MEMO

To:	Bob Schneider, Tuleyome
Cc:	Sara Husby-Good, Tuleyome
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Subject:	Corona and Twin Peaks Mine Drainage Treatment Remediation Project – Year 1 water quality results summary

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Overview

This memo summarizes year 1 baseline water quality monitoring activities and results for the Corona and Twin Peaks Mine Drainage Treatment Remediation Project. The project is led by Tuleyome and managed by McCord Environmental. A key goal of this project is to improve the effectiveness of the existing mine drainage treatment systems (current baseline conditions) and to treat discharges from Lower Corona Drain Tunnel to support healthy aquatic ecosystems in James Creek and farther downstream. James Creek is prime trout habitat.

We use the data to explain why the remediation project is necessary, and how the treatment systems should be designed to account for these current conditions. This baseline dataset, combined with post-project monitoring data, will be used to characterize the effectiveness of the treatment systems at reducing the concentrations and loads of pollutants in drainage waters.

Key findings are that discharges from the Lower Corona Drain Tunnel have high concentrations of nickel and iron, and are low in pH. Dilution in Kidd Creek is not available for most of the year. Conditions downstream of historical discharges from the Upper Corona and Twin Peaks mines were indistinguishable from upstream samples (when flowing), likely as a result of the beneficial effects of existing infiltration trenches. Stormwater runoff was not monitored because the monitoring period was exceptionally dry.

This overview describes the baseline water quality conditions of interest and relevant characteristics of the project site.

Background – Mining Legacy

Half of all toxic mercury pollution that enters the Sacramento River system comes from the Putah and Cache Creek River systems in the Northern Inner Coast Range. Mercury was mined from this region for use in gold mining in the Sierra Nevada. There are over 80 abandoned mercury mines in the Putah and Cache Creek watersheds, some of which were among the largest producers in the state. This mining legacy contributes to the state's listing as impaired of James Creek (nickel and mercury), Lake Berryessa (mercury), and lower Putah Creek (mercury and boron). A fish consumption advisory is posted for Lake Berryessa and for lower Putah Creek because of fish mercury contamination.

Nickel in naturally enriched in the project site's soils. Portal drainages have among the highest recorded concentrations of nickel in northern California.

Project Site

The Corona and Twin Peaks mines are located on private property in northern Napa County, northwest of Pope Valley and due north of the Palisades, and accessible from Oat Hill Mine Road (also named Oat Hill Road in Lake County and Lake County Road 102), which is 5 miles east of Middletown off of Butts Canyon Road (see **Figure 1** and **Figure 2**). The Corona and Twin Peaks mines are inactive mercury mines last operated in the 1970s and 1940s, respectively.

During the rainy season, and continuing for a period afterwards, natural surface creeks flow through the mountainous study area. Although small mine workings can be found higher in the watershed, these are generally small, long-abandoned, and not releasing sub-surface water.

The two main creeks are the larger Bateman Creek which flows eastward along the south side of Twin Peaks, and Kidd Creek which passes directly to the north of Lower Corona Drain Tunnel. Spring Creek reportedly has negligible anthropogenic disturbance.

Discharges from the Upper Corona Mine's Boiler House Portal, Twin Peaks Mine, and the Lower Corona Drain Tunnel have contributed acidic water with metals (principally iron, nickel and mercury) and sediment in James Creek, which may be toxic to aquatic organisms, wildlife, and people.

Pilot semi-passive drainage treatment systems (infiltration trenches), currently in place at Twin Peaks Mine and the upper Corona Mine's Boiler House portal consist of headwall, piping, and infiltration trenches in which sediment and metals in the mine drainage waters filter out before reaching nearby Bateman Creek (for Twin Peaks) and Kidd Creek (for Boiler House). Perennial drainage from the Lower Corona Drain Tunnel contributes nickel, iron and acidic waters directly into Kidd Creek. Kidd Creek and Bateman Creek both drain into James Creek.

Figure 1. Corona and Twin Peaks Mines project area.

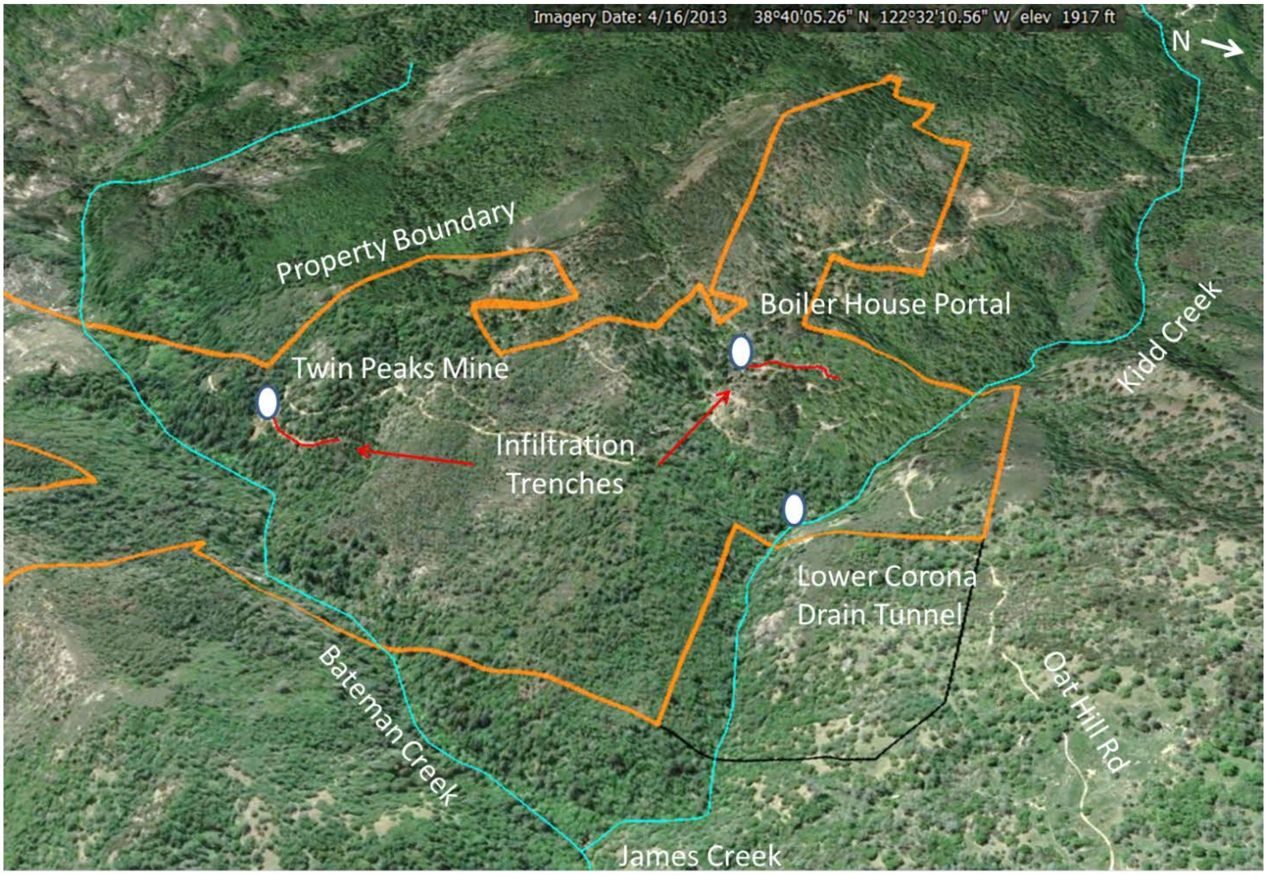


Figure 2. Project area perspective view. Both creeks drain eastward to merge and become James Creek.

Methods and Activities

We monitored influent, effluent, and receiving water quality to assess current conditions and to support the design of new or improved treatment systems. In this section we describe the surface water monitoring sites, parameters monitored, and monitoring protocols followed.

Monitoring Sites

Monitoring sites were selected to represent portal discharges, infiltration trench surface waters, upstream and downstream receiving waters, and other local tributaries. Sites included the three mine portals, the two with adjacent trenches, all nearby creeks when flowing, and some minor tributaries above. An ephemeral stream (dubbed "Corona Creek") in a gulley that passes along the south side of Boiler House Portal and the Upper Corona waste rock piles was sampled several times, and three small tributaries were sampled once in the watershed forming the headwaters of Kidd Creek. James Creek, which is below the confluences of all these, as well as below another medium-sized, seasonal creek (spring), was sampled once. Site information is provided in **Table 1** below and shown in Figure 2 above.

Although we did sample the infiltration trenches during the first 1-2 monitoring events, they had the same composition as their portal discharges. Therefore, sampling at those sites was discontinued and the data are not reported.

Table 1. Monitoring Site Information

Abbrev	Description	Latitude	Longitude
140AZCKAM	Azalea Flat Creek at Mouth	38°40'30.97"N	122°32'59.17"W
140BTNDFM	Bateman Creek Downstream from Mine	38°39'47.13"N	122°31'56.72"W
140BTNLRx	Bateman Creek Lower Reach	38°40'8.21"N	122°31'44.58"W
140BTNURx	Bateman Creek Upper Reach	38°39'27.91"N	122°32'9.92"W
140BTNUFM	Bateman Creek Upstream from Mine	38°39'44.13"N	122°31'59.93"W
140CCKUFM	Corona Creek Upstream from Mine	38°40'7.05"N	122°32'20.96"W
140CFCKAK	Corona Flat Creek above Kidd Creek	38°40'19.71"N	122°32'42.15"W
140CORMLA	Corona Lower Adit	38°40'15.00"N	122°32'10.41"W
140CORMUA	Corona Upper Adit	38°40'7.58"N	122°32'20.64"W
140JCK1KM	James Creek 1km Downstream	38°40'10.46"N	122°31'3.71"W
140KDC2fA	Kidd Creek 200 feet below Adit	38°40'13.41"N	122°32'8.44"W
140KDCUFM	Kidd Creek Upstream from Mine	38°40'15.70"N	122°32'10.95"W
140KCUOHR	Kidd Creek Upstream of Oat Hill Road	38°40'22.98"N	122°32'25.65"W
140MNCRAM	McNabb Creek at Mouth	38°40'21.96"N	122°32'46.15"W
140TPSIBC	Twin Peak Seep into Bateman Creek	38°39'42.79"N	122°32'0.20"W
140TPKADR	Twin Peaks Adit Drainage	38°39'44.37"N	122°32'4.76"W

Monitored Parameters

Monitored parameters included:

- Flow rates
- Field conditions (dissolved oxygen, pH, oxidation-reduction potential, temperature, electrical conductivity,
- Conventional constituent concentrations (carbonate alkalinity, hardness, major cations, sulfate, and total suspended solids)
- Total mercury and methylmercury concentrations
- Trace element concentrations, both filtered and unfiltered

Water samples were collected 13 times, roughly monthly, from April 2012 to May 2013. In every case, filtered and un-filtered samples were collected.

Starting in the summer of 2012, flow rates were measured volumetrically by Justin Smith, the land manager, with a bucket container and stopwatch.

Field conditions were measured using a YSI Pro Plus meter[1] with multiple sensor heads for concurrent measurements of dissolved oxygen (DO), pH, oxidation-reduction potential, temperature, and electrical conductivity. The DO sensor is polarographic. Calibration checks were performed prior to each monitoring event.

Conventional constituent concentrations were measured in the UC Davis analytical lab using standard (EPA and ASTM) ion chromatography and colorimetric methods.

To ensure a thorough survey, nearly 30 different elements were monitored. Water samples were collected 13 times, roughly monthly, from April 2012 to May 2013 by Peter Green and the support crew members listed in **Table 2**.

Table 2. Baseline monitoring dates, crews, locations, and analytes.

Sampling Dates	Support Crew[1]	Additional Locations[2]	Additional Analytes[3]
4/19/2012	Tuleyome staff		bicarb
5/14/2012	Justin Smith	many creeks & small tributaries	bicarb
6/11/2012	Sara Husby-Good		
7/19/2012	Tony Perkins		
8/23/2012	Stephen McCord		
9/18/2012	Henry Calanchini		bicarb, Hg
10/18/2012	Josh Croft		
11/15/2012	Josh Croft; Rachel Connors		
12/10/2012	Henry Calanchini		bicarb
1/17/2013	Josh Croft		
2/24/2013	Josh Croft		bicarb
3/24/2013	Josh Croft		
5/5/2013	Tracy Heidersbach		bicarb, Hg

[1] Peter Green led each sampling event.
[2] Standard locations included each portal's discharge; in the Corona Mine and Boiler House portal infiltration trenches; upstream and downstream of Twin Peaks Mine in Bateman Creek; upstream and downstream of Lower Corona Drain Tunnel in Kidd Creek.
[3] Unless otherwise noted, each event's analytes included trace elements (filtered and unfiltered) and all conventional analytes listed in the table. Field measurements were taken at each site.

Filtered and un-filtered samples were collected during each event. Sites included the three mine portals, the two adjacent infiltration trenches, all nearby creeks (when flowing), and some ephemeral tributaries upstream.

[1] Instrument specifications can be found at http://www.ysi.com/media/pdfs/YSI-Professional-Plus-Spec-Sheet-W14-04-0812.pdf.

All work conformed to the project's "Quality Assurance Project Plan (QAPP) for Surface Water and Soil Sampling." Travel blanks, field blanks, lab blanks and field duplicates were numerous. In the lab, matrix spike and matrix spike duplicates were also analyzed. Analytical MDLs and RLs for mercury (EPA method 1631E) are 0.0002 ng/mL (parts-per-billion, or ppb) and 0.0005 ppb respectively for Hg, and 0.02 and 0.05 pg/mL (parts per trillion) respectively for MeHg – 10-fold lower (EPA method 1630). Anomalously low values (e.g., negative, zero, 1E-13) in the database were replaced with <MDL or < lowest reasonable value reported.

In the fall Hg sampling, samples were collected from Twin Peaks (TP), Upper Corona (UC), and Lower Corona (LC), with a duplicate for LC, as well as a travel blank. In the spring, the duplicate was at UC.

Results

Analytical results and field measures are summarized in this section. These results focus on constituents measured at concentrations that could or should be addressed by the project's remediation activities, and that could be compared to post-project data.

Over 75% of the nearly 30 different elements monitored showed no levels of concern. The latter includes some with quite stringent criteria that are often found around California, including mining areas, at concentrations exceeding applicable criteria. For example, arsenic concentrations here were below drinking water standards.

Flow Rates

Each portal has unique discharge characteristics (**Figure 3**). Lower Corona maintained by far the largest flow during the dry season (18 gpm) and peaked at 50 gpm in January 2013. Twin Peaks released 3.5 gpm in July after a January peak of 33. Upper Corona varied from only 1.5 up to 22 gpm. During very wet years, flows in the range of double to triple these amounts have been observed (J. Smith, pers. comm.).

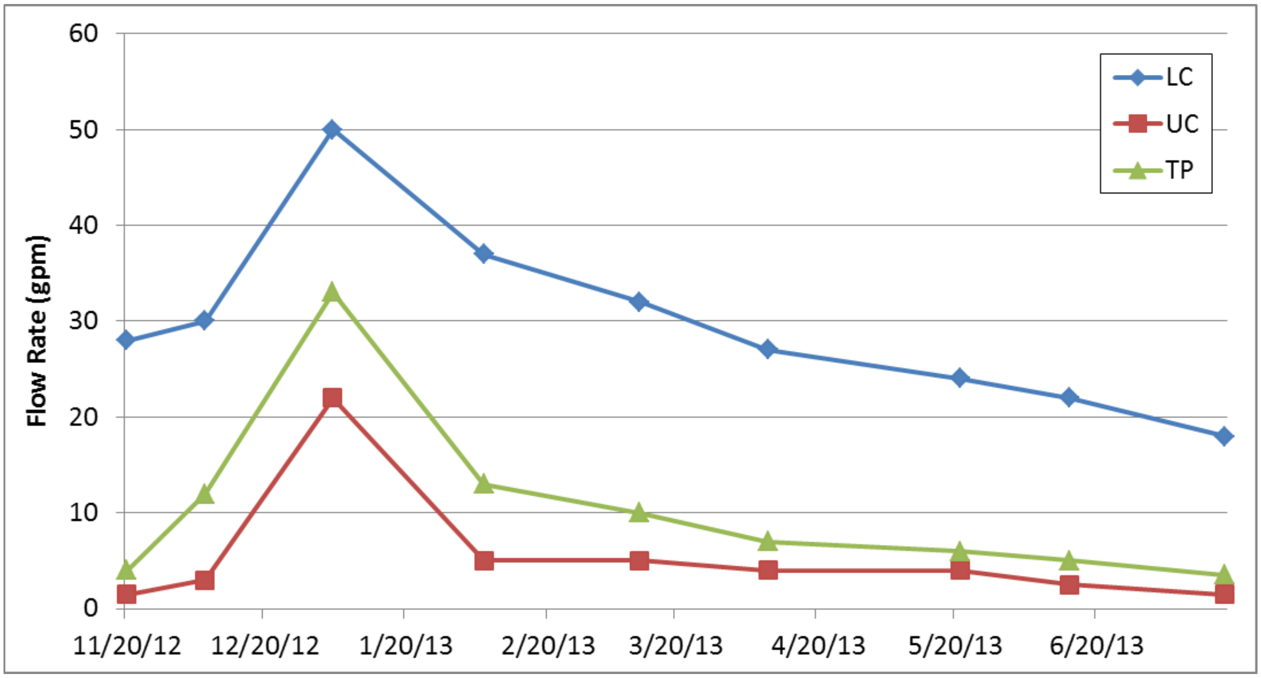


Figure 3. Flow rates measured at each portal during each site visit. LC = Lower Corona; TP = Twin Peaks; UC = Upper Corona

Field Conditions

Field conditions measured at each site during each sampling event included dissolved oxygen, pH, oxidation-reduction potential, temperature, and electrical conductivity.

Acidity

pH was 4.95 to 6.05 at Lower Corona, 6.39 to 7.19 at Upper Corona, and 5.38 to 7.66 at Twin Peaks. The surrounding creeks ranged from 6.78 to 8.11.

Dissolved Oxygen

Dissolved oxygen was 4.1 to 6.3 mg/L at Lower Corona, 8.3 to 10 at Upper Corona, and 7.2 to 9.4 at Twin Peaks.

Oxidation-Reduction Potential

ORP was 14.1 to 139.7mV at Lower Corona, -92.4 to -16.6 at Upper Corona and -65.3 to 117.4 at Twin Peaks. The surrounding creeks varied from -85.9 to 185.7.

Temperature

Temperature was 16.6 to 19.9 C at Lower Corona, 12.9 to 16.9 at Upper Corona, and 15.7 to 19.2 at Twin Peaks. The surrounding creeks tended to have lower temperatures, ranging from 5.1 to 13.5.

Specific Conductance

Specific conductance was 831-1598 uS/cm at Lower Corona, 590-1467 uS/cm at Upper Corona, and 230.5-396 uS/cm at Twin Peaks. The surrounding creeks tended to be lower, in the range of 43.3-855 uS/cm.

Visual Observations

Samples from the Upper Corona mine adit (**Figure 4a**) were typically orange with iron oxides. Kidd Creek approximately 250 yards downstream from the Lower Corona drain tunnel is similarly tainted (**Figure 4b**).

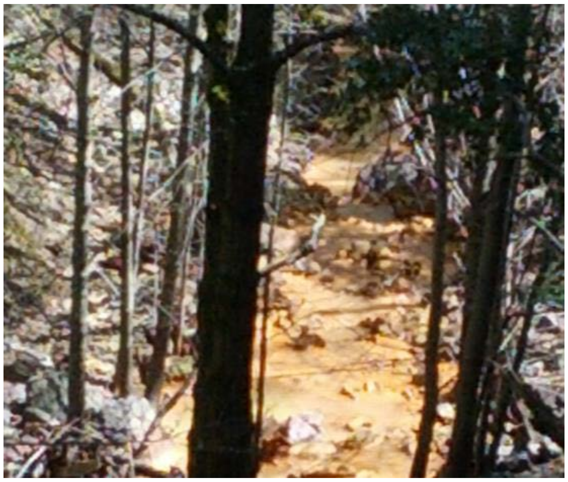
a)  b) 

Figure 4. Photos of site conditions showing a) discharge from Upper Corona and b) Kidd Creek downstream of the Lower Corona drain tunnel.

The same precipitate observed in Kid Creek downstream of the Lower Corona drain tunnel appears to be impacting test pipes installed in the outlet workings (**Figure 5**).

Figure 5. Precipitate clogging a test pipe in the Lower Corona drain tunnel outlet.

Conventional Constituents

Conventional measures are also reported for context.

Hardness

Hardness is a combination of magnesium (more common here) and calcium. Hardness reached 1040 mg/L (all as $CaCO_3$) at Upper Corona, 950 mg/L at Lower Corona and 240 mg/L at Twin Peaks.

Sodium and Potassium

Sodium and potassium concentrations are lower than calcium and magnesium concentrations, only reaching 1300 ppb for K and 11,000 ppb for Na.

Sulfate

Sulfate was 475 to 985 mg/L at Lower Corona, 355 to 1003 at Upper Corona, and 97 to 219 at Twin Peaks. In the surrounding creeks it was often not detectable or below 10, except for Kidd Creek below the Lower Corona discharge where it ranged from 59 to 698.

Total Suspended Solids

TSS varied from 16 to 90 mg/L at Lower Corona, 12 to 68 at Upper Corona, and 2 to 20 at Twin Peaks. The surrounding creeks were usually below 10, but as high as 40 and 90 in Kidd Creek below the Lower Corona discharge.

Alkalinity

Alkalinity was 0.2 mEq/L or lower at all three mine adits, while ranging from 0.5 to 3.7 in surrounding creeks.

Mercury

Mercury (Hg) was measured in water samples in fall (September 2012) and spring (May 2013) to characterize seasonal conditions. Most of the water samples had Hg and MeHg concentrations below the method detection limit (MDL). A few had detectable amounts, but not enough to be above the quantitative reporting limit (RL). Hg is not water soluble, so what is being measured is predominantly attached to fine particles. MeHg concentrations were not detectable except for UC, at a detectable but not quantifiable concentration of 0.03 ng/L. For Hg, TP showed 0.034 ppb, UC had 0.097 ppb and both LC and the duplicate for LC were 'just' detectable at 0.0004 ppb.

Thus, on a solids basis, TP is 2 mg Hg/kg soil, and UC is 8 mg Hg/kg soil. The typical, natural soils around California are 0.1-0.9 mg Hg/kg soil, with a median of 0.2 (Bradford et al., 1996).

In May 2013, MeHg was again mostly ND, with 'just detected' values of 0.02 ng/L at LC and one of the duplicates for UC. Hg was 0.032 at TP, 0.049 in both sample and duplicate for UC, and 0.005 ng/mL at LC. TSS levels were 4, 15 and 5.5 for TP, UC and LC respectively. The resulting Hg-to-solid relative compositions of 8, 3 and 1 mg/kg are 5- to 40-times more concentrated than natural California soil.

Trace Metals

Trace metal concentrations generally measured the same (within handling and instrumental precision) for filtered and unfiltered samples. Since filter blanks came through quite cleanly throughout the study, and filtered concentrations are those more strictly regulated, the following discussion primarily discusses filtered sample results.

Nickel

Although iron is more visible, the most striking metal in these mines' waters is nickel. Compared to a screening level (used for site evaluation) of 39 ppb (ng/mL) at moderate hardness, or 149.5 ppb in very hard water, Upper Corona had nearly 8000 ppb, Lower Corona over 6000 ppb, and Twin Peaks about 1700 ppb. The lowest concentrations seen during the year were about 2000, 3000 and 900 ppb respectively.

California's Maximum Contaminant Level for drinking water is 100 ppb; the highest levels measured in the Sacramento River watershed were on the order of 4 ppb (Domagalski and Dileanis, 2000).

Iron

Concentrations of iron are compared to a screening level of 300 ppb. Upper Corona was 10,000-300,000 ppb; Lower Corona 50,000-250,000; Twin Peaks 7,000-15,000 ppb.

Manganese

Manganese has a screening level of 50 ppb, and was 600-2000 ppb at Upper Corona, 700-1500 ppb at Lower Corona and 300-500 ppb at Twin Peaks.

Chromium

In these rock types and soils, chromium co-occurs with nickel. However, it is much less soluble – barring strongly acidic conditions not found here. No samples were within 60% of the 50 ppb screening level. Many were less than 10 ppb for all three portals.

Aluminum

This common metal is often found in acidic mine drainage, and is screened at 50 ppb. It ranged up to 200 ppb at Upper Corona, but was usually below 50 ppb. Lower Corona only reached 100 ppb, and was sometimes below 50 ppb. Twin Peaks actually held higher levels, ranging into the 100s, and up to more than 1000 ppb.

Other Metals of Interest

Fourteen other metals of possible concern to mine drainage and surface water quality were also monitored. Results for each are summarized as follows:

- Antimony was never found above the detection limit of 1.5 ppb, which is 4-fold below the screening criterion of 6 ppb.
- Barium was always found above the detection limit of 2 ppb, but never near the screening criterion of 1000 ppb. The highest was about 20 ppb.
- Beryllium was never found above the detection limit of 0.2 ppb, which is well below the screening criterion of 4 ppb.

- Cadmium was never found above the detection limit of 0.2 ppb, which is well below the screening criterion of 1.9 ppb.
- Cobalt was always found above the detection limit of 0.2 ppb, and often moderately above the screening criterion of 50 ppb – with a maximum of 300 ppb for Upper Corona, 200 for Lower Corona, and 120 for Twin Peaks. This is discussed further below.
- Copper was usually found above the detection limit of 0.4 ppb, but never above the screening criterion of 6.9 ppb.
- Molybdenum was never found above the detection limit of 0.7 ppb, which is well below the screening criterion of 10 ppb.
- Lead was never found above the detection limit of 0.3 ppb, which is well below the screening criterion of 2 ppb.
- Potassium was always found above the detection limit of 20 ppb, but only in the 300 to 1300 ppb range which is unlikely to be of any concern. (Natural surface water averages about 2000 ppb. Drinking water can be a few 1000's ppb.)
- Silver was never found above the detection limit of 0.1 ppb, not even above the instrumental capability of 0.01ppb.
- Sodium was always found above the detection limit of 20 ppb, but the measurements of 2000 – 11,000 ppb are of no concern. (Natural surface water averages about 6000 ppb. Drinking water can be over 100,000 ppb.)
- Thallium was never found above the detection limit of 0.3 ppb, only glimpsed a few times up to 0.04 ppb.
- Vanadium was never found above the detection limit of 1.5 ppb, and only glimpsed twice in the 0.2 to 0.4 ppb range.
- Zinc was always found above the detection limit of 10 ppb, and often above the screening criterion of 79 ppb; however, the highest 2 values in the 170 ppb range were far below the limit (367 ppb) for very hard water.

Additional Metals and Semi-Metal Elements

Twenty nine total metals and semi-metal elements were monitored. Other results are summarized as follows:

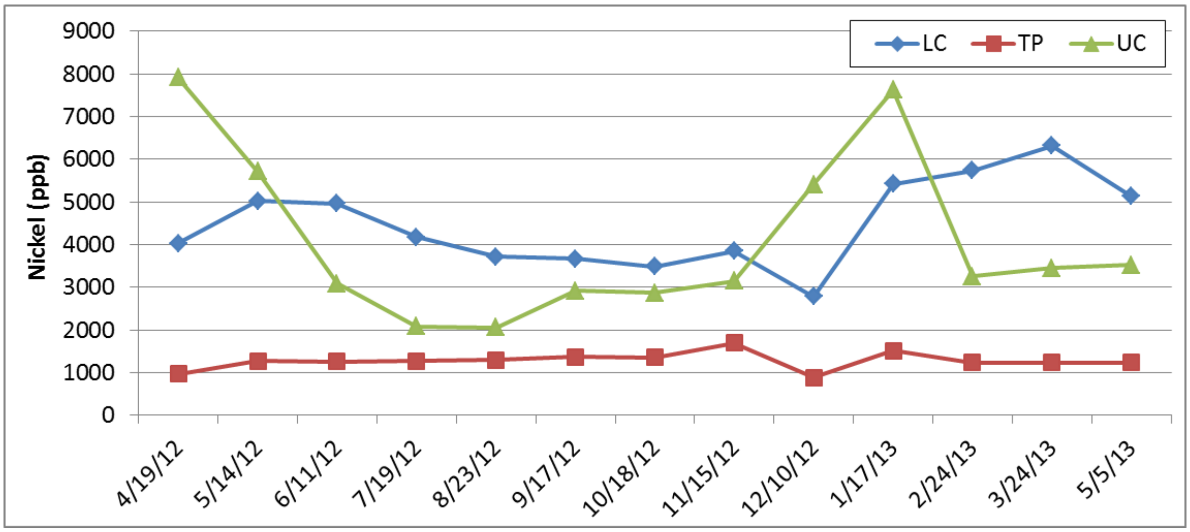
- Li (lithium), Rb (rubidium), Sr (strontium), Cs (cesium), and U (uranium): These elements were marginally detectable but not near levels of concern.
- Arsenic (As) is less toxic to aquatic organisms so has greater concern as a possible drinking water contaminant. These waters are remarkably low: never reaching 0.25 ppb, which is substantially below the California drinking water standard (10 ppb).
- Selenium (Se) was marginally detected in some samples, but well below the chronic toxicity freshwater criterion for California (5 ppb).
- No other elements were detected.

Data Analyses

This data analyses section adds to the results by showing the seasonal variation and calculating the loads with comparison to known sources in the Sacramento River watershed.

Portal Discharges

The concentrations of metals vary monthly, most strikingly for Upper Corona and least for Twin Peaks. Also, Lower Corona responds a bit more slowly to the wet season. Dissolved nickel and iron concentrations are depicted in **Figure 6**. In the case of iron (and to a lesser extent, nickel), a late-summer elevation of concentration is observed, perhaps due to aeration and/or temperature. Also, at the start of the wet season, dilution of both nickel and iron can be discerned.

a) 

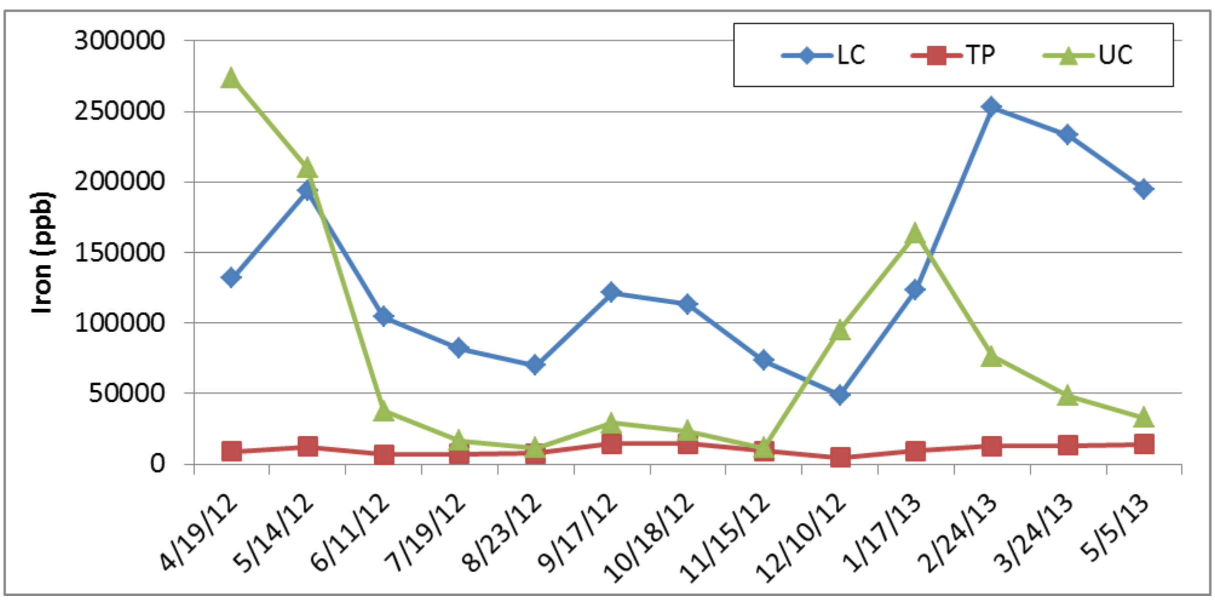
b) 

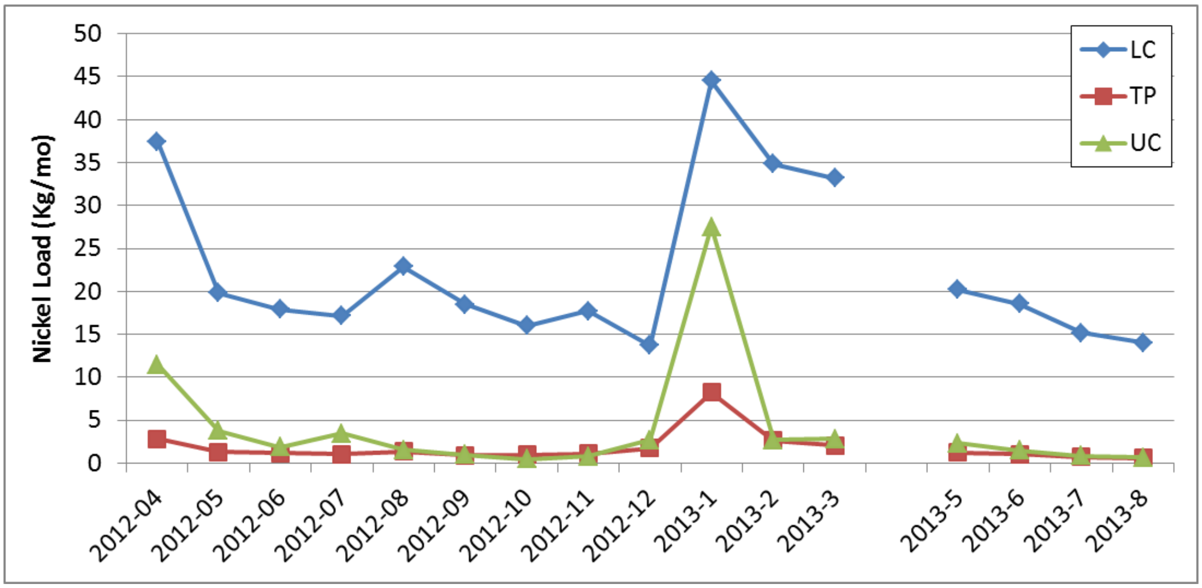
Figure 6. Dissolved metals concentrations sampled monthly in each adit discharge for a) nickel and b) iron.

Mercury is a concern only where (and if) solid material is mobilized. Nickel greatly exceeds discharge limits. Iron is very high, leading to turbidity and downstream siltation. In addition, manganese, aluminum and cobalt (also normally elevated in ultramafic/serpentine sources) are of concern. The numerous other metals and semi-metals analyzed are not of concern.

In a multi-year survey of abandoned mine drainage water during 1987-1991, many locations in the Sacramento Valley watershed were measured multiple times. Twin Peaks and both Corona discharges were each measured for volume of flow and elemental content three times. While negligible for many metals (including arsenic and the low-solubility goal of the mining activity, mercury), concentrations of iron (visibly orange for miles downstream) and nickel (orders of magnitude above current ambient criteria) were observed.

Metals Loadings in Portal Discharges

Monthly mass loads were calculated using measured flow rates and metals concentrations (**Figure 7**).

a) 

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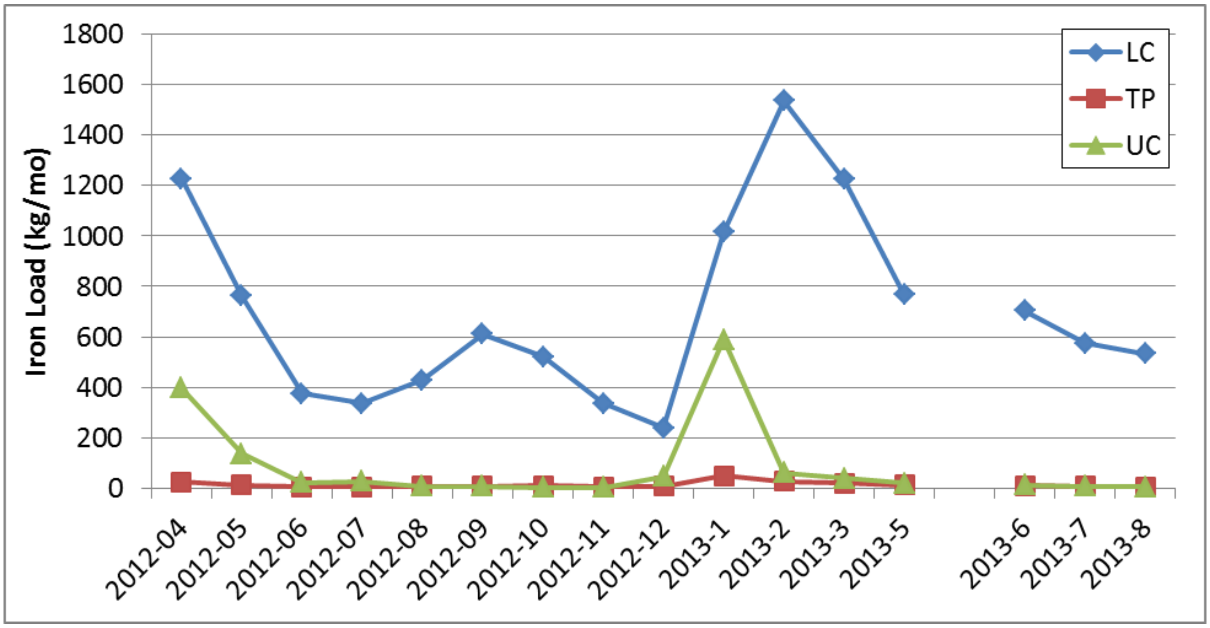

Figure 7. Calculated loads for adit discharges for a) nickel and b) iron.

Discussion

This section discusses the results in context of the project's interests. Baseline conditions are reviewed relative to thresholds of concern (as motivation for implementing site improvements), and for context in designing site improvements. This baseline dataset, combined with post-project monitoring data, will be used to characterize the effectiveness of the treatment systems at reducing the concentrations and loads of pollutants in drainage waters.

Based on our 13 consecutive months of sampling for chemical analysis (plus flow measurements for a full year also) during 2012-2013, compared to ~1990, nickel has declined by half for Corona, and not quite so much for Twin Peaks. Unfortunately, a much greater decline would be needed to meet nickel ambient criteria—if the relative rate of decline were to continue, more than 100 years would be needed. Importantly, both the 1987-1991 and the 2012-2013 periods were quite dry, so the comparison is of similar water years' behavior.

Receiving Waters

For the small tributaries, as well Bateman and Kidd creeks upstream of the mines, no exceedances of any metals were found. The closest was 43 ppb of nickel in Corona Flat Creek, which would only be an exceedance if the water were considerably softer. The small creek adjacent to Upper Corona consistently carried 20-25 ppb of nickel. These two suggest natural release from the local geology, a phenomenon seen in many areas of California, and understood to be natural, such that important water bodies such as San Francisco Bay can end up with natural ("administrative") exceedances.

Upper Kidd Creek (at the road crossing culvert) shows 3 to 5 ppb nickel, but where it approaches Lower Corona, it has increased to 9 to 15 ppb nickel. It has a gaining flow during this reach, in a deep canyon, but is still below the screening level of 39 ppb.

Upper Bateman Creek had 0-4 ppb nickel, and was only 1-7 ppb nickel in the area downhill from Twin Peaks, indicating at most slight impact.

All other elements of concern were below ambient criteria in all of the surface waters monitored. These included some with quite stringent criteria that are often found at problematic levels around California, including mining areas. For example, arsenic here is low enough that it meets drinking water standards.

Kidd Creek below Lower Corona is highly impacted, during the dry season receiving only flow from the portal itself. When Kidd Creek had substantial flow as it approached Lower Corona, there was the possibility for dilution, so Lower Kidd Creek (below mixing with the portal discharge) was sampled. In the wettest periods of April 2012 and December 2012, nickel was about 360 ppb, which is an exceedance, even accounting for the hardness of the water. During five other sampling events, nickel concentrations ranged from 1400 ppb to nearly 4000 ppb.

James Creek, a few miles downstream, was measured at 200 ppb nickel, which exceeds the allowable amount (even for very hard water) – and this was after a few months of above average l rainfall, offering the best possible opportunity for dilution. On the bright side, iron was only 50 ppb—well below the screening level of 300 ppb. Nonetheless, high levels of iron in water tended to precipitate solids, thereby impairing downstream aquatic habitats.

Though not highly acidic at discharge, the mine waters generate more acidity upon exposure to air. The nearby natural surface streams do not carry substantial buffering capacity (concentration of bicarbonate/carbonate combined with sustained volume of flow) to alleviate this acidity.

Iron and nickel were calculated to currently discharge loads of 193 kg/year and 24.7 kg/year respectively at Twin Peaks and 8750 kg/year and 293 kg/year at Corona.

Except where fine particles of mined cinnabar are being suspended, the concentration of mercury (nor biologically derived methyl mercury) is not substantial. The ratios of Hg to total suspended solids in the water from these two mines are only moderately above natural amounts for California (~0.2 ppm per Bradford et al., 1996). These mercury levels are in contrast to the waste rock, which is some locations, is quite high in Hg.

Conclusions

Discharge from the Twin Peaks and Corona mines have been significantly high in iron and nickel historically and to date. After Iron Mountain, they are the most concentrated sources for these two metals of concern, and are expected to remain so.

The discharges from Twin Peaks and from Boiler House Portal have been diverted to infiltration ditches. The Lower Corona Drain Tunnel, however, discharges directly into Kidd Creek unabated. Dilution of discharges from the lower drain tunnel into Kidd Creek is insufficient to prevent downstream toxic conditions.

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