

5.4 SUGGESTIONS FOR FURTHER STUDIES

Based on results of NRMP studies, PCWA operations may affect natural resources conditions within the study area. Higher concentrations of trace metals, particularly aluminum and copper, were observed at sites monitored within the PCWA canal system compared to stream sites for sampling events associated with PCWA's operations during the PG&E yearly outages. These data may inconclusively suggest that the PCWA canal system is a source for loading of some constituents to study area streams.

Additional routine and event-based water quality monitoring should be conducted at sites within the PCWA canal system, and stream sites upstream and downstream from canal system contributions, to characterize potential effects of PCWA operations activities on water quality conditions. One of the focal points for additional studies should be to evaluate aluminum and copper inputs to study area streams from the PCWA canal system. Potential sites for routine and operations event-based water quality monitoring include:

- Boardman Canal below Mammoth Reservoir
- End of Boardman Canal outlet
- End of Yankee Hill Canal outlet
- Secret Ravine at Loomis Basin Park
- Secret Ravine at Rocklin Road
- Clover Valley Reservoir release to Clover Valley Creek and Antelope Canal

Additionally, sediment quality monitoring at numerous sites exhibiting variable soil conditions along the canal system and study area streams may be help to determine potential sources of trace metals in PCWA canals and study area streams. Soil sampling for representative soil types should be coordinated with routine and operations event-based water quality monitoring. Soil samples should be collected from undisturbed sites of representative soil types, as characterized by PCWA (2005), near and upstream from canal and stream water quality monitoring sites, and within watersheds of Clover Valley Creek, Antelope Creek, Secret Ravine, and Miners Ravine.

CHAPTER 6.0 POTENTIAL EFFECTS, REGULATORY FRAMEWORK, AND BEST MANAGEMENT PRACTICES FOR MAINTENANCE ACTIVITIES

This chapter provides an overview of the potential effects of PCWA raw water distribution system maintenance activities on natural resource conditions in the study area, the regulatory framework for effects, and potential BMPs to reduce effects of the maintenance activities on natural resources.

6.1 POTENTIAL EFFECTS OF MAINTENANCE ACTIVITIES ON NATURAL RESOURCES

Potential effects of scheduled and as-needed, site-specific PCWA raw water distribution system maintenance activities are described below.

6.1.1 Scheduled Maintenance Activities

The following sections address scheduled maintenance activities conducted by PCWA within their raw water distribution system.

6.1.1.1 Canal Cleaning and Flushing

PCWA's canal cleaning and flushing activities have the potential to affect natural resource conditions in the study area. The following sections describe potential effects of canal cleaning and flushing activities on natural resources.

Physical Resources

Potential effects of PCWA canal cleaning and flushing activities on hydrology, water quality, and soils and sediment quality conditions in the study area are described in the following sections.

Hydrology

PCWA operations during canal cleaning and flushing activities do not affect hydrologic conditions in Canyon Creek or Auburn Ravine. During the canal cleaning and flushing, PCWA canal system contributions to streamflow in Canyon Creek and Auburn Ravine, and/or diversions from Canyon Creek and Auburn Ravine, do not change as a result of PCWA operations.

Continuous-flow data collected from canal and stream sites within PCWA's lower Zone 1 service area during WDY 2006 (October 16, 2005, to October 15, 2006) were evaluated to determine effects of canal cleaning and flushing activities on hydrologic conditions in Clover Valley Creek, Antelope Creek, Secret Ravine, and Miners Ravine. Continuous-flow monitoring locations used for maintenance evaluations, and their respective watersheds, are listed in **Table 6-1**.

**TABLE 6-1
CONTINUOUS-FLOW MONITORING STATIONS IN ZONE 1 FOR MAINTENANCE**

Secret Ravine Watershed	Miners Ravine Watershed
Secret Ravine at Horseshoe Bar Road	Miners Ravine at Lomida Lane
Yankee Hill Canal Outlet	Ferguson Canal Outlet
Turner Canal Outlet	Stallman Canal Outlet
Boardman Canal Outlet	Baughman Canal Outlet
Secret Ravine at Rocklin Road	Miners Ravine near North Sunrise Avenue

Table 6-2 provides PCWA's schedule of canal outages for cleaning and flushing during March 2006. During these outages for canal cleaning and flushing, canal flows were typically interrupted during business hours to dewater canal segments and allow removal of sediment and debris from canals by PCWA staff.

**TABLE 6-2
CANALS OUTAGES FOR CLEANING AND FLUSHING DURING 2006**

Canal	Time	Dates
Mammoth Reservoir to Boardman Canal Outlet	7:00 a.m. to 11:00 p.m.	March 13, 14, 15, 16, 17, 20, 21, 22, 23, 24
Baughman Canal		
Ferguson Canal		
Stallman Canal		
Yankee Hill Canal		
Turner Canal		
Turner Pump Canal		
Laird Pump Canal		

Average daily flows for canal and stream sites evaluated during WDY 2006 canal cleaning and flushing activities are shown in **Figure 6-1** for sites within the Secret Ravine watershed, and in **Figure 6-2** for sites within the Miners Ravine watershed. As illustrated in **Figures 6-1** and **6-2**, canal system contributions to flow within study area streams through unregulated releases from canal outlets is variable during periods associated with canal cleaning activities.

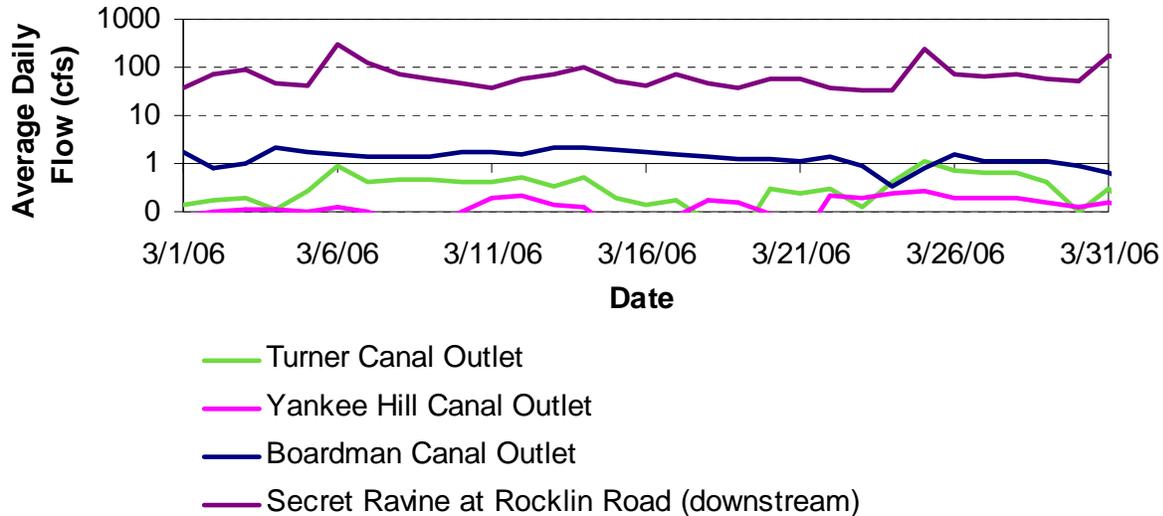


FIGURE 6-1
CANAL OUTLET AND SECRET RAVINE RESPONSES TO CANAL CLEANING AND FLUSHING ACTIVITIES

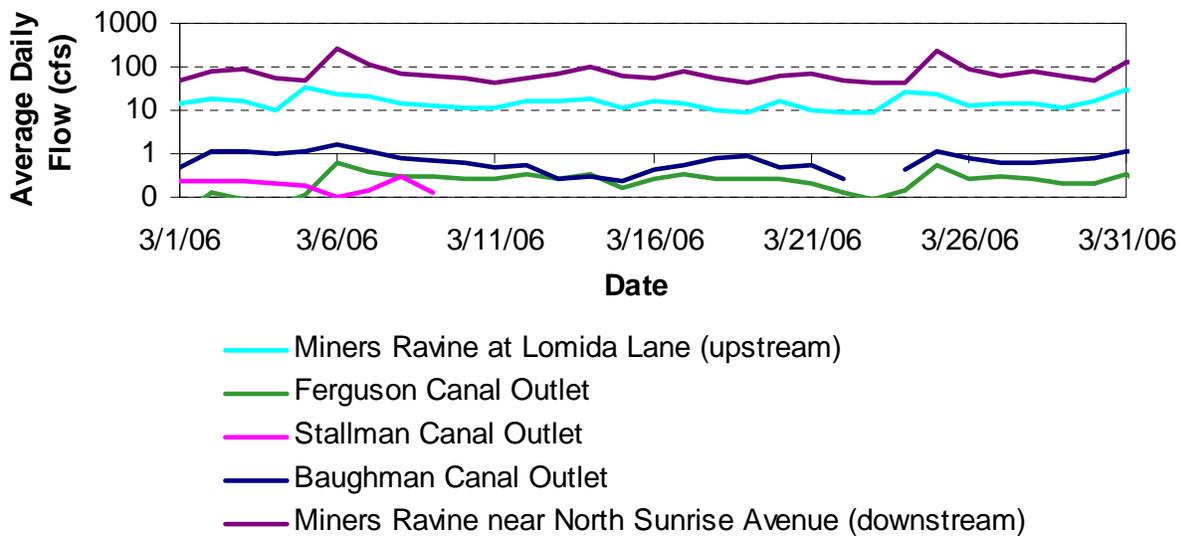


FIGURE 6-2
CANAL OUTLET AND MINERS RAVINE RESPONSES TO CANAL CLEANING AND FLUSHING ACTIVITIES

Based on the average daily flows for sites provided in **Figures 6-1** and **6-2**, the short-duration reduction in flows within the PCWA canal system during canal cleaning and flushing activities is not expected to affect flow conditions in Secret and Miners ravines. Effects on flow conditions in Antelope Creek and Clover Valley Creek are likely similar to conditions shown for Secret and Miners ravines. Precipitation runoff within the watersheds of study area streams is likely to have a much greater influence on stream flow conditions during the time periods that PCWA conducts canal cleaning and flushing activities. Precipitation during March 2006 is shown in **Figure 6-3**.

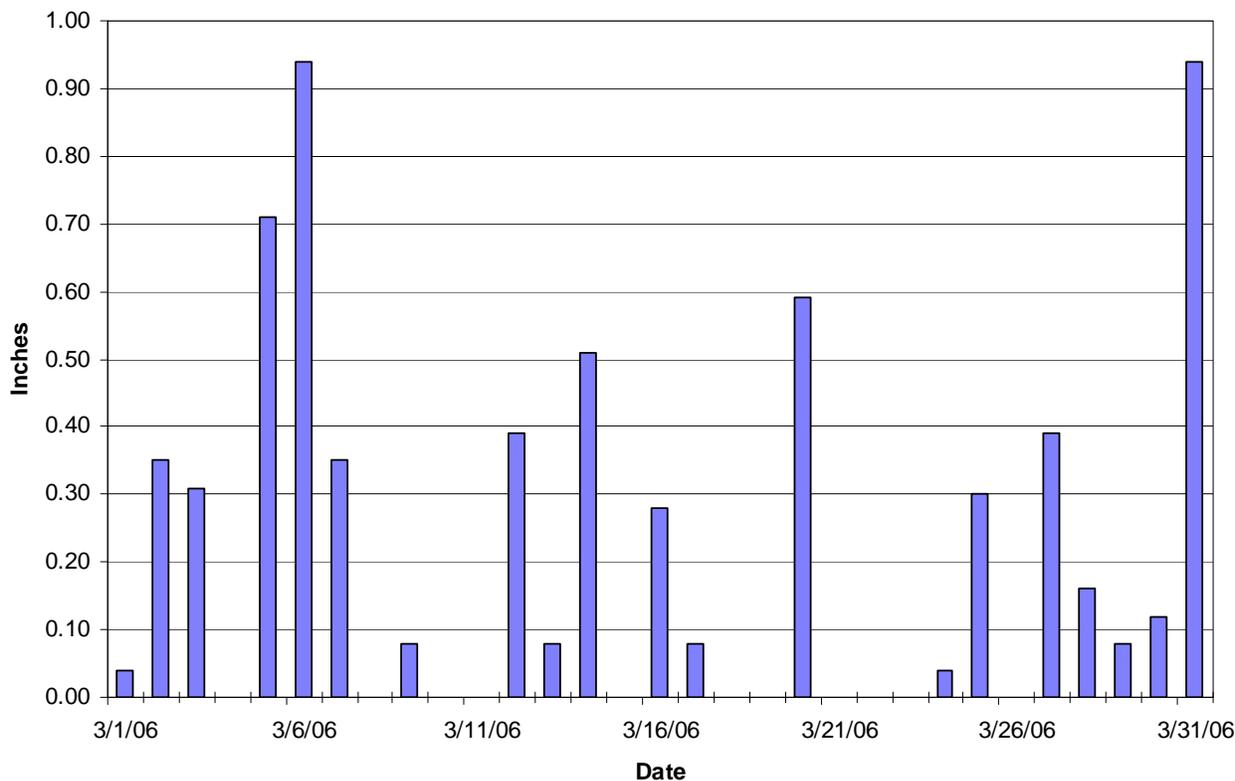


FIGURE 6-3
PRECIPITATION AT CHINA GARDEN ROAD GAGE DURING MARCH 2006

Water Quality

Water quality conditions were monitored at 15 locations within the PCWA canal system and study area streams during PCWA canal cleaning activities. All water quality monitoring locations are located within Zone 1 of the PCWA service area. These locations, shown in **Figures 5-1 and 5-2**, were selected according to canal cleaning locations. **Table 6-3** lists the monitoring site names, site type, associated watershed(s), and information for the canal cleaning activities for which sampling occurred at those locations.

Monitoring for canal cleaning and flushing events along the Boardman, Yankee Hill, Baughman, and Ferguson canals was conducted on March 15, 2007, March 22, 2007, March 26, 2007, and March 27, 2007, respectively. Monitoring sites were located along the canals and stream sites in the Secret Ravine and Miners Ravine watersheds. Results from water quality monitoring and potential effects of canal cleaning activities are discussed below. Water quality conditions were not evaluated in the Auburn Ravine, Clover Valley Creek, and Antelope Creek watersheds, but are likely to be similar to conditions described for Secret Ravine and Miners Ravine. Figures providing a comparison of water quality conditions within the PCWA raw water distribution system and study area streams monitored during canal cleaning activities are included in **Appendix C**.

**TABLE 6-3
WATER QUALITY MONITORING LOCATIONS IN THE PCWA SERVICE AREA FOR CANAL CLEANING ACTIVITIES**

Site Name	Site Identification	Type	Watershed(s)	Canal Cleaning Start/End Time	Weather
Boardman Canal Cleaning, Graveyard Outlet to Hansen Outlet					
Boardman Canal below Mammoth Reservoir	YB81	Canal	Miners Ravine /Secret Ravine	Start: 3/15/2007, 7:15am	Warm and dry
Boardman Canal at Hansen Outlet Release	HANSEN	Canal	Miners Ravine	End: 3/15/2007, 3:50pm	
Miners Ravine at Lomida Lane	MINERSRV7	Stream	Miners Ravine		
Miners Ravine at Moss Lane	MINERSRV5	Stream	Miners Ravine		
Yankee Hill Canal Cleaning					
Boardman Canal at Head of Turner Canal	YB154	Canal	Miners Ravine/ Secret Ravine	Start: 3/22/2007, 6:15pm	Cool and dry
Yankee Hill Canal Outlet Release	YANKEECR	Canal	Secret Ravine	End: 3/22/2007, 3:25pm	
Tributary to Secret Ravine from Yankee Hill Canal	YHTRIB2	Stream	Secret Ravine		
Secret Ravine at Rocklin Road	SECRETRV3	Stream	Secret Ravine		
Baughman Canal Cleaning, Head of Ferguson Canal to Baughman Canal Outlet					
Baughman Canal at Head of Ferguson Canal	YB145	Canal	Miners Ravine	Start: 3/26/2007, 6:10am	Cool with rain at around 2:00 p.m.
Baughman Canal Outlet Release	BAUGHMANCR	Canal	Miners Ravine	End: 3/26/2007, 1:00pm	
Tributary to Miners Ravine from Baughman Canal	BCTTRIB1	Drainage	Miners Ravine		
Miners Ravine near N. Sunrise Avenue	MINERSRV3	Stream	Miners Ravine		
Ferguson Canal Cleaning					
Baughman Canal at Head of Ferguson Canal	YB145	Canal	Miners Ravine	Start: 3/27/2007, 6:10am	Cool and dry
Ferguson Canal Outlet Release	FRGCR	Canal	Miners Ravine	End: 3/27/2007, 11:55am	
Tributary to Miners Ravine from Ferguson Canal	FRGTRIB1	Drainage	Miners Ravine		
Miners Ravine at Auburn-Folsom Road	MINERSRV4	Stream	Miners Ravine		

Secret Ravine Watershed

As shown in **Table 6-3**, water quality monitoring in the Secret Ravine watershed was conducted during one canal cleaning event on March 22, 2007, that occurred along a section of the Yankee Hill Canal. Water quality was monitored at two canal sites, upstream and downstream from the canal section that was cleaned (YB154 and YANKEEER, respectively), and two stream sites downstream from the Yankee Hill Canal Outlet release (YHTRIB2 and SECRETRV3). These monitoring sites are listed below from the most upstream to the most downstream locations:

- **Boardman Canal at the Head of Turner Canal (YB154):** Located along the Boardman Canal at the head of the Turner Canal.
- **Yankee Hill Canal Outlet Release (YANKEEER)**
- **Yankee Hill Canal Tributary (YHBTRIB2)**
- **Secret Ravine at Rocklin Road (SECRETRV3)**

As shown in **Figure 6-1**, potential flow contributions from the Yankee Hill Canal comprise a small proportion of streamflow at SECRETRV3. Precipitation runoff within the Secret Ravine watershed is likely to have a much greater influence on water quality conditions in Secret Ravine during the time periods that PCWA conducts canal cleaning and flushing activities.

Water Temperature and Dissolved Oxygen

Minimal to no effects on water temperatures and DO levels were observed at the two stream sites (YHTRIB2 and SECRETRV3) downstream from the canal cleaning activity during this event. Water temperatures at the canal outlet release downstream from the canal cleaning activity, YANKEEER, increased from about 62°F to up to 67°F for about 15 minutes, then stabilized to reflect water temperature conditions similar to values measured upstream from canal cleaning. The temporary increase in water temperature is likely attributed to the displacement and flushing of water that collected in shallow pools and exposed to direct sunlight in the canal after the canal was dewatered. Measured DO levels across canal and stream sites exhibited similar, but inverse trends.

pH, Alkalinity, and Hardness

Based on measurements at sites during monitoring, canal cleaning activities do not appear to affect pH conditions in Secret Ravine. Measured pH levels at YANKEEER increased for a short duration after canal cleaning, and then stabilized to reflect pH levels similar to values measured upstream from canal cleaning. Measured pH levels at YANKEEER increased by more than 1 unit up to 9.2 during canal flushing after cleaning activities, subsequently decreased by more than 2 units to 6.9, then stabilized at 7.7. The pH measured at YHTRIB2 also increased slightly after canal cleaning, but did not fluctuate at SECRETRV3. Alkalinity and total hardness measured at sites during the canal cleaning monitoring event fluctuated slightly at YANKEEER, but remained consistent at both stream sites downstream from the canal cleaning activity. Stream sites monitored demonstrated higher buffering capacity (alkalinity) and lower total hardness compared to canal sites.

Total Suspended Solids and Turbidity

Despite a temporary increase in TSS and turbidity levels observed at YANKEEER after canal cleaning activities, no effects were observed at stream monitoring sites during this canal cleaning monitoring event.

Specific Conductivity and Ions

No effects on SC, calcium, iron, magnesium, potassium, or sodium levels were observed at stream sites in the Secret Ravine watershed during monitoring for canal cleaning activities. Minimal increases in iron concentrations were observed at YANKEEER after flows were restored to Yankee Hill Canal, but were not reflected in samples collected at stream sites downstream. SC, calcium, magnesium, potassium, and sodium values measured at stream sites were higher than canal sites. Water quality results also suggest that chloride, nitrate, and sulfate concentrations at stream sites are not affected by canal cleaning activities.

Trace Elements

Aluminum, barium, copper, and zinc concentrations at YANKEEER increased after flows were restored to Yankee Hill Canal, but do not appear to affect concentrations in samples collected at stream sites downstream. Cadmium concentrations measured at all sites during the canal cleaning monitoring event were below the detection limit (0.5 µg/L).

Miners Ravine Watershed

Water quality conditions in the Miners Ravine watershed were evaluated during canal cleaning and flushing activities along sections of the Boardman, Baughman, and Ferguson canals, on March 15, 2007, March 26, 2007, and March 27, 2007, respectively. On March 15, 2007, water quality was monitored at two canal sites upstream and downstream from canal cleaning activities, and two stream sites in Miners Ravine also upstream and downstream from canal cleaning activities:

- **Boardman Canal below Mammoth Reservoir (YB81)**
- **Hansen Outlet Release (HANSENR):** located at the Hansen outlet from the Boardman Canal. Regulated releases from this canal flow into an unnamed tributary that contributes flows into Miners Ravine.
- **Miners Ravine at Lomida Lane (MINERSRV7):** located at Lomida Lane upstream from the confluence with the unnamed tributary to Miners Ravine receiving regulated releases from HANSENR.
- **Miners Ravine at Moss Lane (MINERSRV5):** located at Moss Lane, downstream from the confluence with the unnamed tributary to Miners Ravine receiving regulated releases from HANSENR.

On March 26, 2007, water quality parameters were monitored at two canal sites upstream and downstream from canal cleaning activities, and two stream sites downstream from canal cleaning activities:

- **Baughman Canal at the Head of Ferguson Canal (YB145):** located upstream from the cleaning event at the head of the Ferguson Canal.
- **Baughman Canal Outlet Release (BAUGHMANCR)**
- **Tributary to Miners Ravine from Baughman Canal (BCTRIB1)**
- **Miners Ravine near N. Sunrise Avenue (MINERSRV3)**

Due to the extensive length of the unnamed tributary to Miners Ravine from Baughman Canal and long travel time from BAUGHMANCR to BCTRIB1, samples obtained during canal cleaning activities at BCTRIB1 and MINERSRV3 were intended to provide a relative comparison of water quality conditions in receiving waters downstream from BAUGHMANCR.

On March 27, 2007, water quality was monitored at two canal sites upstream and downstream from canal cleaning activities, and two stream sites downstream from canal cleaning activities:

- **Baughman Canal at the Head of Ferguson Canal (YB145)**
- **Ferguson Canal Outlet Release (FRGCR):** located at the Ferguson Canal Outlet. Unregulated releases from this canal flow into an unnamed tributary that contributes flows into Miners Ravine.
- **Tributary to Miners Ravine from Ferguson Canal (FRGTRIB1):** located at Rock Crest Place along the unnamed tributary receiving unregulated releases from the FRGCR.
- **Miners Ravine at Auburn-Folsom Road (MINERSRV4):** located on the west side of Auburn-Folsom Road downstream from the confluence with the unnamed tributary to Miners Ravine receiving regulated releases from FRGCR.

As shown in **Figure 6-2**, potential direct flow contributions from the Ferguson and Baughman canals comprise a small proportion of streamflow at MINERSRV3. Precipitation runoff within the Miners Ravine watershed is likely to have a much greater influence on water quality conditions in Miners Ravine during the time periods that PCWA conducts canal cleaning and flushing activities.

Water Temperature and Dissolved Oxygen

Based on water quality monitoring results, water temperature conditions in Miners Ravine were not affected by the March 15, 2007, and March 26, 2007, canal cleaning activities. Water temperatures observed at HANSENCR on March 15, 2007, increased for a short duration, then stabilized to reflect water temperature conditions similar to values measured upstream from canal cleaning. During the March 27, 2007, canal cleaning monitoring event, water temperatures increased for a short duration at FRGCR, and water temperatures observed at FRGTRIB1 and MINERSRV4 also slightly increased, potentially as an effect of canal cleaning activities. DO

levels measured across stream sites in the Miners Ravine watershed were not affected by canal cleaning activities.

pH, Alkalinity, and Hardness

Although measured pH levels temporarily increased at the canal outlets after flows were restored to the canals following canal cleaning, minimal effects were observed at stream sites during the canal cleaning monitoring events. Sharp decreases and subsequent increases in pH observed at canal release outlets were likely responses to the displacement and flushing of water that collected in shallow pools and exposed to direct sunlight in the canal after the canal was dewatered. Alkalinity of water samples collected was higher across stream sites in the Miners Ravine watershed compared to the canal sites. The higher buffering capacity (alkalinity) at stream sites likely attributed to the minimal effects observed on pH at Miners Ravine sites. The canal cleaning activities also did not appear to affect total hardness values observed at stream sites within the Miners Ravine watershed. Although minimal effects were observed in tributaries receiving unregulated releases from canal outlets on March 26 and 27, 2007, no effects were observed in Miners Ravine. **Figure 6-4** shows pH values measured in the Miners Ravine watershed during the March 27, 2007, canal cleaning event.

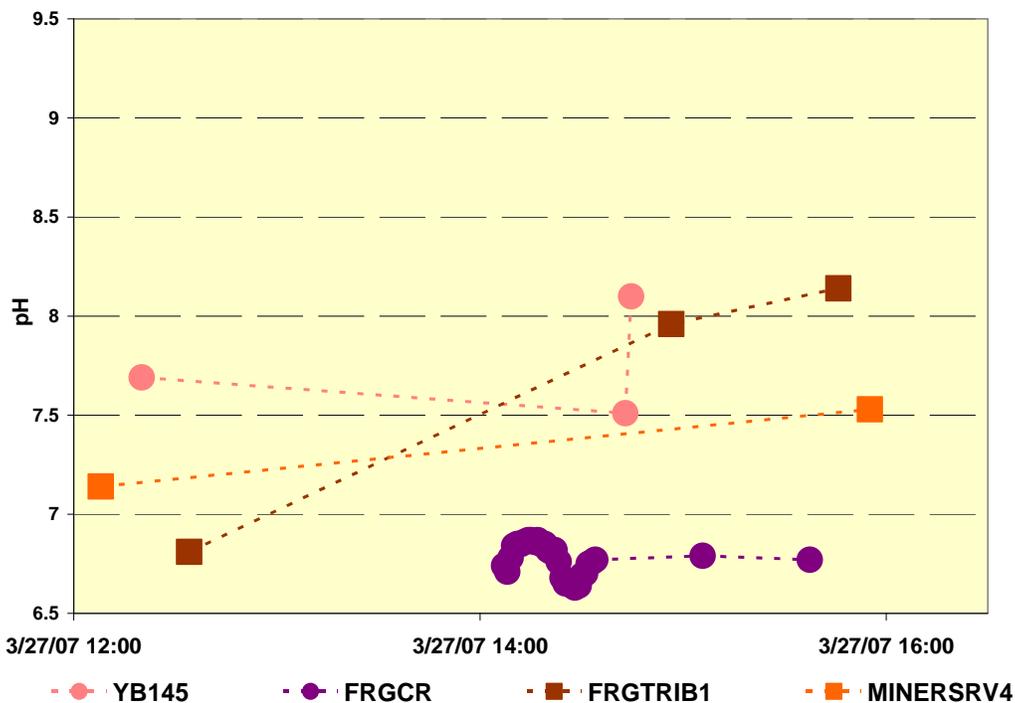


FIGURE 6-4
MEASURED PH LEVELS AT MINERS RAVINE WATERSHED SITES DURING
MARCH 27, 2007, CANAL CLEANING EVENT

Total Suspended Solids and Turbidity

Despite a temporary increase in TSS and turbidity levels observed at canal outlet releases after flows were restored to canals following canal cleaning activities, no related effects were observed at stream monitoring sites in the Miners Ravine watershed during sampling events.

Specific Conductivity and Ions

Based on water quality results, canal cleaning activities did not affect SC and ion concentrations in Miners Ravine. Although calcium, iron, magnesium, potassium, sodium, chloride, and sulfate concentrations increased at canal outlet releases after flows were restored to canals following canal cleaning activities, no changes in SC and ion concentrations were observed at stream monitoring sites. In general, SC and ion concentrations were higher at Miners Ravine watershed stream sites compared to canal sites.

Trace Elements

Following canal cleaning activities, concentrations of aluminum, barium, copper, and zinc increased to very high levels at canal outlet releases for a short duration. During the March 15, 2007, canal cleaning event, aluminum concentrations measured in samples collected in Miners Ravine increased from 120 to 710 µg/L, potentially as a result of canal cleaning activities and aluminum loading to the unnamed tributary to Miners Ravine below the Hansen Outlet (**Figure 6-5**). Aluminum levels also increased at BCTRIB1 and FRGCR on March 26, 2007, and March 27, 2007, respectively, but did not increase at Miners Ravine sites monitored downstream.

Figures 6-5, 6-6 and 6-7 show aluminum concentrations for canal and stream sites monitored during canal cleaning activities.

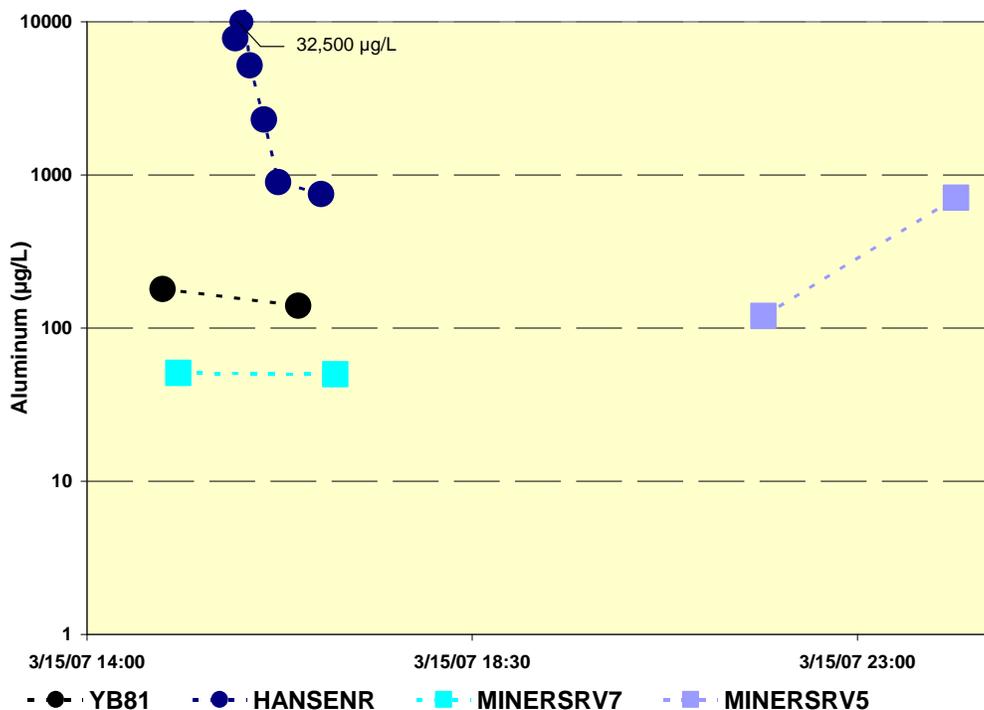


FIGURE 6-5
MEASURED ALUMINUM LEVELS AT MINERS RAVINE WATERSHED SITES
DURING MARCH 15, 2007, CANAL CLEANING EVENT

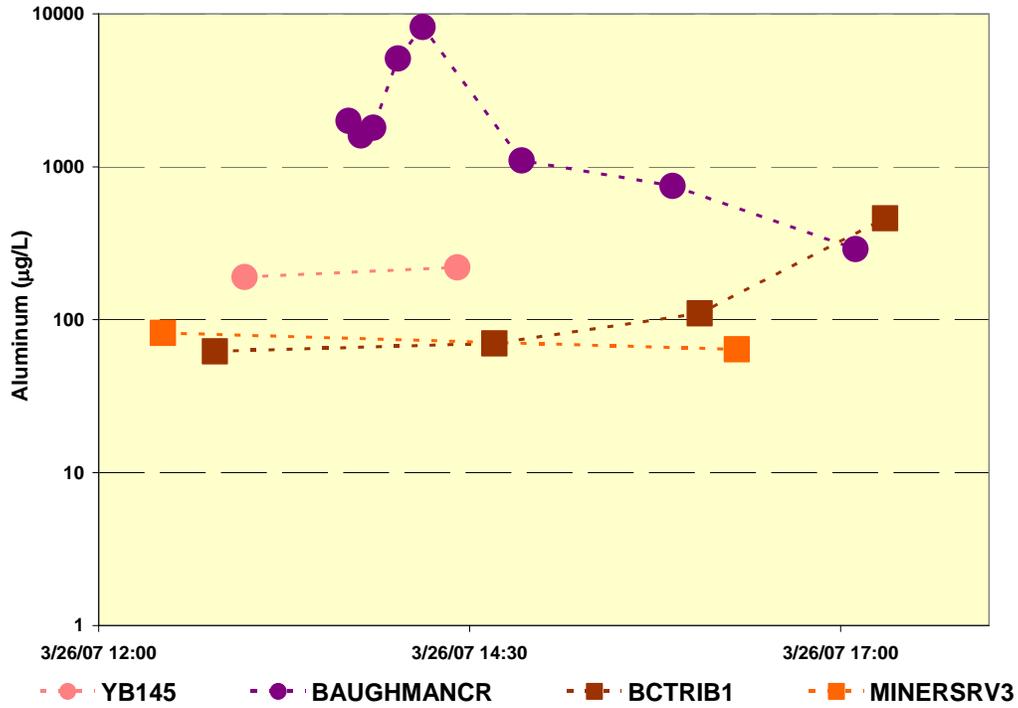


FIGURE 6-6
MEASURED ALUMINUM LEVELS AT MINERS RAVINE WATERSHED SITES
DURING MARCH 26, 2007, CANAL CLEANING EVENT

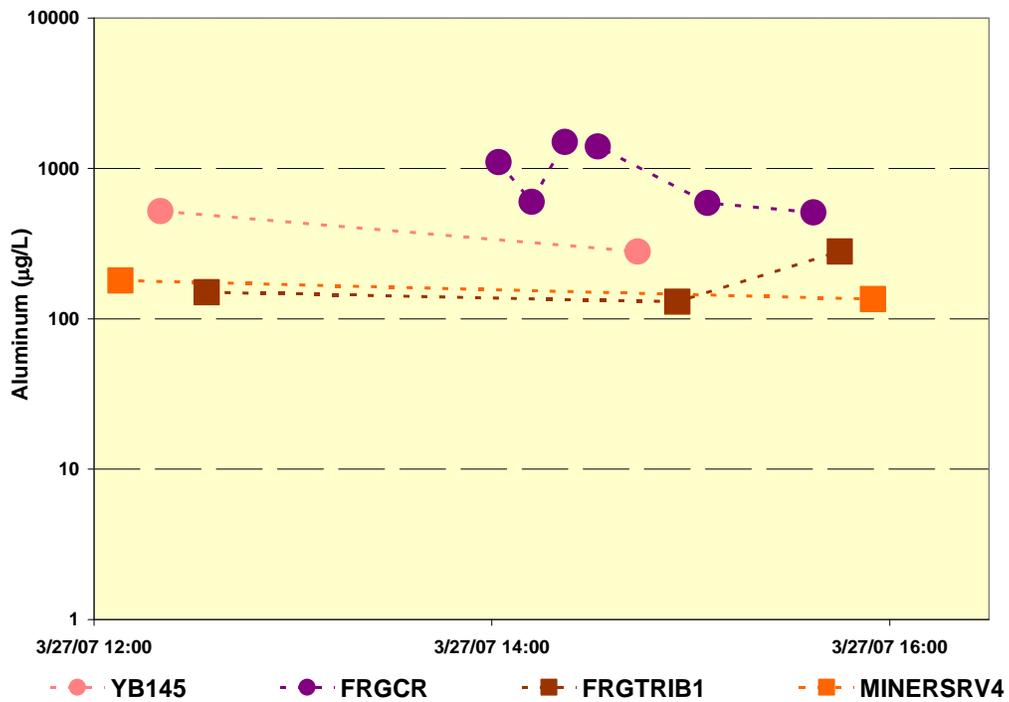


FIGURE 6-7
MEASURED ALUMINUM LEVELS AT MINERS RAVINE WATERSHED SITES
DURING MARCH 27, 2007, CANAL CLEANING EVENT

Barium, copper, and zinc concentrations increased at canal outlet releases for a short duration (about 1 hour) following canal cleaning activities. Water quality data collected during monitoring suggest that these increased concentrations at canal outlets generally did not result in increased concentrations at stream sites downstream from the canal outlet releases. However, the concentration of copper and zinc at MINERSRV5 did increase from 3.2 to 8.8 $\mu\text{g/L}$, and from 5.1 to 7.6 $\mu\text{g/L}$, respectively, during the March 15, 2007, monitoring event. These increases may be attributed to canal cleaning activities. **Figures 6-8 and 6-9** show barium results for sites monitored during the March 26, 2007, and March 27, 2007, canal cleaning events. Copper and zinc results for Miner Ravine watershed sites monitored during the March 15, 2007, canal cleaning event are shown in **Figures 6-10 and 6-11**. Cadmium concentrations measured at all sites during the canal cleaning monitoring event were below the detection limit (0.5 $\mu\text{g/L}$).

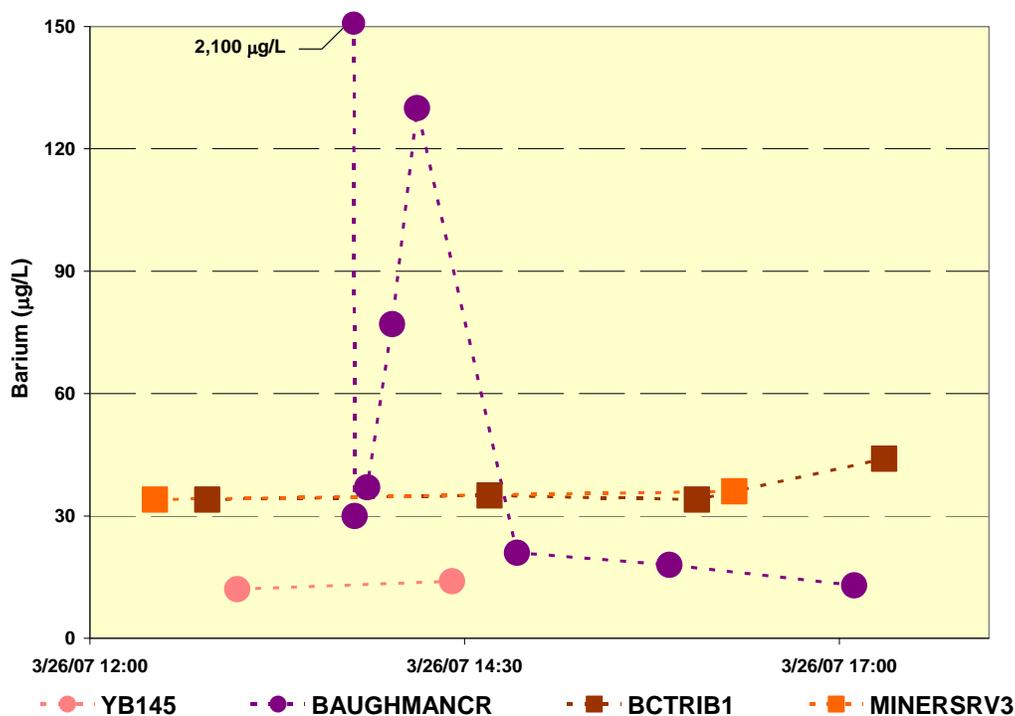


FIGURE 6-8
MEASURED BARIUM LEVELS AT MINERS RAVINE WATERSHED SITES DURING
MARCH 26, 2007, CANAL CLEANING EVENT

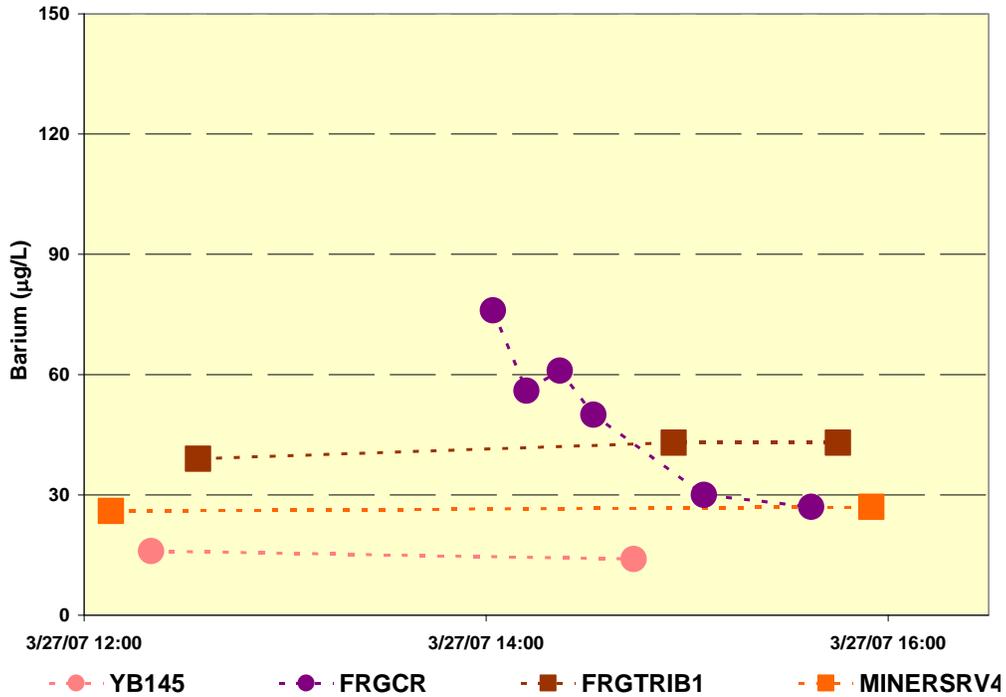


FIGURE 6-9
MEASURED BARIUM LEVELS AT MINERS RAVINE WATERSHED SITES DURING
MARCH 27, 2007, CANAL CLEANING EVENT

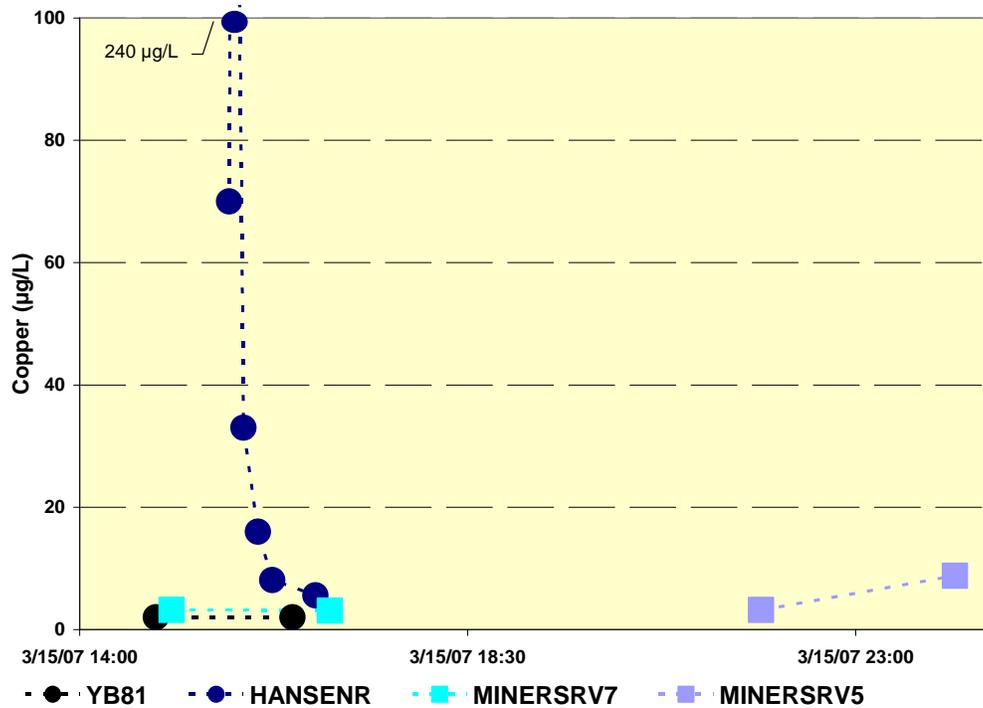


FIGURE 6-10
MEASURED COPPER LEVELS AT MINERS RAVINE WATERSHED SITES DURING
MARCH 15, 2007, CANAL CLEANING EVENT

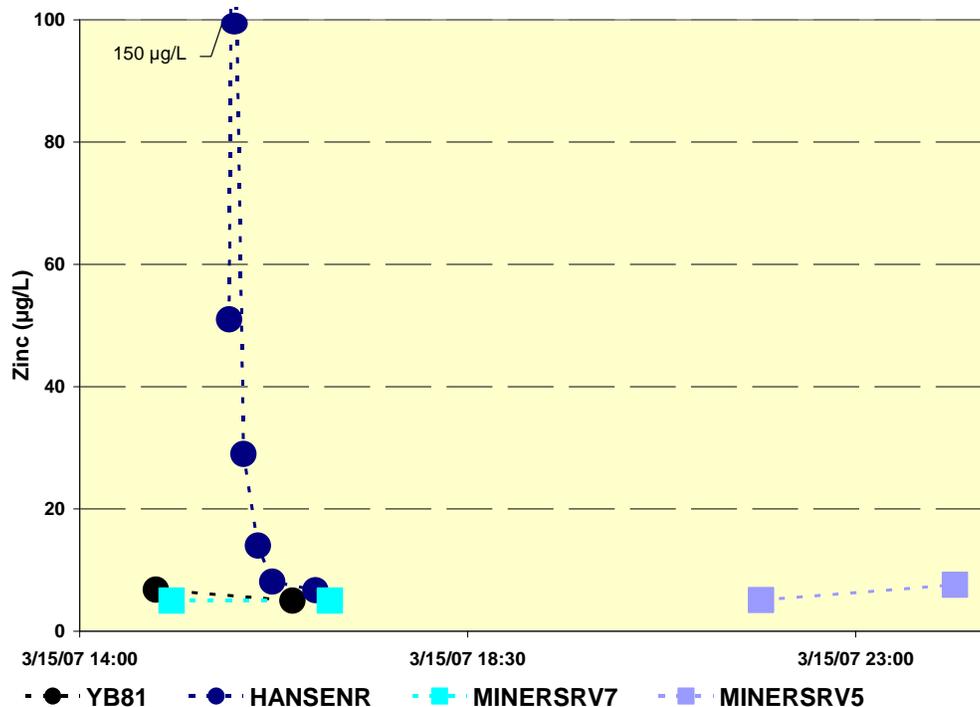


FIGURE 6-11
MEASURED ZINC LEVELS AT MINERS RAVINE WATERSHED SITES DURING
MARCH 15, 2007, CANAL CLEANING EVENT

Soils and Sediment Quality

As described in **Chapter 2**, debris and sediment removed from the canals are typically deposited along canal banks. To quantify the effects of canal cleaning on soil and sediment quality, soils were collected along canal banks where debris had been deposited. Soils were collected in two high-density polyethylene 500-ml canisters from the banks of five canals, the Antelope, Boardman, Yankee Hill, Baughman, and Ferguson canals. These canals were cleaned on February 14, 2007, and March 15, 22, 26, and 27, 2007, respectively. All soil samples were collected on March 30, 2007. These canals were selected and their soils sampled on March 30, 2007, to provide an understanding of the effects of cleaning on soil quality over time. As shown in **Table 6-4**, the selected canals locations for sampling provide data for evaluating soil quality effects after 44, 15, 8, 4, and 3 days, respectively. High air temperatures during the period when the first canal cleaning activity evaluated for soil quality effects to the date of sample collection ranged from 40°F to 80°F, with lows ranging from 27°F to 56°F (**Figure 6-12**). As shown in **Figure 6-3**, rain fell intermittently during the days before the first canal cleaning event and to the sampling date. Air temperature and precipitation may affect the persistence of constituents in soils directly, through chemical and physical interactions, and indirectly, by influencing microbiological communities in soils. At the time of sampling, the weather was sunny, dry, with a high air temperature of 74°F.

**TABLE 6-4
QUALITY OF SEDIMENTS REMOVED FROM CANALS DURING CLEANING AND FLUSHING ACTIVITIES**

Constituent (mg/kg)	Ferguson Canal		Baughman Canal		Yankee Hill Canal		Boardman Canal		Antelope Canal	
	Average	Standard Deviation	Average	Standard Deviation	Average	Standard Deviation	Average	Standard Deviation	Average	Standard Deviation
Aluminum	9,750	+/-1,768	10,000	+/-0	10,800	+/-1,697	4,200	+/-141	12,500	+/-2,121
Barium	89	+/-9.2	62	+/-0.7	62	+/-9.9	41	+/-4.2	125	+/-7.1
Calcium	1,850	+/-354	915	+/-92	4,950	+/-71	1,400	+/-141	2,300	+/-566
Cadmium	Below Detection	Below Detection	Below Detection	Below Detection	0.45	NA	Below Detection	Below Detection	Below Detection	Below Detection
Copper	90	+/-28.3	52	+/-7.8	75	+/-36	22	+/-0.7	55	+/-43
Iron	12,500	+/-2,121	9,500	+/-141	8,450	+/-9,264	6,000	+/-141	20,500	+/-707
Potassium	1,750	+/-354	1,450	+/-71	545	+/-573	860	+/-198	3,000	+/-1,131
Magnesium	3,400	+/-566	2,600	+/-0	2,070	+/-1,739	2,350	+/-212	4,500	+/-283
Sodium	69	+/-11	58	+/-2.8	375	+/-446	54	+/-0	130	+/-14
Zinc	71	+/-1.4	61	+/-3.5	99	+/-73	16	+/-4.2	54	+/-2.8
Days after Cleaning	3		4		8		15		44	

Ten chemical parameters were measured in soil samples collected: aluminum, barium, cadmium, calcium, copper, iron, magnesium, potassium, sodium, and zinc. Results of chemical analyses are shown in **Table 6-4**.

Samples collected had very high concentrations of aluminum, calcium, iron, magnesium, and potassium across all sites. High concentrations of these constituents are not likely attributed to PCWA raw water distribution system O&M activities, because PCWA O&M activities do not introduce these constituents to the study area. High background concentrations of these constituents in study area soils are most likely due to the chemical composition of minerals in parent material comprising soils.

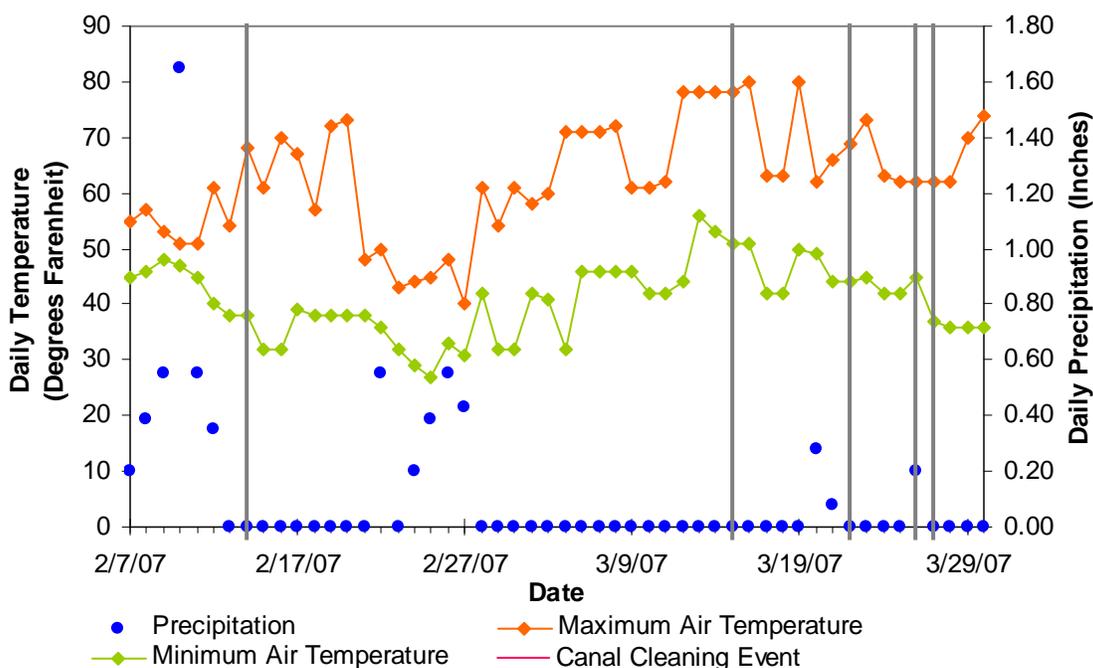


FIGURE 6-12
DAILY AIR TEMPERATURES AND PRECIPITATION BEFORE SOIL SAMPLING
FOR CANAL CLEANING EVENTS

Copper concentrations in soil samples collected across some sites were higher than the mean concentration of copper in soils in the region, while cadmium and zinc concentrations across all sites were consistent with regional mean concentrations for soils shown in **Table 6-5** (Holmgren et al. 1993). These higher copper concentrations may be associated with the removal of sediments from the canal with higher copper concentrations attributed to PCWA's algaecide applications, and deposition of the soils along the canal banks. Barium and sodium concentrations in soil samples collected after PCWA canal cleaning activities varied across sites, but are not expected to be affected by PCWA canal cleaning activities.

Soil compaction and erosion may occur as a result of equipment access and use along canal banks during canal cleaning activities. Mechanical equipment may also introduce chemical contaminants (i.e., petroleum products) to soils at access sites.

**TABLE 6-5
GEOMETRIC MEAN CONCENTRATIONS OF CADMIUM, COPPER,
AND ZINC IN SOILS**

Constituent (mg/kg)	State of California Geometric Mean	California Subtropical Land Resource Region Geometric Mean
Cadmium	0.253	0.254
Copper	37.3	43.4
Zinc	82.7	90.4

Source: Holmgren et al. 1993.

Key:

mg/kg = milligrams per kilogram

Biological Resources

The following sections describe potential effects of PCWA canal cleaning and flushing activities on terrestrial and aquatic habitat and species in the study area.

Terrestrial Habitat and Species

Minimal decreases in study area streams due to a short duration reduction of flows in the PCWA canal system could result in temporary, very minimal decreases in the extent of wetland habitats that may be indirectly supported by canal deliveries. This could have minimal effects on species that use these wetland habitats, such as foraging birds and breeding amphibians, by decreasing the amount of available habitat. Reductions in water levels could expose amphibian eggs in the shallow, vegetated margins of drainages or adjacent wetlands. Potential effects from temporary water reductions on species that use these habitats are expected to be minimal. Flushing after canal cleaning could erode banks and wash away amphibian eggs that may be present on stream margins. The typical timing of the cleaning period in the early part of the year occurs within the breeding period for several amphibian species.

Changes in water quality could indirectly affect terrestrial habitats and species. Increased sedimentation from flushing activities could bury amphibian eggs. Increases in trace elements (such as aluminum and copper) could have some negative effects on plants and wildlife on the margins of canals and tributaries. Amphibians in particular are known to be sensitive to such water quality changes, although effects vary dramatically by type and concentration of contaminant, species, and life stage.

Habitats and species could potentially be affected directly or indirectly by impacts to soils and sediments from equipment, including compaction, erosion, and introduction of petroleum products. Effects on habitats and species could include plant mortality or decreased plant growth. These types of impacts are expected to be relatively minimal and small in aerial extent.

If equipment is used for removal of debris, damage could be caused to habitats by movement of equipment or by placement of debris and soil near canals. Some potential negative effects could occur if raptors are nesting near work areas that may be disturbed by noise. Raptors potentially occurring in the study area include Red-shouldered Hawk, American Kestrel, Red-tailed Hawk, and Great Horned Owl. The nesting period for raptors is generally March 1 to August 15.

Aquatic Habitat and Species

Changes in water quality conditions, particularly aluminum and copper concentrations, observed in study area streams following canal cleaning activities may affect aquatic habitat and species. Most aquatic organisms are relatively unaffected by suspended zinc (Eisler 1993). However, high levels of zinc could result in destruction of the gill epithelium and tissue hypoxia. The temporary increases in zinc in Miners Ravine were still below the acute toxicity levels, and would not substantially affect the fish in Miners Ravine.

Aluminum can affect gill function and growth rates. Aluminum bioavailability is closely tied to pH levels. At elevated aluminum concentrations and pH between 5.5 and 7.0, fish and invertebrates may suffer asphyxiation caused by aluminum adsorption on gill surfaces (NMFS 2006). At lower pH levels, aluminum toxicity can result in erosion of gill epithelium and mortality (NMFS 2006). The EPA standard for the 1-hour maximum concentration exposure of fish to aluminum is 750 µg/L, while the 4-day maximum continuous concentration is 87 µg/L (NMFS 2006). The level of effect is dependent upon other environmental conditions, such as pH and water temperature. Higher pH levels in the water increase the buffering capacity for the effects of aluminum on fishes.

The increase in the aluminum concentration observed at MINERSRV5 following canal cleaning during the March 15, 2007, canal cleaning event may result in negative effects to fish. Because the increase in the aluminum concentration (maximum measured at 710 µg/L) were likely short-lived, and because the pH levels were above 6.5, the long-term effects on the fish present was probably minimal. An increase in aluminum concentrations in study area streams as a result of canal cleaning activities that to levels above 750 µg/L for a prolonged period of time may affect fish, but the degree of effects would be dependent on the length of time and pH levels.

Potential effects of copper on fish include reduced olfactory sensors, and possibly temporary decreased feeding activity. The toxicity of copper on fish is dependent on the chemical form, water hardness, and the lifestage and species exposed. Elevated copper concentrations can result in reduced olfactory sensitivity, affecting the ability to detect predators and prey. Elevated copper concentrations could also reduce survival of benthic macroinvertebrates – prey for many fish species. Copper levels in Miners Ravine resulting from canal cleaning operations on March 15 increased from about 5 µg/L to about 10 µg/L. The increase was likely for a short duration (few hours), but could result in impacts that affect fish gills and benthic invertebrates that are prey for many fish species.

Although not observed during water quality monitoring activities, temporary increases in TSS and/or turbidity levels in streams may affect aquatic species and habitat. Increased sedimentation and turbidity resulting from erosion and/or flushing of sediment associated with canal cleaning activities may result in short-term effects on fish. Prolonged exposure to high levels of suspended sediment can create a loss of visual capability, leading to a reduction in feeding and growth rates; a thickening of the gill epithelium, potentially causing the loss of respiratory function; a clogging and abrasion of gill filaments; and increases in stress levels, reducing the tolerance of fish to disease and toxicants (Waters 1995). In addition, high suspended sediment levels will cause the movement and redistribution of fish populations and

can affect physical habitat. Once the suspended sediment is deposited, it can reduce water depths in pools, decreasing the amount of physical habitat for juvenile and adult fish (Waters 1995). Increased sediment loading can also degrade food-producing habitat downstream of the project area. Sediment loading can interfere with photosynthesis of aquatic flora and result in the displacement of aquatic fauna.

Many fish, including juvenile salmonids, are sight feeders. Turbid waters reduce the fish's efficiency in locating and feeding on prey. Some fish, particularly juveniles, can get disoriented and leave areas where their main food sources are located, which can result in reduced growth rates.

Avoidance is the most common result of increases in turbidity and sedimentation. Fish will not occupy areas that are not suitable for survival, unless they have no other option. Therefore, habitat can become limiting in systems where high turbidity precludes a species from occupying habitat required for specific life stages.

Special Status Species

Minimal streamflow decreases in study area streams due to a short duration reduction of flows in the PCWA canal system could result in temporary, very minimal decreases in the extent of wetland habitats that may be indirectly supported by canal deliveries. This could have minimal effects on special status species that use these wetland habitats, such as special status foraging birds and breeding amphibians, by decreasing the amount of available habitat. Reductions in water levels could expose eggs of special status amphibian species that may occur in the shallow, vegetated margins of drainages or adjacent wetlands. Potential effects from temporary water reductions on species that use these habitats are expected to be minimal. As described above, flushing after canal cleaning could erode banks and wash away amphibian eggs, including those of special status species, which may be present on stream margins. The typical timing of the cleaning period in the early part of the year occurs within the breeding period for several special status amphibian species. The California red-legged frog breeding occurs between late November and March, though most frogs lay eggs in March (USFWS 2002, Stebbins 2003). The foothill yellow-legged frog breeds between mid-March through early June, and the western spadefoot toad breeds late January through July (Stebbins 2003).

Special status plant species (see **Tables 3-12** and **3-13**), if present along the PCWA canal system, could potentially be affected directly or indirectly by impacts to soils and sediments from equipment, including compaction, erosion, and introduction of petroleum products. Effects on species could include plant mortality or decreased plant growth. These types of effects are expected to be unlikely to occur.

If equipment is used to remove debris, damage could be caused to special status plant species, if present, by movement of equipment or by placement of debris and soil near canals. Some potential negative effects could occur if raptors are nesting near work areas that may be disturbed by noise. Special status raptors potentially occurring in the study area include Swainson's hawk, Cooper's hawk, Northern Goshawk, White-tailed Kite, and Northern Harrier. As mentioned above, the nesting period for raptors is generally March 1 to August 15.

Potential water quality effects discussed above could indirectly affect terrestrial habitats and species. Increased sedimentation from flushing activities could bury special status amphibian eggs, if present. Increases in trace elements (such as aluminum and copper) could have some negative effects on special status plants and wildlife, if present, on the margins of canals and tributaries. Amphibians in particular are known to be sensitive to such water quality changes, although effects vary dramatically by species, life stage, and parameters.

Increased levels of aluminum and copper in study area streams during and after canal cleaning activities could potentially affect steelhead and Chinook salmon. As described above, aluminum can affect gill function and growth rates. Pacific salmonids are considered susceptible to copper toxicity, with a mean acute toxicity level at 29.11 µg/L (NMFS 2006). Avoidance by Chinook salmon can occur at levels as low as 0.7 µg/L, and at 1.6 µg/L for rainbow trout. Increased copper levels can result in diminished olfactory sensitivity, which affects the fishes' ability to detect predators, prey, and also to affect imprinting of smolts on their natal stream (NMFS 2006). Exposure to levels at 25 µg/L for 1 and 4 hours indicate a substantial decrease in the number of receptors in the olfactory bulb due to cellular necrosis (cell death) in Chinook salmon. Rainbow trout can tolerate higher concentrations at the 1-hour increment, but have similar effects at the 4-hour interval. Social interactions can also be impaired with copper exposure. Increased stress levels of subordinate fish may also lead to increased copper uptake across the gills. Elevated copper concentrations could also reduce survival of benthic macroinvertebrates – prey for juvenile salmonids. Select examples from research studies of adverse effects with copper to Chinook salmon and steelhead are provided in **Table 6-6**.

**TABLE 6-6
EXAMPLES OF ADVERSE EFFECTS WITH COPPER TO SALMONIDS**

Species (lifestage)	Effect	Effect Concentration ($\mu\text{g/L}$) ^a	Effect statistic	Hardness ^b	Exposure duration	Source
Chinook salmon (<i>Oncorhynchus tshawytscha</i>)						
Juvenile	Avoidance in laboratory exposures	0.75	LOEC	25	20 minutes	Hansen et al. 1999
Juvenile	Loss of avoidance ability	2	LOEC	25	21 days	Hansen et al. 1999
Adult	Spawning migrations in wild apparently interrupted	10-25	LOEC	40	Indefinite	Mebane 2000
NA	Reduced growth (as weight)	1.9	EC ₁₀	25	120 days	Chapman 1982
Fry	Death	19	LC ₅₀	24	96 hours	Chapman 1978
Steelhead (<i>Oncorhynchus mykiss</i>)						
Juvenile – Rainbow trout	Avoidance in laboratory exposures	1.6	LOEC	25	20 minutes	Hansen et al. 1999
NA – Rainbow trout	Loss of homing ability	22	LOEC	63	40 weeks	Saucier et al. 1991
NA	Reduced growth (as weight)	45 to >51	NOEC	24-32	60 days	Mudge et al. 1993
Fry	Death	9-17	LC ₅₀	24-25	96 hours	Chapman 1978, Marr et al. 1996
Adult	Death	57	LC ₅₀	42	96 hours	Chapman and Stevens 1978
Juvenile	Death	24-28	NOEC	24-32	60 days	Mudge et al. 1993
Egg-to-fry	Death	11.9	EC ₁₀	25	120 days	Chapman 1982

Source: NMFS 2007. *An Overview of Sensory Effects on Juvenile Salmonids Exposed to Dissolved Copper.*

Notes:

^a Effects of exposure durations stem from laboratory and field experiments; therefore, in some experiments, multiple routes of exposure may be present (i.e., aqueous and dietary) and water chemistry conditions will likely differ.

^b Toxicity of copper may be influenced by hardness.

Key

EC₁₀ = Effective concentration adversely affecting 10 percent of the test population or percent of the measured response

LC₅₀ = The concentration that kills 50 percent of the test population

LOEC = Lowest observed adverse effect concentration (may not be a threshold, but simply the lowest concentration tested)

NA = Not available

NOEC = No observed adverse effect concentration

6.1.1.2 Weed and Brush Control

The following sections describe potential effects of weed and brush control activities conducted by PCWA on natural resource conditions in the study area. Additionally, the regulatory framework for the weed and brush control activities is provided, along with descriptions of potential BMPs that may reduce potential effects.

Physical Removal of Vegetation

Effects of PCWA's physical removal of vegetation during scheduled canal maintenance activities are described below.

Physical Resources

Potential effects of PCWA's physical removal of vegetation along canal banks on hydrology and water quality conditions in study area streams, and soils and sediment quality in the study area are described below.

Hydrology

Flows within canals are generally not disrupted while PCWA undertakes physical removal of vegetation within or along the canal system. Therefore, physical removal of vegetation is not likely to affect hydrologic conditions within study area streams.

Water Quality

Potential water quality effects of physical removal of vegetation are expected to be minimal to none. Minimal effects on TSS and turbidity may occur if the removal of vegetation results in the dislodging or loosening of soil along canal banks causes loose sediment to be deposited into the canals. During this activity, the removed vegetation is either deposited away from canals or hauled away in trucks, which prevents from potential deposition of debris in the canals. No dewatering or flushing activities are associated with the physical removal of vegetation.

Soils and Sediment Quality

Potential effects of PCWA activities during physical removal of vegetation likely depend on the equipment used for removal, and type and location of vegetation. Equipment used along canal banks may increase erosion, and motorized equipment may introduce petrochemicals to soils and affect sediment quality. These potential effects are likely to be minor.

Biological Resources

The following sections describe potential effects of physical removal of vegetation within the PCWA raw water distribution system on terrestrial and aquatic habitat and species in the study area.

Terrestrial Habitat and Species

Physical removal of vegetation would result in direct loss of vegetation and habitat. Native trees may be trimmed or removed. Bird nests or eggs in vegetation to be trimmed or removed may be disturbed or destroyed. Habitats and species could potentially be affected directly or indirectly by impacts to soils and sediments from equipment used for vegetation removal, including compaction, erosion, and introduction of petroleum products. Potential effects on habitats and

species may include plant mortality or decreased plant growth. These types of impacts are expected to be relatively minimal and small in aerial extent.

If equipment is used to remove vegetation, some potential negative effects could occur if raptors nesting near work areas are disturbed by noise. Raptors potentially occurring in the study area include Red-shouldered Hawk, American Kestrel, Red-tailed Hawk, and Great Horned Owl. The nesting period for raptors is generally March 1 to August 15.

Aquatic Habitat and Species

As described above, flows within canals are generally not disrupted while PCWA undertakes physical removal of vegetation within or along the canal system, and potential water quality effects of physical removal of vegetation are expected to be minimal to none. Therefore, physical removal of vegetation is not likely to affect aquatic habitat and species within study area streams.

Special Status Species

Physical removal of vegetation could result in direct loss of or damage to special status plant species or elderberry shrubs that may host the valley elderberry longhorn beetle, if present. Special status bird nests or eggs in vegetation to be trimmed or removed, if present, may be disturbed or destroyed.

Special status plant species (see **Tables 3-12** and **3-13**), if present, could potentially be affected directly or indirectly by impacts to soils and sediments from equipment used for vegetation removal, including compaction, erosion, and introduction of petroleum products. Effects on species could include plant mortality or decreased plant growth. These types of impacts are expected to be unlikely to occur.

If equipment is used for removal of vegetation, some potential negative effects could occur if raptors are nesting near work areas that may be disturbed by noise. Special status raptors potentially occurring in the study area include Swainson's hawk, Cooper's hawk, Northern Goshawk, White-tailed Kite, and Northern Harrier. As mentioned above, the nesting period for raptors is generally March 1 to August 15.

Algaecide Application

PCWA's raw water distribution system algaecide applications have the potential to affect natural resource conditions in the study area. The following sections describe potential effects of algaecide applications on natural resources.

Physical Resources

The following sections describe potential effects of PCWA's algaecide applications on the hydrology and water quality of study area streams, and soils and sediment quality.

Hydrology

Flows within canals are generally not disrupted while PCWA carries out algaecide applications within the canal system. Therefore, algaecide applications conducted by PCWA in the raw water distribution system are not likely to affect hydrologic conditions in study area streams.

Water Quality

As shown in **Figures 2-8 to 2-11** and discussed in **Table 2-1**, PCWA has 21 established points of algaecide application within the system, with “spot” treatments at other locations as conditions warrant. Water quality conditions at canal and stream sites within the Secret Ravine watershed were monitored during two application events at Boardman Canal below Mammoth Reservoir on May 16, 2007, and August 15, 2007. The locations and times of sampling were selected to determine potential effects of algaecide applications on water quality conditions in receiving waters. These locations are shown in **Figures 5-3 and 5-4**. **Table 6-7** provides details of the algaecide application monitoring events. Potential water quality effects described for sites monitored within the Secret Ravine watershed are assumed to be representative of the potential effects in watersheds of other study area streams affected by PCWA maintenance activities. Figures providing a comparison of water quality conditions within the PCWA raw water distribution system and study area streams monitored during algaecide applications are included in **Appendix C**.

TABLE 6-7
WATER QUALITY MONITORING LOCATIONS FOR ALGAECIDE APPLICATIONS
AT BOARDMAN CANAL BELOW MAMMOTH RESERVOIR

Site Description	Site Identification	Site Type	Application Start /End Time	Weather
Boardman Canal below Mammoth Reservoir ¹	YB81	Canal	Start: 5/16/2007, 8:30 a.m. End: 5/16/2007, 12:00 p.m.	Warm and dry
Yankee Hill Canal Outlet Release	YANKEEER	Canal		
Tributary to Secret Ravine from Yankee Hill Canal	YHTRIB2	Stream		
Secret Ravine at Rocklin Road	SECRETREV3	Stream		
Boardman Canal below Mammoth Reservoir ²	YB81	Canal	Start: 8/15/2007, 8:25 a.m. End: 8/15/2008, 12:00 p.m.	Warm and dry
Yankee Hill Canal Outlet Release	YANKEEER	Canal		
Tributary to Secret Ravine from Yankee Hill Canal	YHTRIB2	Stream		
Secret Ravine at Rocklin Road	SECRETREV3	Stream		

Notes

¹ Cutrine application conducted by PCWA with a target dosage of 800 µg/L

² Cutrine-Plus® application conducted by PCWA with a target dosage of 800 µg/L

Water Temperature and Dissolved Oxygen

No effects on water temperatures were observed during the algaecide application events.

Measured changes in water temperatures during the algaecide events are consistent with diurnal fluctuations with the highest temperatures occurring during the afternoon, and lowest temperatures occurring at night and during the early morning. No effects on DO levels were observed during algaecide application activities.

pH, Alkalinity, and Hardness

Minimal effects on pH were observed during the algaecide application monitoring events. Measured pH levels increased slightly at YANKEE CR and subsequently increased at YHTRIB2 and SECRETRV3. These results are shown in **Figure 6-13** below. According to the Material Safety and Data Sheet for Cutrine-Plus®, the pH of the algaecide ranges from 10.3 to 10.5 (Applied Biochemists 2006). The high pH allows the copper to stay in solution even under conditions of high hardness and alkalinity.

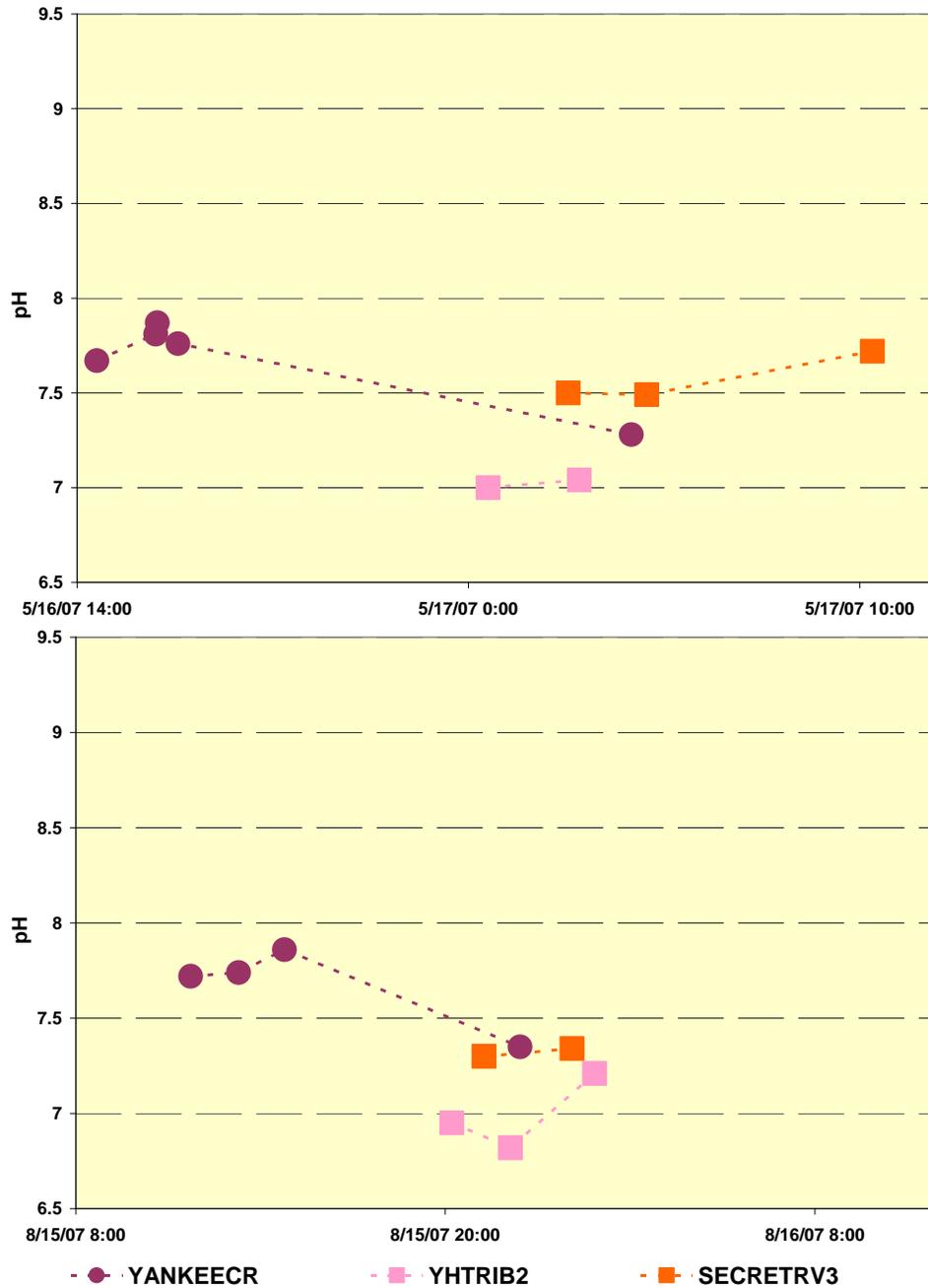


FIGURE 6-13
MEASURED PH LEVELS AT SECRET RAVINE WATERSHED SITES DURING MAY 16, 2007, AND AUGUST 15, 2007, ALGAECIDE APPLICATION EVENTS

No effects on alkalinity and calculated total hardness were observed during algaecide application events. In general, alkalinity and total hardness levels were higher at stream sites compared to canal sites.

Total Suspended Solids and Turbidity

TSS was not sampled during the algaecide application events. No effects on turbidity were observed during the events.

Specific Conductivity and Ions

Measured values in samples collected during monitoring suggest that SC and major ion (calcium, iron, magnesium, potassium, sodium, chloride, nitrate, and sulfate) concentrations at Secret Ravine watershed sites were not affected by algaecide applications.

Trace Elements

Algaecide applications do not appear to affect aluminum, barium, cadmium, and zinc concentrations in study area streams. Copper concentrations at YANKEE CR did increase in response to algaecide applications upstream at Boardman Canal below Mammoth Reservoir. Based on measured values of copper in samples collected during monitoring, minimal to no effects on copper concentrations were observed at YHTRIB2 and SECRETRV3. Copper concentrations at sites monitored during the algaecide application events are shown in **Figures 6-14 and 6-15**. Cadmium and zinc concentrations measured at all sites during algaecide application monitoring events were below the detection limit (0.5, and 20 µg/L, respectively).

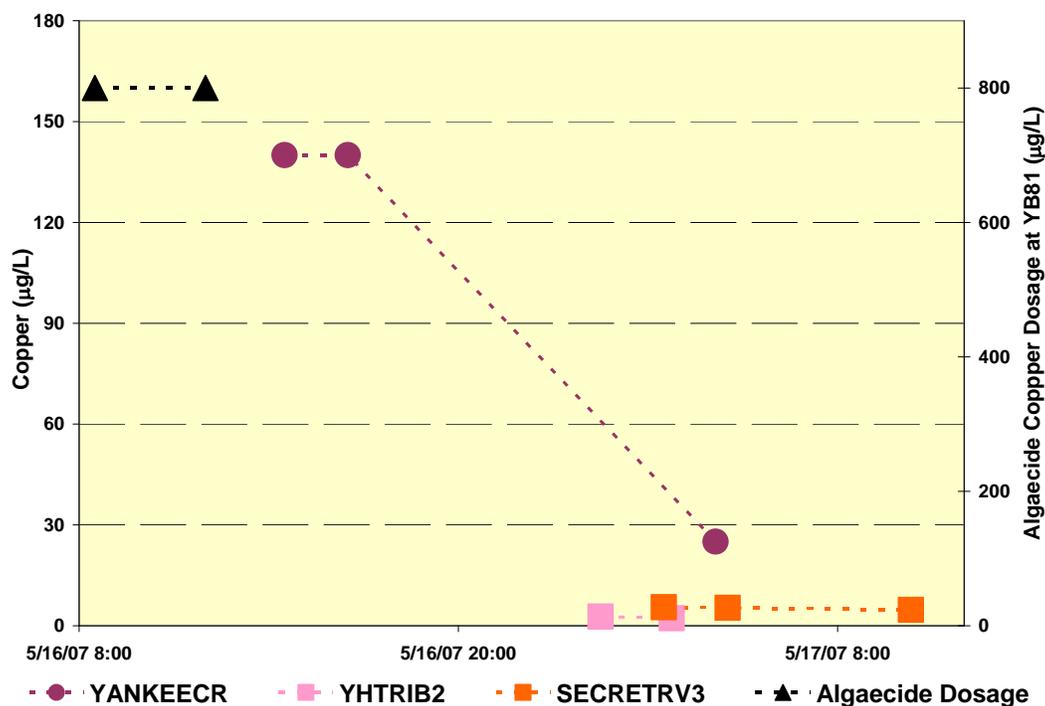


FIGURE 6-14
MEASURED COPPER LEVELS AT SECRET RAVINE WATERSHED SITES DURING
MAY 16, 2007, ALGAECIDE APPLICATION EVENT

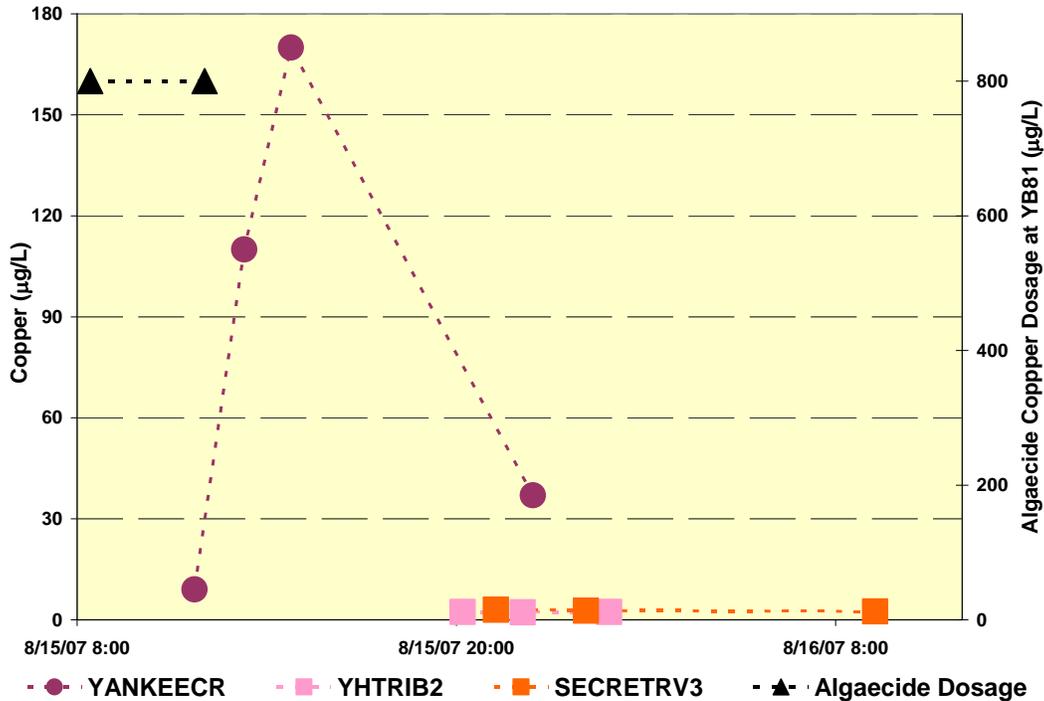


FIGURE 6-15
MEASURED COPPER LEVELS AT SECRET RAVINE WATERSHED SITES DURING
AUGUST 15, 2007, ALGAECIDE APPLICATION EVENT

Soils and Sediment Quality

Algaecides are released directly to water supplies at PCWA canal system locations by staff; therefore, effects of applications on soils and sediment quality in the study area are minimal. Potential effects are likely associated with unintentional discharges to the environment during transport of algaecides to application sites and/or leaks from algaecide storage vessels at application sites. These potential effects are not likely due to training and qualifications requirements for staff involved in algaecide applications.

Biological Resources

The following sections describe potential effects of PCWA’s algaecide applications on biological resources in the study area.

Terrestrial Habitat and Species

Copper in applied algaecides could have some negative effects on plants and wildlife on the margins of canals and tributaries. Exposure routes for copper through dietary consumption of contaminated prey items or direct contact with contaminated sediments are important and may affect a broad range of terrestrial species (NMFS 2007). Heavy metals, especially copper, have been found to be very toxic to amphibians, particularly at the egg and tadpole life stages (U.S. EPA 2008, B.C. Ministry of Water, Land and Air Protection 2004). Algaecides are typically applied starting in April through summer, which coincides with the breeding season and tadpole stages for several amphibian species. Birds and mammals appear to be less sensitive to copper than aquatic organisms; however, toxic effects have been documented, including reduced growth

rates, lowered egg production, and developmental abnormalities in birds, and various physiological effects on mammals, such as liver cirrhosis, damage to kidneys and the brain, and fetal mortality (U.S. EPA 2008, EXTTOXNET 1994a).

Very minimal effects could occur to terrestrial habitats and species associated with trampling of vegetation at application points while algaecides are being applied.

Aquatic Habitat and Species

Based on water quality monitoring results, aquatic habitat and species in study area streams are not likely affected by PCWA activities during algaecide application events. Potential indirect effects are associated with mobilization of constituents associated with fine sediment and organic material that had settled when canals were dewatered during the outage, as described for canal cleaning activities and discussed in **Chapter 7**.

Special Status Species

Copper in applied algaecides could have some negative effects on special status species, if present, on the margins of canals and tributaries. Amphibians in particular are known to be sensitive to such water quality changes, although effects vary dramatically by species, life stage, and contaminant. Algaecides applications typically start during April through summer, which coincides with the breeding season and tadpole stages for several special status amphibians. California red-legged frog breeding occurs between late November and March, though most frogs lay eggs in March (USFWS 2002, Stebbins 2003). The foothill yellow-legged frog breeds between mid-March through early June, and the western spadefoot toad breeds late January through July (Stebbins 2003).

If present, special status plant species could also be affected by trampling while algaecide is being applied.

Based on water quality monitoring results, special status fish species in study area streams are not likely affected by PCWA activities during algaecide application events. Potential indirect effects on special status fish species are associated with mobilization of constituents associated with fine sediment and organic material that had settled when canals were dewatered during the outage, as described for canal cleaning activities and discussed in **Chapter 7**.

Herbicide Application

PCWA's herbicide application activities have the potential to affect natural resource conditions in the study area. The following sections describe potential effects of PCWA's herbicide applications on natural resources.

Physical Resources

The following sections describe potential effects of herbicide applications within the PCWA raw water distribution system on hydrologic and water quality conditions in study area streams, and soils and sediment quality.

Hydrology

Flows within canals are generally not disrupted while PCWA carries out herbicide applications within or near the canal system. Therefore, herbicide applications conducted by PCWA are not likely to affect hydrologic conditions in study area streams.

Water Quality

Potential effects of PCWA herbicide applications for managing pre-emergent vegetation, woody plants, and annual and perennial broadleaf weeds along canal berms were not evaluated through water quality monitoring. Herbicide applications along canal berms are not likely to affect water quality conditions in study area streams due to the rapid degradation of these herbicides, as described in **Chapter 2**.

Water quality was monitored at six locations to evaluate potential effects associated with AquaMaster™ glyphosate aquatic herbicide application events that occurred at Clover Valley and Mammoth reservoirs on August 2, 2007. Two canal monitoring sites and one stream site were sampled downstream from Clover Valley Reservoir in the Antelope Creek watershed, and two canal monitoring sites and one stream site were sampled below Mammoth Reservoir in the Secret Ravine watershed (**Figure 5-4**). Water quality conditions were not monitored at Auburn Ravine, Clover Valley Creek, or Miners Ravine sites, but are likely to be similar to conditions described below for Antelope Creek and Secret Ravine. **Table 6-8** below lists the aquatic herbicide application information and sites monitored for each sampling event. Water quality parameters evaluated through monitoring during the aquatic herbicide application events include water temperature, DO, pH, SC, turbidity, alkalinity, and glyphosate. The results from water quality monitoring during herbicide application events are discussed in this section by watershed. Figures providing a comparison of water quality conditions within the PCWA raw water distribution system and study area streams monitored during herbicide application monitoring events are included in **Appendix C**.

**TABLE 6-8
WATER QUALITY MONITORING LOCATIONS IN THE PCWA SERVICE AREA FOR
HERBICIDE APPLICATION**

Site Description	Site Identification	Site Type	Watershed(s)	Application Start /End Time	Weather
Herbicide Application at Mammoth Reservoir (Glyphosate)					
Boardman Canal below Mammoth Reservoir	YB81	Canal	Miners Ravine/Secret Ravine	Start: 8/2/2007, 8:00 a.m. End: 8/2/2007, 11:30am	Warm and dry, light rain at night
Boardman Canal Outlet Release	BOARDMANCR	Canal	Secret Ravine		
Secret Ravine at Rocklin Road	SECRETRV3	Stream	Secret Ravine		
Herbicide Application at Clover Valley Reservoir (Glyphosate and Reward)					
Clover Valley Reservoir release to Clover Valley Creek and Antelope Canal	CLVRESR	Canal	Antelope Creek/Clover Valley Creek	Start: 8/15/2007, 8:25 a.m. End: 8/15/2008, 12:00 p.m.	Warm and dry
Antelope Stub Canal near Antelope Canal	ANTSTUBCR	Canal	Antelope Creek		
Antelope Creek at Midas Avenue	ANTC3B	Stream	Antelope Creek		

Antelope Creek Watershed

AquaMaster™ was applied to emergent aquatic vegetation along the perimeter of Clover Valley Reservoir on August 2, 2007. Water quality was monitored at:

- **Clover Valley Reservoir release to Clover Valley Creek and Antelope Canal (CLVRESR)**
- **Antelope Stub Canal near Antelope Canal (ANTSTUBCR)**
- **Antelope Creek near Midas Avenue (ANTC3B)**

Based on water quality results, Antelope Creek water temperatures, DO, pH, alkalinity, SC, and turbidity conditions were not affected by the aquatic herbicide application event at Clover Valley Reservoir. Minimal changes in water temperature and DO observed during monitoring are likely due to diurnal fluctuations. The aquatic herbicide application event also did not appear to affect glyphosate concentrations in Antelope Creek; all water quality samples collected at Antelope Creek watershed sites during the monitoring event had glyphosate concentrations below the measurable detection limit (6 µg/L).

Secret Ravine Watershed

AquaMaster™ was applied to emergent aquatic vegetation along the perimeter of Mammoth Reservoir on August 2, 2007. Water quality was monitored at:

- **Boardman Canal below Mammoth Reservoir (YB81)**
- **Boardman Canal Outlet Release (BOARDMANCR)**
- **Secret Ravine at Rocklin Road (SECRETRV3)**

Similar to the conditions described above within the Antelope Creek watershed, the aquatic herbicide application event did not appear to affect water temperature, DO, pH, alkalinity, SC, turbidity, or glyphosate conditions at Secret Ravine watershed sites. All water quality samples collected during the monitoring event had glyphosate concentrations below the measurable detection limit (6 µg/L).

Soils and Sediment Quality

PCWA's application of herbicides along canal berms likely result in temporary effects on soil chemistry. Chemical constituents of herbicides applied by PCWA may include triclopyr, glyphosate, dithiopyr, diquat dibromide, and non-ionic alkylphenol ethoxylate surfactants. As described in **Chapter 2**, these constituents, with the exception of diquat dibromide, degrade rapidly to inert compounds or products with low toxicity. Diquat dibromide is tightly adsorbed to soil particles, persistent, toxic to fish and wildlife, and is unavailable to soil microbes' microbial degradation and for plant uptake.

Biological Resources

The following sections describe potential effects of PCWA's herbicide applications on biological resources in the study area.

Terrestrial Habitat and Species

Application of herbicide may result in indirect mortality or damage to non-target vegetation. Herbicides may also affect wildlife species, particularly amphibians. Glyphosate herbicides, which are used near water, are generally less toxic to wildlife than other types of herbicide; however, effects vary dramatically by concentration of contaminant, species, and life stage. Some studies of glyphosates on amphibians have found negative effects at various life stages, including mortality, developmental defects, and behavioral abnormalities (B.C. Ministry of Water, Land and Air Protection 2004). Other components, such as surfactants, commonly contained in glyphosate formulations, including Roundup®, have also been found to cause severe negative effects to amphibians (USFWS 2002). Herbicides are typically applied in early spring through summer, which coincides with the breeding season for several amphibian species. Glyphosates have been found to be only slightly toxic to birds and mammals (EXTOXNET 1994b, Tu et al. 2001). Triclopyr was also found to be only slightly toxic to birds and mammals (EXTOXNET 1994b, Tu et al. 2001). According to these sources, triclopyr is not expected to bioaccumulate in wildlife. A study in Canada, however, found triclopyr to be harmful to amphibians under normal field use (Thompson et al. 2007).

Aquatic Habitat and Species

Based on results from water quality monitoring during herbicide applications, aquatic habitat and species in study area streams are not likely affected by the application of AquaMaster™ glyphosate aquatic herbicide at PCWA reservoirs. Glyphosate herbicides designed for aquatic use, such as AquaMaster™, have minimal surfactants, and thus have a low toxicity level to fish. Glyphosate dissipates in water by binding to soil particles and organic material or through microbial degradation. Any fish present in Mammoth and Clover Valley reservoirs are likely to suffer minimal effects resulting from the use of AquaMaster™ as an herbicide.

Special Status Species

Application of herbicide may result in indirect mortality or damage to untargeted special status plants or elderberry shrubs hosting the valley elderberry longhorn beetle, if present near the application area. Herbicides may also affect special status wildlife species, particularly amphibians, if present. Herbicides are typically applied in early spring through summer, which coincides with the breeding season for several special status amphibians. California red-legged frog breeding occurs between late November and March, though most frogs lay eggs in March (USFWS 2002, Stebbins 2003). The foothill yellow-legged frog breeds between mid-March through early June, and the western spadefoot toad breeds late January through July (Stebbins 2003).

Special status fishes are not likely affected by the application of the herbicides within the canal system. Herbicides applied by PCWA have a relatively short half life, and AquaMaster™ is relatively nontoxic to fishes.

Other special status species, particularly amphibians, may be negatively affected by applications of herbicides if in close proximity to the application. Water quality monitoring results during the herbicide application event do not show effects to stream habitat.

6.1.2 As-Needed Site-Specific Maintenance Activities

The following sections address potential effects of PCWA's as-needed site-specific maintenance activities on natural resource conditions in the study area. These activities include canal lining/guniting, canal repair, and pipe repair.

6.1.2.1 Canal Lining/Guniting

This section provides an overview of the potential effects of PCWA's canal lining/guniting activities.

Physical Resources

The following sections describe potential effects of PCWA canal repair activities on hydrologic and water quality conditions in study area streams, and soils and sediment quality.

Hydrology

PCWA operations during canal lining/guniting activities do not affect hydrologic conditions in Canyon Creek or Auburn Ravine. During the canal cleaning and flushing, PCWA canal system contributions to streamflow in Canyon Creek and Auburn Ravine, and/or diversions from

Canyon Creek and Auburn Ravine, do not change as a result of PCWA operations. As described above for canal cleaning and flushing activities, continuous-flow data collected from canal and stream sites within PCWA’s lower Zone 1 service area during WDY 2006 were evaluated to determine effects of canal lining/guniting activities on hydrologic conditions in Clover Valley Creek, Antelope Creek, Secret Ravine, and Miners Ravine. Continuous-flow monitoring locations, and their respective watersheds, are listed in **Table 6-1**.

Table 6-9 provides PCWA’s schedule of canal lining/guniting within a portion of PCWA’s raw water distribution system during 2006. During these outages for canal lining/guniting, canal flows were typically interrupted during business hours to dewater canal segments, apply gunite to dewatered segments, and allow sufficient time for the new canal lining to dry.

**TABLE 6-9
CANAL OUTAGES FOR CANAL LINING/GUNITE DURING 2006**

Canal	Date
East Perry near Horseshoe Bar Road	March 6, 7, 8
Boardman near Valley Quail Drive	March 13, 14, 15
Baughman near headgate	March 15, 16
Baughman downstream from Mutoza spill	March 17, 20
Ferguson at Morgan Place/Wells Lane	March 17, 20
End of Stallman Canal	July 18
Boardman at Rocklin road	September 14, 21

Average daily flows for canal and stream sites evaluated during March 2006 canal lining/guniting are shown in **Figure 6-1** for sites within the Secret Ravine watershed, and in **Figure 6-2** for sites within the Miners Ravine watershed. Based on the average daily flows for sites provided in **Figures 6-1** and **6-2**, the short duration reduction in flows within the PCWA canal system during March 2006 canal lining/guniting activities are not likely to affect flow conditions in study area streams. Precipitation runoff within the watersheds of study area streams is likely to have a much greater influence on stream flow conditions during spring season canal lining/guniting activities. Precipitation during March 2006 is shown in **Figure 6-3**. Effects on flow conditions in Antelope Creek and Clover Valley Creek are likely similar to conditions shown for Secret and Miners ravines.

Canal lining/guniting activities during September 2006 are likely to have some effect on flow conditions in study area streams, although canal system contributions to flow within study area streams through unregulated releases from canal outlets are variable. Average hourly flows for the end of Boardman Canal outlet, downstream from canal lining/guniting activities, are shown in **Figure 6-16**. Average daily flows for Secret Ravine at Rocklin Road, which is located just upstream from the Boardman Canal outlet, are also shown in **Figure 6-16**. Based on flow data observed during September 2006, canal lining/guniting during the dry season does have the potential to affect hydrologic conditions in study area streams. **Figure 6-16** shows releases from the end of Boardman Canal potentially comprise approximately one-third of flow in Secret Ravine during September 2006.

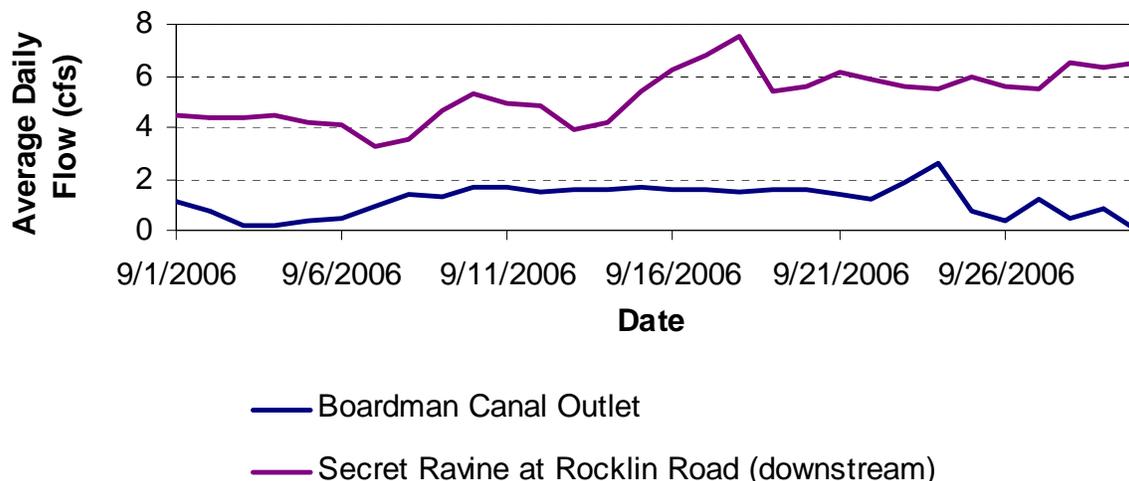


FIGURE 6-16
CANAL OUTLET AND SECRET RAVINE FLOW RESPONSES TO
CANAL LINING/GUNITING ACTIVITIES

Water Quality

Water quality conditions were monitored for PCWA canal lining/guniting activities on February 16, 2007, March 16, 2007, and March 20, 2007, at sites within the Clover Valley Creek, Secret Ravine, and Miners Ravine watersheds, respectively. These locations, shown in **Figures 5-3 and 5-4**, were selected according to canal lining activity locations. **Table 6-10** lists the monitoring site names, site type, associated watershed, and information related to the canal lining/guniting activity. Water quality conditions were not evaluated in the Auburn Ravine, Antelope Creek, or Miners Ravine watersheds, but are likely to be similar to conditions described below for Clover Valley Creek, Secret Ravine, and Miners Ravine. Figures providing a comparison of water quality conditions within the PCWA raw water distribution system and study area streams monitored during monitoring events for canal lining/guniting are included in **Appendix C**.

Clover Valley Creek Watershed

Water quality conditions in the Clover Valley Creek watershed were evaluated at the following sites during canal lining/guniting activities along sections of the Antelope Canal on February 16, 2007:

- **Antelope Canal (ANTCA):** located on the Antelope Canal upstream from the Antelope Canal Outlet. This site was upstream from the canal lining activity, but was located within a dewatered section of the canal.
- **Antelope Canal Outlet Release (ANTCR):** Unregulated releases from this canal flow into an unnamed tributary that contributes flows to Clover Valley Creek.
- **Clover Valley Creek at Rawhide Road (CLVRC6):** located on Clover Valley Creek at Rawhide Road upstream from Antelope Canal Outlet.
- **Clover Valley Creek near Argonaut Avenue (CLVRC3B)**

**TABLE 6-10
WATER QUALITY MONITORING LOCATIONS IN THE PCWA SERVICE AREA FOR CANAL LINING/GUNTING
ACTIVITIES**

Site Description ¹	Site Identification	Type	Watershed(s)	Canal Lining Start/End Time	Weather
Antelope Canal near Antelope Canal Outlet					
Antelope Canal above Outlet Release	ANTCA	Canal	Clover Valley Creek	Start: 2/16/2007, 5:00am End: 2/16/2007, 8:00pm	Warm and dry
Antelope Canal Outlet Release	ANTCR	Canal	Clover Valley Creek		
Clover Valley Creek near Rawhide Road	CLVRC6	Stream	Clover Valley Creek		
Clover Valley Creek near Argonaut Avenue (near Golf Course)	CLVRC3B	Stream	Clover Valley Creek		
Boardman Canal downstream from Baughman Canal					
Boardman Canal below Head of Baughman Canal	YB155	Canal	Secret Ravine	Start: 3/15/2007, 5:00am End: 3/15/2007, 8:10pm	Warm and dry
Boardman Canal below Head of Baughman Canal – downstream	YB155DS	Canal	Secret Ravine		
Boardman Canal Outlet Release	BOARDMANCR	Canal	Secret Ravine		
Secret Ravine at Rocklin Road	SECRETRV3	Stream	Secret Ravine		
Secret Ravine at Roseville Parkway	SECRETRV2	Stream	Secret Ravine		
Boardman Canal near Laird Pump					
Boardman Canal near Laird Pump	315BDU	Canal	Miners Ravine/ Secret Ravine	Start: 3/20/07, 5:00am End: 3/20/07 at 6:30pm	Light Rain
Boardman Canal near Laird Pump	315BDD	Canal	Miners Ravine/ Secret Ravine		
Baughman Canal Outlet Release	BAUGHMANCR	Canal	Miners Ravine		
Tributary to Miners Ravine from Baughman Canal	BCTRIB1	Drainage	Miners Ravine		
Miners Ravine at Moss Lane	MINERSRV5	Stream	Miners Ravine		