zeolite media since testing has shown that this zeolite species has the highest thallium loading capacity at the lowest cost. Two suppliers (St. Cloud Minerals and Steelhead Specialty Minerals) of clinoptilolite zeolite have been identified and their products have been tested extensively during the pilot tests. It is likely that both clinoptilolite suppliers could be used from time to time. However, it should also be noted that chabazite (zeolite) was used to remove thallium at Kendall for many years, and chabazite continues to constitute an effective treatment media, capable of reaching the required effluent concentrations, but at somewhat lower loading rates, and potentially higher cost, than

clinoptilolite. Therefore, it is also possible that chabazite media may be used in the future should the need arise (e.g., a lapse in clinoptilolite production) or should conditions favor chabazite (e.g., excessive clinoptilolite cost).

6.5 TREATED WATER DISPOSAL

Treated water will flow to the backwash water tank (capacity of approximately 1,000 gallons) for re-use in the multi-media filtration system or to groundwater discharge at the Kendall Pit.

6.6 CHARACTERISTICS AND DISPOSAL OF TREATMENT RESIDUALS

Treatment residuals will consist of TSS from multimedia backwashing and spent zeolite media. Backwash water containing TSS from the water multimedia filter will be transferred back to Pond 7. Spent zeolites will also be placed and disposed in Pond 7.

Operational experience with the full size zeolite columns and the pilot test columns indicates that the TSS material is largely algae or other biological growth and very fine-grained sediment (clay and silt) and possibly mineral precipitates (i.e., iron and manganese oxides or other scale).

Spent zeolites contain approximately 0.3 percent thallium adsorbed from water in the treatment system. At the conclusion of the pilot tests, spent zeolites from column 1 (highest loaded material) was subjected to whole rock or total digestion metals analysis, Toxicity Characteristic Leaching Procedure (TCLP), and Synthetic Precipitation Leaching Procedure (SPLP) tests. Each sample was a composite sample from within the column, as the zeolites were mixed with an air hose prior to sampling. Leaching results for the eight RCRA metals plus thallium for pilot test zeolites are shown in Table 6-2. Since all metals other than thallium were non-detect, this spent material is classified as nonhazardous waste. In addition, the SPLP results indicate a low leachability of thallium with precipitation water, thus the zeolites are not expected to release thallium to the mine water during disposal in Pond 7.

TABLE 6-2. SPENT ZEOLITE TOTAL METALS AND LEACH TEST RESULTS

	St. Cloud Clinoptiloloite			Steelhead Clinoptilolite		
Metal	**Total Metals (mg/kg)**	**TCLP (mg/L)**	**SPLP (mg/L)**	**Total Metals (mg/kg)**	**TCLP (mg/L)**	**SPLP (mg/L)**
Arsenic	10	< 0.5	< 0.5	13	< 0.5	< 0.5
Barium	232	< 10	< 1	784	< 10	< 1
Cadmium	<1	< 0.1	< 0.1	<1	< 0.1	< 0.1
Chromium	<5	< 0.5	< 0.5	<5	< 0.5	< 0.5
Lead	5	< 0.5	< 0.5	8	< 0.5	< 0.5
Mercury	<1	< 0.02	< 0.02	<1	< 0.02	< 0.02
Selenium	<5	< 0.1	< 0.1	<5	< 0.1	< 0.1
Silver	<5	< 0.5	< 0.5	<5	< 0.5	< 0.5
Thallium	3,160	1.89	0.08	3,760	2.66	<0.5

The quantity of zeolites required in the treatment system can be estimated based on the range of flow rates and thallium concentrations of predicted water treatment plant inflow. Table 6-3 shows the zeolite requirements for the dry, normal, and wet flow conditions and thallium concentration ranges evaluated in the mixing model (Section 4.0). Annual zeolite requirements are predicted to average approximately 32,000 lbs/yr and could range from less than 15,000 to nearly 70,000 lbs/yr. The quantity of zeolites required is expected to decrease in the future as site-wide thallium concentrations continue to decrease.

The volume of spent zeolites requiring disposal in Pond 7 can be similarly estimated as shown in Table 6-3. Given a zeolite density of 50 lbs/cubic foot, on average approximately 650 cubic feet or a little less than 5,000 gallons of zeolite would be generated each year. At this initial zeolite generation rate, disposal of spent zeolites in Pond 7 (5.47 Mgal) would consume a little less than 0.1 percent of the storage capacity in Pond 7 per year or 5 percent of Pond 7 storage capacity over the next 50 years. Since all pumpback water and pad drainage is predicted to meet water quality standards within the next 50 years, disposal of zeolites in Pond 7 is not expected to significantly reduce the available pond water storage capacity.

TABLE 6-3. ESTIMATED ANNUAL ZEOLITE REQUIREMENTS

	Low Flow Average Concentration	Low Flow Maximum Concentration	Average Flow Average Concentration	Average Flow Maximum Concentration	Maximum Flow Average Concentration	Maximum Flow Maximum Concentration
Inflow rate (gpm)	35.6	36.6	69.4	70.4	108.7	109.7
Treatment Plant Inflow Annual Average Thallium Concentration (mg/L)	0.301	0.386	0.329	0.426	0.355	0.462
Thallium Loads in Inflow (kg/yr)	21.3	28.1	45.4	59.7	76.8	100.8
Zeolite Required at 0.32 % Tl Loading (kg)	6,655	8,787	14,196	18,645	23,985	31,490
Zeolite Required at 0.32 % Tl Loading (lbs)	14,659	19,356	31,268	41,069	52,831	69,361
Zeolite Required at 0.32 % Tl Loading (cubic ft)	293	387	625	821	1,057	1,387
Zeolite Required at 0.32 % Tl Loading (gallons)	2,193	2,896	4,678	6,144	7,904	10,376

7.0 OPERATION, MAINTENANCE AND MONITORING

7.1 SUPPORT FACILITIES

The primary support facilities for the water management system are:

1. The water treatment system, consisting of the multi-media filter system, zeolite columns and associated buildings, piping, pumps and controls.
2. The pumpback system consisting of wells, pumps and piping.
3. The storage pond system consisting of Ponds 2B, 3B, 7 and 8 and associated piping.

Operation, maintenance and monitoring of the treatment, pumpback, and piping systems has been conducted routinely by Kendall personnel for the past fifteen years and is expected to continue throughout the water management plan. These systems consist of materials and equipment that are commonly used and readily available in the construction industry. Repair and replacement of these systems is expected to be an ongoing, but routine part of the water management plan. At times, it may be necessary to temporarily shut down the water treatment system in order to make repairs. In this case, water will be stored in the ponds until the treatment system is operational. The zeolite system is not negatively affected by cessation of flows.

Operation, maintenance and monitoring of the pond systems also has been conducted routinely by Kendall personnel for the past fifteen years and is expected to continue for the duration of the water management plan. At times it may be necessary to suspend use of a pond in order to make repairs or to replace or overlay a pond liner. Because of the ample storage capacity of the pond system and the multi-pond configuration, this is easily achievable by taking the pond out of service while the repair is made. The most likely scenarios would be:

1. In the event Pond 7 needs repair, all pumpback and drainage flows would be diverted to Pond 8, which would act as the primary mixing and storage pond.

2. In the event Pond 8 needs repair, the Pond 7 overflow line to Pond 8 would be closed until the repair is made.
3. In the event, Pond 2B needs repair, water would be pumped from Ponds 7 or 8 directly to Pond 3B, which would act as the feedwater pond. In this case the treatment plant would most likely be run in batch mode to ensure a consistent flow of water.
4. In the event Pond 3B needs repair, 2B would operate in normal mode as the feedwater pond but the treatment plant would most likely be run in batch mode to ensure a consistent flow of water.

7.2 MANPOWER REQUIREMENTS

It is anticipated that the water treatment plant will require minimal operator attention, for tasks including periodic sampling and checking multimedia filter operation, zeolite column operation and flow rates. An operator may be required for as little as two hours a day, three times a week. Controls will be used to automatically start and shut down the treatment system depending on pond levels. An "auto-dialer" will be used to notify an operator/supervisor off-site in the event of any alarm conditions.

7.3 FUEL AND POWER

The existing power system will be maintained because electricity will be required to operate the pumpback systems, pump water from the storage ponds to the treatment system, run the multi-media filtration system, and control the zeolite water treatment system.

Fuel for support vehicles (gasoline and diesel) and propane for heating purposes will be stored in existing storage tanks on the mine site.

7.4 TRANSPORTATION

The existing road system will be used for transportation of personnel, equipment and water treatment supplies (zeolites). As described in Section 6.0, an average of approximately 16 tons of zeolites will be required per year.

7.5 WASTE

The primary waste from the water management system is spent zeolites and suspended solids from the water treatment plant which will be permanently disposed in Pond 7. Routine domestic waste will be collected by a waste management contractor and disposed at a licensed off-site landfill. Oily waste, if any, will be temporarily stored on-site and periodically removed for recycling or disposal by a licensed handler. No hazardous waste will be generated, disposed or stored on-site.

7.6 MONITORING

Routine monitoring will continue under the approved water monitoring plan. The water monitoring plan provides for monitoring of surface water and groundwater throughout the mine site. Monitoring to support the water management plan will include:

- Pumpback flow rates and water quality;
- Pad drainage flow rates and water quality;
- Water treatment plant inflow and effluent rates and water quality; and
- Storage pond water quality.

Monitoring will include field monitoring and analyses (e.g., pH, conductivity, nitrate) to support treatment plant operation and ensure compliance.

7.7 CONTINGENCY ACTIONS

Contingency actions are actions that could be taken to address non-routine or unexpected conditions that may arise. Potential contingency actions, and the conditions which may trigger the need for contingency actions, are described below.

7.7.1 Pond Mixing

As described in Section 4.0, inflow to the storage ponds could exceed applicable water quality standards or effluent limits for some parameters (particularly nitrate + nitrite) for short periods of time. However, water quality in the ponds and quality of water flowing to the water treatment plant is not expected to exceed water quality standards for parameters

other than thallium, due to mixing in the ponds. To ensure that sufficient mixing occurs, the ponds will be routinely monitored for pH, specific conductivity, and nitrate using field meters or a field test kit (Hach kit or equivalent). If pond water is found to exceed the water quality standard for nitrate (10 mg/L), one or more of the following contingency actions would be taken:

1. A water sample will be collected and submitted for laboratory confirmation analysis to determine if the sample meets water quality standards for all parameters except thallium (which would be removed by the water treatment system). If laboratory analysis indicates that water quality standards are met (except for thallium) then the water will be treated for thallium and released according to normal operating protocols.
2. If laboratory analysis indicates that water quality standards are not met only for nitrate +nitrite or cyanide, the water could be treated for thallium removal and then land applied for nitrate + nitrite and cyanide removal in accordance with the mine operating permit.
3. Water could be held further in the ponds to allow for more mixing and dilution.
4. The ponds could be modified to promote better mixing (e.g., baffles, curtains, pumping or other means to control circulation and mixing).

7.7.2 Land Application

The land application area has been used effectively for treatment and discharge of mine water. The land application area is fully reclaimed and re-vegetated and will not be disturbed by application of water at agronomic uptake rates. Although use of the land application area is not anticipated, it will be retained as a contingency component of the water management system. If unforeseen conditions arise, the land application area could be used as a supplemental water treatment method for removal of nitrogen compounds (nitrate, nitrite, ammonia, cyanide) by vegetative uptake after thallium removal.

7.7.3 Zeolite Disposal

Spent zeolite material has been tested and found to be non-hazardous and non-leaching. The volume of zeolites that will be generated annually is expected to comprise less than 0.1 percent of Pond 7 volume and less than 0.02 percent of the total pond capacity. The quantity of zeolite waste generated is expected to decrease as thallium concentrations in mine water continue to decline. Based on current declining trends, thallium concentrations are predicted to meet water quality standards (background concentrations) within the next 40 years, at which time zeolite treatment for thallium removal will no longer be needed and spent zeolite generation will cease.

In the event that zeolite generation is higher than anticipated and adversely affects pond storage capacity and/or water treatment plant operation, zeolites would either be 1) transported off-site and disposed at a non-hazardous landfill; or 2) stored in a purpose-built, on-site repository.

8.0 REFERENCES

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APPENDIX A

HELP MODEL

APPENDIX B

WATER QUALITY STATISTICAL SUMMARIES

APPENDIX C

WATER QUALITY GRAPHS AND TREND ANALYSIS

APPENDIX D

PREDICTED WEEKLY POND OUTFLOW CONCENTRATIONS

APPENDIX E

STEELHEAD CLINOPTILOLITE ZEOLITE PILOT TEST

APPENDIX F

ST. CLOUD CLINOPTILOLITE ZEOLITE PILOT TEST

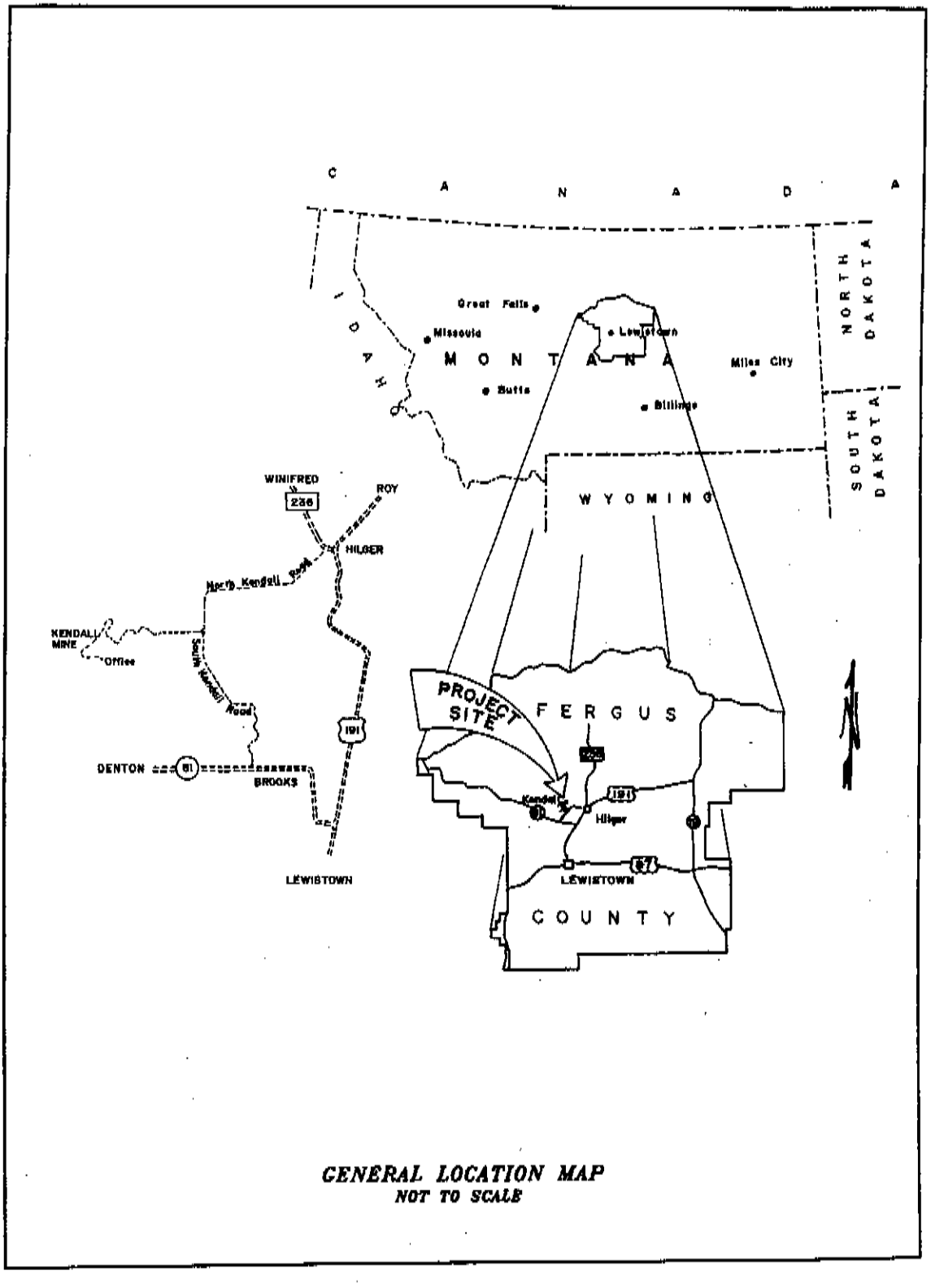
EXHIBIT 1

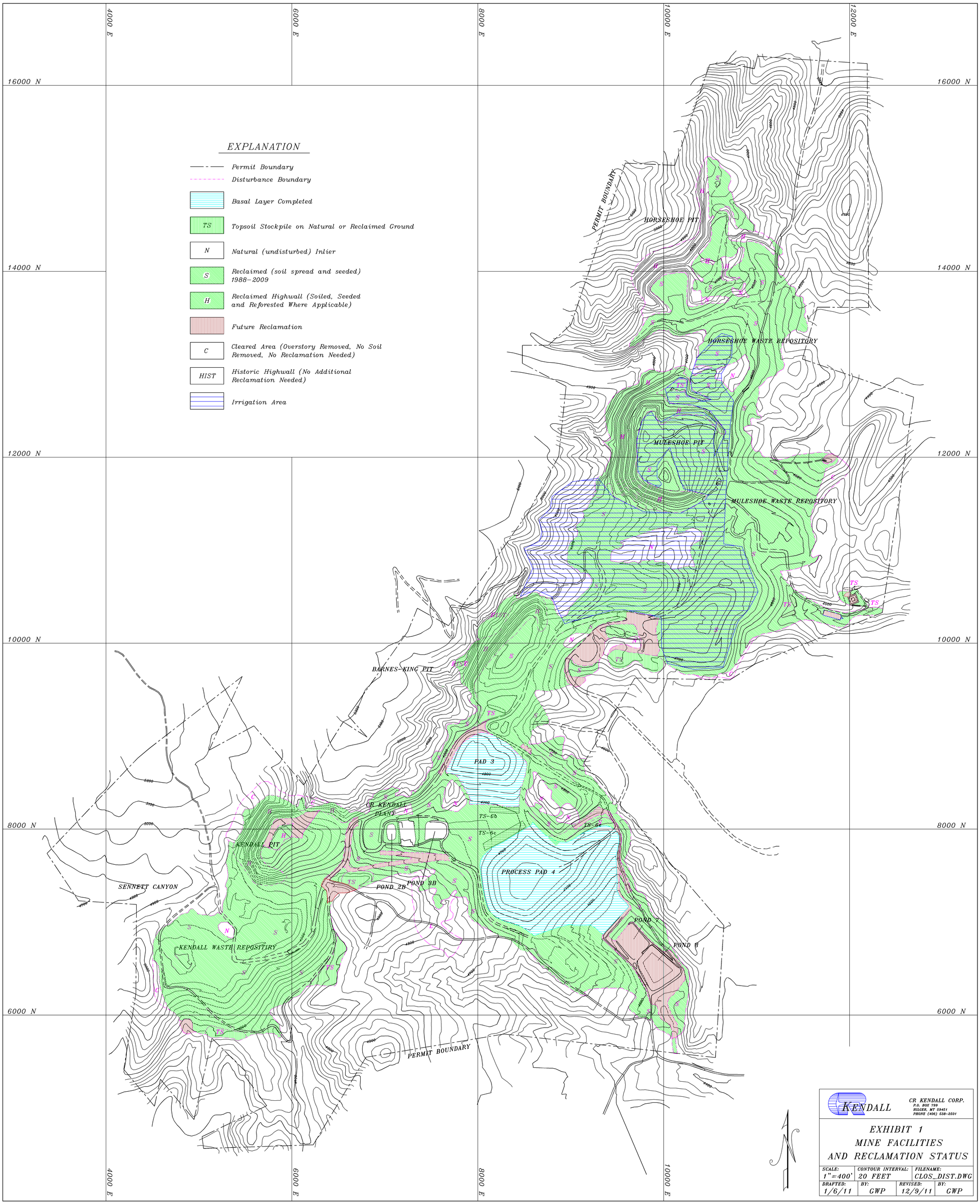
MINE FACILITIES AND RECLAMATION STATUS

EXHIBIT 2

WATER MANAGEMENT SYSTEM

FIGURE 1-1. LOCATION MAP, KENDALL MINE




EXPLANATION
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Disturbance Boundary
Basal Layer Completed
TS Topsoil Stockpile on Natural or Reclaimed Ground
N Natural (undisturbed) Inlier
S Reclaimed (soil spread and seeded) 1988-2009
H Reclaimed Highwall (Soiled, Seeded and Reforested Where Applicable)
Future Reclamation
C Cleared Area (Overstory Removed, No Soil Removed, No Reclamation Needed)
HIST Historic Highwall (No Additional Reclamation Needed)
Irrigation Area
PERMIT BOUNDARY
HORSESHOE PIT
HORSESHOE WASTE REPOSITORY
MULESHOE PIT
MULESHOE WASTE REPOSITORY
BARNES-KING PIT
PAD 3
CR KENDALL PLANT
TS-6b
TS-6c
TS-6e
KENDALL PIT
PROCESS PAD 4
SENNETT CANYON
POND 2B
POND 3B
POND 7
POND 8
KENDALL WASTE REPOSITIRY
PERMIT BOUNDARY
16000 N
14000 N
12000 N
10000 N
8000 N
6000 N
4000 E
6000 E
8000 E
10000 E
12000 E
KENDALL
CR KENDALL CORP.
P.O. BOX 799
HILGER, MT 59451
PHONE (406) 538-2501
EXHIBIT 1
MINE FACILITIES
AND RECLAMATION STATUS
SCALE: 1"=400'
CONTOUR INTERVAL: 20 FEET
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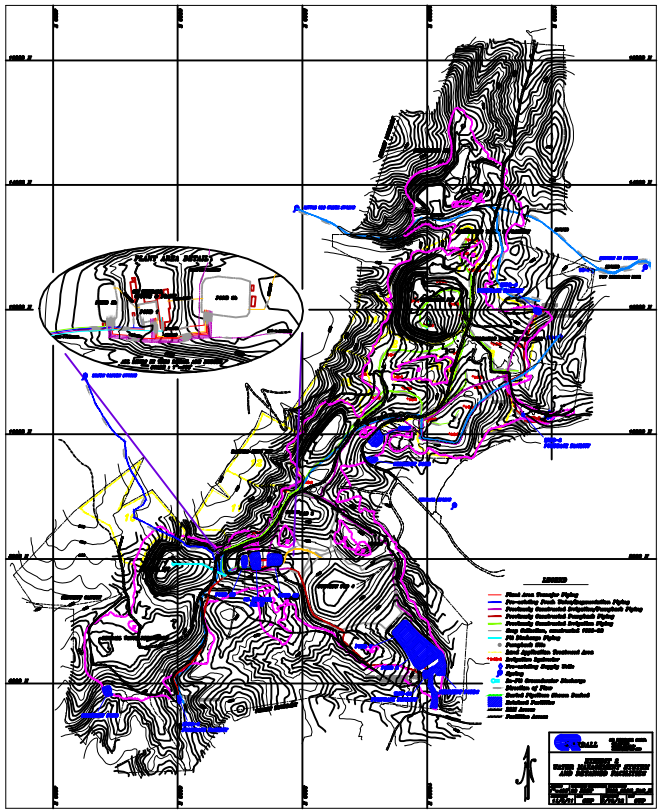
DRAFTED: 1/6/11
BY: GWP
REVISED: 12/9/11
BY: GWP


PLANT AREA DETAIL
LEGEND

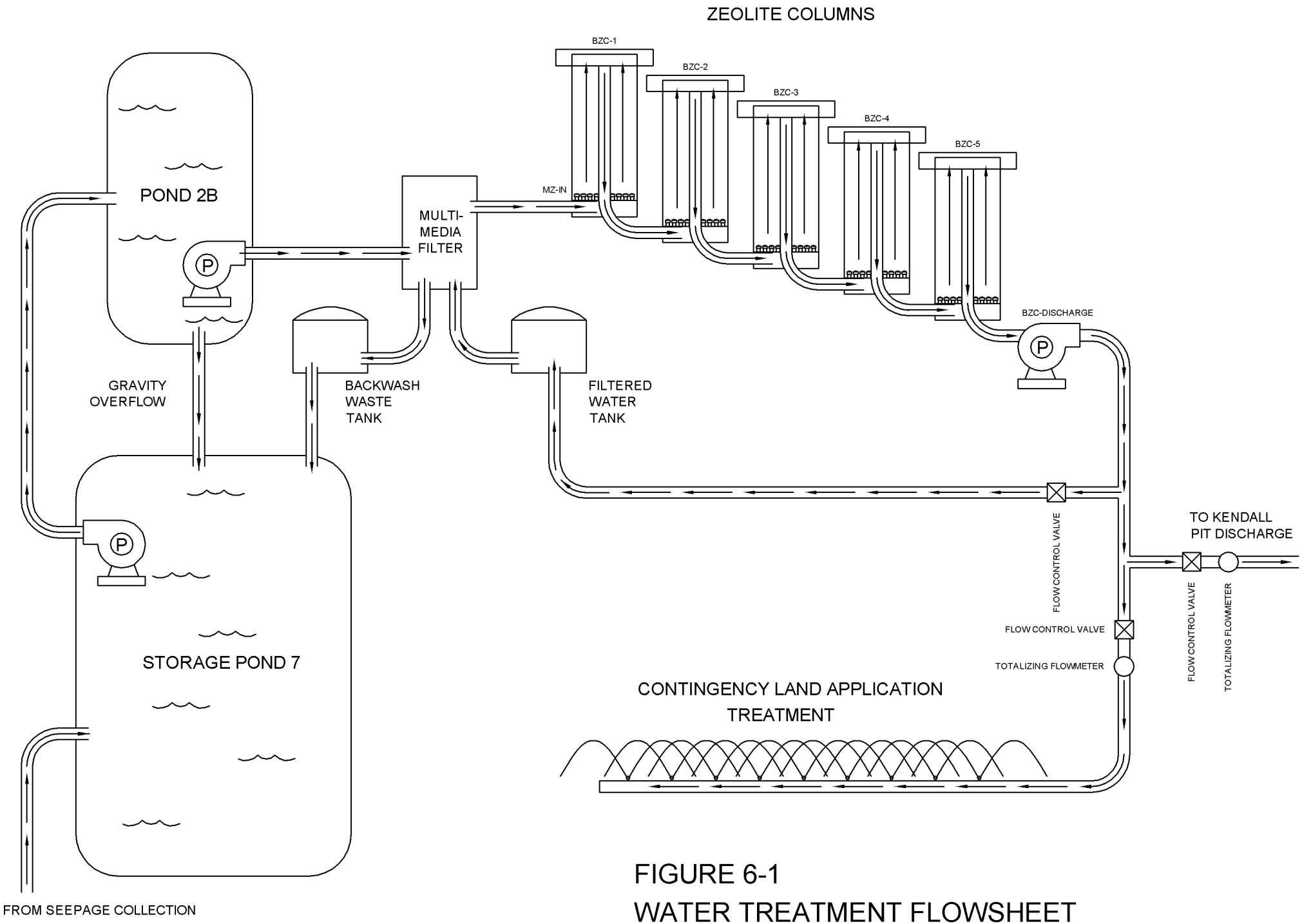


FIGURE 6-1
WATER TREATMENT FLOWSHEET

Apex Engineering, PLLC
4050 Fieldstone Crossing
Missoula, MT 59802
http://apexengineering.us
Phone: 406-493-0368
Fax: 406-493-0368
Email: reinsel39@msn.com

TECHNICAL MEMORANDUM

DATE: December 7, 2011

TO: Scott Mason
Jim Volberding

FROM: Mark Reinsel

SUBJECT: Summary Report - Zeolite Pilot Test #1, Steelhead Clinoptilolite

Summary

Pilot Test #1 using 14x40 mesh clinoptilolite (zeolite) from Steelhead Specialty Minerals was operated at the Kendall site from November 29, 2010 until February 2, 2011 (65 days). Five small columns were operated in series using gravity flow. The test was terminated after thallium breakthrough above the minimum detection limit of 0.0002 mg/L was consistently measured in Column 5 effluent. Nearly 500,000 gallons of North End pumpback water were treated during the test.

The pilot test was operated at constant flow to avoid bed packing. A higher thallium adsorption capacity (delayed breakthrough) was noted at a lower flow rate. Water quality parameters other than thallium were not affected by zeolite treatment. The influent concentration of 0.6 mg/L thallium in this test was very representative of anticipated site conditions.

Leach testing of the spent zeolites showed that they are classified as nonhazardous waste. A thallium loading of 0.376% was measured in the Column 1 material. A mass balance between the thallium adsorbed to the zeolites, and the thallium removed from water passing through the columns, agreed within about 20 percent.

Test Setup

On November 29, 2010, Kendall Mine personnel began operating a pilot test using zeolites of a different type and smaller size, compared to the zeolites used in the old carbon columns at the site. The new material, 14x40 mesh clinoptilolite from Steelhead Specialty Minerals, was used in Zeolite Pilot Test #1. The previous zeolites are 8x20 mesh chabazite from St. Cloud Minerals.

A schematic of the pilot test system using “mini-columns” is shown in Figure 1. Figure 2 is a photo of the system.

FIGURE 1. MINI ZEOLITE COLUMN PROFILE

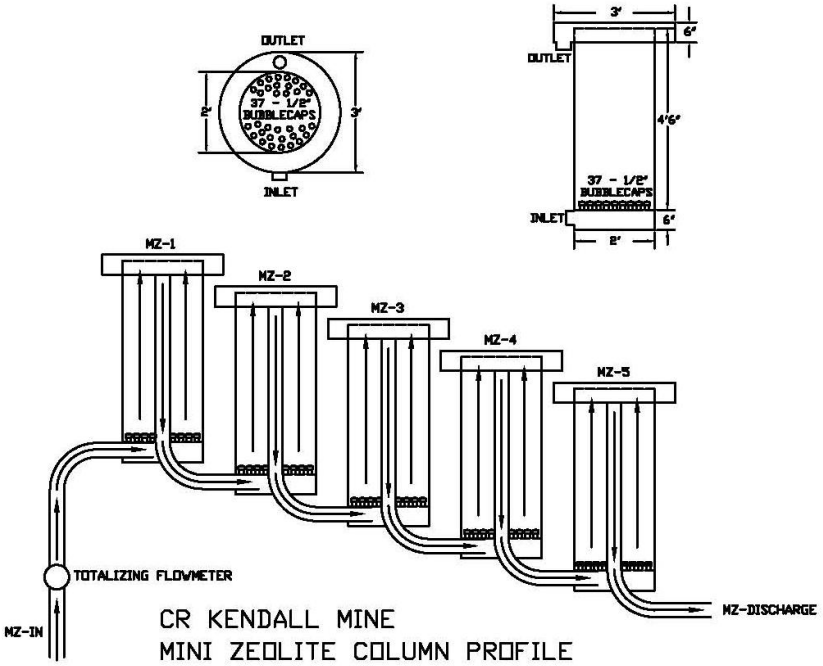


FIGURE 2. MINI-COLUMNS FOR PILOT TESTING

The zeolite columns were set up as follows:

1. A quantity of clinoptilolite sufficient to fill all five columns (24-inch-diameter) was washed in the attrition tank, using South End water after zeolite treatment (no thallium).
2. Clinoptilolite was loaded into each column to a height of 30 inches. The clinoptilolite specific gravity was determined in the lab to be about 0.81. The volume of zeolites in each column was 7.85 ft^3 so the weight in each column was 7.85 * 0.81 * 62.4 = 397 lbs.
3. Approximately half of the required clinoptilolite was slurried into each column, with the remainder added via five-gallon buckets. A yardstick was used to measure down 25 inches from the top of the overflow launder of the 55-inch-deep columns.
4. There is a 15-inch elevation drop between each column to allow gravity flow.
5. South End water before zeolite treatment, containing a low concentration of thallium, was pumped through the columns at 10 gpm. This washed the clinoptilolite fines out of the columns and was enhanced by stirring with a PVC pipe.
6. It was found that flow up to 22 gpm could be run through the mini-columns. At higher flow rates, the pressure drop between columns caused one or more columns to overflow. Using a PVC pipe, each column felt fluidized at this flow rate.
7. Flow was shut off temporarily to check the clinoptilolite depth in each column. After adding more clinoptilolite to Column 5, the top of each clinoptilolite bed measured 24-27 inches down from the launder. That means each column contained 28-31 inches of clinoptilolite.

Operations

- After a long weekend with no flow through the system, it was discovered that the clinoptilolite had packed into hard beds in each column. The material was again fluidized but it was decided to maintain flow through the weekends for the remainder of the test.
- It was found that the maximum flow without overflowing the columns was 17 gpm. The flow was set at 16-17 gpm. Flows and other field data are summarized in Table 1.
- When each sample was taken, an operator recorded the influent pH and specific conductance (SC), and Column 5 effluent pH, temperature and SC, along with the flow rate and total flow readings.
- The flow rate was reduced to 4 gpm on Day 4 of the test, December 3, 2010, to maintain a minimum flow through the columns over the weekend and avoid bed packing.
- It was decided to maintain flow at 4 gpm for a week to see whether this would improve thallium adsorption in the columns.
- After results showed that thallium removal improved at lower flow rates, the flow was increased back to 17 gpm for one day to confirm these results.
- After higher thallium concentrations were confirmed at high flow rates, the system was operated at 4-5 gpm for the remainder of the test.
- "Breakthrough" was defined as the time when thallium was first detected (the concentration exceeded the detection limit). The pilot test was operated until February 2, 2011 (65 days), when consistent breakthrough was seen from Column 5 at the minimum detection limit of 0.0002 mg/L. A total of 486,340 gallons were treated through the system (Tables 1 and 2).

TABLE 1. PILOT TEST #1 FIELD DATA SHEET

			Influent		Col. 5 Effluent			Sampling		
Day	Flow (gpm)	Total Flow	pH	SC	pH	T (^oC)	SC	Date	Time	Comments
0										
1	16.5	27,050	7.91	2920	8.21	8.3	2380	30-Nov	9:00 AM	Influent for Tl and commons; each column effluent for Tl
2	16	50,260	8.01	2630	8.33	5.2	2450	1-Dec	9:00 AM	Each column effluent for Tl
3	16.5	73,770	7.78	2460	8.08	6.2	2600	2-Dec	9:00 AM	Influent for Tl and commons; sample each column for Tl
4	4	80,500	7.99	2620	8.27	6.0	2650	3-Dec	9:00 AM	Sample each column effluent for Tl daily until breakthrough is reached
7	4	96,300	7.61	2680	8.20	5.3	2460	6-Dec	9:00 AM	
8	4	101,020	8.13	2390	7.86	6.8	2500	7-Dec	9:00 AM	
9	4	107,710	8.10	2660	8.30	6.3	2480	8-Dec	9:00 AM	
10	4.1	113,710	7.88	2400	8.09	6.6	2530	9-Dec	9:00 AM	
11	17	137,690	7.91	2530	8.16	4.2	2540	10-Dec	9:00 AM	
14	3.8	154,220	7.99	2460	8.19	5.9	2530	13-Dec	9:00 AM	
15	4.3	160,370	8.22	2450	8.04	5.2	2370	14-Dec	9:00 AM	
16	4.25	166,490	8.13	2460	7.99	5.2	2555	15-Dec	9:00 AM	
17	4.25	172,610	8.18	2520	8.09	5.7	2530	16-Dec	9:00 AM	
18	4.9	179,680	7.70	2590	7.68	7.1	2610	17-Dec	9:00 AM	
21	5	201,150	8.25	2690	8.03	5.2	2560	20-Dec	9:00 AM	
22	5	208,350	8.21	2590	8.05	5.8	2650	21-Dec	9:00 AM	
23	5	215,530	8.17	2450	7.98	6.1	2470	22-Dec	9:00 AM	
24	5	222,650	8.25	2450	8.07	5.2	2540	23-Dec	9:00 AM	
29	5	257,670	8.09	2700	8.27	4.9	2600	28-Dec	9:00 AM	
30	5	264,490	8.02	2580	7.93	4.7	2660	29-Dec	9:00 AM	
31	4.7	271,270	8.12	2510	8.01	6.1	2650	30-Dec	9:00 AM	
35	5	300,660	8.22	2460	8.01	4.7	2510	3-Jan	11:00 AM	
36	5	307,360	8.56	2530	7.98	5.0	2560	4-Jan	8:00 AM	
37	5.2	314,990	8.23	2390	8.03	4.4	2420	5-Jan	8:00 AM	
38	5.3	322,650	8.18	2460	8.13	2.6	2600	6-Jan	8:00 AM	
39	4.9	329,960	8.14	2580	8.08	5.6	2650	7-Jan	9:00 AM	
42	5	350,740	8.12	2370	7.77	4.8	2550	10-Jan	8:00 AM	
43	4.8	357,670	8.06	2400	7.74	4.7	2390	11-Jan	8:00 AM	
44	4.9	364,680	7.88	2500	7.81	4.8	2520	12-Jan	8:00 AM	
45	5	371,670	8.04	2490	7.85	4.2	2540	13-Jan	8:00 AM	
46	5	378,910	7.81	2510	8.08	5.2	2550	14-Jan	9:00 AM	
49	5	399,330	8.10	2670	7.94	5.6	2620	17-Jan	8:00 AM	
50	4.8	406,200	8.08	2670	7.91	4.1	2650	18-Jan	8:00 AM	
51	4.83	413,160	8.21	2530	8.02	4.3	2560	19-Jan	8:00 AM	
52								20-Jan		Influent line frozen

53								21-Jan		Influent line frozen

TABLE 1. PILOT TEST #1 FIELD DATA SHEET (continued)

			Influent		Col. 5 Effluent			Sampling		
Day	**Flow (gpm)**	**Total Flow**	**pH**	**SC**	**pH**	**T (^oC)**	**SC**	**Date**	**Time**	**Comments**
56								24-Jan		influent line frozen
57	5	428,070	8.33	2440	8.37	4.3	2540	25-Jan	8:00 AM	
58	4.6	434,740	7.85	2590	8.06	5.4	2580	26-Jan	8:00 AM	
59	5.2	442,240	7.82	2530	8.01	5.4	2560	27-Jan	8:00 AM	
60	5.2	449,770	7.72	2570	7.91	5.6	2580	28-Jan	8:00 AM	
63	5.1	472,090	8.00	2580	8.80	4.5	2600	31-Jan	8:00 AM	
64	4.9	479,130	7.79	2510	7.99	4.1	2650	1-Feb	8:00 AM	
65	4.9	486,340	7.67	2670	7.85	4.2	2610	2-Feb	8:30 AM	

TABLE 2. PILOT TEST #1 LAB RESULTS

			Tl Conc. (mg/L) from Column #					
Date	**Day**	**Gallons**	**In**	**1**	**2**	**3**	**4**	**5**
11/29/10	0							
11/30/10	1	27,050	0.623	0.107	0.006	<0.002	<0.002	<0.002
12/1/10	2	50,260		0.145	0.013	0.003	<0.002	<0.002
12/2/10	3	73,770		0.159	0.02	0.003	<0.002	<0.002
12/6/10	7	96,300	0.612	0.057	0.009	<0.002	<0.002	<0.0002
12/7/10	8	101,020		0.047	0.009	<0.002	<0.002	<0.0002
12/8/10	9	107,710		0.049	0.009	<0.002	<0.002	<0.0002
12/9/10	10	113,710		0.054	0.008	<0.002	<0.002	<0.0002
12/10/10	11	137,690		0.205	0.029	0.006	<0.002	0.0005
12/13/10	14	154,220		0.116	0.017	<0.002	<0.002	<0.0002
12/14/10	15	160,370		0.108	0.018	<0.002	<0.002	<0.0002
12/15/10	16	166,490		0.104	0.017	<0.002	<0.002	<0.0002
12/16/10	17	172,610						<0.0002
12/17/10	18	179,680						<0.0002
12/20/10	21	201,150						<0.0002
12/21/10	22	208,350	0.608					<0.0002
12/22/10	23	215,530						<0.0002
12/23/10	24	222,650						<0.0002
12/28/10	29	257,670						<0.0002
12/29/10	30	264,490	0.588					0.0002
12/30/10	31	271,270						<0.0002
1/3/11	35	300,660				0.0038		0.0002
1/4/11	36	307,360	0.595			0.0085		0.0003
1/5/11	37	314,990		0.294	0.083	0.006	<0.002	<0.0002
1/6/11	38	322,650				0.0091		<0.0002
1/7/11	39	329,960				0.0144		0.0002
1/10/11	42	350,740				0.0069		<0.0002
1/11/11	43	357,670				0.007		0.0004
1/12/11	44	364,680		0.299	0.069	0.007	<0.002	0.0002
1/13/11	45	371,670				0.0083		<0.0002
1/14/11	46	378,910				0.0079		<0.0002
1/17/11	49	399,330				0.0102		<0.0002
1/18/11	50	406,200				0.0205		<0.0002
1/19/11	51	413,160		0.330	0.083	0.019	<0.002	<0.0002
1/25/11	57	428,070		0.293	0.098	0.017	0.003	0.0004
1/26/11	58	434,740						
1/27/11	59	442,240						
1/28/11	60	449,770						
1/31/11	63	472,090		0.281	0.086	0.013	0.002	0.0002
2/2/11	65	486,340	0.568	0.324	0.090	0.014	0.003	0.0004

Sampling and Analysis

- All water samples were filtered and sent to Energy Labs, with most submitted for rush (24-hour) analysis.
- We began the test by sampling effluent (overflow) from all five columns every day, using the standard detection limit of 0.002 mg/L. After several days, we requested the minimum detection limit of 0.0002 mg/L for Column 5 samples.
- Influent water from the pond was sampled on Day 1 and periodically throughout the test.

Results and Discussion

Field data from throughout the pilot test are shown in Table 1. SC remained near 2500 uS during the test, with little difference seen between the influent and Column 5 effluent. The Day 1 influent SC was 2920 uS but all other readings were less than 2700 uS.

pH values were near 8.0 throughout the test, with little difference between the influent and Column 5 effluent. The water temperature ranged from 2.6 to 8.3^{o}C during the test.

Thallium concentrations from all five columns are shown in Table 2. The influent concentration steadily decreased from 0.623 mg/L to 0.568 during the test, probably due to dilution from precipitation. Breakthrough was noted on Day 1 from Columns 1 and 2 at the higher flow rate of 16 gpm, at a total flow of 27,050 gallons. Concentrations decreased substantially when the flow rate decreased to 4 gpm on Day 7, but were still measurable in Columns 1 and 2. It is difficult to estimate when breakthrough from these columns would have occurred with an initial flow rate of 4 gpm.

Breakthrough from Column 3 was noted on Day 35, at a total flow of about 300,000 gallons (Table 2). Column 3 had last been sampled after 166,000 gallons, so breakthrough occurred sometime between 166,000 and 300,000 gallons.

Breakthrough from Column 4 was first noted on Day 57, after 428,000 gallons had been treated (Table 2). Breakthrough from the first four columns was compared to the standard detection limit of 0.002 mg/L.

At the lower detection limit of 0.0002 mg/L, Column 5 breakthrough was first noted on Day 11 after 137,000 gallons. This occurred, however, when the flow rate was temporarily increased to 17 gpm. Thallium was not again detected after Column 5 at this lower detection limit until Day 30 (264,000 gallons), as shown in Table 2. Periodic breakthrough was then seen throughout the test. The last three readings all had measurable thallium concentrations, suggesting that consistent breakthrough occurred at 428,000 gallons. These breakthrough marks are highlighted in yellow in Table 2.

Pilot test results are shown graphically in Figure 3, which shows the large effect of flow on thallium concentrations in Column 1. To better show the low-concentration data, the same results are shown in Figure 4 using a log scale.

FIGURE 3. PILOT TEST RESULTS – NORMAL SCALE

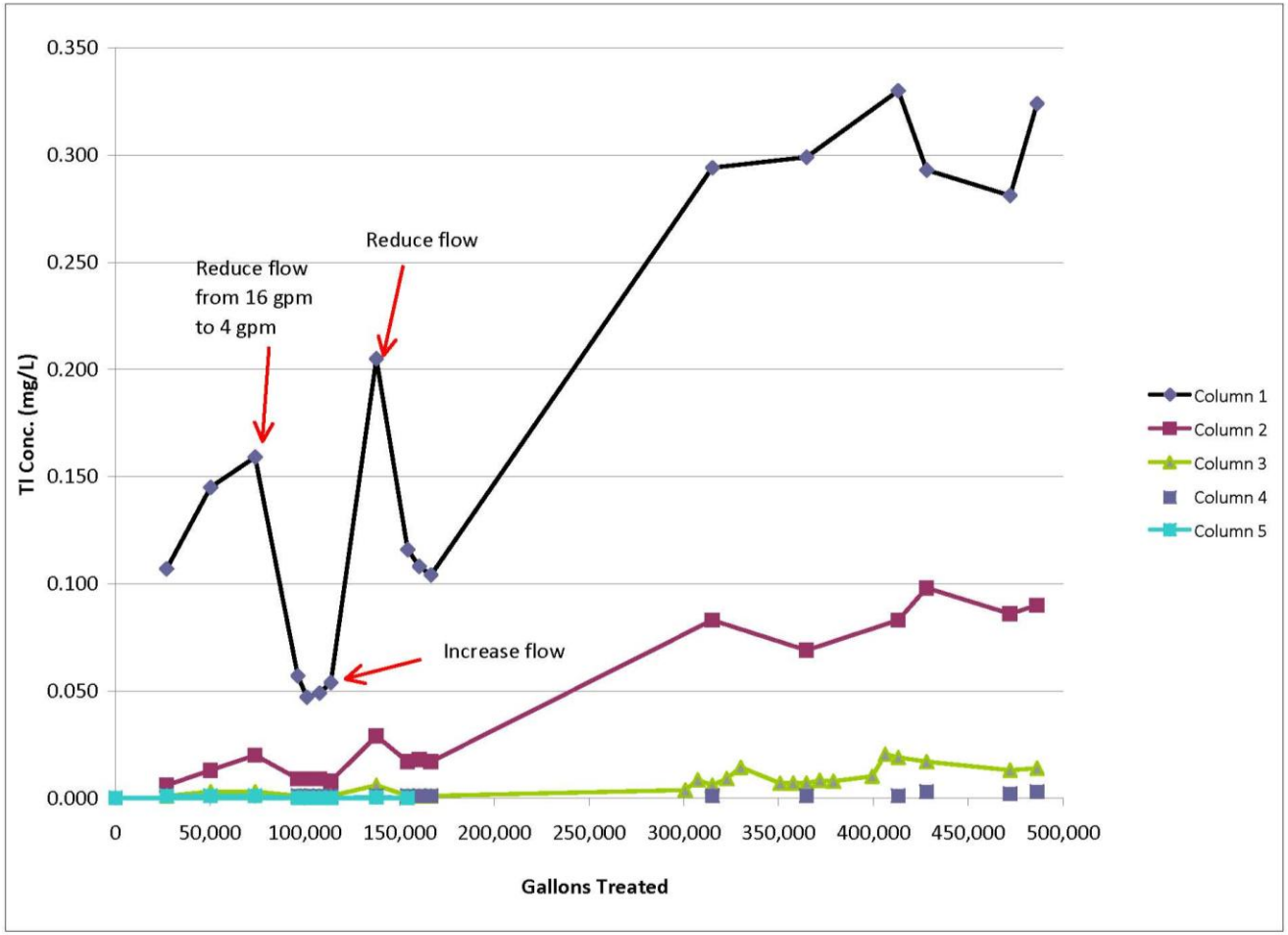
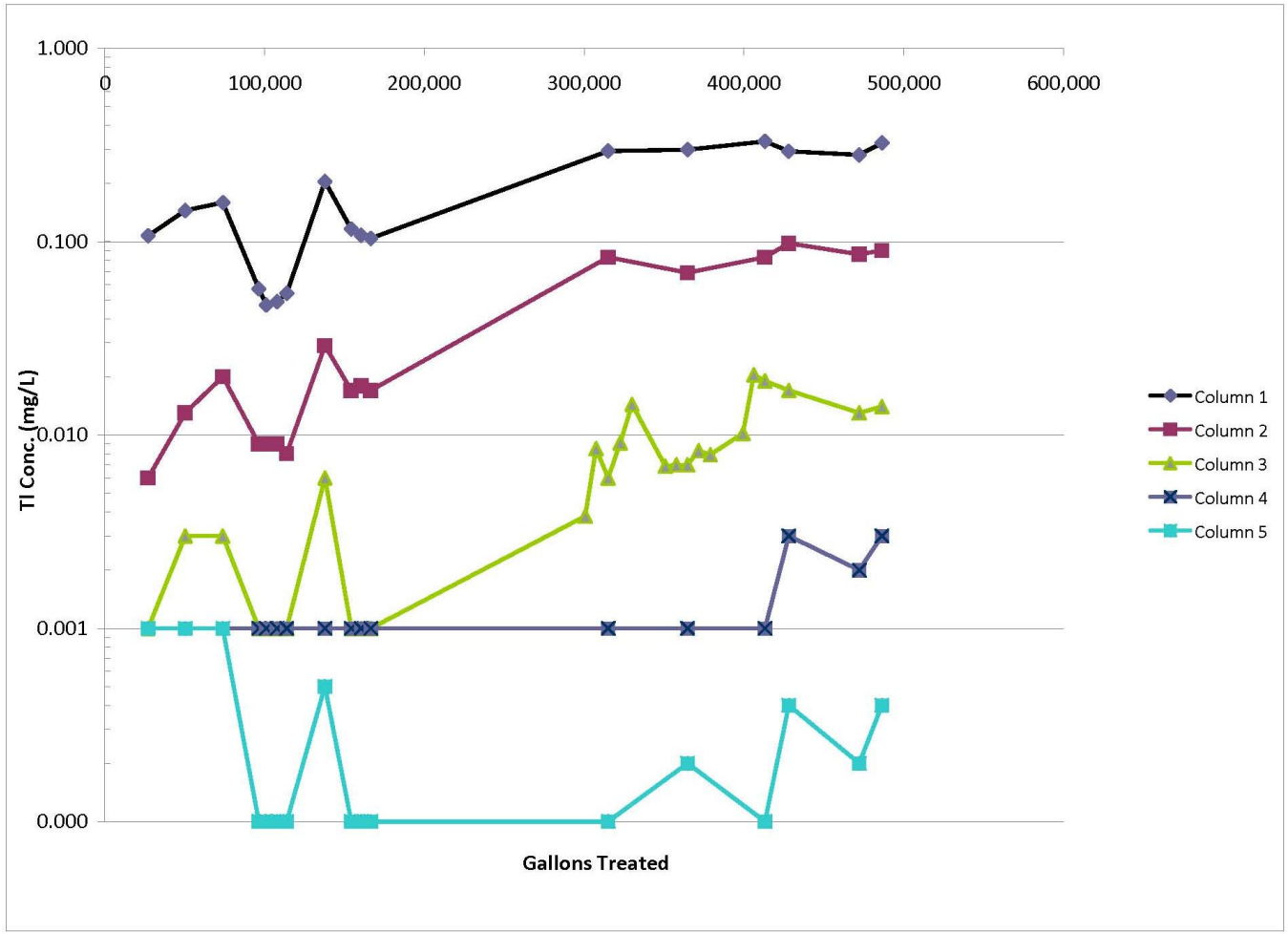


FIGURE 4. PILOT TEST #1 RESULTS – LOG SCALE



Other Parameters

Samples were taken on 11/30/10, near the beginning of the test, and analyzed for parameters other than thallium. These results are shown in Table 3.

TABLE 3. OTHER PARAMETERS
Sampling on 11/30/10

	Concentration (mg/L)	
Parameter	**Influent**	**Column 5**
pH (s.u.)	7.9	
Conductivity (uS)	2340	
Alkalinity	265	
Bicarbonate	323	
Sulfate	1200	
Hardness	1370	
Phosphorus	0.009	
Arsenic	0.011	0.006
Calcium	339	
Magnesium	127	
Potassium	7	
Selenium	0.025	0.029
Sodium	41	

Zeolite Analysis

Near the conclusion of the test, the Toxicity Characteristic Leaching Procedure (TCLP) and Synthetic Precipitation Leaching Procedure (SPLP) were performed on a sample of the Column 1 zeolites, which would have contained the highest loading of any material used. This was a composite sample from within the column, as the zeolites were mixed with an air hose prior to sampling. Those leaching results for the eight RCRA metals plus thallium are shown in Table 4. Since all metals other than thallium were non-detect, this spent material would be classified as nonhazardous waste. The TCLP test is conducted with a ratio of 50 g of zeolite to 1 L of leach solution. Assuming that the 50 g sample of zeolite leached in the TCLP test contains 3,760 mg/kg thallium (as measured in the whole rock analysis described below), the zeolite sample would have contained a total of approximately 188 mg of thallium prior to the leach test. In the TCLP test, 2.66 mg or 1.4 percent of thallium was leached from the zeolite sample. These leach results are similar to previous leach tests of St. Cloud chabazite and suggests that the thallium retained by the zeolites is not readily leachable.

TABLE 4. LEACHING RESULTS
Column 1, sampled on 1/20/11

	Concentration (mg/L)	
Metal	**TCLP**	**SPLP**
Arsenic	< 0.5	< 0.5
Barium	< 10	< 10
Cadmium	< 0.1	< 0.1
Chromium	< 0.5	< 0.5
Lead	< 0.5	< 0.5
Mercury	< 0.02	< 0.02
Selenium	< 0.1	< 0.1
Silver	< 0.5	< 0.5
Thallium	2.66	< 0.5

At the conclusion of the test, samples from each column were directly analyzed for the same parameters by strong acid digestion ("whole rock analysis"); results are in Table 5. Each column sample was a blended composite from throughout the column, as the material had been removed from the columns and placed in bags. The decreasing amounts of thallium adsorbed to the zeolites are in line with the decreasing concentrations exiting each successive column (Figure 4).

TABLE 5. WHOLE ROCK ANALYSIS
Sampled on 2/2/11

	Concentration (mg/kg)				
Metal	**Col. 1**	**Col. 2**	**Col. 3**	**Col. 4**	**Col. 5**
Arsenic	13	13	10	13	13
Barium	784	660	603	805	826
Cadmium	< 1	< 1	< 1	< 1	< 1
Chromium	< 5	< 5	< 5	< 5	< 5
Lead	8	8	7	11	15
Mercury	< 1	< 1	< 1	< 1	< 1
Selenium	< 5	< 5	< 5	< 5	< 5
Silver	< 5	< 5	< 5	< 5	< 5
Thallium	3760	1010	170	33	10

A thallium mass balance from each column shows that we removed the following quantities of thallium:

- Column 1: 400 lbs * 1 kg/2.2 lb * 3760 mg/kg = 684,000 mg Tl
- Column 2: 400/2.2 * 1010 = 184,000 mg
- Column 3: 400/2.2 * 170 = 31,000 mg
- Column 4: 400/2.2 * 33 = 6,000 mg
- Column 5: 400/2.2 * 10 = 2,000 mg

907,000 mg

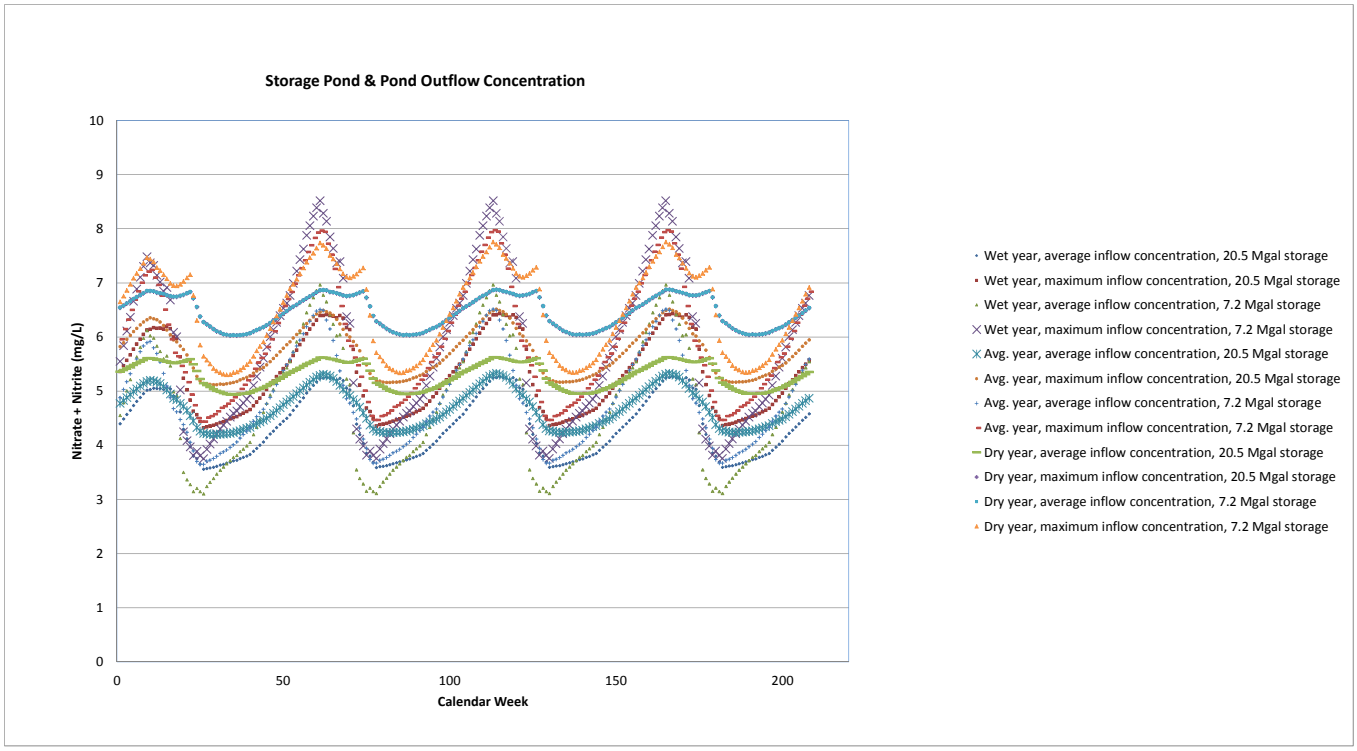
Now we can compare this to the amount theoretically removed from the water. The influent thallium concentration steadily decreased during the test; let's assume it was the average of the high reading at the beginning (0.623 mg/L) and the low reading at the end (0.568 mg/L), or 0.596 mg/L. According to our flowmeter, we treated 486,340 gallons. Therefore, we removed the following quantity of thallium:

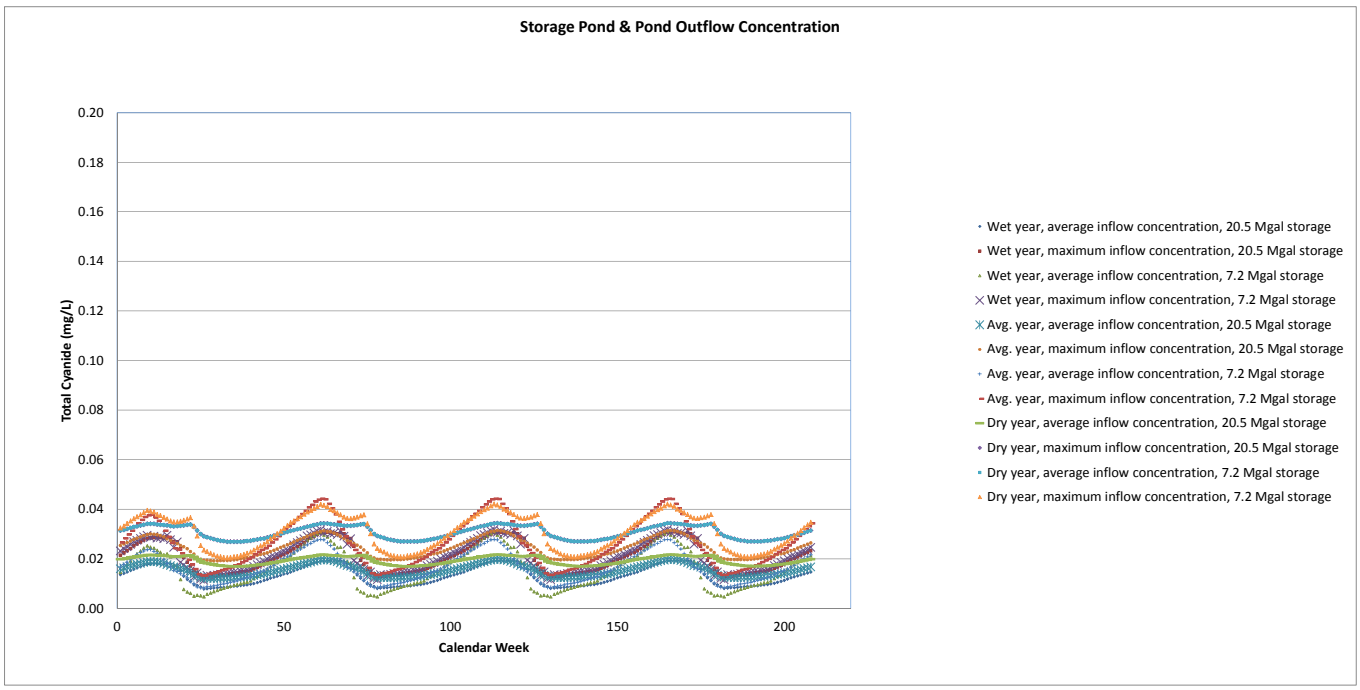
0.596 mg/L * 486,340 gal * 3.785 L/gal = **1,097,100 mg**

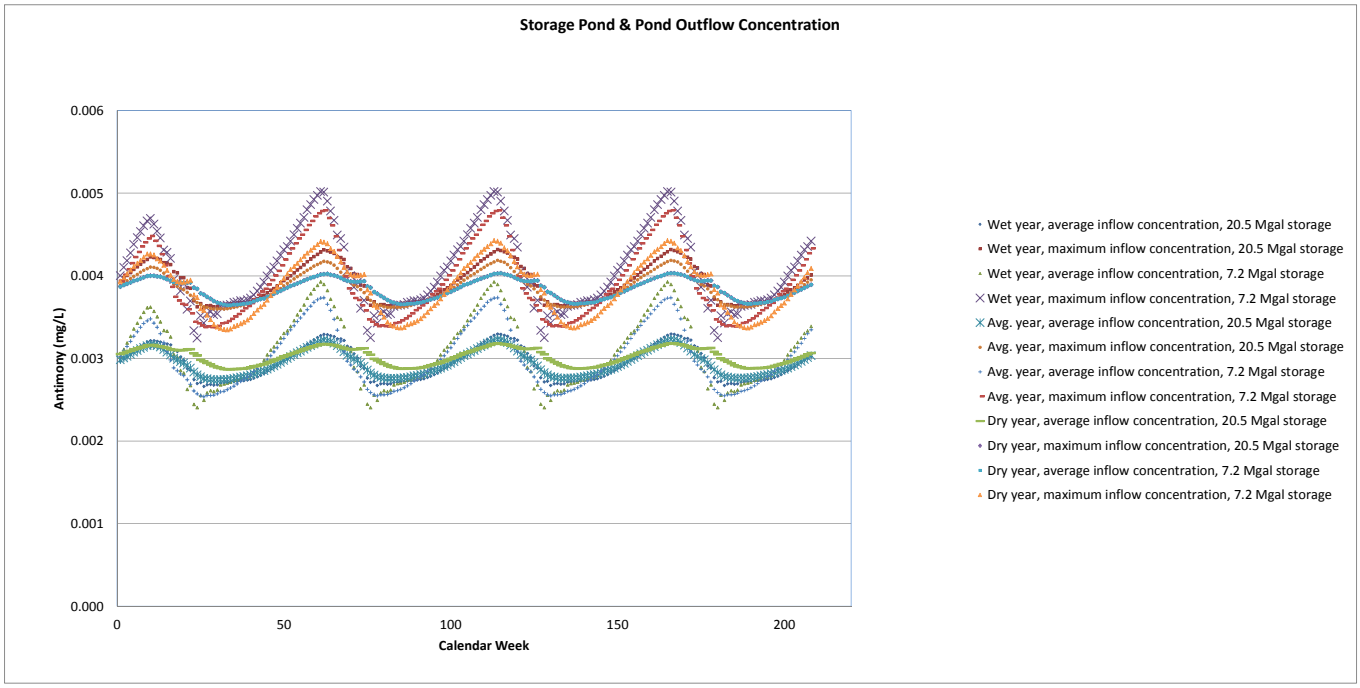
This quantity is 21% higher than the 907,000 mg calculated from the whole rock analysis. Both numbers are in the same range but it is unclear why the difference is so high.

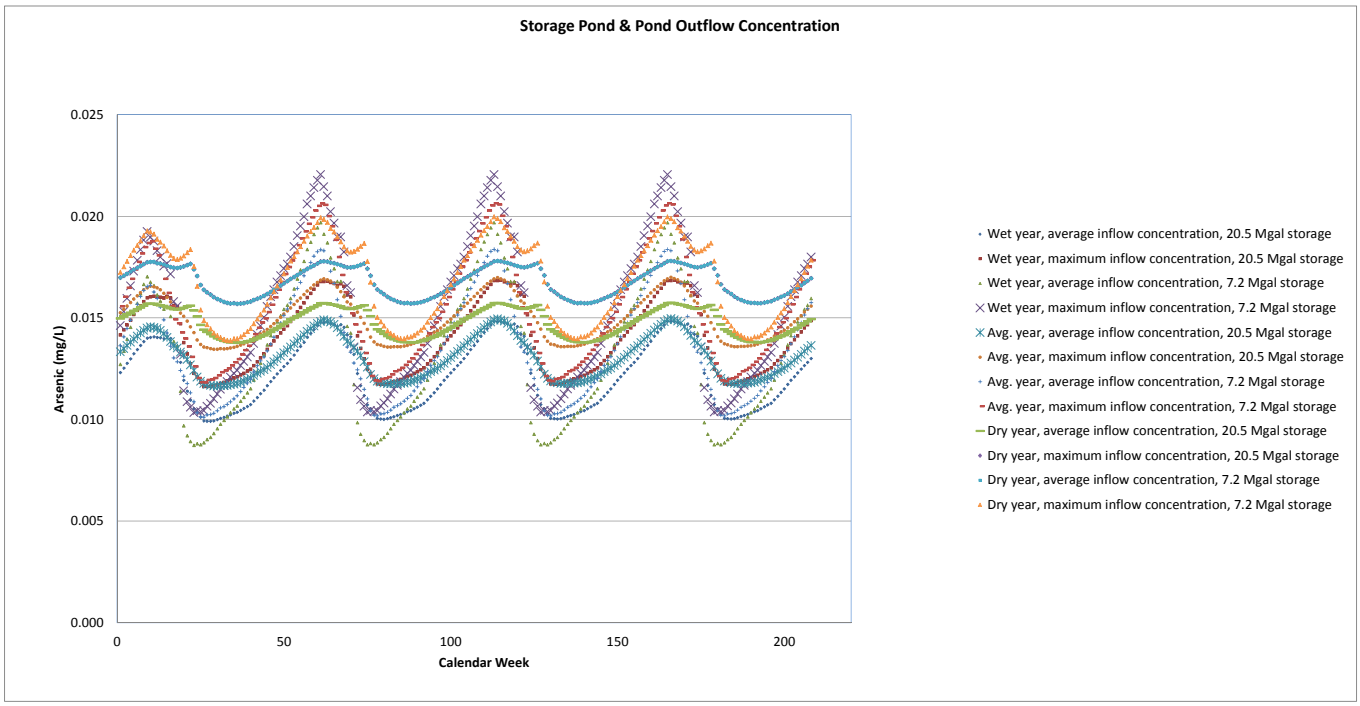
Adsorption Capacity

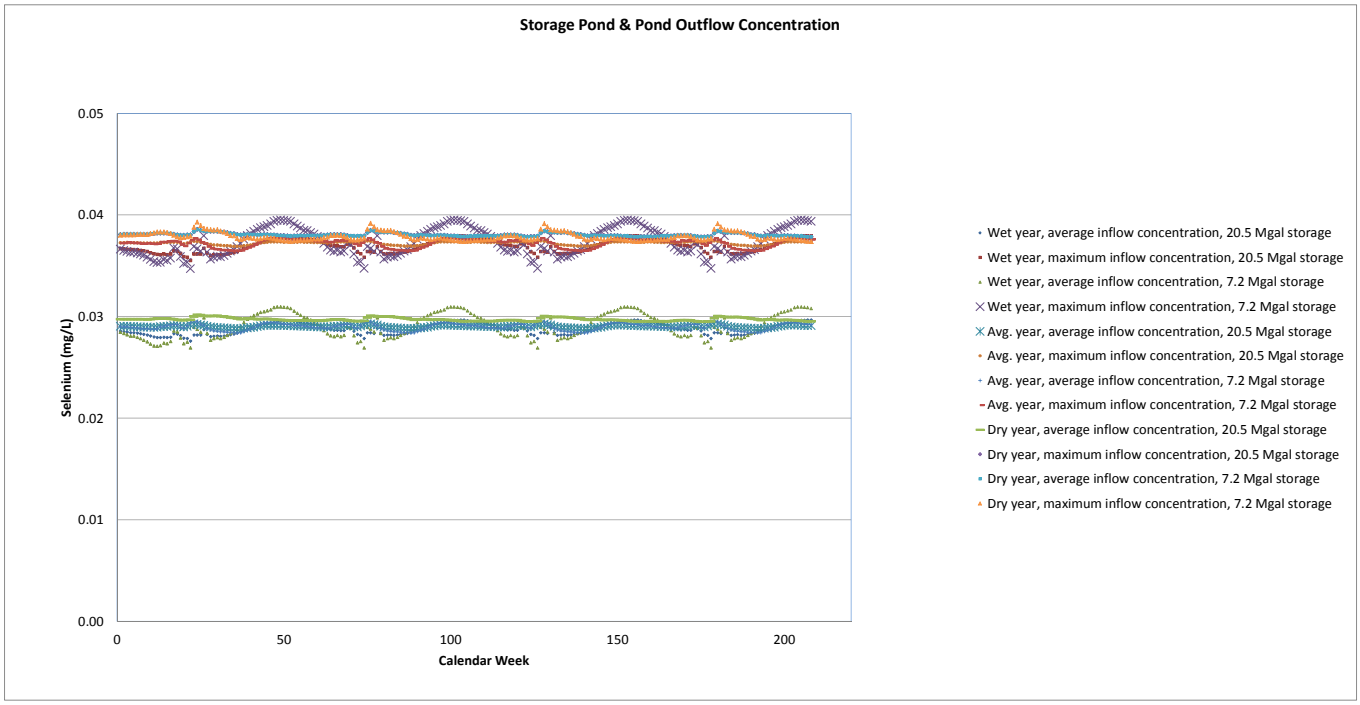
The Table 5 numbers show a thallium adsorption capacity of 3760 mg/kg (0.376%) in Column 1, with lesser amounts in the following columns. At the beginning of the pilot test, we had estimated thallium loading of 0.2% in the lead column, based on bench testing and the adsorption isotherms generated. Therefore, we obtained substantially better results in the pilot test than anticipated. Had we run another iteration of Pilot Test #1 with partially loaded zeolites, I anticipate we would have seen breakthrough before 486,000 gallons. This would mean a slightly lower loading rate.

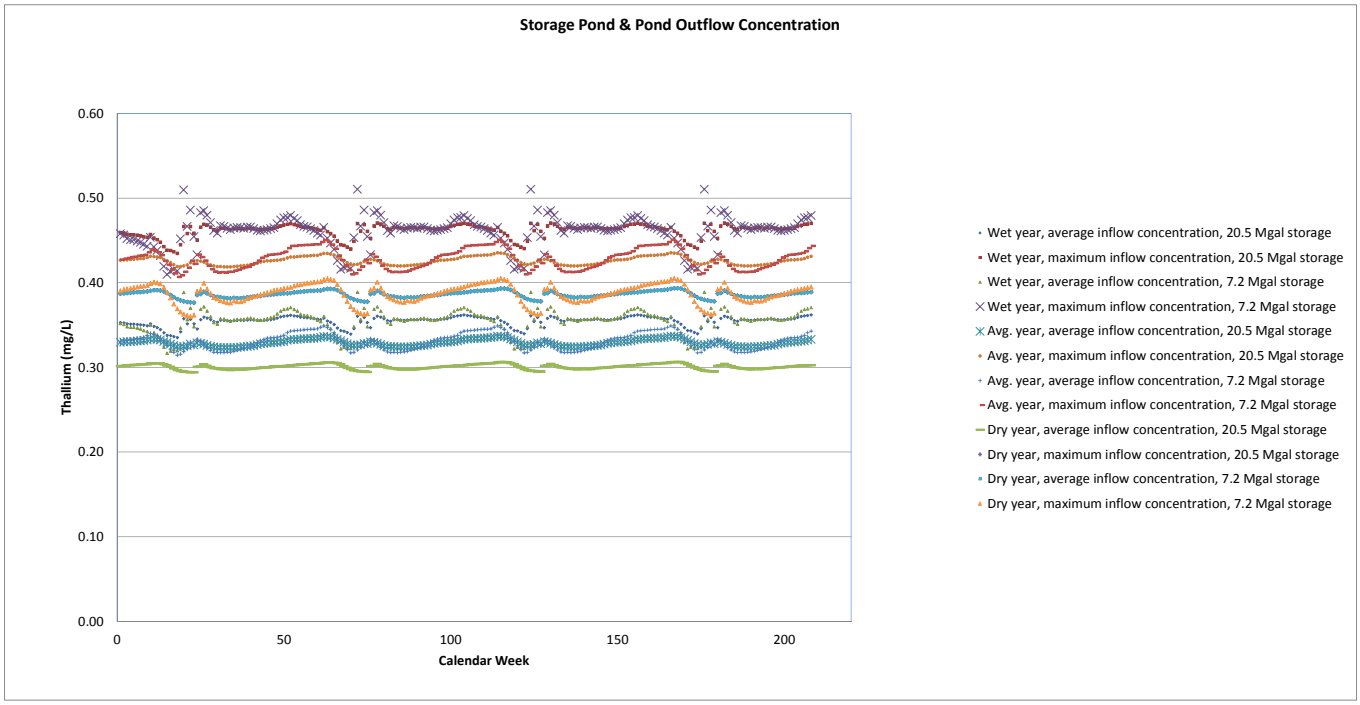

Storage Pond & Pond Outflow Concentration
Nitrate + Nitrite (mg/L)
Calendar Week
0
1
2
3
4
5
6
7
8
9
10
0
50
100
150
200
Wet year, average inflow concentration, 20.5 Mgal storage
Wet year, maximum inflow concentration, 20.5 Mgal storage
Wet year, average inflow concentration, 7.2 Mgal storage
Wet year, maximum inflow concentration, 7.2 Mgal storage
Avg. year, average inflow concentration, 20.5 Mgal storage
Avg. year, maximum inflow concentration, 20.5 Mgal storage
Avg. year, average inflow concentration, 7.2 Mgal storage
Avg. year, maximum inflow concentration, 7.2 Mgal storage
Dry year, average inflow concentration, 20.5 Mgal storage
Dry year, maximum inflow concentration, 20.5 Mgal storage
Dry year, average inflow concentration, 7.2 Mgal storage
Dry year, maximum inflow concentration, 7.2 Mgal storage

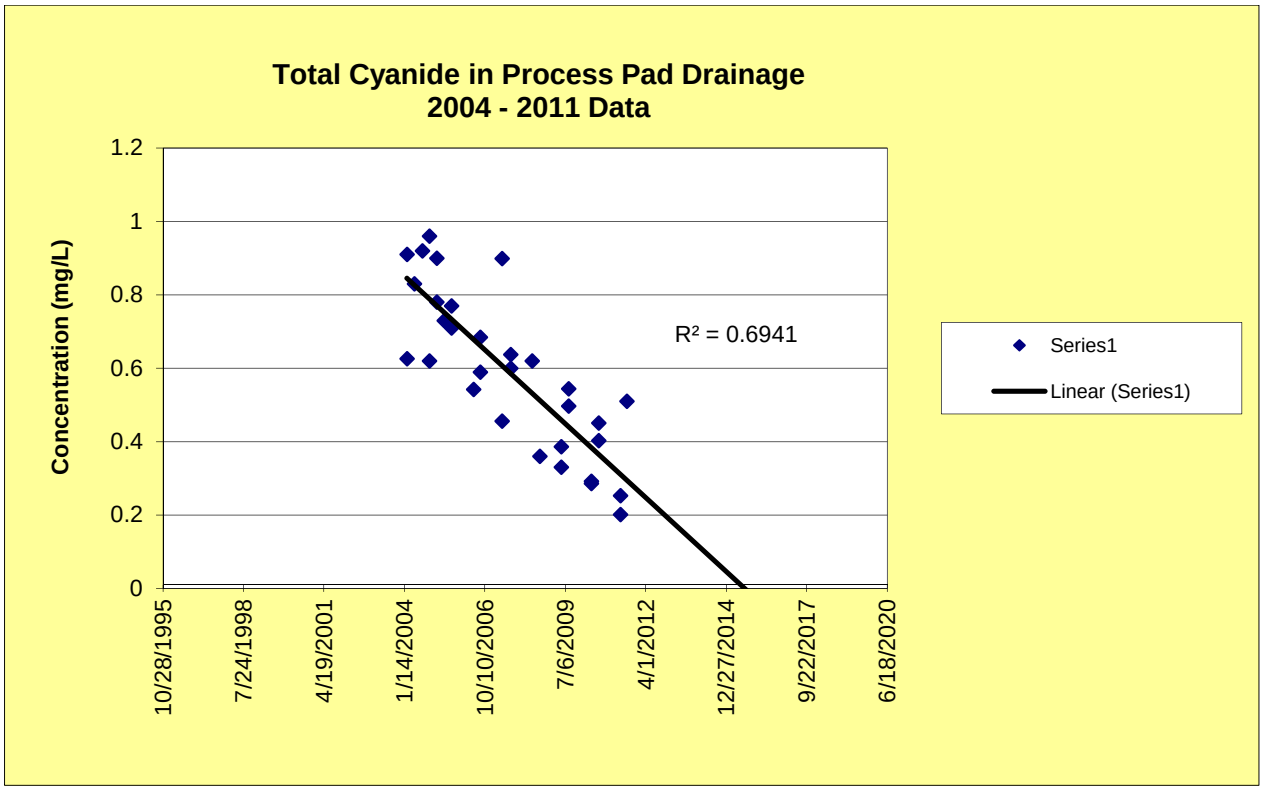

Storage Pond & Pond Outflow Concentration
Total Cyanide (mg/L)
Calendar Week
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
0.20
0
50
100
150
200
Wet year, average inflow concentration, 20.5 Mgal storage
Wet year, maximum inflow concentration, 20.5 Mgal storage
Wet year, average inflow concentration, 7.2 Mgal storage
Wet year, maximum inflow concentration, 7.2 Mgal storage
Avg. year, average inflow concentration, 20.5 Mgal storage
Avg. year, maximum inflow concentration, 20.5 Mgal storage
Avg. year, average inflow concentration, 7.2 Mgal storage
Avg. year, maximum inflow concentration, 7.2 Mgal storage
Dry year, average inflow concentration, 20.5 Mgal storage
Dry year, maximum inflow concentration, 20.5 Mgal storage
Dry year, average inflow concentration, 7.2 Mgal storage
Dry year, maximum inflow concentration, 7.2 Mgal storage

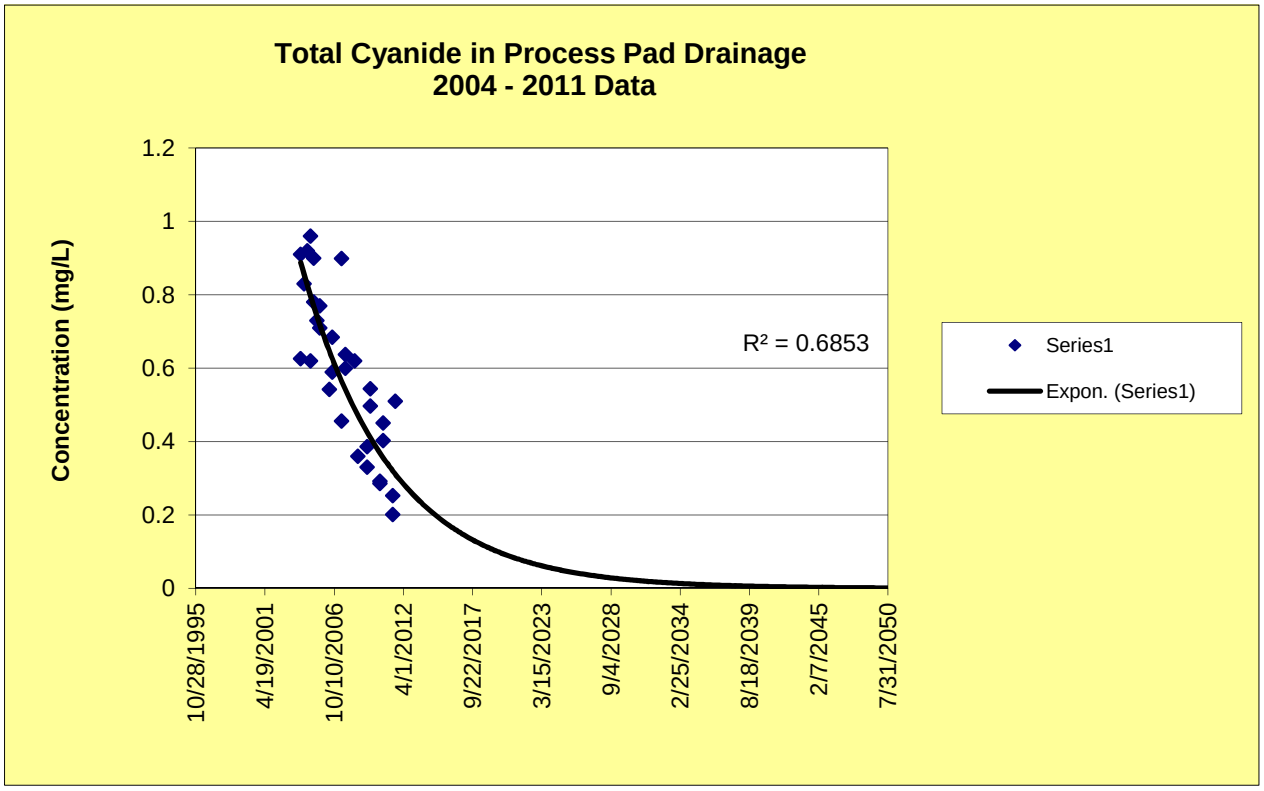

Storage Pond & Pond Outflow Concentration
Antimony (mg/L)
0.006
0.005
0.004
0.003
0.002
0.001
0.000
0
50
100
150
200
Calendar Week
Wet year, average inflow concentration, 20.5 Mgal storage
Wet year, maximum inflow concentration, 20.5 Mgal storage
Wet year, average inflow concentration, 7.2 Mgal storage
Wet year, maximum inflow concentration, 7.2 Mgal storage
Avg. year, average inflow concentration, 20.5 Mgal storage
Avg. year, maximum inflow concentration, 20.5 Mgal storage
Avg. year, average inflow concentration, 7.2 Mgal storage
Avg. year, maximum inflow concentration, 7.2 Mgal storage
Dry year, average inflow concentration, 20.5 Mgal storage
Dry year, maximum inflow concentration, 20.5 Mgal storage
Dry year, average inflow concentration, 7.2 Mgal storage
Dry year, maximum inflow concentration, 7.2 Mgal storage

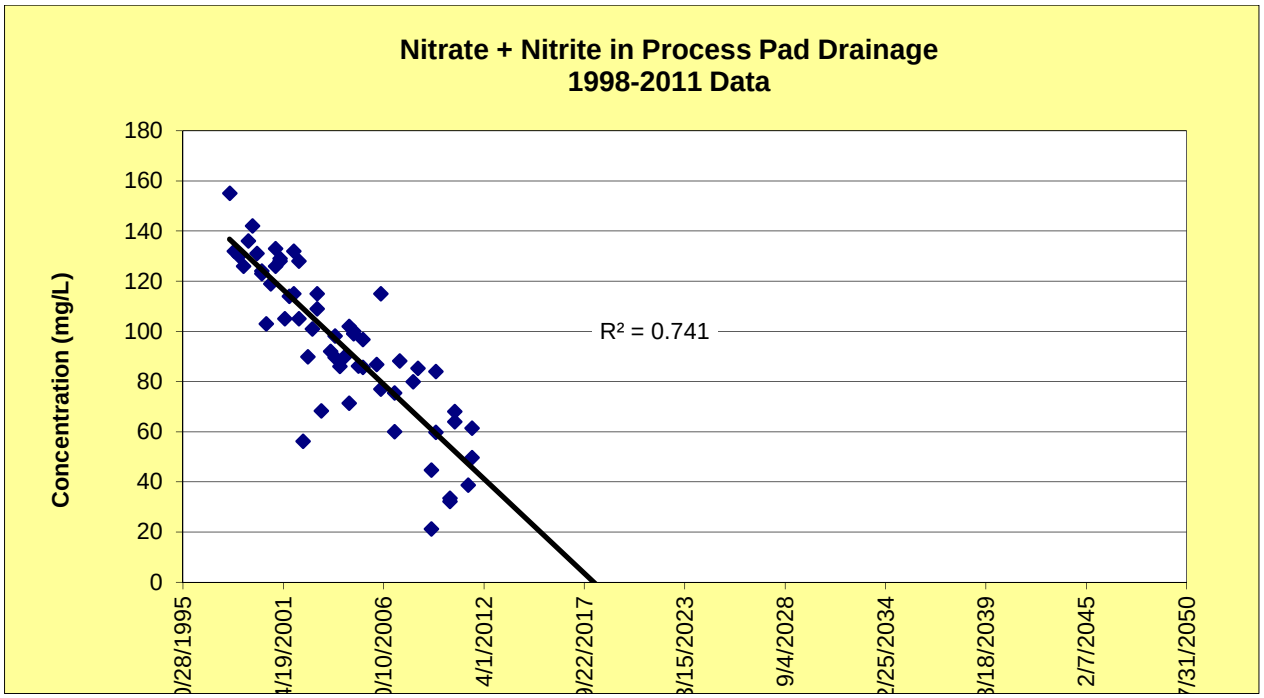

Storage Pond & Pond Outflow Concentration
Arsenic (mg/L)
0.025
0.020
0.015
0.010
0.005
0.000
0
50
100
150
200
Calendar Week
Wet year, average inflow concentration, 20.5 Mgal storage
Wet year, maximum inflow concentration, 20.5 Mgal storage
Wet year, average inflow concentration, 7.2 Mgal storage
Wet year, maximum inflow concentration, 7.2 Mgal storage
Avg. year, average inflow concentration, 20.5 Mgal storage
Avg. year, maximum inflow concentration, 20.5 Mgal storage
Avg. year, average inflow concentration, 7.2 Mgal storage
Avg. year, maximum inflow concentration, 7.2 Mgal storage
Dry year, average inflow concentration, 20.5 Mgal storage
Dry year, maximum inflow concentration, 20.5 Mgal storage
Dry year, average inflow concentration, 7.2 Mgal storage
Dry year, maximum inflow concentration, 7.2 Mgal storage

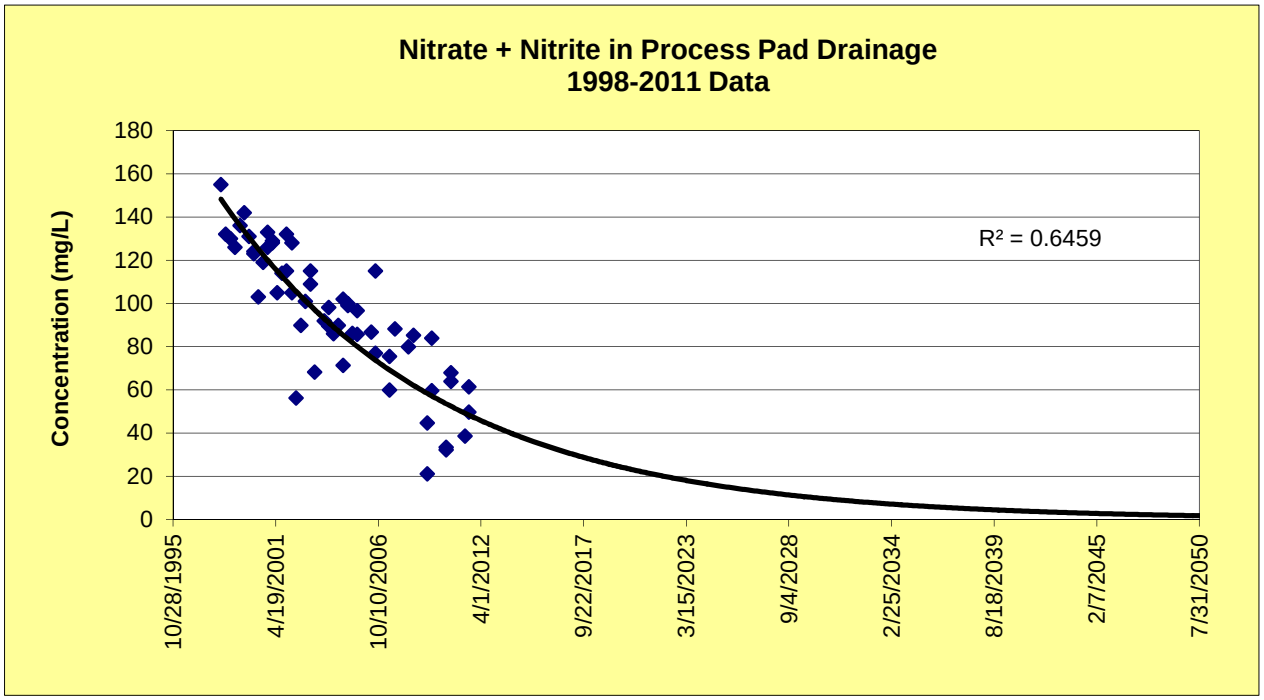

Storage Pond & Pond Outflow Concentration
Selenium (mg/L)
0.05
0.04
0.03
0.02
0.01
0.00
0
50
100
150
200
Calendar Week
Wet year, average inflow concentration, 20.5 Mgal storage
Wet year, maximum inflow concentration, 20.5 Mgal storage
Wet year, average inflow concentration, 7.2 Mgal storage
Wet year, maximum inflow concentration, 7.2 Mgal storage
Avg. year, average inflow concentration, 20.5 Mgal storage
Avg. year, maximum inflow concentration, 20.5 Mgal storage
Avg. year, average inflow concentration, 7.2 Mgal storage
Avg. year, maximum inflow concentration, 7.2 Mgal storage
Dry year, average inflow concentration, 20.5 Mgal storage
Dry year, maximum inflow concentration, 20.5 Mgal storage
Dry year, average inflow concentration, 7.2 Mgal storage
Dry year, maximum inflow concentration, 7.2 Mgal storage

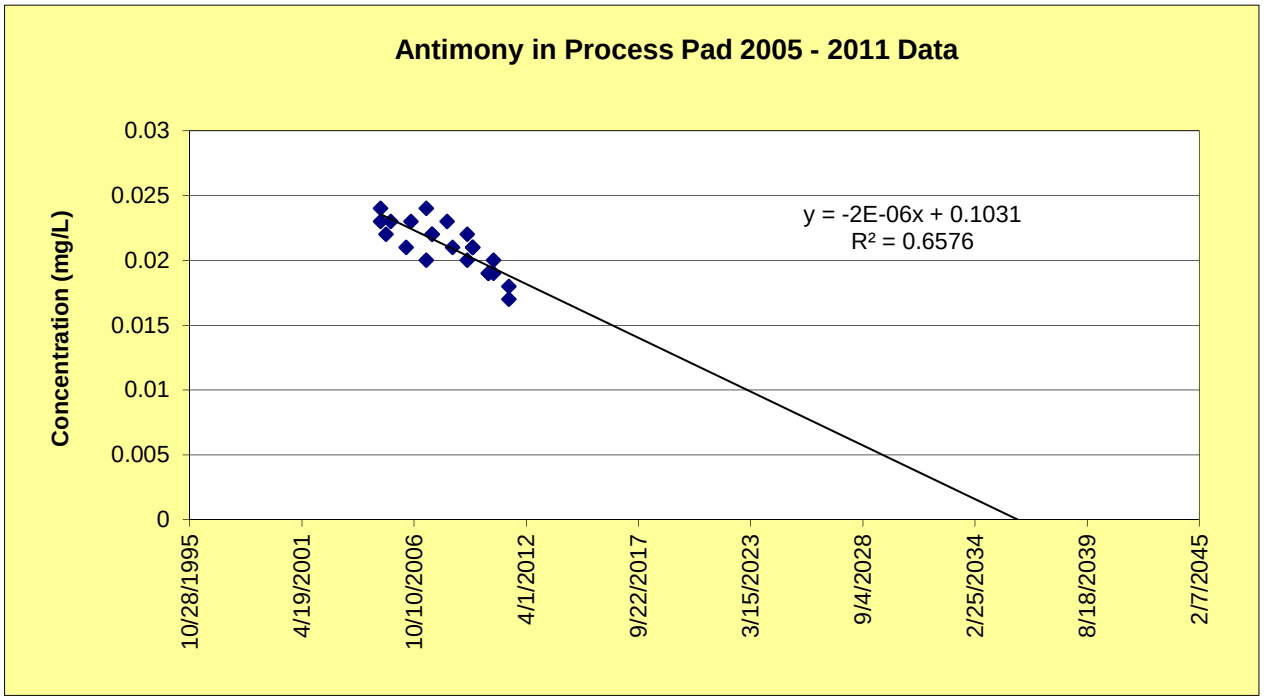

Storage Pond & Pond Outflow Concentration
Thallium (mg/L)
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0
50
100
150
200
Calendar Week
Wet year, average inflow concentration, 20.5 Mgal storage
Wet year, maximum inflow concentration, 20.5 Mgal storage
Wet year, average inflow concentration, 7.2 Mgal storage
Wet year, maximum inflow concentration, 7.2 Mgal storage
Avg. year, average inflow concentration, 20.5 Mgal storage
Avg. year, maximum inflow concentration, 20.5 Mgal storage
Avg. year, average inflow concentration, 7.2 Mgal storage
Avg. year, maximum inflow concentration, 7.2 Mgal storage
Dry year, average inflow concentration, 20.5 Mgal storage
Dry year, maximum inflow concentration, 20.5 Mgal storage
Dry year, average inflow concentration, 7.2 Mgal storage
Dry year, maximum inflow concentration, 7.2 Mgal storage

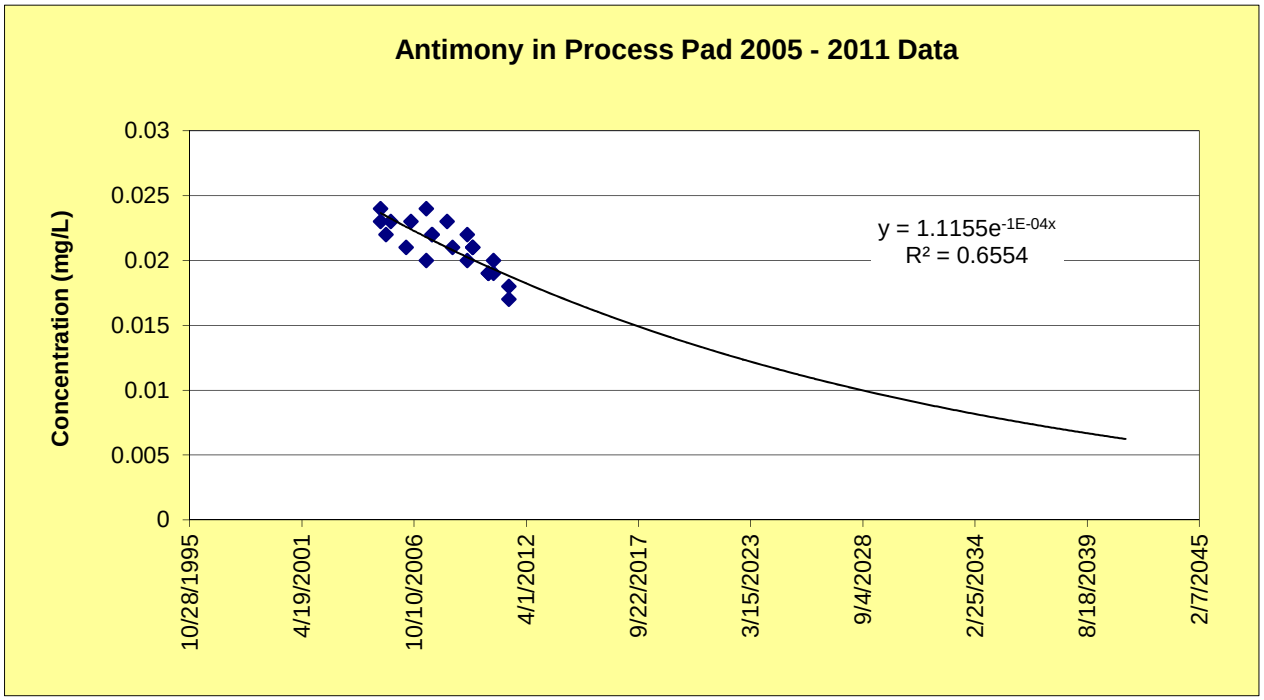

Total Cyanide in Process Pad Drainage
2004 - 2011 Data
Concentration (mg/L)
1.2
1
0.8
0.6
0.4
0.2
0
10/28/1995
7/24/1998
4/19/2001
1/14/2004
10/10/2006
7/6/2009
4/1/2012
12/27/2014
9/22/2017
6/18/2020
R² = 0.6941
Series1
Linear (Series1)

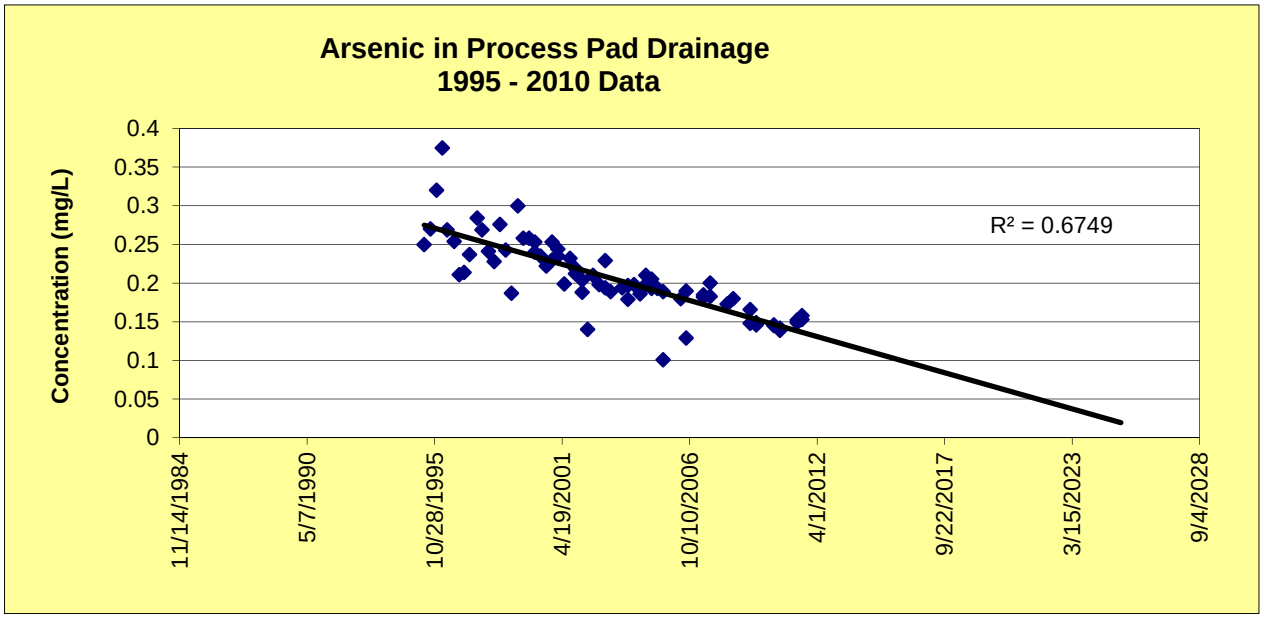

Total Cyanide in Process Pad Drainage
2004 - 2011 Data
Concentration (mg/L)
1.2
1
0.8
0.6
0.4
0.2
0
10/28/1995
4/19/2001
10/10/2006
4/1/2012
9/22/2017
3/15/2023
9/4/2028
2/25/2034
8/18/2039
2/7/2045
7/31/2050
R² = 0.6853
Series1
Expon. (Series1)

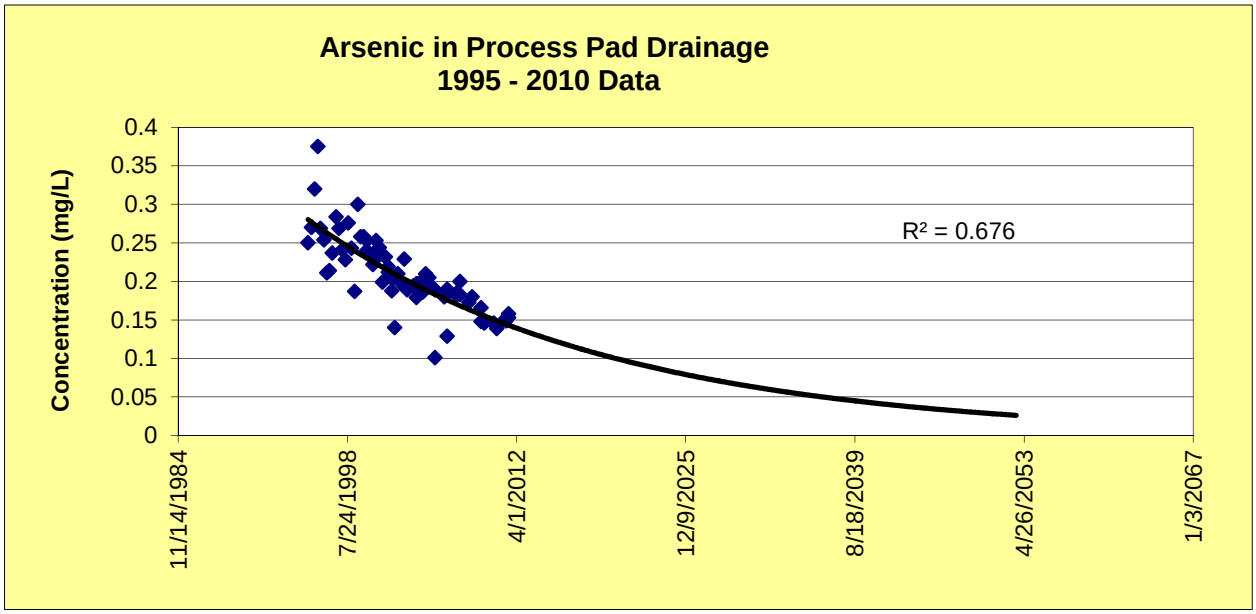

Nitrate + Nitrite in Process Pad Drainage
1998-2011 Data
Concentration (mg/L)
180
160
140
120
100
80
60
40
20
0
R² = 0.741
0/28/1995
4/19/2001
0/10/2006
4/1/2012
9/22/2017
3/15/2023
9/4/2028
2/25/2034
8/18/2039
2/7/2045
7/31/2050

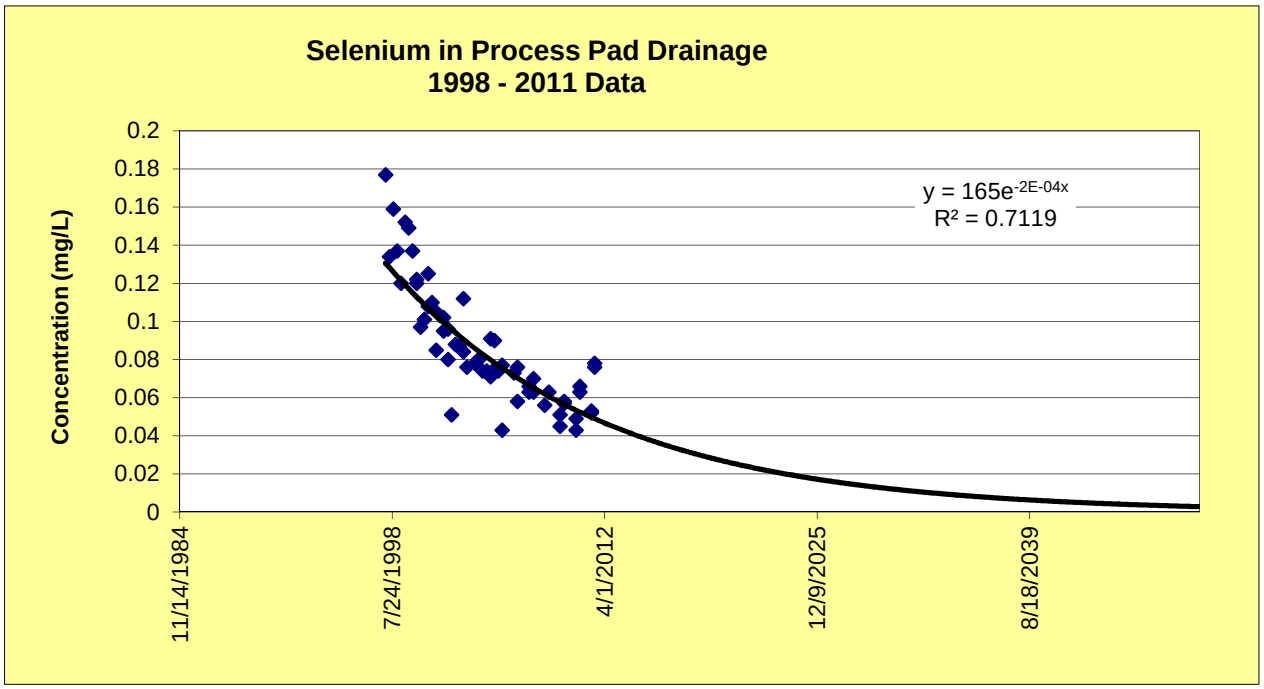

Nitrate + Nitrite in Process Pad Drainage
1998-2011 Data
Concentration (mg/L)
180
160
140
120
100
80
60
40
20
0
R² = 0.6459
10/28/1995
4/19/2001
10/10/2006
4/1/2012
9/22/2017
3/15/2023
9/4/2028
2/25/2034
8/18/2039
2/7/2045
7/31/2050

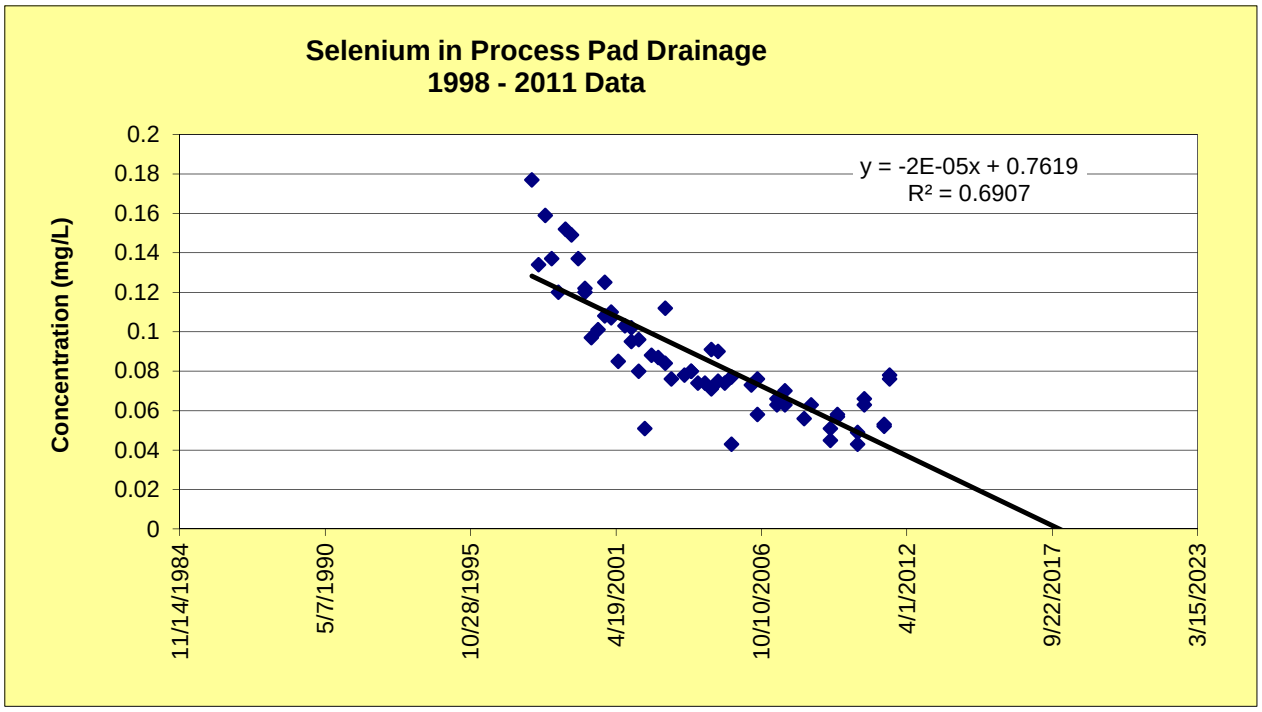

Antimony in Process Pad 2005 - 2011 Data
Concentration (mg/L)
0.03
0.025
0.02
0.015
0.01
0.005
0
y = -2E-06x + 0.1031
R² = 0.6576
10/28/1995
4/19/2001
10/10/2006
4/1/2012
9/22/2017
3/15/2023
9/4/2028
2/25/2034
8/18/2039
2/7/2045

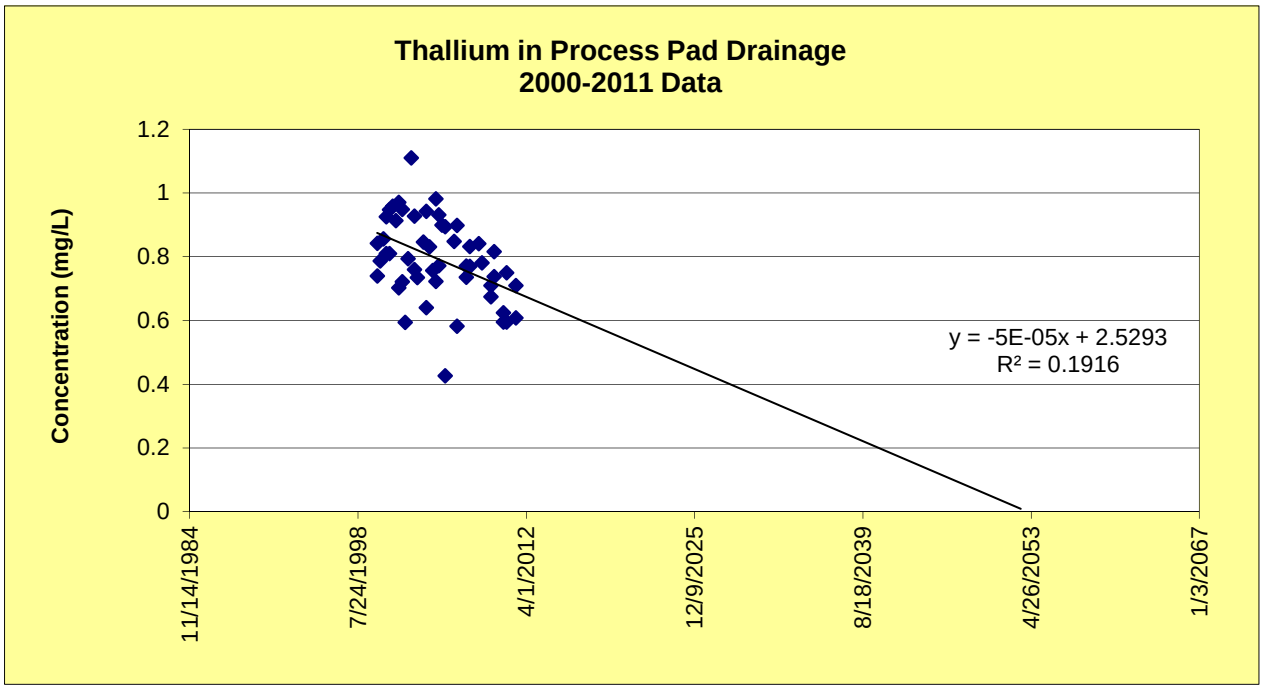

Antimony in Process Pad 2005 - 2011 Data
Concentration (mg/L)
0.03
0.025
0.02
0.015
0.01
0.005
0
y = 1.1155e-1E-04x
R² = 0.6554
10/28/1995
4/19/2001
10/10/2006
4/1/2012
9/22/2017
3/15/2023
9/4/2028
2/25/2034
8/18/2039
2/7/2045

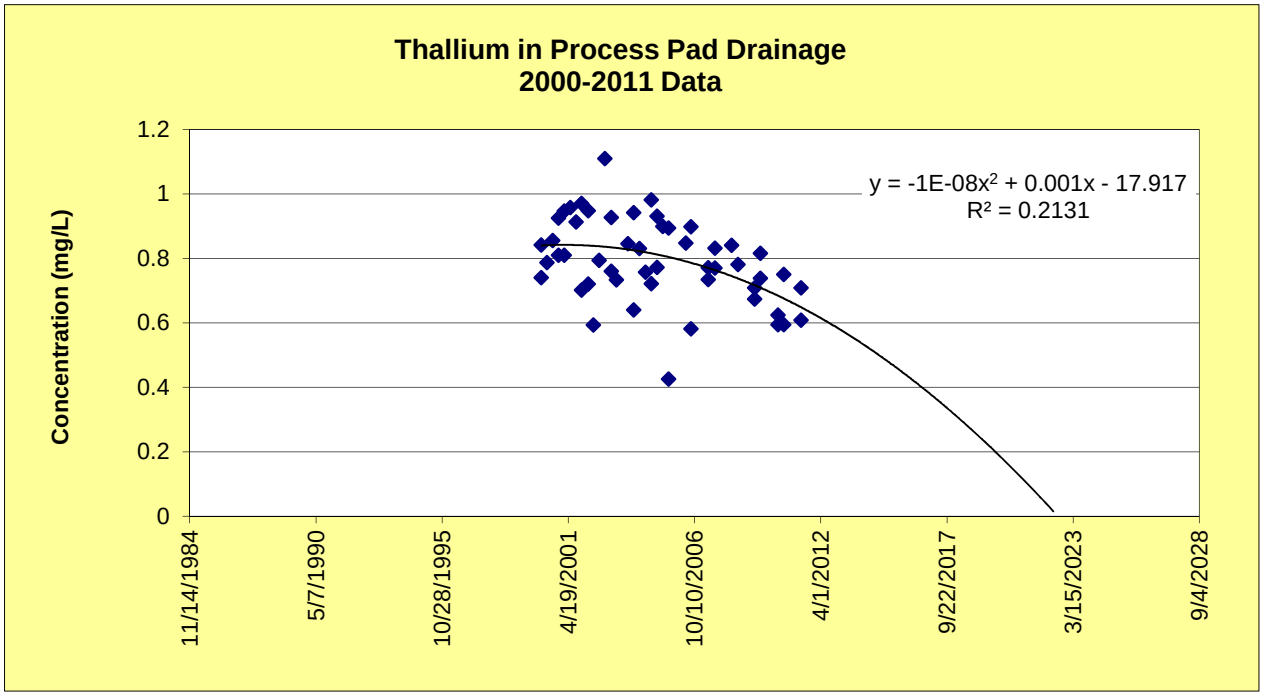

Arsenic in Process Pad Drainage
1995 - 2010 Data
Concentration (mg/L)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
R² = 0.6749
11/14/1984
5/7/1990
10/28/1995
4/19/2001
10/10/2006
4/1/2012
9/22/2017
3/15/2023
9/4/2028

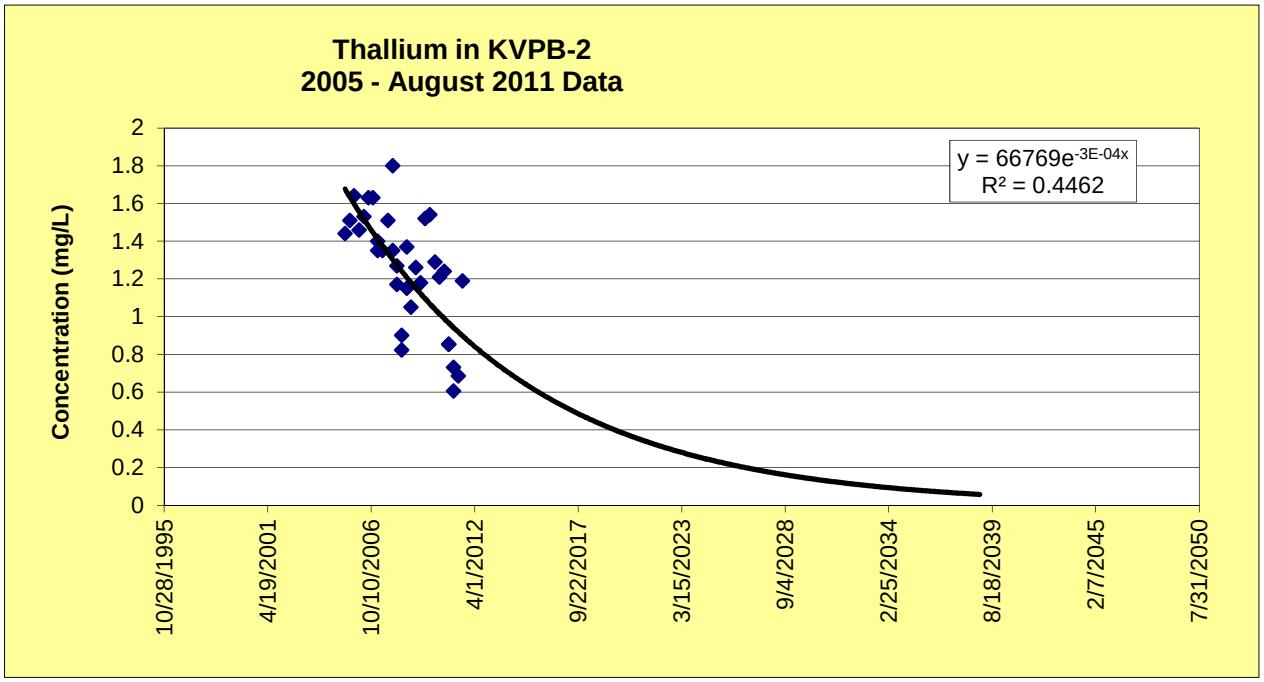

Arsenic in Process Pad Drainage
1995 - 2010 Data
Concentration (mg/L)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
R² = 0.676
11/14/1984
7/24/1998
4/1/2012
12/9/2025
8/18/2039
4/26/2053
1/3/2067

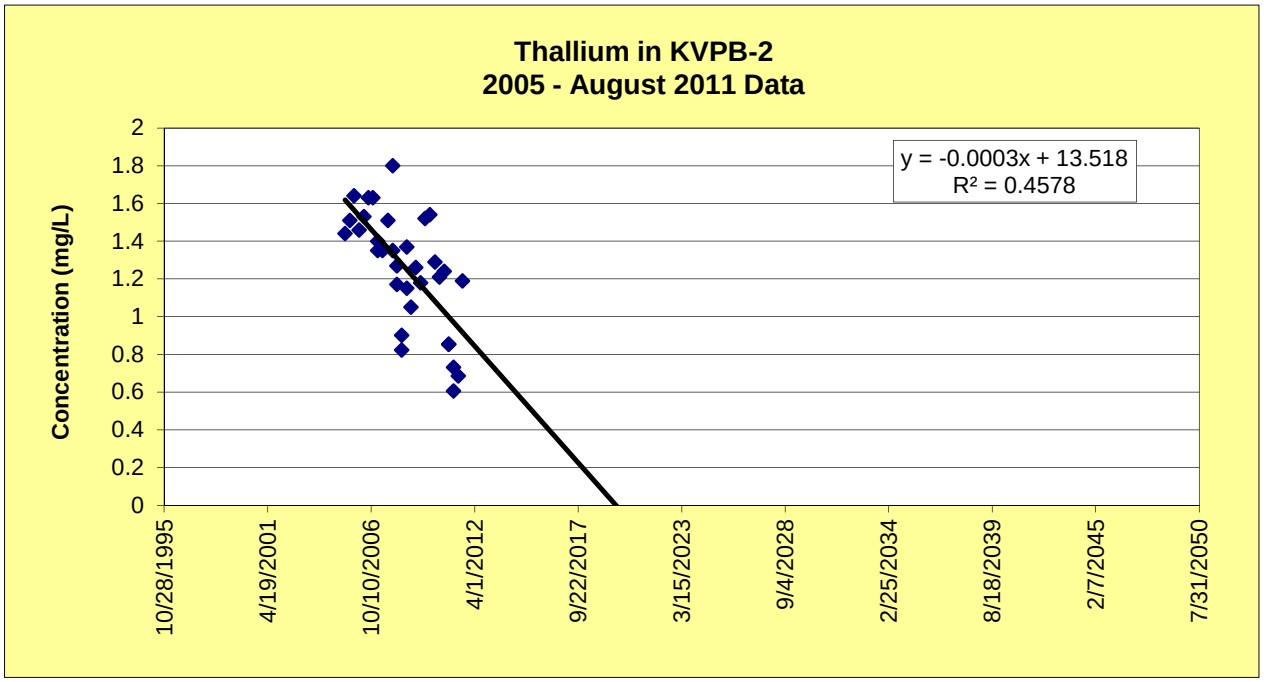

Selenium in Process Pad Drainage
1998 - 2011 Data
Concentration (mg/L)
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
y = 165e-2E-04x
R² = 0.7119
11/14/1984
7/24/1998
4/1/2012
12/9/2025
8/18/2039

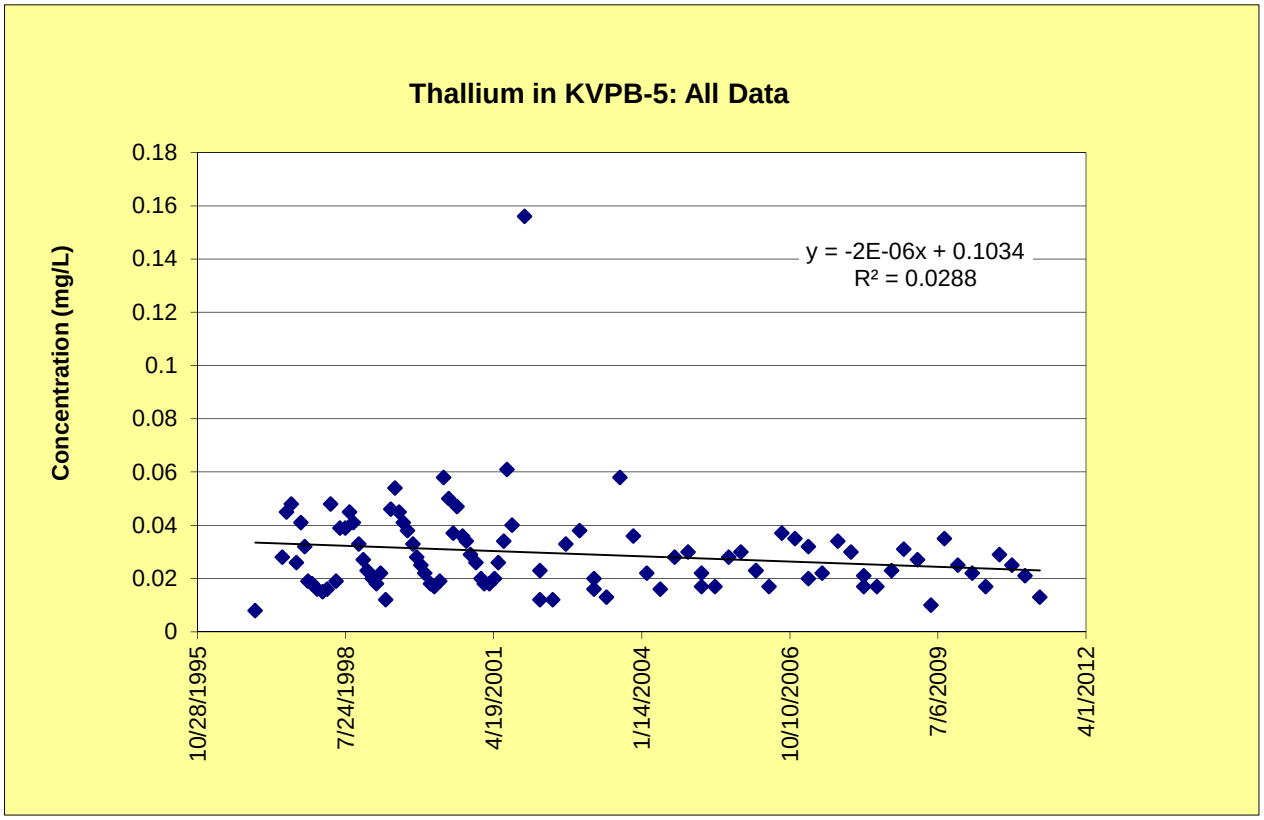

Selenium in Process Pad Drainage
1998 - 2011 Data
Concentration (mg/L)
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
y = -2E-05x + 0.7619
R² = 0.6907
11/14/1984
5/7/1990
10/28/1995
4/19/2001
10/10/2006
4/1/2012
9/22/2017
3/15/2023

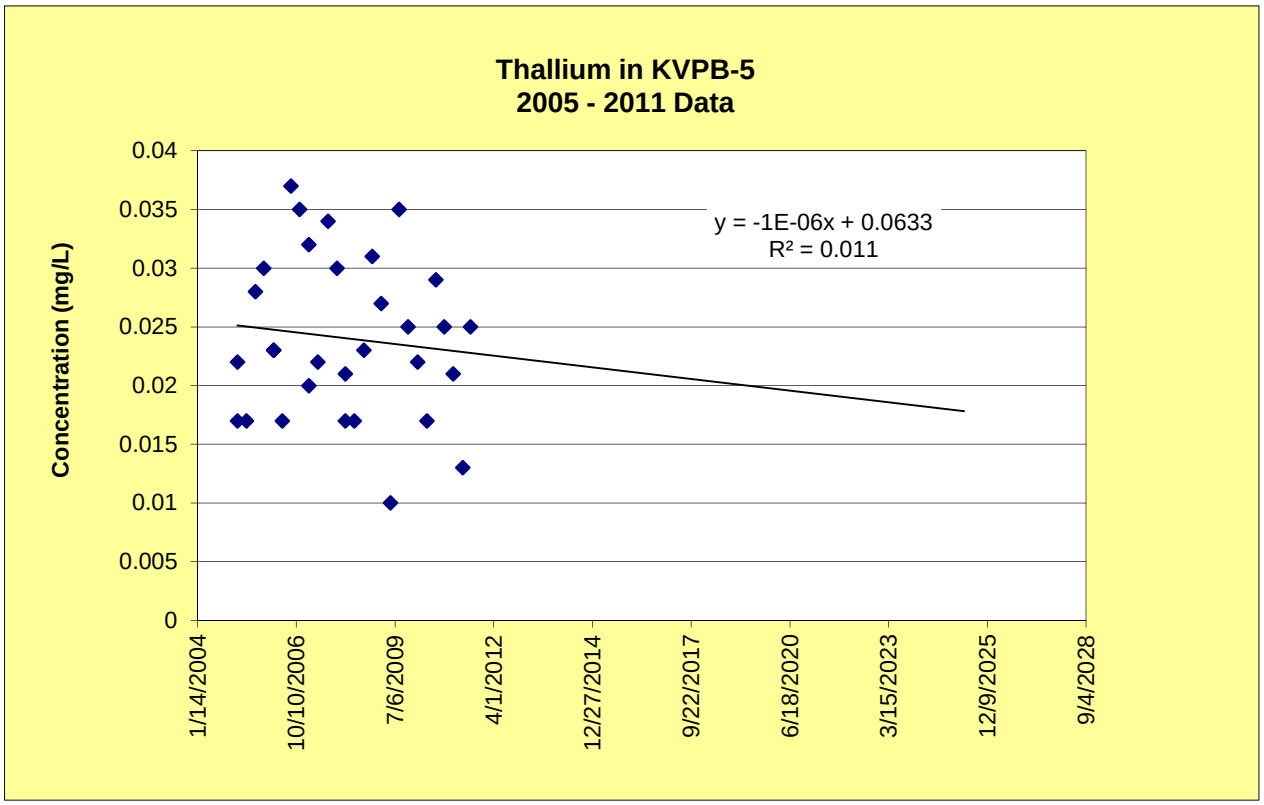

Thallium in Process Pad Drainage
2000-2011 Data
Concentration (mg/L)
1.2
1
0.8
0.6
0.4
0.2
0
11/14/1984
7/24/1998
4/1/2012
12/9/2025
8/18/2039
4/26/2053
1/3/2067
y = -5E-05x + 2.5293
R² = 0.1916

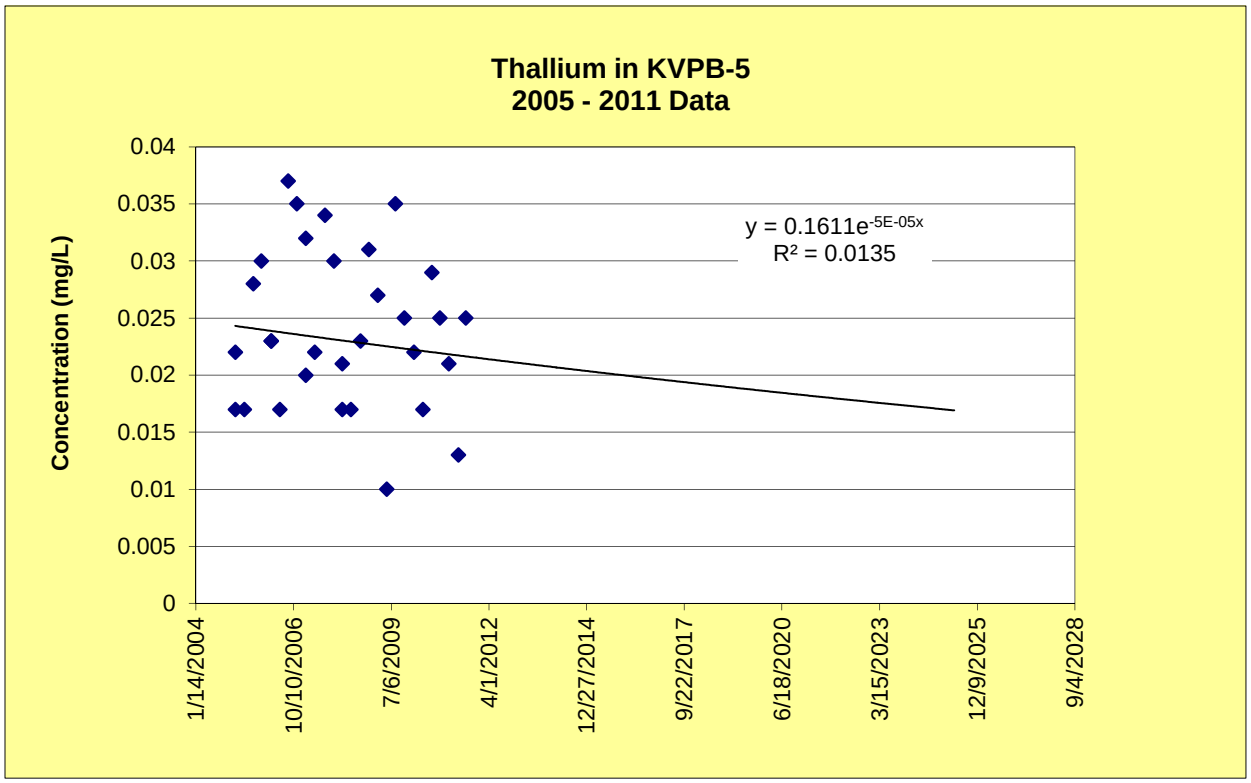

Thallium in Process Pad Drainage
2000-2011 Data
Concentration (mg/L)
1.2
1
0.8
0.6
0.4
0.2
0
11/14/1984
5/7/1990
10/28/1995
4/19/2001
10/10/2006
4/1/2012
9/22/2017
3/15/2023
9/4/2028
y = -1E-08x² + 0.001x - 17.917
R² = 0.2131

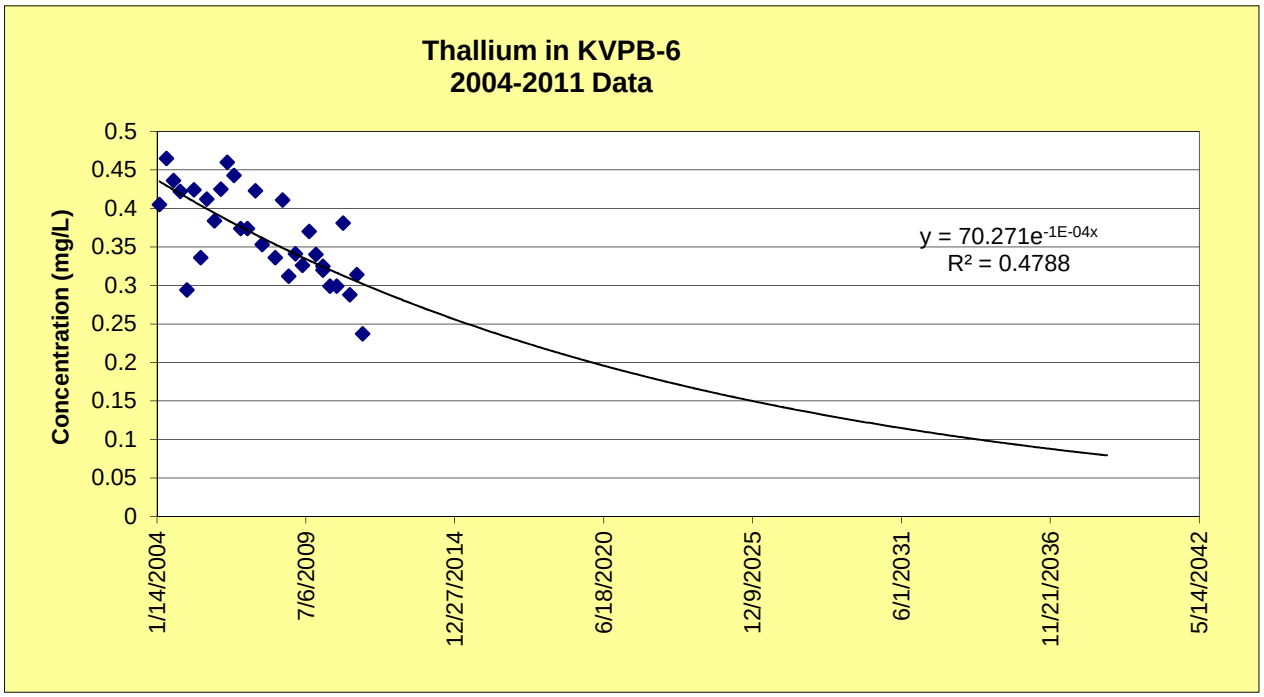

Thallium in KVPB-2
2005 - August 2011 Data
Concentration (mg/L)
y = 66769e-3E-04x
R² = 0.4462
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
10/28/1995
4/19/2001
10/10/2006
4/1/2012
9/22/2017
3/15/2023
9/4/2028
2/25/2034
8/18/2039
2/7/2045
7/31/2050

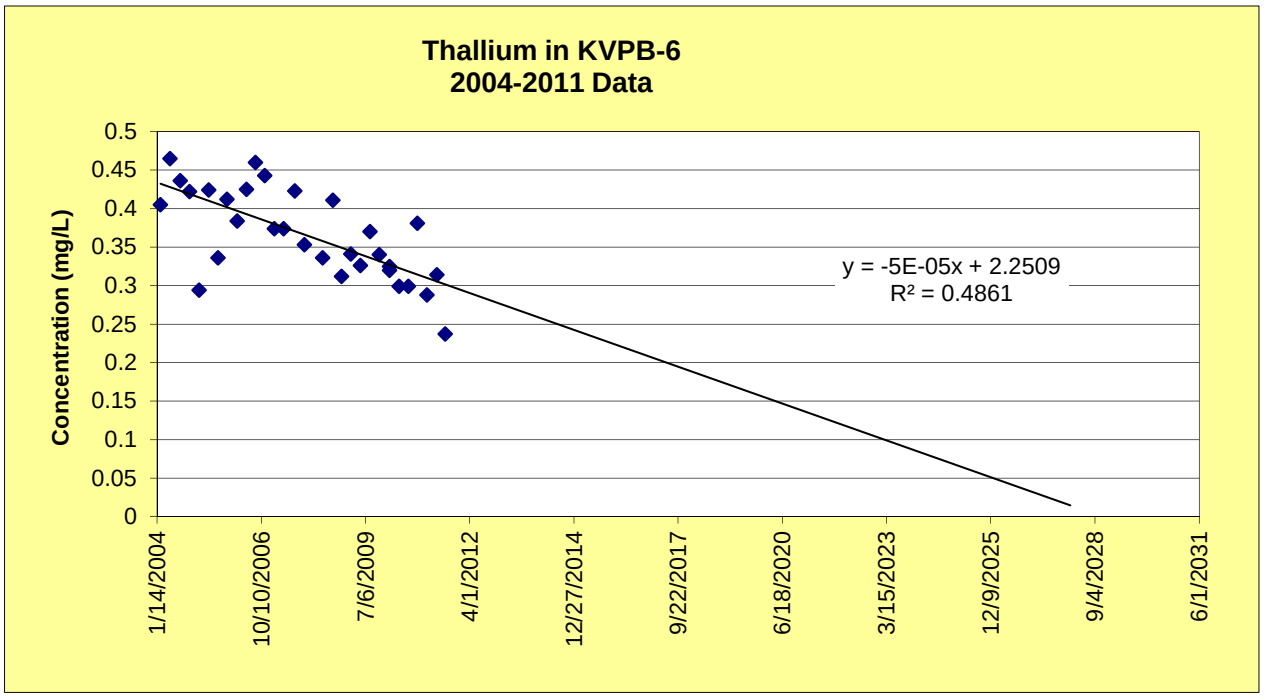

Thallium in KVPB-2
2005 - August 2011 Data
Concentration (mg/L)
y = -0.0003x + 13.518
R² = 0.4578
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
10/28/1995
4/19/2001
10/10/2006
4/1/2012
9/22/2017
3/15/2023
9/4/2028
2/25/2034
8/18/2039
2/7/2045
7/31/2050

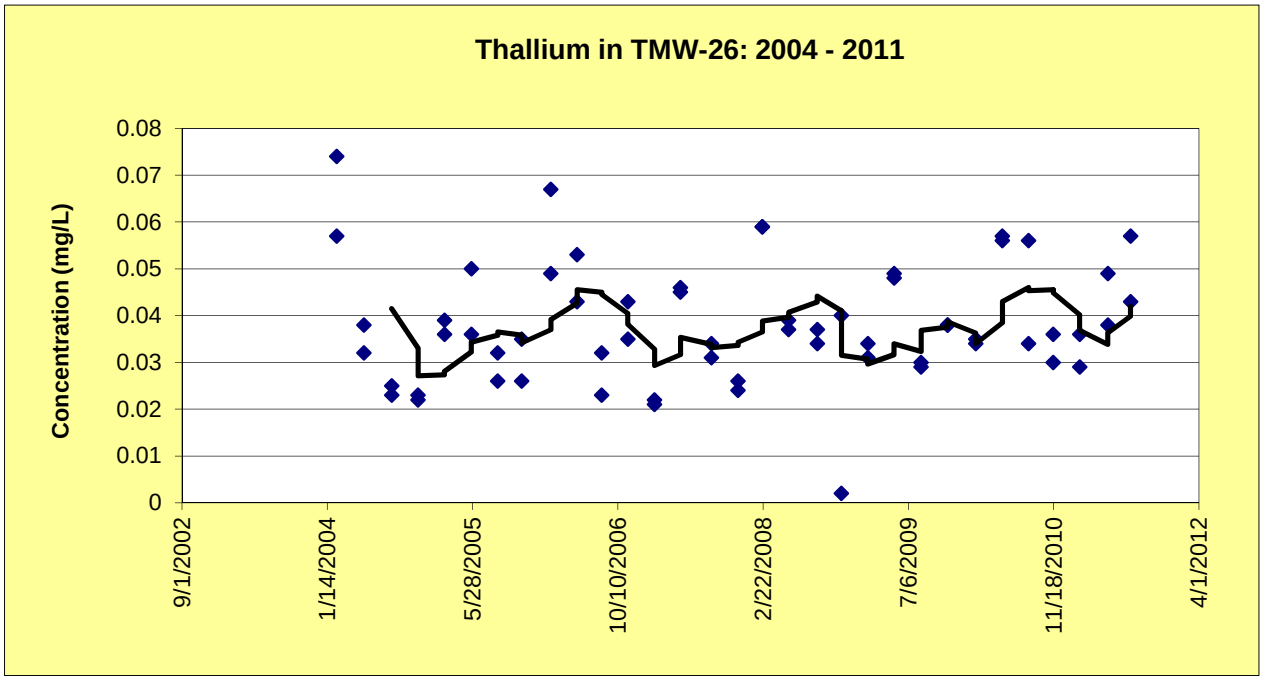

Thallium in KVPB-5: All Data
Concentration (mg/L)
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
y = -2E-06x + 0.1034
R² = 0.0288
10/28/1995
7/24/1998
4/19/2001
1/14/2004
10/10/2006
7/6/2009
4/1/2012

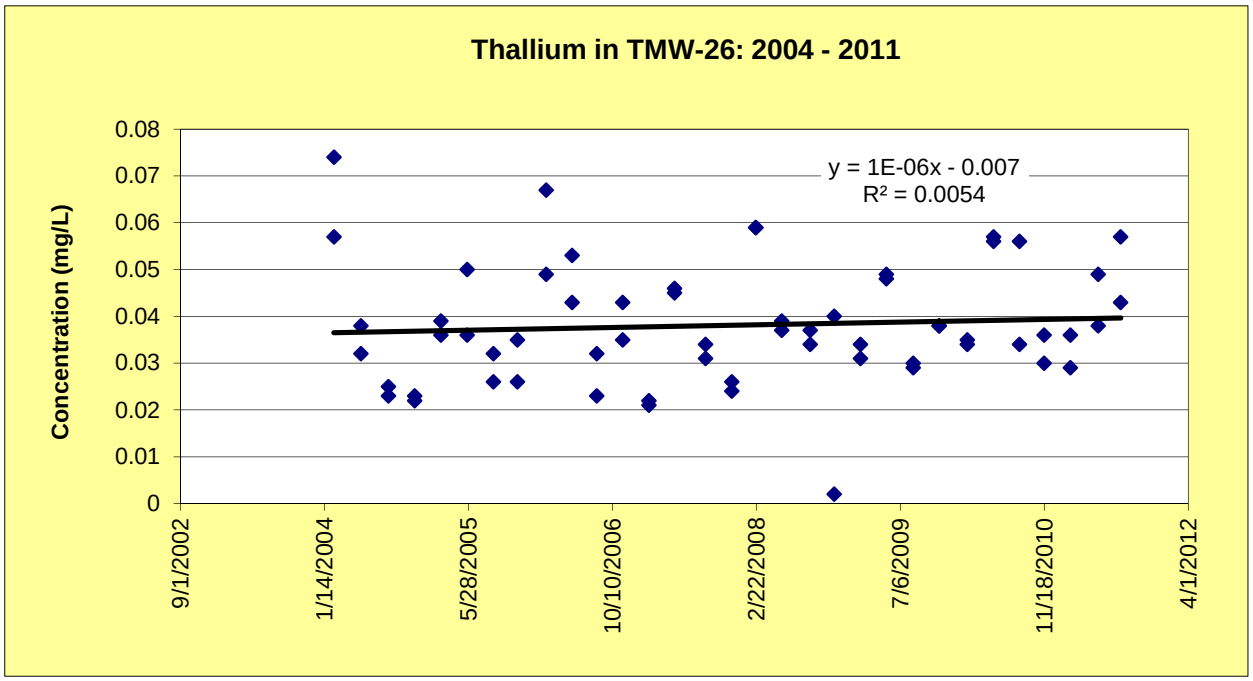

Thallium in KVPB-5
2005 - 2011 Data
Concentration (mg/L)
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
y = -1E-06x + 0.0633
R² = 0.011
1/14/2004
10/10/2006
7/6/2009
4/1/2012
12/27/2014
9/22/2017
6/18/2020
3/15/2023
12/9/2025
9/4/2028

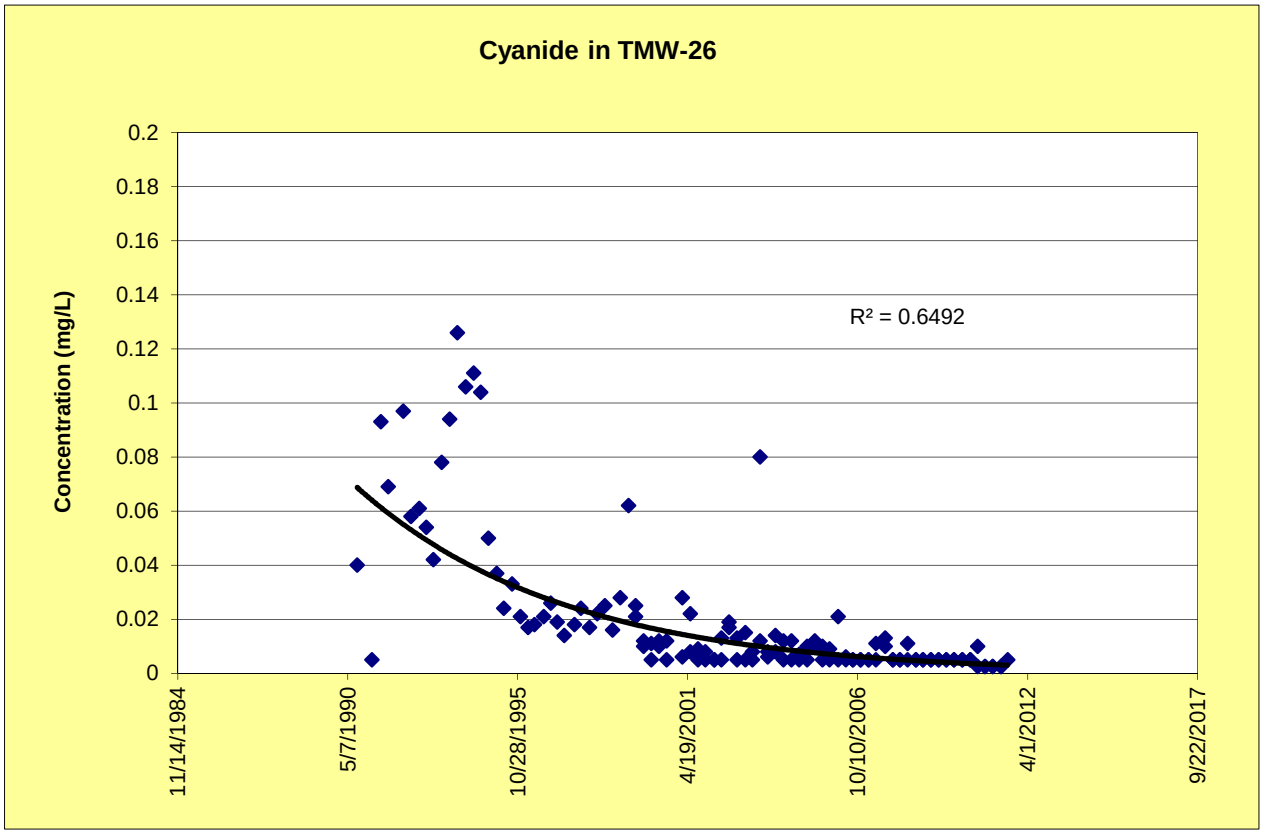

Thallium in KVPB-5
2005 - 2011 Data
Concentration (mg/L)
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
y = 0.1611e-5E-05x
R² = 0.0135
1/14/2004
10/10/2006
7/6/2009
4/1/2012
12/27/2014
9/22/2017
6/18/2020
3/15/2023
12/9/2025
9/4/2028

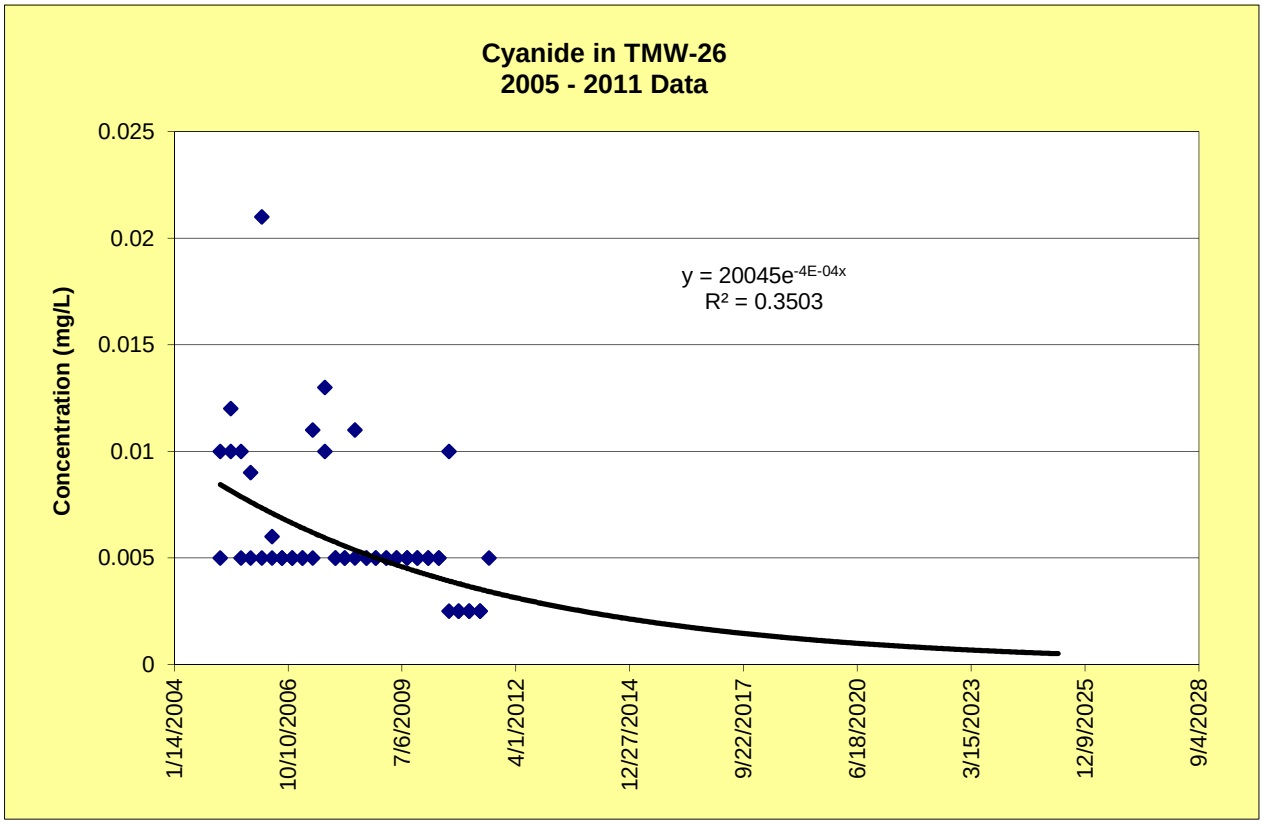

Thallium in KVPB-6
2004-2011 Data
Concentration (mg/L)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
y = 70.271e-1E-04x
R² = 0.4788
1/14/2004
7/6/2009
12/27/2014
6/18/2020
12/9/2025
6/1/2031
11/21/2036
5/14/2042

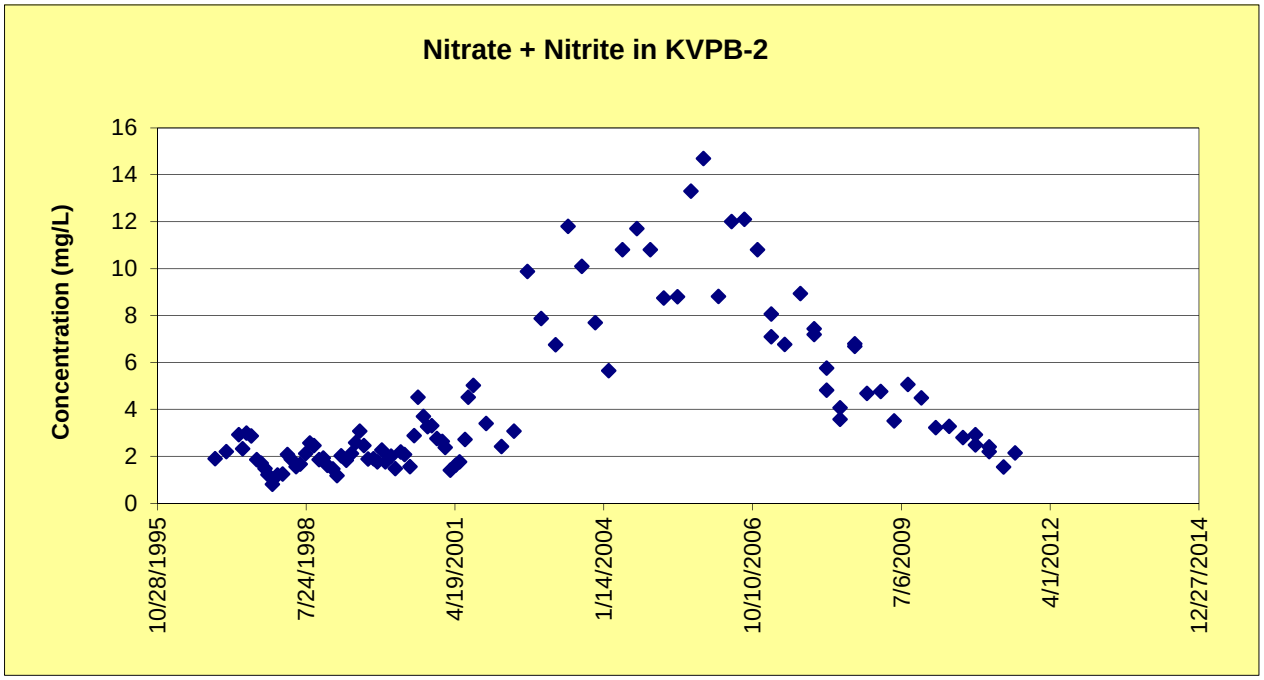

Thallium in KVPB-6
2004-2011 Data
Concentration (mg/L)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
y = -5E-05x + 2.2509
R² = 0.4861
1/14/2004
10/10/2006
7/6/2009
4/1/2012
12/27/2014
9/22/2017
6/18/2020
3/15/2023
12/9/2025
9/4/2028
6/1/2031

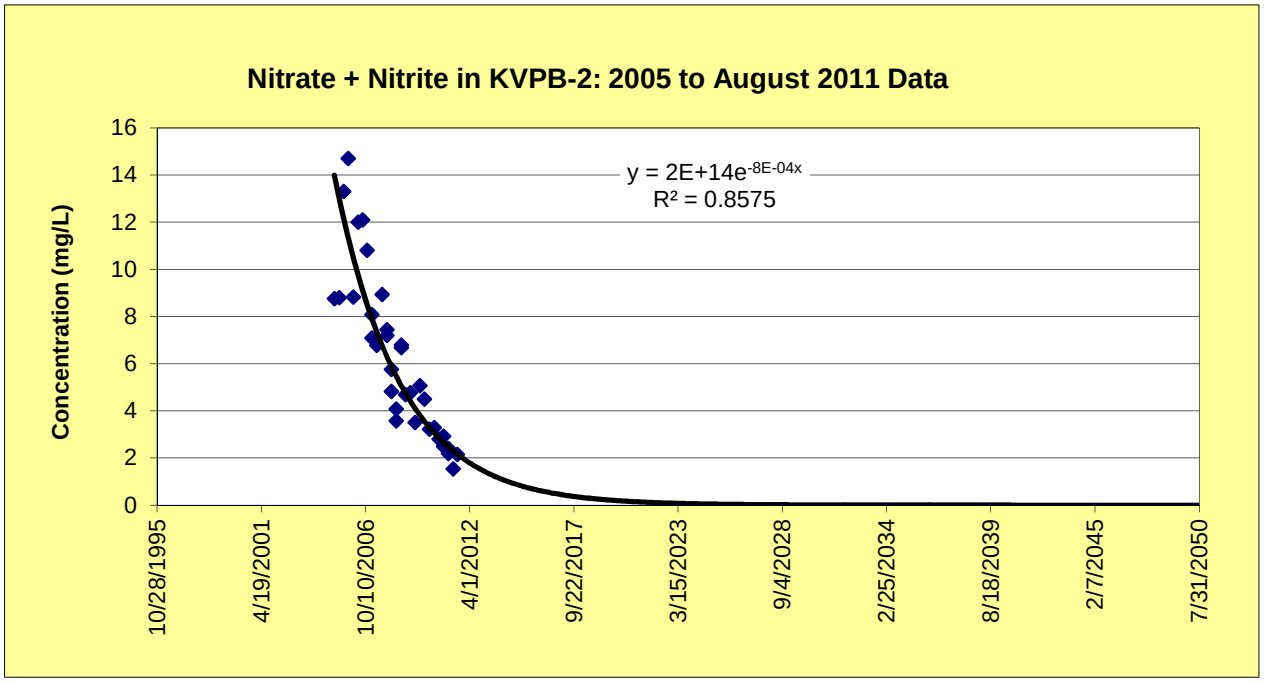

Thallium in TMW-26: 2004 - 2011
Concentration (mg/L)
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
9/1/2002
1/14/2004
5/28/2005
10/10/2006
2/22/2008
7/6/2009
11/18/2010
4/1/2012

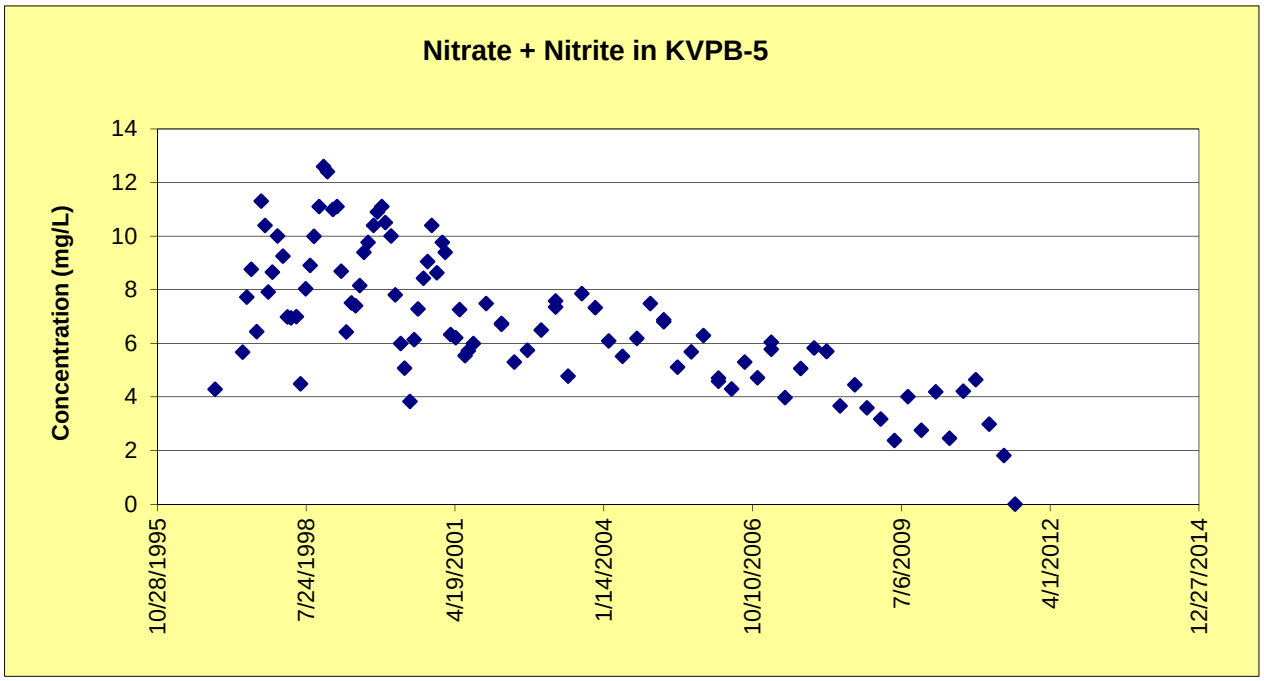

Thallium in TMW-26: 2004 - 2011
Concentration (mg/L)
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
y = 1E-06x - 0.007
R² = 0.0054
9/1/2002
1/14/2004
5/28/2005
10/10/2006
2/22/2008
7/6/2009
11/18/2010
4/1/2012

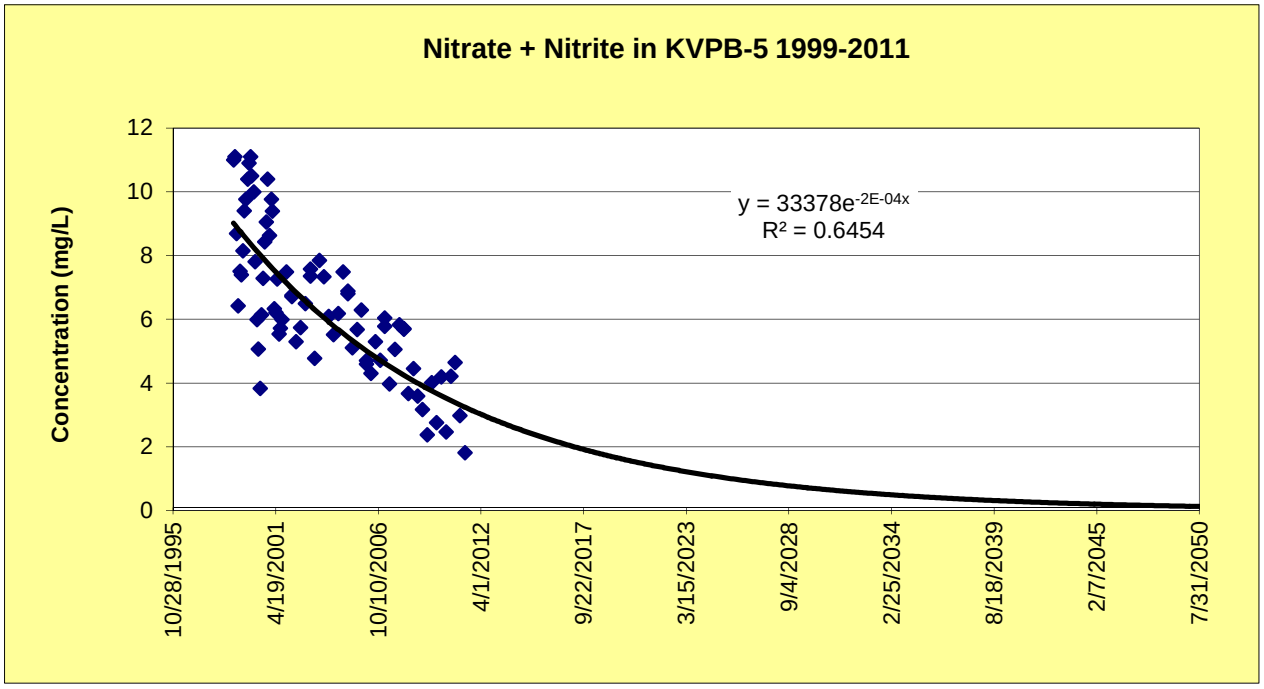

Cyanide in TMW-26
Concentration (mg/L)
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
R² = 0.6492
11/14/1984
5/7/1990
10/28/1995
4/19/2001
10/10/2006
4/1/2012
9/22/2017

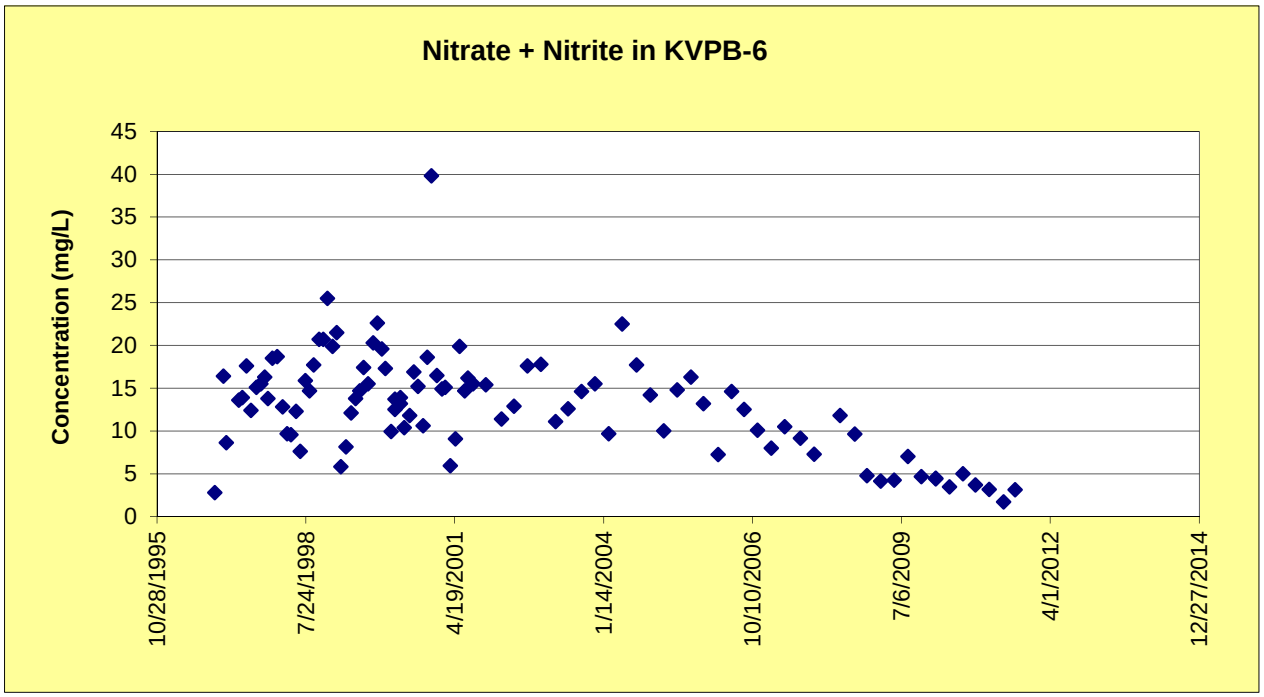

Cyanide in TMW-26
2005 - 2011 Data
Concentration (mg/L)
0.025
0.02
0.015
0.01
0.005
0
y = 20045e-4E-04x
R² = 0.3503
1/14/2004
10/10/2006
7/6/2009
4/1/2012
12/27/2014
9/22/2017
6/18/2020
3/15/2023
12/9/2025
9/4/2028

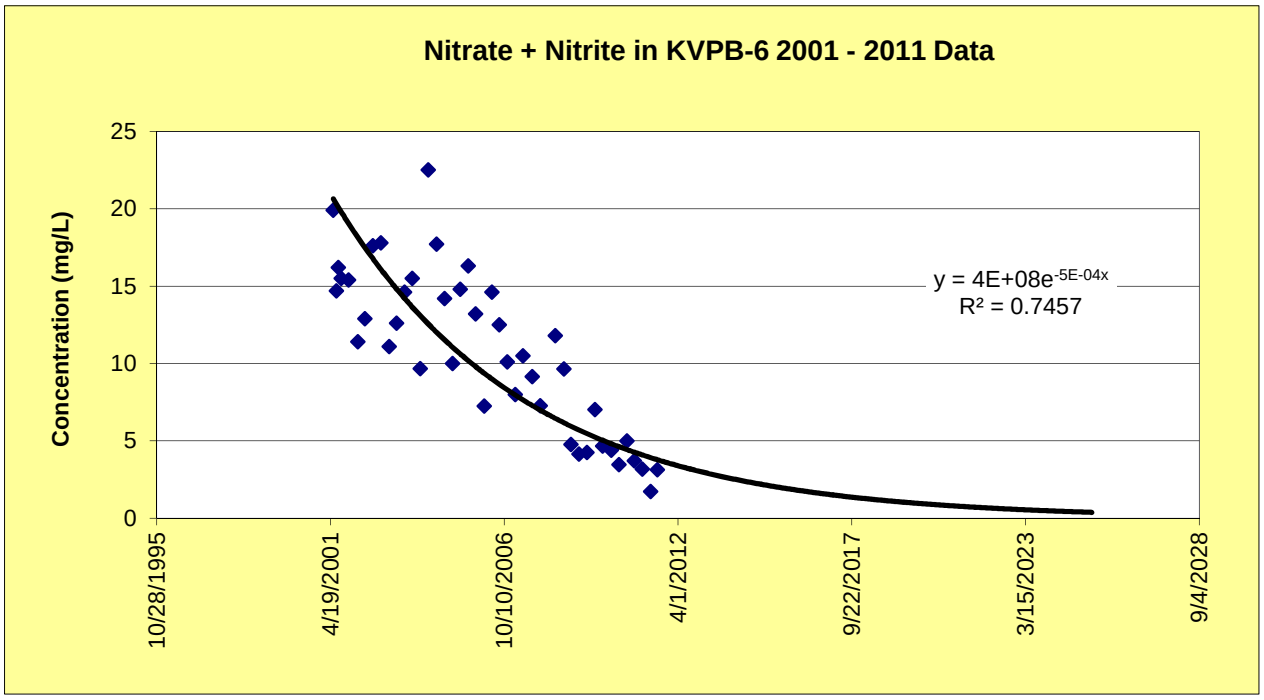

Nitrate + Nitrite in KVPB-2
Concentration (mg/L)
16
14
12
10
8
6
4
2
0
10/28/1995
7/24/1998
4/19/2001
1/14/2004
10/10/2006
7/6/2009
4/1/2012
12/27/2014

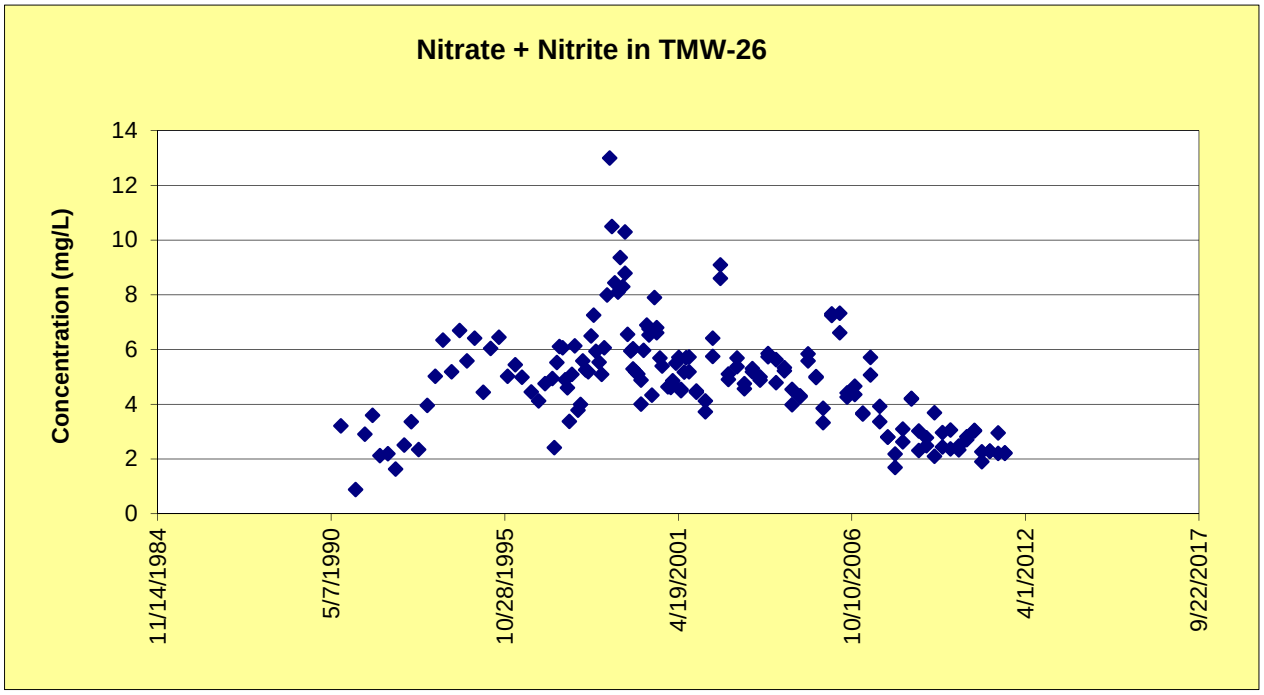

Nitrate + Nitrite in KVPB-2: 2005 to August 2011 Data
y = 2E+14e-8E-04x
R² = 0.8575
Concentration (mg/L)
16
14
12
10
8
6
4
2
0
10/28/1995
4/19/2001
10/10/2006
4/1/2012
9/22/2017
3/15/2023
9/4/2028
2/25/2034
8/18/2039
2/7/2045
7/31/2050

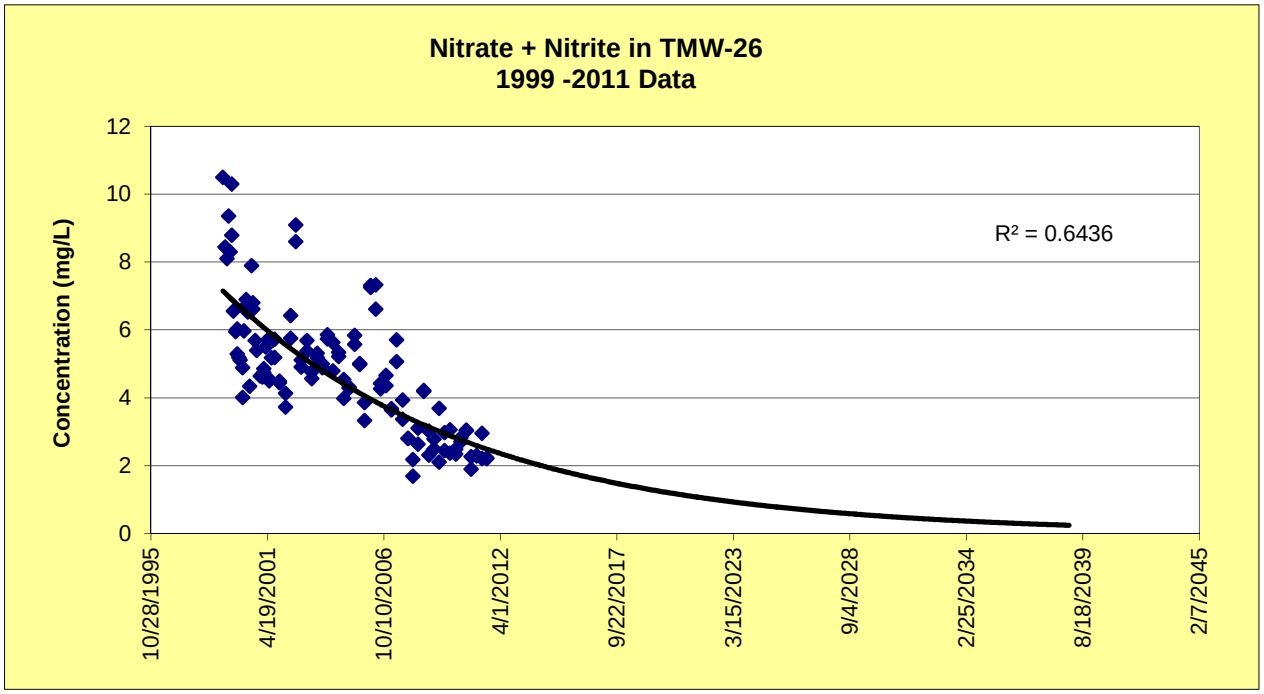

Nitrate + Nitrite in KVPB-5
Concentration (mg/L)
14
12
10
8
6
4
2
0
10/28/1995
7/24/1998
4/19/2001
1/14/2004
10/10/2006
7/6/2009
4/1/2012
12/27/2014

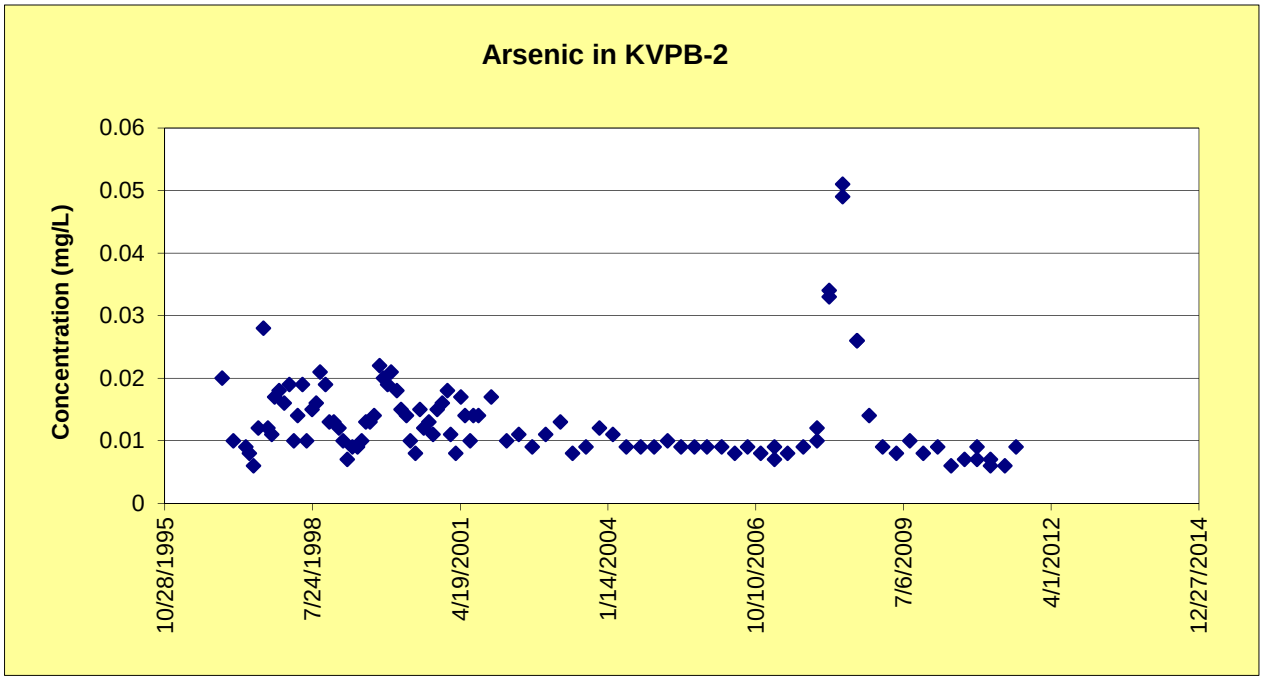

Nitrate + Nitrite in KVPB-5 1999-2011
Concentration (mg/L)
12
10
8
6
4
2
0
y = 33378e-2E-04x
R² = 0.6454
10/28/1995
4/19/2001
10/10/2006
4/1/2012
9/22/2017
3/15/2023
9/4/2028
2/25/2034
8/18/2039
2/7/2045
7/31/2050

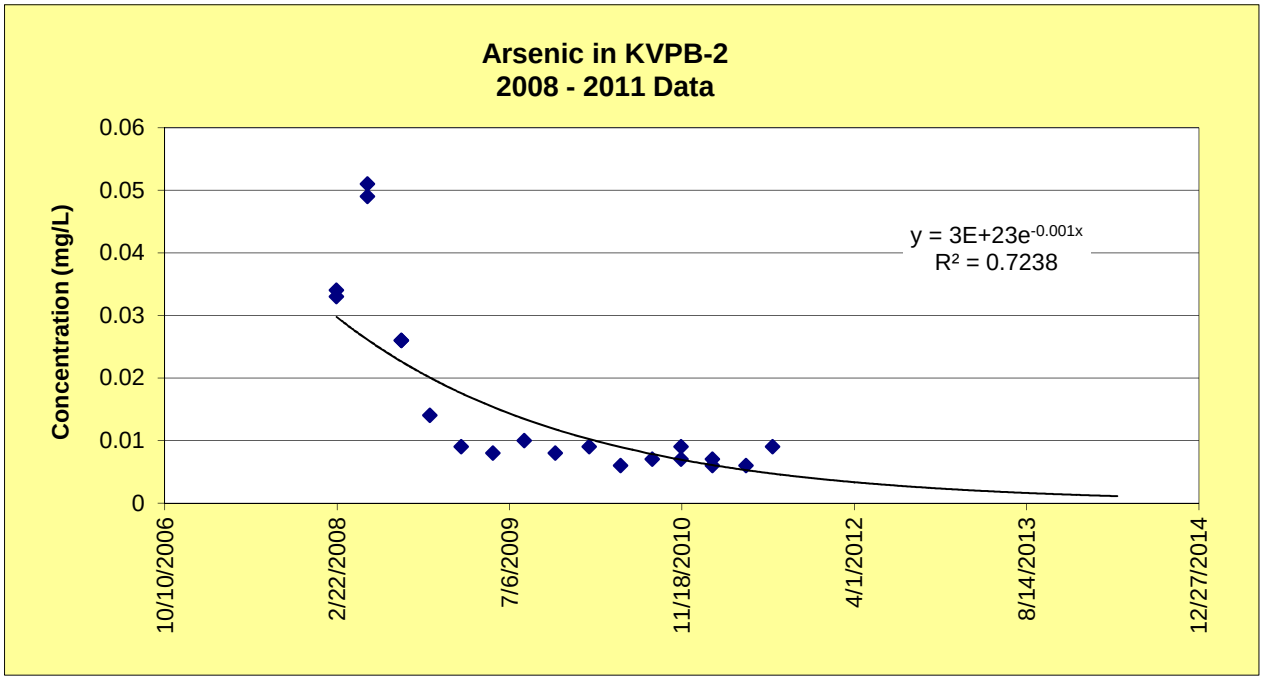

Nitrate + Nitrite in KVPB-6
Concentration (mg/L)
45
40
35
30
25
20
15
10
5
0
10/28/1995
7/24/1998
4/19/2001
1/14/2004
10/10/2006
7/6/2009
4/1/2012
12/27/2014

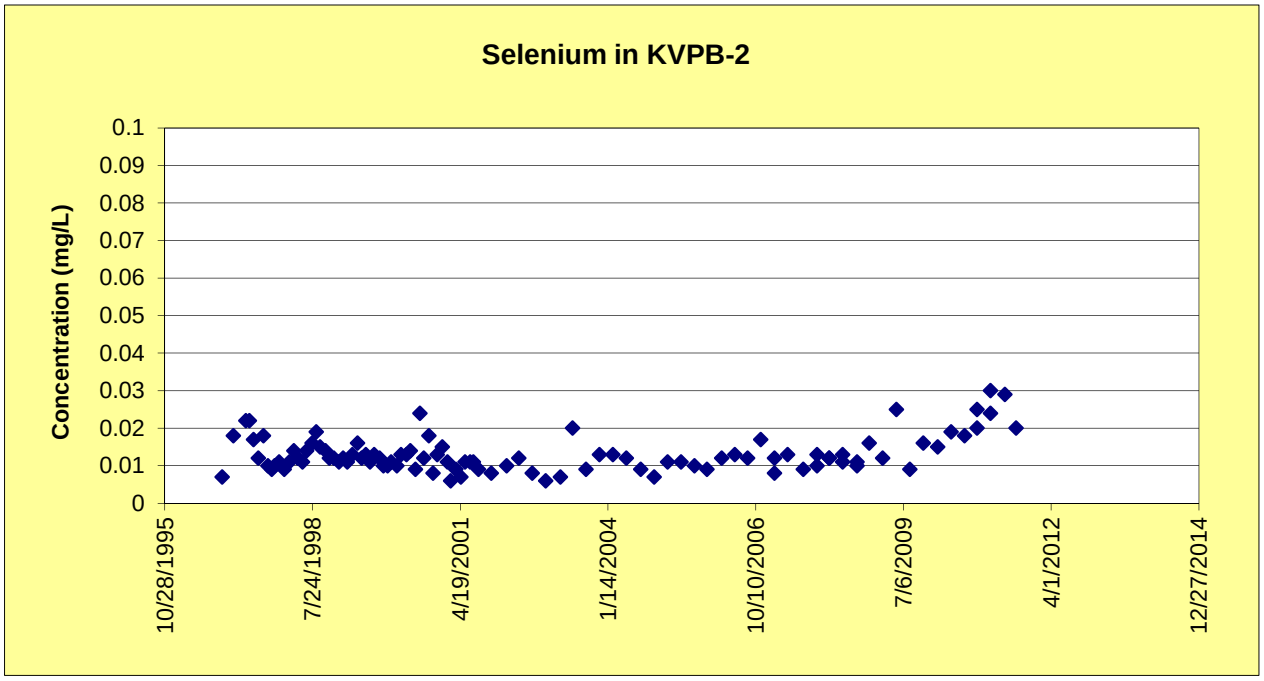

Nitrate + Nitrite in KVPB-6 2001 - 2011 Data
Concentration (mg/L)
25
20
15
10
5
0
y = 4E+08e-5E-04x
R² = 0.7457
10/28/1995
4/19/2001
10/10/2006
4/1/2012
9/22/2017
3/15/2023
9/4/2028

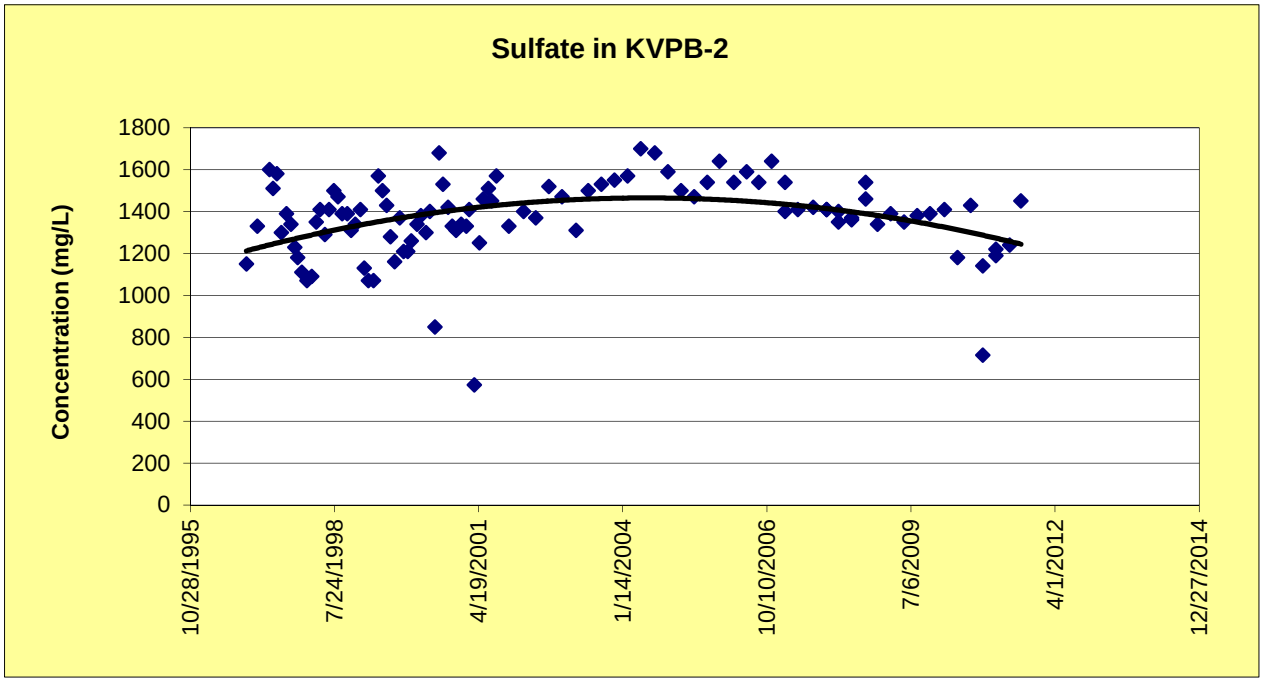

Nitrate + Nitrite in TMW-26
Concentration (mg/L)
0
2
4
6
8
10
12
14
11/14/1984
5/7/1990
10/28/1995
4/19/2001
10/10/2006
4/1/2012
9/22/2017

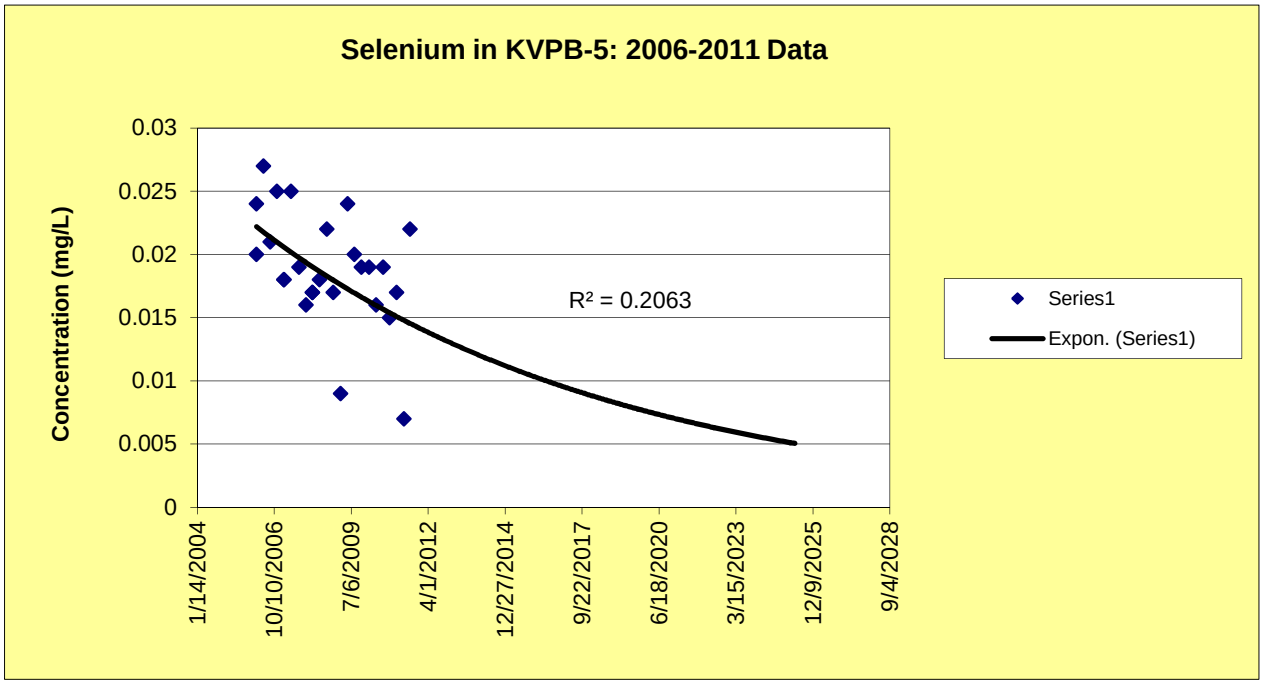

Nitrate + Nitrite in TMW-26
1999 -2011 Data
Concentration (mg/L)
0
2
4
6
8
10
12
R² = 0.6436
10/28/1995
4/19/2001
10/10/2006
4/1/2012
9/22/2017
3/15/2023
9/4/2028
2/25/2034
8/18/2039
2/7/2045

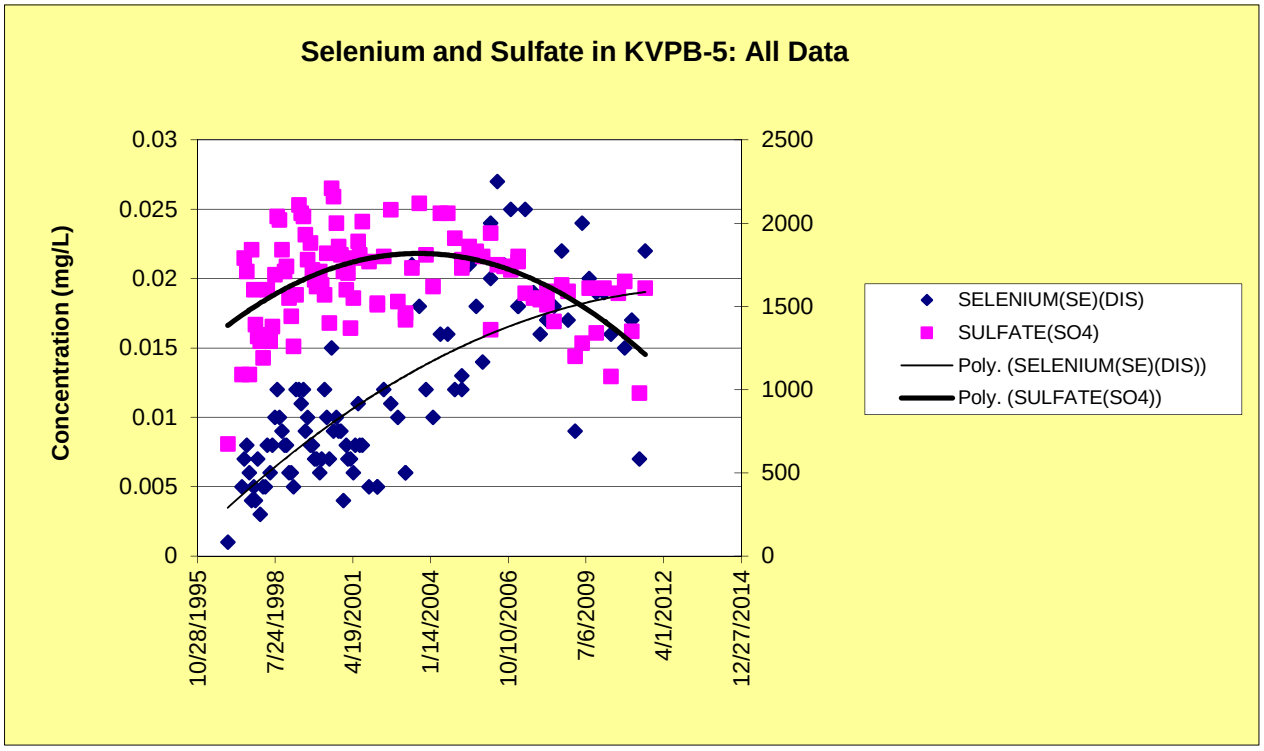

Arsenic in KVPB-2
Concentration (mg/L)
0.06
0.05
0.04
0.03
0.02
0.01
0
10/28/1995
7/24/1998
4/19/2001
1/14/2004
10/10/2006
7/6/2009
4/1/2012
12/27/2014

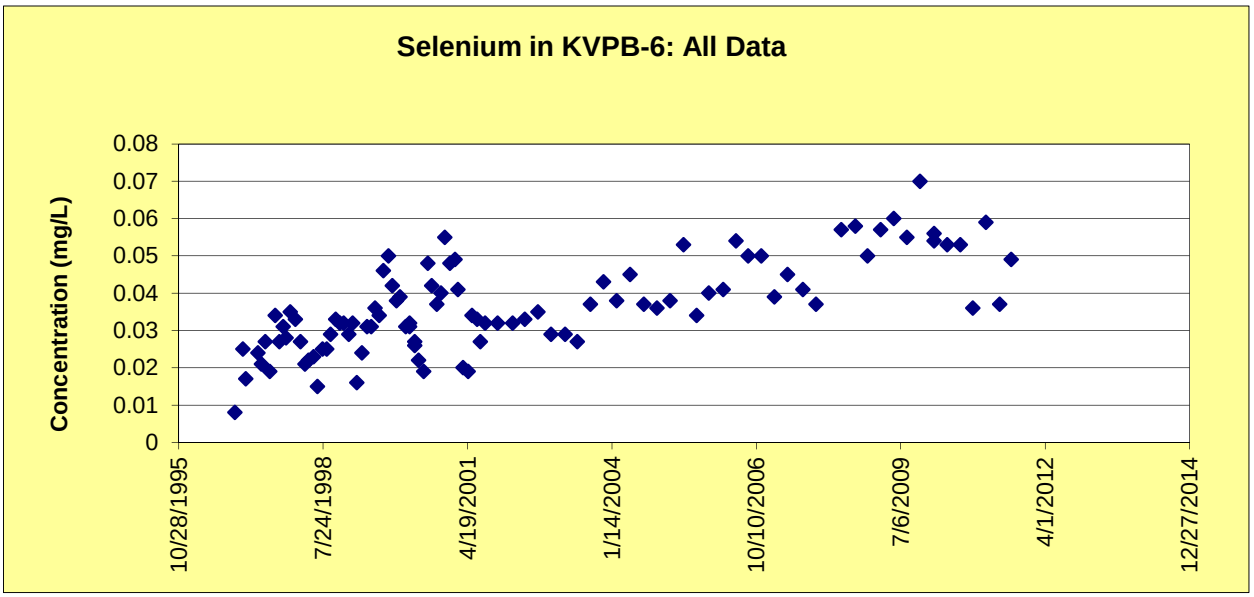

Arsenic in KVPB-2
2008 - 2011 Data
Concentration (mg/L)
0.06
0.05
0.04
0.03
0.02
0.01
0
y = 3E+23e-0.001x
R² = 0.7238
10/10/2006
2/22/2008
7/6/2009
11/18/2010
4/1/2012
8/14/2013
12/27/2014

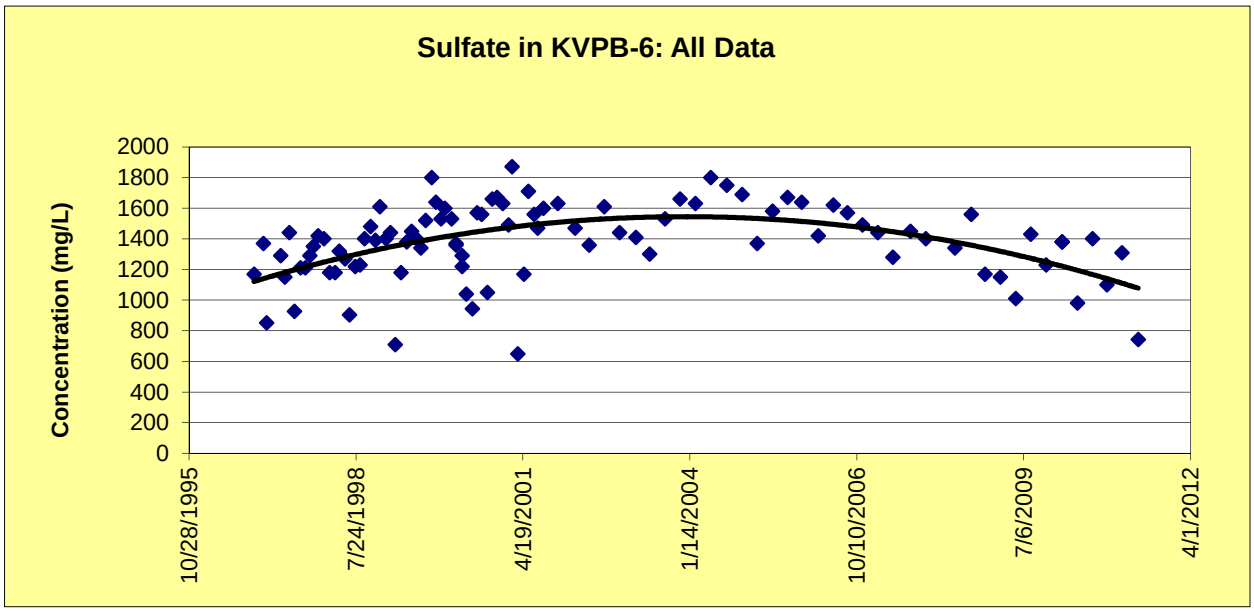

Selenium in KVPB-2
Concentration (mg/L)
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
10/28/1995
7/24/1998
4/19/2001
1/14/2004
10/10/2006
7/6/2009
4/1/2012
12/27/2014

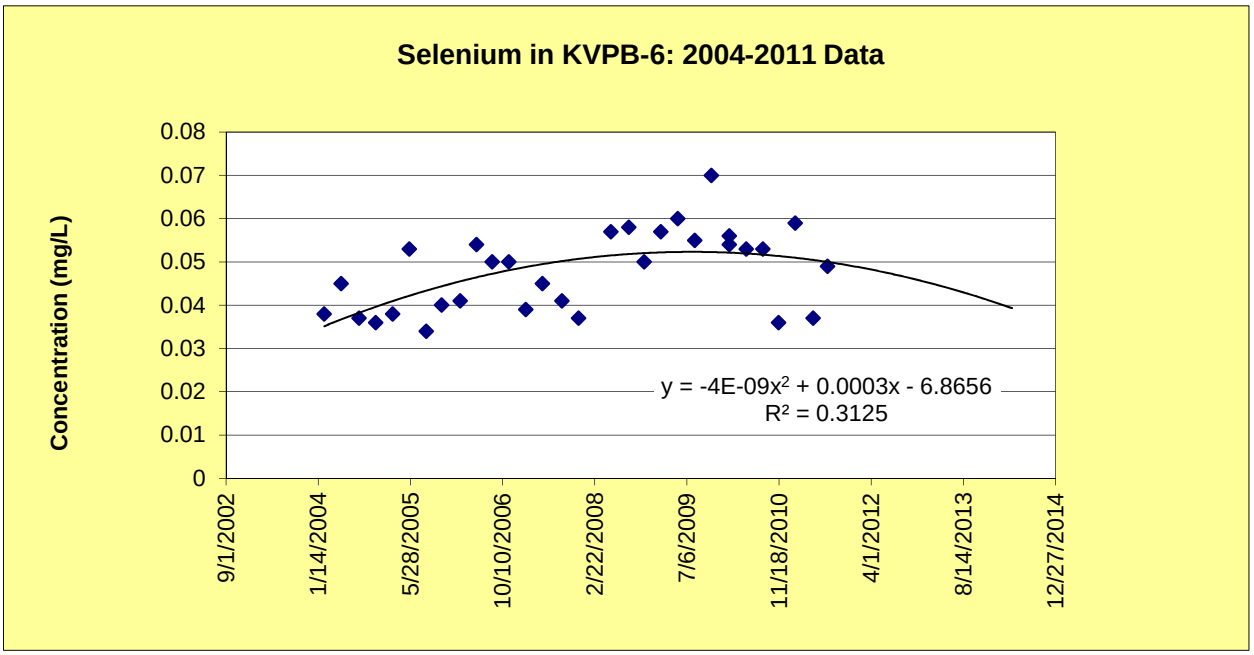

Sulfate in KVPB-2
Concentration (mg/L)
1800
1600
1400
1200
1000
800
600
400
200
0
10/28/1995
7/24/1998
4/19/2001
1/14/2004
10/10/2006
7/6/2009
4/1/2012
12/27/2014


Selenium in KVPB-5: 2006-2011 Data
Concentration (mg/L)
0.03
0.025
0.02
0.015
0.01
0.005
0
R² = 0.2063
1/14/2004
10/10/2006
7/6/2009
4/1/2012
12/27/2014
9/22/2017
6/18/2020
3/15/2023
12/9/2025
9/4/2028
Series1
Expon. (Series1)

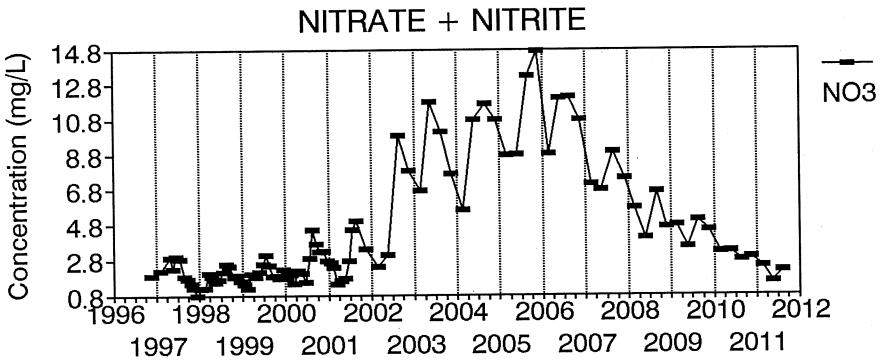

Selenium and Sulfate in KVPB-5: All Data
Concentration (mg/L)
0.03
0.025
0.02
0.015
0.01
0.005
0
2500
2000
1500
1000
500
0
10/28/1995
7/24/1998
4/19/2001
1/14/2004
10/10/2006
7/6/2009
4/1/2012
12/27/2014
SELENIUM(SE)(DIS)
SULFATE(SO4)
Poly. (SELENIUM(SE)(DIS))
Poly. (SULFATE(SO4))

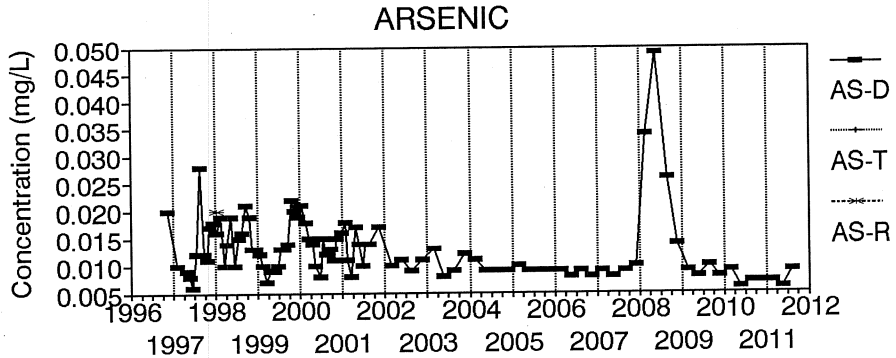

Selenium in KVPB-6: All Data
Concentration (mg/L)
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
10/28/1995
7/24/1998
4/19/2001
1/14/2004
10/10/2006
7/6/2009
4/1/2012
12/27/2014

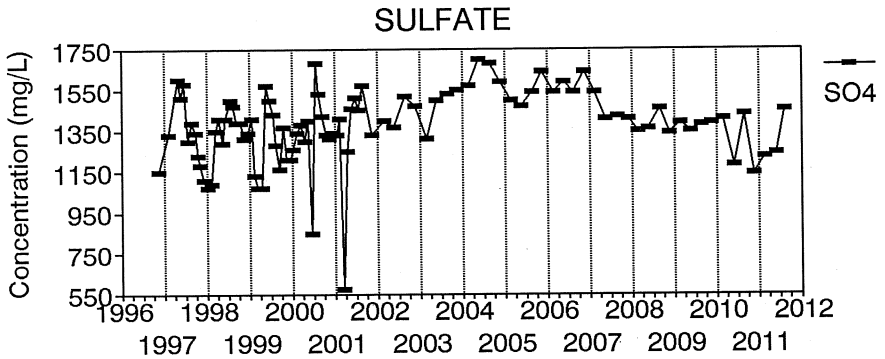

Sulfate in KVPB-6: All Data
Concentration (mg/L)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
10/28/1995
7/24/1998
4/19/2001
1/14/2004
10/10/2006
7/6/2009
4/1/2012

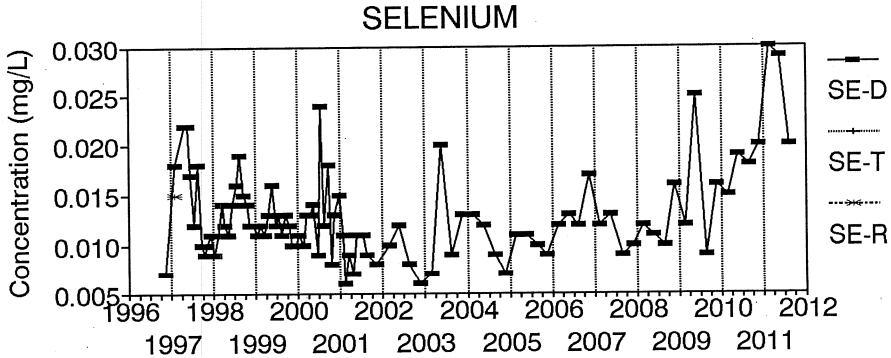

Selenium in KVPB-6: 2004-2011 Data
Concentration (mg/L)
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
y = -4E-09x² + 0.0003x - 6.8656
R² = 0.3125
9/1/2002
1/14/2004
5/28/2005
10/10/2006
2/22/2008
7/6/2009
11/18/2010
4/1/2012
8/14/2013
12/27/2014

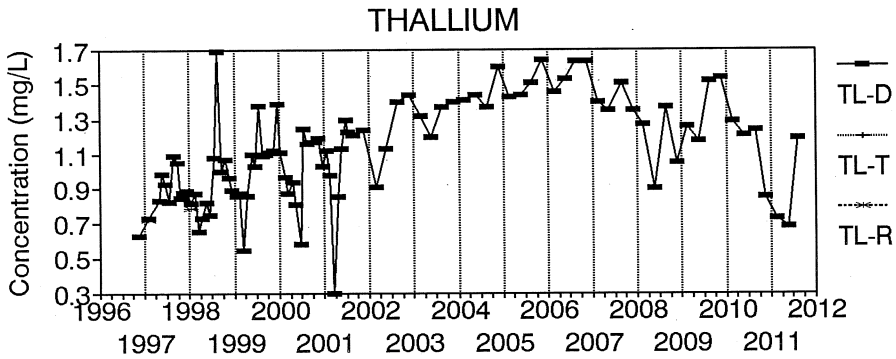
KVPB-2

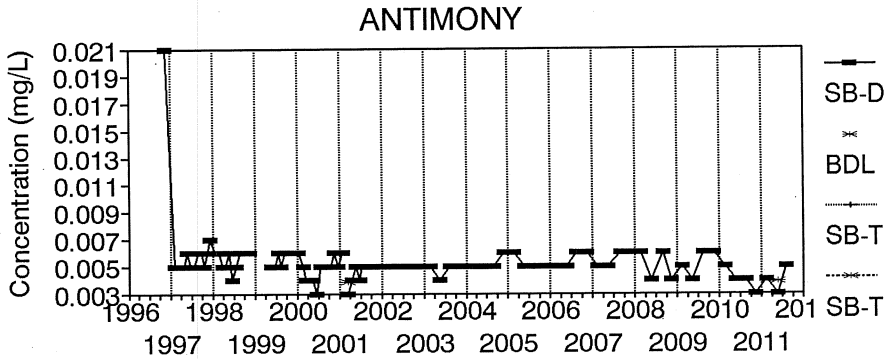






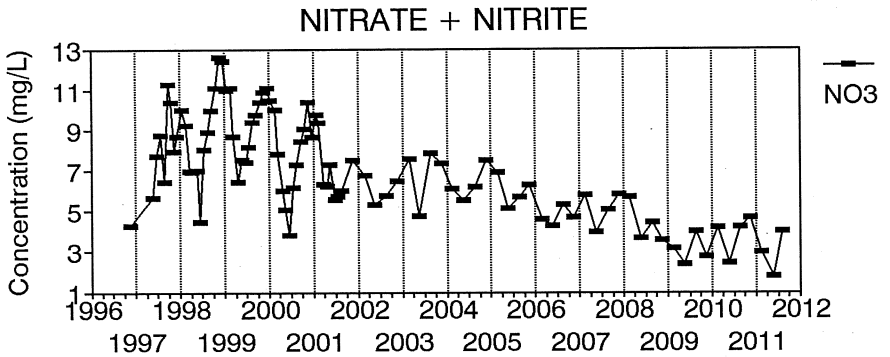


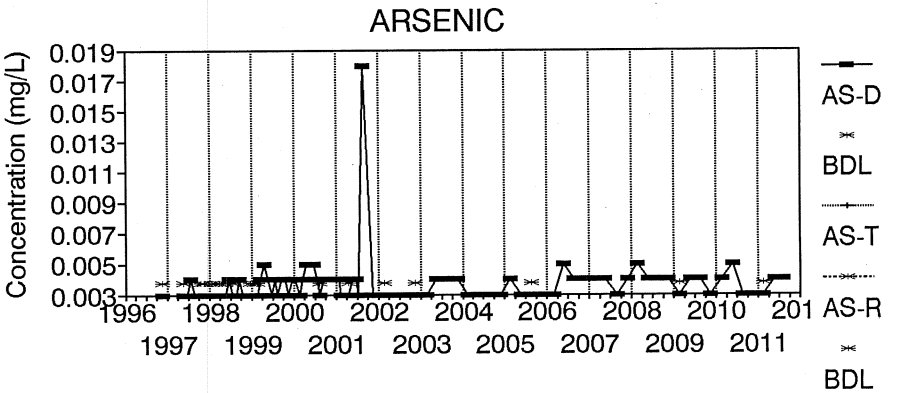


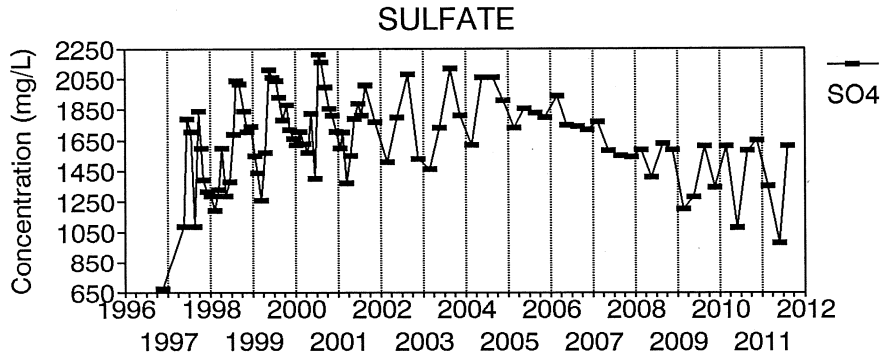


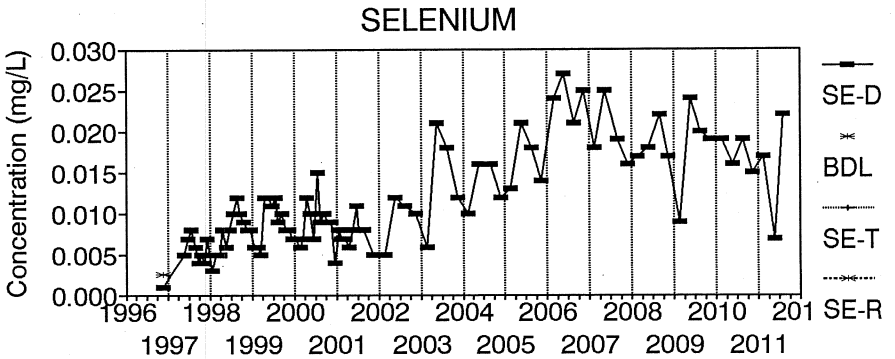
BDL - Below Analytical Detection Limit

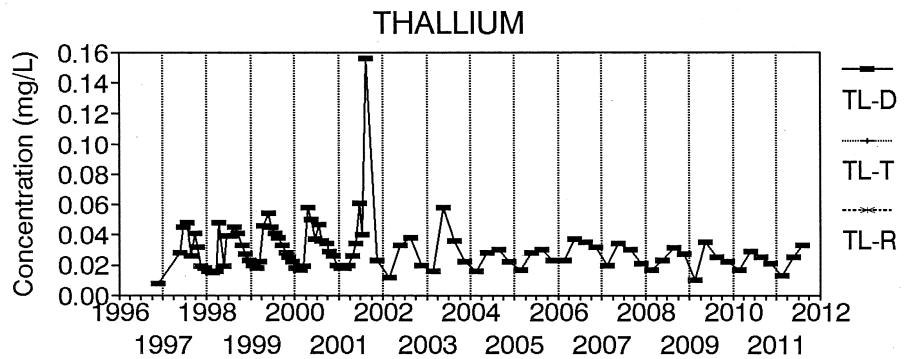
KVPB-5

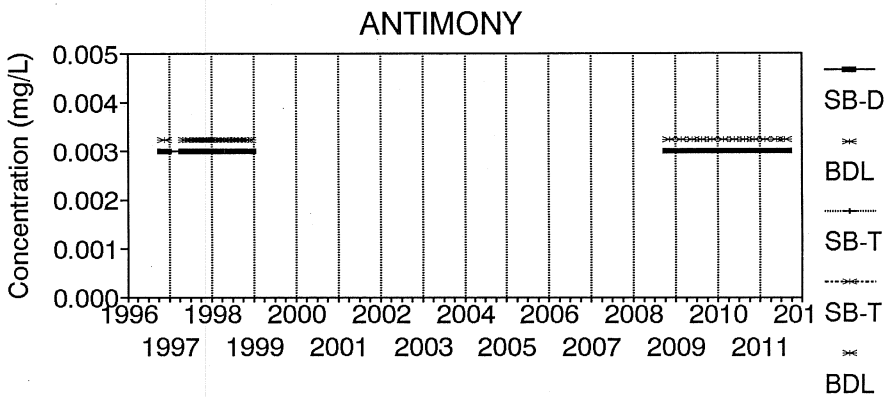






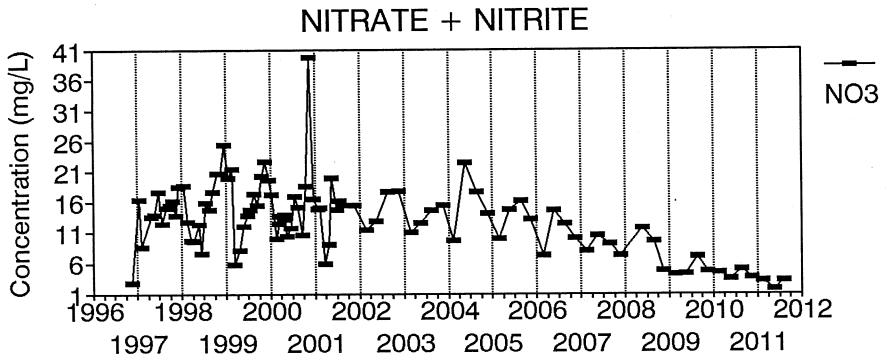


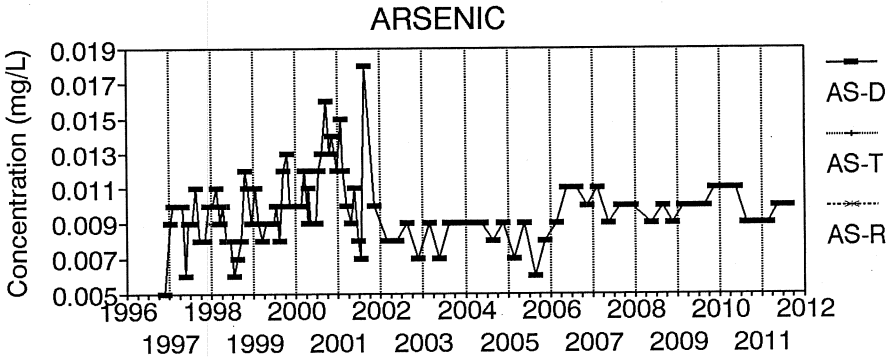


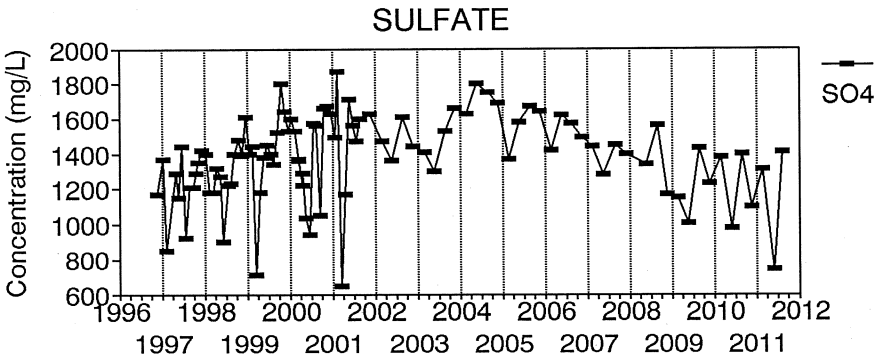


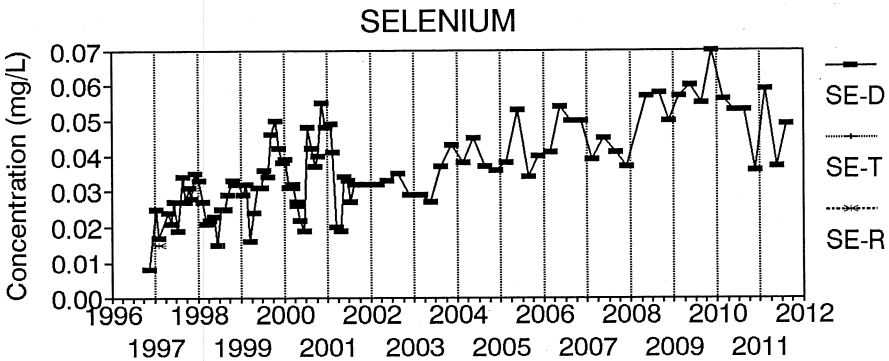
BDL - Below Analytical Detection Limit

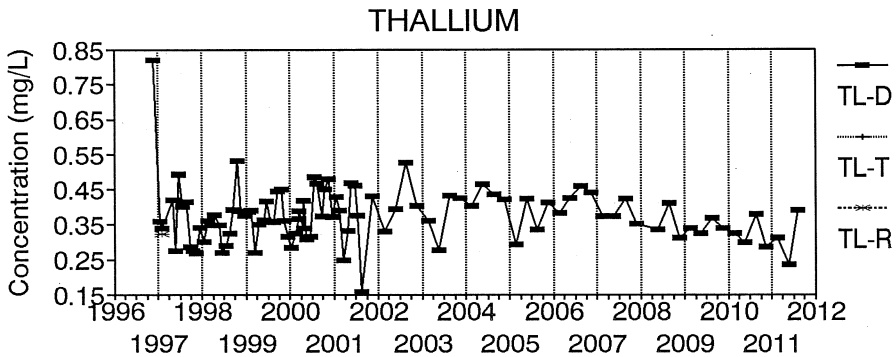
KVPB-6

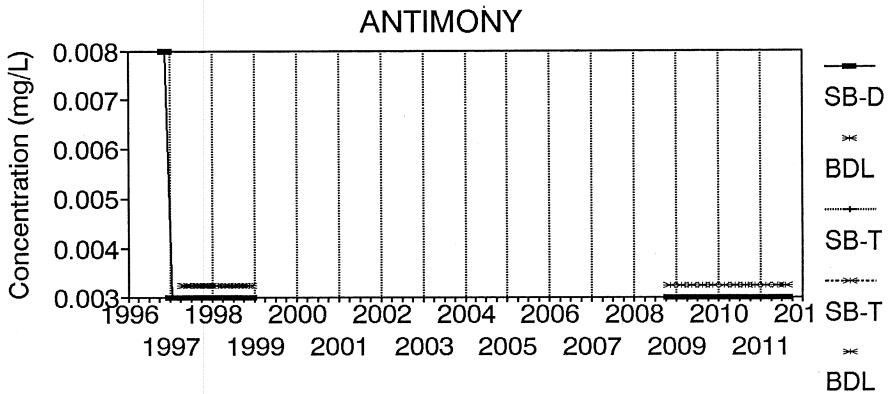






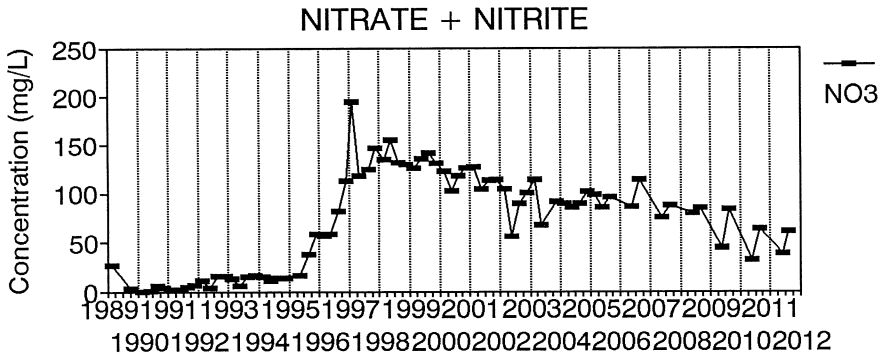


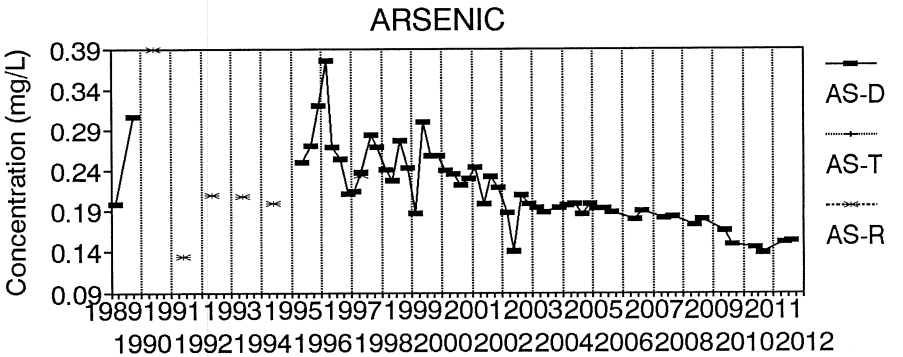


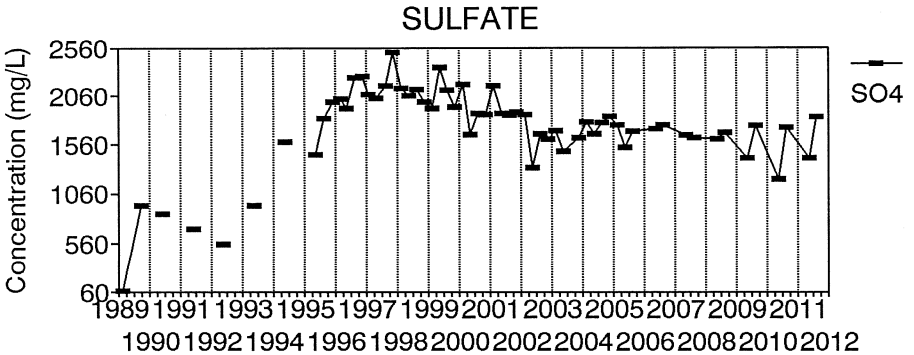


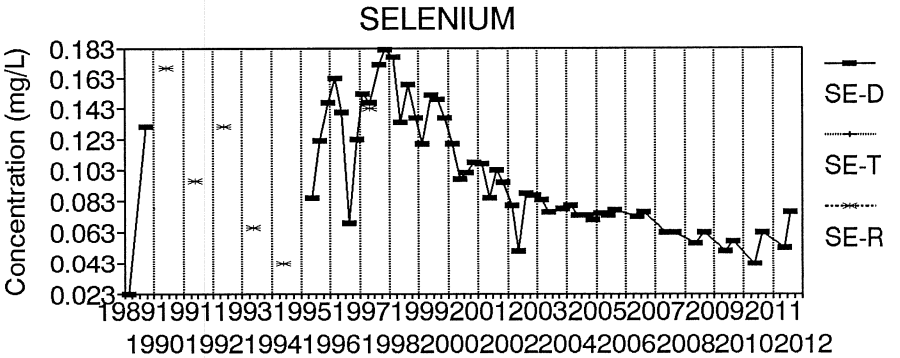
BDL - Below Analytical Detection Limit

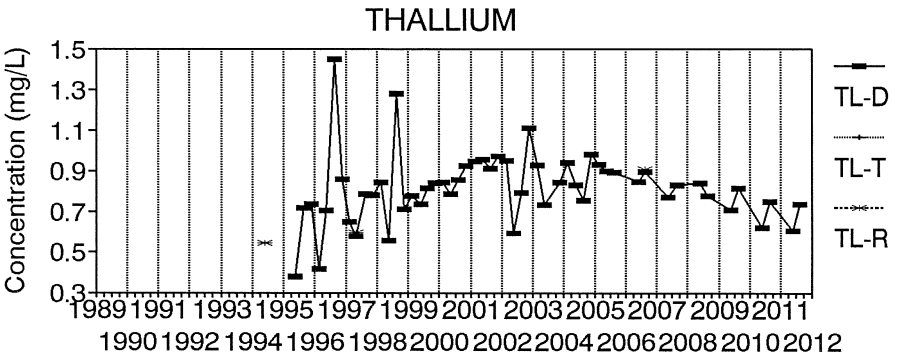
Process Pond

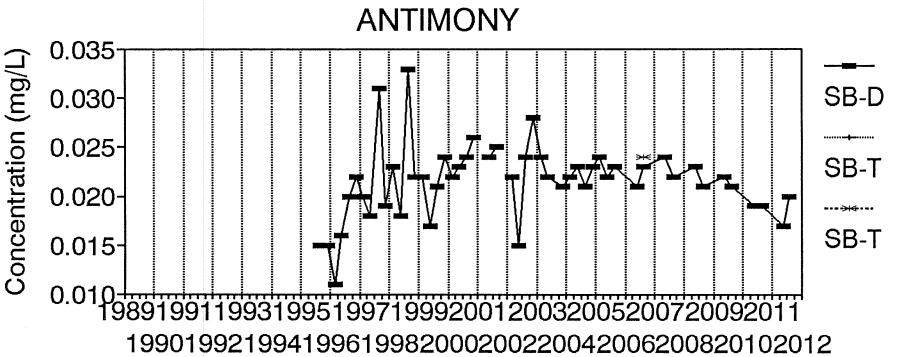




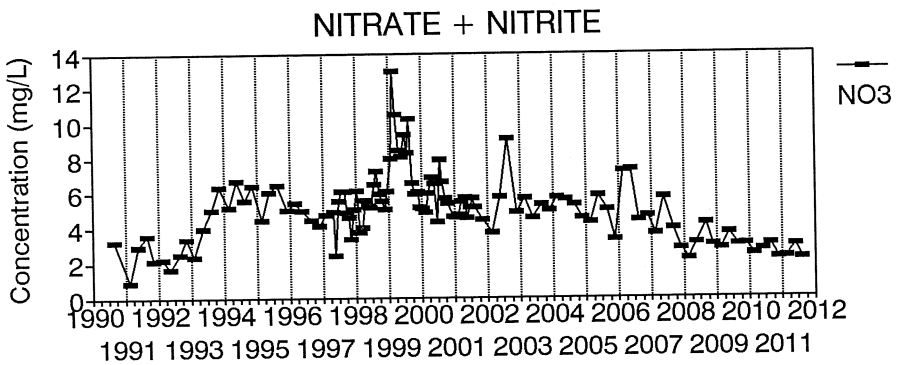


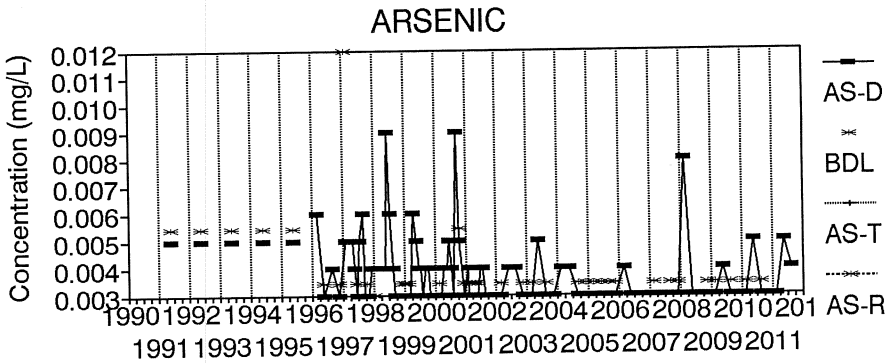


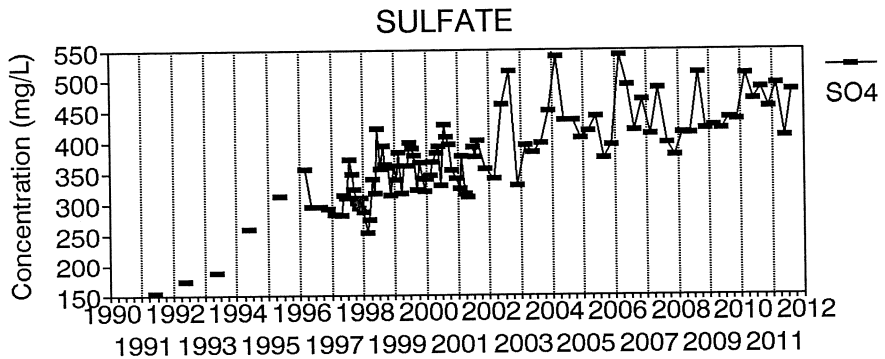


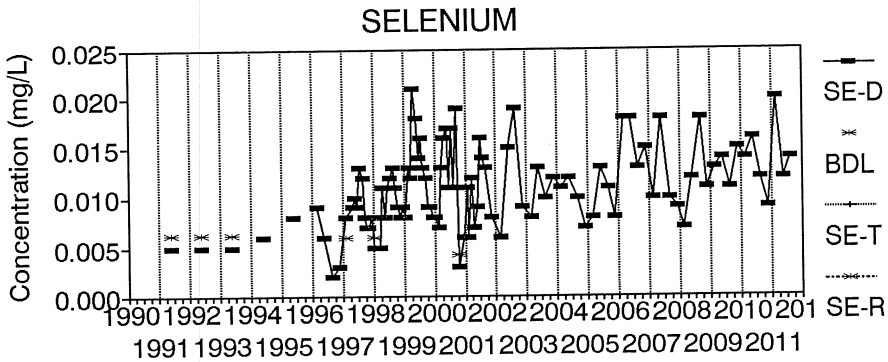


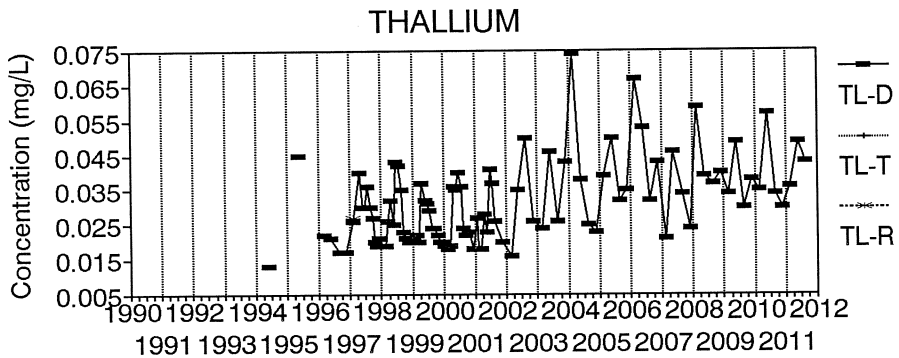
TMW-26

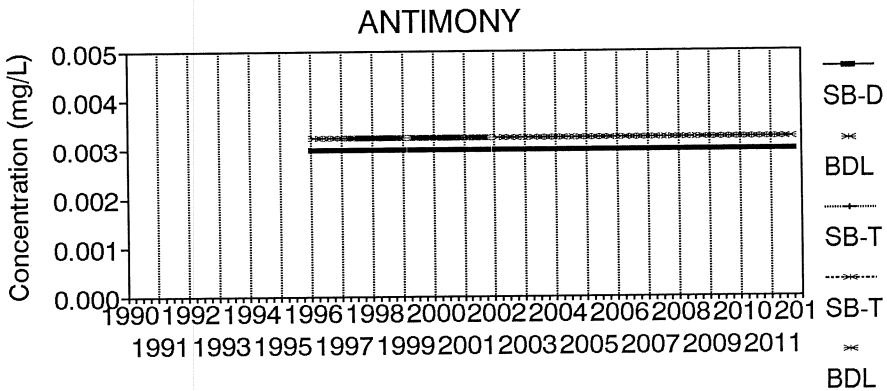






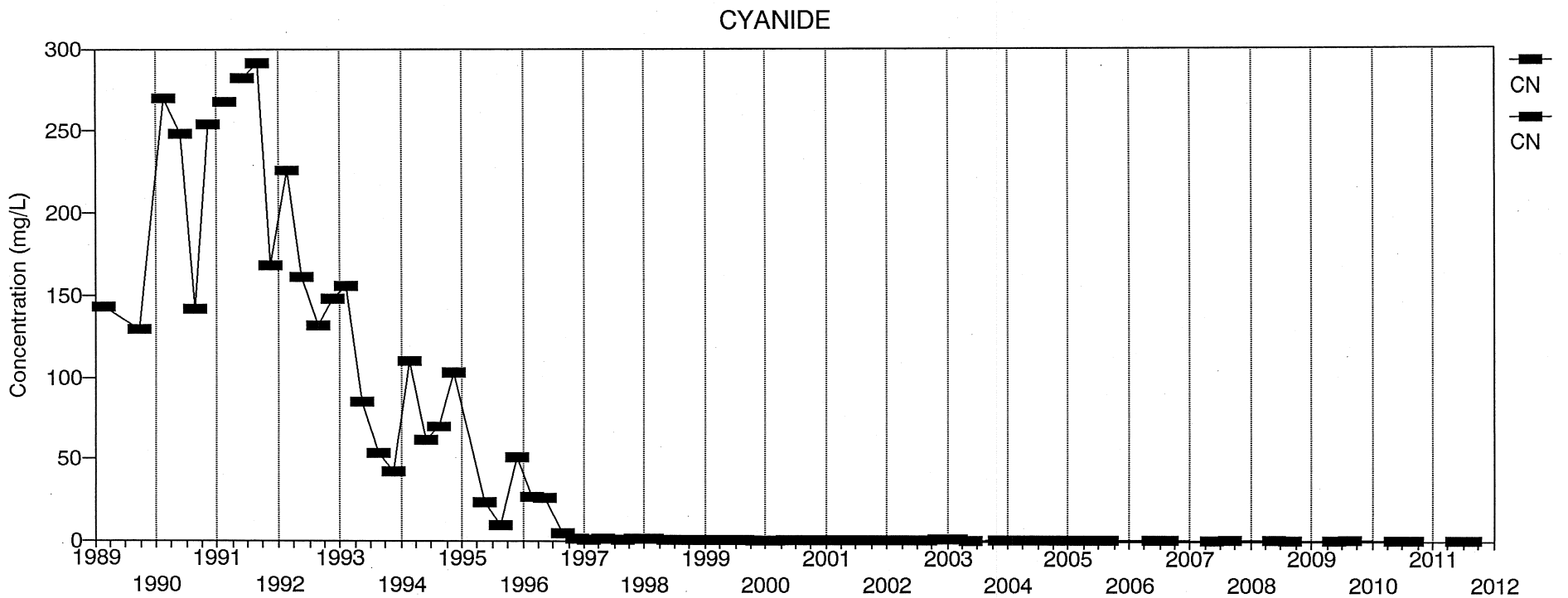




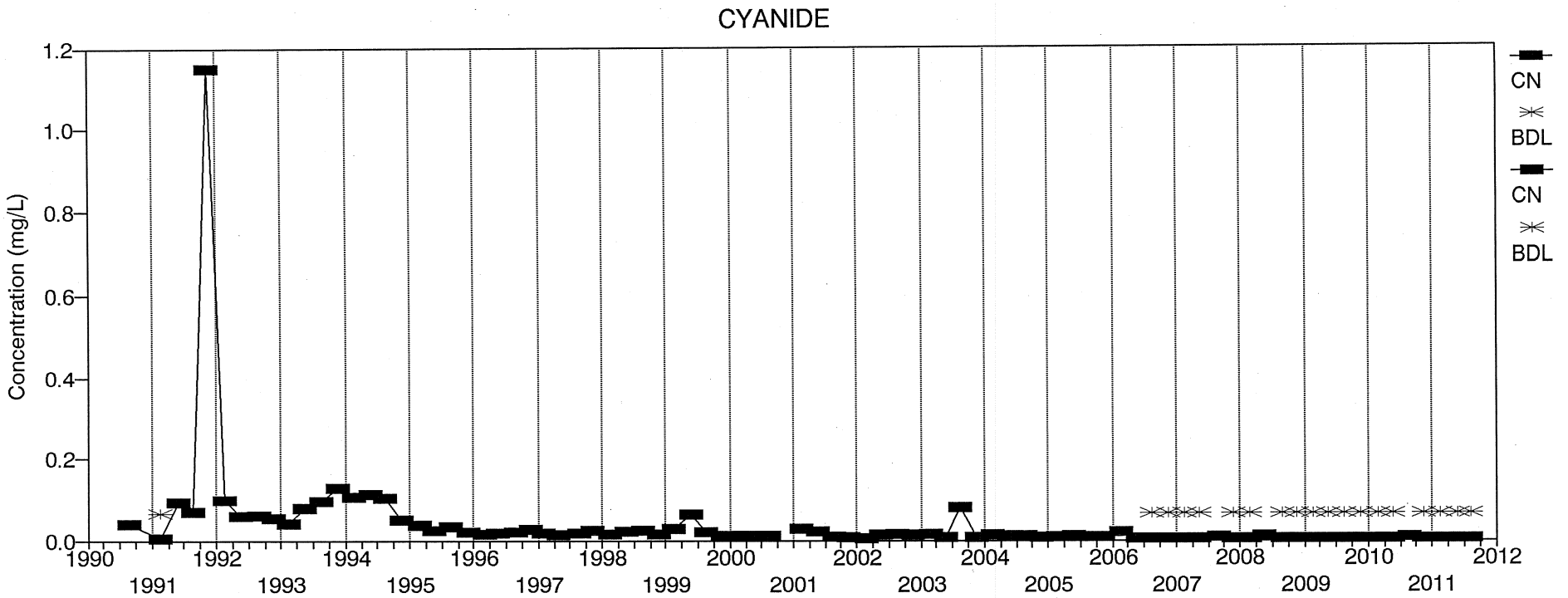


BDL - Below Analytical Detection Limit

Process Pond



TMW-26



BDL - Below Analytical Detection Limit

Statistical Summary

CRWR01 - CR Kendall Water Resource

SITE: KVPB-2

PARAMETER	PERIOD OF DATA	N	# OF DET	MIN	MAX	MEAN	MEDIAN	SD	MEAN + 2 SD	UPPER 95th PERCENTILE
DEPTH TO WATER LEVEL (FEET)	N/A	0	0			0.0000		0.0000	0.0000	
FLOW GPM	05/23/1997-08/18/1998	8	8	0.0000	10.0000	4.8250	3.5000	3.4735	11.7719	9.6000
PH (FLD)	11/19/1996-08/08/2011	88	88	6.4800	8.0900	7.2553	7.2450	0.3532	7.9618	7.7760
PH	11/19/1996-08/08/2011	95	95	6.3000	7.8000	7.2158	7.2000	0.2574	7.7305	7.7000
SC (UMHOS/CM AT 25 C)	11/19/1996-08/08/2011	95	95	662.0000	3560.0000	2528.8632	2530.0000	354.4655	3237.7941	3002.5000
TDS (MEASURED AT 180 C)	04/28/1997-05/21/2001	7	7	2140.0000	2630.0000	2398.5714	2400.0000	168.6642	2735.8999	2605.5000
TOTAL SUSPENDED SOLIDS	02/03/1997-11/17/2008	5	0	<10.0000	<10.0000					
WATER TEMPERATURE (C) (FLD)	11/19/1996-08/08/2011	87	87	4.6000	14.8000	9.7322	9.6000	2.6556	15.0433	13.9300
TOTAL HARDNESS AS CACO3	04/28/1997-05/21/2001	7	7	1560.0000	1880.0000	1760.0000	1780.0000	134.1641	2028.3282	1876.5000
CALCIUM (CA) DIS	04/28/1997-05/21/2001	7	7	379.0000	463.0000	425.2857	430.0000	28.9063	483.0982	457.4000
MAGNESIUM (MG) DIS	04/28/1997-05/21/2001	7	7	138.0000	190.0000	169.5714	174.0000	17.4533	204.4781	187.2000
SODIUM (NA) DIS	04/28/1997-05/21/2001	7	7	4.0000	9.0000	5.7143	6.0000	1.7043	9.1230	7.9500
POTASSIUM (K) DIS	04/28/1997-05/21/2001	7	7	7.0000	10.0000	8.5714	9.0000	0.9759	10.5232	9.6500
TOTAL ALKALINITY AS CACO3	04/28/1997-05/21/2001	7	7	278.0000	389.0000	350.1429	360.0000	40.9285	431.9999	386.5500
BICARBONATE (HCO3)	04/28/1997-05/21/2001	7	7	339.0000	475.0000	427.4286	440.0000	50.0095	527.4476	471.8500
CARBONATE AS CO3	04/28/1997-05/21/2001	7	5	0.0000	<1.0000	0.1429	0.0000	0.2440	0.6308	<1.0000
SULFATE (SO4)	11/19/1996-08/08/2011	95	95	572.0000	1700.0000	1375.6947	1390.0000	177.3314	1730.3575	1610.0000
CHLORIDE (CL)	04/28/1997-05/18/1998	2	2	8.0000	14.0000	11.0000	11.0000	4.2426	19.4853	13.4000
NITRATE + NITRITE AS N	11/19/1996-08/08/2011	95	95	0.8000	14.7000	4.2222	2.7600	3.3616	10.9455	11.7250
PHOSPHORUS (P) TOT	04/28/1997-05/21/2001	8	4	<0.0010	1.1600	0.1501	<0.0053	0.4081	0.9663	0.7012
ANTIMONY (SB) DIS	11/19/1996-08/08/2011	89	87	<0.0030	0.0210	0.0053	0.0050	0.0000	0.0053	0.0060
ANTIMONY (SB) TRC	02/03/1997-01/13/1998	2	2	0.0050	0.0060	0.0055	0.0055	0.0000	0.0055	0.0059
ARSENIC (AS) DIS	11/19/1996-08/08/2011	95	95	0.0060	0.0490	0.0129	0.0110	0.0063	0.0254	0.0213
ARSENIC (AS) TRC	02/03/1997-01/13/1998	2	2	0.0100	0.0200	0.0150	0.0150	0.0071	0.0291	0.0190
CADMIUM (CD) DIS	04/28/1997-11/16/1998	4	3	<0.0001	0.0002	0.0001	0.0001	0.0000	0.0001	0.0002
CHROMIUM (CR) DIS	08/14/2000-08/14/2000	1	1	0.0050	0.0050	0.0050	0.0050	0.0000	0.0050	**********
COPPER (CU) DIS	04/28/1997-11/16/1998	4	2	<0.0010	0.0040	0.0020	<0.0018	0.0000	0.0020	0.0038
IRON (FE) DIS	11/19/1996-05/21/2001	25	19	<0.0100	1.5100	0.1138	0.0600	0.2940	0.7017	0.1525
IRON (FE) TRC	02/03/1997-01/13/1998	2	2	0.0400	1.4800	0.7600	0.7600	1.0182	2.7965	1.3360
LEAD (PB) DIS	04/28/1997-11/16/1998	4	0	<0.0030	<0.0030					
MANGANESE (MN) DIS	11/19/1996-05/21/2001	25	25	0.0180	0.1030	0.0572	0.0560	0.0218	0.1009	0.0900
MANGANESE (MN) TRC	02/03/1997-01/13/1998	2	2	0.0400	0.0580	0.0490	0.0490	0.0127	0.0745	0.0562
MERCURY (HG) DIS	04/28/1997-05/18/1998	2	0	<0.0006	<0.0006					
NICKEL (NI) DIS	04/28/1997-05/18/1998	2	1	<0.0200	0.0400	0.0250	<0.0250	0.0212	0.0674	0.0380
SELENIUM (SE) DIS	11/19/1996-08/08/2011	95	95	0.0060	0.0300	0.0129	0.0120	0.0046	0.0222	0.0220
SELENIUM (SE) TRC	02/03/1997-01/13/1998	2	2	0.0110	0.0150	0.0130	0.0130	0.0000	0.0130	0.0146
SILVER (AG) DIS	04/28/1997-05/18/1998	2	0	<0.0030	<0.0030					
THALLIUM (TL) DIS	11/19/1996-08/08/2011	95	95	0.3000	1.6900	1.1184	1.1200	0.2851	1.6887	1.5550
THALLIUM (TL) TRC	02/03/1997-01/13/1998	2	2	0.7220	0.7910	0.7565	0.7565	0.0488	0.8541	0.7841
ZINC (ZN) DIS	04/28/1997-05/21/2001	7	7	0.1700	0.3500	0.2429	0.2400	0.0594	0.3616	0.3255

NOTES: All quantities in mg/L (Water) or mg/kg (Soil) unless noted. All results LABORATORY unless field (FLD) or calculated (CALCN: Number of samples in comparison data set; # OF DET: Number of samples in data set above detection limit; SD: is Standard Deviat50% of data set must be above lab detection limit before mean, median, standard deviation, and 95th percentile are calculated.

HP

Statistical Summary

CRWR01 - CR Kendall Water Resource

SITE: KVPB-5

PARAMETER	PERIOD OF DATA	N	# OF DET	MIN	MAX	MEAN	MEDIAN	SD	MEAN + 2 SD	UPPER 95th PERCENTILE
FLOW GPM	05/23/1997-01/13/1998	6	6	4.5000	18.0000	10.9167	9.5000	5.8345	22.5857	18.0000
PH (FLD)	11/20/1996-08/09/2011	85	85	6.5200	8.0900	7.5073	7.5100	0.2935	8.0943	8.0075
PH	11/20/1996-08/09/2011	94	94	6.4000	7.9000	7.4117	7.4000	0.2290	7.8697	7.7000
SC (UMHOS/CM AT 25 C)	11/20/1996-08/09/2011	94	94	1750.0000	3370.0000	2676.4894	2730.0000	306.3300	3289.1494	3110.0000
TDS (MEASURED AT 180 C)	11/11/1997-05/21/2001	6	6	2140.0000	3300.0000	2740.0000	2820.0000	416.3172	3572.6344	3198.0000
TOTAL SUSPENDED SOLIDS	01/13/1998-11/17/2008	4	1	1.0000	<10.0000					
WATER TEMPERATURE (C) (FLD)	11/20/1996-08/09/2011	86	86	3.3000	13.6000	8.5081	8.6500	2.6863	13.8808	12.5700
TOTAL HARDNESS AS CACO3	11/11/1997-05/21/2001	6	6	1610.0000	2580.0000	2003.3333	1965.0000	346.9102	2697.1537	2460.0000
CALCIUM (CA) DIS	11/11/1997-05/21/2001	6	6	331.0000	486.0000	401.8333	392.5000	54.1606	510.1545	471.3000
MAGNESIUM (MG) DIS	11/11/1997-05/21/2001	6	6	166.0000	332.0000	243.3333	256.5000	63.7924	370.9181	315.2000
SODIUM (NA) DIS	11/11/1997-05/21/2001	6	6	9.0000	12.0000	10.3333	10.0000	1.0328	12.3989	11.7000
POTASSIUM (K) DIS	11/11/1997-05/21/2001	6	6	5.0000	9.0000	6.0000	5.5000	1.5492	9.0984	8.1000
TOTAL ALKALINITY AS CACO3	11/11/1997-05/21/2001	6	6	203.0000	431.0000	293.6667	283.5000	76.4975	446.6617	394.1000
BICARBONATE (HCO3)	11/11/1997-05/21/2001	6	6	247.0000	526.0000	358.1667	346.0000	93.4717	545.1102	480.7000
CARBONATE AS CO3	11/11/1997-05/21/2001	6	4	0.0000	<1.0000	0.1667	0.0000	0.2582	0.6831	<1.0000
SULFATE (SO4)	11/20/1996-08/09/2011	94	94	673.0000	2210.0000	1650.9787	1675.0000	283.7514	2218.4815	2066.0000
CHLORIDE (CL)	05/20/1998-05/20/1998	1	1	14.0000	14.0000	14.0000	14.0000	0.0000	14.0000	**********
NITRATE + NITRITE AS N	11/20/1996-08/09/2011	94	94	1.8100	12.6000	6.8991	6.4650	2.4876	11.8744	11.1000
PHOSPHORUS (P) TOT	11/11/1997-05/21/2001	7	6	<0.0010	0.0360	0.0176	0.0180	0.0126	0.0428	0.0339
ANTIMONY (SB) DIS	11/20/1996-08/09/2011	32	0	<0.0030	<0.0030					
ANTIMONY (SB) TRC	01/13/1998-01/13/1998	1	0	<0.0030	<0.0030					
ARSENIC (AS) DIS	11/20/1996-08/09/2011	94	75	<0.0030	0.0180	0.0034	0.0030	0.0000	0.0034	0.0050
ARSENIC (AS) TRC	01/13/1998-01/13/1998	1	0	<0.0030	<0.0030					
CADMIUM (CD) DIS	11/11/1997-11/19/1998	3	0	<0.0001	<0.0001					
COPPER (CU) DIS	11/11/1997-11/19/1998	3	1	<0.0010	0.0020					
IRON (FE) DIS	11/20/1996-05/21/2001	23	5	<0.0100	1.5000					
IRON (FE) TRC	01/13/1998-01/13/1998	1	1	1.4900	1.4900	1.4900	1.4900	0.0000	1.4900	**********
LEAD (PB) DIS	11/11/1997-11/19/1998	3	0	<0.0030	<0.0030					
MANGANESE (MN) DIS	11/20/1996-05/21/2001	23	22	<0.0050	0.3790	0.0906	0.0740	0.0765	0.2437	0.1723
MANGANESE (MN) TRC	01/13/1998-01/13/1998	1	1	0.0730	0.0730	0.0730	0.0730	0.0000	0.0730	**********
MERCURY (HG) DIS	05/20/1998-05/20/1998	1	0	<0.0006	<0.0006					
NICKEL (NI) DIS	05/20/1998-05/20/1998	1	0	<0.0200	<0.0200					
SELENIUM (SE) DIS	11/20/1996-08/09/2011	94	93	<0.0010	0.0270	0.0115	0.0100	0.0060	0.0234	0.0226
SELENIUM (SE) TRC	01/13/1998-01/13/1998	1	1	0.0050	0.0050	0.0050	0.0050	0.0000	0.0050	**********
SILVER (AG) DIS	05/20/1998-05/20/1998	1	0	<0.0030	<0.0030					
THALLIUM (TL) DIS	11/20/1996-08/09/2011	94	94	0.0080	0.1560	0.0301	0.0270	0.0174	0.0650	0.0512
THALLIUM (TL) TRC	01/13/1998-01/13/1998	1	1	0.0160	0.0160	0.0160	0.0160	0.0000	0.0160	**********
ZINC (ZN) DIS	11/11/1997-05/21/2001	6	6	0.0200	0.0700	0.0417	0.0400	0.0172	0.0761	0.0640

NOTES: All quantities in mg/L (Water) or mg/kg (Soil) unless noted. All results LABORATORY unless field (FLD) or calculated (CALCN: Number of samples in comparison data set; # OF DET: Number of samples in data set above detection limit; SD: is Standard Deviat50% of data set must be above lab detection limit before mean, median, standard deviation, and 95th percentile are calculated.

HP

Statistical Summary

CRWR01 - CR Kendall Water Resource

SITE: KVPB-6

PARAMETER	PERIOD OF DATA	N	# OF DET	MIN	MAX	MEAN	MEDIAN	SD	MEAN + 2 SD	UPPER 95th PERCENTILE
FLOW GPM	05/23/1997-02/20/2008	7	7	0.0000	25.0000	8.9643	4.0000	9.4697	27.9037	21.5000
PH (FLD)	11/20/1996-08/09/2011	88	88	6.8500	8.4400	7.7395	7.7800	0.2999	8.3394	8.1800
PH	11/20/1996-08/09/2011	96	96	6.7000	8.1000	7.7229	7.8000	0.2198	8.1625	8.0000
SC (UMHOS/CM AT 25 C)	11/20/1996-08/09/2011	97	97	760.0000	2950.0000	2367.2165	2390.0000	363.6096	3094.4358	2856.0000
TDS (MEASURED AT 180 C)	01/16/1997-05/21/2001	8	8	1780.0000	2730.0000	2276.2500	2290.0000	278.8209	2833.8917	2618.0000
TOTAL SUSPENDED SOLIDS	02/04/1997-11/17/2008	4	1	<10.0000	11.0000					
WATER TEMPERATURE (C) (FLD)	11/20/1996-08/09/2011	88	88	1.7000	12.7000	8.1136	8.3500	2.3691	12.8518	11.4000
TOTAL HARDNESS AS CACO3	04/29/1997-05/21/2001	7	7	1170.0000	1810.0000	1561.4286	1570.0000	218.7410	1998.9105	1803.0000
CALCIUM (CA) DIS	04/29/1997-05/21/2001	7	7	305.0000	439.0000	390.2857	393.0000	43.0841	476.4539	434.1000
MAGNESIUM (MG) DIS	04/29/1997-05/21/2001	7	7	99.0000	176.0000	142.5714	144.0000	27.5128	197.5970	174.9500
SODIUM (NA) DIS	04/29/1997-05/21/2001	7	7	5.0000	60.0000	16.2857	9.0000	19.5935	55.4727	44.6000
POTASSIUM (K) DIS	04/29/1997-05/21/2001	7	7	6.0000	10.0000	7.8571	8.0000	1.3452	10.5475	9.6500
TOTAL ALKALINITY AS CACO3	04/29/1997-05/21/2001	7	7	125.0000	226.0000	180.0000	178.0000	31.4696	242.9391	218.3000
BICARBONATE (HCO3)	04/29/1997-05/21/2001	7	7	153.0000	276.0000	219.7143	217.0000	38.1825	296.0793	266.2000
CARBONATE AS CO3	04/29/1997-05/21/2001	7	5	0.0000	<1.0000	0.1429	0.0000	0.2440	0.6308	<1.0000
SULFATE (SO4)	11/20/1996-08/09/2011	97	97	649.0000	1870.0000	1376.1546	1400.0000	243.5251	1863.2049	1693.0000
CHLORIDE (CL)	04/29/1997-05/19/1998	2	2	7.0000	9.0000	8.0000	8.0000	1.4142	10.8284	8.8000
NITRATE + NITRITE AS N	11/20/1996-08/09/2011	97	97	1.7300	39.8000	13.1033	13.7000	5.8570	24.8173	20.8200
PHOSPHORUS (P) TOT	04/29/1997-05/21/2001	8	6	0.0020	0.4670	0.0666	0.0085	0.1620	0.3906	0.2886
ANTIMONY (SB) DIS	11/20/1996-08/09/2011	35	4	<0.0030	0.0080					
ANTIMONY (SB) TRC	02/04/1997-01/13/1998	2	1	<0.0030	0.0030	0.0023	<0.0023	0.0000	0.0023	0.0030
ARSENIC (AS) DIS	11/20/1996-08/09/2011	96	96	0.0050	0.0180	0.0097	0.0090	0.0000	0.0097	0.0130
ARSENIC (AS) TRC	02/04/1997-01/13/1998	2	2	0.0090	0.0100	0.0095	0.0095	0.0000	0.0095	0.0099
CADMIUM (CD) DIS	04/29/1997-11/17/1998	4	0	<0.0001	<0.0001					
COPPER (CU) DIS	04/29/1997-11/17/1998	4	3	<0.0010	0.0030	0.0019	0.0020	0.0000	0.0019	0.0030
IRON (FE) DIS	11/20/1996-05/21/2001	26	3	<0.0100	1.6600					
IRON (FE) TRC	02/04/1997-01/13/1998	2	2	0.0100	1.5900	0.8000	0.8000	1.1172	3.0345	1.4320
LEAD (PB) DIS	04/29/1997-11/17/1998	4	0	<0.0030	<0.0030					
MANGANESE (MN) DIS	11/20/1996-05/21/2001	26	6	<0.0050	0.0130					
MANGANESE (MN) TRC	02/04/1997-01/13/1998	2	0	<0.0050	<0.0050					
MERCURY (HG) DIS	04/29/1997-05/19/1998	2	0	<0.0006	<0.0006					
NICKEL (NI) DIS	04/29/1997-05/19/1998	2	0	<0.0200	<0.0300					
SELENIUM (SE) DIS	11/20/1996-08/09/2011	97	97	0.0080	0.0700	0.0361	0.0340	0.0120	0.0600	0.0570
SELENIUM (SE) TRC	02/04/1997-01/13/1998	2	2	0.0150	0.0330	0.0240	0.0240	0.0127	0.0495	0.0312
SILVER (AG) DIS	04/29/1997-05/19/1998	2	0	<0.0030	<0.0030					
THALLIUM (TL) DIS	11/20/1996-08/09/2011	97	97	0.1590	0.8200	0.3754	0.3740	0.0803	0.5360	0.4799
THALLIUM (TL) TRC	02/04/1997-01/13/1998	2	2	0.3020	0.3230	0.3125	0.3125	0.0148	0.3422	0.3209
ZINC (ZN) DIS	04/29/1997-05/21/2001	7	7	0.0300	0.1200	0.0557	0.0500	0.0310	0.1177	0.0990

NOTES: All quantities in mg/L (Water) or mg/kg (Soil) unless noted. All results LABORATORY unless field (FLD) or calculated (CALCN: Number of samples in comparison data set; # OF DET: Number of samples in data set above detection limit; SD: is Standard Deviat50% of data set must be above lab detection limit before mean, median, standard deviation, and 95th percentile are calculated.

HP

Statistical Summary

CRWR01 - CR Kendall Water Resource

SITE: PROCESS PAD DRAINAGE

PARAMETER	PERIOD OF DATA	N	# OF DET	MIN	MAX	MEAN	MEDIAN	SD	MEAN + 2 SD	UPPER 95th PERCENTILE
DEPTH TO WATER LEVEL (FEET)	05/21/2001-05/21/2001	1	1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	**********
FLOW GPM	11/17/1992-02/17/1999	3	3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
PH (FLD)	05/19/1992-08/10/2011	62	62	7.0600	11.7300	8.6273	8.1100	1.2350	11.0972	11.3990
PH	02/21/1989-08/10/2011	75	75	6.9000	12.0000	8.7653	7.8000	1.5069	11.7791	11.5500
SC (UMHOS/CM AT 25 C)	02/21/1989-08/10/2011	75	75	2150.0000	5370.0000	3583.2000	3520.0000	624.6408	4832.4816	4570.0000
TDS (MEASURED AT 180 C)	02/21/1989-05/21/2001	19	19	1020.0000	5100.0000	3765.7895	4040.0000	851.3148	5468.4190	4454.0000
TOTAL SUSPENDED SOLIDS	09/28/1989-08/16/2006	9	5	<1.0000	16.0000	5.6111	<10.0000	4.4284	14.4680	12.4000
WATER TEMPERATURE (C) (FLD)	05/19/1992-08/10/2011	63	63	1.7000	18.2000	9.9983	10.2000	3.1234	16.2451	13.3700
TOTAL HARDNESS AS CACO3	02/21/1989-05/21/2001	25	25	367.0000	2090.0000	1381.4800	1460.0000	431.8597	2245.1995	1822.5000
CALCIUM (CA) DIS	02/21/1989-05/21/2001	25	25	147.0000	820.0000	541.1200	584.0000	165.4102	871.9404	714.7500
MAGNESIUM (MG) DIS	02/21/1989-05/21/2001	25	19	<1.0000	21.0000	7.7200	4.0000	6.8846	21.4892	18.5000
SODIUM (NA) DIS	02/21/1989-05/21/2001	26	26	221.0000	588.0000	413.0000	441.5000	87.7118	588.4236	498.9000
POTASSIUM (K) DIS	02/21/1989-05/21/2001	25	25	6.0000	17.0000	10.7600	10.0000	2.5703	15.9007	14.7500
TOTAL ALKALINITY AS CACO3	02/21/1989-05/21/2001	26	26	25.0000	582.0000	124.0769	62.5000	149.2780	422.6329	426.5000
BICARBONATE (HCO3)	02/21/1989-05/21/2001	25	25	0.0000	79.0000	28.2000	30.0000	22.6016	73.4032	69.5000
CARBONATE AS CO3	02/21/1989-05/21/2001	25	23	0.0000	223.0000	40.3600	<1.0000	60.7136	161.7871	149.0000
SULFATE (SO4)	02/21/1989-08/10/2011	60	60	66.0000	2510.0000	1717.8833	1770.0000	443.1157	2604.1148	2250.0000
CHLORIDE (CL)	02/21/1989-02/17/1999	22	22	15.0000	83.0000	38.2727	36.0000	17.5396	73.3519	58.9000
FLUORIDE (F)	02/21/1989-02/04/1997	13	13	1.4000	5.9000	2.3600	1.9500	1.2643	4.8886	4.7950
TOTAL AMMONIA (NH3+NH4 AS N)	08/24/1995-08/20/2001	25	13	<0.0500	24.1000	4.1824	0.0500	7.8952	19.9727	21.2250
TOTAL KJELDAHL NITROGEN AS N	05/31/1990-08/20/2001	24	21	<0.1000	91.7000	26.9104	7.0000	30.3707	87.6518	82.0400
NITROGEN, TOTAL (NO3 + NO2 +	02/16/2000-02/16/2000	1	1	129.0000	129.0000	129.0000	129.0000	0.0000	129.0000	**********
NITRATE + NITRITE AS N	02/21/1989-08/10/2011	75	75	0.1700	195.0000	71.6416	84.0000	49.7558	171.1532	137.5000
ORTHOPHOSPHATE (PO4-P)	11/29/1995-11/29/1995	1	1	0.1600	0.1600	0.1600	0.1600	0.0000	0.1600	**********
PHOSPHORUS (P) TOT	08/24/1995-05/21/2001	17	14	<0.0050	0.8560	0.0823	0.0230	0.2017	0.4858	0.2219
ALUMINUM (AL) DIS	08/24/1995-02/17/1999	6	0	<0.1000	<0.1000					
ALUMINUM (AL) TRC	04/29/1997-04/29/1997	1	0	<0.1000	<0.1000					
ANTIMONY (SB) DIS	08/24/1995-08/10/2011	50	50	0.0110	0.0330	0.0215	0.0220	0.0038	0.0292	0.0270
ANTIMONY (SB) TRC	04/29/1997-08/16/2006	2	2	0.0180	0.0240	0.0210	0.0210	0.0042	0.0295	0.0234
ARSENIC (AS) DIS	02/21/1989-08/10/2011	55	55	0.1390	0.3750	0.2169	0.1990	0.0482	0.3134	0.3018
ARSENIC (AS) TRC	05/31/1990-08/16/2006	7	7	0.1340	0.3900	0.2237	0.2080	0.0795	0.3828	0.3354
BARIUM (BA) DIS	08/24/1995-04/29/1997	5	5	0.0160	0.0210	0.0184	0.0170	0.0000	0.0184	0.0210
BARIUM (BA) TRC	04/29/1997-04/29/1997	1	1	0.0130	0.0130	0.0130	0.0130	0.0000	0.0130	**********
BERYLLIUM (BE) DIS	08/24/1995-05/13/1996	4	0	<0.0010	<0.0010					
CADMIUM (CD) DIS	02/21/1989-02/17/1999	17	12	<0.0001	0.0330	0.0058	0.0004	0.0106	0.0271	0.0322
CADMIUM (CD) TRC	05/31/1990-04/29/1997	6	6	0.0003	0.0520	0.0284	0.0250	0.0183	0.0650	0.0499
CHROMIUM (CR) DIS	08/24/1995-08/15/2000	5	2	<0.0010	0.0240					
COPPER (CU) DIS	02/21/1989-02/17/1999	17	17	0.0040	3.1100	0.4390	0.0220	0.8083	2.0555	1.8180
COPPER (CU) TRC	05/31/1990-04/29/1997	6	6	0.0110	2.6100	1.6018	1.5900	0.9859	3.5737	2.6010
IRON (FE) DIS	02/21/1989-05/21/2001	21	20	<0.0100	0.3200	0.1483	0.1500	0.0753	0.2988	0.2295
IRON (FE) TRC	05/31/1990-04/29/1997	6	6	0.0600	0.4600	0.1933	0.1200	0.1576	0.5085	0.4150
LEAD (PB) DIS	02/21/1989-02/17/1999	16	6	<0.0030	0.0100					
LEAD (PB) TRC	04/29/1997-04/29/1997	1	1	0.0060	0.0060	0.0060	0.0060	0.0000	0.0060	**********
MANGANESE (MN) DIS	08/24/1995-05/21/2001	18	10	<0.0050	0.0410	0.0124	<0.0128	0.0110	0.0344	0.0266
MANGANESE (MN) TRC	04/29/1997-04/29/1997	1	1	0.0290	0.0290	0.0290	0.0290	0.0000	0.0290	**********

NOTES: All quantities in mg/L (Water) or mg/kg (Soil) unless noted. All results LABORATORY unless field (FLD) or calculated (CALCN: Number of samples in comparison data set; # OF DET: Number of samples in data set above detection limit; SD: is Standard Deviat50% of data set must be above lab detection limit before mean, median, standard deviation, and 95th percentile are calculated.

HP

Statistical Summary

CRWR01 - CR Kendall Water Resource

SITE: PROCESS PAD DRAINAGE

PARAMETER	PERIOD OF DATA	N	# OF DET	MIN	MAX	MEAN	MEDIAN	SD	MEAN + 2 SD	UPPER 95th PERCENTILE
MERCURY (HG) DIS	02/21/1989-02/17/1999	16	6	<0.0006	0.2200					
MERCURY (HG) TRC	05/30/1991-04/29/1997	5	4	<0.0006	0.0580	0.0151	0.0070	0.0242	0.0635	0.0455
NICKEL (NI) DIS	08/24/1995-02/17/1999	12	11	<0.0200	0.7900	0.2558	0.0300	0.3402	0.9363	0.7360
NICKEL (NI) TRC	04/29/1997-04/29/1997	1	0	<0.0200	<0.0200					
SELENIUM (SE) DIS	02/21/1989-08/10/2011	55	55	0.0230	0.1820	0.0990	0.0850	0.0388	0.1766	0.1653
SELENIUM (SE) TRC	05/31/1990-08/16/2006	7	7	0.0430	0.1700	0.1036	0.0960	0.0459	0.1953	0.1606
SILVER (AG) DIS	08/24/1995-02/17/1999	12	4	<0.0030	0.0780					
SILVER (AG) TRC	04/29/1997-04/29/1997	1	0	<0.0030	<0.0030					
STRONTIUM (SR) DIS	04/29/1997-04/29/1997	1	1	1.6000	1.6000	1.6000	1.6000	0.0000	1.6000	**********
STRONTIUM (SR) TRC	04/29/1997-04/29/1997	1	1	1.7000	1.7000	1.7000	1.7000	0.0000	1.7000	**********
THALLIUM (TL) DIS	05/17/1995-08/10/2011	53	53	0.3800	1.4500	0.8159	0.8160	0.1762	1.1684	1.0268
THALLIUM (TL) TRC	05/26/1994-08/16/2006	3	3	0.5450	0.9080	0.6830	0.5960	0.1965	1.0760	0.8612
ZINC (ZN) DIS	02/21/1989-05/21/2001	20	20	0.0100	42.0000	3.7060	0.0850	9.4680	22.6420	9.3200
ZINC (ZN) TRC	05/31/1990-04/29/1997	6	6	0.0700	33.2000	21.4950	25.1000	11.9105	45.3161	31.8200
CYANIDE (CN) FRE	02/22/1990-08/20/2001	41	29	<0.2000	115.0000	32.3024	10.4000	37.7863	107.8750	101.9000
CYANIDE (CN) TMD	02/21/1989-08/10/2011	73	73	0.1190	291.0000	47.2610	0.9600	81.1496	209.5602	250.1000
CYANIDE (CN) TOT	02/14/1991-05/25/2011	2	2	0.2530	268.0000	134.1265	134.1265	189.3257	512.7779	241.2253
CYANIDE (CN) WAD	02/21/1989-08/20/2001	48	46	<0.2000	232.0000	46.3641	23.7500	54.0728	154.5098	134.8000

NOTES: All quantities in mg/L (Water) or mg/kg (Soil) unless noted. All results LABORATORY unless field (FLD) or calculated (CALCN: Number of samples in comparison data set; # OF DET: Number of samples in data set above detection limit; SD: is Standard Deviat50% of data set must be above lab detection limit before mean, median, standard deviation, and 95th percentile are calculated.

HP

Statistical Summary

CRWR01 - CR Kendall Water Resource

SITE: TMW-26

PARAMETER	PERIOD OF DATA	N	# OF DET	MIN	MAX	MEAN	MEDIAN	SD	MEAN + 2 SD	UPPER 95th PERCENTILE
DEPTH TO WATER LEVEL (FEET)	N/A	0	0			0.0000		0.0000	0.0000	
ELEC COND (UMHOS/CM AT 25 C)	N/A	0	0			0.0000		0.0000	0.0000	
FLOW GPM	11/17/1992-11/11/1997	25	25	0.0000	23.6300	4.5252	2.0000	6.0920	16.7091	15.0000
PH (FLD)	02/19/1992-08/10/2011	103	103	3.3000	7.7800	7.1678	7.2200	0.4608	8.0893	7.6300
PH	08/28/1990-08/10/2011	117	117	6.2000	7.9000	7.2291	7.2000	0.2360	7.7011	7.6000
SC (UMHOS/CM AT 25 C)	08/28/1990-08/10/2011	117	117	802.0000	1610.0000	1334.7863	1340.0000	132.4155	1599.6173	1530.0000
TDS (MEASURED AT 180 C)	02/28/1996-05/17/2000	10	10	841.0000	1040.0000	941.0000	925.5000	63.9218	1068.8437	1025.0000
TOTAL SUSPENDED SOLIDS	02/04/1997-11/18/2008	4	1	<10.0000	62.0000					
WATER TEMPERATURE (C) (FLD)	02/19/1992-08/10/2011	105	105	5.5000	13.4000	9.6486	9.6000	1.7045	13.0575	12.5500
TOTAL HARDNESS AS CACO3	05/30/1991-05/21/2001	16	16	559.0000	829.0000	716.2500	725.0000	73.5096	863.2693	811.4000
CALCIUM (CA) DIS	05/30/1991-05/21/2001	16	16	147.0000	228.0000	194.8125	200.0000	22.6281	240.0686	219.2000
MAGNESIUM (MG) DIS	05/30/1991-05/21/2001	16	16	46.0000	66.0000	56.0000	54.5000	5.3417	66.6833	65.2000
SODIUM (NA) DIS	05/30/1991-05/21/2001	16	16	12.0000	28.0000	21.3125	21.0000	4.2066	29.7258	27.2000
POTASSIUM (K) DIS	05/30/1991-05/21/2001	16	16	3.0000	4.0000	3.1875	3.0000	0.4031	3.9937	4.0000
TOTAL ALKALINITY AS CACO3	05/30/1991-05/17/2000	15	15	354.0000	449.0000	399.5333	396.0000	24.2807	448.0947	434.7500
BICARBONATE (HCO3)	05/30/1991-05/17/2000	15	15	433.0000	547.0000	487.7333	484.0000	29.4339	546.6011	530.5000
CARBONATE AS CO3	05/30/1991-05/17/2000	15	14	0.0000	<1.0000	0.0333	0.0000	0.1291	0.2915	<0.2500
SULFATE (SO4)	05/30/1991-08/10/2011	101	101	154.0000	541.0000	374.2772	376.0000	73.5664	521.4101	492.9500
CHLORIDE (CL)	05/30/1991-11/18/1998	12	12	4.0000	45.0000	28.8333	29.0000	10.9115	50.6563	42.0000
FLUORIDE (F)	05/30/1991-08/28/1996	8	8	0.4300	0.7200	0.5425	0.5050	0.1172	0.7769	0.7200
TOTAL AMMONIA (NH3+NH4 AS N)	02/28/1996-08/20/2001	22	0	<0.0500	<0.0500					
TOTAL KJELDAHL NITROGEN AS N	05/30/1991-08/20/2001	20	11	<0.1000	1.1000	0.3825		0.2899	0.9622	0.8000
NITROGEN, TOTAL (NO3 + NO2 +	02/16/2000-02/16/2000	1	1	4.9000	4.9000	4.9000	4.9000	0.0000	4.9000	**********
NITRATE + NITRITE AS N	08/28/1990-08/10/2011	118	118	0.8800	13.0000	5.0417	5.0250	1.9261	8.8938	8.3140
PHOSPHORUS (P) TOT	02/28/1996-05/21/2001	12	9	<0.0050	0.1050	0.0225	0.0160	0.0287	0.0799	0.0660
ALUMINUM (AL) DIS	02/28/1996-05/14/1996	2	0	<0.1000	<0.1000					
ANTIMONY (SB) DIS	02/28/1996-08/10/2011	90	0	<0.0030	<0.0030					
ANTIMONY (SB) TRC	02/04/1997-01/13/1998	2	1	<0.0030	0.0030	0.0023	<0.0023	0.0000	0.0023	0.0030
ARSENIC (AS) DIS	05/30/1991-08/10/2011	102	65	<0.0030	0.0090	0.0032	0.0030	0.0000	0.0032	0.0060
ARSENIC (AS) TRC	02/04/1997-01/13/1998	2	2	0.0030	0.0120	0.0075	0.0075	0.0064	0.0202	0.0111
BARIUM (BA) DIS	02/28/1996-05/14/1996	2	2	0.0460	0.0550	0.0505	0.0505	0.0064	0.0632	0.0541
BERYLLIUM (BE) DIS	02/28/1996-05/14/1996	2	0	<0.0010	<0.0010					
CADMIUM (CD) DIS	05/30/1991-11/18/1998	12	2	<0.0001	0.0006					
CHROMIUM (CR) DIS	02/28/1996-08/14/2000	3	0	<0.0010	<0.0030					
COPPER (CU) DIS	05/30/1991-11/18/1998	12	2	<0.0010	<0.0100					
IRON (FE) DIS	05/30/1991-05/21/2001	33	9	<0.0100	0.8400					
IRON (FE) TRC	02/04/1997-01/13/1998	2	2	0.9000	1.0100	0.9550	0.9550	0.0778	1.1106	0.9990
LEAD (PB) DIS	02/28/1996-11/18/1998	7	0	<0.0030	<0.0030					
MANGANESE (MN) DIS	02/28/1996-05/21/2001	28	27	<0.0050	0.0640	0.0310	0.0330	0.0181	0.0671	0.0606
MANGANESE (MN) TRC	02/04/1997-01/13/1998	2	2	0.0500	0.0660	0.0580	0.0580	0.0113	0.0806	0.0644
MERCURY (HG) DIS	05/30/1991-11/18/1998	11	0	<0.0006	<0.0010					
NICKEL (NI) DIS	02/28/1996-11/18/1998	6	0	<0.0200	<0.0200					
SELENIUM (SE) DIS	05/30/1991-08/10/2011	102	98	<0.0030	0.0210	0.0107	0.0110	0.0042	0.0192	0.0180
SELENIUM (SE) TRC	02/04/1997-01/13/1998	2	2	0.0060	0.0060	0.0060	0.0060	0.0000	0.0060	0.0060
SILVER (AG) DIS	02/28/1996-11/18/1998	6	0	<0.0030	<0.0030					

NOTES: All quantities in mg/L (Water) or mg/kg (Soil) unless noted. All results LABORATORY unless field (FLD) or calculated (CALCN: Number of samples in comparison data set; # OF DET: Number of samples in data set above detection limit; SD: is Standard Deviat50% of data set must be above lab detection limit before mean, median, standard deviation, and 95th percentile are calculated.

HP

Statistical Summary

CRWR01 - CR Kendall Water Resource

SITE: TMW-26

PARAMETER	PERIOD OF DATA	N	# OF DET	MIN	MAX	MEAN	MEDIAN	SD	MEAN + 2 SD	UPPER 95th PERCENTILE
THALLIUM (TL) DIS	05/26/1994-08/10/2011	99	99	0.0130	0.0740	0.0311	0.0300	0.0117	0.0545	0.0502
THALLIUM (TL) TRC	02/04/1997-01/13/1998	2	2	0.0190	0.0270	0.0230	0.0230	0.0057	0.0343	0.0262
ZINC (ZN) DIS	05/30/1991-05/21/2001	15	15	0.0400	0.1800	0.0853	0.0800	0.0421	0.1695	0.1650
CYANIDE (CN) FRE	05/30/1991-08/20/2001	38	0	<0.2000	<0.2000					
CYANIDE (CN) TMD	08/28/1990-08/10/2011	82	64	<0.0050	1.1500	0.0397	0.0140	0.1277	0.2952	0.1033
CYANIDE (CN) TOT	05/24/2011-05/24/2011	1	0	<0.0050	<0.0050					
CYANIDE (CN) WAD	08/28/1990-08/20/2001	42	31	<0.0050	<0.2000	0.0141	0.0065	0.0213	0.0566	0.0414

NOTES: All quantities in mg/L (Water) or mg/kg (Soil) unless noted. All results LABORATORY unless field (FLD) or calculated (CALCN: Number of samples in comparison data set; # OF DET: Number of samples in data set above detection limit; SD: is Standard Deviat50% of data set must be above lab detection limit before mean, median, standard deviation, and 95th percentile are calculated.

HP

Hydrometrics, Inc.®
consulting scientists and engineers

M E M O R A N D U M

DATE: November 29, 2011

TO: Jim Volberding, CR Kendall

FROM: Mark Rhodes, P.E. Hydrometrics Inc.

SUBJECT: HELP Model Results for the Approved Leach Pad Soil Cover Alternative

This memorandum summarizes the results of the Hydrologic Evaluation of Landfill Performance (HELP) model (version 3.07, Schroeder et.al., 1994) analysis for the approved soil cover at the Kendall Mine leach pad area. Climate and soil inputs to the model were obtained from the CDM Technical Memorandum "Draft CR Kendall Leach Pad Alternatives" (CDM 2004). The approved soil cover alternative consists of a water balance cover with 17 inches of topsoil underlain by 6 inches of 5% to 8% (only 5% was modeled) by volume sodium bentonite amended soil and 12 inches of subsoil. The analysis of the cover alternative was broken into two components, leach pad tops (10% slope) and leach pad slopes (34% slope). The model was then run to simulate performance over 100 years of precipitation input. Climate input parameters, soil input parameters and HELP model results are summarized in Tables 1 and 2, and Attachment A respectively.

Table 1. HELP Model Design Climate Inputs

Parameter	Input & Units
Curve Number	79.8 Pad Top, 86.0 Pad Slope
Area	16.4 ac. Pad Top, 40 ac. Pad Slope
Evaporative Zone Depth	17 in. Pad Top, 12 in. Pad Slope
Station Latitude	47.04 Degrees
Max LAI	1.5 Pad Top, 1.0 Pad Slope
Start of Growing Season	24-Mar
End of Growing Season	14-Sep
Average Annual Wind Speed	10.6 mph
Avg. 1st Quarter RH	69%
Avg. 2nd Quarter RH	57%
Avg. 3rd Quarter RH	49%
Avg. 4th Quarter RH	66%

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Table 2. HELP Model Design Soil Inputs

Parameter Input	**Input & Units**
Topsoil porosity	0.4 (unitless)
Topsoil texture	Loam
Topsoil field capacity	0.232 (unitless)
Topsoil wilting point	0.116 (unitless)
Topsoil Ksat	3.7 x 10-4 cm/sec
Topsoil thickness	17 inches
Subsoil porosity	0.4 (unitless)
Subsoil texture	Sandy clay loam
Subsoil field capacity	0.34 (unitless)
Subsoil wilting point	0.24 (unitless)
Subsoil Ksat	1.14 x 10-4 cm/sec
Subsoil thickness	18 inches
5% Bentonite soil porosity	0.427 (unitless)
5% Bentonite soil ksat	7.0 x 10-7 cm/sec
5% Bentonite soil thickness	6 inches
Leach pad waste porosity	0.397 (unitless)
Leach pad waste field capacity	.032 (unitless)
Leach pad waste wilting point	.013 (unitless)
Leach pad waste Ksat	0.3 cm/sec
Leach pad waste thickness	600 inches

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Results of the HELP model indicate the approved leach pad soil cover could reduce the amount of leachate generation to an average of 3.4 gpm or 4.7% of total annual precipitation. It is important to note that due to limitations of the HELP model and estimates of actual cover soil properties, the actual seepage volumes may vary higher or lower than the predicted values. However, the results of the analyses are useful in determining the effectiveness of the approved leach pad soil cover.

CDM, 2004. Technical Memorandum, "Draft CR Kendall Leach Pad Alternatives".

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ATTACHMENT A
HELP MODEL RESULTS

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HELP MODEL RESULTS FOR LEACH PAD TOPS

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**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


PRECIPITATION DATA FILE:    c:\help\KEN100Y.D4
TEMPERATURE DATA FILE:      c:\help\KEND100.D7
SOLAR RADIATION DATA FILE:  c:\help\KEND100.D13
EVAPOTRANSPIRATION DATA:    c:\help\KEND100.D11
SOIL AND DESIGN DATA FILE:  c:\help\KENDAL7.D10
OUTPUT DATA FILE:           c:\help\TOP4.OUT


TIME:  16:49     DATE:  11/18/2011


******************************************************************************

     TITLE:  KENDALL MINE LEACH PAD TOPS-6" OF 5% BENTONITE AMENDED SOIL

******************************************************************************


     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                  LAYER  1
                                  --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER   0
          THICKNESS                  =     17.00   INCHES
          POROSITY                   =      0.4000 VOL/VOL
          FIELD CAPACITY             =      0.2320 VOL/VOL
          WILTING POINT              =      0.1160 VOL/VOL
          INITIAL SOIL WATER CONTENT =      0.2296 VOL/VOL
          EFFECTIVE SAT. HYD. COND.  =  0.369999994000E-03 CM/SEC


                                  LAYER  2
                                  --------

                         TYPE 3 - BARRIER SOIL LINER
                         MATERIAL TEXTURE NUMBER   0
          THICKNESS                  =      6.00   INCHES
          POROSITY                   =      0.4270 VOL/VOL
          FIELD CAPACITY             =      0.4180 VOL/VOL
          WILTING POINT              =      0.3670 VOL/VOL
          INITIAL SOIL WATER CONTENT =      0.4270 VOL/VOL
```

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EFFECTIVE SAT. HYD. COND.   =  0.699999987000E-07 CM/SEC
                       LAYER  3
                       --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                   =     12.00   INCHES
POROSITY                    =      0.4000 VOL/VOL
FIELD CAPACITY              =      0.3400 VOL/VOL
WILTING POINT               =      0.2400 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.3400 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.114000002000E-03 CM/SEC


                       LAYER  4
                       --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER  21
THICKNESS                   =    600.00   INCHES
POROSITY                    =      0.3970 VOL/VOL
FIELD CAPACITY              =      0.0320 VOL/VOL
WILTING POINT               =      0.0130 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0337 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.300000012000     CM/SEC


           GENERAL DESIGN AND EVAPORATIVE ZONE DATA
          ----------------------------------------

 NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
          SOIL DATA BASE USING SOIL TEXTURE # 8 WITH A
          FAIR STAND OF GRASS, A SURFACE SLOPE OF 10.%
          AND A SLOPE LENGTH OF  400. FEET.

SCS RUNOFF CURVE NUMBER             =     79.80
FRACTION OF AREA ALLOWING RUNOFF    =    100.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE  =     16.400  ACRES
EVAPORATIVE ZONE DEPTH              =     17.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE   =      3.903  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE  =      6.800  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE  =      1.972  INCHES
INITIAL SNOW WATER                  =      0.000  INCHES
INITIAL WATER IN LAYER MATERIALS    =     30.770  INCHES
TOTAL INITIAL WATER                 =     30.770  INCHES
TOTAL SUBSURFACE INFLOW             =      0.00   INCHES/YEAR


           EVAPOTRANSPIRATION AND WEATHER DATA
           -----------------------------------

 NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
          Lewistown             MT

     STATION LATITUDE                       =  47.04 DEGREES
     MAXIMUM LEAF AREA INDEX                =   1.50
     START OF GROWING SEASON (JULIAN DATE)  =     83
     END OF GROWING SEASON (JULIAN DATE)    =    257
     EVAPORATIVE ZONE DEPTH                 =  17.0  INCHES
     AVERAGE ANNUAL WIND SPEED              =  10.60 MPH
     AVERAGE 1ST QUARTER RELATIVE HUMIDITY  =  69.00 %
     AVERAGE 2ND QUARTER RELATIVE HUMIDITY  =  57.00 %
```

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AVERAGE 3RD QUARTER RELATIVE HUMIDITY = 49.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY = 66.00 %

NOTE: PRECIPITATION DATA FOR LEWISTOWN MONTANA
WAS ENTERED FROM AN ASCII DATA FILE.

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR BILLINGS MONTANA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
21.00	24.10	30.70	41.20	50.20	58.00
65.50	64.30	54.50	44.90	32.50	24.40

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR BILLINGS MONTANA
AND STATION LATITUDE = 47.05 DEGREES

****

MONTHLY TOTALS (IN INCHES) FOR YEAR 1

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION	0.42	0.79	0.98	1.21	5.05	5.07
	0.93	5.22	0.53	0.41	1.29	0.75
RUNOFF	0.000	0.000	0.042	0.382	0.273	0.753
	0.000	0.560	0.000	0.000	0.000	0.000
EVAPOTRANSPIRATION	0.249	0.481	0.544	1.940	3.182	4.658
	3.171	1.834	1.891	0.551	0.548	0.441
PERCOLATION/LEAKAGE THROUGH	0.0827	0.0697	0.0106	0.0468	0.1956	0.2027
LAYER 2	0.0944	0.0515	0.1253	0.1035	0.0923	0.0882
PERCOLATION/LEAKAGE THROUGH	0.0000	0.0000	0.0000	0.0000	0.0009	0.0009
LAYER 4	0.0000	0.0000	0.0013	0.0001	0.0000	0.0000

MONTHLY SUMMARIES FOR DAILY HEADS (INCHES)

AVERAGE DAILY HEAD ON	0.723	0.270	0.005	1.829	9.896	11.025
TOP OF LAYER 2	3.321	2.200	4.521	2.414	1.756	1.167
STD. DEVIATION OF DAILY	0.144	0.122	0.014	2.498	3.148	3.211
HEAD ON TOP OF LAYER 2	2.857	3.247	1.030	0.210	0.177	0.164

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ANNUAL TOTALS FOR YEAR 1

	INCHES	CU. FEET	PERCENT
PRECIPITATION	22.65	1348400.000	100.00
RUNOFF	2.010	119678.992	8.88
EVAPOTRANSPIRATION	19.488	1160148.370	86.04
PERC./LEAKAGE THROUGH LAYER 2	1.163138	69243.953	5.14
AVG. HEAD ON TOP OF LAYER 2	3.2604		
PERC./LEAKAGE THROUGH LAYER 4	0.003243	193.060	0.01
CHANGE IN WATER STORAGE	1.149	68379.227	5.07
SOIL WATER AT START OF YEAR	30.770	1831800.000	
SOIL WATER AT END OF YEAR	31.919	1900179.250	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.299	0.00

****

**********YEARS 2-99 NOT SHOWN**********

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MONTHLY TOTALS (IN INCHES) FOR YEAR 100

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION	0.22	1.40	0.78	3.14	1.72	6.78
	2.13	1.74	1.47	3.29	0.01	3.06
RUNOFF	0.000	0.088	0.088	0.000	0.000	0.083
	0.077	0.000	0.000	0.000	0.000	0.271
EVAPOTRANSPIRATION	0.220	0.632	0.655	2.776	2.164	4.602
	5.967	0.505	2.044	1.284	0.545	0.665
PERCOLATION/LEAKAGE THROUGH	0.0810	0.0581	0.0171	0.1648	0.1430	0.1701
LAYER 2	0.1040	0.0000	0.0000	0.0047	0.1140	0.1038
PERCOLATION/LEAKAGE THROUGH	0.0496	0.0414	0.0179	0.0859	0.0637	0.0284
LAYER 4	0.0234	0.0008	0.0181	0.0929	0.1176	0.1203

MONTHLY SUMMARIES FOR DAILY HEADS (INCHES)

AVERAGE DAILY HEAD ON	0.586	0.142	0.523	7.843	5.622	8.292
TOP OF LAYER 2	3.568	0.000	0.000	0.091	3.579	2.440
STD. DEVIATION OF DAILY	0.141	0.114	1.285	2.103	0.722	3.302
HEAD ON TOP OF LAYER 2	3.819	0.000	0.000	0.407	0.359	0.181

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ANNUAL TOTALS FOR YEAR 100

	INCHES	CU. FEET	PERCENT
PRECIPITATION	25.74	1532353.500	100.00
RUNOFF	0.607	36116.406	2.36
EVAPOTRANSPIRATION	22.059	1313243.000	85.70
PERC./LEAKAGE THROUGH LAYER 2	0.960779	57197.105	3.73
AVG. HEAD ON TOP OF LAYER 2	2.7238		
PERC./LEAKAGE THROUGH LAYER 4	0.659993	39290.711	2.56
CHANGE IN WATER STORAGE	2.414	143703.125	9.38
SOIL WATER AT START OF YEAR	41.465	2468477.500	
SOIL WATER AT END OF YEAR	43.123	2567206.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.755	44974.715	2.94
ANNUAL WATER BUDGET BALANCE	0.0000	0.344	0.00

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 100

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	0.92	0.97	1.38	1.94	3.61	4.18
	2.56	2.09	1.60	1.74	1.14	1.15
STD. DEVIATIONS	0.53	0.57	0.70	1.13	1.91	2.00
	1.38	1.30	1.08	0.97	0.85	0.79
RUNOFF						
TOTALS	0.032	0.197	0.624	0.570	0.353	0.252
	0.079	0.011	0.004	0.003	0.010	0.046
STD. DEVIATIONS	0.072	0.341	0.772	0.699	0.778	0.603
	0.374	0.060	0.015	0.019	0.054	0.148
EVAPOTRANSPIRATION						
TOTALS	0.534	0.483	0.537	1.742	3.250	4.109

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	4.015	1.982	1.422	1.146	0.772	0.511
STD. DEVIATIONS	0.188	0.164	0.231	0.945	1.043	1.194
	1.510	1.295	0.862	0.546	0.264	0.212

PERCOLATION/LEAKAGE THROUGH LAYER 2

TOTALS	0.0289	0.0231	0.0232	0.0732	0.1377	0.1321
	0.0728	0.0075	0.0055	0.0144	0.0312	0.0348
STD. DEVIATIONS	0.0431	0.0365	0.0369	0.0593	0.0556	0.0594
	0.0564	0.0183	0.0201	0.0346	0.0506	0.0489

PERCOLATION/LEAKAGE THROUGH LAYER 4

TOTALS	0.0530	0.0434	0.0448	0.0451	0.0523	0.0440
	0.0263	0.0099	0.0115	0.0327	0.0520	0.0592
STD. DEVIATIONS	0.0355	0.0329	0.0372	0.0360	0.0372	0.0338
	0.0217	0.0120	0.0179	0.0274	0.0325	0.0362

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 2

AVERAGES	0.4787	0.3259	0.3831	2.9148	5.8249	5.7471
	2.6199	0.1827	0.1602	0.3781	0.9556	0.7717
STD. DEVIATIONS	0.8141	0.5981	0.8347	3.0274	3.5591	3.9035
	2.5497	0.5274	0.6578	1.0819	1.9189	1.4074

****

****

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 100

	INCHES		CU. FEET	PERCENT
PRECIPITATION	23.29	(5.044)	1386458.5	100.00
RUNOFF	2.181	(2.0135)	129850.97	9.366
EVAPOTRANSPIRATION	20.503	(3.6013)	1220576.75	88.036
PERCOLATION/LEAKAGE THROUGH LAYER 2	0.58422	(0.28372)	34779.984	2.50855
AVERAGE HEAD ON TOP OF LAYER 2	1.729	(0.998)		
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.47415	(0.28767)	28227.236	2.03592
CHANGE IN WATER STORAGE	0.131	(1.4220)	7803.81	0.563

****

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```
*******************************************************************************

              PEAK DAILY VALUES FOR YEARS    1 THROUGH  100
   ----------------------------------------------------------------------
                                              (INCHES)      (CU. FT.)
                                             ----------   -------------
      PRECIPITATION                            3.90        232174.797

      RUNOFF                                   2.526       150359.6410

      PERCOLATION/LEAKAGE THROUGH LAYER  2     0.009128       543.38654

      AVERAGE HEAD ON TOP OF LAYER  2         17.000

      PERCOLATION/LEAKAGE THROUGH LAYER  4     0.005680       338.14426

      SNOW WATER                               5.53        328971.9370

      MAXIMUM VEG. SOIL WATER (VOL/VOL)                 0.4000

      MINIMUM VEG. SOIL WATER (VOL/VOL)                 0.1160
*******************************************************************************


*******************************************************************************

                 FINAL WATER STORAGE AT END OF YEAR  100
    ------------------------------------------------------------------
                  LAYER        (INCHES)       (VOL/VOL)
                  -----        --------       ---------
                    1            5.2487         0.3087

                    2            2.5620         0.4270

                    3            4.0800         0.3400

                    4           31.2325         0.0521

                SNOW WATER       0.755
*******************************************************************************
*******************************************************************************
```

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HELP MODEL RESULTS FOR LEACH PAD SLOPES

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```
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


PRECIPITATION DATA FILE:    c:\help\KEN100Y.D4
TEMPERATURE DATA FILE:      c:\help\KEND100.D7
SOLAR RADIATION DATA FILE:  c:\help\KEND100.D13
EVAPOTRANSPIRATION DATA:    c:\help\KEND100.D11
SOIL AND DESIGN DATA FILE:  c:\help\KENDAL8.D10
OUTPUT DATA FILE:           c:\help\SLOPE4.OUT


TIME:  16:43     DATE:  11/18/2011

******************************************************************************

     TITLE:  KENDALL MINE LEACH PAD SLOPES WITH 6" OF 5% BENTONITE AMENDED SOIL

******************************************************************************


     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                  LAYER  1
                                  --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER   0
          THICKNESS                  =     17.00   INCHES
          POROSITY                   =      0.4000 VOL/VOL
          FIELD CAPACITY             =      0.2320 VOL/VOL
          WILTING POINT              =      0.1160 VOL/VOL
          INITIAL SOIL WATER CONTENT =      0.2657 VOL/VOL
          EFFECTIVE SAT. HYD. COND.  =  0.369999994000E-03 CM/SEC


                                  LAYER  2
                                  --------

                         TYPE 3 - BARRIER SOIL LINER
                         MATERIAL TEXTURE NUMBER   0
          THICKNESS                  =      6.00   INCHES
          POROSITY                   =      0.4270 VOL/VOL
          FIELD CAPACITY             =      0.4180 VOL/VOL
          WILTING POINT              =      0.3670 VOL/VOL
          INITIAL SOIL WATER CONTENT =      0.4270 VOL/VOL
          EFFECTIVE SAT. HYD. COND.  =  0.699999987000E-07 CM/SEC
```

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```
                         LAYER  3
                         --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                   =     12.00   INCHES
POROSITY                    =      0.4000 VOL/VOL
FIELD CAPACITY              =      0.3400 VOL/VOL
WILTING POINT               =      0.2400 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.3400 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.114000002000E-03 CM/SEC


                         LAYER  4
                         --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER  21
THICKNESS                   =    600.00   INCHES
POROSITY                    =      0.3970 VOL/VOL
FIELD CAPACITY              =      0.0320 VOL/VOL
WILTING POINT               =      0.0130 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0341 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.300000012000     CM/SEC


          GENERAL DESIGN AND EVAPORATIVE ZONE DATA
          ----------------------------------------

 NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
          SOIL DATA BASE USING SOIL TEXTURE # 8 WITH A
          POOR STAND OF GRASS, A SURFACE SLOPE OF 34.%
          AND A SLOPE LENGTH OF  900. FEET.

SCS RUNOFF CURVE NUMBER             =     86.00
FRACTION OF AREA ALLOWING RUNOFF    =    100.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE  =     40.000  ACRES
EVAPORATIVE ZONE DEPTH              =     12.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE   =      2.833  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE  =      4.800  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE  =      1.392  INCHES
INITIAL SNOW WATER                  =      0.000  INCHES
INITIAL WATER IN LAYER MATERIALS    =     31.646  INCHES
TOTAL INITIAL WATER                 =     31.646  INCHES
TOTAL SUBSURFACE INFLOW             =      0.00   INCHES/YEAR


           EVAPOTRANSPIRATION AND WEATHER DATA
           -----------------------------------

 NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
          Lewistown            MT

     STATION LATITUDE                       =  47.04 DEGREES
     MAXIMUM LEAF AREA INDEX                =   1.00
     START OF GROWING SEASON (JULIAN DATE)  =     83
     END OF GROWING SEASON (JULIAN DATE)    =    257
     EVAPORATIVE ZONE DEPTH                 =  12.0  INCHES
     AVERAGE ANNUAL WIND SPEED              =  10.60 MPH
     AVERAGE 1ST QUARTER RELATIVE HUMIDITY  =  69.00 %
     AVERAGE 2ND QUARTER RELATIVE HUMIDITY  =  57.00 %
```

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AVERAGE 3RD QUARTER RELATIVE HUMIDITY = 49.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY = 66.00 %

NOTE: PRECIPITATION DATA FOR LEWISTOWN MONTANA
WAS ENTERED FROM AN ASCII DATA FILE.

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR BILLINGS MONTANA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
21.00	24.10	30.70	41.20	50.20	58.00
65.50	64.30	54.50	44.90	32.50	24.40

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR BILLINGS MONTANA
AND STATION LATITUDE = 47.05 DEGREES

****

MONTHLY TOTALS (IN INCHES) FOR YEAR 1

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION	0.42	0.79	0.98	1.21	5.05	5.07
	0.93	5.22	0.53	0.41	1.29	0.75
RUNOFF	0.034	0.026	0.223	0.660	0.545	0.662
	0.000	1.118	0.000	0.000	0.000	0.020
EVAPOTRANSPIRATION	0.246	0.478	0.536	1.783	3.145	4.227
	1.880	2.184	1.722	0.521	0.548	0.445
PERCOLATION/LEAKAGE THROUGH	0.1082	0.0912	0.0941	0.1039	0.1940	0.2050
LAYER 2	0.1636	0.1565	0.1613	0.1364	0.1217	0.1170
PERCOLATION/LEAKAGE THROUGH	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
LAYER 4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

MONTHLY SUMMARIES FOR DAILY HEADS (INCHES)

AVERAGE DAILY HEAD ON	2.797	2.205	1.652	2.730	9.768	11.219
TOP OF LAYER 2	7.295	6.720	7.546	5.091	4.220	3.513
STD. DEVIATION OF DAILY	0.189	0.159	0.164	2.097	2.857	3.083
HEAD ON TOP OF LAYER 2	1.227	2.958	1.218	0.377	0.210	0.204

****

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****

ANNUAL TOTALS FOR YEAR 1

	INCHES	CU. FEET	PERCENT
PRECIPITATION	22.65	3288780.500	100.00
RUNOFF	3.289	477599.031	14.52
EVAPOTRANSPIRATION	17.715	2572227.250	78.21
PERC./LEAKAGE THROUGH LAYER 2	1.652896	240000.562	7.30
AVG. HEAD ON TOP OF LAYER 2	5.3963		
PERC./LEAKAGE THROUGH LAYER 4	0.000000	0.000	0.00
CHANGE IN WATER STORAGE	1.646	238951.547	7.27
SOIL WATER AT START OF YEAR	31.646	4595027.000	
SOIL WATER AT END OF YEAR	33.292	4833978.500	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	2.769	0.00

****

**********YEARS 2-99 NOT SHOWN**********

****

MONTHLY TOTALS (IN INCHES) FOR YEAR 100

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION	0.22	1.40	0.78	3.14	1.72	6.78
	2.13	1.74	1.47	3.29	0.01	3.06
RUNOFF	0.000	0.227	0.273	0.000	0.000	0.317
	0.273	0.000	0.000	0.036	0.000	0.710
EVAPOTRANSPIRATION	0.220	0.628	0.659	2.843	2.091	4.172
	4.117	0.461	2.083	1.371	0.644	0.665
PERCOLATION/LEAKAGE THROUGH LAYER 2	0.1138	0.0991	0.0987	0.1481	0.1334	0.1629
	0.1501	0.1287	0.1308	0.1354	0.1700	0.1293
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.1336	0.1317	0.1464	0.1560	0.1036	0.1158
	0.0894	0.1056	0.1256	0.1261	0.1288	0.0911

MONTHLY SUMMARIES FOR DAILY HEADS (INCHES)

AVERAGE DAILY HEAD ON TOP OF LAYER 2	3.247	2.614	2.025	6.443	4.847	7.686
	6.198	4.460	4.988	5.006	8.281	4.508

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STD. DEVIATION OF DAILY	0.199	0.173	0.171	2.457	0.294	2.844
HEAD ON TOP OF LAYER 2	1.862	0.225	0.336	1.230	1.309	0.226

****
****

ANNUAL TOTALS FOR YEAR 100

	INCHES	CU. FEET	PERCENT
PRECIPITATION	25.74	3737447.750	100.00
RUNOFF	1.836	266576.594	7.13
EVAPOTRANSPIRATION	19.956	2897545.750	77.53
PERC./LEAKAGE THROUGH LAYER 2	1.600404	232378.672	6.22
AVG. HEAD ON TOP OF LAYER 2	5.0254		
PERC./LEAKAGE THROUGH LAYER 4	1.453613	211064.562	5.65
CHANGE IN WATER STORAGE	2.495	362260.687	9.69
SOIL WATER AT START OF YEAR	44.451	6454294.000	
SOIL WATER AT END OF YEAR	46.190	6706860.500	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.755	109694.430	2.94
ANNUAL WATER BUDGET BALANCE	0.0000	0.087	0.00

****

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 100

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	0.92	0.97	1.38	1.94	3.61	4.18
	2.56	2.09	1.60	1.74	1.14	1.15
STD. DEVIATIONS	0.53	0.57	0.70	1.13	1.91	2.00
	1.38	1.30	1.08	0.97	0.85	0.79
RUNOFF						
TOTALS	0.092	0.349	0.885	0.704	0.352	0.269
	0.138	0.044	0.022	0.016	0.036	0.127
STD. DEVIATIONS	0.150	0.447	0.882	0.795	0.666	0.551
	0.398	0.135	0.063	0.056	0.130	0.258
EVAPOTRANSPIRATION						
TOTALS	0.534	0.480	0.529	1.701	3.073	3.770
	2.932	1.907	1.406	1.238	0.838	0.516
STD. DEVIATIONS	0.188	0.166	0.246	0.961	1.177	1.309
	1.356	1.211	0.901	0.618	0.318	0.222

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```
  PERCOLATION/LEAKAGE THROUGH LAYER  2
  ------------------------------------
    TOTALS                  0.0929   0.0747   0.0752   0.0935   0.1359   0.1421
                            0.1339   0.1203   0.1115   0.1142   0.1134   0.1054

    STD. DEVIATIONS         0.0348   0.0359   0.0397   0.0463   0.0425   0.0400
                            0.0330   0.0227   0.0218   0.0275   0.0356   0.0341

  PERCOLATION/LEAKAGE THROUGH LAYER  4
  ------------------------------------
    TOTALS                  0.1015   0.0988   0.1163   0.1204   0.1202   0.0906
                            0.0717   0.0744   0.0878   0.0999   0.0986   0.0976

    STD. DEVIATIONS         0.0487   0.0454   0.0510   0.0507   0.0547   0.0434
                            0.0405   0.0428   0.0400   0.0441   0.0446   0.0478


-------------------------------------------------------------------------------
               AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)
-------------------------------------------------------------------------------


  DAILY AVERAGE HEAD ON TOP OF LAYER  2
  ------------------------------------
    AVERAGES                2.2059   1.7093   1.4051   2.9308   5.3457   6.0744
                            5.0440   3.9022   3.4894   3.4042   3.6902   2.9428

    STD. DEVIATIONS         1.4157   1.2339   1.1774   2.5215   2.9325   3.0696
                            2.1848   1.3192   1.3411   1.8575   2.6305   1.8952
*******************************************************************************


*******************************************************************************

     AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS    1 THROUGH  100
-------------------------------------------------------------------------------
                                       INCHES            CU. FEET       PERCENT
                                  -------------------   -------------   ---------
 PRECIPITATION                     23.29    (   5.044)    3381606.2     100.00

 RUNOFF                             3.034   (  1.9904)     440606.06     13.029

 EVAPOTRANSPIRATION                18.924   (  3.5463)    2747785.50     81.257

 PERCOLATION/LEAKAGE THROUGH        1.31314 (  0.27965)    190668.000     5.63839
   LAYER  2

 AVERAGE HEAD ON TOP                3.512 (    1.294)
   OF LAYER  2

 PERCOLATION/LEAKAGE THROUGH        1.17768 (  0.47668)    170999.312     5.05675
   LAYER  4

 CHANGE IN WATER STORAGE            0.153   (  1.3399)      22215.28      0.657
*******************************************************************************
```

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```
*******************************************************************************

              PEAK DAILY VALUES FOR YEARS    1 THROUGH  100
   ----------------------------------------------------------------------
                                              (INCHES)      (CU. FT.)
                                             ----------   -------------
      PRECIPITATION                            3.90        566280.000

      RUNOFF                                   2.035       295495.0310

      PERCOLATION/LEAKAGE THROUGH LAYER  2     0.009127      1325.28870

      AVERAGE HEAD ON TOP OF LAYER  2         17.000

      PERCOLATION/LEAKAGE THROUGH LAYER  4     0.008429      1223.86243

      SNOW WATER                               5.53        802370.5620

      MAXIMUM VEG. SOIL WATER (VOL/VOL)                 0.4000

      MINIMUM VEG. SOIL WATER (VOL/VOL)                 0.1160
*******************************************************************************


*******************************************************************************

                 FINAL WATER STORAGE AT END OF YEAR  100
    ---------------------------------------------------------------
                  LAYER        (INCHES)       (VOL/VOL)
                  -----        --------       ---------
                    1            5.5153         0.3244

                    2            2.5620         0.4270

                    3            4.0800         0.3400

                    4           34.0331         0.0567

                 SNOW WATER       0.755
*******************************************************************************
*******************************************************************************
```

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TECHNICAL MEMORANDUM

DATE: December 7, 2011

TO: Scott Mason
Jim Volberding

FROM: Mark Reinsel

SUBJECT: Summary Report - Zeolite Pilot Test #2, St. Cloud Clinoptilolite

Summary

Pilot Test #1 using 14x40 mesh clinoptilolite (zeolite) from Steelhead Specialty Minerals was operated at the Kendall site from November 29, 2010 until February 2, 2011 (65 days). Pilot Test #2 using 16x50 mesh St. Cloud clinoptilolite was operated immediately afterward, from February 7, 2011 until June 6, 2011 (120 days). In both tests, five small columns were operated in series using gravity flow. The test was terminated after a thallium concentration above the minimum detection limit of 0.0002 mg/L ("breakthrough") was consistently measured in Column 5 effluent. Approximately 869,000 gallons of North End pumpback water were treated during Pilot Test #2.

The pilot test was operated at constant flow to avoid bed packing. A low flow rate of 5 gpm was used throughout the test because a higher thallium adsorption capacity (delayed breakthrough) was noted at this low flow rate in Test #1. Water quality parameters other than thallium were not affected by zeolite treatment. The average influent concentration of 0.379 mg/L thallium in this test was somewhat lower than anticipated future site conditions.

Leach testing of the spent zeolites showed that they are classified as nonhazardous waste. A thallium loading of 0.32% was measured in the Column 1 material. A mass balance between thallium adsorbed to the zeolites, and thallium removed from water passing through the columns, differed by about 50 percent.

Test Setup

On February 7, 2011, Kendall Mine personnel began operating a pilot test using 16x50 mesh clinoptilolite from St. Cloud Minerals, the current zeolite supplier. This contrasts with the 14x40 mesh clinoptilolite from Steelhead Specialty Minerals used in Test #1, and 8x20 mesh chabazite from St. Cloud currently used in the full-scale treatment system.

A schematic of the pilot test system using "mini-columns" is shown in Figure 1. Figure 2 is a photo of the system.

FIGURE 1. ZEOLITE MINI-COLUMN PROFILE

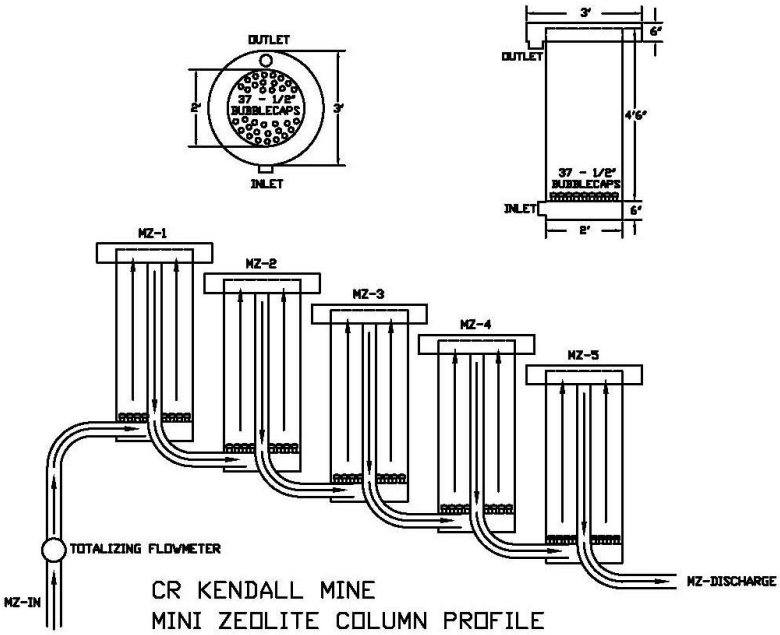


FIGURE 2. MINI-COLUMNS FOR PILOT TESTING

A summary of the zeolite column setup is as follows:

1. Clinoptilolite was loaded into each column to a height of 30 inches. A yardstick was used to measure down 25 inches from the top of the overflow launder of the 55-inch-deep columns.
2. According to the MSDS, the clinoptilolite dry density is approximately 50 lb/ft^3. The volume of zeolites in each column was 7.85 ft^3 so the weight in each column was 7.85 * 50 = 393 lbs.
3. There was a 15-inch elevation drop between each column to allow gravity flow.
4. South End water before zeolite treatment, containing a low concentration of thallium, was pumped through the columns at 10 gpm. This washed the clinoptilolite fines out of the columns and was enhanced by stirring with a PVC pipe.

Operations

- At the beginning of Test #2, the flow was set at about 5 gpm. Flows and other field data are summarized in Table 1.
- When each sample was taken, an operator recorded the influent pH and specific conductance (SC), and Column 5 effluent pH, temperature and SC, along with the flow rate and total flow readings.
- "Breakthrough" was defined as the time when thallium was first detected (the concentration exceeded the detection limit). The pilot test was operated until June 6, 2011 (120 days), when consistent breakthrough was seen from Column 5 at the minimum detection limit of 0.0002 mg/L. A total of 868,930 gallons were treated through the system (Tables 1 and 2).

Sampling and Analysis

- All water samples were filtered and sent to Energy Labs, with most submitted for rush (24-hour) analysis.
- We began the test by sampling effluent (overflow) from all five columns every day, using the standard detection limit of 0.002 mg/L for Columns 1-4 samples and the minimum detection limit of 0.0002 mg/L for Column 5 samples.
- On Day 22, we began submitting only the Column 1 sample and archiving the other samples. When the Column 1 sample showed breakthrough on Day 22, we submitted the Column 2 sample for that day. Samples from Columns 1 and 2 were then submitted until Column 2 breakthrough was noted on Day 36, when samples from Column 3 were added to the analysis. A similar procedure was followed when breakthrough was noted at Columns 3 and 4.
- Influent water was sampled on Day 1 and then approximately monthly throughout the test.

TABLE 1. PILOT TEST #2 FIELD DATA SHEET

				Influent		Col. 5 Effluent			Sampling		
Day	Flow (gpm)	Total Flow	Test Flow	pH	SC	pH	T (oC)	SC	Date	Time	Comments
0		487,240	0						6-Feb	9:00 AM	
1	5.3	494,870	7,630	7.74	2370	7.9	4.7	2580	7-Feb	9:00 AM	
2	4.8	501,460	14,220	7.64	2530	7.81	5.3	2620	8-Feb	8:00 AM	
3	5.1	508,830	21,590	7.78	2580	7.98	5	2540	9-Feb	8:00 AM	
4	5.1	516,220	28,980	7.75	2640	7.95	4.6	2580	10-Feb	8:00 AM	
8	5.1	545,790	58,550	7.76	2560	7.91	4.4	2610	14-Feb	8:00 AM	
9	5.0	552,730	65,490	8.04	2590	8.47	4.4	2590	15-Feb	7:00 AM	
10	5.0	560,250	73,010	8.17	2610	8.02	3.9	2630	16-Feb	8:00 AM	
11	5.0	567,460	80,220	7.57	2570	7.71	4.8	2560	17-Feb	8:00 AM	
12	5.0	574,680	87,440	7.91	2480	7.74	3.8	2610	18-Feb	8:00 AM	
16	5.0	603,600	116,360	7.79	2630	7.91	4.7	2560	22-Feb	8:00 AM	
17	6.0	612,310	125,070	7.68	2590	7.85	4.6	2520	23-Feb	8:00 AM	
18	5.1	619,730	132,490	7.64	2510	7.78	4.4	2570	24-Feb	8:00 AM	
19	5.1	627,120	139,880	7.53	2650	7.74	4.4	2660	25-Feb	8:00 AM	
22	5.1	649,250	162,010	7.88	2580	7.63	4.5	2640	28-Feb	8:00 AM	
23	5.1	656,910	169,670	7.96	2630	7.75	4.2	2690	1-Mar	9:00 AM	
24	4.9	663,710	176,470	7.66	2650	7.86	4.9	2570	2-Mar	8:00 AM	
25	4.9	670,770	183,530	7.69	2610	7.79	6	2630	3-Mar	8:00 AM	5-micron filter installed
26	4.9	677,850	190,610	7.75	2590	7.7	5.1	2610	4-Mar	8:00 AM	
29	4.4	696,960	209,720	7.79	2490	7.79	4.5	2600	7-Mar	8:00 AM	
30	4.8	703,990	216,750	7.82	2660	7.77	4.5	2660	8-Mar	8:00 AM	Filter removed
31	5.0	711,250	224,010	7.79	2720	7.82	5.7	2700	9-Mar	8:00 AM	30-micron filter installed
32	5.0	718,580	231,340	7.78	2630	7.8	4.8	2720	10-Mar	8:30 AM	
33	5.1	725,770	238,530	7.7	2490	7.75	4.9	2740	11-Mar	8:00 AM	1 psi pressure drop across filter
36	5.1	747,650	260,410	7.71	2570	7.71	6.6	2380	14-Mar	8:00 AM	
37	5.1	755,060	267,820	7.74	2450	7.8	4.6	2490	15-Mar	8:00 AM	
38	5.1	762,500	275,260	7.78	2350	7.74	5.8	2420	16-Mar	8:00 AM	
39	5.1	769,850	282,610	7.74	2360	7.77	4.5	2490	17-Mar	8:00 AM	
40	5.1	777,180	289,940	7.83	2420	7.87	5.4	2470	18-Mar	8:00 AM	2 psi pressure drop across filter
41	5.1	784,840	297,600	7.74	2450	7.78	4.8	2480	19-Mar	9:00 AM	
42	5.1	792,170	304,930	7.84	2460	7.85	5	2480	20-Mar	9:00 AM	
43	5.1	799,220	311,980	7.84	2400	7.83	4.7	2490	21-Mar	8:00 AM	
44	5.1	806,580	319,340	7.75	2320	7.83	4.8	2370	22-Mar	8:00 AM	
45	5.1	814,260	327,020	7.72	2330	7.76	5.5	2360	23-Mar	9:00 AM	
46	5.3	821,650	334,410	7.7	2370	7.76	5.1	2380	24-Mar	8:00 AM	
47	5.3	829,450	342,210	7.67	2330	7.73	5.3	2390	25-Mar	8:30 AM	3 psi pressure drop across filter
50	5.3	852,160	364,920	7.75	2330	7.77	5.9	2400	28-Mar	8:00 AM	4 psi pressure drop across filter
51	5.3	859,760	372,520	7.7	2350	7.77	5	2330	29-Mar	8:00 AM	
52	5.3	867,370	380,130	7.75	2350	7.78	4.7	2380	30-Mar	8:00 AM	
53	5.3	874,940	387,700	7.74	2360	7.79	4.4	2380	31-Mar	8:00 AM	
54	5.3	882,500	395,260	7.73	2390	7.79	4.4	2410	1-Apr	8:00 AM	5 psi pressure drop across filter
55	6.2	891,620	404,380	7.75	2370	7.78	4.4	2360	2-Apr	8:30 AM	6 psi pressure drop across filter
56	5.2	899,070	411,830	7.77	2300	7.79	4.1	2290	3-Apr	8:30 AM	
57	5.0	906,140	418,900	7.78	2260	7.87	4.3	2250	4-Apr	8:00 AM	
58	5.0	913,340	426,100	7.81	2200	7.8	5.3	2280	5-Apr	8:00 AM	
59	5.0	920,650	433,410	7.75	2300	7.77	5.3	2340	6-Apr	8:30 AM	
60	4.9	927,260	440,020	7.71	2240	7.75	5.6	2270	7-Apr	8:00 AM	8 psi pressure drop across filter
61	4.8	934,360	447,120	7.73	2160	7.78	5.3	2170	8-Apr	8:30 AM	
63	5.1	949,700	462,460	7.75	2210	7.77	5.5	2230	10-Apr	10:30 AM	11 psi pressure drop across filter
64	5.2	956,160	468,920	7.75	2140	7.81	4.8	2140	11-Apr	7:00 AM	12 psi pressure drop across filter
65	5.2	963,830	476,590	7.82	2080	7.9	4.8	2100	12-Apr	7:30 AM	
66	5.2	971,280	484,040	7.89	2070	7.88	5.8	2100	13-Apr	7:30 AM	14 psi pressure drop across filter
67	5.0	978,700	491,460	7.88	2050	7.91	4.7	2060	14-Apr	8:00 AM	
68	5.3	986,370	499,130	7.86	2020	7.88	4.8	2110	15-Apr	8:00 AM	16 psi pressure drop across filter
71	5.2	1,008,790	521,550	7.93	1370	7.94	5.4	2010	18-Apr	8:00 AM	20 psi pressure drop across filter
72	5.1	1,016,330	529,090	7.95	1320	7.95	5.2	1860	19-Apr	9:00 AM	New 30 micron filter installed
73	5.1	1,023,690	536,450	7.94	1740	7.92	6	1720	20-Apr	9:00 AM	
74	5.1	1,030,880	543,640	7.86	1680	7.88	5.8	1640	21-Apr	9:00 AM	
75	5.0	1,038,200	550,960	7.87	1740	7.91	5.4	1730	22-Apr	9:00 AM	1 psi pressure drop across filter
78	4.9	1,059,850	572,610	7.9	1930	7.89	6.9	1930	25-Apr	9:00 AM	2 psi pressure drop across filter
79	5.0	1,066,750	579,510	7.89	1810	7.89	5.6	1820	26-Apr	8:00 AM	3 psi pressure drop across filter
80	5.0	1,074,050	586,810	7.88	1830	7.89	6.5	1810	27-Apr	8:00 AM	
81	5.2	1,081,880	594,640	7.92	1700	7.92	7	1710	28-Apr	9:00 AM	
82	5.2	1,089,180	601,940	7.97	1590	7.96	6.5	1620	29-Apr	8:30 AM	4 psi pressure drop across filter
85	5.1	1,111,020	623,780	8.19	1570	8.14	8.2	1470	2-May	8:00 AM	8 psi pressure drop across filter
86	5.0	1,118,230	630,990	8.23	1420	8.15	8.6	1410	3-May	8:00 AM	
87	4.9	1,125,270	638,030	8.31	1520	8.19	8.8	1700	4-May	8:00 AM	12 psi pressure drop across filter
88	5.0	1,132,500	645,260	8.31	1510	8.21	8.6	1670	5-May	8:00 AM	14 psi pressure drop across filter
89	5.1	1,139,960	652,720	8.32	1550	8.22	9.7	1560	6-May	8:30 AM	20 psi pressure drop across filter, change filter
90	4.7	1,146,410	659,170	7.67	1850	7.83	9.6	1890	7-May	7:30 AM	14 psi pressure drop across filter
92	4.1	1,158,360	671,120	7.89	1670	7.85	10.5	1650	9-May	7:00 AM	36 psi pressure drop across filter, change filter

TABLE 1. PILOT TEST #2 FIELD DATA SHEET (continued)

				Influent		Col. 5 Effluent			Sampling		
Day	Flow (gpm)	Total Flow	Test Flow	pH	SC	pH	T (oC)	SC	Date	Time	Comments
93	5.3	1,166,440	679,200	7.91	1590	7.88	10.6	1540	10-May	8:30 AM	2 psi pressure drop across filter
94	5.2	1,173,990	686,750	8.12	1580	8.04	10	1610	11-May	8:30 AM	4 psi pressure drop across filter
95	5.1	1,181,350	694,110	8.16	1560	8.07	10.2	1570	12-May	8:30 AM	6 psi pressure drop across filter
96	5.0	1,188,730	701,490	8.19	1510	8.07	11.9	1500	13-May	9:00 AM	
97	5.1	1,195,940	708,700	8.27	1500	8.16	11.4	1500	14-May	8:30 AM	10 psi pressure drop across filter
99	5.1	1,210,630	723,390	8.37	1520	8.25	11.1	1510	16-May	8:00 AM	17 psi pressure drop across filter
100	4.9	1,217,730	730,490	8.39	1500	8.26	10.4	1510	17-May	8:00 AM	18 psi pressure drop across filter
101	5.1	1,225,250	738,010	8.38	1530	8.27	11.3	1520	18-May	8:30 AM	22 psi pressure drop across filter, change filter
102	5.2	1,232,690	745,450	8.37	1470	8.26	11.2	1460	19-May	8:30 AM	4 psi pressure drop across filter
103	4.9	1,239,620	752,380	8.37	1450	8.24	12	1460	20-May	8:00 AM	8 psi pressure drop across filter
104	5.2	1,247,310	760,070	8.39	1360	8.26	11.1	1360	21-May	8:00 AM	16 psi pressure drop across filter
106	4.8	1,261,120	773,880	8.41	1240	8.22	11.9	1320	23-May	8:00 AM	18 psi pressure drop across filter
107	5.0	1,268,280	781,040	8.37	1280	8.2	12.9	1290	24-May	8:00 AM	Changed filter; 1 psi pressure drop across filter
108	5.0	1,275,630	788,390	8.41	1230	8.22	11.4	1240	25-May	8:30 AM	8 psi pressure drop across filter
109	4.7	1,282,230	794,990	8.39	1250	8.18	11.6	1280	26-May	8:00 AM	14 psi pressure drop across filter
110	3.6	1,287,540	800,300	8.41	1260	8.16	10.6	1270	27-May	8:30 AM	20 psi across filter, change filter
114	4.8	1,313,120	825,880	8.46	1240	8.23	8.4	1280	31-May	8:30 AM	Filter removed
115	5.1	1,320,320	833,080	8.42	1250	8.03	10.5	1240	1-Jun	8:00 AM	
116	4.5	1,326,880	839,640	8.41	1250	8.07	12.5	1240	2-Jun	8:00 AM	
117	4.9	1,334,040	846,800	8.39	1230	8.13	10.6	1230	3-Jun	8:30 AM	
120	5.0	1,356,170	868,930	8.38	1290	7.97	14.4	1300	6-Jun	7:30 AM	End of Test

TABLE 2. PILOT TEST #2 LAB RESULTS

			Tl Conc. (mg/L)					
Date	Day	Gallons	In	1	2	3	4	5
2/7/11	1	7,630	0.441	<0.002	<0.002	<0.002	<0.002	<0.0002
2/14/11	8	58,550		<0.002	<0.002	<0.002	<0.002	<0.0002
2/22/11	16	116,360		<0.002	<0.002	<0.002	<0.002	<0.0002
2/28/11	22	162,010		0.020	<0.002			
3/7/11	29	209,720		0.032	<0.002			
3/14/11	36	260,410	0.554	0.131	0.003	<0.002		
3/21/11	43	311,980		0.132	0.003	<0.002		
3/28/11	50	364,920		0.178	0.008	<0.002		
4/4/11	57	418,900	0.408	0.159	0.015	<0.002		
4/11/11	64	468,920		0.171	0.029	<0.002		
4/18/11	71	521,550		0.156	0.023	<0.002		
4/25/11	78	572,610	0.325	0.190	0.029	0.005	<0.002	
5/2/11	85	623,780		0.192	0.038	0.003	<0.002	
5/9/11	92	671,120		0.228	0.051	0.002	0.0003	
5/16/11	99	723,390	0.321	0.234	0.060	0.004	0.0004	0.0003
5/23/11	106	773,880		0.230	0.090	0.003	0.0004	<0.0002
5/31/11	114	825,880		0.200	0.090	0.017	0.0017	0.0003
6/6/11	120	868,930	0.226	0.239	0.109	0.017	0.0016	0.0004

Results and Discussion

Field data from throughout the pilot test are shown in Table 1. The initial SC was greater than 2500 uS and then steadily decreased throughout the test (Figure 3). The influent thallium concentration also decreased (Table 2), indicating the effect of dilution due to snowmelt and rainfall. Little difference was seen between the influent and Column 5 effluent SC values (Figure 3).

pH values also varied somewhat during the test, increasing at the end (Figure 4). Effluent pH was lower than influent pH at the end of the test.

Thallium concentrations from all five columns are shown in Table 2. The influent concentration began decreasing in March and April. "Breakthrough" was noted on Day 22 from Column 1 at the flow rate of 5 gpm, at a test flow of 162,000 gallons. Breakthrough from the first four columns was determined by when column effluent exceeded the standard detection limit of 0.002 mg/L, and is shown by the highlighted cells in Table 2. Breakthrough was noted on Day 36 from Column 2, at a test flow of 260,000 gallons. Breakthrough from Column 3 was noted on Day 78, at a test flow of about 573,000 gallons. Breakthrough from Column 4 was first observed on Day 92, after 671,000 gallons had been treated.

At the lower detection limit of 0.0002 mg/L, Column 5 breakthrough was first observed on Day 99 after 723,000 gallons. The last two readings had measurable thallium concentrations, suggesting that consistent breakthrough occurred at 826,000 gallons on Day 114. This breakthrough is also highlighted in Table 2.

Pilot test results are shown graphically in Figure 5. To better show the low-concentration data, the same results are shown in Figure 6 using a log scale.

Because of concerns that algae or other solids present in springtime runoff could plug the zeolite columns, a 30-micron cartridge filter was evaluated beginning on Day 31. The first filter lasted 41 days but the filters lasted progressively shorter times after that (Table 3). On Day 110, the filter was removed and left out for the last ten days of the test.

TABLE 3. FILTER CHANGES

Filter #	Test Day			Test Gallons		
	In	Out	Duration	In	Out	Duration
1	31	72	**41**	224,010	529,090	**305,080**
2	72	89	**17**	529,090	652,720	**123,630**
3	89	92	**3**	652,720	671,120	**18,400**
4	92	101	**9**	671,120	738,010	**66,890**
5	101	107	**6**	738,010	781,040	**43,030**
6	107	110	**3**	781,040	800,300	**19,260**

FIGURE 3. PILOT TEST #2 SC

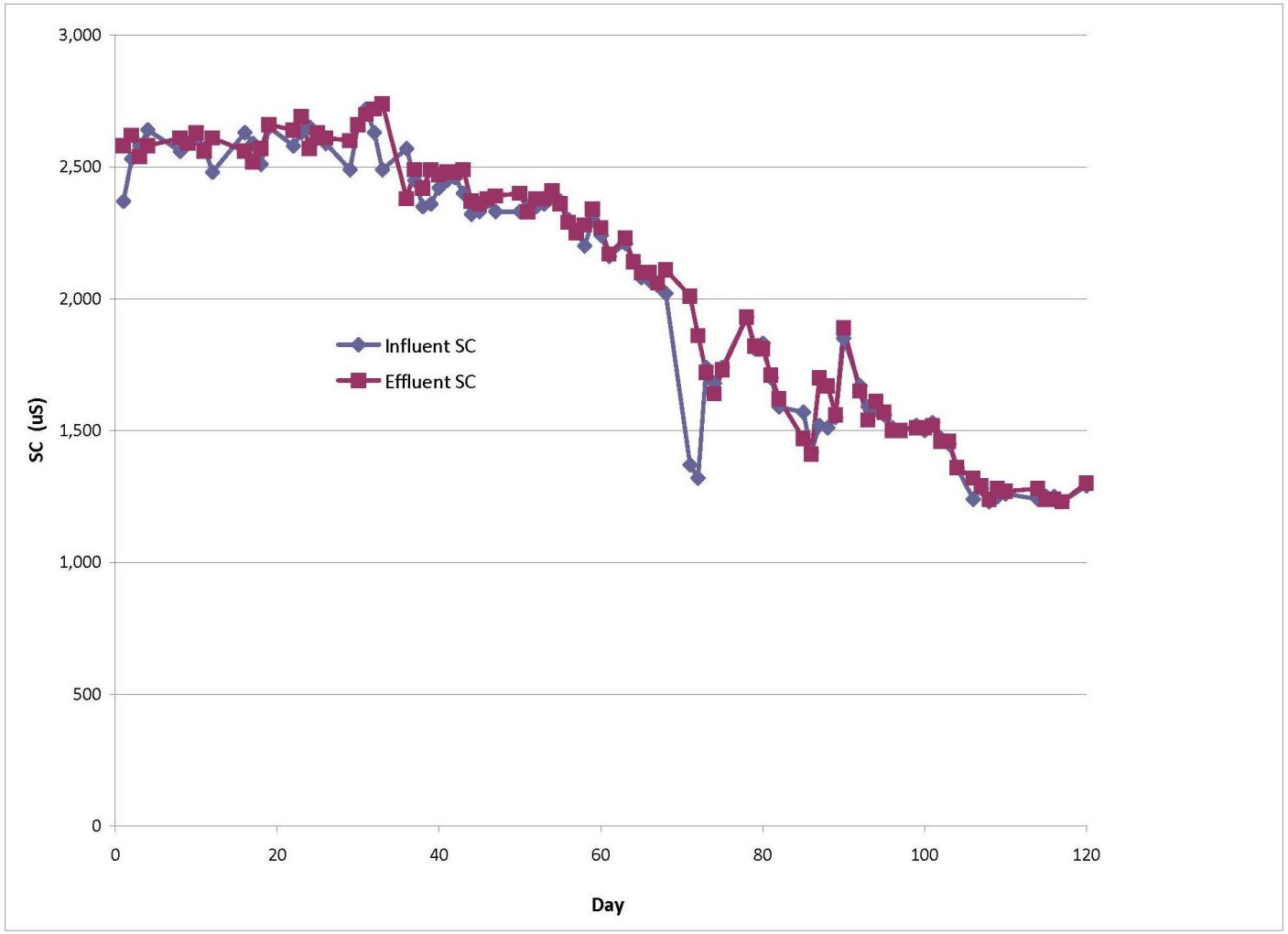


FIGURE 4. PILOT TEST #2 pH

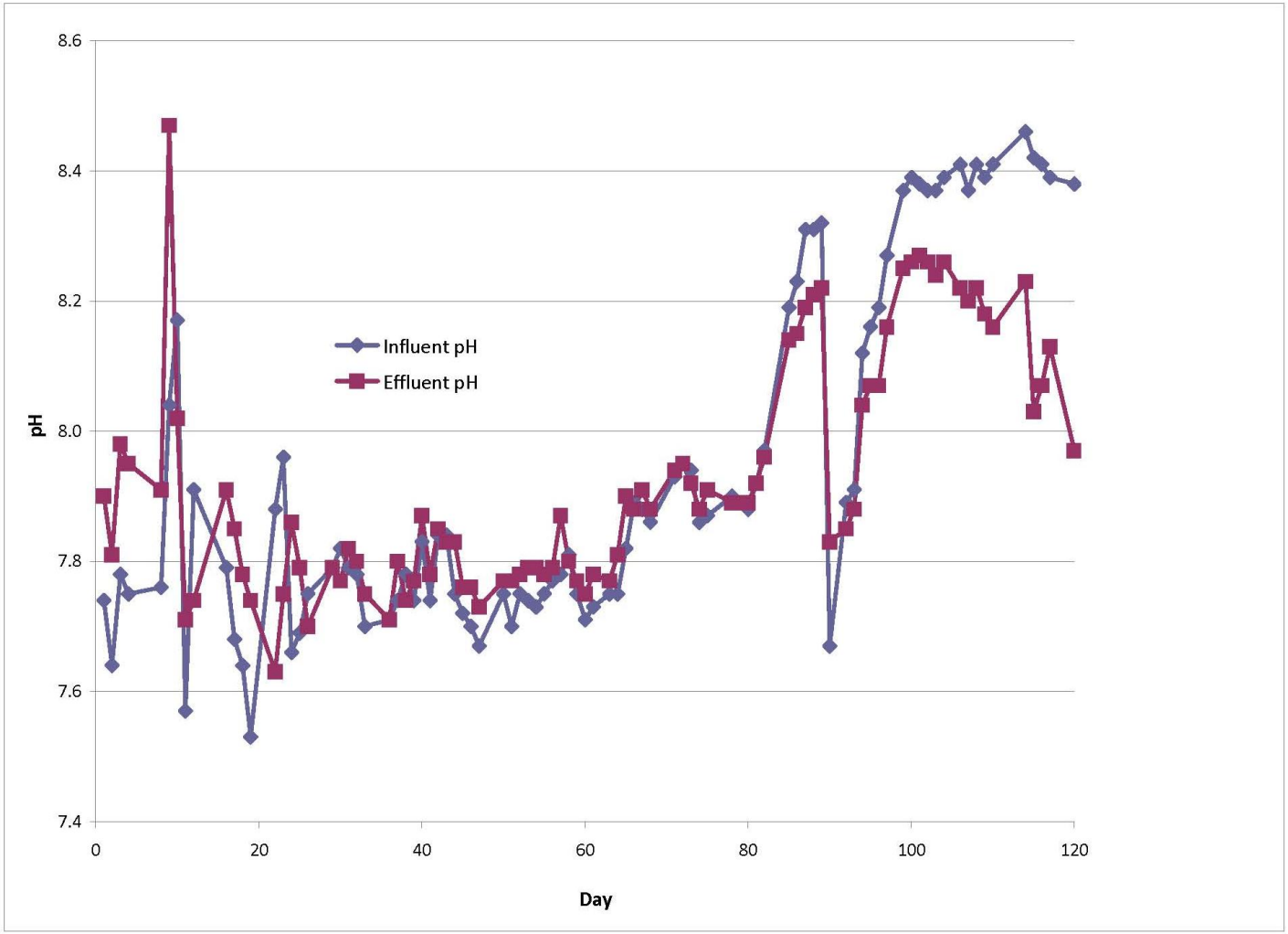


FIGURE 5. PILOT TEST #2 RESULTS – NORMAL SCALE

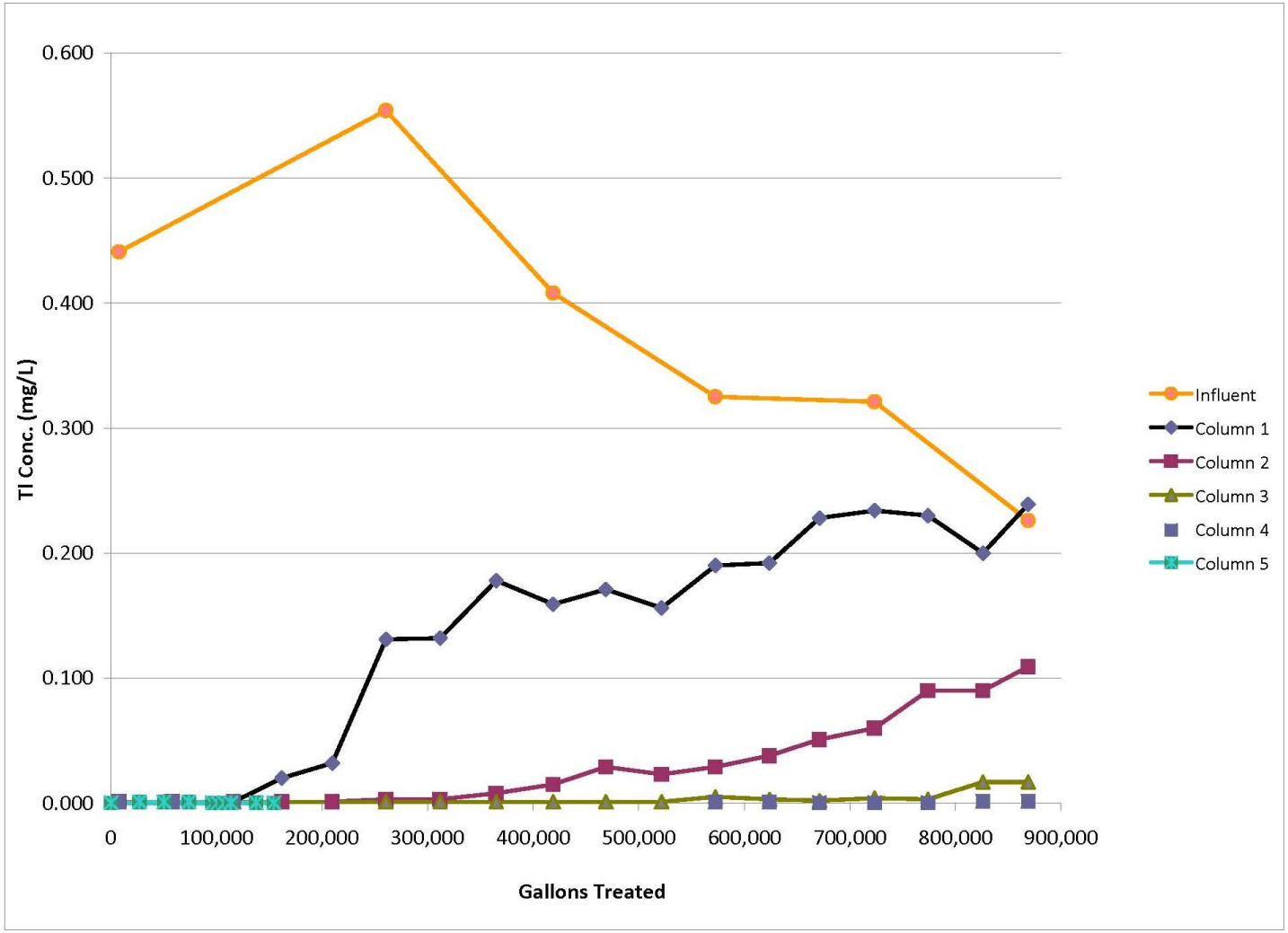
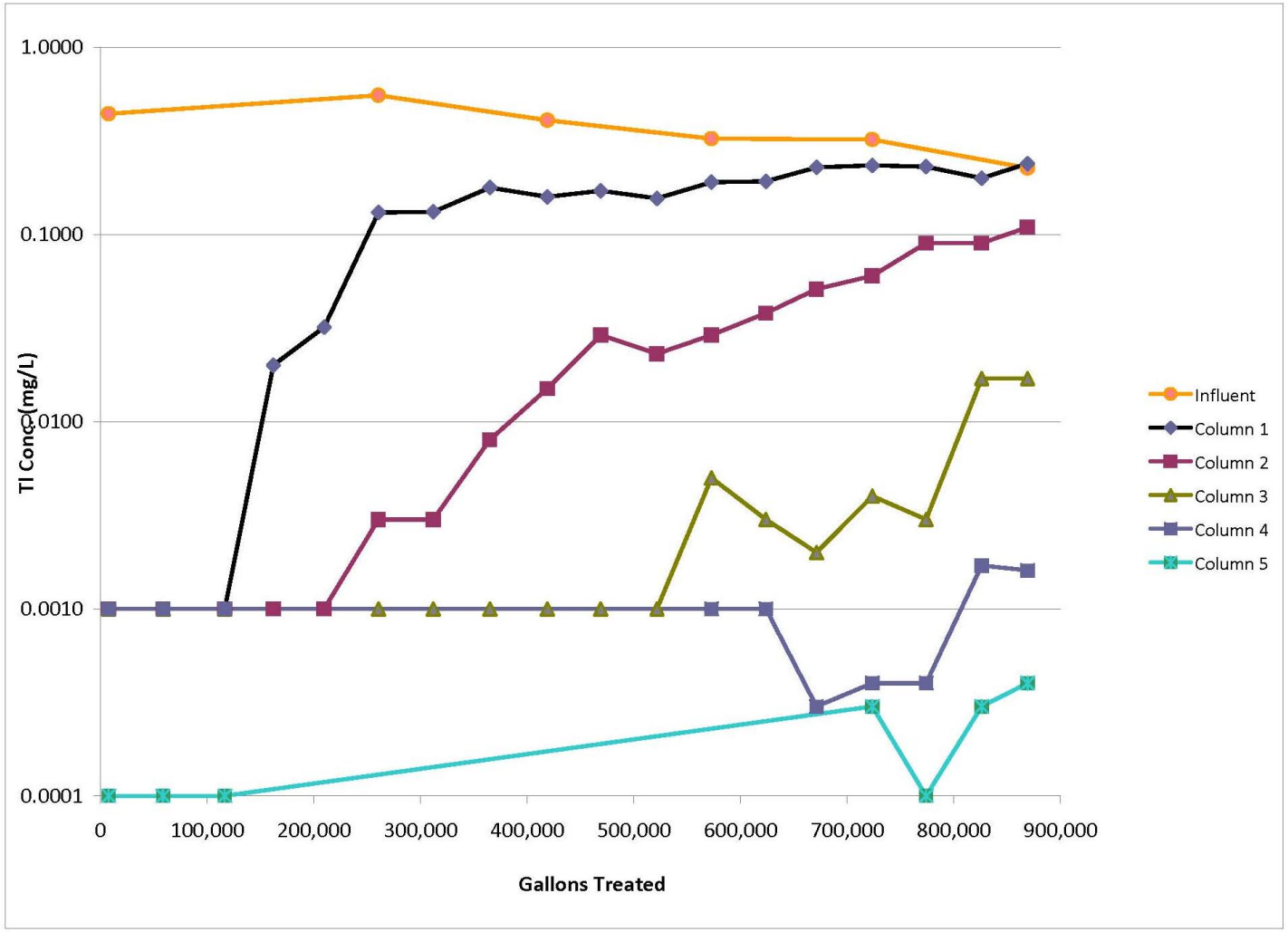


FIGURE 6. PILOT TEST #2 RESULTS – LOG SCALE



Other Parameters

Samples were taken on 2/07/11, Day 1 of the test, and analyzed for parameters other than thallium. These results are shown in Table 4.

TABLE 4. OTHER PARAMETERS
Sampling on 2/07/11

Parameter	Concentration (mg/L)	
	Influent	**Column 5**
Alkalinity	228	222
Bicarbonate	278	271
Sulfate	1,160	1,140
Hardness	1,270	1,240
Arsenic	0.006	0.005
Calcium	316	309
Magnesium	117	114
Potassium	7	4
Selenium	0.028	0.028
Sodium	31	60

Zeolite Analysis

At the conclusion of the test, the Toxicity Characteristic Leaching Procedure (TCLP) and Synthetic Precipitation Leaching Procedure (SPLP) were performed on a sample of the Column 1 zeolites, which would have contained the highest loading of any material used. This was a composite sample from within the column, as the zeolites were mixed with an air hose prior to sampling. Those leaching results for the eight RCRA metals plus thallium are shown in Table 5. Since all metals other than thallium were non-detect, this spent material would be classified as nonhazardous waste.

TABLE 5. LEACHING RESULTS
Column 1, sampled on 6/6/11

Metal	Concentration (mg/L)	
	TCLP	**SPLP**
Arsenic	< 0.5	< 0.5
Barium	< 10	< 1
Cadmium	< 0.1	< 0.1
Chromium	< 0.5	< 0.5
Lead	< 0.5	< 0.5
Mercury	< 0.02	< 0.02
Selenium	< 0.1	< 0.1
Silver	< 0.5	< 0.5
Thallium	1.89	0.08

The TCLP test is conducted with a ratio of 50 g of zeolite to 1 L of leach solution. Assuming that the 50 g sample of zeolite leached in the TCLP test contained 3,160 mg/kg thallium (as measured in the whole rock analysis described below), the zeolite sample contained a total of approximately 158 mg of thallium prior to the leach test. In the TCLP test, 1.89 mg or 1.2 percent of the thallium was leached from the zeolite sample. This leach result is similar to previous leach tests of St. Cloud chabazite and to the Pilot Test 1 result, and demonstrates that the thallium retained by the zeolites is not readily leachable.

At the conclusion of the test, samples from each column were directly analyzed for the same parameters by strong acid digestion ("whole rock analysis"); results are in Table 6. Each column sample was a blended composite from throughout the column. Column 1 was analyzed for all TCLP metals plus thallium; the other columns were only analyzed for thallium, since Pilot Test #1 analysis showed that thallium was the only metal that varied across the columns. The decreasing amounts of thallium adsorbed to the zeolites agree with the decreasing concentrations exiting each successive column (Figure 6).

TABLE 6. WHOLE ROCK ANALYSIS
Sampled on 6/6/11

	Concentration (mg/kg)				
Metal	**Col. 1**	**Col. 2**	**Col. 3**	**Col. 4**	**Col. 5**
Arsenic	10	NA	NA	NA	NA
Barium	232	NA	NA	NA	NA
Cadmium	< 1	NA	NA	NA	NA
Chromium	< 5	NA	NA	NA	NA
Lead	5	NA	NA	NA	NA
Mercury	< 1	NA	NA	NA	NA
Selenium	< 5	NA	NA	NA	NA
Silver	< 5	NA	NA	NA	NA
Thallium	3,160	1,210	214	5	< 5

A thallium mass balance from each column shows that we removed the following quantities of thallium:

- Column 1: 393 lbs * 1 kg/2.2 lb * 3,160 mg/kg = 564,000 mg Tl
- Column 2: 393/2.2 * 1,210 mg/kg = 216,000 mg Tl
- Column 3: 393/2.2 * 214 mg/kg = 38,000 mg Tl
- Column 4: 393/2.2 * 5 mg/kg = 900 mg Tl
- Column 5: 393/2.2 * 2.5 mg/kg = 400 mg Tl

819,300 mg

Now we can compare this to the amount theoretically removed from the water. The influent thallium concentration steadily decreased during the test; we will assume it was the average of the six readings taken during the test, or 0.379 mg/L. According to the flowmeter, we treated 868,930 gallons. Therefore, we removed the following quantity of thallium:

0.379 mg/L * 868,930 gal * 3.785 L/gal = **1,246,000 mg**

This quantity is 52% higher than the 819,300 mg calculated from the whole rock analysis. Both numbers are in the same range but it is unclear why the difference is so large. The mass balance in Pilot Test #1 differed by 21%.

Adsorption Capacity

The Table 6 numbers show a thallium adsorption capacity of 3,160 mg/kg (0.316%) in Column 1, with lesser amounts in the following columns. In Pilot Test #1, we achieved a thallium loading of 0.376% in Column 1.