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Technical Memorandum

To:	Mary Beth Marks US Forest Service On Scene Coordinator – New World Mining District	**From:**	Jennifer Hudson
Company:	Tetra Tech	**Date:**	April 6, 2009
Re:	McLaren Subsurface Drain Anaerobic Bioreactor System Review	**Project #:**	1157561506A
CC:	Allan Kirk, Tetra Tech		

1. Introduction

In the *Draft Adit Discharge Engineering Evaluation/Cost Analysis (EE/CA): New World Mining District Response and Restoration Project* (Tetra Tech, 2006) several alternative treatment technologies for acid rock drainage (ARD) and acid mine drainage (AMD) were evaluated and the recommended treatment technology was selected for each source in the New World Mining District. The reader is referred to that document for site history and detailed information regarding the New World Site.

The recommended treatment technology for the collective flow from the McLaren Pit subsurface drains was a passive or semi-passive bioreactor system. Passive or semi-passive treatment of acid mine drainage has been shown to be a relatively effective and low-maintenance alternative to active treatment under favorable conditions including providing an acceptable energy source and proper water quality conditions conducive for bacterial growth as discussed in detail in this report. This type of treatment takes advantage of natural chemical and biological processes and is particularly suited for remote locations and those which may be inaccessible during a portion of the year as is the case for the McLaren subsurface drains and the McLaren Adit discharge.

This review is a reexamination of the anaerobic bioreactor system proposed for the McLaren drains in the EE/CA. A passive solid substrate bioreactor (SSBR) and a semi-passive liquid substrate bioreactor system (LSBR) are compared. The water flow rate and quality data have been reevaluated for each source. An estimated cost analysis for bench scale pilot studies is presented, and the sensitivity of the system to changing flow and chemistry conditions is discussed. Finally, the construction, operations and maintenance cost analysis presented in the EE/CA has been updated to provide further detail and refined cost estimates for the SSBR and LSBR systems based on these analyses.

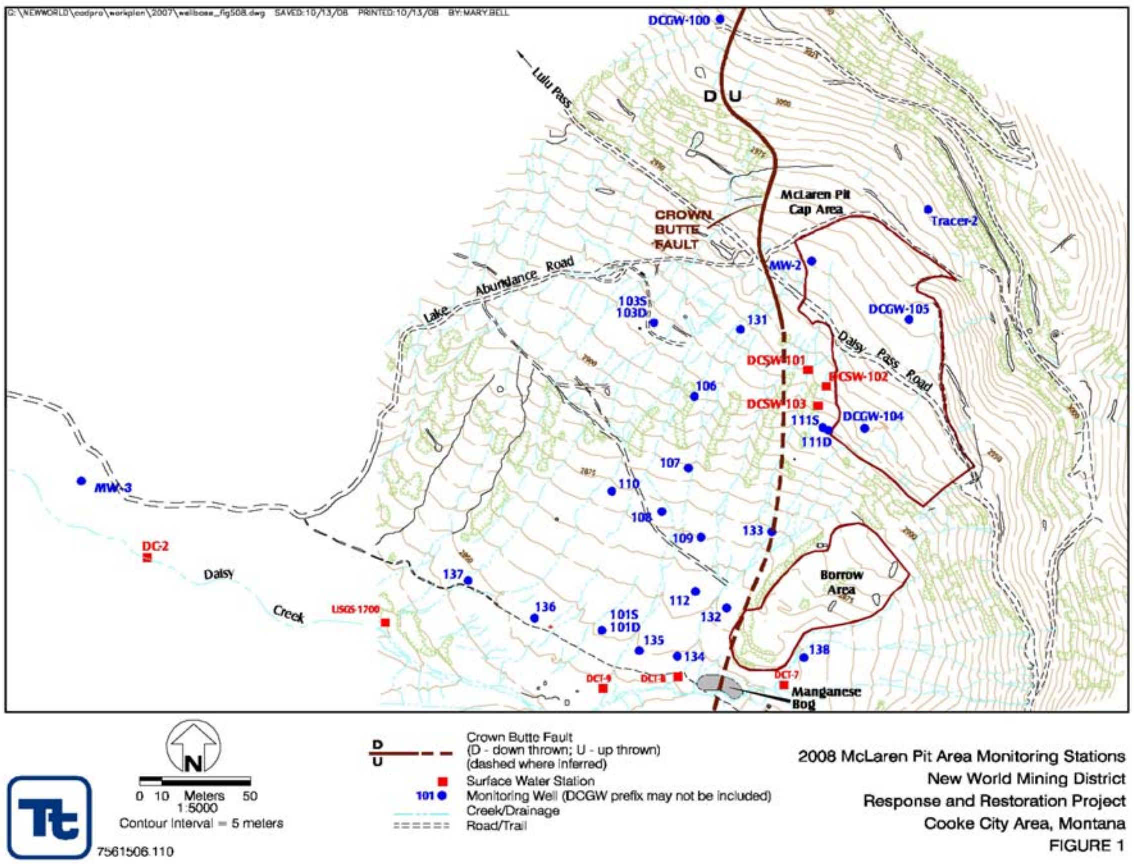
2. Site Description

The nature of the McLaren massive sulfide ore deposit, history of the open-pit mine and general site characteristics are detailed in the Adit EE/CA. Briefly, the site is located immediately north of Daisy Pass, on the west side of Fisher Mountain about four miles north of Cooke City, Montana. The open pit mine occurs at elevations between 9,600 to 9,800 feet, and access to the site is limited to only a few months each year due to adverse weather and snow conditions. As a result of the site conditions, a bioreactor treatment system for water treatment of flow from the drains was recommended as a possible treatment alternative in the EE/CA to reduce metals-loading to Daisy Creek. The technology is well-suited for remote locations, which are inaccessible for a portion of the year and where active treatment may not be feasible. The technology has been shown to be effective for treatment of AMD under favorable conditions, and improvements in long term operation of these systems are routinely being made. Although the currently constructed bioreactor treatment systems have not been in operation for more than a few years, in theory under the optimal operating conditions, passive or semi-passive bioreactor systems should operate effectively for many years without requiring a major system overhaul or ongoing construction, and should require only minimal operator input.

3. McLaren Pit Subsurface Drains

In July 2002 as a result of the McLaren Pit Response Action, the historically operated open pit was re-graded and capped with an impermeable geomembrane cover to minimize surface run-on, and the effects of precipitation and snowmelt infiltration into mine wastes back-filling the pit; thereby mitigating some of the acid generation and potential metals-loading to nearby Daisy Creek.

Four bedrock-hosted springs were encountered during excavation and drains were constructed during re-grading efforts to redirect subsurface drainage away from mine waste back-filled areas of the pit and the construction site. These drains were constructed to collect water in a perforated drain-pipe in a geotextile lined and covered, gravel-filled trench. The trenches were laid-out to bring the spring-fed groundwater near the base of the pit to the westernmost and downhill edge of the pit. These drains were left in place after regrading and completion of the capping. Three of the terminal ends are accessible as they drain into two separate constructed surface water tributary channels to Daisy Creek, immediately down-gradient of the pit. These three discharges to surface water are referred to as sample locations DCSW-101, DCSW-102 and DCSW-103 as shown in **Figure 1**. Construction of the McLaren cap was completed in October 2003.



The data for the combined flow of the three drains (see **Appendix A**) indicate an overall downward trend in combined peak flow since 2004, with the exception of the high flow sampling event in 2008, as shown in **Figure 2**. The sampling event on 7/15/2008 shows higher flow rates for the combined drain flow and indicate that 2008 precipitation and subsequent snowmelt was greater than that of 2006 or 2007. Although the flow rates measured in July 2008 indicate that the peak flow for this year was higher than peak flows measured in 2006 and 2007, the rapidly peaking flows generated by very high winter snowfalls/snowmelt quickly dropped back down to expected flow values for this time of year by the 8/12/2008 sampling event.

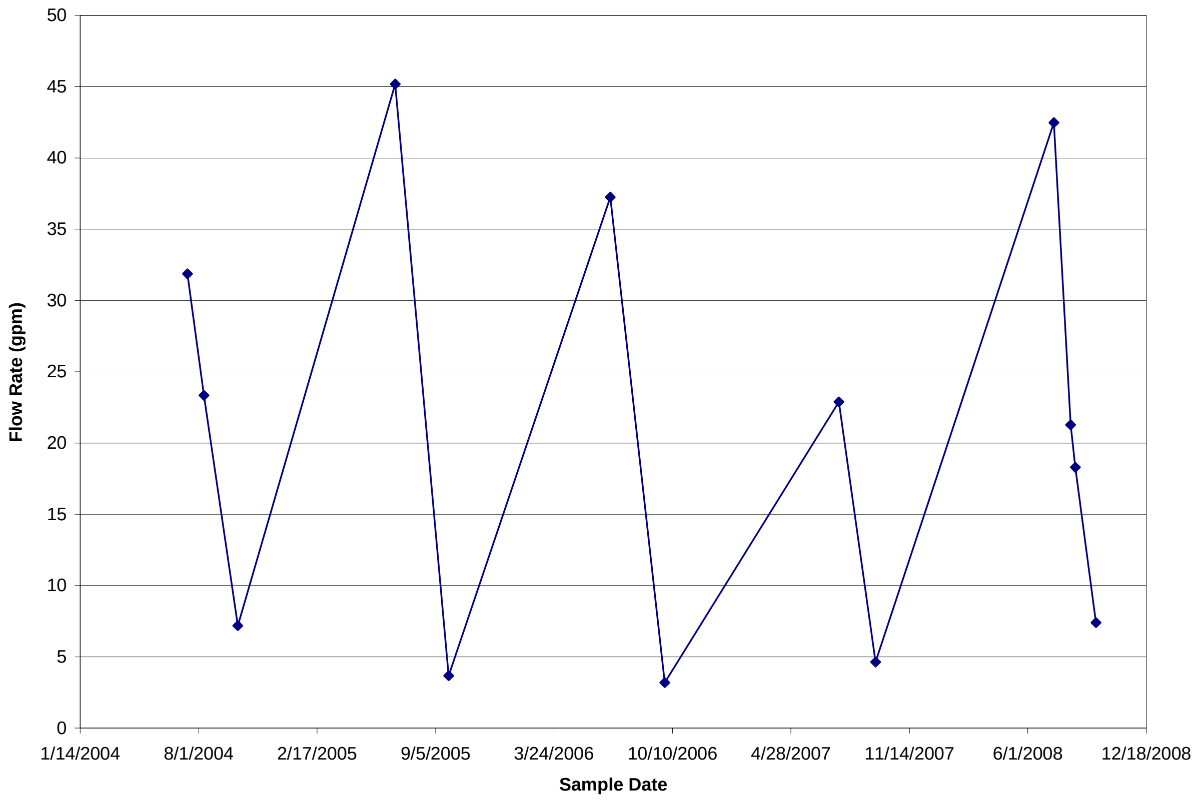


Figure 2 - Combined Flow for DCSW-101, -102, -103 Post-Capping

The combined metals concentrations show similar decreasing trends from the under-drains as seen in the combined drain concentration determined as a weighted average based on the flow rates for the three contributing drains (**Figure 3**) for each metal sampled. The exception to this relationship is lead during high flows of 2008, which was higher than any sample dating back to 2004. Typically, the total metals concentrations during the high flow periods decrease, due to the larger volumes of water, which act to dilute the metals and then increase during the lower flow periods. With the exception of lead, the overall trend for metals concentrations shows that the peak metals concentration decreases from each of the subsequent year over the period from 2004-2007. This trend indicates that the cap is effectively reducing the exposure for water to the source rock beneath the cap.

While a geo-synthetic membrane and revegetated cover soil prevent meteoric water and snowmelt from infiltrating into the backfilled McLaren Pit, groundwater continues to flow into and through the pit backfill. Spring 101, located along the pit margin at the base of the high wall, is the most upgradient source of groundwater entering the pit. Spring 101 flows at the most consistent flow rate compared to other flashier flowing springs originating further down gradient in bedrock, beneath the overlying pit footprint.

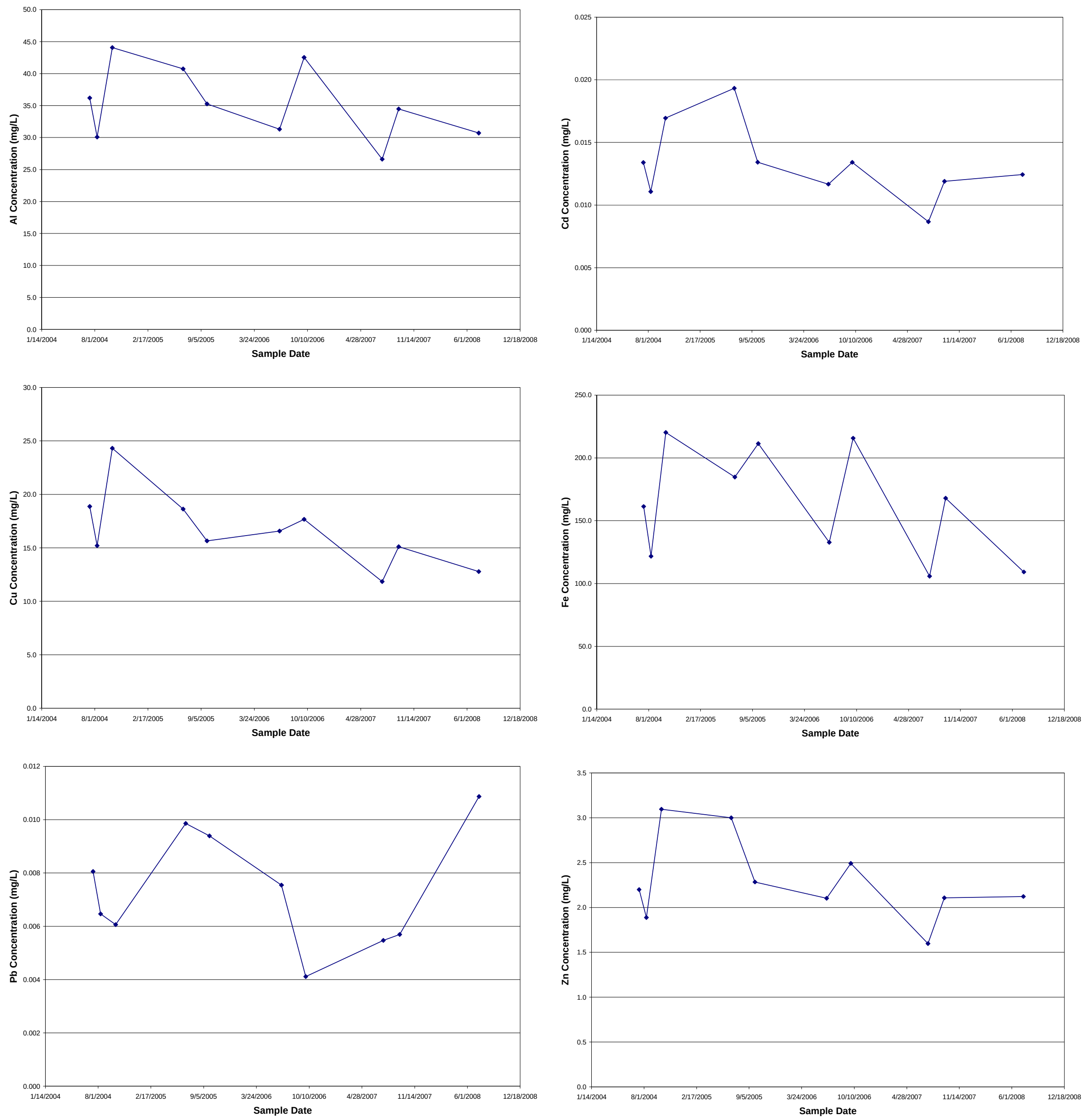


Figure 3 – DCSW-101, -102, -103 Combined Metals Concentrations

Flow from these springs and other springs that does not get captured by the sub-drain system, along with a seasonally fluctuating groundwater table, is the source of groundwater accumulation in the pit backfill. The elevation of this water is measured in two backfill monitoring wells, DCGW-105 close to the high wall near the middle of the pit, and DCGW-104 near the down gradient edge of the pit (**Figure 1**). Rising and falling water elevations are measured seasonally at each backfill well and also in nearby bedrock wells. Both the onset of rising and falling water elevations are initially detected first at DCGW-105 and about two to three weeks later at DCGW-104. Well DCGW-105 typically reaches its lowest level of the year in early November, whereas DCGW-104 often lags behind with the annual low water level being reached in late January.

Fluctuating water levels within the pit backfill promotes formation and subsequent dissolution of oxidation products and mobilization of soluble metals. Periods of falling groundwater head within the mine waste drives seepage of the resulting solute-rich water back into bedrock beneath the pit. This water is then sampled in both in groundwater wells within the pit, and from portions of the springs as it exits the pit at the three under-drain outlets.

Installation of the pit cap has decreased the overall maximum head of water in the pit backfill (7 feet lower at DCGW-104). The decrease in head reduces the magnitude of the backfill water level fluctuation, and therefore, reduces the volume of material that is intermittently saturated. Because less material is intermittently saturated, fewer oxidation products are generated and dissolved, therefore reducing the solute load delivered to groundwater underlying the pit. Reduced solute loading to groundwater beneath the McLaren Pit is believed to be the reason for decreasing trends in metal concentrations measured in under-drain water samples.

The original analysis presented in the Adit EE/CA for the drain flow and chemistry data used the data collected in June 2006 during the high flow sampling event. This analysis indicated that a substantial portion of the metals loading to Daisy Creek was from the McLaren drains. For the analysis presented in this report, the average metals loading at the nearest down-stream Daisy Creek sampling location (DC-2) was determined using the 2004-2007 mean flow data, average high flow and average low flow data from the various sampling events. Using these values, the total metals contribution to Daisy Creek from the under-drains ranged from 22.5% at mean flow rates to 39.3% at average low flow rates as shown in **Figure 4** and detailed in **Table 1**. Using the average data for flow is likely to give a better overall picture of volumes that would need to be treated in a SSBR or LSBR system, rather than using one point in time for evaluation such as was done with the 2006 data in the Adit EE/CA. However, for system sizing and cost purposes, rather than using high flow data, the mean flow data will be used in the analysis presented in this report. A provision for a system bypass will be included for the relatively short high flow period each season. This will minimize cost and system footprint, while ensuring that the greatest metals loading, during lower flows will be treated as effectively as possible. It is assumed for this analysis that the water quality will remain consistent from the under-drains. Under this assumption, the average combined drain flow and water quality values were used for analysis in the balance of this report.

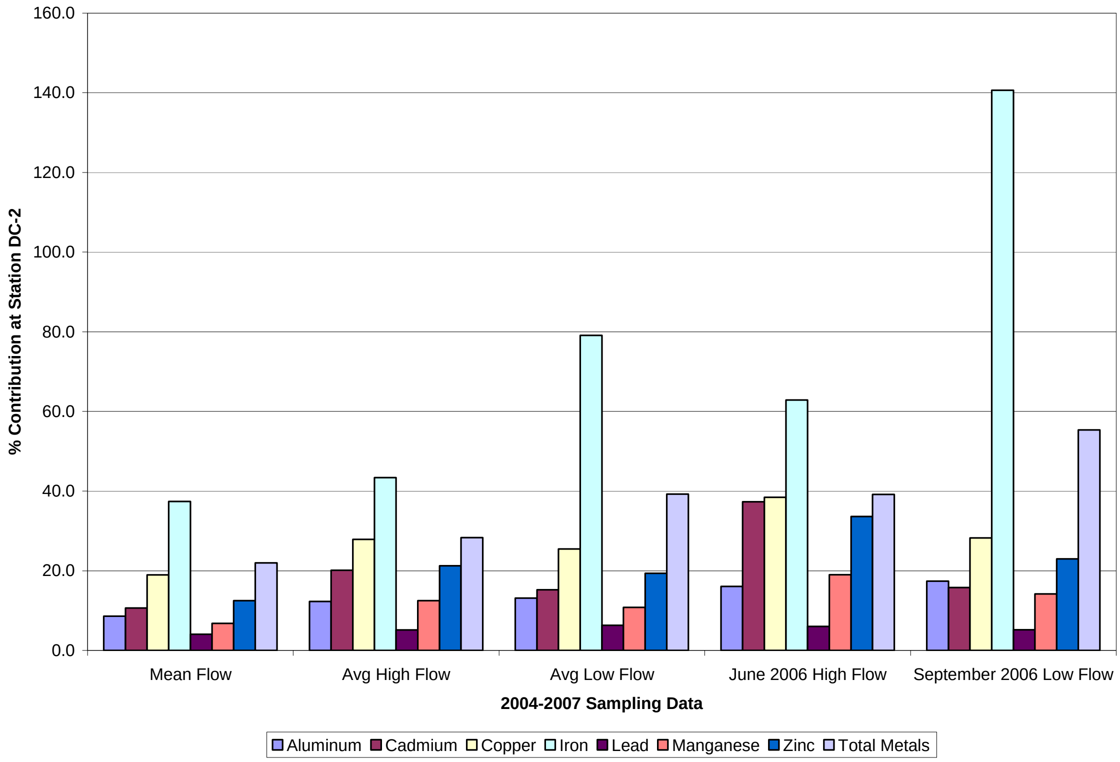


Figure 4 - Metals Loading at DC-2 from McLaren Pit Subsurface Drains

The combined total metals loading from the subsurface drains and the percent contribution at DC-2, the nearest down-stream sampling location in Daisy Creek, are shown in **Table 1** below for the June 2006 high flow and September 2006 low flow periods as presented in the EE/CA, as well as the loading using the average high flow and average low flow water chemistry data for 2004-2007. Also shown are the mean flow metals loading values used for the current analysis.

Table 1. Metals Loading from the McLaren Subsurface Drains

	Average High Flow Metals Loading (kg/month)	Average Low Flow Metals Loading (kg/month)	Mean Flow Metals Loading (kg/ month)	June 2006 Metals Loading (kg/month)	September 2006 Metals Loading (kg/month)
Aluminum	215.5	27.9	123.8	190.6	22.2
Cadmium	0.087	0.010	0.049	0.071	0.007
Copper	106.6	13.3	61.5	101.0	9.2
Iron	928	148	592	809	112
Lead	0.047	0.005	0.026	0.046	0.002
Manganese	26.26	3.80	16.03	24.62	3.12
Zinc	14.63	1.82	8.45	12.81	1.30
Total	1291.4	194.6	802.2	1138.0	148.2
% Contribution at DC-2	21.3%	39.3%	22%	39.1%	55.4%

This table indicates that while the percent contribution at DC-2 is higher for the 2006 sampling event data, the total metals loading to Daisy Creek is less when using 2006 data than for the data using average high flow values. This is a result of the average high flow and average low flow, 39.6 gpm and 4.6 gpm respectively, being greater than the 2006 high flow and 2006 low flow, 37.2 gpm and 3.2 gpm, respectively. The design flow rate used in the EE/CA was 22 gpm for the combined flow for the drains. The current analysis also indicates an average mean flow of 22 gpm which will be the flow rate used for the current analysis. The average values for metals concentrations determined as a weighted average based on the flow rates for the three contributing drains will be used for system sizing and design considerations in this evaluation as shown in **Table 2** and detailed in **Appendix A**.

Table 2. Mean Flow Rate and Water Quality Data for McLaren Drains

Station Name	Flow (gpm)[(1)]	Aluminum (mg/L)	Cadmium (mg/L)	Copper (mg/L)	Iron (mg/L)	Lead (mg/L)	Manganese (mg/L)	Zinc (mg/L)
DCSW-101	13.5	28.6	0.010	14.0	139	0.009	3.20	1.78
DCSW-102	7.2	30.6	0.016	17.3	145	0.003	4.74	2.72
DCSW-103	1.3	91.7	0.025	35.8	432	0.003	12.7	4.35
Combined	22.0	32.8	0.013	16.3	157	0.007	4.2	2.2

(1) Combined mean flow rate used for full scale design

4. Sulfate Reducing Bioreactor Systems

a. Anoxic Limestone Drains

In the Adit EE/CA it was suggested that the bioreactor systems incorporate an anoxic limestone drain (ALD) into the design, in order to add alkalinity and increase the pH of waters prior to entering the bioreactor. It is well known that armoring of the limestone can occur quickly when high levels of iron and aluminum are present and thereby risk clogging of the influent piping by their precipitation. In addition, armoring of the limestone with these chemical precipitates in the ALDs greatly reduces its effective acid buffering potential. It has been recommended that ALDs not be used when high levels of aluminum are present due to the complexity and lack of understanding of aluminum chemistry (Gusek, 2001). As an alternative to an ALD, limestone is typically incorporated into the matrix of a SSBR system to add alkalinity to the water and raise the pH. When the limestone is incorporated into the matrix, the precipitation of metals which leads to the armoring effect in an ALD is minimized by effectively distributing the area for precipitation throughout the reactor rather than allowing precipitation to occur primarily at the location of the inlet pipe. This also reduces the armoring effect of the limestone at the inlet piping as discussed above. As a result, the ALD has been eliminated for consideration in the proposed design. For addition of alkalinity and increase in pH for a LSBR, in addition to the limestone incorporated into the matrix, sodium hydroxide is metered into the influent water upstream of the bioreactor and the resulting iron and aluminum precipitates formed are allowed to settle out of suspension in a settling pond prior to flowing through the bioreactor.

b. Solid Substrate Bioreactor

There are two types of sulfate reducing bioreactor systems commonly employed for treatment of AMD. The first, a solid substrate bioreactor (SSBR) is considered a passive system in that once the system is set up and running, there is little support needed for operations, assuming the conditions of the reactor bed are conducive for bacterial growth. There are challenges associated with this type of system as well, which are discussed below. The SSBR employs a solid matrix of organic material, which serves as both a physical support and carbon energy source for bacteria. The bacteria are used to oxidize the carbon source, which in turn results in a subsequent reduction of dissolved oxygen (DO), sulfate and ferric iron. As the DO is reduced, this system begins to operate as an anaerobic (without oxygen) system, where sulfate reducing bacteria biochemically reduce sulfate and iron to form iron-sulfides. The sulfate reducing bacteria function best at a pH of 5.5 or higher (URS, 2003), and typically the pH acidic waters at a mine site must be increased for successful operation of a bioreactor. The pH in a passive SSBR system is typically increased and alkalinity added to the system using limestone. The limestone also acts to oxidize and precipitate much of the iron present as an iron hydroxide phase, which in turn minimizes the load of metals that needs to be reduced biologically. In a SSBR, many of the metals in the pH adjusted water are reduced to metal sulfide precipitates within the reactor, and the treated water is then typically sent to an oxic limestone drain where additional alkalinity and oxygen are added to the water prior to discharge. This is important for maintaining conditions of pH and DO in the receiving stream favorable to aquatic life.

c. Liquid Substrate Bioreactor

The second type of bioreactor system considered is a semi-passive system called a liquid substrate bioreactor (LSBR). The LSBR is more complex and may require more operational support (semi-passive) than a SSBR in order to be successful. Like the SSBR, a LSBR also reduces metals in an anaerobic system; however, the support media for the bacteria is typically a mix of large and small rock, and the carbon source for the bacteria is a liquid carbon source, such as ethanol, that is fed into the system with the influent wastewater. As discussed above, the bacteria are more productive at a pH greater than 5.5. In a LSBR, the pH is typically raised through the upstream addition of sodium hydroxide (NaOH) liquid to the waste water stream and the resulting bulk metal precipitates allowed to settle from suspension in a settling pond prior to entering the bioreactor. This settling of precipitates reduces the metals load in the LSBR and results in a smaller metals load to be biologically treated in the reactor. The effluent from the LSBR is also sent to an oxic limestone drain to add alkalinity and oxygen to the water before discharge.

d. Discussion

The main differences between the SSBR and LSBR are the materials used for the support matrix for the bacteria and the nature of the carbon used as an energy source by the bacteria. A typical support matrix for a SSBR consists of a mixture of solid organic materials (i.e., hay, wood chips, etc.), manure for the establishment of a bacterial population, and limestone for addition of alkalinity. Theoretically, the bacteria will continue to reduce sulfate and form metal sulfide precipitates as long as there is sufficient limestone to ensure the incoming water is not too acidic for bacteria survival, and there is enough available organic material to facilitate bacterial growth. The most common operational problems encountered with the SSBR are; invasion of plants resulting in the introduction of oxygen to the subsurface treatment system, creation of preferential flow pathways due to compaction and low permeability of the organic matrix, inundation of acidity and metals loading due to storm surges, and system desaturation (URS, 2003). It is possible that a passive system could run unattended for decades without intervention due to the small amount of process sludge generated, relative to active systems. In addition, it should be standard practice that passive treatment systems be designed to treat for several decades without a major system overhaul or substrate reconstruction (Gusek, 2001); however this has not been the case to date.

The system design for a SSBR may incorporate measures intended to mitigate some of these challenges such as burying the reactor below the root zone for most native plants at the site or covering the reactor in oxygen impenetrable membranes, providing a surge pond to minimize fluctuations in flow rate and metals loading to the bioreactor, and providing a bypass when the flows are too high to mitigate with a surge pond. Due to one or more of the problems cited above, the longest reported run time for a SSBR has only been 3 to 4 years before significant modifications were required (URS, 2003).

Many of the difficulties typically associated with the SSBR systems have been overcome through implementation of LSBR systems. The use of rock for the solid support matrix in the LSBR for bacterial growth allows for sufficient pore space for infiltration of wastewater to the system and steady-state permeability conditions for metals precipitation without forming preferential flow pathways such as those that form in a SSBR. Constant permeability is not possible in a SSBR because the organic matrix breaks down over the course of systems operation as the carbon source is used by the bacteria and results in a collapse of the matrix and filling of the pore spaces. Over time, the system is unable to treat the design flow of wastewater, and the system must be shut down for removal and replacement of the substrate.

In a LSBR the pH of the water is raised with the addition of NaOH liquid to the influent water. The NaOH can be added and the water sent to a settling pond where the metal hydroxides (primarily iron) are allowed to precipitate out of solution before entering the bioreactor. This reduces the metals loading in a LSBR from what is seen in a SSBR where the limestone is an integral part of the solid matrix. The carbon source in a LSBR is a liquid alcohol carbon substrate, such as ethanol, which is added to the influent water after pH adjustment and eliminates the problems associated with the breakdown of carbon substrate as discussed above for a SSBR. An additional benefit of using a liquid carbon source in a freezing climate is that the alcohol will act to reduce or eliminate freezing of the system during winter operations and result in higher bacterial efficiency. A full scale LSBR has been successfully operated at the Leviathan Mine in California from 2003-2007 (Zamzow, 2008) and indicates that continued operation of the system is feasible into the future.

5. Bioreactor System Sensitivity to Changing Parameters

When designing a treatment system, it is important to consider how changing conditions may affect the performance and effectiveness of the system. The flow rate and water chemistry, namely metals loading and sulfate concentration, are important in designing a bioreactor system. It is necessary for sulfate to be present in excess of the total metals for successful metals removal in this type of system. The pH and temperature of the influent water are critical to the health of the bacterial population. If the pH is too acidic (<5.5) or the temperature too low, the bacteria are less likely to flourish. It has been found that the effectiveness of a bioreactor treatment system is lower in the winter months than in the warmer months (Johnson & Hallberg, 2002); however, for the LSBR, this temperature fluctuation would be less important due to the addition of alcohol acting as an anti-freeze in the influent water.

The flow rate will affect the dynamics of a bioreactor system. If the system should become overwhelmed due to a higher flow rate than the design allows for, the bacterial population will be unable to treat the metals load and a severe die-off of the bacterial population may be seen in the system. It is also possible that at too high a flow rate, a portion of the bacterial population may be washed out of the system. In either case the population may be unable to recover once the flow rate returns to normal and the bacterial population would therefore have to be reestablished. It is recommended that a holding pond be installed upstream of the bioreactor to minimize flow fluctuations during high flow events, and the system design should include a bypass should the holding pond have insufficient capacity to store high flows.

At a low sustained flow rate, some of the anaerobic substrate in a SSBR may become oxidized and precipitated metals may be flushed out of the system into the effluent. For the current design, it is suggested that in order to minimize the difficulties presented by flow variations, the system design should regulate flow through the use of a holding pond, and placement of a layer of inert gravel covering the SSBR to accommodate fluctuations in head (URS, 2003). To strike a balance between treating the high metals load to Daisy Creek present during the low flows, while accommodating higher flows when needed, the current system sizing is based on the average flows and water chemistry with a holding pond to provide surge protection to the system, and a system bypass to eliminate excessively large flows through the system. The SSBR design also contains a layer of inert gravel to further accommodate head fluctuations.

6. Bioreactor Bench-Scale Pilot Studies

The ability to size and design the proper bioreactor treatment system depends on the influent water quality, including flow rate and metals loading. Whether a SSBR or a LSBR is chosen, it is important to determine the operating conditions best suited for the particular AMD of concern. These factors are best determined through pilot studies. Through pilot testing, the determination of which carbon source is most effective under what pH conditions can be tested for each type of bioreactor, and the systems sensitivity to varying conditions may be verified. Using this information, combined with the cost analysis, the appropriate full scale treatment technology for the McLaren under-drains can be best evaluated.

It is assumed for purposes of the bench and pilot scale testing cost analyses that since this bioreactor technology has been established in the literature to be appropriate for the type of AMD from the McLaren drains, a laboratory-scale pilot test may be omitted and that a bench scale study would first be conducted. The bench scale testing can be performed in the laboratory or in the field; however, for this cost analysis, it is assumed that the testing for this phase would be performed in the laboratory to minimize travel and labor costs due to the location of the site. The bench scale testing would be conducted using the AMD collected in proper proportions from the three drains. At the bench scale, it is necessary to determine for a SSBR the mixture of organic materials best suited for this discharge as well as the optimal configuration; and for a LSBR, which liquid carbon source and dose is optimal for use by the bacteria. The ability to vary the water flow and quality for testing purposes are also much more controllable in a laboratory, prior to testing under field conditions. During the bench scale testing phase, the optimal pH can be determined and factors affecting the bioreactor such as temperature and flow fluctuations can be controlled and evaluated. The goal of the bench scale testing is to determine whether a SSBR or a LSBR would be the more appropriate technology for this site and to focus subsequent field scale pilot studies on one of these technologies.

The costs associated with laboratory scale testing include; raw materials necessary for each type of bioreactor including test units, carbon sources, limestone and/or chemical addition of NaOH; collection and shipment of source waters; setup and operating time for the laboratory technician; and sampling costs. Bench scale test units can typically be put together using items readily found in a hardware store such as trash cans and kiddie wading pools (Gusek, 2001). The assumed testing matrix includes a control reactor for each SSBR and LSBR, as well as one reactor for each SSBR and LSBR to study the effects of pH, temperature, flow variations and chemistry variations, for a total of 10 bioreactors.

The time required for inoculation and acclimatization of the bacteria can be on the order of weeks to months depending on the available carbon source and bacteria present. The bench scale testing design and setup is assumed to take approximately one week. The inoculation and establishment period for the bacteria is assumed to be six weeks. During this period, one effluent sample per week per reactor should be sufficient to determine the establishment of a suitable bacterial population in each bioreactor, and in addition one influent sample should be collected each week, for a total of 11 samples/week. Once the bioreactors are established, the variable factors can be changed to determine the dynamic responses of the system. It is estimated that this may take up to an additional ten weeks. The cost for labor includes a full one week set up time, one hour per week during the acclimatization period and three hours per week during the ten week run time with changing variables.

The following table (**Table 3**) details the estimated cost for a bench scale pilot test for water from the McLaren under-drains.

Table 3. Cost Estimate for Bench Scale Testing

Component	Unit	Unit Cost	Quantity	Total Cost
Bioreactor/Raw Materials	each	$150	10	$1,500
Labor	hour	$110	76	$8,360
Sampling	week	$2,200	16	$35,200
Total Bench Scale Costs				$45,060

7. Bioreactor Field-Scale Pilot Studies

Once the appropriate type of bioreactor is determined through the bench scale testing, a field pilot scale test would be suitable to get a better picture of how the actual operating conditions at the site may affect the bioreactor. The cost associated with each type of bioreactor is discussed and costs presented below.

If during bench scale testing, it is determined that a SSBR is the desired technology for the McLaren site, the costs associated with the setup and pilot testing in the field include raw materials delivered to the site, travel to the site, shipping of miscellaneous items, mobilization/demobilization, chemicals, sampling and labor. For the field scale pilot test for a SSBR, AMD Treat software Version 4.1c was used for sizing and preparation of the cost estimate. Results from AMD Treat and system costs are found in **Appendix B**.

The assumptions for the SSBR field scale pilot testing system are as follows:

- The water chemistry used for sizing was taken directly from the mean values recorded during site sampling from 2004-2007 (**Table 1**),
- Flow rate is 2 gallons per minute,
- All raw materials for the system are delivered directly to the site,
- System setup requires two technicians, two weeks to install,
- Acclimatization time for the bacteria is six weeks from startup,
- System setup would commence in early July and would run through September (approximately 10 weeks run time after acclimatization),
- Sampling would be done weekly from startup for both influent and effluent and require one full day each week to complete,
- SSBR sizing from *AMDTreat* Software
- SSBR costs obtained from *RSMeans* and experience,
- Travel to the site for sampling is from the Tetra Tech Bozeman office,
- Freezing will not be an issue for the duration of the testing and therefore the reactor will be above ground,
- Once the system is set up, there is no additional maintenance or modification required for the duration of the testing,
- Some engineering would be required for system design, 10 percent of total is assumed.

Table 4. Cost Estimate for Field Pilot Scale SSBR

Component	Unit	Unit Cost	Quantity	Total Cost
Organic/Limestone Fill for Bed	Ls	$6,871	1	$6,871
Shipping/Delivery of Materials	ls	$2,500	1	$2,500
Bed Liner	ls	$2,587	1	$2,587
Miscellaneous Building Materials	ls	$1,500	1	$1,500
Labor	hour	$110	288	$31,680
Travel (mileage)	week	$135	18	$2,430
Estimated Per Diem	day	$112	18	$2,016
Sampling	week	$2200	16	$35,200
Sub Total Field Pilot Scale Costs SSBR				$84,784
Engineering	ls	$8,234	1	$8,478
Total Field Pilot Scale Costs SSBR				$93,262

The assumptions made for determining sizing and cost for a pilot scale LSBR are as follows:

- The residence time in the reactor is 2 days (Zamzow, 2008),
- The water chemistry used for sizing was taken directly from the mean values recorded during site sampling from 2004-2007 (**Table 1**),
- Flow rate is 2 gallons per minute,
- Bed porosity is 35 percent,
- All raw materials for the system are delivered directly to the site,
- System setup requires two technicians two weeks to install,
- Acclimatization time for the bacteria is six weeks from startup,
- System setup would commence in early July and would run through September (approximately 10 weeks run time after acclimatization),
- Sampling would be done weekly from startup for both influent and effluent,
- LSBR costs obtained from *RSMeans* and experience,
- Travel to the site for sampling is from the Tetra Tech Bozeman office,
- Freezing will not be an issue for the duration of the testing and therefore the reactor will be above ground,
- Once the system is set up, there is no additional maintenance or modification required for the duration of the testing,
- Some engineering would be required for system design, 10 percent of total is assumed.

Table 5. Cost Estimate for Field Pilot Scale LSBR

Component	Unit	Unit Cost	Quantity	Total Cost
Rock Fill for Bed	cy	$25	82	$2,050
Shipping/Delivery of Materials	ls	$2,500	1	$2,500
Bed Liner	sy	$3.00	110	$330
Miscellaneous Building Materials	ls	$1,500	1	$1,500
Chemical Costs	ls	$450	1	$450
Labor	hour	$110	288	$31,680
Travel (mileage)	week	$135	18	$2,430
Estimated Per Diem	day	$112	18	$2,016
Sampling	week	$2200	16	$35,200
Sub Total Field Pilot Scale Costs LSBR				$78,156
Engineering	ls	$7,810	1	$7,816
Total Field Pilot Scale Costs LSBR				$85,972

8. Full Scale Bioreactor Design Considerations and Cost Analysis

Several considerations must be taken into account for a full scale design of a bioreactor treatment system. The water quality and flow rate data are essential for design of either type of SBR system. In addition, the location must allow for a large area to accommodate the footprint of the system complete with holding pond, bioreactor unit and oxic limestone drain. It is also necessary to consider a settling pond for a LSBR system. The site near the McLaren drains is relatively steep at the location where they currently discharge. The slope decreases west of the drains, down towards the valley bottom and this is likely the best location for placement of the bioreactor system. The groundwater tends to be shallow along the hillside south of the sub-drain discharge points and as one moves closer to the tributary drainage to Daisy Creek, and is generally deeper west of the drains and north of the tributary drainage, again down towards the valley bottom; however while this valley bottom area may be a possible location for sighting of the facility, a detailed analysis of available land and water levels must be considered during the project engineering design phase.

The following general assumptions are made for either type of substrate bioreactor (SBR):

- All bulk fill materials are delivered directly to the site,
- Subsurface drain flows are combined at the existing discharge locations and piped downhill to the holding pond for the SBR,
- System flow rate is 22 gpm based on combined mean flow data,
- A geotextile will cover the holding pond and SBR to minimize infiltration of runoff, precipitation and snowmelt and to minimize oxygen infiltration,
- The holding pond, SBR and oxic limestone drain are lined with geotextile to minimize water loss,
- The holding pond hydraulic retention time is 24 hours at design flow,
- The holding pond will be filled with geochemically inert gravel so that pond can be buried,
- The holding pond and SBR will be buried and covered with 4 feet of soil to minimize freezing,
- Soil cover for the holding pond and SBR will be obtained locally, perhaps from the borrow area,
- The system would not require maintenance and sampling would be unnecessary during the winter weather months.
- Conservation of mass upon mixing of the drains is assumed,

Solid Substrate Bioreactor Costs

As discussed previously, the location of the discharge of the drains is in an area which is not conducive for placement of a bioreactor treatment system. It is assumed that a single pipe conveying the combined flow from the drains would extend from the existing drain outlets approximately 400 feet down slope to the west. The design allows for piping and associated valving for water conveyance to the system. The combined drain flow will feed the front end of the reactor system at the lined and covered holding pond (**Figure 5**), which will serve to minimize flow fluctuations into the SSBR. The influent will flow from the holding pond to the SSBR, which consists of a layer of geochemically inert gravel at the top to accommodate head fluctuations and at the bottom to minimize metals plugging of the piping at the influent to the SSBR. The SSBR will be lined and consist of a mix of limestone, organic substrate and manure. The limestone will add alkalinity and raise the pH, the manure is incorporated to provide an inoculum of bacteria necessary for sulfate reduction, and the organic substrate is the matrix which provides the carbon energy source and support for the bacteria. It is assumed that the organic substrate is a mixture of hay and wood chips, although the optimal material and mixture would be determined during the bench scale testing. The effluent from the SSBR is directed to an oxic limestone drain (OLD) before discharging to Daisy Creek. The system is fitted with a bypass from the holding pond to the discharge at the OLD for flows which may not be accommodated by the treatment system at the highest flow rates.

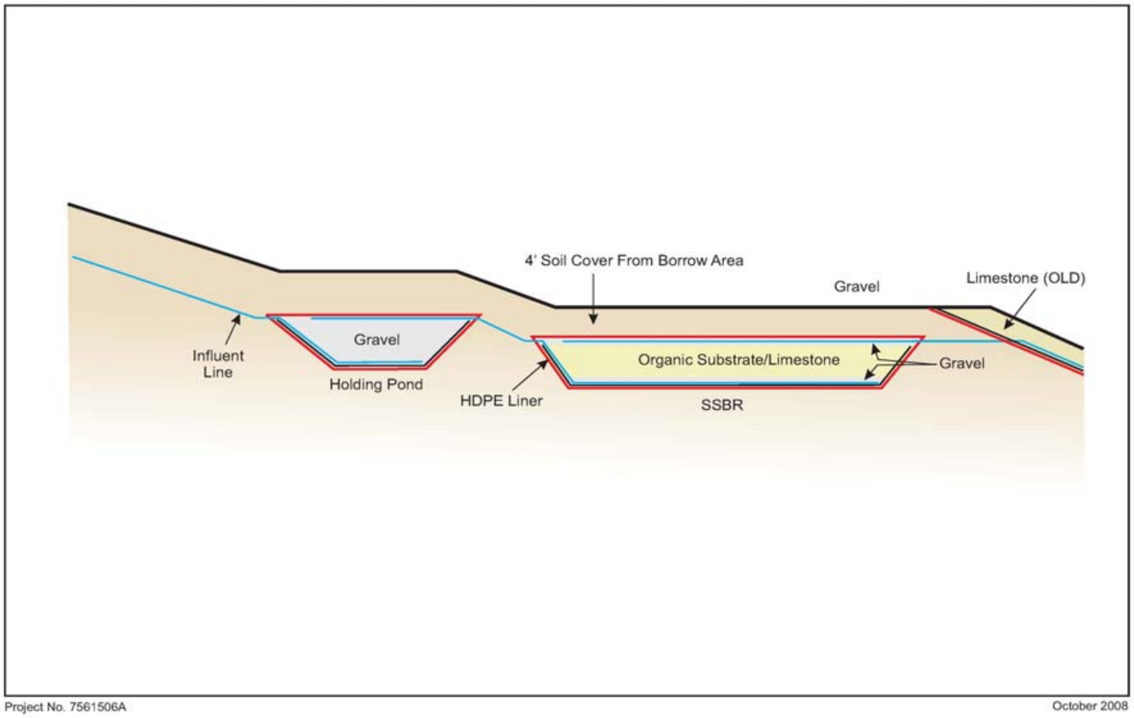


Figure 5
Solid Substrate Bioreactor (SSBR) Schematic
Holding Pond-Oxic Limestone Drain (OLD)

The total area required for the SSBR is just over 1 acre for the holding pond and the SSBR and a 100 foot long channel for the OLD.

It has been reported that sulfate concentrations typically do not drop below a few hundred milligrams per liter (mg/L) in a sulfate reducing bioreactor (URS, 2003). The measured sulfate in the combined drains is 804 mg/L. It is assumed that the sulfate reduction is 500 mg/L for purposes of design. The longest operating period for an SSBR has been reported to be only three or four years without requiring replacement of the organic substrate (URS, 2003). The expected life of the SSBR for this study is assumed to be five years before cell replacement is necessary. The present worth analysis for system operations and maintenance was assessed assuming a 20 year life for the project.

The SSBR was sized using *AMDTreat* Software Version 4.1c and cost estimates that would be expected for this type of project are provided using *AMDTreat*, *RSMeans* Building Construction Data for 2008 and project experience as detailed in Appendix C. A cost summary presented below in **Table 6**.

Table 6. Capital and Operational Cost Estimate Summary for Solid Substrate Reactant Bioreactor (SSBR) for Typical System

Total Direct Capital Costs	$329,632
Total Indirect Capital Costs	$144,682
O&M Costs (Present Worth)	$1,277,955
Total	**$1,752,270**

Experience at the New World site has proven that construction costs commonly exceed those typically expected. As a result, a comparative cost analysis was performed using construction cost data from former projects at the New World site. The cost analysis using information from the New World McLaren Pit Response Action Construction Report (Civil Consulting Services, PLLC, 2006) and the Selective Source Response Action Construction Report (Civil Consulting Services, PLLC, 2006) is presented in Appendix E. The changes from the above cost analysis are indicated in red. A summary of the project costs using this data is presented in **Table 7.**

Table 7. Capital and Operational Cost Estimate Summary for Solid Substrate Reactant Bioreactor (SSBR) Using New World Cost Data

Total Direct Capital Costs	$543,642
Total Indirect Capital Costs	$272,189
O&M Costs (Present Worth)	$1,623,790
Total	**$2,439,622**

Liquid Substrate Bioreactor Costs

Again, it is assumed that a single pipe conveying the combined flow from the drains would extend from the existing drain outlets approximately 400 feet downhill to the west. The design allows for piping and associated valving for the conveyance of water to the treatment system. The combined drain flow will feed the front end of the reactor system at the lined holding pond (**Figure 6**), which will serve to minimize flow fluctuations into the LSBR. The sodium hydroxide (NaOH) will be added to the effluent from the holding pond to increase the pH of the water to sustain the bacterial community and provide conditions conducive for bulk metals precipitation. The freezing temperature of 20% NaOH is -15°F. It is likely that the temperature at the McLaren site will reach temperatures lower than this during the winter months and a solar system or propane tank would be necessary to run heat tape to keep the solution from freezing and to run the chemical injection pump and has been included in the cost analysis. It is possible to design the system, such that should a problem occur with the chemical feed system, the operator of the site would be notified.

The holding pond effluent is directed into the lined settling pond. The settling pond is sized for a 14 day hydraulic residence time for metals precipitation, and will be buried to provide frost protection and lined and covered to minimize in/exfiltration. It is assumed that both ponds will be covered with four feet of soil cover from the borrow area at the site. The pH adjusted water will flow from the settling pond into the LSBR and the carbon source, assumed to be ethanol, added just before the flow enters the reactor. The reactor is lined and filled with a mixture of smaller and larger rock to balance the need for greater surface area while providing sufficient porosity to prevent plugging. The design also incorporates manure for inoculation of bacteria necessary for sulfate reduction. The hydraulic residence time for the LSBR is two days.

The treated water from the LSBR flows through a lined oxic limestone drain to further increase the pH and to add oxygen back into the discharge prior to discharging to Daisy Creek. The system is fitted with a bypass from the holding pond to the discharge at the OLD for flows which may not be accommodated by the treatment system at the highest flow rates. The expected life of the LSBR is assumed to be fifteen years before cell replacement is necessary. The present worth analysis for system operations and maintenance was assessed assuming a 20 year life for the project.

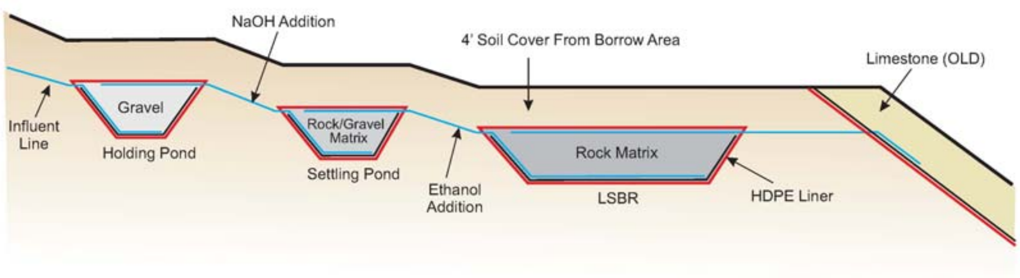


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Figure 6
Liquid Substrate Bioreactor (LSBR) Schematic
Holding Pond-Settling Pond-Oxic Limestone Drain (OLD)

The total area required for the SSBR is just over 2 acres for the holding pond, settling pond and the LSBR and a 100 foot channel for the OLD.

Cost estimates that would be expected for this type of project are provided using *AMDTreat*, *RSMeans* Building Construction Data for 2008 and project experience as provided in **Appendix D**. A cost summary is presented below in **Table 8**.

Table 8. Capital and Operational Cost Estimate Summary for Liquid Substrate Reactant Bioreactor (LSBR) for Typical System

Total Direct Capital Costs	$476,917
Total Indirect Capital Costs	$194,999
O&M Costs (Present Worth)	$544,817
Total	**$1,216,733**

Experience at the New World site has proven that construction costs commonly exceed those typically expected. As a result, a comparative cost analysis was performed using construction cost data from former projects at the New World site. The cost analysis using information from the New World McLaren Pit Response Action Construction Report (Civil Consulting Services, PLLC, 2006) and the Selective Source Response Action Construction Report (Civil Consulting Services, PLLC, 2006) is presented in Appendix E. The changes from the above cost analysis are indicated in red. A summary of the project costs using this data is presented in **Table 9.**

Table 9. Capital and Operational Cost Estimate Summary for Liquid Substrate Reactant Bioreactor (LSBR) Using New World Cost Data

Total Direct Capital Costs	$1,177,089
Total Indirect Capital Costs	$492,664
O&M Costs (Present Worth)	$602,807
Total	**$2,272,559**

Comparison of SSBR and LSBR

The tables above indicate that while the capital cost of a solid substrate bioreactor is less than that of a liquid substrate bioreactor, the operations and maintenance costs result in greater overall project expenditure. This is due mainly to the breakdown of the organic matrix in the SSBR and the requirement of replacement of the entire bed at intervals assumed to be every five years. The cost information provided in the construction reports for the New World site indicate that the costs associated with construction are considerably more than what is expected for this type of project. The analyses indicate that the cost for the SSBR may be 140% and the LSBR almost 190% of what was determined using standard cost estimate data.

Summary and Comparison of Various Cost Estimates for SSBR and LSBR

Table 10 compares the cost estimates for the construction of the SSBR and LSBR prepared for this report, using New World Cost data (revised for the remote New World location and under more extreme climatic conditions), vs. those generated in the original EE/CA for the same site conditions (Tetra Tech 2006).

Table 10. Comparison of Cost Estimates.

	SSBR		LSBR	
Cost	**2005 EE/CA Costs**	**This Report New World Cost Data**	**2005 EE/CA Costs**	**This Report New World Cost Data**
Direct Capital	$573,046	$543,642	$865,525	$1,177,089
Indirect Capital	$315,175	$272,189	$471,089	$492,664
Total Capital	$888,221	$815,831	$1,327,614	$1,669,733
O & M Cost	$2,350,000	$1,623,790	$3,535,485	$602,807

When comparing costs in **Table 10**, it is important to note that for the EE/CA, cost analysis were developed for a system designed to treat an average flow of 35 gallons per minute that included flow from the combined McLaren Adit as well as the McLaren under-drains; whereas, the costs developed for this report were for a system designed for an average flow of 22 gallons per minute from the under drains only. Overall, direct and indirect costs from the two reports for the SSBR are reasonably similar; however, in the case of the LSBR the cost generated for this report are slightly higher.

Operational costs (**Table 10**) for the LSBR in the EE/CA assumed replacement of the entire system every 10-years, whereas; in this report the cost of the LSBR using adjusted New World costs assumed replacement of the liquid substrate portion of system only every 15-years. Therefore, the reason for the rather large discrepancy in operational and maintenance cost results principally from the frequency of replacement of the liquid substrate and because the costs developed for both systems in this report did not call for replacement of the piping supply portion of the system, replacement of the gravel/rock materials contained in the holding or settling ponds, or site specific sampling costs, whereas the EE/CA did. In addition, bench and pilot scale testing costs for this report are not included in the overall cost of either the SSBR or the LSBR in **Tables 6 through 10**.

Expected Improvement in Water Quality at DC-2

The percent reduction in metals concentration for the LSBR treatment were taken from the results from the Leviathan Mine (EPA, 2006) and for the SSBR from the results of the Golinsky Mine (Golder Associates, 2007), and are presented in **Table 11**.

Table 11. Removal Efficiencies for Metals Concentrations

Parameter	SSBR Removal (%)	LSBR Removal (%)
Aluminum	99.0	99.0
Cadmium	99.0	65.3
Copper	99.0	99.0
Iron	92.0	98.0
Lead	90.0*	35.8
Manganese	10.0*	10.0*
Zinc	96.0	99.0

*Removal efficiencies assumed

While the results indicate a significant overall metals reduction from the McLaren under-drains (**Figure 7**), there is still a major contribution of metals loading from other sources. The total overall metals loading to DC-2 before treatment from the under-drains is 22 percent. This contribution drops to a total metals contribution post-SSBR treatment to 2.2 percent and post-LSBR treatment to 0.8 percent. While this reduction shows that the bioreactor treatment system is both appropriate and successful at metals removal from this type of discharge, the overall results indicate that the total reduction in metals loading to Daisy Creek will not be impacted significantly by implementing this technology.

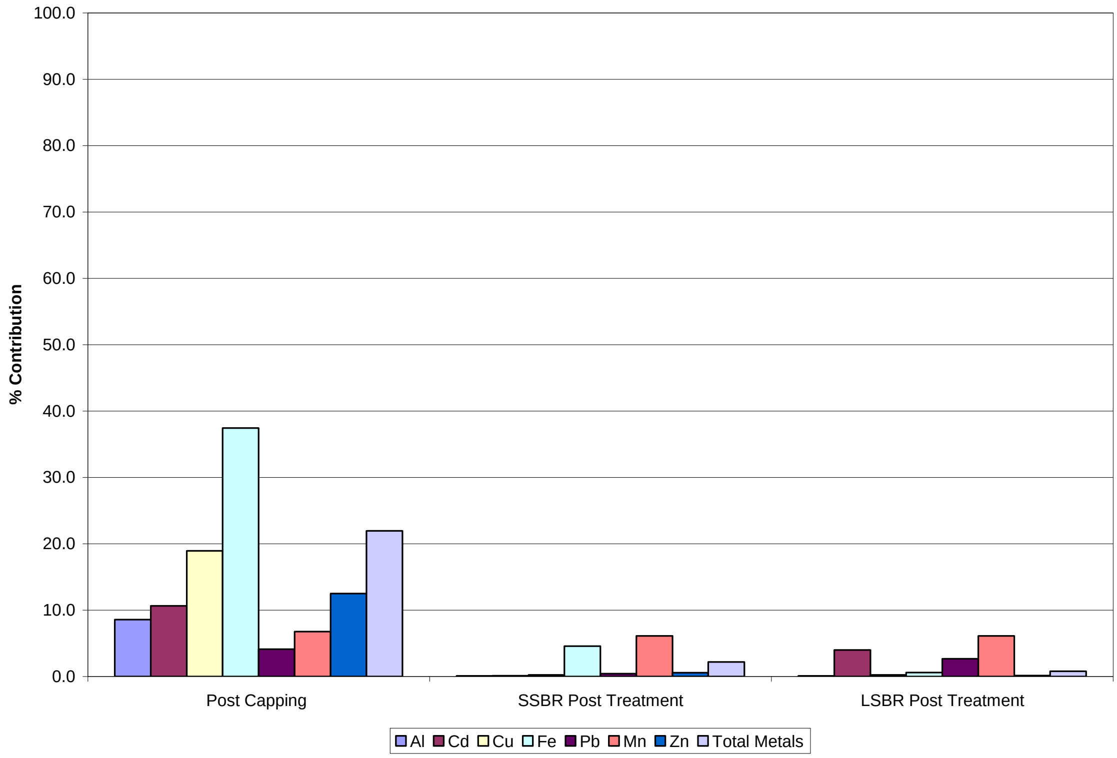

Figure 7. Total Metals Percent Contribution to DC-2 Before and After Treatment

The impact to the DC-2 sampling station after biological treatment is presented in **Figure 8**. The total metals loading from all sources including the McLaren under-drains to DC-2 prior to bioreactor treatment of the McLaren under-drains is 3,653 kilograms per month (kg/month). After SSBR treatment of the McLaren under-drains, the total metals contribution from all sources to DC-2 drops to 2,915 kg/month, an overall reduction in loading of only 20.2 percent. After LSBR treatment of the McLaren under-drains, this value drops to 2,873kg/month total metals loading resulting in an overall total metals reduction to DC-2 of 21.4 percent.

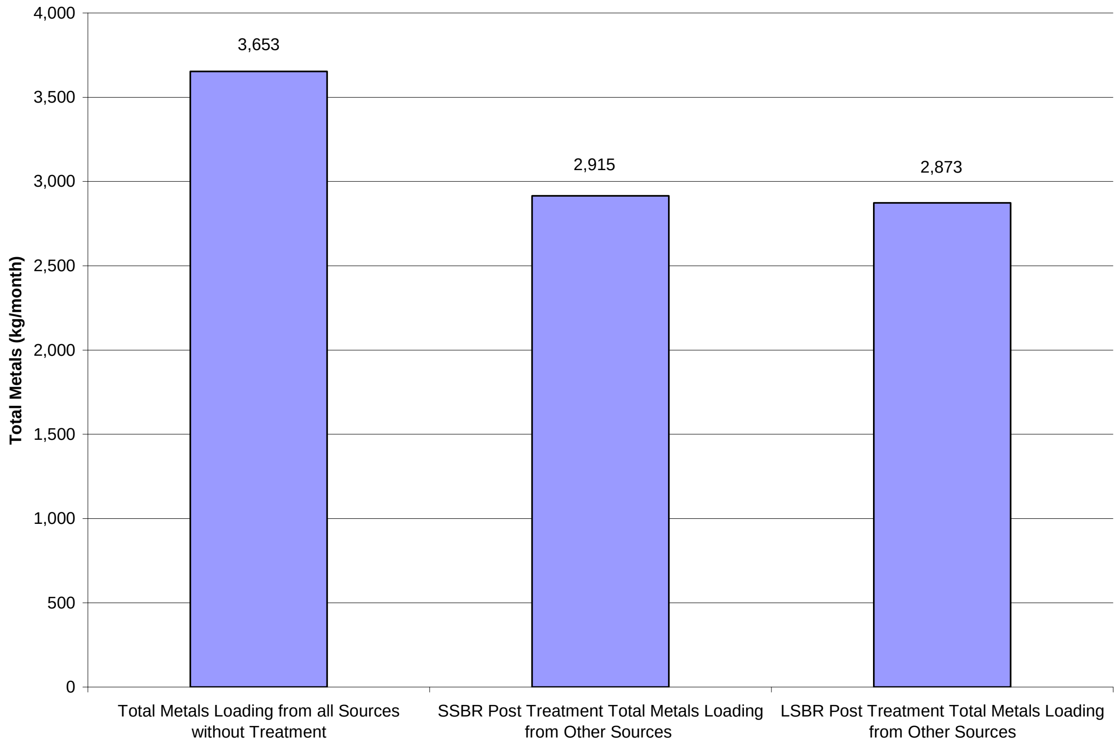

Figure 8. Total Metals Loading to Daisy Creek (DC-2)

The ideal situation of meeting or attempting to meet the Circular WQB-7 for aquatic life standards is unrealistic through treatment of the McLaren under-drain discharges. **Table 12** indicates the expected combined water quality from all sources to DC-2 before and after treatment and compares these values to the standards.

Table 12. Water Quality Standards[1] and Expected Water Quality After Treatment

Parameter	WQB-7 Chronic Aquatic Life Standard (Calculated for Hardness = 50 mg/L)	WQB-7 Chronic Aquatic Life Standard (Calculated for Hardness = 100 mg/L)	Mean Measured Concentration at DC-2 without Treatment	Estimated Concentration After SSBR Treatment[2]	Estimated Concentration After LSBR Treatment[2]
Concentration (mg/L)					
Al	0.087[3]	0.087	8.1	7.4	7.4
Cd	0.00016	0.00027	0.0026	0.0023	0.0025
Cu	0.005	0.009	1.82	1.48	1.48
Fe	1	1	8.88	5.82	5.59
Pb	0.001	0.003	0.004	0.003	0.003
Mn	0.05[4]	0.05	1.33	1.32	1.32
Zn	0.07	0.012	0.38	0.33	0.33

(1) Values as Reported in Tetra Tech EE/CA, 2006.
(2) Based on removal efficiencies presented in Table 8.
(3) Aluminum standard is based on dissolved concentrations and is applicable to water with pH between 6.6 to 9.0.
(4) Manganese standard is a secondary MCL based on aesthetic qualities.

The results clearly indicate that the $2.44 million and $2.28 million expenditures for the SSBR or LSBR system, respectively, would do little to bring the water quality in Daisy Creek near the values, which would make a significant impact to the water quality. The most to be gained from implementation of a bioreactor treatment system would be some reduction in metals loading resulting in modest improvement in the overall water quality to the creek.

9 References Cited

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Zamzow, 2008. Personal communication to Mary Beth Marks, US Forest Service. March

Appendix A

SURFACE WATER SUMMARY FOR McLAREN PIT DRAINS																																		
				Anions (mg/L)									Cations (mg/L)													Total Recoverable Metals (mg/L)								
						Alkalinity as																												
Station Name	Sample Date	Flow Rate (cfs)	Flow Rate (gpm)	Acidity as CaCO3	CaCO3 Flag	HCO3	HCO3 Flag	Total CaCO3	CaCO3 Flag	Chloride	Cl Flag	Sulfate	Calcium	Ca Flag	Hardness as CaCO3	Magnesium	Mg Flag	Potassium	K Flag	Sodium	Na Flag	Field SC (umhos/cm)	Field pH (s.u.)	Total Suspended Solids (mg/L)	TSS Flag	Total Metals	Aluminum	Cadmium	Copper	Iron	Lead	Manganese	Zinc	Zinc Flag
DCSW-101	7/13/2004	0.043	19.30	473		1	<	1	<	6		628	32		125	11		2		2		1270	2.9	2	<	166.9	29.3	0.01	15.8	117	0.012	3.08	1.7	
	8/10/2004	0.035	15.71	440		1	<	1	<	4		560	32		125	11		2		2		1140	3	29		150.0	26	0.0094	13.5	106	0.009	2.91	1.59	
	10/6/2004	0.013	5.83	586	JF%	1	<	1	<	8		686	44		176	16		2		3		1550	3	38	JF	235.9	34.3	0.016	20.7	173	0.007	5.1	2.82	
	6/29/2005	0.05481	24.60	548		1	<	1	<	3		736	37	d	142	12	d	2	d	3	d	1259	2.7	2		201.2	33.7	0.011	15.8	147	0.014	2.81	1.85	
	9/27/2005	0.0074	3.32	593		1	<	1	<	3		748	46	d	185	17	d	2	d	3	d	1415	2.73	3		250.5	31.5	0.012	14.2	199	0.01	3.64	2.09	
	6/27/2006	0.046	20.65	392		0		1	<	1		515	32		114	10		2		2		1198	4.36	10		148.9	26.1	0.0082	13.5	105	0.012	2.74	1.5	
	9/27/2006	0.005	2.24	577		1	<	1	<	1		797	39	d	175	17	d	1	d	3	d	1374	2.93	19	JF%	225.5	29	0.01	13.2	178	0.005	3.41	1.87	
	9/27/2006	--	--	584		1	<	1	<	1		826	43	d	181	18	d	1	d	3	d	--	--	13	JF%	230.9	30.6	0.01	14	181	0.005	3.51	1.79	
	7/18/2007	0.037	16.61	350		1	<	1	<	1		450	27		104	9		2		3		1021	2.8	30		128.5	23.3	0.0069	9.91	91.6	0.007	2.38	1.29	
	9/18/2007	0.0088	3.95	417		1	<	1	<	1		607	40		155	14		2		3		1134	3.04	7		176.1	25.4	0.01	12.6	133	0.006	3.34	1.77	
	7/15/2008	0.0575	25.81	406		1	<	1	<	1		555	35		122	10		2		2				1	<	133.3	25.5	0.0074	10.5	93.7	0.016	2.28	1.32	
	8/12/2008	0.0362	16.26																															
	8/20/2008	0.0321	14.40																															
		Min	2.24	350		0		1		1		450	27		104	9		1		2		1021	2.70	1		128.4	23.3	0.007	9.9	92	0.005	2.28	1.29	
n*=	11	Mean	14.06	488		1		1		3		646	37		146	13		2		3		1262	3.05	14		186.2	28.6	0.010	14.0	139	0.009	3.20	1.78	
		Max	25.81	593		1		1		8		826	46		185	18		2		3		1550	4.36	38		262.0	34.3	0.016	20.7	199	0.016	5.10	2.82	
		Avg High Flow	21.39	441		0.8		1		2.8		582	32		121	10.5		2		2.5		1187	3.19	11.0		161.4	28.1	0.009	13.8	115	0.011	2.75	1.59	
		Avg Low Flow	3.84	543		1.0		1		3.3		710	42		173	16.0		1.8		3		1368	2.93	16.8		222.0	30.1	0.012	15.2	171	0.007	3.87	2.14	
DCSW-102	7/13/2004	0.023	10.32	646		1	<	1	<	4		862	43		186	19		1	<	3		1710	2.6	2	<	201.8	33.5	0.017	19	142	0.002	4.62	2.69	
	8/10/2004	0.013	5.83	496		1	<	1	<	3		641	34		155	17		1	<	2		1360	2.6	4		132.4	23.2	0.011	13.8	90	0.001	3.47	1.95	
	10/6/2004	0.001	0.45	899	JF%	1	<	1	<	30		1160	59		275	31		1	<	3		2010	2.7	4	JF	341.3	39.1	0.017	27.7	265	0.002	6.31	3.18	
	6/29/2005	0.04184	18.78	745		1	<	1	<	2		1030	58	d	240	23	d	1	d<	2	d	1874	2.5	1	<	259.3	42.2	0.029	19.6	187	0.005	6.22	4.29	
	9/27/2005	0.0001	0.04	558		1	<	1	<	4		791	54	d	234	24	d	1	d<	3	d	1613	2.55	4		193.7	24.8	0.016	15.9	146	0.009	4.69	2.33	
	6/27/2006	0.033	14.81	588		0		1	<	1		771	52		192	18		1	<	2		1833	4.17	3		193.4	32.5	0.015	18.5	135	0.002	4.76	2.66	
	9/27/2006	0.0001	0.04	540		1	<	1	<	1	<	876	47	d	220	25	d	1	d<	3	d	1537	2.69	2	JF%	160.4	24.2	0.012	14.2	116	0.002	4.04	1.97	
	6/13/2007	0.052	23.34	665		1	<	1	<	1		875	83		244	20		2		3		1733	2.8	4	<	224.2	31.4	0.019	16.4	168	0.004	4.88	3.49	
	7/18/2007	0.011	4.94	455		1	<	1	<	1		595	40		162	15		1		3		1522	2.59	1	<	139.4	24.3	0.011	13.3	96.3	0.001	3.54	1.96	
	9/18/2007	0.00004	0.02	565		1	<	1	<	2		828	52		235	24		1	<	3		1704	2.65	1	<	181.8	27.1	0.012	16.2	132	0.002	4.38	2.13	
	7/15/2008	0.03420	15.35	609		1	<	1	<	2		852	60		218	21		1		2				1	<	173.2	34.4	0.02	15.2	115	0.003	5.22	3.32	
	8/12/2008	0.00869	3.90																															
	8/20/2008	0.00579	2.60																															
		Min	0.02	455		0		1		1		595	34		155	15		1		2		1360	2.50	1		131.9	23.2	0.011	13.3	90	0.001	3.47	1.95	
n=	11	Mean	7.73	615		1		1		5		844	53		215	22		1		3		1690	2.79	2		200.1	30.6	0.016	17.3	145	0.003	4.74	2.72	
		Max	23.34	899		1		1		30		1160	83		275	31		2		3		2010	4.17	4		345.5	42.2	0.029	27.7	265	0.009	6.31	4.29	
		Avg High Flow	16.52	609		0.8		1		2.0		815	48		195	18.8		1		2.5		1735	2.97	1.8		198.5	33.1	0.018	17.6	140	0.003	4.79	2.90	
		Avg Low Flow	0.14	641		1.0		1		9.3		914	53		241	26.0		1.0		3		1716	2.65	2.8		219.3	28.8	0.014	18.5	165	0.004	4.86	2.40	
DCSW-103	7/13/2004	0.005	2.24	2060		1	<	1	<	105		2920	118		7.23	104		1	<	5		3350	2.5	5		802.2	108	0.026	44.6	632	0.002	13.3	4.24	
	8/10/2004	0.004	1.80	1570		1	<	1	<	18		2220	108		591	78		1	<	5		2730	2.5	10	<	502.7	88.1	0.026	34.8	363	0.002	12.5	4.29	
	10/6/2004	0.002	0.90	1920	JF%	1	<	1	<	2		2550	127		745	104		1	<	5		3200	2.6	2	JF<	682.7	110	0.023	46.1	505	0.002	16.7	4.84	
	6/29/2005	0.00401	1.80	2290		1	<	1	<	30		3050	127	d	750	105	d	1	d<	5	d	3530	2.4	1		866.8	122	0.032	47.3	678	0.004	14.2	5.25	
	9/27/2005	0.0007	0.31	1340		1	<	1	<	4		1910	117	d	642	85	d	1	d<	5	d	2897	2.42	6		475.8	76.6	0.028	31	352	0.003	11.8	4.33	
	6/27/2006	0.004	1.80	1510		0		1	<	1		2210	120		619	83		1	<	5		3264	4.13	9		568.8	81.1	0.024	36.1	434	0.002	13.1	4.44	
	9/27/2006	0.002	0.90	1340		1	<	1	<	1		1980	129	d	688	89	d	1	d<	5	d	2711	2.62	2	JF%<	437.9	77.3	0.022	29	315	0.002	12.5	4.07	
	7/18/2007	0.003	1.35	1260		1	<	1	<	1		1760	113		570	70		1	<	5		2674	2.44	1	<	437.3	76.1	0.022	30.4	316	0.003	10.7	4.07	
	9/18/2007	0.0015	0.67	1360		1	<	1	<	3		2220	117		686	84		1	<	5		2940	2.59	2	<	508.5	87.9	0.023	29.8	374	0.004	12.7	4.09	
	7/15/2008	0.0029	1.31	1500		1	<	1	<	3		2080	108		553	72		1	<	4				1	<	480.1	89.9	0.023	29.3	347	0.002	9.95	3.92	
	8/12/2008	0.0025	1.11																															
	8/20/2008	0.0029	1.30																															
		Min	0.31	1260		0		1		1		1760	108		7	70		1		4		2674	2.40	1		434.0	76.1	0.022	29.0	315	0.002	10.0	3.92	
n=	10	Mean	1.29	1615		1		1		17		2290	118		585	87		1		5		3033	2.69	4		576.3	91.7	0.025	35.8	432	0.003	12.7	4.35	
		Max	2.24	2290		1		1		105		3050	129		750	105		1		5		3530	4.13	10		869.3	122.0	0.032	47.3	678	0.004	16.7	5.25	
		Avg High Flow	1.70	1805		0.8		1		34.8		2600	121		516	94.0		1		5.0		3271	2.91	4.3		686.6	99.8	0.026	39.5	530	0.003	13.33	4.51	
		Avg Low Flow	0.61	1465		0.8		1		2.0		2050	120		521	87.0		1.0		5		2871	2.51	2.8		507.6	85.0	0.024	33.8	372	0.002	12.74	4.29	

SURFACE WATER SUMMARY FOR McLAREN PIT DRAINS

Station Name	Sample Date	Flow Rate (cfs)	Flow Rate (gpm)	Anions (mg/L) Acidity as CaCO3	CaCO3 Flag	Alkalinity as HCO3	HCO3 Flag	Alkalinity as Total CaCO3	CaCO3 Flag	Chloride	Cl Flag	Sulfate	Cations (mg/L) Calcium	Ca Flag	Hardness as CaCO3	Magnesium	Mg Flag	Potassium	K Flag	Sodium	Na Flag	Field SC (umhos/cm)	Field pH (s.u.)	Total Suspended Solids (mg/L)	TSS Flag	Total Recoverable Metals (mg/L) Total Metals	Aluminum	Cadmium	Copper	Iron	Lead	Manganese	Zinc	Zinc Flag
Combined Flow for DCSW-101, -102, 103	7/13/2004	0.071	31.87	640.8		1.0		1.0		12.3		865.2	41.6		136.5	20.1		1.6		2.5		1559.0	2.8	2.2		223.0	36.2	0.013	18.9	161.4	0.008	4.3	2.2	
	8/10/2004	0.052	23.34	540.9		1.0		1.0		4.8		707.9	38.3		168.3	17.7		1.7		2.2		1317.3	2.9	21.3		172.8	30.1	0.011	15.2	121.8	0.006	3.8	1.9	
	10/6/2004	0.016	7.18	772.3		1.0		1.0		8.6		948.6	55.3		253.3	27.9		1.8		3.3		1785.0	2.9	31.4		298.4	44.1	0.017	24.3	220.3	0.006	6.6	3.1	
	6/29/2005	0.10066	45.18	699.3		1.0		1.0		3.7		950.4	49.3		207.0	20.3		1.5		2.7		1605.1	2.6	1.5		251.9	40.8	0.019	18.6	184.8	0.010	4.7	3.0	
	9/27/2005	0.0082	3.68	656.3		1.0		1.0		3.1		847.7	52.2		224.6	22.9		1.9		3.2		1543.9	2.7	3.3		269.0	35.3	0.013	15.7	211.4	0.009	4.3	2.3	
	6/27/2006	0.083	37.25	523.8		0.0		1.0		1.0		698.5	44.2		169.3	16.7		1.6		2.1		1550.0	4.3	7.2		186.8	31.3	0.012	16.6	132.8	0.008	4.0	2.1	
	9/27/2006	0.0071	3.19	791.4		1.0		1.0		1.0		1131.4	64.5		320.1	37.4		1.0		3.6		1752.9	2.8	14.0		284.4	42.5	0.013	17.7	215.7	0.004	6.0	2.5	
	7/18/2007	0.051	22.89	426.2		1.0		1.0		1.0		558.3	34.9		143.9	13.9		1.7		3.1		1226.3	2.7	22.0		149.0	26.6	0.009	11.8	105.8	0.005	3.1	1.6	
	9/18/2007	0.01034	4.64	554.4		1.0		1.0		1.3		841.8	51.2		232.3	24.2		1.9		3.3		1398.2	3.0	6.3		224.4	34.5	0.012	15.1	168.0	0.006	4.7	2.1	
	7/15/2008	0.0946	42.47	513.1		1.0		1.0		1.4		709.4	46.3		170.0	15.9		1.6		2.1				1.0		158.4	30.7	0.012	12.8	109.2	0.011	3.6	2.1	
	8/12/2008	0.0474	21.27																															
	8/20/2008	0.0408	18.30																															
		Min	2.58	461.7		0.0		1.0		1.0		610.8	36.9		92.6	16.5		1.0		2.2		1224.9	2.7	1.0		165.7	29.7	0.009	12.3	113.8	0.005	3.2	1.6	
		Mean	23.07	593.5		0.9		1.0		4.2		804.3	46.9		193.4	20.1		1.5		2.8		1504.4	2.9	9.6		212.6	32.8	0.013	16.3	157.0	0.007	4.2	2.2	
		Max	51.39	806.1		1.0		1.0		22.2		1074.8	66.4		250.5	27.7		2.0		3.1		1845.4	4.3	21.3		326.4	41.7	0.023	25.0	249.9	0.012	6.2	3.6	
		Avg High Flow	39.61	569.2		0.8		1.0		3.8		765.7	42.6		168.9	17.5		1.5		2.6		1504.8	3.1	6.9		199.4	33.3	0.014	16.5	143.3	0.007	4.1	2.3	
		Avg Low Flow	4.58	668.1		1.0		1.0		3.3		892.9	52.9		220.8	25.7		1.6		3.2		1577.4	2.9	14.5		259.7	37.3	0.014	17.7	197.1	0.006	5.1	2.4	
DC-2	4/6/2004	0.181	81.24	54		1	<	1	<	3		271	67		213	11		2		2		500	4.4	7	JF	20.4	10.1	0.0036	2.15	5.94	0.005	1.67	0.5	JF%
	6/29/2004	9.56	4290.81	2	<	8		7		2		84	29		93	5		1		1		207	7.7	30		8.1	2.97	0.0007	0.58	4.16	0.003	0.31	0.1	
	8/11/2004	0.36	161.58	66		1	<	1	<	2	<	248	56		193	13		2		2		474	4.5	21		25.2	9.38	0.0032	2.79	11.1	0.004	1.44	0.45	
	10/6/2004	0.53	237.88	34	JF%	2		1		6		224	57		196	13		2		2		431	4.8	27	JF	17.4	6.58	0.0024	1.9	7.36	0.002	1.25	0.35	
	4/6/2005	0.05	22.44	95		1	<	1	<	9		339	80		270	17		2		2		609	4.47	15		32.7	11.6	0.0046	2.49	15.5	0.003	2.25	0.87	JF%(1)
	6/29/2005	6.8	3052.04	2	<	7		6		2		78	28	d	91	5	d	1	d	1	d	183.1	5.8	20		6.6	2.37	0.0008	0.31	3.42	0.002	0.31	0.14	
	9/27/2005	0.19	85.28	92		1	<	1	<	2		284	64	d	217	14	d	2	d	3	d	560	3.7	30		30.2	13.2	0.0035	2.57	12.1	0.006	1.82	0.51	
	4/25/2006	0.08	35.91	65		2		1		3		254	66		211	14		2		2		520	4.74	12		22.8	9.15	0.003	1.54	10.2	0.002	1.95	0..5	
	6/27/2006	5.19	2329.43	2	<	18		15		1	<	77	29		98	6		1		1	<	221	6.25	22		7.6	3.12	0.0005	0.69	3.38	0.002	0.34	0.1	
	9/27/2006	0.14	62.84	94		1	<	1	<	2		240	61		214	15		2		2		645	3.76	13	JF%	26.0	12.4	0.0043	3.17	7.78	0.004	2.14	0.55	
	4/11/2007	0.05	22.44	40		1	<	1	<	2		292	63		211	13		1		2		473	6.93	18		24.0	8.3	0.0036	1.44	12	0.003	1.76	0.46	
	6/13/2007	10.2	4578.07	6	<	11		9		1	<	53	19		64	4		1		1	<	121	7.1	41		9.8	3.7	0.0004	0.41	5.36	0.009	0.23	0.07	
	7/18/2007	0.507	227.56	58		1	<	1	<	1	<	197	47		167	12		1		2		387	4.72	28		22.8	8.9	0.0023	2.2	10.2	0.002	1.12	0.34	
	9/18/2007	0.154	69.12	96		1	<	1	<	1		366	75		270	20		2		3		699	4.15	23		32.9	13.4	0.0042	3.58	12.9	0.004	2.37	0.61	
	7/15/2008	9.229	4142.25																															
		Min	22.44	2		1		1		1		53	19		64	4		1		1		121	3.70	12		6.4	2.37	0.0004	0.31	3.38	0.002	0.23	0.07	
n=	15	Mean	1293.26	50		4		4		3		210	52		177	12		2		2		425	5.28	23		20.5	8.1	0.0026	1.82	8.88	0.004	1.33	0.38	
		Max	4578.07	96		18		15		9		366	80		270	20		2		3		699	7.70	41		35.7	13.4	0.0046	3.58	15.50	0.009	2.37	0.87	
		Avg High Flow	3678.52	16		8.5		7.3		1.5		109	33		112	7.0		1.0		1.3		250	6.12	25		11.3	4.3	0.001	0.9	5.3	0.002	0.52	0.17	
		Avg Low Flow	113.78	79		1.3		1.0		2.8		279	64		224	15.5		2.0		2.5		584	4.10	23		26.6	11.4	0.004	2.8	10.0	0.004	1.90	0.51	

Notes:

* - No duplicate flow data measured
cfs - Cubic feet per second
gpm - Gallons per minute
s.u. - Standard units
mg/L - Milligrams per liter
umhos/cm - Micromhos per centimeter
n - Number of samples
(1) - Verified by second analysis
(2) - High flow month for each year used
(3) - Low flow month for each year used

-- - Indicates data not collected or parameter not analyzed
< - Indicates analyte not detected above practical quantitation limit (PQL)
d - The associated values are dissolved not total recoverable metals
JF - The associated values are estimated quantities because field duplicate results exceed acceptable limits by absolute value determination
JF% - The associated values are estimated quantities because field duplicate results exceed acceptable limits by relative percent difference determination
Flow Rate - Some of the flow rates shown have been converted from gallons per minute (gpm) to cubic feet per second (cfs). Please refer to original field notes for exact values.

Appendix B

Company Name Tetra Tech

Project Solid substrate bioreactor pil

Site Name New World

Printed on 01/08/2009

AMD TREAT
BIO REACTOR (BIO)

AMDTREAT

BIO Reactor Name: Solid Substrate Bioreactor Pilot Scale Test

☐ Opening Screen Water Parameters

Influent Water Parameters that Affect BIO Reactor

Parameter	Value	Unit
Calculated Acidity	689.60	mg/L
Alkalinity	1.00	mg/L

(•) Calculate Net Acidity (Acid-Alkalinity)

( ) Enter Net Acidity manually

Parameter	Value	Unit
Net Acidity (Hot Acidity)	688.60	mg/L
Design Flow	2.00	gpm
Typical Flow	2.00	gpm
Total Iron	157.00	mg/L
Aluminum	32.80	mg/L
Manganese	4.20	mg/L
Sulfate	804.30	mg/L

Record Number

1 of 1

SIZING METHODS Select One

(•) **BIO Reactor Based on Sulfate Reduction**

1. Sulfate Reduction Rate	0.300	
2. Amount of Sulfate Reduction	500.00	

( ) **BIO Reactor Based on Dimensions**

3. Length at Top of Freeboard		ft
4. Width at Top of Freeboard		ft

( ) **BIO Reactor Based on Alkalinity Generation Rate**

5. Alkalinity Generation Rate		g/m2/day

	BIO Mixture % Volume		BIO Density	
6. Manure	5.00	%	40.80	lbs/ft3
7. Hay	19.00	%	8.30	lbs/ft3
8. Limestone	16.00	%	94.10	lbs/ft3
9. Wood Chips	60.00	%	18.10	lbs/ft3

10. Manure Unit Cost	20.00	$/ton
11. Hay Unit Cost	100.0	$/ton
12. Limestone Unit Cost	30.00	$/ton
13. Wood Chips Unit Cost	100.0	$/ton
14. Shrinkage Factor for BIO Mix	30.00	%
15. Limestone Purity	85.00	%
16. Limestone Efficiency	60.00	%
17. BIO Mix Placement Unit Cost	4.50	$/yd3

	Run of Slope		Rise of Slope
18. Slope of Pond Sides	2.0	:	1

19. Freeboard Depth	3.00	ft
20. Free Standing Water Depth	2.0	ft
21. BIO Mix Depth	3.0	ft
22. Excavation Unit Cost	0.00	$/yd3
23. Siphon System Cost	0.00	$
24. Nbr. of Valves	0	nbr
25. Unit Cost of Valves	3500.00	$ ea.

Liner Cost

( ) No Liner

( ) Clay Liner

26. Clay Liner Unit Cost		$/yd3
27. Thickness of Clay Liner		ft

(•) Synthetic Liner

28. Synthetic Liner Unit Cost	3.00	$/yd2

☑ 29. Clearing and Grubbing?

(•) 30. Land Multiplier	1.50	ratio
( ) 31. Clear/Grub Acres		acres
32. Clear and Grub Unit Cost	0.00	$/acre

Piping Cost

( ) AMDTreat Piping Costs

33. Total Length of Effluent / Influent Pipe		ft
34. Pipe Install Rate		ft/hr
35. Labor Rate		$/hr
36. Segment Len. of Trunk Pipe		ft/pipe seg.
37. Trunk Pipe Cost		$/ft
38. Trunk Coupler Cost		$/coupler
39. Spur Cost		$/ft
40. Spur Coupler Cost		$/spur
41. "T" Connector Cost		$/T coupler
42. Segment Len. of Spur Pipe		ft/pipe seg.
43. Spur Pipe Spacing		ft

(•) Custom Piping Costs

	Length		Diameter		Unit Cost	
44. Pipe #1	0.00	ft	0.0	in	0.00	$
45. Pipe #2	0.00	ft	0.0	in	0.00	$
46. Pipe #3	0.00	ft	0.0	in	0.00	$

BIO Reactor Sizing Summaries

47. Length at Top of Freeboard			79.88	ft
48. Width at Top of Freeboard			49.94	ft
49. Freeboard Volume			362	yd3
50. Water Surface Area			2,575	ft2
51. Total Water Volume			1,250	yd3
52. Bio Mix Surface Area			1,793	ft2
53. Bio Mix Total Volume			241.92	yd3
54. Manure	9.4	yd3	5.1	tons
55. Hay	35.7	yd3	4.0	tons
56. Limestone	66.5	yd3	84.5	tons
57 Wood Chips	130.2	yd3	31.8	tons
58. Excavation Volume			1,395.3	yd3
59. Clear and Grub Area			0.1	acr.
60. Liner Area			862.5	ft2
61. Life of Limestone in Bio Mix			17.16	yrs

BIO Reactor Cost Summaries

62. Manure Cost	103	$
63. Hay Cost	400	$
64. Limestone Cost	2,536	$
65. Wood Chips Cost	3,181	$
66. BIO Mix Placement Cost	651	$
67. Excavation Cost	0	$
68. Siphon System Cost	0	$
69. Valve Cost	0	$
70. Liner Cost	2,587	$
71. Clear and Grub Cost	0	$
72 Pipe Cost	0	$
73. Total Cost	9,461	$

Appendix C

McLaren Subsurface Drains Combined Flow - 22 gpm
Solid Reactant Sulfate Reducing Bioreactor (SSBR) with Holding Pond and Oxic Limestone Drain (OLD)

A Solid Reactant Sulfate Reducing Bioreactor (SSBR) would be constructed to treat the combined average flow (22 gpm) from the three McLaren Pit Cap drains. The flow from the drains would flow into a holding pond before entering the SSBR. The discharge from the SSBR would flow to an oxic limestone drain (OLD). The SSBR, holding pond and OLD were designed using AMDTreat software Version 4.1c (see attachments). The SSBR cell was designed for a sulfate reduction rate of 500 mg/L and includes a geochemically inert layer of gravel at the top for head fluctuations and at the bottom for minimizing metals plugging at the inlet piping to the cell. The cell is comprised of a mixture of limestone for adding alkalinity and raising pH, manure to provide bacterial inoculum and organic matrix of hay and wood chips. The cell will be covered with 4 feet of soil for frost protection. The holding pond, SSRB and OLD are lined to minimize water loss. A system bypass is included for high flows which may not be accomodated by the SSBR. It is assumed that the cell would need replacement every five years due to Replacement would include disposal of the organic material and limestone at $50/ton. Access would not be required during winter-weather months. Cost estimate sources are from AMDTreat software Version 4.1c (Office of Surface Mining Reclamation and Enforcement (OSMRE), 2006); RSMeans Building Construction Cost Data, 2008 and professional judgement if blank.

DIRECT CAPITAL COSTS

Component	**Unit**	**Unit Cost**	**Total Quantity**	**Total Cost**	**Source**
Holding Pond					
Gravel (includes placement)	cy	$ 26.85	657	$ 17,640	RSMeans 31 23 23.17 0020
Fill from borrow area (placement)	cy	$ 1.54	1030	$ 1,586	RSMeans 31 23 23.13 1300
Excavation, 1 1/2 cy bucket	cy	$ 8.27	1687	$ 13,951	RSMeans 31 23 16.16 6050
Liner & Cover (installed)	sy	$ 3.00	1756.6	$ 5,270	
Clear & Grub	ac	$ 1,350.00	0.08	$ 108	AMD Treat
Revegetation	ac	$ 1,500.00	0.08	$ 120	AMD Treat
System Bypass	ls	$ 2,500.00	1	$ 2,500	
Holding Pond Total				**$ 41,176**	
Solid Substrate Bioreactor					
Piping and valves from drains to pond (400 feet)	ls	$ 61,904.00	1	$ 61,904	AMD Treat
Fill from borrow area (placement)	cy	$ 1.54	3197	$ 4,923	RSMeans 31 23 23.13 1300
Organic Matrix/Limestone Material	ls	$ 68,447.00	1	$ 68,447	AMD Treat
Bio Mix Placement	ls	$ 7,162.00	1	$ 7,162	AMD Treat
Excavation, 1 1/2 cy bucket	ls	$ 118,582.00	1	$ 118,582	AMD Treat & RSMeans 31 23 16.16 6050
Liner & Cover (installed)	ls	$ 17,303.00	1	$ 17,303	
Clear & Grub	ls	$ 1,350.00	1	$ 1,350	AMD Treat
Revegetation	ac	$ 1,500.00	1	$ 1,500	
SSBR Bypass System	ls	$3,500	1	$ 3,500	
Solid Substrate Bioreactor Total				**$ 284,671**	
Oxic Limestone Drain					
Oxic Limestone Drain with Liner Installed	ls	$ 3,785.00	1	$ 3,785	AMD Treat
Oxic Limestone Drain Total				**$ 3,785**	
TOTAL DIRECT CAPITAL COSTS				**$ 329,632**	

INDIRECT CAPITAL COSTS

Component	Unit	Unit Cost	Total Quantity	Total Cost	Source
Material Delivery Costs					
Gravel for pond, manure, hay, limestone, wood chips & piping for bioreactor, limestone for OLC	ton-mile	$ 0.074	360900	$ 26,707	
Material Delivery Costs Total				**$ 26,707**	
Mobilization/Demobilization					
Backhoe and Dozer (<50 miles round trip)	each	$ 217.00	2	$ 434	RSMeans 01 54 36.50 0020
Mileage	5 miles	$ 21.70	100	$ 2,170	RSMeans 01 54 36.50 0020
Mobilization/Demobilization Total				**$ 2,604**	
Engineering and Design (10% of Direct)				**$ 32,963**	
Contingency (25% of direct)				**$ 82,408**	
TOTAL INDIRECT CAPITAL COSTS				**$ 144,682**	
TOTAL CAPITAL COSTS				**$ 474,314**	

DIRECT OPERATION AND MAINTENANCE COSTS

Component	Unit	Unit Cost	Years		Total Cost
Annual sampling	ls	$ 9,638.00		20	$ 140,622
Pipe Cleaning and Maintenance	ls	$ 5,000.00		20	$ 72,952
Replace system every 5 years	ls	$ 284,671.38		20	$ 714,297
Residual disposal every 5 years	ls	$ 139,520.00		20	$ 350,084
OPERATION AND MAINTENANCE PRESENT WORTH (20YEARS)					**$ 1,277,955**
GRAND TOTAL					**$ 1,752,270**

Company Name Tetra Tech

Project Solid substrate bioreactor

Site Name New World

Printed on 01/08/2009

AMDTREAT

AMD TREAT
BIO REACTOR (BIO)

BIO Reactor Name: Solid Substrate Bioreactor

☐ Opening Screen Water Parameters

Influent Water Parameters that Affect BIO Reactor

Calculated Acidity: 689.60 mg/L

Alkalinity: 1.00 mg/L

(•) Calculate Net Acidity (Acid-Alkalinity)

( ) Enter Net Acidity manually

Net Acidity (Hot Acidity): 688.60 mg/L

Design Flow: 22.00 gpm

Typical Flow: 22.00 gpm

Total Iron: 157.00 mg/L

Aluminum: 32.80 mg/L

Manganese: 4.20 mg/L

Sulfate: 804.30 mg/L

Record Number: 1 of 1

SIZING METHODS Select One

(•) **BIO Reactor Based on Sulfate Reduction**

1. Sulfate Reduction Rate: 0.300
2. Amount of Sulfate Reduction: 500.00

( ) **BIO Reactor Based on Dimensions**

3. Length at Top of Freeboard: ft
4. Width at Top of Freeboard: ft

( ) **BIO Reactor Based on Alkalinity Generation Rate**

5. Alkalinity Generation Rate: g/m2/day

	BIO Mixture % Volume		BIO Density	
6. Manure	5.00	%	40.80	lbs/ft3
7. Hay	19.00	%	8.30	lbs/ft3
8. Limestone	16.00	%	94.10	lbs/ft3
9. Wood Chips	60.00	%	18.10	lbs/ft3

10. Manure Unit Cost	20.00	$/ton
11. Hay Unit Cost	100.0	$/ton
12. Limestone Unit Cost	30.00	$/ton
13. Wood Chips Unit Cost	100.0	$/ton
14. Shrinkage Factor for BIO Mix	30.00	%
15. Limestone Purity	85.00	%
16. Limestone Efficiency	60.00	%
17. BIO Mix Placement Unit Cost	4.50	$/yd3

18. Slope of Pond Sides (Run of Slope : Rise of Slope): 2.0 : 1

19. Freeboard Depth	3.00	ft
20. Free Standing Water Depth	2.0	ft
21. BIO Mix Depth	3.0	ft
22. Excavation Unit Cost	8.27	$/yd3
23. Siphon System Cost	0.00	$
24. Nbr. of Valves	4	nbr
25. Unit Cost of Valves	3500.00	$ ea.

Liner Cost

( ) No Liner

( ) Clay Liner

26. Clay Liner Unit Cost: $/yd3
27. Thickness of Clay Liner: ft

(•) Synthetic Liner

28. Synthetic Liner Unit Cost: 3.00 $/yd2

☑ 29. Clearing and Grubbing?

( ) 30. Land Multiplier: ratio

(•) 31. Clear/Grub Acres: 1 acres

32. Clear and Grub Unit Cost: 1350.00 $/acre

Piping Cost

(•) AMDTreat Piping Costs

33. Total Length of Effluent / Influent Pipe	400	ft
34. Pipe Install Rate	11.00	ft/hr
35. Labor Rate	35.00	$/hr
36. Segment Len. of Trunk Pipe	20	ft/pipe seg.
37. Trunk Pipe Cost	15.00	$/ft
38. Trunk Coupler Cost	6.60	$/coupler
39. Spur Cost	7.00	$/ft
40. Spur Coupler Cost	3.00	$/spur
41. "T" Connector Cost	90.00	$/T coupler
42. Segment Len. of Spur Pipe	20	ft/pipe seg.
43. Spur Pipe Spacing	10.0	ft

( ) Custom Piping Costs

	Length	Diameter	Unit Cost
44. Pipe #1	ft	in	$
45. Pipe #2	ft	in	$
46. Pipe #3	ft	in	$

BIO Reactor Sizing Summaries

47. Length at Top of Freeboard			198.21	ft
48. Width at Top of Freeboard			109.10	ft
49. Freeboard Volume			2,203	yd3
50. Water Surface Area			18,083	ft2
51. Total Water Volume			9,550	yd3
52. Bio Mix Surface Area			15,880	ft2
53. Bio Mix Total Volume			2,661.17	yd3
54. Manure	103.4	yd3	56.9	tons
55. Hay	393.1	yd3	44.0	tons
56. Limestone	732.1	yd3	930.0	tons
57 Wood Chips	1,432.4	yd3	350.0	tons
58. Excavation Volume			11,141.8	yd3
59. Clear and Grub Area			1.0	acr.
60. Liner Area			3,370.0	ft2
61. Life of Limestone in Bio Mix			17.16	yrs

BIO Reactor Cost Summaries

62. Manure Cost	1,139	$
63. Hay Cost	4,405	$
64. Limestone Cost	27,902	$
65. Wood Chips Cost	35,001	$
66. BIO Mix Placement Cost	7,162	$
67. Excavation Cost	92,143	$
68. Siphon System Cost	0	$
69. Valve Cost	14,000	$
70. Liner Cost	10,110	$
71. Clear and Grub Cost	1,350	$
72 Pipe Cost	61,904	$
73. Total Cost	255,118	$

Company Name Tetra Tech

Project Solid substrate bioreactor

Site Name New World

Printed on 01/08/2009

AMDTREAT

AMD TREAT

PONDS

Pond Name: Holding Pond

Pond Design Based On:

- (selected) Retention Time
  - 1. Desired Retention Time: 24.0 hours
  - ☐
  - 3. Sludge Removal Frequency: ___ times/year
  - ☐ 4. Titration?
    - 5. Sludge Rate: ___ gal sludge/gal H2O
    - 6. Percent Solids: ___ %
    - 7. Sludge Density: ___ lbs./gal
- Pond Size
  - 8. Pond Length at Top of Freeboard: ___ ft
  - 9. Pond Width at Top of Freeboard: ___ ft

	Run		Rise	
10. Slope Ratio of Pond Sides	2.0	:	1	

11. Freeboard Depth	2.0	ft
12. Water Depth	4.0	ft
13. Excavation Unit Cost	8.27	$/yd3
14. Total Length of Effluent / Influent Pipe	0.00	ft
15. Unit Cost of Pipe	10.00	$/ft

Liner Cost

- No Liner
- Clay Liner
  - 16. Clay Liner Unit Cost: ___ $/yd3
  - 17. Thickness of Clay Liner: ___ ft
- (selected) Synthetic Liner
  - 18. Synthetic Liner Unit Cost: 3.00 $/yd2

☑ 19. Clearing and Grubbing?

- 20. Land Multiplier: ___ ratio
- (selected) 21. Clear/Grub Acres: 1.00 acres
- 22. Clear and Grub Unit Cost: 1350.00 $/acre

23. Revegetation Cost	1500.00	$/acre
24. Cost of Baffles	0	$

Calculated Pond Dimensions per Pond

25. Length at Top of Freeboard	114	ft
26. Width at Top of Freeboard	61	ft
27. Freeboard Volume	1,123	yd3
28. Water Volume	657	yd3
29. Estimated Annual Sludge	0	yd3/yr
30. Volume of Sludge per Removal	0	yd3/removal
31. Excavation Volume	0.40	acre ft
32. Excavation Volume	657	yd3
33. Clear and Grub Area	1.00	acres
34. Liner Area	984	yd2
35. Calculated Retention Time	24	hours

Ponds Sub-Totals per Pond

36. Excavation Cost	5,441	$
37. Pipe Cost	0	$
38. Liner Cost	2,953	$
39. Clearing and Grubbing Cost	1,350	$
40. Revegetation Cost	119	$
41. Baffle Cost	0	$

42. Estimated Cost: 9,864 $

☐ **Opening Screen Water Parameters**

Influent Water Parameters that Affect Ponds

Calculated Acidity: 689.60 mg/L

Alkalinity: 1.00 mg/L

- (selected) Calculate Net Acidity (Acid-Alkalinity)
- Enter Net Acidity manually

Net Acidity (Hot Acidity): 688.60 mg/L

Design Flow	92.28	gpm
Typical Flow	92.28	gpm
Total Iron	0.00	mg/L
Aluminum	0.00	mg/L
Manganese	0.00	mg/L

Record Number
1 of 1

Company Name Tetra Tech

Project Solid substrate bioreactor

Site Name New World

Printed on 01/08/2009

AMDTREAT

AMD TREAT

Oxic Limestone Channel (OLC)

Oxic Limestone Channel Name: SSBR/LSBR OLC post-treat

1. Ditch Length Rock	100	ft
2. Bottom Width of the Ditch	4.0	ft
3. Ditch Depth	3.00	ft
4. Geo Textile Unit Cost	3.00	$/yd2
5. Length of GeoTextile	100	ft
6. Slope Ratio of Ditch Sides (Run : Rise)	2.00 : 1.00	
☐ 7. Surveying?		
8. Survey Rate		acres/day
9. Survey Unit Cost		$/day
☑ 10. Clearing and Grubbing?		
11. Clear and Grub Cost	1350.00	$/acre
12. Ditch Depth of Limestone	1.00	ft
13. Cost of Limestone	30.00	$/yd3
14. Cost to Place Limestone	4.50	$/yd3
15. Excavation Unit Cost	8.27	$/yd3
16. Revegetation Unit Cost	0.00	$/acre

OLC Sub-Totals

17. Excavation Cost	919	$
18. Survey Cost	0	$
19. Clear and Grub Cost	60	$
20. Limestone Cost	2,225	$
21. Filter Fabric Cost	581	$
22. Revegetation Cost	0	$
23. Total Cost	3,785	$

Record Number 1 of 1

Appendix D

McLaren Subsurface Drains Combined Flow - 22 gpm
Liquid Reactant Sulfate Reducing Bioreactor (LSBR) with Holding Pond and Oxic Limestone Drain (OLD)

A Liquid Reactant Sulfate Reducing Bioreactor (LSBR) would be constructed to treat the combined flow (22 gpm) from the McLaren Pit Cap drains. The flow from the drains would be conveyed into a holding pond before entering a settling pond for metals precipitation. The discharge from the settling pond then flows to the LSBR. The discharge from the LSBR would flow to an oxic limestone drain (OLD) prior to discharge. The LSBR was sized using a 2 day hydraulic retention time at a porosity of 35%. The holding pond and oxic limestone channel were sized using AMD Treat software Version 4.1c (see attachments). Sodium hydroxide (NaOH) would be fed to the system with a solar driven pump for alkalinity addition, and ethanol would be fed to the system using a solar driven pump for the carbon source for bacterial growth. The cell will be covered with 4 feet of soil from the borrow area for frost protection. The holding pond, SSRB and OLD are lined to minimize water loss. A system bypass is included for high flows which may not be accomodated by the SSBR. It is assumed that the cell would need replacement every 15 years.

Replacement would include disposal of the cell fill material at $50/ton. Access would not be required during winter-weather months. Cost estimate sources are from AMD Treat software Version 4.1c (Office of Surface Mining Reclamation and Enforcement (OSMRE), 2006); RSMeans Building Construction Cost Data, 2008 and professional judgement if blank.

DIRECT CAPITAL COSTS

Component	**Unit**	**Unit Cost**	**Total Quantity**	**Total Cost**	**Source**
Holding Pond					
Gravel (includes placement)	cy	$ 26.85	657	$ 17,640	RSMeans 31 23 23.17 0020
Fill from borrow area (placement)	cy	$ 1.54	1030	$ 1,586	RSMeans 31 23 23.13 1300
Excavation, 1 1/2 cy bucket	cy	$ 8.27	1687	$ 13,951	RSMeans 31 23 16.16 6050
Liner & Cover (installed)	sy	$ 3.00	1756.6	$ 5,270	
Clear & Grub	ac	$ 1,350.00	0.08	$ 108	AMD Treat
Revegetation	ac	$ 1,500.00	0.08	$ 120	AMD Treat
System Bypass	ls	$ 2,500.00	1	$ 2,500	
Holding Pond Total				**$ 41,176**	
Settling Pond					
Gravel (includes placement)	cy	$ 26.85	6274	$ 168,457	RSMeans 31 23 23.17 0020
Fill from borrow area (placement)	cy	$ 1.54	6274	$ 9,662	RSMeans 31 23 23.13 1300
Excavation, 1 1/2 cy bucket	cy	$ 8.27	12548	$ 103,772	RSMeans 31 23 16.16 6050
Liner & Cover (installed)	sy	$ 3.00	9682	$ 29,046	
Clear & Grub	ac	$ 1,350.00	1	$ 1,350	AMD Treat
Revegetation	ac	$ 1,500.00	1	$ 1,500	AMD Treat
Settling Pond Total				**$ 313,787**	

Liquid Substrate Bioreactor							
Piping and valves from drains to pond (400 feet)	ls	$	64,061.00	1	$	64,061	AMD Treat
Chemical Feed Systems and Storage	ls	$	6,000.00	1	$	6,000	
Gravel/Rock Fill for Cell (includes placement)	cy	$	26.85	896	$	24,058	
Manure for bacterial inoculation	ton	$	20.00	59.7	$	1,194	
Fill from borrow area (placement)	cy	$	1.54	896	$	1,380	RSMeans 31 23 23.13 1300
Excavation, 1 1/2 cy bucket	cy	$	8.27	1882	$	15,564	AMD Treat & RSMeans 31 23 16.16 6050
Liner & Cover (installed)	ls	$	4,472.00	1	$	4,472	
Clear & Grub	ac	$	1,350.00	0.33	$	446	
Revegetation	ac	$	1,500.00	0.33	$	495	
LSBR Bypass System	ls		$3,500	1	$	3,500	
Liquid Substrate Bioreactor Total					**$**	**121,169**	
Oxic Limestone Channel							
Oxic Limestone Channel with Liner Installed	ls	$	3,785.00	1	$	3,785	AMD Treat
Oxic Limestone Channel Total					**$**	**3,785**	
TOTAL DIRECT CAPITAL COSTS					**$**	**479,917**	

INDIRECT CAPITAL COSTS

Component	Unit	Unit Cost	Total Quantity	Total Cost	Source
Material Delivery Costs					
Gravel for pond, limestone for OLC & Gravel/rock mix for bioreactor	ton-mile	$ 0.074	344250	$ 25,475	
Material Delivery Costs Total				**$ 25,475**	
Mobilization/Demobilization					
Backhoe and Dozer (<50 miles round trip)	each	$ 217.00	2	$ 434	RSMeans 01 54 36.50 0020
Mileage	5 miles	$ 21.70	100	$ 2,170	RSMeans 01 54 36.50 0020
Mobilization/Demobilization Total				**$ 2,604**	
Engineering and Design (10% of Direct)				**$ 47,992**	
Contingency (25% of direct)				**$ 119,979**	
TOTAL INDIRECT CAPITAL COSTS				**$ 196,049**	
TOTAL CAPITAL COSTS				**$ 675,966**	

DIRECT OPERATION AND MAINTENANCE COSTS

Component	Unit	Unit Cost	Years	
Annual sampling	ls	$ 9,638.00	20	$ 140,622
Chemical Costs	ls	$ 14,801.00	20	$ 215,953
Pipe Cleaning and Maintanance	ls	$ 5,000.00	20	$ 72,952
Replace system every 15 years	ls	$ 121,169.08	20	$ 85,719
Residual disposal every 15 years	ls	$ 44,800.00	20	$ 31,693
OPERATION AND MAINTENANCE PRESENT WORTH (20YEARS)				**$ 546,939**
GRAND TOTAL				**$ 1,222,905**

Appendix E

McLaren Subsurface Drains Combined Flow - 22 gpm
Solid Reactant Sulfate Reducing Bioreactor (SSBR) with Holding Pond and Oxic Limestone Drain (OLD)

A Solid Reactant Sulfate Reducing Bioreactor (SSBR) would be constructed to treat the combined average flow (22 gpm) from the three McLaren Pit Cap drains. The flow from the drains would flow into a holding pond before entering the SSBR. The discharge from the SSBR would flow to an oxic limestone drain (OLD). The SSBR, holding pond and OLD were designed using AMDTreat software Version 4.1c (see attachments). The SSBR cell was designed for a sulfate reduction rate of 500 mg/L and includes a geochemically inert layer of gravel at the top for head fluctuations and at the bottom for minimizing metals plugging at the inlet piping to the cell. The cell is comprised of a mixture of limestone for adding alkalinity and raising pH, manure to provide bacterial inoculum and organic matrix of hay and wood chips. The cell will be covered with 4 feet of soil for frost protection. The holding pond, SSRB and OLD are lined to minimize water loss. A system bypass is included for high flows which may not be accomodated by the SSBR. It is assumed that the cell would need replacement every five years due to pluging Replacement would include disposal of the organic material and limestone at $50/ton. Access would not be required during winter-weather months. Cost estimate sources are from AMDTreat software Version 4.1c (Office of Surface Mining Reclamation and Enforcement (OSMRE), 2006); New World Mining District Actual Cost Data from McLaren Pit Response Action Construction Report, 2006 and Selective Source Response Action Construction Report, 2006 each adjusted using construction cost indicies, and professional judgement.

DIRECT CAPITAL COSTS

Component	Unit	Unit Cost	Total Quantity	Total Cost	Source
Holding Pond					
Gravel (includes placement)	cy	$ 69.00	657	$ 45,333	
Fill from borrow area (placement)	cy	$ 7.67	1030	$ 7,900	
Excavation, 1 1/2 cy bucket	cy	$ 19.10	1687	$ 32,222	
Liner & Cover (installed)	sy	$ 13.42	1756.6	$ 23,574	
Clear & Grub	ac	$ 2,576.00	0.08	$ 206	AMD Treat
Revegetation	ac	$ 2,600.00	0.08	$ 208	AMD Treat
System Bypass	ls	$ 2,500.00	1	$ 2,500	
Holding Pond Total				**$ 111,942**	
Solid Substrate Bioreactor					
Piping and valves from drains to pond (400 feet)	ls	$ 61,904.00	1	$ 61,904	AMD Treat
Fill from borrow area (placement)	cy	$ 7.67	3197	$ 24,521	
Organic Matrix/Limestone Material	ls	$ 68,447.00	1	$ 68,447	AMD Treat
Bio Mix Placement	ls	$ 47,748.00	1	$ 47,748	AMD Treat
Excavation, 1 1/2 cy bucket	ls	$ 163,674.00	1	$ 163,674	AMD Treat & Construction Costs
Liner & Cover (installed)	ls	$ 47,528.00	1	$ 47,528	
Clear & Grub	ls	$ 2,576.00	1	$ 2,576	AMD Treat
Revegetation	ac	$ 2,600.00	1	$ 2,600	
SSBR Bypass System	ls	$3,500	1	$ 3,500	
Solid Substrate Bioreactor Total				**$ 422,498**	
Oxic Limestone Drain					
Oxic Limestone Drain with Liner Installed	ls	$ 9,202.00	1	$ 9,202	AMD Treat
Oxic Limestone Drain Total				**$ 9,202**	
TOTAL DIRECT CAPITAL COSTS				**$ 543,642**	

INDIRECT CAPITAL COSTS

Component	Unit	Unit Cost	Total Quantity	Total Cost	Source
Material Delivery Costs					
Gravel for pond, manure, hay, limestone, wood chips & piping for bioreactor, limestone for OLC	ton-mile	$ 0.074	360900	$ 26,707	
Material Delivery Costs Total				**$ 26,707**	
Mobilization/Demobilization					
Mobilization	ls	$ 50,000.00	1	$ 50,000	
Backhoe and Dozer (<50 miles round trip)	each	$ 217.00	4	$ 868	
Mileage	5 miles	$ 21.70	200	$ 4,340	
Mobilization/Demobilization Total				**$ 55,208**	
Engineering and Design (10% of Direct)				**$ 54,364**	
Contingency (25% of direct)				**$ 135,911**	
TOTAL INDIRECT CAPITAL COSTS				**$ 272,189**	
TOTAL CAPITAL COSTS				**$ 815,832**	

DIRECT OPERATION AND MAINTENANCE COSTS

Component	Unit	Unit Cost	Years	
Annual sampling	ls	$ 9,638.00	20	$ 140,622
Pipe Cleaning and Maintenance	ls	$ 5,000.00	20	$ 72,952
Replace system every 5 years	ls	$ 422,497.99	20	$ 1,060,132
Residual disposal every 5 years	ls	$ 139,520.00	20	$ 350,084
OPERATION AND MAINTENANCE PRESENT WORTH (20YEARS)				**$ 1,623,790**
GRAND TOTAL				**$ 2,439,622**

McLaren Subsurface Drains Combined Flow - 22 gpm
Liquid Reactant Sulfate Reducing Bioreactor (LSBR) with Holding Pond and Oxic Limestone Drain (OLD)

A Liquid Reactant Sulfate Reducing Bioreactor (LSBR) would be constructed to treat the combined flow (22 gpm) from the McLaren Pit Cap drains. The flow from the drains would be conveyed into a holding pond before entering a settling pond for metals precipitation. The discharge from the settling pond then flows to the LSBR. The discharge from the LSBR would flow to an oxic limestone drain (OLD) prior to discharge. The LSBR was sized using a 2 day hydraulic retention time at a porosity of 35%. The holding pond and oxic limestone channel were sized using AMD Treat software Version 4.1c (see attachments). Sodium hydroxide (NaOH) would be fed to the system with a solar driven pump for alkalinity addition, and ethanol would be fed to the system using a solar driven pump for the carbon source for bacterial growth. The cell will be covered with 4 feet of soil from the borrow area for frost protection. The holding pond, SSRB and OLD are lined to minimize water loss. A system bypass is included for high flows which may not be accomodated by the SSBR. It is assumed that the cell would need replacement every 15 years.

Replacement would include disposal of the cell fill material at $50/ton. Access would not be required during winter-weather months. Cost estimate sources are from AMD Treat software Version 4.1c (Office of Surface Mining Reclamation and Enforcement (OSMRE), 2006); New World Mining District Actual Cost Data from McLaren Pit Response Action Construction Report, 2006 and Selective Source Response Action Construction Report, 2006 each adjusted using construction cost indicies, and professional judgement.

DIRECT CAPITAL COSTS

Component	Unit	Unit Cost	Total Quantity	Total Cost	Source
Holding Pond					
Gravel (includes placement)	cy	$ 69.00	657	$ 45,333	
Fill from borrow area (placement)	cy	$ 7.67	1030	$ 7,900	
Excavation, 1 1/2 cy bucket	cy	$ 19.10	1687	$ 32,222	
Liner & Cover (installed)	sy	$ 13.42	1756.6	$ 23,574	
Clear & Grub	ac	$ 2,576.00	0.08	$ 206	AMD Treat
Revegetation	ac	$ 2,600.00	0.08	$ 208	AMD Treat
System Bypass	ls	$ 2,500.00	1	$ 2,500	
Holding Pond Total				**$ 111,942**	
Settling Pond					
Gravel (includes placement)	cy	$ 69.00	6274	$ 432,906	
Fill from borrow area (placement)	cy	$ 7.67	6274	$ 48,122	
Excavation, 1 1/2 cy bucket	cy	$ 19.10	12548	$ 239,667	
Liner & Cover (installed)	sy	$ 13.42	9682	$ 129,932	
Clear & Grub	ac	$ 2,576.00	1	$ 2,576	AMD Treat
Revegetation	ac	$ 2,600.00	1	$ 2,600	AMD Treat
Settling Pond Total				**$ 855,803**	

Liquid Substrate Bioreactor					
Piping and valves from drains to pond (400 feet)	ls	$ 64,061.00	1	$ 64,061	AMD Treat
Chemical Feed Systems and Storage	ls	$ 10,000.00	1	$ 10,000	
Gravel/Rock Fill for Cell (includes placement)	cy	$ 69.00	896	$ 61,824	
Manure for bacterial inoculation	ton	$ 3.90	59.7	$ 233	
Fill from borrow area (placement)	cy	$ 7.67	896	$ 6,872	
Excavation, 1 1/2 cy bucket	cy	$ 19.10	1882	$ 35,946	AMD Treat & Construction Costs
Liner & Cover (installed)	ls	$ 19,997.00	1	$ 19,997	
Clear & Grub	ac	$ 2,576.00	0.33	$ 850	
Revegetation	ac	$ 2,600.00	0.33	$ 858	
LSBR Bypass System	ls	$3,500	1	$ 3,500	
Liquid Substrate Bioreactor Total				**$ 204,141**	
Oxic Limestone Channel					
Oxic Limestone Channel with Liner Installed	ls	$ 9,202.00	1	$ 9,202	AMD Treat
Oxic Limestone Channel Total				**$ 9,202**	
TOTAL DIRECT CAPITAL COSTS				**$ 1,181,089**	

INDIRECT CAPITAL COSTS

Component	Unit	Unit Cost	Total Quantity	Total Cost	Source
Material Delivery Costs					
Gravel for pond, limestone for OLC & Gravel/rock mix for bioreactor	ton-mile	$ 0.074	344250	$ 25,475	
Material Delivery Costs Total				**$ 25,475**	
Mobilization/Demobilization					
Mobilization	ls	$ 50,000.00	1	$ 50,000	
Backhoe. Grader, Dump Truck and Dozer (<50 miles round trip)	each	$ 217.00	4	$ 868	
Mileage	5 miles	$ 21.70	200	$ 4,340	
Mobilization/Demobilization Total				**$ 55,208**	
Engineering and Design (10% of Direct)				**$ 118,109**	
Contingency (25% of direct)				**$ 295,272**	
TOTAL INDIRECT CAPITAL COSTS				**$ 494,064**	
TOTAL CAPITAL COSTS				**$ 1,675,152**	

DIRECT OPERATION AND MAINTENANCE COSTS

Component	Unit	Unit Cost	Years	
Annual sampling	ls	$ 9,638.00	20	$ 140,622
Chemical Costs	ls	$ 14,801.00	20	$ 215,953
Pipe Cleaning and Maintanance	ls	$ 5,000.00	20	$ 72,952
Replace system every 15 years	ls	$ 204,141.43	20	$ 144,416
Residual disposal every 15 years	ls	$ 44,800.00	20	$ 31,693
OPERATION AND MAINTENANCE PRESENT WORTH (20YEARS)				**$ 605,636**
GRAND TOTAL				**$ 2,280,788**