SILVER BOW CREEK LIVES! REMEDIAL ACTIONS AND WATER QUALITY IMPROVEMENTS IN SILVER BOW CREEK IN BUTTE, MONTANA[1]

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Abstract. Silver Bow Creek has gained notoriety over the years for its extremely poor water quality. Mining-related discharges from Butte have resulted in surface water quality that has not been suitable for aquatic life since mining began more than 120 years ago. Indeed, it was widely believed that water quality standards would never be met in Silver Bow Creek. However, in the upstream segment flowing through Butte, remedial actions targeting surface water have been highly successful, and it is now believed that achieving water quality standards is within reach.

The major mining-related impacts to Silver Bow Creek as it flows through Butte have been direct contact with wastes, inflow of contaminated groundwater, and storm water runoff. In addition to extensive land reclamation on the Butte Hill, remedial actions over the past decade have focused on preventing contaminated groundwater in the floodplain (primarily alluvial groundwater) from flowing into Silver Bow Creek. These integrated actions have evolved into a relatively simple, yet highly effective system to control, capture, and treat contaminated groundwater, thereby protecting Silver Bow Creek during base flow conditions. Extensive reclamation and improvements to the storm water system are lessening impacts from storm water. This paper presents an overview of the remedial actions and the resulting "system" of hydraulic controls and treatment that have been implemented to date, and the resulting water quality trends. Also presented are potential future actions that would ensure that water quality continues to improve and that the creek returns to its full potential.

Additional Key Words: stream restoration, metals

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Introduction

Historic mining-related discharges into Silver Bow Creek from the Butte, Montana mining district resulted in surface water quality that has not been suitable for aquatic life since mining began more than 120 years ago. When remedial investigations were initiated in the 1980s under Superfund, it was found that contamination was so ubiquitous and water quality exceedances so large that it was widely believed that water quality standards could never be met in Silver Bow Creek. However, in the upstream segment flowing through Butte, remedial actions over the last 15 years targeting protection of surface water have been highly successful. Recently collected data show Cu and Zn concentrations less than Montana chronic aquatic water quality standards. It is likely that consistently achieving water quality standards during base flow conditions is an achievable goal.

The progress that has been made in improving Silver Bow Creek water quality has not happened overnight. Remedial actions have been conducted over the last 15 years with involvement from the Atlantic Richfield company, the local Butte-Silver Bow government, academia, and regulatory experts from the U.S. Environmental Protection Agency (EPA) and the state of Montana. The intent of this paper and presentation is in no way meant to individually take credit for the extensive work that has been done. Rather, the intent is to inform scientists and engineers in the environmental field of the success that remedial actions have had. In addition, this paper and presentation will explain how the remedial actions were designed and how they are functioning to protect Silver Bow Creek. If nothing else, the intent is to spread awareness that Silver Bow Creek is starting to meet water quality standards for the first time in over a century and that similarly contaminated streams in other locations may be remediated through the implementation of site-specific remediation strategies.

Background

A Brief History of Butte

Butte, Montana is located in southwestern Montana, just west of the continental divide. Silver Bow Creek, which flows through Butte, is one of the primary streams at the headwaters of the Clark Fork River, which drains most of western Montana, and eventually drains to the Columbia River.

The following text from the EPA 2004 National Remedy Review Board Presentation Package presents key highlights from Butte's mining history that are relevant to surface water contamination in Silver Bow Creek:

> *Historically, Butte has served as a globally important mining, milling, and smelting district. Gold was first discovered near Butte in 1864. Metal-sulfide deposits rich in copper and zinc were discovered later and became the primary ores in Butte. These low-grade ores proved difficult to recover, and Butte remained a small mining camp compared to others in the region.*
>
> *By the 1870s, dozens of silver and copper claims had been located and successful treatment processes developed, prompting the construction of mills and smelters capable of refining arsenic-laden copper ores. A world-class copper industry began to develop. In 1881, the purchase of mining claims by future copper baron, Marcus Daly, marked a significant turning point for Butte. Daly and his financial partners organized the Anaconda*

Copper Mining Company (ACMC) and rapidly accumulated surrounding mining properties on the Butte Hill. By 1884, there were some 300 operating copper mines, at least 10 silver mines, 8 smelters, and over 4,000 posted claims in Butte.

By 1910, the Butte district had produced over 284 million pounds of copper, making it the largest producer of copper in North America. All of the mines produced waste piles of various compositions, and the mills and smelters produced large quantities of tailings which were disposed of in ponds or dumped in Silver Bow Creek. Between 1910 and 1927, ACMC completed consolidation, with few exceptions, of all of the major mines, smelters, and mills in Butte. Milling and smelting continued in Butte until the 1920s but, as the copper smelting capacity at Anaconda grew, Butte became primarily a mining center.

Mining in Butte was entirely underground until 1955, when ACMC began surface mining at the Berkeley Pit. Immense quantities of low-grade ore were moved from the Berkeley Pit to Anaconda. In the 1960s and early 1970s, changes in mining and processing procedures significantly reduced rail traffic. The Weed Concentrator (now known as the Montana Resources Concentrator) was an ore concentrating facility in Butte that produced large quantities of waste in the active mine area and discharged large volumes of contaminated water to the Metro Storm Drain (former Silver Bow Creek channel).

In 1977, ACMC merged with ARCO. Open pit mining operations continued in the Berkeley Pit until 1982 and in the adjacent Continental Pit until 1983, when ARCO suspended all mining operations. Montana Resources, which bought the Butte mining operations, began mining in the adjacent Continental Pit in 1985 and continues today.

EPA and Superfund

EPA designated the original Silver Bow Creek Site as a Superfund site in September 1983 largely due to water quality issues associated with Silver Bow Creek. Data collected in the 1980s and early 1990s demonstrated elevated metals concentrations in Silver Bow Creek during base flow and storm flow conditions. The water quality was poor and often failed to achieve state water quality standards.

During the course of the initial investigations, which began in 1984, the importance of Butte as a source of contamination to Silver Bow Creek was formally recognized. Preliminary results indicated that upstream sources were partly responsible for the contamination observed in the creek. After a thorough analysis of the relationship between the two sites (Butte and Silver Bow Creek), EPA concluded that they should be treated as one site.

The Butte Priority Soils Operable Unit (BPSOU, Fig. 1) focused on remediating human health and environmental risks immediately within the Butte urban area, and surface water and alluvial groundwater contamination along the Silver Bow Creek floodplain. Contaminated groundwater in the Berkeley Pit and the underground mining is addressed separately under the Butte Mine Flooding Operable Unit.

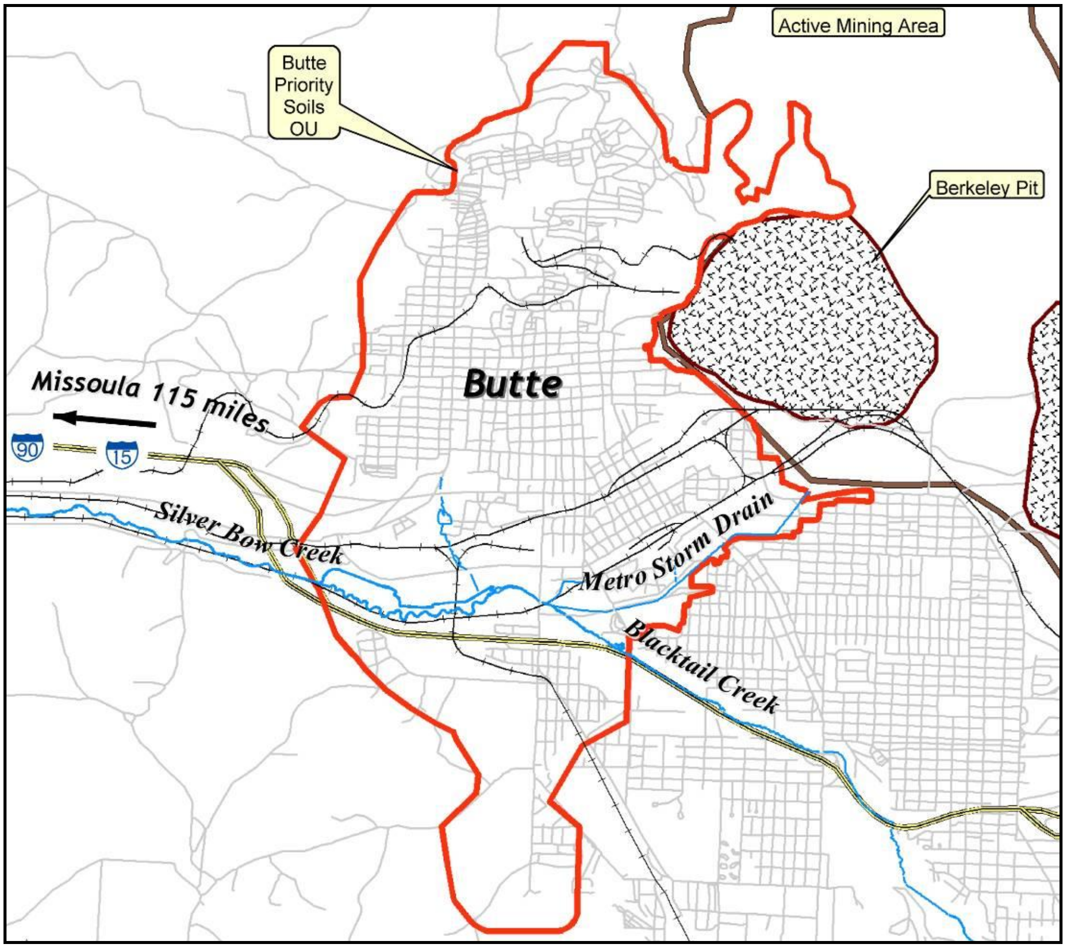

Figure 1. Butte Priority Soils Operable Unit Site Boundary and Site Features

Silver Bow Creek has not been the sole focus of Superfund activities in the BPSOU. Much of the work done to date has been reclamation of mine wastes on the Butte Hill with elevated arsenic and lead concentrations that posed a risk to human health. The extensive reclamation performed to protect human health from lead and arsenic exposures has had a positive impact on Silver Bow Creek water quality. However, these actions will only be discussed briefly while this paper will instead focus on the actions that have been done along the Silver Bow Creek floodplain.

Silver Bow Creek Characterization and History

Deposition of Wastes

Prior to the onset of mining in Butte, the Silver Bow Creek floodplain was a low-lying wetland area. Because it was the closest water source to the Butte Hill, numerous milling and smelting plants were constructed along Silver Bow Creek in the late 1800s. An estimated total of 10 million tons of waste was generated from 1878-1925. Although a significant portion of wastes released to surface water were transported downstream out of the Butte area, a sizeable volume remained within and adjacent to the historic stream channel and in large impoundments constructed within the floodplains and low-lying wetlands. Figure 2 is an aerial photograph from

1954 showing the Silver Bow Creek floodplain. The major tailings deposits and streamside wastes are clearly visible as bright white areas.

Silver Bow Creek originally extended from its mountain headwaters through what is now the mine area. With the advent of mining, the creek was rerouted and the original channel and floodplain has been completely obliterated by the Berkeley Pit and the Yankee Doodle Tailings Pond.

Silver Bow Creek now begins at the confluence of the Metro Storm Drain and Blacktail Creek. The Metro Storm Drain is a man-made surface water conveyance constructed during the 1930s to provide a means of transporting mine water, sewage, and storm water out of Butte. The Metro Storm Drain was constructed by realigning and filling the original Silver Bow Creek channel around and through the mine waste impoundments. It was later used by the ACMC to discharge waste and wastewater from the Berkeley Pit operation.

Wastes present in the Metro Storm Drain area today are largely buried below the surface. A portion of these wastes are in direct contact with groundwater and serve as a primary source of contaminants to alluvial groundwater.

West and downstream of the Metro Storm Drain, the Silver Bow Creek floodplain (former Colorado Tailings and Butte Reduction Works), has been host to at least four very large milling and smelting facilities, all of which contributed to the deposition of ore processing wastes and tailings to the area. These wastes are clearly visible in Fig. 2. Prior to remedial actions in the mid-1990s, Silver Bow Creek flowed directly through these tailings deposits.

Hydrology

As previously described, Silver Bow Creek originally extended from its mountain headwaters through what is now the mine area. With the advent of mining, the original channel and floodplain was completely obliterated by the Berkeley Pit and the Yankee Doodle Tailings Pond.

Dewatering for underground and open pit mining lowered the potentiometric surface creating a "cone of depression" centered on the Berkeley Pit. In the upper Metro Storm Drain, this resulted in a groundwater divide in the alluvial aquifer. West of the divide, groundwater drains towards Metro Storm Drain and Silver Bow Creek. East of the divide, groundwater drains toward the Berkeley Pit. Therefore, nearly all of the water that once flowed down through Silver Bow Creek is now captured in the Berkeley Pit. Only a small amount of the groundwater flows westward toward Silver Bow Creek via the Metro Storm Drain.

Because of the obliteration of the northern portion of the Silver Bow Creek channel, the primary source of flow in Silver Bow Creek is inflow from Blacktail Creek, which normally contributes 11 to 15 cubic feet per second (cfs). The upper portion of Metro Storm Drain is dry except during storm runoff or snowmelt episodes. Lower Metro Storm Drain joins Blacktail Creek to form Silver Bow Creek. The lower portion receives flow via groundwater discharge during normal flow conditions and contributes between 0.3 and 0.5 cfs to Silver Bow Creek.

The Metro Storm Drain and Silver Bow Creek floodplains also receive flow from sub-basins on the Butte Hill. Except for the lower Missoula Gulch sub-basin, discharge from the Butte Hill occurs only during storm runoff and snowmelt events. The Lower Missoula Gulch sub-basin intercepts shallow groundwater and maintains a base flow of 0.1 to 0.3 cfs.

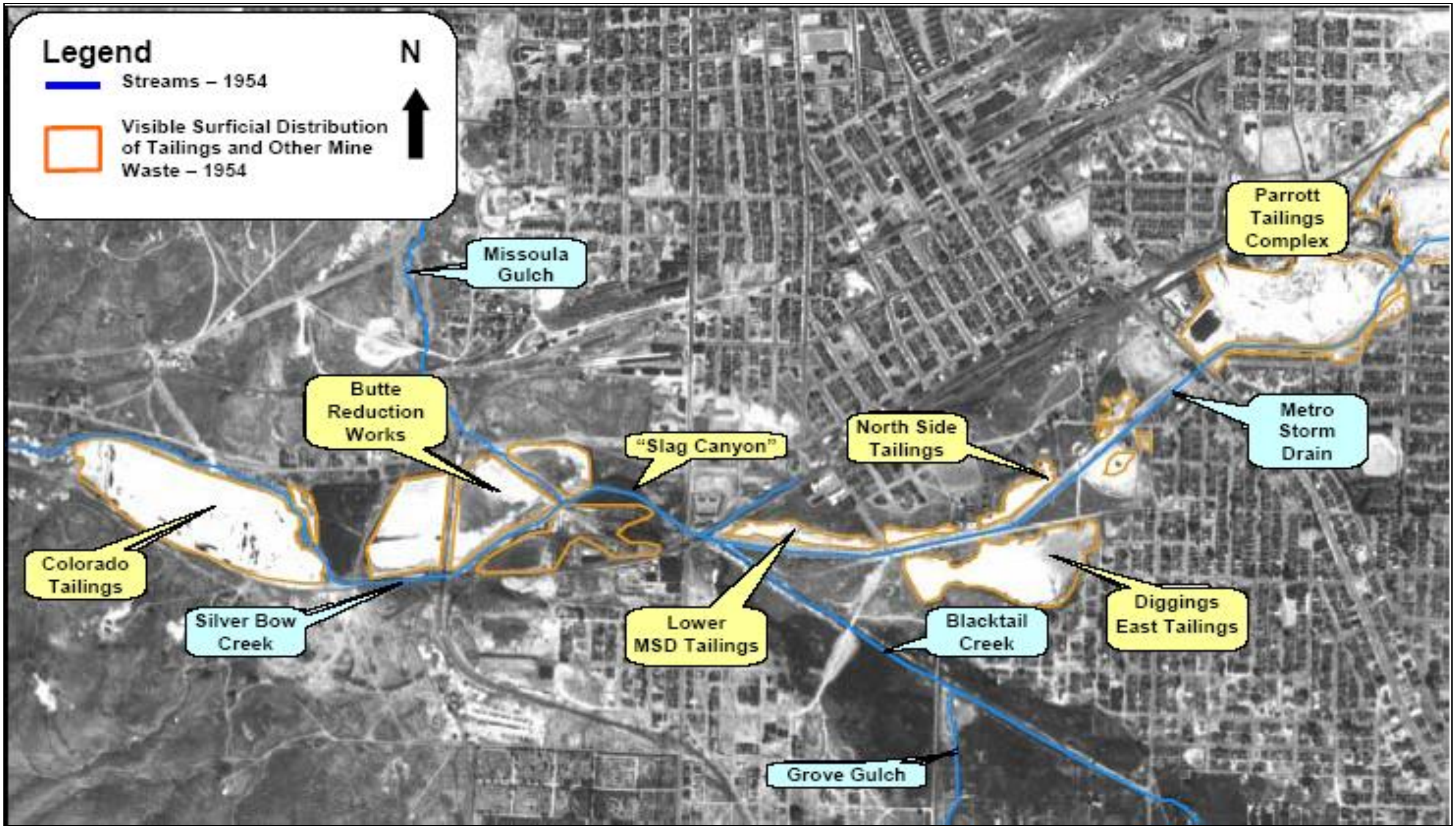

Figure 2. 1954 Surficial Distribution of Tailings and Mine Waste in the Metro Storm Drain/Silver Bow Creek Corridor (modified from EPA 2006)

In addition to the perennial flow and storm water runoff, Silver Bow Creek receives regulated discharge from the Metro Sewage Treatment Plant outfall located west of the former Colorado Tailings at the western edge of the site. Discharge from the plant is normally between 5 and 9 cfs, constituting roughly 30 percent of the total base flow in Silver Bow Creek.

Water Quality

Base Flow

Two surface water sampling locations are key to the discussion of base flow water quality. One is a sampling station located on Blacktail Creek upstream of the Metro Storm Drain. The downstream station, SS-07, is located on Silver Bow Creek at the western border of the BPSOU (Figure 3).

The pre-1998 base flow water quality in Blacktail Creek was considered relatively good. In comparison, water quality in Silver Bow Creek was very poor prior to 1998. Total recoverable concentrations for all metal contaminants of concern (COC)s were above their respective standards; at times orders of magnitude above the standards for Cd, Cu, Pb, and Zn.

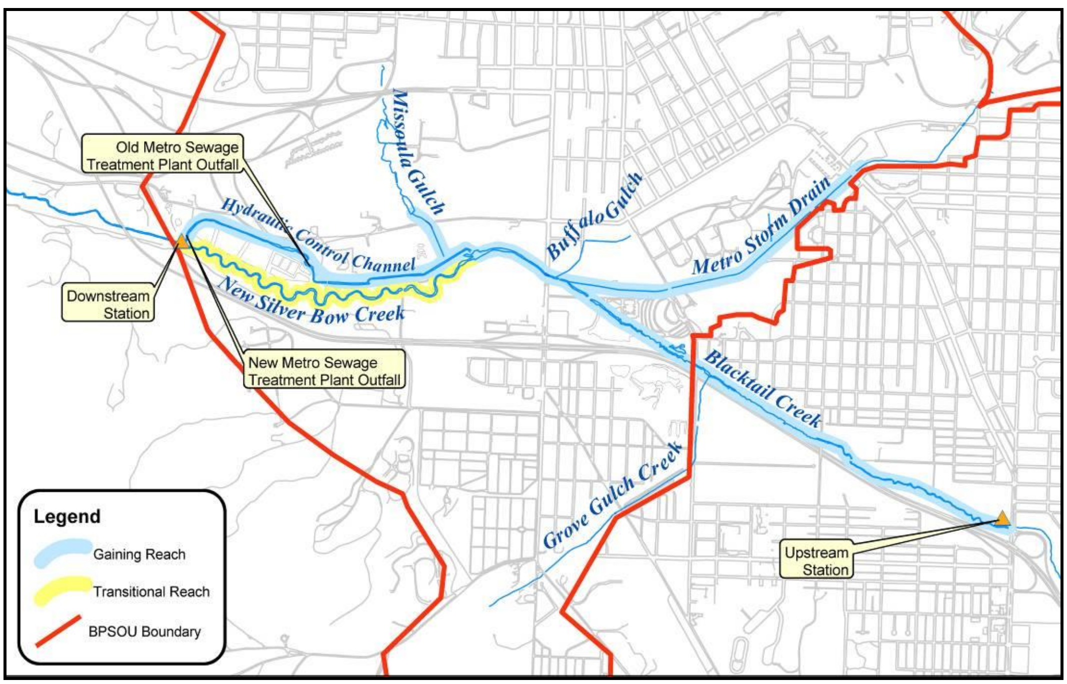

Figure 3. Key surface water features and monitoring stations for Silver Bow Creek. Compare surface water features with 1954 aerial photograph in Fig. 2.

The major contributors of metals to Silver Bow Creek, during periods of base flow, were:

- Surficial Colorado and Butte Reduction Works tailings (through which Silver Bow Creek flowed prior to 1997).
- Groundwater contaminated by the Colorado tailings expressed directly as surface water to Silver Bow Creek.

- Metals laden sediment deposits distributed along the Silver Bow Creek stream channel.
- Groundwater contaminated by buried tailings expressed as surface water in Metro Storm Drain.
- Surficial tailings along Metro Storm Drain (through which surface water flowed prior to 2004).
- Contaminated groundwater in the Missoula Gulch drainage expressed as surface flow prior to entering Silver Bow Creek.

<u>Wet Weather Conditions</u>

Storm water run-off from the Butte Hill is a contributor of both dissolved phase contaminants of concern (COCs) and metals laden sediments to Silver Bow Creek.

Significant water quality exceedances (at times orders of magnitude above the standard) have been reported for both Cu and Zn and still occur. As a result of the serious nature of these past exceedances, actions were taken in the mid to late 1990s and in the early part of this decade to reduce the impact of storm water discharge to Silver Bow Creek.

Superfund Response Actions

Based on the remedial investigation findings, the remedy for protection of Silver Bow Creek consists of three needs:

1) Control, capture, and treat contaminated groundwater to prevent it from flowing into Silver Bow Creek
2) Remove solid media contaminants from the stream corridor to prevent direct erosion and sediment contamination
3) Improve the quality of storm water runoff from the Butte Hill to prevent acute water quality exceedances in Silver Bow Creek

The actions described below have been aimed at one or more of these facets of the remedy.

<u>Response Action for Colorado Tailings and Butte Reduction Works area</u>

Because of the poor water quality in Silver Bow Creek, mitigation efforts were undertaken in the mid-1990s. The response action work plan included the following critical elements for the cleanup:

- Removal of tailings and backfilling
- Realignment and stabilization of Silver Bow Creek
- Establishment of a productive and diverse plant community
- Construction of a groundwater collection, extraction, and treatment system

In 1997, 1.2 million cubic yards (mcy) of tailings were removed from this area as part of Phase I. Due to the presence of immovable structures and limitations in removal depth, not all tailings and contaminated soils could be removed. Tailings remain beneath a predetermined depth-of-excavation, beneath the Metro Sewage Treatment Plant, and beneath historic slag walls. Following the removal, the area was partially backfilled and the Silver Bow Creek channel and floodplain were reconstructed. Figure 4 shows a portion of the Colorado Tailings area before and after removal and channel reconstruction.

Figure 4. Aerial photographs of the Silver Bow Creek floodplain at the east end of the Colorado Tailings before (1969) and after (2002) waste removal and stream channel reconstruction. Notice the municipal waste water treatment plant in both photographs.

Phase II was an interim hydrologic equilibration and monitoring period and this included ground and surface water sampling, water level monitoring, and water treatability studies. Phase II groundwater and surface water monitoring was completed in late 2000. Post removal groundwater monitoring indicates that groundwater capture is highly effective, especially because bedrock shallows and outcrops at the western edge of the site, forcing groundwater to the surface. However, COCs in the alluvial aquifer remain at concentrations exceeding groundwater quality standards.

Phase III, scheduled for completion after EPA Region 8 issues the record of decision this year, will include the design and construction of both the final reclamation plan and construction of a permanent groundwater collection, extraction, and treatment system.

Storm Water Response Actions

In 1996 action was initiated to minimize the impacts of storm water run-off on Silver Bow Creek for storm magnitudes up to the 24-hour, 25-year event. To control storm water flow and minimize soil erosion and transport of contaminated sediment to Silver Bow Creek, storm water conveyance structures were built and large areas of barren land and contaminated soil were reclaimed with coversoil and vegetation. Storm water channels and detention ponds were placed in critical areas to minimize erosion and reduce the release and transport of contaminants from historic mining areas. This was accomplished, in part, by routing storm water run-off from the upper east portion of the Butte Hill to the Berkeley Pit. Run-off from Missoula Gulch (west-central portion of the Butte Hill) was captured and routed to a series of three sediment catch basins prior to discharge to Silver Bow Creek.

Although the source areas were targeted for human health issues related to lead and arsenic, they had also acted as significant contributors of metal laden sediments to Silver Bow Creek during storm events. The vegetative caps act as barriers preventing contact of waste materials with storm water, minimizing contaminant transport.

Additionally, work was initiated to meet the human health goals by either removing or capping contaminated railroad bed materials. These caps also aided in meeting the goal of controlling storm water run-off by providing a protective barrier that reduced sediment transport.

As a result of the storm water, railroad bed, and other waste source work, most of the storm water run-off from the Butte Hill is either diverted to the Berkeley Pit or is detained in catch basins for sediment reduction prior to discharge to Silver Bow Creek.

<u>Metro Storm Drain channel reconstruction</u>

In 2003, ARCO was granted EPA Region 8 approval to reconstruct the Metro Storm Drain channel in a manner that is intended to improve water quality in Silver Bow Creek during base flow and storm flow conditions. The reconstructed channel is designed to eliminate contaminated groundwater from discharging to the channel (using a subsurface groundwater capture system) and to prevent storm water from contacting tailings and other waste material as it runs along Metro Storm Drain. The Metro Storm Drain reconstruction was completed in 2005. Today, captured groundwater is conveyed via pipeline for combined treatment with captured groundwater in the Colorado Tailings and Butte Reduction Works area.

<u>Understanding the groundwater control, capture, and treatment system.</u>

As previously discussed, the key to achieving surface water quality standards during base flow is to prevent contaminated groundwater from discharging to Silver Bow Creek – separation of surface water and groundwater. There are two groundwater capture and control systems, one along Silver Bow Creek and one in the Metro Storm Drain.

The routing of flows is shown in the schematic shown in Fig. 5. Here, the Metro Storm Drain collection system and the Silver Bow Creek hydraulic control systems are shown along with their separation from surface water. Groundwater collected in the Metro Storm Drain is pumped to the hydraulic control channel to manage and treat these waters together.

To protect Silver Bow Creek, the invert of the reconstructed channel was elevated to ensure the creek remained a losing reach (i.e., groundwater does not discharge to surface water). A hydraulic control channel was constructed to capture and route contaminated groundwater. Four large open areas were left un-backfilled to facilitate hydraulic control and capture of groundwater (Fig. 5).

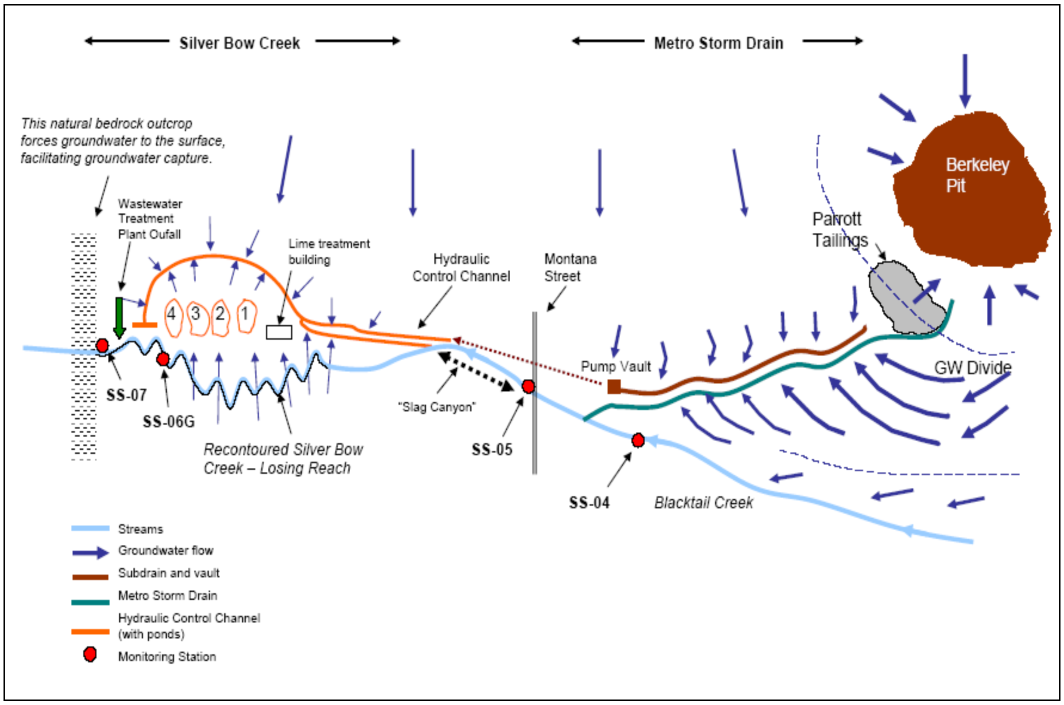

Figure 5. Schematic showing the hydraulic control, capture, and treatment system for alluvial groundwater along the Silver Bow Creek floodplain (not to scale). Key surface water monitoring stations are also shown.

Water surface elevations in the open areas and hydraulic control channel are maintained at a lower elevation than Silver Bow Creek to maintain the gradient away from the creek. A typical cross section of the former Colorado Tailings area is shown in Fig. 6. One of the four open areas was re-contoured and subdivided into separate lagoons to conduct a treatability study to test the "Treatment Lagoons in a Wetland Setting" technology (described below).

In the Metro Storm Drain, separation of surface water and groundwater was also a challenge due to infrastructure constraints – the surface water and groundwater conveyances needed to follow the existing channel. A subdrain (i.e., permeable pipeline) was constructed in the invert of the Metro Storm Drain channel to collect groundwater that formerly discharged as surface water to the channel. The subdrain was covered with geotextile and the channel was cleaned out and reclaimed to convey storm water flows. The Metro Storm Drain reconstruction is shown in Fig. 7.

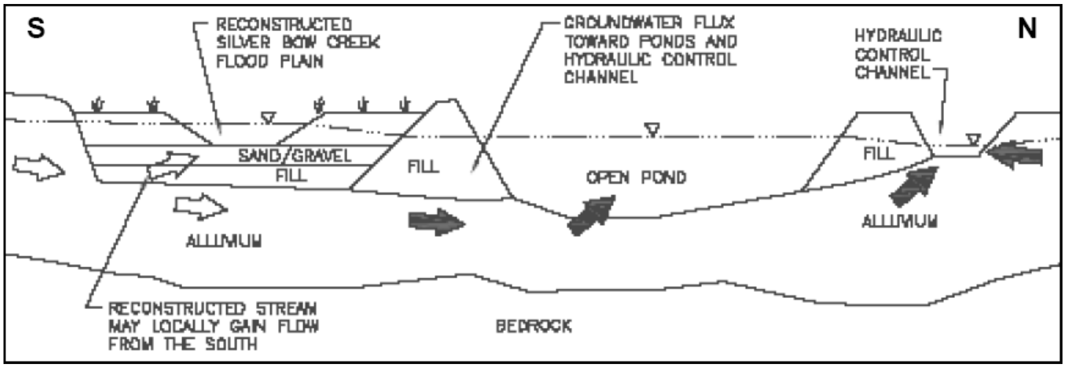

Figure 6. Cross section of the reconstructed Silver Bow Creek channel in relation to the open ponds and hydraulic control channel showing relative water surface elevations to be maintained (modified from PRP Group 2002).

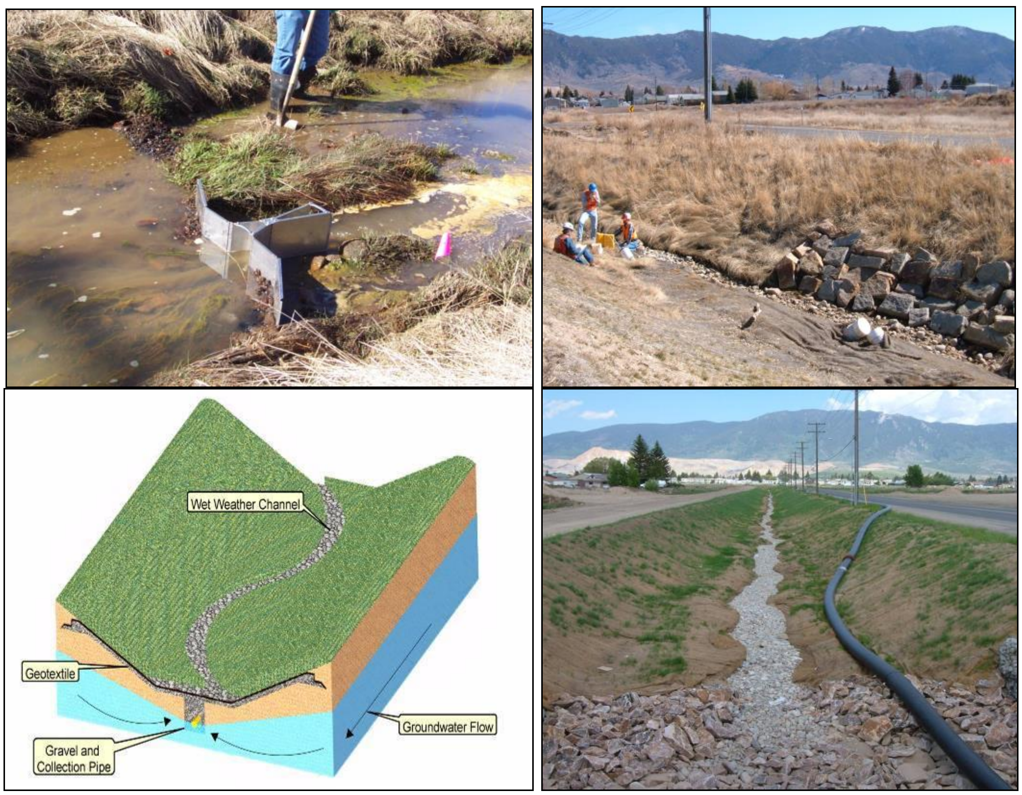

Figure 7. Metro Storm Drain prior to reconstruction (upper left). The remaining three pictures show the reconstructed channel and subdrain. The infrastructure constraints are evident in the lower right photograph.

Both of these systems are made more effective by the shallowing of the bedrock from east to west, which forces alluvial groundwater to the surface. Also, the flux of contaminated groundwater is lessened in the upper Metro Storm Drain due to the groundwater divide created by the Berkeley Pit cone of depression. This is shown in Fig. 8.

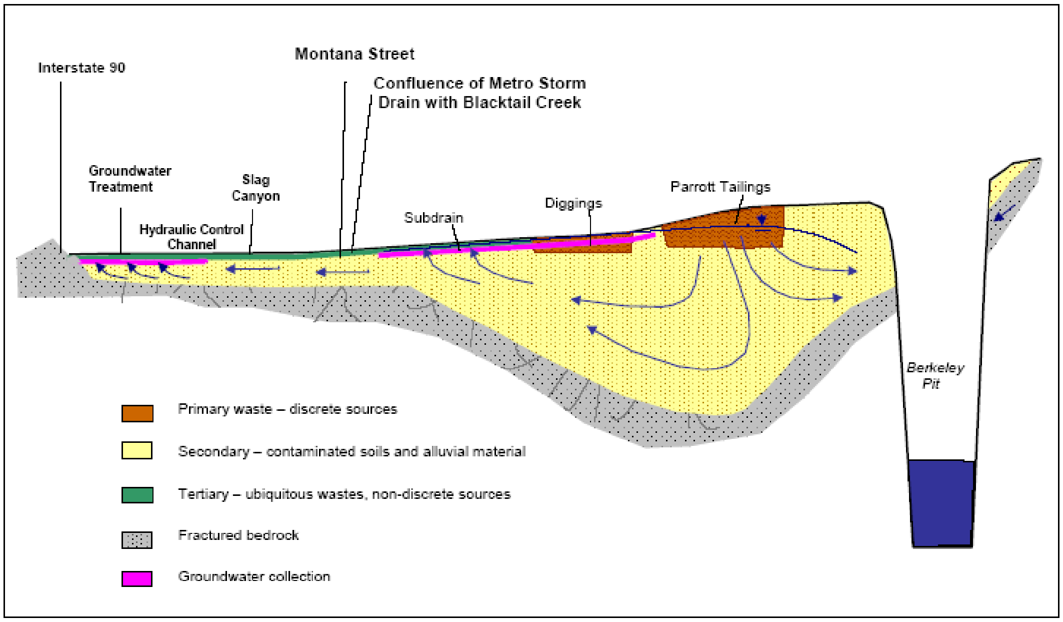

Figure 8. Cross section showing general groundwater flow paths as they are directed to the groundwater capture systems (vertically exaggerated, not to scale). Notice that the shallowing and outcropping of bedrock at the west end of the site forces groundwater to the surface, facilitating groundwater capture.

To be protective of surface water, alluvial groundwater from the Metro Storm Drain and Silver Bow Creek will need to be captured and treated indefinitely. Since completing Phase I of the waste removal and reconstruction of Silver Bow Creek floodplain in 1998, the PRP Group has performed a treatability study has been conducted to assist in the selection of groundwater treatment methods.

The study was conducted in a series of three unlined lagoons that were constructed within one of the larger open areas that remained un-backfilled following the removal of the Colorado Tailings. The treatment system is designed to treat contaminated groundwater captured by the hydraulic control channel and open water areas. The treatment system utilizes lime addition to modify the pH and chemistry of influent water to reduce metal solubility. Treatment within the lagoon system is accomplished primarily by lime precipitation. An additional parallel set of three lagoons was constructed in 2001 to increase capacity, supplement treatment in the original lagoons, and for independent use when maintenance is required on the original lagoons. The treatment system is shown in Fig. 9.

The study showed that the lagoon system was generally capable of effectively treating influent waters to achieve discharge standards during periods of normal operation, but it is uncertain whether effective treatment can be maintained through periods of lagoon maintenance (e.g., when sludge/sediments are removed). Therefore, the final remedy requires construction of a conventional lime treatment plant, unless further demonstrations show effective treatment through periods of maintenance.

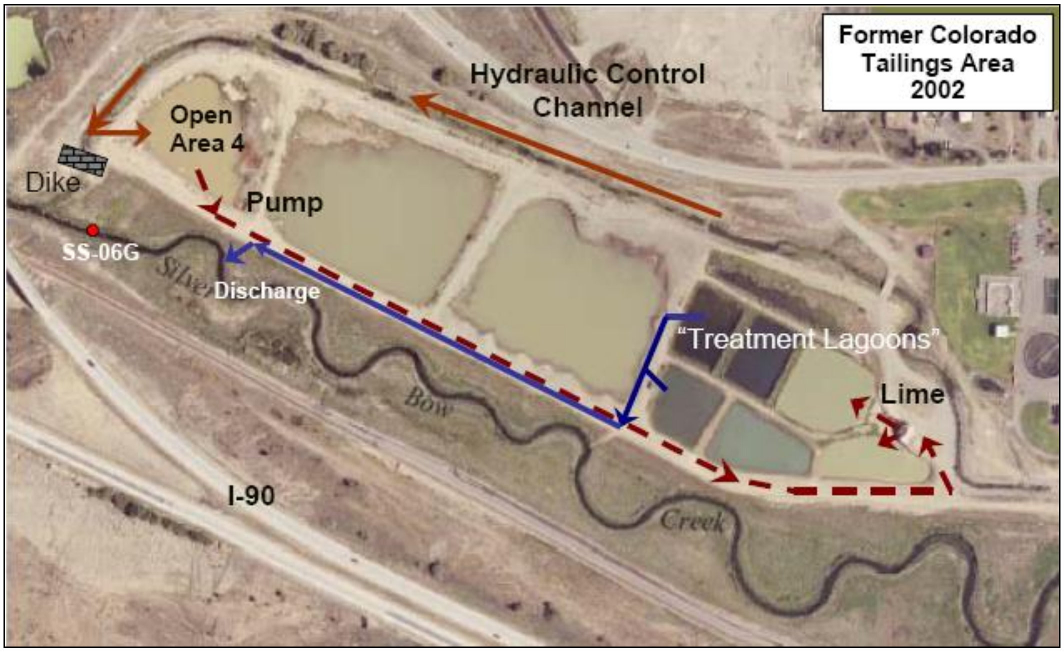

Figure 9. Aerial photograph showing routing of captured groundwater, treated water, and discharge to Silver Bow Creek.

<u>Surface Water Quality Data</u>

Figures 10 and 11 show water quality data in Silver Bow Creek downstream of Butte since 1993, prior to major remedial actions. Copper and Zn data are shown because they are the primary stressors to aquatic life in Silver Bow Creek, particularly Cu. Remedial action milestones are also shown on the graphs. An obvious improvement in water quality is apparent. Monitoring station SS-07 is shown as the "downstream station" in Fig. 3 and is shown on Fig. 5. Station SS-06G is shown in Fig. 5 and Fig. 9 above.

The first improvement in water quality can be seen immediately after the removals in the Colorado Tailings and Butte Reduction Works, largely because the creek was no longer flowing directly through the Colorado Tailings. After the removal, groundwater was directed away from Silver Bow Creek for collection in the hydraulic control channel. However, the captured groundwater was discharged back to Silver Bow Creek just upstream of station SS-07. Only a portion of the contaminated water was diverted for use in treatability studies. Therefore, surface water quality was still impacted by contaminated groundwater.

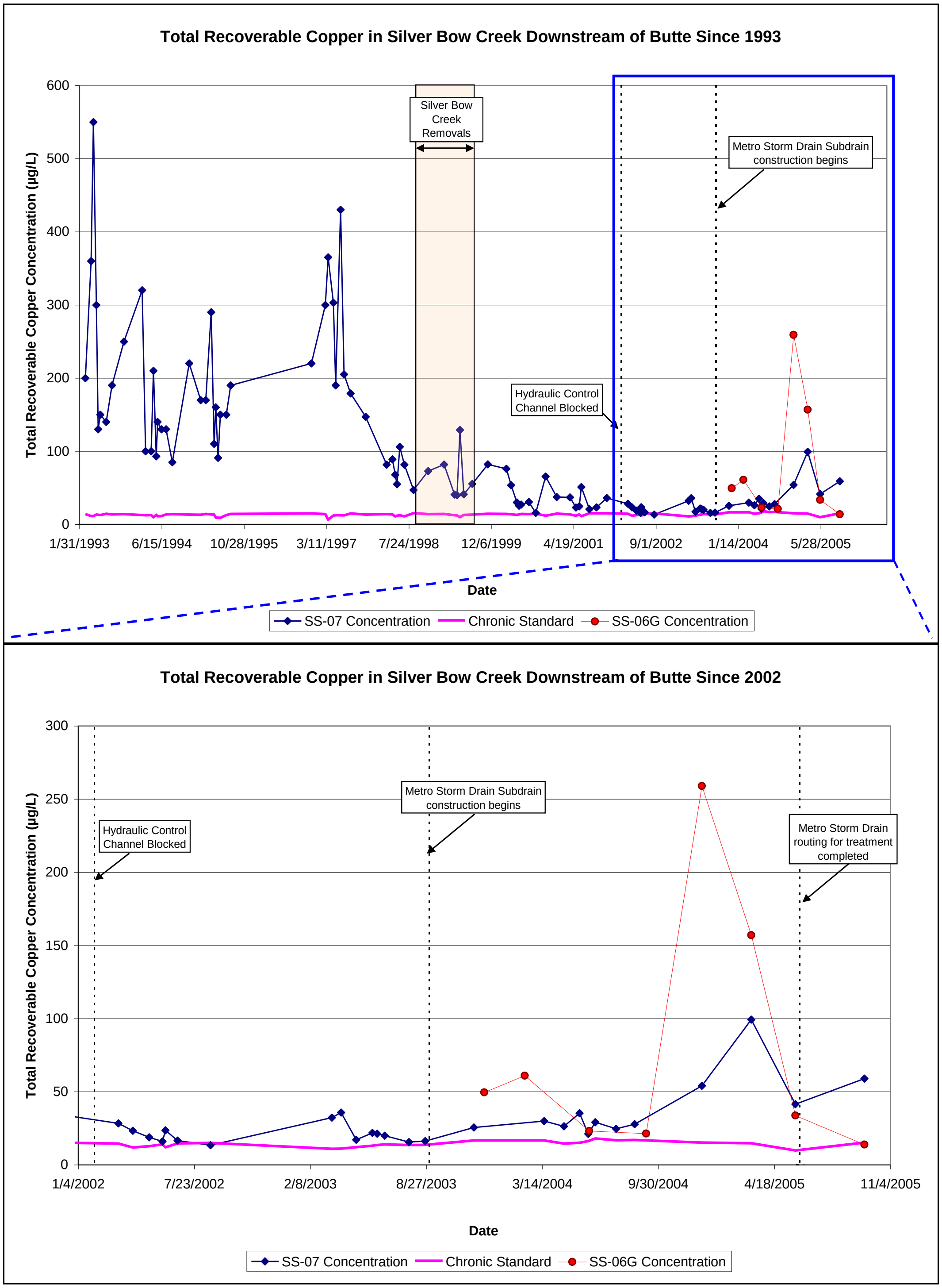

Figure 10. Total recoverable copper concentrations in Silver Bow Creek downstream of Butte along with remedial action milestones. The lower graph shows concentrations since 2002 to increase the scale. Station SS-07 has been monitored since the 1980s and includes impacts from the wastewater treatment plant. After reconstruction of Silver Bow Creek, station SS-06G was established just upstream of SS-07 and the wastewater treatment plant effluent. (Data from USGS and Atlantic Richfield 2005b)

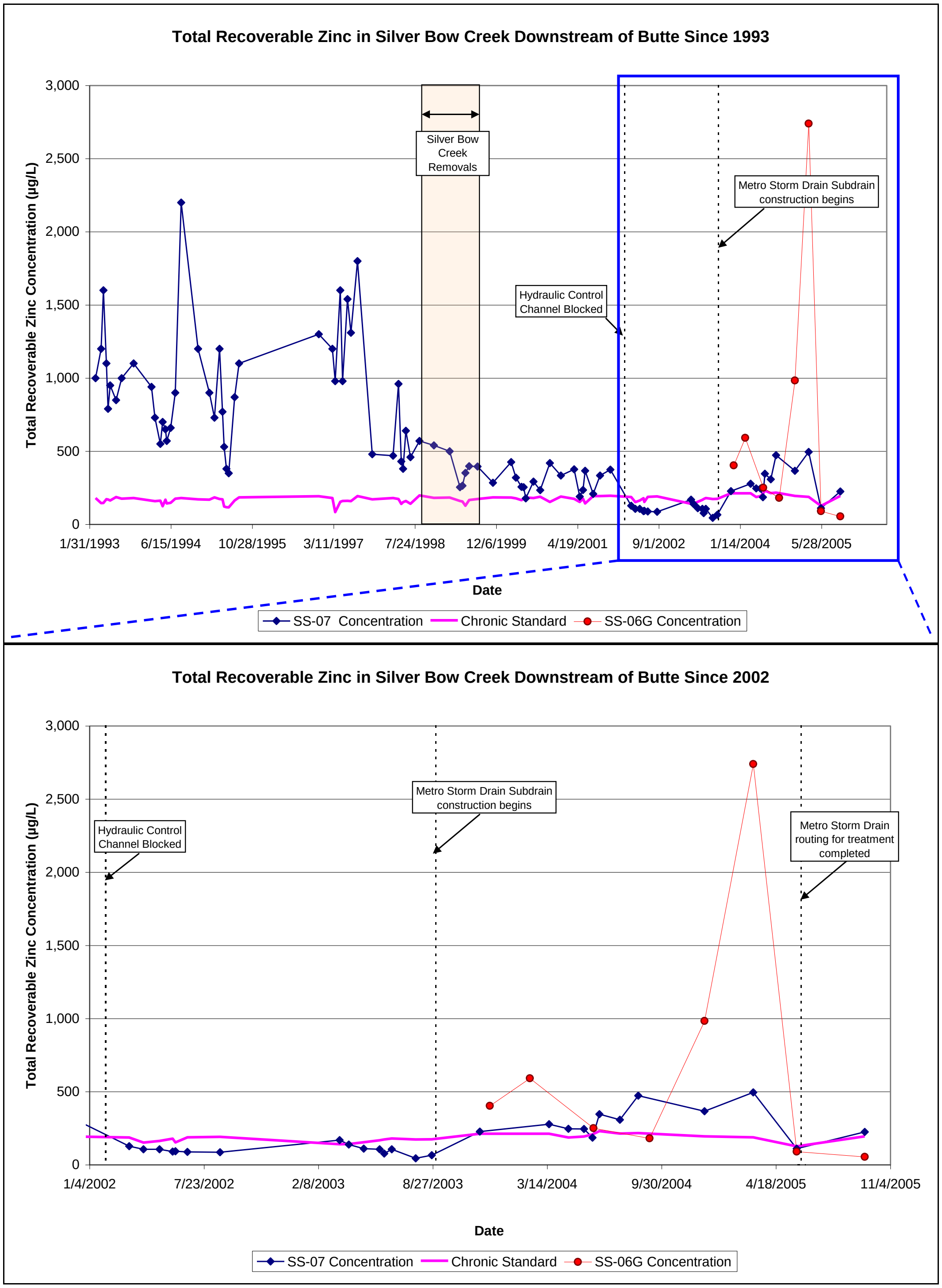

Figure 11. Total recoverable zinc concentrations in Silver Bow Creek downstream of Butte along with remedial action milestones. The lower graph shows concentrations since 2002 to increase the scale. Station SS-07 has been monitored since the 1980s and includes impacts from the wastewater treatment plant. After reconstruction of Silver Bow Creek, station SS-06G was established just upstream of SS-07 and the wastewater treatment plant effluent. (Data from USGS and Atlantic Richfield 2005b)

In 2002, ARCO expanded the treatment lagoon system to handle all of the flow being collected by the hydraulic control channel at Lower Area One. This is noted on the graphs as the blocking of the hydraulic control channel, and its effect can be seen on the figures as another drop in concentrations. This step alone was nearly enough to achieve water quality standards as measured at SS-07. However, contaminated groundwater from the Metro Storm Drain was still not controlled.

Prior to remedial actions, contaminant contributions from tailings deposits and alluvial groundwater were clearly much greater than those contributed by the wastewater treatment plant. However, after 2002, the relative importance of the contribution from the wastewater treatment plant was becoming more significant to water quality as measured at SS-07. The wastewater treatment plant increases the flows in Silver Bow Creek by roughly 50 percent. Prior to 2002, the wastewater treatment plant discharge was most likely having a dilution effect on concentrations as measured at station SS-07. After 2002, discharge from the wastewater treatment plant complicates interpretation of the data at SS-07. The data do not clearly show the impacts of remedial actions. Thus, stream concentrations at station SS-06G, just upstream of the wastewater treatment plant discharge, were added to the evaluation because they are a more accurate measurement of the impact that remedial actions have had on Silver Bow Creek. On Fig. 10 and 11, water quality data as measured at station SS-06G are included for comparison against SS-07. These data show that concentrations in Silver Bow Creek were still above water quality standards at SS-06G, even though concentrations at SS-07 were at or below standards.

The Metro Storm Drain subdrain construction began in 2003. Concentrations in Silver Bow Creek show an increase during this time due to the construction disturbance. In spring 2005, collected groundwater from Metro Storm Drain was routed to the treatment lagoon system for treatment. This is shown as an obvious decrease in concentrations as measured at station SS-06G. At station SS-07, the impact from the removal of Metro Storm Drain groundwater is not clear.

The improvement in Silver Bow Creek dissolved and total recoverable Cu concentrations are also shown in Fig. 12. These graphs show concentrations from quarterly sampling conducted in May and September 2005, before and after rerouting of MSD groundwater (Atlantic Richfield 2005b). The stations shown on the graphs are established monitoring stations from upstream to downstream and show how water quality is changing as it flows downstream through Butte. Key inputs and location information are shown on the graphs.

Concentrations measured at SS-06G show a clear decrease to near or below water quality standards. Dissolved Cu concentrations decreased to be below water quality standards for the entire stream reach. Total recoverable Cu was still slightly above the standard in the middle reach of the creek, but was below the standard at SS-06G.

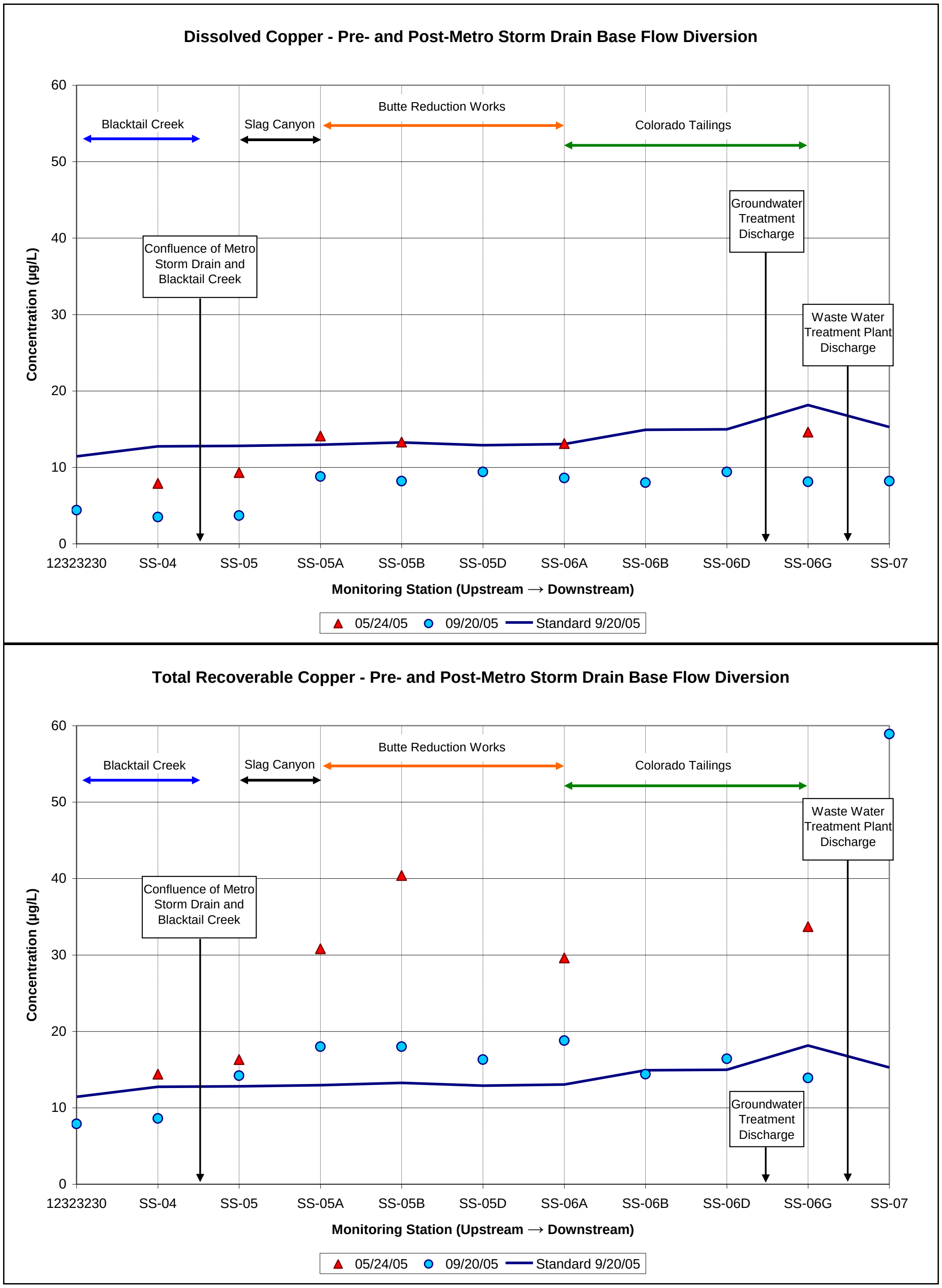

Figure 12. Dissolved and total recoverable copper concentrations from May and September 2005 from upstream to downstream through Butte. (Data from Atlantic Richfield 2005b).

After diversion of the Metro Storm Drain, dissolved concentrations show very little change from upstream to downstream, this is what one would expect if all of the groundwater were being captured and treated. This is the result anticipated; concentrations should roughly equal upstream concentrations in Blacktail Creek. Notice that some increases in total recoverable concentrations were measured through the middle reaches of the creek. These increases are likely due to stream bank and stream sediment wastes along the “slag canyon” between Metro Storm Drain and the reconstructed Silver Bow Creek channel that has not yet been addressed, but will be removed as part of the final remedy.

These figures also show the relative contribution of the wastewater treatment plant. During the September 2005 sampling event, total recoverable concentrations exceeded water quality standards as measured at SS-07. Because concentrations were below standards just upstream at SS-06G, this increase would be due to the contribution from the wastewater treatment plant.

Discussion

Surface Water Summary

Actions taken to date have drastically improved base flow water quality in Silver Bow Creek (in Butte, Montana) to the point where concentrations are starting to meet water quality standards. This is a great achievement that was not believed possible when remedial investigations were initiated in the 1980s. Apart from massive waste removals and stream reconstruction, success is primarily due to effective control, capture, and treatment of alluvial groundwater. Metal concentrations should be further improved as removals of streambank and stream sediments through the “slag canyon” between the Metro Storm Drain and reconstructed channel are completed.

Future of Silver Bow Creek in Butte

Significant exceedances of water quality standards still occur during periods of runoff from the Butte Hill. The in-stream contaminant concentrations for wet weather flow have not been reduced by the same magnitude as those for base flow. However, the total volume of contaminants reaching Silver Bow Creek from wet weather has been reduced by diverting much of the run-off to the Berkeley Pit and by removing metals laden sediments in catch basins. Storm water will be further addressed through a rigorous diagnostic monitoring program to identify and remedy areas contributing contaminants to storm water.

In the near future, water from the Berkeley Pit will be treated and then discharged to Silver Bow Creek. The discharge will effectively double the flow in Silver Bow Creek through Butte. As groundwater equilibrium is reestablished, in effect, all of the water that Silver Bow Creek once carried before mining activities and dewatering obliterated the upper portion of the watershed will be treated. Because the discharge must meet water quality standards, it will effectively provide some dilution capacity to Silver Bow Creek to better assimilate wet weather flows.

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