Draft Final
Engineering Evaluation/Cost Analysis and Environmental Assessment For Water Treatment of Acid Mine Discharges In Belt, Montana

Prepared for:

Montana Department of Environmental Quality
Mine Waste Cleanup Bureau
Helena, Montana

Prepared by:

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July 2016

DRAFT FINAL

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LIST OF ACRONYMS AND ABBREVIATIONS

˚F	Degrees Fahrenheit
>	Greater than
<	Less than
µg/L	Microgram per Liter
%	Percent
Al	Aluminum
ALD	Anoxic limestone drains
AMC	Anaconda Mining Company
AML	Montana Abandoned Mine Lands
amsl	Above mean sea level
ARAR	Applicable or Relevant and Appropriate Requirements
BOD	Biological oxygen demand
$CaCO_3$	Calcium carbonate
CaO	Calcium oxide
$Ca(OH)_2$	Calcium hydroxide (Hydrated lime)
$CaSO_4\ 2H_2O$	Gypsum
CFR	Code of Federal Regulations
cfs	Cubic feet per second
CO_2	Carbon dioxide
COC	Contaminant of concern
CSM	Conceptual Site Model
DEQ	Montana Department of Environmental Quality
DO	Dissolved oxygen
EA	Environmental Assessment
EE/CA	Engineering Evaluation and Cost Analysis
EPA	U.S. Environmental Protection Agency
EPCM	Engineering Procurement and Construction Management
Fe	Iron
FEMA	Federal Emergency Management Agency
ft^3	Cubic feet
ft^2	Square feet
GIS	Geographic Information System
gpm	Gallons per minute
HDPE	High density polyethylene
HDS	High density sludge
Hp	Horsepower
km^2	Square kilometer
kW	Kilowatt
kWh	Kilowatt hour

LIST OF ACRONYMS AND ABBREVIATIONS

(Continued)

lbs/ft^3	Pounds per cubic foot
M	Million
MBMG	Montana Bureau of Mines and Geology
MDT	Montana Department of Transportation
mg/L	Milligrams per liter
MIW	Mine-impacted water
Mn	Manganese
m/s	Meters per second
NaOH	Sodium hydroxide
NCP	National Contingency Plan
NF	Nanofiltration
NPS	Northern Power Systems
NPV	Net Present Value
O&M	Operation and Maintenance
OSM	Office of Surface Mining and Enforcement
PRAO	Preliminary remedial action objective
RCRA	Resource Conservation and Recovery Act
RO	Reverse osmosis
SHPO	State Historic Preservation Office
SO_4^{2-}	Sulfate
SRB	Sulfate -reducing bacteria
TCLP	Toxicity characteristics leaching procedure
TDS	Total dissolved solids
Tl	Thallium
TMDL	Total Maximum Daily Load
TRC	Total recoverable concentrations
TSS	Total suspended solids
USGS	U.S. Geological Survey
WQS	Water quality standards
WTP	Water treatment plant
yd^3	Cubic yards
ZVI	Zero-valent iron

1.0 INTRODUCTION

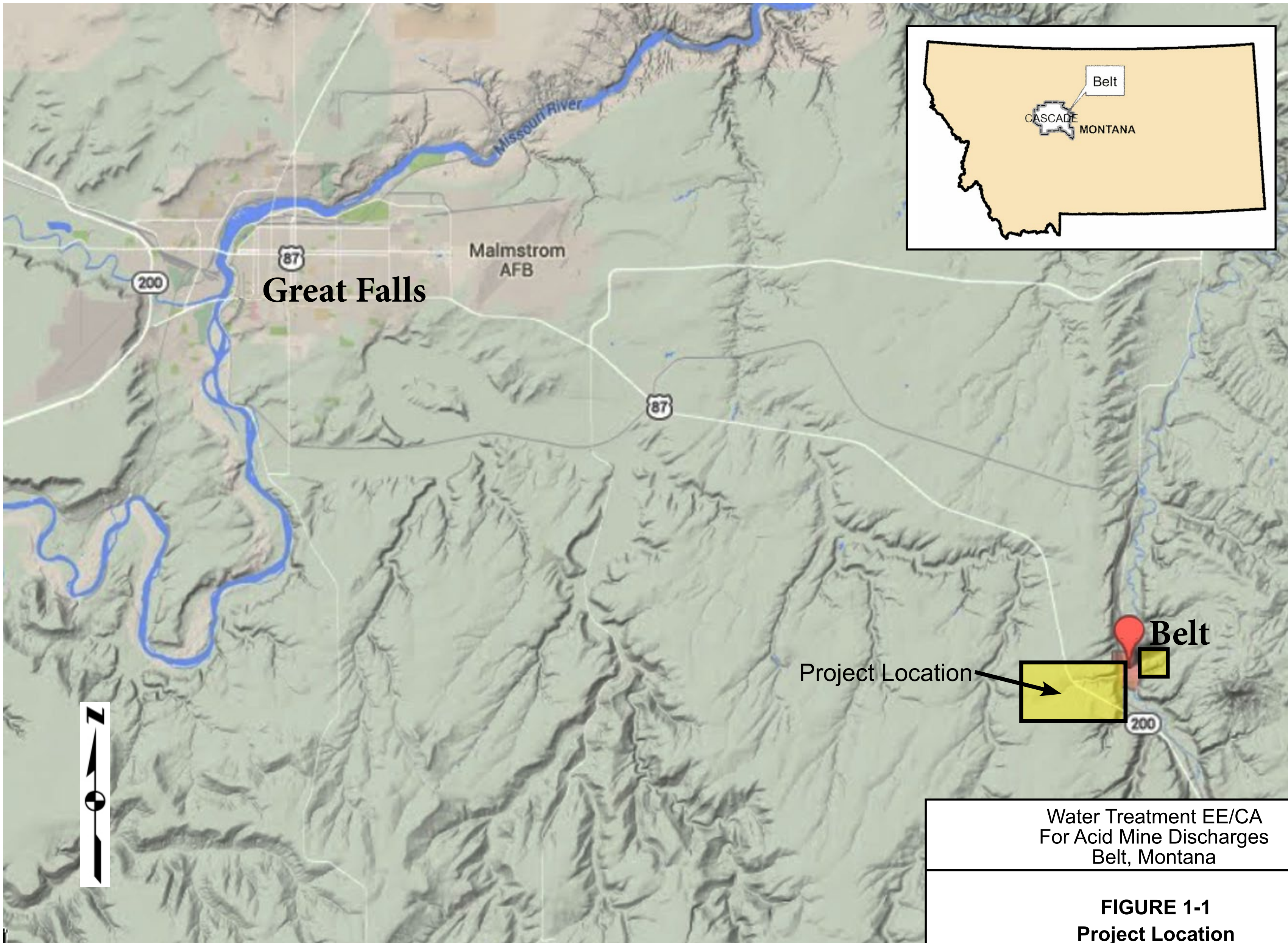
Decades of underground coal mining in the Great Falls Coal Field resulted in acidic mine-impacted water (MIW) that has contaminated groundwater and surface-water in and around Belt, Montana (Figure 1-1). The MIW lowered the pH of Belt Creek and increased trace-metals concentrations in the stream. The Montana Department of Environmental Quality (DEQ) and others completed numerous investigations and studies of the Great Falls Coal Field and related environmental issues over the last 25 years. The investigations have included water quality sampling and metal loading analysis (Karper 1998; Reiten et al. 2006; Hydrometrics 2012; Hydrometric 2013), geochemical and isotopic investigations (Gammons et al. 2006; Gammons et al. 2010), and cost assessments for chemical treatment of the MIW (Tetra Tech 2007; Hydrometrics 2012). The Missouri-Cascade and Belt Total Maximum Daily Loads (TMDLs) Planning Area Metals TMDLs and Framework Water Quality Improvement Plan was published January 24, 2011.

DEQ held a public meeting in Belt on September 30, 2013 to discuss water quality and present plans for evaluation of water treatment options and to solicit public input. To date, sufficient data have been collected to develop an understanding of the MIW and its interaction in the environment; allowing for a complete and detailed evaluation of potential treatment technologies to permanently address the MIW and minimize its impacts to the environment.

This engineering evaluation and cost analysis (EE/CA) of active water treatment alternatives and sludge handling and disposal for five MIW discharges near Belt, Montana includes four main MIW discharges and a single seep, including:

1. Anaconda Belt Mine
2. French Coulee Collection System
3. Lewis Coulee
4. Brodie Mine
5. Coke Oven Flats seepage

This EE/CA also serves as an Environmental Assessment (EA) document as set forth in 40 Code of Federal Regulations (CFR) Number 1508.9. The combined EE/CA and EA is a concise public document that provides the purpose and need for the project, the identification and analysis of alternatives, the evaluation of environmental impacts for the proposed action and alternatives, and the agencies and individuals consulted on this project. This EE/CA and EA presents the preferred water treatment plant design, along with the infrastructure, pre-treatment and plant components, and operations and maintenance tasks for the proposed water treatment selected. Capital costs and future cost obligations for operations and maintenance will also be evaluated.



3 Miles 0 3 Miles

Water Treatment EE/CA
For Acid Mine Discharges
Belt, Montana

FIGURE 1-1
Project Location

TETRA TECH

2.0 SITE LOCATION AND BACKGROUND

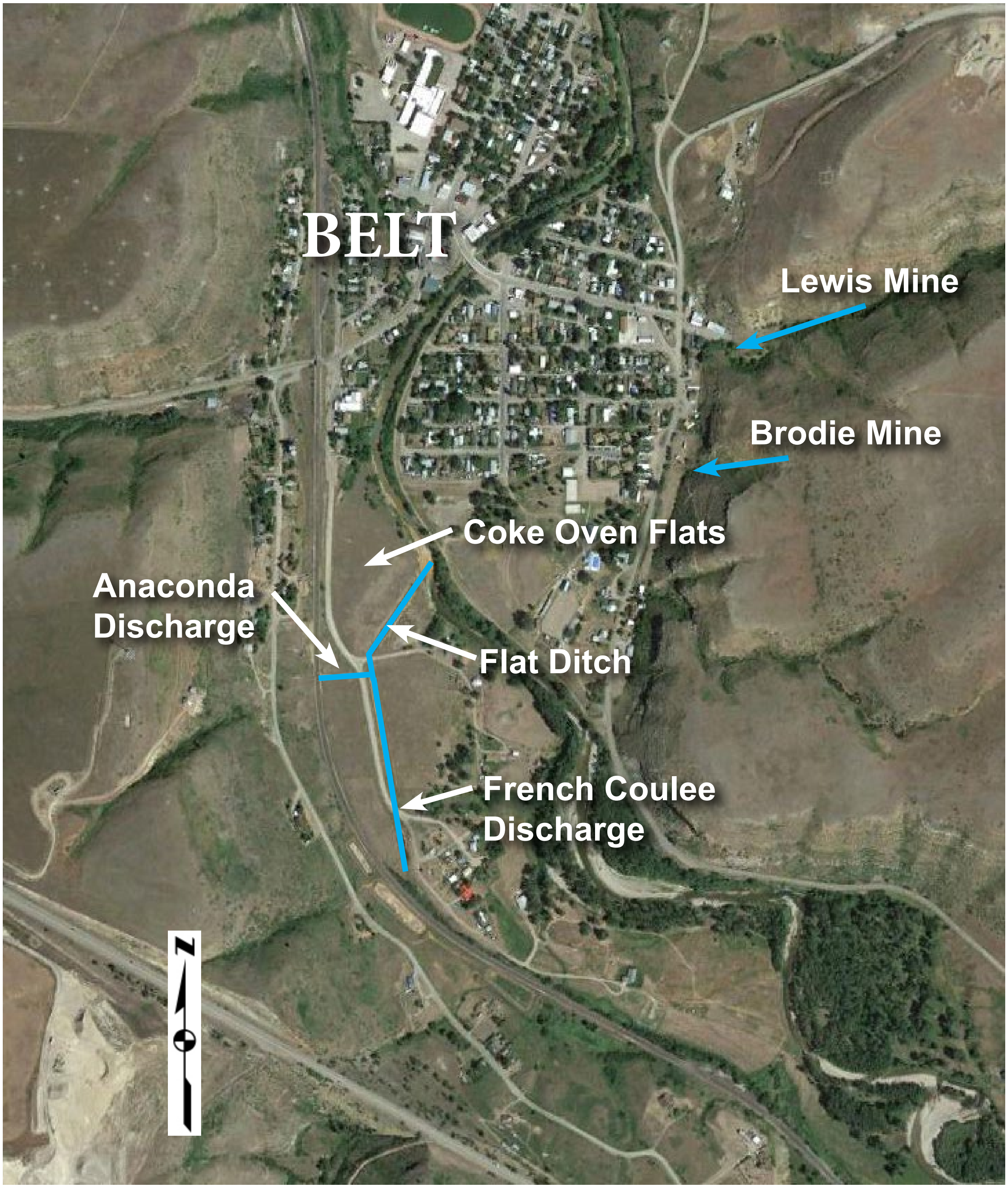
The community of Belt was established as a coal mining town in the Great Falls Coal Field, with extensive underground mines developed around the community (Figure 2-1). The mines were a primary source of coal for operation of the Great Northern Railway, and for the Anaconda Copper Company's mining and beneficiation operations in Butte, Anaconda, and Great Falls, Montana. The coal mines operated from the late-1870s to the mid-1940s with limited operations continuing into the 1950s (Renewable Technologies Inc. 2009).

The mining activity left miles of abandoned underground workings surrounding Belt to the west and east. MIW is generated from the abandoned mines as groundwater seeps into the underground workings and reacts with metal-sulfide minerals under oxidized aqueous conditions. MIW discharges from the mines contaminated adjacent streams and their underlying alluvial groundwater systems. The main surface water channel through the community of Belt is Lower Belt Creek, which has been determined to be a gaining and losing stream through this area (Hydrometric 2013). The 2012 DEQ 303(d) list of impaired water bodies identifies metals impairment of Lower Belt Creek from MIW discharges. The metal identified in the Belt TMDL and Water Quality Improvement Plan (DEQ 2011) were arsenic, cadmium, iron, lead, and zinc.

The Mine Waste Cleanup Bureau of the Montana Department of Environmental Quality (formerly part of the Department of State Lands) carried out numerous mine reclamation projects in the area since the 1980s. Most of the reclamation measures were directed at removing mine wastes, closing mine portals, implementing drainage improvements, and reclaiming disturbed lands. DEQ implemented constructed wetland-based water treatment methodologies to treat MIW discharges, but these techniques were not successful because of high metal and acidity loadings and extended winter season in the area. The removal of the French Coulee treatment wetlands was identified as the preferred alternative by DEQ in the 2014 Environmental Assessment (DEQ and the Office of Surface Mining and Enforcement [OSM] 2014), and will likely be removed in 2016.

2.1 ANACONDA MINE AND COKE OVEN FLATS AREA

The Anaconda Mine is the largest mine in the Belt area and is located immediately southwest of Belt (Figure 2-2). Although there were several smaller mines developed east of town, the Anaconda Mine is the primary source of MIW discharge in this area (Hydrometrics 2012). Most of the discharge from the Anaconda Mine (average of 105 gallons per minute [gpm]) originates at the Anaconda Mine drain (United States Geological Survey [USGS] Site No. 5) that was installed by the Montana Department of

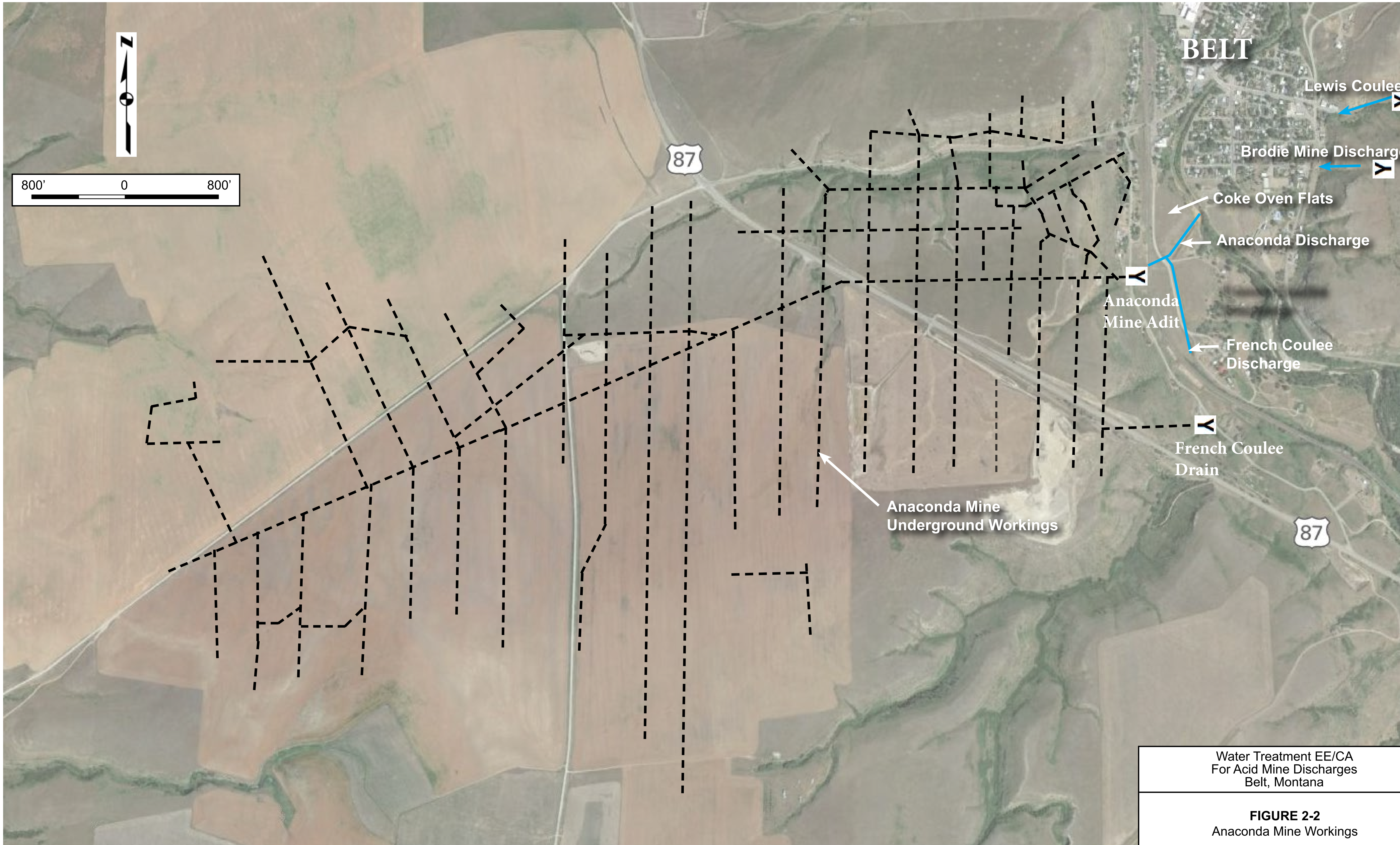


600’ 0 600’

Water Treatment EE/CA
For Acid Mine Discharges
Belt, Montana

FIGURE 2-1
Project Features

TETRA TECH



Water Treatment EE/CA
For Acid Mine Discharges
Belt, Montana

FIGURE 2-2
Anaconda Mine Workings

TETRA TECH

State Lands when the mine portal was closed in the 1980s. MIW also discharges from the French Coulee collection system south of the Anaconda Mine drain. When the Montana Department of Transportation (MDT) constructed the earthen embankment for the U.S. Highway 87 crossing at French Coulee, a collection system was installed for MIW discharging from abandoned mines in French Coulee that were covered by the embankment. The USGS identified this discharge as the French Coulee Wetlands inflow (USGS Site No 11). The USGS monitored a second inflow into the French Coulee wetlands (Site No 12) that apparently discharged from additional backfilled mine adits in the area. Mean discharges from sites 11 and 12 have been approximately 24 and 14 gpm, respectively (Hydrometrics 2012).

MIW from the Anaconda Mine drain and both French Coulee mine sites discharge to a common collection ditch, referred to as Flat Ditch. It is an open, unlined, approximately 1,600-foot long ditch that traverses Coke Oven Flats and discharges to Belt Creek approximately 500 feet northeast of the Anaconda Mine drain at a site adjacent to Castner Park; this area is commonly used for recreational wading and swimming. Infiltration of MIW from diagonal ditch to Coke Oven Flats has been identified as a source of groundwater contamination. Diffuse MIW seepage via groundwater into Belt Creek is evident along the stream banks on the west side of Belt Creek immediately upstream and downstream of the Flat Ditch outfall. White to light gray colloidal discharges into Belt Creek are visible near the Belt "city swimming hole" and caused from high concentrations of aluminum hydroxide in the MIW flowing into relatively fresh surface water (Reiten et al. 2006; Hydrometrics 2012). MIW has been identified at surface water monitoring locations on Belt Creek, above and below the Flat Ditch outfall (Reiten et al. 2006).

Belt Creek is an intermittent stream with flows ranging from no-flow in late summer to nearly 800 cfs in the spring. The annual average flow of Belt Creek is approximately 154 cfs, based on two years of monitoring (Reiten et al. 2006). The main recharge to Belt creek is snow melt from the Little Belt Mountains about 20 miles south of Belt. Segments of Belt Creek are losing water to the ground while other segments are gaining water from the ground. The segment of Belt Creek that flows by Coke Oven Flats loses water to the alluvium (Reiten et al. 2006). Downstream of Coke Oven Flats, Belt Creek become a gaining reach (Reiten et al. 2006). Other minor gaining and losing reaches of Belt Creek have been observed, but were less significant and not as identifiable. Belt Creek, which ultimately receives the MIW discharges, has high flows in the runoff season but low flows late in the year and reportedly goes dry during some winters. During 2 years of monitoring, Reiten et al. (2006) reported an average annual flow rate in Belt Creek of 154 cfs with flows ranging seasonally from 0 to 800 cfs. During low flow periods, Reiten et al. (2006) indicates the only source of flow in Belt Creek at Belt is associated with the MIW discharges.

From late fall through spring, flow in the Belt Creek channel decreases dramatically (from 4 cubic feet per second [cfs] to unmeasurable flows observed in early 2016). During this time period, the flow from Flat Ditch is the primary source of flow in Belt Creek through the Town of Belt (observed in early spring of 2016 from north of the Town of Belt to ½ mile south of the Flat Ditch outfall). Iron oxide sludge accumulates along both sides of the channel flowing slowly downstream. Orange iron oxide staining of rock in the creek channel is visible for at least one mile downstream of the Flat Ditch outfall, and is evident again at the Lewis Coulee outfall. Belt Creek though the Town of Belt is a source of recreation for residents near Castner Park and the reach could be a recreational fishing stream if not for the aquatic toxicity of the MIW inputs.

Coke Oven Flats is an open field where a 27-acre pile of burning coal waste was extinguished, regraded, and reclaimed by DEQ in 1987. Groundwater in contact with the metals and other soluble constituents in the buried coal waste has been shown to contribute a small but concentrated metals load to Belt Creek (Hydrometrics 2013). The total flow from this area has not been quantified but may be approximately 1 gpm. The flow may vary seasonally, but quantifying it is very difficult because it contributes a low flow to a much larger stream beneath the surface water level of the stream. Potential sources of the groundwater moving through the coal wastes include seepage from Flat Ditch, infiltration of precipitation, groundwater inflow, and seasonal contributions from Belt Creek during high water periods. The groundwater in contact with the buried coal waste is the probable source for the seepage along the west side of Belt Creek.

There are two MIW discharges that originate from abandoned coal mines on the east side of Belt. The Lewis Coulee Mine was reclaimed in 1985. The average MIW flow from the Lewis Coulee Mine (USGS Site 21 has been estimated at approximately 18 gpm, however flow rates of 30 to 100 gpm have been reported in Lewis Coulee after precipitation events (Reiten et al. 2006, Hydrometrics 2012). A Lewis Coulee storm water channel was installed in the 1980s to manage the high flows and facilitate the development of the residential and recreational areas along the lower reach of the Lewis Coulee. The second mine drain is from the Brodie Mine that discharges approximately 5 gpm of MIW to a shallow open swale just south of Lewis Coulee. The Brodie Mine MIW flows through a series of culverts and open, unlined, stormwater ditches toward Castner Park where it infiltrates into the ground.

2.1.1 Location, Topography and Features

Belt, Montana, and the project area in general, are approximately 20 miles southeast of Great Falls, Montana. The Great Falls Coal Field is in a transitional zone between plains and mountain topography (DEQ 2014). Topography of the area consists of broad gently sloping plateaus traversed by numerous mountain streams and steep coulees. Most notable in the project area are French Coulee and Castner Coulee west of Belt and Lewis Coulee east of Belt. Belt Creek, originating in the Little Belt Mountains south of Belt, flows generally from south to north through Belt.

The Federal Emergency Management Agency (FEMA) flood insurance rate map was reviewed to determine floodplains in the area. The Castner Park conveyance Ditch from the Brodie Mine to Belt Creek transverses both the 100-year floodplain and the floodway. The discharge point for the Lewis Coulee to Belt Creek is located within the floodway. The southern portion of Coke Oven Flats is outside (above) the floodplain and floodway areas where base flood elevations have been determined. The northern portion of Coke Oven Flats is shown to be in an area with a 0.2 percent chance of flood or an area of 1 percent annual chance flood with average depths of less than 1 foot or drainage area of less than one square mile. All other areas of interest for this report are not within the floodplain or floodway (FEMA 2013).

2.1.2 Site History

Belt was named for Belt Butte, a nearby mountain that has a belt or girdle of rocks around it. The Belt Mountains (once called the Girdle Mountains) also took their name from this butte. The town was originally called Castner for its founder, John Castner. His coal mine, the first in Montana, supplied fuel for Fort Benton. In 1893, the Boston and Montana Mining Company began operations in the Belt coal fields and supplied fuel for the smelter at Great Falls.

Rossillon, McCormick, and Hufstetler (2009) were contracted by DEQ to complete a historical overview of the Great Falls Coal Field. The Great Falls Coal Field was the earliest and most significant producer of coal for industrial and non-transportation, and it remained the largest producer in Montana into the early twentieth century. The Anaconda Mining Company (AMC) operated the Belt Mine from 1894 to 1913 (20 years) producing a total of about 7.5 million tons of coal and coke. The late 1890s was the peak production period for the AMC Belt Mine. During this period, the mine had up to 1,200 employees and a daily coal and coke production of 3,000 tons (Rossillon, McCormick, and Hufstetler 2009).

The bituminous Great Falls Coal Field is primarily located in east-central Cascade County, southeast of the city of Great Falls. In its entirety, it extends some 60 miles in an east-west direction, continuing into Judith Basin and Fergus Counties. The coal of the Great Falls field occurs in three non-contiguous basins. The Sand Coulee Basin, near the western end of the field, is by far the largest, and was the source of most of the commercial production in the field (USGS 1949).

The largest of the Great Falls field operations for non-railroad industrial consumption was the Belt Mine that a predecessor company began aggressively developing in 1894. The Belt Mine supplied AMC operations in Butte, Anaconda, and Great Falls with coal and coke. On March 31, 1913, AMC closed the Belt Mine due to increasingly poor mine economics. AMC sold the mine to George W. Merkle in early 1914. Merkle and his company continued to work the mine for 10 more years, but at its peak only had a crew of 100 men and a daily rate of 750 tons of coal (Rossillon, McCormick, and Hufstetler 2009).

2.1.3 Climate

Belt has a semiarid climate with warm summers, cold winters and moderate amounts of precipitation. Because of the location near the boundary between the Great Plains and the Rocky Mountains, the climate is influenced by characteristics of both regions. The climate summary is based on records from the closest long-term climatic station, about 25 miles northwest of Belt at the Great Falls Airport (http://www.wrcc.dri.edu). The average annual precipitation for the period of record (July, 1948-December, 2004) is 14.77 inches. The average snowfall is 60.6 inches. Much of the precipitation falls during the growing season. The average monthly maximum temperature is 56.4 degrees Fahrenheit (˚F) and the average monthly minimum is 33.2 ˚F. Winters are cold, but temperatures are often moderated by extended periods of mild temperatures brought on by strong, southwesterly Chinook winds. Average monthly low temperatures are below freezing from November through March with January having the coldest temperatures. Record low temperatures have been below minus 40 ˚F in months of December, January, and February (Great Falls Historic Weather). Based on average data from July 1996 to December 2008, 170 days per year have average minimum temperatures below freezing and 41 days have maximum temperatures below freezing (Western Regional Climate Center 2016). Spring is usually cloudy and cool with frequent episodes of rain or snow. Summer characteristically has warm days and cool nights with frequent afternoon and evening thunderstorms. Fall months cycle between cool, moist and warm, and dry conditions (Reiten et al. 2006).

2.1.4 Geology and Soils

The coal seams of the Great Falls Coal Field are located at the top of the Jurassic-Cretaceous Morrison Formation—mainly shale and siltstone—and are conformably overlain by clastic sediments of the Cretaceous Kootenai Formation (Vuke et al. 2002; Duaime et al. 2004). Erosionally-resistant sandstone units in the Kootenai Formation., including the Cutbank and Sunburst members, form the backbone of the broad, grassy uplands in this portion of the Rocky Mountain foothills. The coal seams crop out in deeply incised valleys formed by ephemeral streams that drain generally northward toward the Missouri River.

The surface geology of the project area consists of weathered mudstone and sandstone of the Kootenai Formation. Thin soils, containing abundant cobble and boulder-sized tabular slabs of weathered sandstone, are developed on the fractured sandstone beds. The floodplain and alluvial deposits underlying the Belt Creek valley are up to 40 feet thick. The alluvium is composed of yellowish-brown to gray gravel, sand, silt, and clay (Reiten et al. 2006).

2.1.5 Hydrology and Hydrogeology

The Madison aquifer is an important local and regional source of potable groundwater. The Madison feeds two very large natural springs named Giant Springs and Big Spring, which are located at the north and east ends of the Great Falls Coal Field. Giant Springs is one of the largest fresh water springs in the U.S. with a discharge of approximately 300 cfs of groundwater near the banks of the Missouri River in the city of Great Falls (Davis et al. 2001). The recharge zone for Giant Springs has traditionally been thought to be outcrops of the Madison Group in the Little Belt Mountains, approximately 31 miles south of Great Falls. However, recent tritium analyses of Giant Springs (Davis et al. 2001; Duaime et al. 2004) indicate a component of recharge that is relatively young and therefore inferred to be more local. Big Spring, near Lewistown, Montana, has an average discharge of 130 cfs and is thought to be recharged in the Big Snowy Mountains, approximately15 kilometers to the south.

Near Belt, the coal seams of the Great Falls Coal Field are located above the regional water table. A perched water table of considerable lateral extent overlies the coal seams in permeable sandstone units (Cutbank, Sunburst members) of the Kootenai Formation. This water drains into the underlying mine workings, and is the main source of groundwater recharge to the mines (Duaime et al. 2004). The mines followed a 1 to 4 meter thick coal seam with a shallow, undulatory dip, and for this reason the mine workings are spread laterally over a huge area but have a limited vertical extent. Portions of the mines are now completely flooded with groundwater, other portions are partially flooded, and others are freely draining to surface discharge points.

Underground mines may have extensive groundwater pools with elevations controlled by spill-over points in the underground workings. The Anaconda Mine in Belt is a good example of this condition (Gammons et al. 2006). Most of the MIW from the Anaconda Mine exits at the Anaconda drain; a lesser amount exits at the French Coulee drain. The combined MIW flows directly to Belt Creek, causing severe contamination of this otherwise high quality water (Reiten et al. 2006).

2.1.6 Vegetation and Wildlife

In the project area, larger upland plateau areas between mountain streams and coulees have been converted to mostly agriculture uses, with small grain production being prominent. Valley slopes and deeply incised drainages contain slopes and rocky outcrop areas consisting of grazing lands vegetated with residual native plant communities. These native plant communities largely consist of foothill grasslands containing wheatgrass, needle and thread grass, black hawthorn, and chokecherry along the valley benches. Streams and undifferentiated river bottom areas are characterized by narrow leaf cottonwood, willows, and wild rose (DEQ 2014).

The project area is adjacent to the Town of Belt and is mainly rural/suburban. While the area is moderately developed, it is adjacent to park land, agricultural land, and open space that fronts on the Belt Creek riparian corridor. Consequently, the project area is used by mule deer and whitetail deer as it provides connections to both cover and browse. Non-game species such as rabbits, coyotes, skunks, and fox may be present in the project area as well. The project area is not considered prime wildlife habitat and does not serve as essential habitat for any threatened or endangered species (DEQ 2014).

2.2 SIGNIFICANT HISTORICAL AND ARCHEOLOGICAL FEATURES

Montana’s Abandoned Mine Lands (AML) plan requires cultural resource inventory and evaluation of historic properties more than 50 years old. Montana’s AML program completed cultural resource inventories on the French Coulee, Anaconda Bog, and Anaconda/French Bog sites in 1988. Consultation with the State Historic Preservation Office (SHPO) covered the French Coulee Site (Number 24CA96) and the Anaconda Copper Mining Company Mine Site (Number 24CA93). The sites were not considered to be eligible for listing on the National Register of Historic Places (DEQ 2014). Further resource inventory and evaluation of historic properties was completed in 2015 (Rossillon 2015).

2.3 LAND USE AND POPULATION

As of the 2010 census, there were 597 people, 261 households, and 159 families residing in Belt. The population density was 1,705.7 inhabitants per square mile (658.6 per square kilometer [km^{2}]). There were 295 housing units at an average density of 842.9 per square mile (325.4 /km^2). The racial makeup of the town was 95.5 percent White, 1.7 percent Native American, 0.5 percent Asian, 0.2 percent from other races, and 2.2 percent from two or more races. Hispanic or Latino of any race were 1.0 percent of the population (2010 Census).

As of the 2000 census (2010 Census did not evaluate financial metrics), the median income for a household in the town was $25,469, and the median income for a family was $30,104. The per capita income for the city was $14,970. About 10.2 percent of families and 12.9 percent of the population were below the poverty line, including 19.8 percent of those under 18 and 16.5 percent of those 65 or over (2000 Census).

3.0 SITE INVESTIGATION SUMMARY

Numerous investigations and studies of the Great Falls Coal Field and related environmental issues have been conducted over the last 25 years. Some pertinent investigations included the *Geochemistry and Stable Isotopes of Acid Mine Drainage in the Belt-Stockett Area, Montana* (Gammons, Duaime, and Botsford, 2006), *Long Term Water Treatment Cost for Three Acidic Coal Mine Discharges in the Great Falls Coal Field, Cascade County, Montana* (Tetra Tech 2007), *Great Falls Coal Field Water Treatment Assessment* (Hydrometrics, Inc. 2012), and *Environmental Assessment for the French Coulee Acid Mine Drainage Treatment Wetlands Removal* (DEQ 2014).

3.1 PREVIOUS ENVIRONMENTAL INVESTIGATIONS

The following presents a brief summary of four investigations:

- *Geochemistry and Stable Isotopes of Acid Mine Drainage in the Belt-Stockett Area, Montana* (Gammons, Duaime, and Botsford, 2006). This study utilizes stable isotope data to place constraints on the sources of water and sulfate in the flooded mine complexes, and the underlying groundwater aquifers. The study provides a brief overview of historic MIW treatment projects, along with concepts for future projects. The study concluded that "construction and long-term operation of water treatment plants would be very costly and at present exceeds the financial ability of the State of Montana". In lieu of passive or chemical treatment, the most promising mitigation approach identified involves some form of MIW source control. Due to the large extent of the mine workings (approximately 13 km^2 for the Anaconda Mine at Belt, approximately 46 km^2 for the complex of mines at Stockett and Sand Coulee), solutions such as locating and grouting of fractures to reduce the migration of water into the underground workings are impractical and would likely have limited effectiveness. Conversely, experience shows that simply plugging or bulk-heading the points of discharge from adits and drains merely results in diffuse MIW seepage on surrounding hillsides. A short-term pilot program in the mid-1980's to reduce the infiltration of meteoric water from the overlying crop lands to the mine workings showed some potential but could not be sustained due to the lack of the necessary funding and administrative infrastructure. An alternative idea (described by Osborne et al., 1987) is to install a series of drain wells into the Kootenai Formation, which would route the shallow, clean groundwater overlying the coal-bearing strata by gravity into the underlying Morrison Formation, bypassing the coal-bearing strata. If successful, this could cut off the primary source of recharge into the coal beds, with a resultant decrease in adit seepage.

However, in some cases, it may be more practical to take the opposite approach and completely flood the mine workings – which have extensive horizontal but limited vertical extent – by plugging the existing adit drains, or installing grout curtains in portions of the interior of the mines. Although this would not prevent mine drainage entirely, the quality of the water exiting the subsurface would likely improve, due to reduction of oxygen infiltration rates into the coal-bearing strata.

- *Long Term Water Treatment Cost for Three Acidic Coal Mine Discharges in the Great Falls Coal Field, Cascade County, Montana* (Tetra Tech 2007). An estimate of long term water treatment costs was developed for three acidic coal mine discharges in the Great Falls Coal Field in the southeast portion of Cascade County, Montana. The sites were:

    1. Anaconda Coal Mine, Belt, Montana. The three discharge points for this mine are the Anaconda Mine main adit drain, a secondary adit discharge east of the main adit, and the discharges from the MDT dewatering system on both abutments of the Highway 87/89 embankment across French Coulee. These discharges are identified in the USGS Open File Report 98-94 as Sites 5, 11 and 12 (USGS 1988).

    2. Tracy No. 1 Coal Mine, Tracy, Montana. The two discharge points for this mine are two collapsed adits identified locally as the Pipe Spring and the Stock Tank Spring. These discharges are identified in the USGS Open File Report 98-94 as Sites 22 and 23 (USGS 1998).

3. Tracy No. 2 Coal Mine, Tracy, Montana. The three discharge points for this mine are three collapsed adits identified locally as the Johnson Badwater Mine, the Johnson Small Wetlands inflow, and the Johnson Goodwater Mine. These discharges are identified in the USGS Open File Report 98-94 sites 24, 25 and 27 (USGS 1998).

The type of water treatment selected was based on mine discharge water quality, as discussed in the USGS Open File Report 98-94 (USGS 1998). The cost estimates were developed based on the selection of a water treatment facility capable of achieving Montana discharge standards for in-stream discharge. The cost estimates included a determination of the Net Present Value (NPV) of capital sufficient to fund the construction, including engineering and project management, and operation and maintenance of the water treatment facility for 100 years. The NPV determination was based on U.S. Environmental Protection Agency (EPA) guidance (EPA 2000) and included consideration of the periodic replacement of critical components based on their 30-year useful life. The estimate of operation costs of the water treatment facility included the cost of disposal of all treatment residuals (sludges) generated by the treatment facility in an off-site, licensed, solid waste facility (landfill).

- *Great Falls Coal Field Water Treatment Assessment* (Hydrometrics, Inc. 2012). The purpose of this investigation was to evaluate options and costs for active treatment of MIW from abandoned coal mines in the Sand Coulee/Stockett and Belt areas. A prioritization matrix was developed to compare and rank the potential treatment sites with regard to their current environmental and human health impacts and estimated treatment costs. The tasks accomplished to address project objectives included:

1. A site reconnaissance was to identify the locations of abandoned coal mines, point and non-point MIW discharges, and the hydrologic basins impacted by MIW.

2. Historical data were compiled into a Geographic Information System (GIS) database including water quality data, measured flow rates, sampling location coordinates, previously mapped abandoned mine workings, and other relevant project data. The database was used to assess MIW sources and associated surface water impacts, and to identify data gaps.

3. Synoptic stream flow and water quality data were collected at representative MIW discharge points and at select locations in the receiving waters for quantitative contaminant loading analyses.

4. MIW discharges were grouped based on the potential for combined treatment, and the treatability of combined discharges was assessed. The treatment assessment included bench-scale testing of two prospective lime-based water treatment technologies.

5. The MIW discharges in the study area were assigned a prioritization ranking based on contaminant loads, receiving water impacts, potential for human health exposure, resource potential of the impacted water bodies, MIW treatability, and cost considerations.

6. NPV determinations for four water treatment plants using the assumptions and methods employed by Tetra Tech (2007).

Belt Creek was found to have the highest final prioritization ranking for treatment, followed by Sand Coulee, Cottonwood Coulee and then Number Five Coulee. The ranking methodology compared the sites based on a range of factors and was intended to provide an initial framework for examining treatment prioritization.

- *Environmental Assessment for the French Coulee Acid Mine Drainage Treatment Wetlands Removal* (DEQ and OSM 2014). The 2014 EA for the French Coulee Acid Mine Drainage Treatment Wetlands Removal was completed to assess impacts related to the decommissioning and removal of the inactive constructed wetland treatment system. The Anaconda/French Bog site, or French Coulee Wetland was constructed in the fall of 1990 and spring of 1991 by the Montana Department of State Lands, Abandoned Mine Reclamation Bureau as an experimental test bed for biological treatment of MIW. Montana's abandoned mine program now proposes to remove this no longer operational MIW treatment system as the system is no longer needed. The sludge and spent compost beds that remain at the facility were constructed on private property with the consent of owners who were interested in providing a place for testing passive MIW treatment technology. Now that the experiments and system monitoring have ended, the landowners have requested that the remnants of the facility be removed and the land restored to a usable condition. Area residents have expressed concerns about dust that blows off the dry treatment ponds. AML proposed to remove the metal-saturated compost, pond liners, pipes and flumes, and restore the areas to grass and pasture.

  The EA evaluated two alternatives including: Alternative 1 – No Action, and Alternative 2 – Remove Treatment System. DEQ also considered and rejected the alternative of replacing the French Coulee treatment system with another treatment system designed to treat acidic mine water from the French Coulee Drain. This potential alternative was ultimately rejected as construction of a new treatment system at French Coulee would not result in significant water improvements to Belt Creek because it would only treat a small portion of the discharges to Belt Creek. Evaluation of the two alternatives resulted in the selection of Alternative 2 as the preferred alternative.

3.2 CONTAMINANTS OF CONCERN

The Belt MIW sources evaluated for treatment by some designed water treatment processes come from five different sources. A summary of the water quality and quantity data from previous Belt MIW sampling is provided in Table 3-1. Tetra Tech (2007) previously calculated flow-weighted mean concentrations for aluminum, cadmium, copper, iron, and zinc using the concentrations from combined Anaconda Mine and French Coulee MIW sources using the USGS data from 1994 through 1996 (USGS 1998). Hydrometrics (2012) also evaluated water treatment alternatives for multiple MIW sources in the Great Falls coal field and included water quality determinations of Belt MIWs in their evaluation.

Water treatment alternatives for MIW in the Belt area must consider treatment of the combined MIW flows. The combined Belt MIW water quality estimate, as shown in Table 3-1, would have a low pH of approximately 2.5 standard units and elevated levels of various metals as the contaminants-of-concern (COCs) during low flow periods in Belt Creek. Data from Table 3-1 are from samples at Belt collected in August and September of 2011 (Hydrometrics 2012).

The projected COCs in the combined MIW are dissolved aluminum (~206 milligrams per liter [mg/L]) and the following estimated total recoverable concentrations (TRC) for: arsenic (~0.0126 mg/L), beryllium (~0.0239 mg/L), cadmium (~0.0207 mg/L), copper (~0.1522 mg/L), iron (~315 mg/L), thallium (~0.0012 mg/L), and zinc (~4.89 mg/L). These metals concentrations all exceed the most stringent standard criteria in DEQ-7 (DEQ 2012). Water quality standard exceedances in Belt Creek downstream of the MIW discharges have generally been for the aquatic life standards for dissolved aluminum and total recoverable iron sampled during baseflow conditions.

TABLE 3-1
BELT SUMMARY TABLE

Site Code	B-2	B-3	B-4	B-5	B-6	B-7	B-8	B-9	B-10	B-12	B-13			
Site Description	**Mine Portal Discharge to Lewis Coulee**	**Lewis Coulee above collection drain**	**Lewis Coulee outfall to Belt Ck**	**Upstream of Castner Park**	**Open ditch at Castner Park**	**Pipe Discharge Above French Coulee Wetlands**	**MDT outfall adjacent to French Coulee wetlands**	**Flat Ditch below USGS 11&12**	**Flat Ditch upstream of Anaconda Drain**	**Flat Ditch below Anaconda Drain after Culvert at Road Crossing**	**Flat Ditch Outfall to Belt Ck**	**Combined WTP Influent**	**Most Stringent Standard Value from Circular DEQ-7 (mg/L, except for pH)**	**Potential Contaminant-of-Concern? (Notes)**
Flow (gpm)	3	5	6	5	5	6	19	15	0	--	135	199*	None	No
Field pH	2.9	3.1	2.8	2.4	2.5	2.3	2.5	2.6	2.4	2.5	2.5	2.51	6.5-9.0	**Yes**
Acidity as $CaCO_3$	2200	2500	2600	3200	2900	3700	4100	4200	4200	1500	1700	2,301	None	No
Alkalinity as $CaCO_3$	4	4	4	4	4	4	4	4	4	4	4	4.00	None	No
Sulfate	3300	3700	3900	3900	3800	4800	5000	4900	5100	2200	2200	2,938	None	No
Fluoride	3	3	4	3	3	6	3	4	4	4	4	3.87	4	No
Aluminum (dissolved)	244	289	298	279	274	363	364	360	384	147	147	**206**	**0.087**	**Yes, standard based on dissolved Al from pH 6.5 to 9.0**
Antimony TRC	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.0030	0.0056	No
Arsenic TRC	0.006	0.005	0.004	0.004	0.004	0.005	0.052	0.047	0.027	0.005	0.005	**0.0126**	**0.010**	**Yes**
Barium TRC	0.016	0.013	0.015	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0057	1	No
Beryllium TRC	0.019	0.017	0.024	0.022	0.023	0.038	0.035	0.035	0.037	0.022	0.021	**0.0239**	**0.004**	**Yes**
Cadmium TRC	0.0268	0.0302	0.0291	0.0612	0.0625	0.013	0.0106	0.011	0.0116	0.0198	0.0196	**0.0207**	**0.0008**	**Yes, hardness-based parameter**
Chromium TRC	0.1	0.098	0.078	0.187	0.187	0.158	0.152	0.158	0.16	0.081	0.082	0.1025	0.268	No, hardness-based for Cr(III) (Also need hex-chrome data)
Copper TRC	0.332	0.352	0.325	0.232	0.211	0.161	0.122	0.133	0.142	0.132	0.134	**0.1522**	**0.0305**	**Yes, hardness-based parameter**
Iron TRC	359	363	272	433	354	558	800	764	685	179	180	**315**	**1**	**Yes**
Lead TRC	0.0082	0.0057	0.0068	0.0005	0.0006	0.0005	0.0086	0.0076	0.0068	0.0012	0.0012	0.0027	0.0186	No, hardness-based parameter
Manganese TRC	1.94	1.92	2.47	0.685	0.733	0.734	0.481	0.506	0.541	0.504	0.504	0.6357	None	Not in 2012 DEQ-7 circular
Mercury TRC	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00005	No
Nickel TRC	1.19	1.38	1.43	1.73	1.65	0.89	0.68	0.75	0.75	1.31	1.05	1.0413	0.1685	No, hardness-based parameter
Selenium TRC	0.002	0.002	0.002	0.003	0.003	0.004	0.004	0.004	0.004	0.002	0.002	0.0025	0.005	No
Silver TRC	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0006	0.0006	0.0006	0.0005	0.0006	0.0006	0.0440	No, hardness-based parameter
Strontium TRC	1.3	1.3	1.3	1.1	1.1	2.2	1.2	1.3	1.4	1.3	1.3	1.3075	4	No
Thallium TRC	0.0017	0.002	0.0018	0.0008	0.0007	0.0007	0.0026	0.0024	0.0021	0.0009	0.0009	**0.0012**	**0.00024**	**Yes**
Zinc TRC	3.56	4.15	4.3	5.39	5.49	4.21	2.94	3.34	3.78	5.38	5.41	**4.8905**	**0.388**	**Yes, hardness-based parameter**
TSS	84	14	26	10	68	14	28	10	18	10	14	18	None	No
TDS	4800	5490	5630	5490	5360	7110	7330	7260	7940	3140	3270	4,332	None	No
Chloride	20	13	15	10	11	23	20	28	32	7	6	10	None	No
Calcium	192	199	214	133	140	239	153	162	175	152	153	159	None	No
Magnesium	131	133	140	93	95	97	79	81	87	66	66	76	None	No
Hardness (calculated)	1019	1044	1111	715	741	996	707	738	795	651	654	708	None	No

*Note: These data were used to estimate representative water quality data for the combined effluent. A more comprehensive set of flowrate data were used to estimate average and design flowrates for the WTP.
CaCO3 = calcium carbonate
gpm = Gallons per minute
TDS = Total dissolved solids
TRC = Total recoverable concentrations
TSS = Total suspended solids

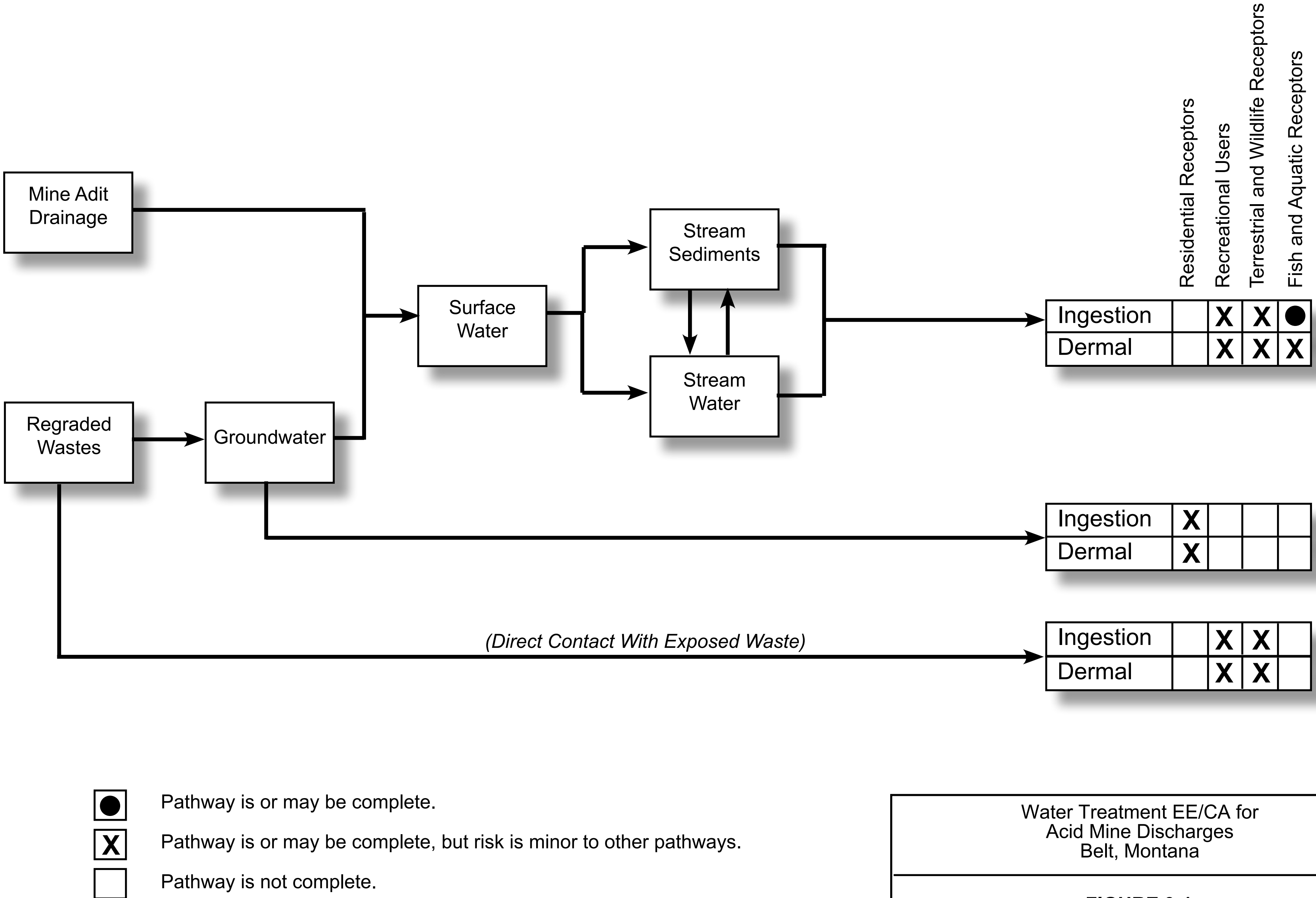
3.3 CONCEPTUAL SITE MODEL

The Anaconda Mine was the largest coal mine in the Belt area and is the primary source of MIW to Belt Creek in this area. The largest discharge component (approximately 105 gpm, or 69 percent) of the total average discharge (estimated to be approximately 152 gpm) comes from the Anaconda Mine drain that was installed by the Montana Department of State Lands when the mine portal was closed in the 1980s. Three other smaller MIWs come from (1) the main French Coulee collection system (USGS Site 11), south of the Anaconda Mine, (2) a second inflow to the French Coulee collection (USGS Site No 12), and (3) seepage from groundwater under Coke Oven Flats into Belt Creek. Flat Ditch is a man-made, unlined, approximately 1,600-foot long ditch that crosses Coke Oven Flats and discharges to Belt Creek approximately 500 feet northeast of the Anaconda Mine drain outfall (Figure 2-1). There is acidic groundwater seepage that flows into Belt Creek and is evident along the western bank of Belt Creek immediately upstream and downstream of the Flat Ditch outfall (Reiten et al. 2006).

There are two MIWs that originate from mines east of the Town of Belt. The Lewis Coulee discharge (USGS Site No. 21) has an estimated average flow rate of 18 gpm, however flow rates of 30 to 100 gpm have been reported in Lewis Coulee after precipitation events (Reiten et al. 2006). The second MIW comes from the site known as the Brodie Mine (USGS Site No. 13) and has an approximate flow of 5 gpm. The Brodie Mine MIW generally flow west toward Belt Creek, but the acid waters pool and pond in low areas as it traverses through culverts and open unlined stormwater ditches through a residential area toward Castner Park where it primarily infiltrates into the alluvium and rarely flows all the way to Belt Creek.

Based on the known MIWs and familiarity of the environmental pathways, a conceptual site model (CSM) has been developed for the Belt Water Treatment project and local area (Figure 3-1). The CSM includes information gained through previous sampling and analyses, review of background documents, and observations of the local setting.

The CSM identifies three sources of COCs with the two water sources (surface water and groundwater to surface water) being evaluated for treatment by the Belt water treatment plant. The Belt COC sources are: (1) mine adit drainage from both sides of Belt Creek, (2) groundwater impacted by regraded mine wastes underlying Coke Oven Flats, and (3) the mine wastes underlying Coke Oven Flats.



Water Treatment EE/CA for
Acid Mine Discharges
Belt, Montana

FIGURE 3-1
Belt Water Treatment
Conceptual Site Model

TETRA TECH

The Mine Adit Drainage contaminant source is composed of four known MIWs:

1. The Anaconda Mine drainage, the largest and most consistent component of the total volume of acid mine drainage to be treated (approximate mean flow of 105 gpm).
2. The French Coulee seeps composed of the main collection system flow and a second smaller inflow (approximate mean combined flow of 35 gpm).
3. The Lewis Coulee and Brodie Mine discharges on the east side of Belt (approximate combined mean flow of 23 gpm).
4. Shallow groundwater seepage, potentially impacted by buried mine wastes in Coke Oven Flats and surrounding area (estimated discharge of 1 gpm to Belt Creek).

The groundwater impacted by regraded wastes could also be a source for metals and other mine-related contaminants at the Belt site. The regraded wastes are primarily composed of coal and coke waste materials regraded during the abandoned mine reclamation work at Coke Oven Flats. Groundwater underlying Coke Oven Flats is contaminated and discharges to Belt Creek. Previous site investigations and general observations indicate groundwater seasonally infiltrates Flat Ditch as it crosses Coke Oven Flats and there is evidence of acidic seepage along the west bank of Belt Creek (Hydrometrics 2013).

The primary mechanisms for transfer and potential accumulation of source contaminants (metals in surface water and groundwater) to human and environmental receptors are shown in the CSM (Figure 3-1). The dominant mechanism or route is by surface water flow, and groundwater to surface water flow, across the site and into Belt Creek. Surface water includes the open ditches conveying the MIW and Belt Creek adjacent to and downstream of Coke Oven Flats. As the acid mine drainage water enters Belt Creek, there are interactions of metals and contaminants with the stream water and stream sediments. The ingestion and dermal pathways may transfer the contaminants to residential and recreational human receptors, terrestrial and wildlife receptors, and to fish and aquatic receptors.

A secondary potential pathway exists through the residential use of groundwater for cooking, drinking, and bathing. A public water supply well that draws water from the Madison aquifer for the City of Belt is located 350 feet south of the diagonal ditch outfall. The regraded wastes could be a source for direct contact by burrowing animals, other terrestrial animals, and recreational human receptors by ingestion and dermal contact. The direct contact with regraded waste exposure pathway is not being addressed by this Belt water treatment evaluation. The wastes were graded, covered by a soil cap, and revegetated by the AML program. Given these conditions, minor human health risks are posed are currently posed by the regraded waste.

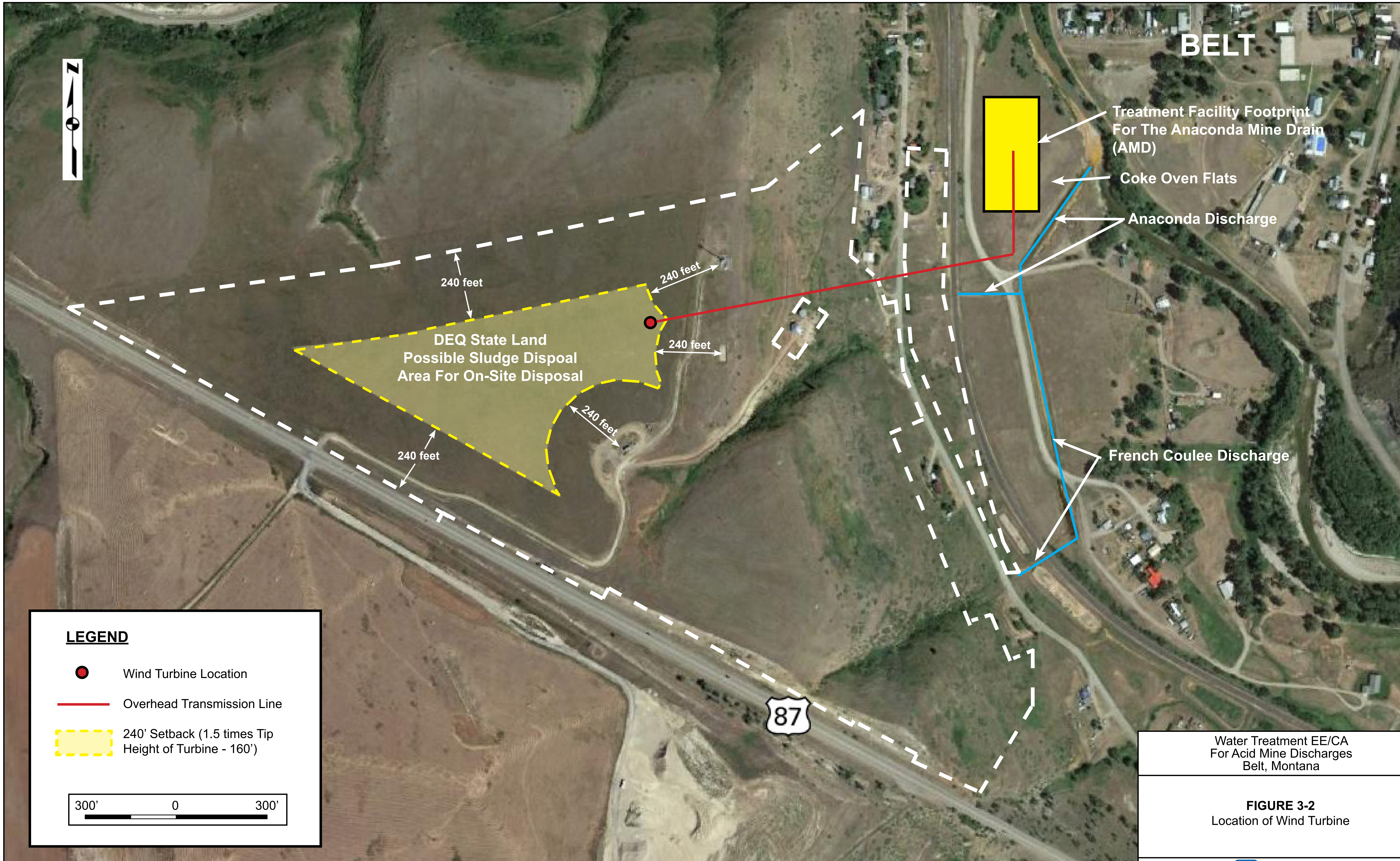
3.4 EVALUATION OF POTENTIAL FOR POWERING BELT WTP WITH WIND POWER

Montana DEQ requested an analysis of utilization of wind-powered electricity generated from turbines constructed on DEQ-owned property located on the terrace west of Coke Oven Flats to assist with the energy demands of a water treatment plant at Belt. Tetra Tech completed a preliminary conceptual analysis of the wind potential at the site, selection of a suitable wind turbine for this application, and the estimated cost/benefit of utilizing wind power. No on-site studies or investigations were completed as part of this evaluation.

3.4.1 Site Location

The area where the wind turbine could be located is shown on Figure 3-2. Key factors in locating the wind turbine are setback requirements from existing structures and site boundaries (typically 1.5 times the maximum tip height of the turbine), avoidance of obstructions or sudden topographic changes that could impact wind flow, and proximity to the water treatment plant. The latter is important because greater distance means higher cost for transmission and power losses over the transmission line. For this evaluation the closest locations that meet these general criteria are approximately 1600 feet away from the possible water treatment plant locations.

Other typical siting factors that would have to be considered in a detailed analysis include sensitive environments (wetlands, flora or fauna habitats), local siting codes (often based on setback, visual and noise factors), local building codes and site access or obstructions that could impact construction. Broader scale siting considerations may include migratory bird, bat and eagle concerns and cultural resources. Other than an assumed setback requirement as mentioned in the previous paragraph, none of these other siting factors were evaluated as part of this EE/CA.



Water Treatment EE/CA
For Acid Mine Discharges
Belt, Montana

FIGURE 3-2
Location of Wind Turbine

TETRA TECH

3.4.2 Electrical Power Requirements for Water Treatment Plant

For purposes of selecting a wind turbine for this application, the power requirements for the most likely treatment plant design, Conventional Lime Treatment, were considered. Based on the operation and maintenance (O&M) Cost tables for Conventional Lime Treatment/One Stage Process, the total power requirement in the plant would be equivalent to 59.6 horsepower or approximately 45 kilowatts (kW). This load is with all motors operating at full name capacity. However, typical operating electrical loads would likely be lower. The same O&M Cost table estimates that the annual power consumption at the plant will be approximately 316,500 kilowatt hours (kWh). Using a unit cost of $0.08/kWh, the estimated annual power cost would be approximately $25,500.

3.4.3 Wind Resource at Terrace Mesa West of Coke Oven Flats

No site specific wind resource data is known to be available for the terrace where the turbine would be located. However, regional wind resource maps are available and were used by Tetra Tech to give an indication of the potential wind resource. The maps used is titled "Montana Wind Power Resource Estimates" and was prepared by U.S. Department of Energy, National Renewable Energy Laboratory. This map provides estimated wind power resources at 50 meters heights across the state of Montana. Of course the information is generalized based on the scale of the map but it does give a good indication of the potential wind resource. The wind class at the site is rated "Wind Power Class 3" or "Fair" with average wind speeds in the 6.4 to 7.0 meters per second (m/s) (14.3 to 15.7) miles per hour range. For a perspective, this site is not one that would likely be developed for commercial wind power production because of the relatively modest wind speeds but it can provide some wind-generated electrical power for this project.

Once Tetra Tech selected a turbine for this evaluation as described in the next section, Northern Power Systems was able to look more closely at the potential wind resource. They have access to proprietary software and data bases that provide a more refined resolution for estimating wind resources. Based on their analysis, the average wind speed at this site would be 6.3 m/s with a one standard deviation range of 5.9 to 6.6 m/s. The wind direction is predominantly SW to W. Their data also includes information on the wind velocity versus time which Tetra Tech used in our power output/cost evaluation.

Another factor affecting wind power output is the cold temperatures during the winter months. When temperatures are below negative 4 °F, standard wind turbines shut down to avoid damage. However, wind turbines can be procured with a cold weather package to allow operation during cold weather. The cold weather package is basically a heater system to maintain a safe operational temperature for the components in the nacelle when the winds are too slow to keep the turbine operational and warm. Once the wind speed increases, the turbine can generate power even though the outside temperatures remain low. The power required to operate the heating system is generally more than made up for by the extra power generated when the turbine would otherwise be shut down. There is a secondary benefit from operating at low temperatures due to the greater air density which in turn allows the wind turbine to produce more power at the same wind velocity as on a warm day.

3.4.4 Wind Turbine Selection

The first selection criterion for this evaluation was the potential power output of a turbine. A 100 kW turbine was selected because it would produce approximately the amount of electricity needed to power the water treatment plant on an annual basis. A larger turbine would produce excess power much of the time it was operational and the value of that power is relatively low for this application since Northwestern Energy does not offer a "Net Metering" option for projects over 50 kW in output size. A smaller turbine would not provide a significant amount of power for the plant and would likely have a higher cost per kWh. Wind turbines are not custom made so size selection is limited and 100 kW appeared to be an appropriate size for this application.

The next step was to select a turbine manufacturer to enable Tetra Tech to obtain actual cost data for use in the cost analysis that follows in a later section of this engineering evaluation. For this, Tetra Tech selected a 100 kW wind turbine built by Northern Power Systems (NPS), Model NPS 100C-24 with a cold weather package.

The NPS 100C-24 wind turbine has a 24.4 meters (80 foot) diameter rotor, a tower hub height of 117 feet, and a maximum tip height of 160 feet. It is designed for Class III/A low wind conditions and has a larger rotor diameter than the similar turbine that is designed for Class II/A high wind conditions. This turbine has a cut-in wind speed of 3 m/s, a rated wind speed of 12 m/s and a cut-out wind speed of 25 m/s.

3.4.5 Wind Power Production Potential

Based on the site specific estimates prepared by Northern Power Systems, the NPS 100C-24 turbine will annually, on average generate approximately 248,000 net kWh of electrical power which yields a capacity factor of approximately 28 percent. This is a relatively low capacity factor and reflects the relatively modest average wind speed at this site. It should be reiterated at this point that no site specific wind data exists for this location and the actual wind speeds and distribution of those speeds could be lower or higher and that could have a significant impact on the estimates that follow. The term "net" referred to in relation to the average annual power production takes into account the consumptive power required by the wind turbine to maintain communications and provide heat in cold temperatures. The wind turbine would be connected to the local electrical grid and its heater would consume power during low wind periods.

The turbine will produce approximately 45 kW of energy at a wind speed of approximately 8 m/s. Based on the projected distribution of wind speed versus time, the wind speed at this location would be 8 m/s or higher about 32 percent of the year or stated another way about 40 percent of the time that the wind speed is 3 m/s or greater. About 21 percent of the time there will not be enough wind to generate any electricity because the wind speed is less than the cut-in speed.

The 45 kW of energy wind speed was selected for the evaluation because that is approximately the normal water treatment plant load. Therefore, at this wind speed or any speed below this level essentially 100 percent of the power generated by the wind turbine will be consumed in plant operations. At higher wind speeds, the turbine will generate more power than the plant can use and the assumption is that excess power will be "purchased" by Northwestern Energy. The assumption here is that Northwestern Energy will engage in a Power Purchase Agreement and will purchase the excess power albeit at a reduced rate below typical retail net metering rates, similar to the arrangement at the Zortman/Landusky Mines.

The result of this evaluation of average power generated annually of 248,000 kWh is that the majority of this power will be consumed by the water treatment plant but a portion of the power generated when the wind speed exceeds 8 m/s will be excess power. Tetra Tech estimates that approximately 198,000 kWh will be used directly by the plant and that approximately 50,000 kWh will be excess power that will be purchased by NorthWestern Energy. The reason that essentially 20 percent of the power generated will be excess power is that the power output of all wind turbines is a function of the cube of the wind speed. Doubling the wind speed generates eight times as much power. Therefore, the approximately 32 percentage of the time that the wind speed exceeds 8 m/s generates a large percentage of the total annual wind energy production from this or any wind turbine.

3.4.6 Cost Analysis

The proposed water treatment plant located in Belt, Montana would be powered by utility grid power supplied by Northwestern Energy since the plant is located in an area already served electrical power by Northwestern Energy. The possibility of using wind power to offset a large portion of the grid power is being evaluated as a potential cost savings for the plant operations as well as a means to use renewable energy for this environmental cleanup project.

Since there are no fuel costs associated with the use of wind power, the cost of wind generated power is essentially entirely related to the capital cost amortization of the wind turbine and associated appurtenances plus the annual O&M costs associated with operating and maintaining the turbine. The following costs have been estimated based on information provided by Northern Power Systems, the actual costs incurred at the Zortman/Landusky Mine installation, research, and Tetra Tech experience. As with the wind regime estimates, no site specific design data or testing was completed for this EE/CA and the costs would be updated and revised after those detailed engineering and construction studies were completed and the costs reevaluated.

Preliminary Capital Costs for NPS 100C-24 Wind Turbine Acquisition/Install	
Turbine acquisition and install (complete)*	$450,000
Cold Weather Package	$20,000
Pad mount step-up transformer	$20,000
Overhead transmission line (1600 ft)	$86,000
Switch gear specific to plant/metering	$50,000
Construction oversight, misc. (DEQ)	$80,000
Subtotal Acquisition/Installation	$706,000
Annual O&M and Replacement Parts	
O&M by contract from NPS	$4,200
Parts (1% of install cost)	$7,100

*Includes engineering design, geotechnical investigation, transportation, foundation, erection, Standard 480 Volt 3 phase install, 2 year warranty.

A typical application for a 100kW or similar-sized wind turbine would place the turbine within a short distance of 200 feet or less from the point of use. This eliminates a transmission line and negates the need to step up the turbine output voltage to minimize losses. The NPS 100C-24 turbine produces 3 phase, 480 voltage alternating current, 60 horsepower (Hp). However, in this case the wind turbine as shown on Figure 3-2 would be approximately 1,600 feet from either water treatment plant location. Therefore, a short transmission line will be required. For this case an overhead transmission line was selected for the cost analysis because it is generally much less costly than an underground cable. Two components of the costs shown above are directly related to the distance of the wind turbine from the water treatment plant. These are the pad mount transformer to step up the voltage to the local Northwestern Energy distribution voltage and the overhead transmission line.

This wind turbine is designed to a 20 year life with an expected service life of 25 to 30 years. For purposes of this cost analysis a 20 year life will be used and straight line depreciation. On that basis the estimated annualized capital cost for this single wind turbine acquisition and installation is $35,300. The O&M and replacement parts estimate totals $11,300. Therefore, the total annual cost for this turbine is approximately $46,600. The estimated cost per kWh is approximately $0.188 which is slightly more than twice what the kWh electrical rate is assumed to be from Northwestern Energy.

Another more direct way to evaluate the cost benefit of the turbine is to compare the electrical cost offset to the cost of owning and operating the turbine. Based on previous information presented in Section 1.6, the estimated water treatment plant usage of wind generated power will be approximately 198,000 kWh/year with another 50,000 kWh/year being "purchased by Northwestern Energy. In the O&M Cost tables for Conventional Lime Treatment/One Stage Process, electrical power was assumed to cost $0.08/kWh and the total annual consumption was 316,500 kWh at a cost of $25,320. For the Landusky wind turbine the purchase rate was $0.027/kWh. Assuming these rates apply to the Belt water treatment plant case, then the value of the energy produced by the wind turbine would be approximately $15,840 for the power used by the water treatment plant and approximately $1,350 for the power purchased by Northwestern Energy. The total of these is $17,190 which is well below the estimated annual ownership and O&M cost of the wind turbine of approximately $46,600.

If, however, the wind turbine capital costs for purchase and installation were covered by a grant or other means and were not included in the cost analysis, then the estimated annual O&M cost of $11,200 would be the total cost. The estimated net saving in power cost would be $17,190 and a net savings of approximately $5,860 per year could be realized.

4.0 BASIS FOR MINE DISCHARGE WATER TREATMENT ACTION

An average combined MIW flowrate of 152 gpm currently flows from up to five mine drainages and seeps, and discharges directly into Belt Creek or infiltrates into the alluvium near the town of Belt. The combined flows of the Anaconda Mine, French Coulee Mine collection system, and a second mine seepage, flow into Belt Creek, via Flat ditch, near adjacent to Castner Park commonly used for recreational wading and swimming. Two additional MIWs flow from abandoned mines on the east side of Belt coming from the Lewis Coulee Mine and the Brodie Mine discharges. The east side MIWs currently flow through open stormwater drainage ditches through the Belt City Public Park and recreational area (Castner Park and ball fields).

The MIWs are highly acidic and have decreased the pH of Belt Creek and increased metals concentrations in the stream and sediments. DEQ, Montana Bureau of Mines and Geology (MBMG), USGS, and others (Karper 1998; Gammons et al. 2006; Reiten et al. 2006; Tetra Tech 2007; Gammons et al. 2010; Hydrometrics, Inc. 2012; Hydrometrics, Inc, 2013) have completed numerous investigations and studies of the Great Falls Coal Field and related environmental issues over the last 25 years. The pH of the MIWs in Belt ranges from approximately 2.3 to 3.0. Fluoride, arsenic, beryllium, cadmium, chromium, copper, iron, nickel, thallium, and zinc have been detected in the MIW above DEQ-7 criteria. The primary cations in the discharges from the abandoned mines are iron and aluminum (approximately 470 and 270 mg/L, respectively).

The concentrations of metals are not uniform across the different MIW sources (see Table 3-1; Reiten et al. 2006). The Anaconda Mine has generally had lower metal levels with an average dissolved iron concentration of 152 mg/L, average dissolved aluminum concentration of 104 mg/L, and an average dissolved manganese concentration of 0.417 mg/L. The French Coulee Mine MIW has had the highest concentrated metals' levels with iron at 939 mg/L, aluminum at 468 mg/L, and manganese at 0.9 mg/L. The combined flows from Lewis Coulee Mine and Brodie Mine MIWs have generally had intermediate metal concentrations with an average dissolved iron of 615 mg/L, average dissolved aluminum of 336 mg/L, and average dissolved manganese concentration of 1.15 mg/L.

Formal human health and ecological risk assessments have not been conducted for the site. The concentrations of dissolved metals and acidity of the MIW, and the potential exposure pathways for risks to human health and the environment (see Section 3.3), and the loss of beneficial uses in Lower Belt Creek indicate there is a need for action. The potential risks to humans and ecological receptors arise from the actual or potential direct exposure to nearby human populations and terrestrial and aquatic animals from the dissolved metals in the MIW and Belt Creek and through transfer and accumulation mechanisms into the food chain. Based on these potential risks to human health and the environment, the construction of a water treatment plant near Belt would be an appropriate action to treat MIW and prevent or minimize human and ecological exposure to high levels of metals and the negative effects it has on the aquatic community in Belt Creek.

5.0 APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARAR)

This section identifies and evaluates potential ARARs and sets forth DEQ's determinations regarding those potential ARARs for Belt water treatment action alternatives retained for detailed analysis in this EE/CA. DEQ has primary responsibility for identifying the ARARs for the Belt water treatment plant.

The ARARs are currently under development and review by DEQ and are expected to be finalized with the final version of the EE/CA. The project will comply with the National Environmental Policy Act of 1969 (NEPA) and related environmental laws, regulations, and executive orders as stipulated in Part 4 of the Federal Assistance Manual (FAM).

When the ARARs are finalized Section 5.1 will summarize the definitions and concepts pertinent to ARARs determinations. The three categories of ARARs, chemical-, location- and action-specific, will be described in Sections 5.2, 5.3, and 5.4, respectively.

6.0 WATER TREATMENT ACTION OBJECTIVES AND GOALS

The overall water treatment goal is to protect human health and the environment and restore affected portions of Lower Belt Creek to supporting its beneficial uses. The water treatment action specific objectives and goals are discussed in the following sections.

6.1 WATER TREATMENT ACTION OBJECTIVES

The water treatment action objective is intended to remove the site conditions that trigger National Contingency Plan (NCP) criterion for a removal action. The NCP includes a framework for responding to hazardous substance releases and authorizes the lead agency to initiate appropriate remedial actions in the event of a hazardous substances release. In this case, the release is the continual MIW discharge from the coal mines. The criterion is:

- Actual or potential exposure to nearby human populations, animals, or the food chain from hazardous substances or pollutants or contaminants. Administrative Rules of Montana 17.30 prohibits discharges to surface water and groundwater that are toxic or harmful to human, animal, plant, or aquatic life. Recreationists that frequently visit Castner Park or swim in Belt Creek could potentially be exposed to acidic conditions in the water and elevated metals concentrations both in Belt Creek and the conveyance ditch from Brodie Mine to Belt Creek. Potential for exposure to acidic conditions also exists in the water and elevated metals concentrations in Lewis Coulee, flat and diagonal ditches, and the French Coulee conveyance system and associated ponds. The potential exposure routes for humans are dermal and ingestion. The diversity and population of aquatic macroinvertebrates and fish decreases significantly in Belt Creek because of MIW discharge from the Anaconda Mine Drain, the French Coulee collection system, Lewis Coulee, Brodie Mine, and groundwater discharging from Coke Oven Flats.

Based on this NCP removal action criterion the following preliminary remedial action objectives (PRAO) are identified for the site:

- Prevent the potential exposure to humans, animals, and the food chain by capturing and treating the water currently discharging from Anaconda Mine Drain, the French Coulee collection system, Lewis Coulee, Brodie Mine and contaminated groundwater underlying Coke Oven Flats to achieve Circular DEQ-7 Water Quality standards for surface water.

Achieving this objective is expected to result in mitigation of NCP removal action criteria, protection of human and ecological receptors, and protection of water quality in Belt Creek.

6.2 PRELIMINARY REMOVAL ACTION GOALS

Cleanup levels applicable to metals concentrations in surface water discharged from treatment of MIW are defined in DEQ Circular DEQ-7. Mixing zones may have to be used for several of the treatments described below to meet DEQ-7 surface water quality standards. However, use of a mixing zone to achieve water quality standards in Belt Creek will be problematic during low flow conditions at the site because the plant discharge will be the primary source of water. Water quality standards (WQS) may not be met during low flow in this scenario.

7.0 IDENTIFICATION AND SCREENING OF RESPONSE ACTIONS, TECHNOLOGY TYPES, AND PROCESS OPTIONS

Selection of the appropriate treatment alternatives for the MIW at Belt depends on: (1) the treatment water quality goals, (2) influent water quality of the MIW, (3) the effectiveness of the potentially applicable technology and process options, and (4) cost.

The alternative selection process involves five steps that include: (1) identification of general response actions, technologies, and process options; (2) initial technology screening and alternative development; (3) detailed analysis of alternatives; (4) analysis of implementability of identified alternatives; and (5) comparative analysis of alternatives. General response actions, technologies, and process options are identified in Section 7.1. The results of the initial technology screening and alternative development process for addressing Belt MIW are described in Section 7.2. The detailed analysis of alternatives is presented in Section 8.0. The comparative analysis of alternatives and presentation of the recommended site strategy are presented in Section 9.0.

7.1 IDENTIFICATION OF GENERAL RESPONSE ACTIONS, TECHNOLOGIES, AND PROCESS OPTIONS

The first step in the removal action alternative selection process is identifying general response actions that may satisfy the PRAOs. General response actions are then progressively refined into technology types and process options. The process options are then screened in Section 7.2 and the retained technologies and process options are combined into potential treatment alternatives. The purpose of the initial screening is to eliminate from further consideration process options that are not feasible, and retain those process options that are potentially feasible.

Sources of metals contamination and acid mine drainage identified at Belt that will be addressed by this reclamation action are: (1) Anaconda Belt Mine; (2) French Coulee Collection System; (3) Lewis Coulee; (4) Brodie Mine; and (5) Coke Oven Flats groundwater seepage. General technologies potentially capable of meeting the PRAOs for these sources of contamination are discussed in Sections 7.1.2 through 7.1.5 and are summarized in Table 7-1.

TABLE 7-1
GENERAL TREATMENT TECHNOLOGIES

Treatment Technology	Treatment Can Achieve DEQ-7 Surface Water Quality Standards	Treatment to Improve Water Quality Without Achieving DEQ-7 Surface Water Quality Standards	Treatment Can Meet PRAOs
No Action			
Water-Powered CaO Addition System		X	
Pumping and Treating Water from Western Anaconda Mine Workings	X		X
Single Stage Lime Treatment		X	X
Two Stage Lime Treatment	X		X
Reverse Osmosis Water Treatment	X		X
Zero Valent Iron		X	
Bioreactors and Wetlands		X	
Anoxic Limestone Drains		X	
Coal Fly Ash Addition		X	

Notes:
DEQ Montana Department of Environmental Quality
PRAOs Preliminary Remedial Action Objectives

7.1.1 No Action

Under the no action option, no treatment of MIW would occur at the site. The no action response is a stand-alone response used as a baseline against which other removal actions are compared. The no action alternative will be retained through the detailed analysis of alternatives.

7.1.2 Water-Powered Calcium Oxide Addition

A low maintenance, water-powered calcium oxide (CaO) addition system could be used to reduce metals concentrations in Belt Creek by raising the pH of the water flows from the abandoned coal mines. The CaO addition is adjusted by flow regulation into the unit to achieve the desired pH in the receiving water system. The CaO addition oxidizes metals which then precipitate from the water in the form of sludge. The amount of metals that would precipitate with the CaO addition, the sludge amounts produced by the systems, and the resulting water quality would need to be determined by pilot-scale testing. The precipitate sludge is settled in settling ponds and excavated, dried, and disposed of as-needed. The sludge could be disposed on-site at a DEQ owned repository that would be developed to dispose of the sludge, or off-site at High Plains Landfill north of Great Falls.

Under this alternative, water-powered CaO addition systems would be constructed at the acid mine drainage and French Coulee MIW discharges. MIW flows from the Anaconda Belt Mine and French Coulee Collection System have the flow necessary (10 gpm) to power their own CaO addition systems. To use a water-powered CaO addition system at the other MIWs at Lewis Coulee, Brodie Mine, and Coke Oven Flats, holding ponds with pumps and simple control systems would have to be installed to pump 10 gpm through the CaO addition system units when the holding ponds fill. This is not considered feasible and is not evaluated further. The Aquafix technology has been used at former coal mines to treat MIW in the eastern United States and at hard rock mines sites with MIW in Montana and Colorado.

7.1.3 Pumping and Treating Water from the Western Anaconda Mine Workings

Under this alternative water from the Western Anaconda Mine workings would be pumped or drained from the western side of the Anaconda Mine, treated to meet DEQ WQS and discharged to Box Elder Creek. There is currently no MIW discharge to Box Elder Creek. This alternative assumes that water is pooled toward the western side of the mine and is flowing through the workings to the east side of the mine where it exits at the Anaconda Belt Mine entrance and potentially the French Coulee Collection System. If this assumption is correct, draining the western workings could decrease or eliminate the MIW discharges. If the assumption is incorrect, draining the western workings may have minimal effect on the MIW discharges from the eastern side of the mine.

If this alternative is to be further developed, additional investigations will be necessary to determine the current conditions inside the mine. The investigations would ideally include:

- Test borings to locate the potential pond area,
- Installation of monitoring and pumping wells necessary to perform a pump test,
- Several pump tests during different seasons to determine drawdown in the pond area and recharge rates,
- Sampling of the monitoring wells at different seasons to determine water quality from the pond area, and

7.1.4 Active Water Treatment

Active water treatment has several advantages over passive water treatment. One major advantage of active water treatment is that it allows for much better control of the treatment process and can generally produce better quality water compared to passive water treatment, so that specific discharge water criteria can be met more consistently with careful process design compared to passive water treatment. For example, by designing, building, and implementing an active water treatment plant that has two or more physical removal steps that can be operated at varying pH, either with two clarifiers or one clarifier and one filter that are operated at different pH, there would be flexibility in adjusting the pH levels at varying stages in the treatment process to maximize the removal of contaminants that are pH–dependent. That way the treatment process would not be hindered by trying to find a compromise pH for removing most COCs to satisfactory or near satisfactory levels. Active water treatment processes are also easier to control with varying climate conditions, especially during the cold winter months, where slower reaction kinetics can be compensated for by allowing for longer hydraulic residence time in the treatment facility if and when necessary. Additionally, plugging of limestone or organic matrices that leads to premature hydraulic failure is a major concern and disadvantage for passive treatment systems. Some disadvantages of active water treatment are that active water treatment systems are significantly more expensive to build and operate than passive water treatment systems and require more manpower to operate and maintain.

The design flowrate of the Belt MIW water treatment plant (WTP) has been set at 160 gpm based on the 75th percentile flowrate from historic flow data. Because an equalization basin is proposed, the design flowrate is set using the 75th percentile flowrate of 160 gpm instead of the 90th percentile flowrate, which is the flowrate that is generally used for the design flowrate for WTPs with no equalization basin. The chemical consumption costs are also estimated based on the design flowrate of 160 gpm instead of the average flowrate of 152 gpm to provide a slight level of conservatism in the cost estimates. The preliminary design for the equalization basin is to have a capacity of approximately 14,500 cubic feet (ft^3) or 108,000 gallons. At the design flowrate of 160 gpm, the equalization basin would provide approximately 11 hours of retention time. At the historical maximum flowrate condition of 357 gpm, the equalization basin would provide approximately 5 hours of retention time.

The hydrated lime dosages and sludge production (dry weight) were estimated by analyzing recent water quality and flow data for the four major MIW discharges that will contribute to the Belt MIW WTP, namely the Anaconda Belt Mine (USGS 5), French Coulee Collection System (USGS 11), Lewis Coulee (USGS 21), and Brodie Mine (USGS 13). A flow-weighted, mass conservation approach was used to estimate the combined influent water quality without conducting geochemical modeling. This straightforward mass conservation approach is reasonable due to the low pH of the waters, where mixing would not produce significant precipitation or adsorption of dissolved species.

Traditionally, the acidity as calcium carbonate ($CaCO_3$) and associated hydrated lime dosage for treating MIW is estimated based on the following formula: **$50[(2Fe^{2+}/56) + (3Fe^{3+}/56) + (3Al/27) + 2Mn/55 +1000(10^{-pH})]$** ; however, when there is high sulfate concentration in the water, as is the case for the Belt MIW, it is more accurate to base the acidity and associated hydrated lime dosage on **$Acidity_{calculated}$, eq/L** $= \sum \varepsilon_i M_i$, where ε_i is the number of equivalents per mole of the i^{th} species that contributes acidity and M_i is the concentration in moles per liter of the i^{th} species, which takes into account the acidity of sulfate at low pH, where bisulfate can exert a significant amount of acidity that would otherwise be unaccounted for (Kirby and Cravotta 2005). These theoretical considerations were taken into account when analyzing estimated hydrated lime dosages and analyzing theoretical vs. measured acidities in the water. Besides theoretical considerations, TKT Consulting found from bench-scale testing that the Belt combined water required 1,528 mg/L sodium hydroxide (NaOH) to achieve a pH of 9.5 compared to 1,600 mg/L of hydrated lime to achieve the same pH in the treated water (Hydrometrics, Inc. 2012). Additionally, data were collected and analyzed which showed that dissolved CO_2 did not exert a significant hydrated lime demand in the MIW at Belt, which was also taken into consideration in the WTP design. Specifically, samples taken from sampling points B-1 (Lewis Coulee above mine adit at Belt), B-2 (mine portal discharge to Lewis Coulee), B-3 (Lewis Coulee above collection drain), and B-4 (Lewis Coulee outfall to Belt Creek) in August 2014 were tested for the amount of base that would be required to titrate the samples to pH 8.3 when comparing between samples that were purged with air for 15-30 minutes and samples that were not purged. The samples were collected with minimal agitation and in containers without headspace to minimize loss of carbon dioxide during collection or transport. And the results showed <3 percent difference in the amount of base required between purged and non-purged samples to titrate to pH 8.3, which is consistent with little dissolved carbon dioxide in collected samples.

7.1.4.1 Physical and Chemical Treatments

The active water treatment processes evaluated (Sections 8.3–8.6) consist of combinations of physical and chemical treatment processes. Because of the high acidity and high metals loadings of the influent MIW at the Belt WTP, treating the water with a base such as calcium hydroxide (hydrated lime) or sodium hydroxide (caustic soda) would be necessary for any of the active treatment options, including the nanofiltration (NF) options discussed in Sections 8.5 and 8.6. The reason why base treatment would be necessary for the NF option where the NF concentrate/brine is sent to a brine evaporator is because the solids would still need to be brought to a higher pH in order to stabilize the solids so that they could possibly pass toxicity characteristics leaching procedure (TCLP) testing and not be considered hazardous waste. This is because without base treatment, the solids generated from NF concentrate would still be acidic and would leach metals upon exposure to water. The rationale for choosing hydrated lime over caustic soda for all of the alternatives that were evaluated is explained in Section 7.1.4.3.

Besides chemical treatment to neutralize acidity and precipitate metals or precipitate sulfate as gypsum, physical treatment such as NF are also evaluated. For the alternative where NF concentrate stream is treated with hydrated lime, the primary function of the NF is to concentrate the MIW stream to make chemical treatment more effective at precipitating and removing COCs. For the NF alternative where the NF concentrate stream is directed to a brine evaporator, the NF process combined with the evaporation processes serve as physical processes for treating the water for discharge, while hydrated lime addition is for stabilizing the solid and is not directly related to treating the water so that it becomes suitable for discharge.

Because of the relatively high sulfate concentrations in the Belt MIWs (approximately 2,900 mg/L sulfate average in the combined water), addition of calcium from quicklime (CaO) or hydrated lime ($Ca(OH)_2$) in the water treatment process could lead to gypsum precipitation and potential scaling issues on process equipment in the water treatment facility. For waters with relatively low ionic strength or where most of the TDS is from sulfate with sulfate concentrations above 2,000 mg/L, such as the Belt MIWs, gypsum will typically precipitate when sufficient calcium is added so that the treated water sulfate concentration becomes approximately 1,500 to 2,000 mg/L. The exact treated water sulfate concentration depends on the ionic strength and concentration of other ions in solution (International Network for Acid Prevention 2003). Because gypsum precipitation will occur from adding quicklime or hydrated lime to the Belt MIW, it is important to consider mitigation of gypsum scaling on water treatment equipment. Unlike calcite or other carbonate-based minerals, gypsum's solubility is essentially independent of pH because it is a sulfate-based scale. Consequently, gypsum scale is not easily cleaned using acidic solutions and typically requires manual cleaning. Therefore, it is crucial during detailed design to ensure that adequate thought and provisions are included in the design of a water treatment facility to both ensure easy access to remove scaling and to design processes to minimize gypsum scaling formation wherever possible. Although details about these strategies are beyond the scope of the EE/CA, some general examples include providing removable covers to various process equipment for easy access to clean the equipment, providing multiple reactors to allow for taking a reactor off-line for cleaning without shutting down the treatment facility, and designing sludge lines with sufficient flow velocity to minimize gypsum scale buildup in the lines.

7.1.4.2 Sludge Disposal

Sludge disposal options that are considered in this study are divided into on–site and off–site disposal options. The on–site disposal options are further divided into aboveground and underground disposal, while the off–site disposal assumes that all solids that will be disposed of off–site will be considered non–hazardous. For the detailed design phase of the Belt MIW WTP, these assumptions will need to be verified by TCLP testing.

7.1.4.3 Hydrated Lime vs. Caustic Soda for Neutralization and Metals Precipitation

The most important chemical treatment in the MIW treatment process at the Belt MIW WTP is to add base to neutralize the acidity in the water and precipitate and remove the metals. There are several reasons why hydrated lime (calcium hydroxide) was chosen over caustic soda (sodium hydroxide). One reason is that hydrated lime is much cheaper than caustic soda. While chemical prices fluctuate, the current cost of hydrated lime is approximately $180 per dry short ton, while sodium hydroxide is $600 per dry short ton for bulk deliveries. Because the molar mass of $Ca(OH)_2$ nearly twice that of NaOH, but hydrated lime supplies twice as much base hydroxide per mole as caustic soda, approximately the same amount of lime or caustic soda are needed to treat acidic waters to the same pH. This means that hydrated lime chemical costs would likely be approximately three times more for caustic soda than for hydrated lime at current chemical prices, even accounting for the higher reaction efficiency of caustic soda compared to hydrated lime. Another reason why hydrated lime is superior to caustic soda at the Belt MIW WTP is that it would remove some sulfate in the MIW by forming gypsum, whereas caustic soda will not remove any sulfate. And while some of the calcium from hydrated lime addition will also be removed as gypsum, all of the sodium from adding caustic soda will remain in solution and leave the WTP in the discharge. For example, in Appendix D of the Water Treatment Assessment Report (Hydrometrics, Inc. 2012), TKT Consulting, LLC found from bench-scale testing that the Belt combined water required 1,528 mg/L NaOH to achieve pH 9.5 compared to 1,600 mg/L of hydrated lime to achieve the same pH in the treated water. The required NaOH dosage would add 878 mg/L of sodium to the treated water.

Because of this, the treated water sulfate, total dissolved solids (TDS), and sodium concentrations will be lower when hydrated lime is used instead of caustic soda. Even though the DEQ–7 standards do not stipulate numeric standards for sulfate, TDS, or sodium in the discharge, it is clear that hydrated lime treatment will provide superior treated water quality compared to caustic soda treatment. Another major advantage to using hydrated lime in the treatment is that it is much safer than caustic soda and will be more protective of the health and safety of the WTP operations staff. Hydrated lime is also more readily available than caustic soda. Although there are some potential advantages to using caustic soda compared to hydrated lime, such as the higher solubility and faster reaction of caustic soda and the lower amounts of water treatment sludge generated using caustic soda or the decreased tendency to form gypsum scale in the water treatment facility, the better treated water quality, lower costs, and safer chemical handling of hydrated lime vs. caustic soda make hydrated lime the preferred reagent for raising the pH in the water treatment process.

The use of hydrated lime and not of slaked quicklime was evaluated for this EE/CA because of the complexities and the extra equipment and operations involved in slaking quicklime.

7.1.5 Other Treatment Technologies

This section describes four additional treatment technologies that could be applicable to the site. These treatment technologies are zero-valent iron (ZVI), bioreactors, anoxic limestone drains (ALD), and coal fly ash neutralization.

7.1.5.1 Zero-Valent Iron (ZVI)

ZVI has been used successfully in bench and pilot scale tests to treat MIW water, especially the removal of metals such as cadmium, copper, mercury, uranium and zinc. Metals removal by ZVI is accomplished by reductive precipitation/coprecipitation and adsorption onto the iron surface, and for some metals, adsorption onto the corrosion products. Metals removal rates by ZVI decrease at lower pH (Suponik and Blanco 2014), so the viability of this technology at Belt is doubtful, especially at the low pH (2.5) for the MIWs at Belt. ZVI systems typically cause an increase in iron concentrations, and are ineffective to marginally effective at manganese and sulfur removal.

ZVI is typically sourced from iron scrap from the machining of steel or iron in the form of granules or powder. ZVI prices have increased significantly in the past decade, from less than $100 per ton in the 1990s to over $500 per ton currently, reducing the cost effectiveness of ZVI treatment.

Few case studies of the long term effectiveness are available, but it is likely that at such high flow rates (200 gpm) corrosion of the ZVI surface would occur rapidly with MIW exposure leading to reduced effectiveness and reduction in hydraulic capacity. It is estimated that in field scale MIW treatment systems, the ZVI would require replacement every 1 to 5 years (Ford 2008). This alternative is not carried forward for evaluation due its likely ineffectiveness at low pH.

7.1.5.2 Bioreactors

Bioreactors have been used to treat MIW at remote mine sites. Typical MIW bioreactors rely on sulfate-reducing bacteria (SRB) to oxidize organic matter, generate alkalinity and raise pH, and anaerobically reduce sulfates to sulfides. The sulfides, in turn, react with dissolved metals to create insoluble metal sulfides (Zagury and Neculita 2007).

To promote SRB growth, an organic carbon source is necessary. Simple, short chain organic carbon sources such as ethanol, methanol, and lactate are typically the most reliable carbon sources, but are usually more expensive than natural organic agricultural wastes materials. Cellulosic wastes, such as sawdust, straw, corncobs or agricultural wastes, such as manure or molasses have been successfully used as carbon sources (Zagury and Neculita 2007).

Proper design of the bioreactor is critical to maintain anaerobic conditions, positive contact between the SRB growth, the organic substrate, and the MIW. Clogging of the media by algal growth and precipitated metals can also increase long term O&M costs (Gusek 2005). Providing adequate residence time for large flow rates also poses a significant engineering challenge, especially in climates such as in Montana with long cold winters. Increased residence time and larger ponds are necessary for colder weather because lower temperatures slow the metabolisms of microbes and other organisms.

The main problems with passive bioreactors is the depletion rate of the organic matter that typically requires replacement every 1 to 5 years (Zagury and Neculita 2007). Passive bioreactors are less effective at low pH (< 3) (Doshi 2006). Oxygenated water in the system can suppress SRB growth significantly reducing system effectiveness (Johnson and Hallberg 2005). Ecotoxicity of the bioreactor effluent may require tertiary treatment by constructed wetland for biological oxygen demand (BOD) removal. Hydrogen sulfide may be generated in a bioreactor and can present occupational health and nuisance concerns (ITRC 2013). Most successful passive bioreactors have been small scale systems with flow rates less than 50 gpm (Doshi 2006). Because of the low pH and high flow rate and high metal loading rates, the Belt site bioreactors are not a viable alternative for long-term water treatment at the Belt site.

7.1.5.3 Anoxic Limestone Drains (ALD)

ALDs are a passive treatment system that consist of an engineered drain filled with limestone (with greater than 90 percent calcium carbonate). The MIW is routed to passively flow through the ALD media. The ALD is typically lined with plastic on the bottom and sides to contain the media and the acid mine drainage liquid. The top of the ALD is lined with plastic to minimize infiltration of rainwater, limit atmospheric exposure to oxygen, and limit escape of carbon dioxide. The limestone dissolves in the acid water, raising pH and increasing alkalinity. The carbon dioxide accelerates the rate of limestone dissolution (Johnson and Hallberg 2005). If anoxic conditions are well-maintained, ferric hydroxide precipitation is reduced (Skousen 1995). Influent water at the Belt site contains dissolved oxygen (DO) at concentrations up to 8.9 mg/L that would hinder efforts at maintaining anoxic conditions. Pretreatment of the influent with organic matter to promote aerobic bacterial growth and consume DO is a potential option to lower DO levels.

For waters with high sulfate (greater than 1,500 mg/L), as is the case at the Belt site, gypsum ($CaSO_4$ $2H_2O$) is likely to precipitate (Nairn et al. 1991). This gypsum precipitate is likely to clog the limestone pore space, reduce system effectiveness, and require replacement of the limestone media. For these reasons ALDs are not evaluated further for the Belt Site.

7.1.5.4 Coal Fly Ash

Coal fly ash has been used to treat MIW successfully at some sites. Coal fly ash is highly silaceous, calcium rich, and alkaline (pH greater than [>] 12) residual product from coal-fired power plants. The product is typically inexpensive, but costs depend on distance from the production source. Fly ash contains calcium oxide at 5 to 15 percent and magnesium oxide at 0.5 to 2 percent. Dissolution of calcium oxide and, and to a lesser extent, magnesium oxide (Gitari et al 2005) increases the pH, neutralizing the MIW. Some heavy metal removal is achieved by sorption of these trace metals onto the silicate surfaces, which can act similar to zeolites, but at much lower efficiency (Michalkova et al 2013).

Fly ash is typically mixed into the MIW constantly agitated with residence times ranging from 15 to 60 minutes. Because of it relatively low concentration of calcium oxide, the fly ash to MIW ratio is typically near 3:1 by volume. Thus, fly ash treatment require significantly more raw material handling than hydrated lime or sodium hydroxide treatment. Sludge generation rates are also significantly higher (approximately 4 to 5 times higher) than hydrated lime or sodium hydroxide treatment. Fly ash treatment is most economical for treating MIW at sites adjacent to coal-fired power plants (Pradhan and Deshmukh 2008).

Successful application of fly ash is highly dependent on the fly ash source, as each material can have different chemical makeup (especially concentration of calcium oxide and magnesium oxide) and different levels of trace metals. Bench testing is necessary to establish the fly ash dosage and confirm that leaching of heavy metals meets effluent requirements.

Potential sources of the coal fly ash for the Belt site are the Colstrip Steam Plant near Colstrip, Montana, approximately 300 miles from Belt. The Corrette Power Plant in Billings, Montana, is closer to the site but was decommissioned in 2015.

7.2 TECHNOLOGY SCREENING SUMMARY AND DEVELOPMENT OF WATER TREATMENT ALTERNATIVES

The purpose of treatment technology and process alternative screening, the second step in the treatment alternative development process, is to (1) evaluate the identified treatment technologies based on the NCP criteria of effectiveness, implementability, and relative costs; and (2) eliminate treatment technologies to reduce the number of alternatives developed and carried forward for detailed analysis in Section 8.0. A treatment alternative can be eliminated from further consideration if it does not meet the effectiveness or implementability criteria, or if its cost is substantially higher than other treatment technologies, and at least one other technology option is retained that offers equal protectiveness. A summary of the initial screening of treatment technologies and process options for MIW is provided in Table 7-2.

The technologies and process options that were retained with their respective waste generation and disposal options are shown in Table 7-3. In accordance with contract requirements and guidance from DEQ, four alternatives that appear to be most feasible for water treatment at the site, plus the no action alternative, will be carried through to the detailed analysis in Section 8.0. Because the number of alternatives is not unreasonably high, and since none of these alternatives could obviously be eliminated through an additional screening step, all of these alternatives will be carried through to the detailed analysis in Section 8.0.

TABLE 7-2
TECHNOLOGY SCREENING FOR EFFECTIVENESS, IMPLEMENTABILITY, AND RELATIVE COST

Treatment Technology	Effectiveness	Implementable	Relative Cost
No Action	Not Effective	Yes	No Cost
Water-Powered CaO Addition System	Moderately Effective	Yes	Low
Pumping and Treating Water from Western Anaconda Mine Workings	Not Effective*	Yes	Moderate to High
Single Stage Lime Treatment	Effective	Yes	Moderate to High
Two Stage Lime Treatment	Effective	Yes	Moderate to High
Reverse Osmosis Water Treatment	Effective	Yes	High
Zero Valent Iron	Not Effective*	Yes	High
Bioreactors and Wetlands	Not Effective	Yes	Low
Anoxic Limestone Drains	Not Effective	Yes	Low
Coal Fly Ash Addition	Not Effective*	Yes	Low to Moderate

Notes:*Treatments not considered effective until shown effective through investigation or bench or pilot scale testing

TABLE 7-3
RETAINED TREATMENT TECHNOLOGIES AND ASSOCIATED WASTE DISPOSAL OPTIONS AND TYPES

Treatment Technology	Waste Disposal Options	Waste Type
No Action	NA	NA
Water-Powered CaO Addition System	On-Site Disposal	Precipitate Sludge
	Off-Site Disposal	Precipitate Sludge
Single Stage Lime Treatment	On-Site Disposal	High Density Sludge
		Low Density Sludge
	On-Site Underground Disposal	High Density Sludge
		Low Density Sludge
	Off-Site Disposal	High Density Sludge
		Low Density Sludge
Two Stage Lime Treatment	On-Site Aboveground Disposal	High Density Sludge
		Low Density Sludge
	On-Site Underground Disposal	High Density Sludge
		Low Density Sludge
	Off-Site Disposal	High Density Sludge
		Low Density Sludge
Reverse Osmosis Water Treatment	On-Site Aboveground Disposal	Brine Evaporate
	Off-Site Disposal	Brine Evaporate

The technologies identified to be carried through for detailed analysis are:

1. Water-powered calcium oxide (quicklime) addition
2. Single Stage hydrated lime treatment
3. Two stage hydrated lime treatment
4. Nanofiltration

Each of these technologies is evaluated with several sludge disposal alternatives in the remainder of the report.

8.0 DETAILED ANALYSIS OF WATER TREATMENT AND WASTE DISPOSAL OPTIONS

The third step in the alternative selection process for the treatment of Belt MIW treatment is the detailed analysis. The purpose of the detailed analysis is to evaluate the removal action alternatives for their effectiveness, implementability, and cost to control and reduce toxicity, mobility, and volume of metals in MIW in Belt Creek. All developed alternatives except for the No Action alternative meet the EPA Feasibility Study threshold criteria of protection of human health and the environment and meeting ARARs. The treatment alternatives that were retained after the technology and process option identification and screening processes in Section 7.0 are included in the detailed analysis.

As suggested in "Guidance on Conducting Non-Time Critical Removal Actions Under CERCLA" (EPA 1993), removal action alternatives that were retained after the technology and process option identification and screening processes will be evaluated individually against the following three broad criteria: effectiveness, implementability, and cost. Descriptions of the qualitative evaluation criteria are in the following paragraphs.

Effectiveness Evaluation

During an evaluation of the effectiveness of a removal action alternative, the ability of the process to protect human health and the environment is reviewed (EPA 1993). Protection is achieved by reducing the toxicity, mobility, and/or volume of metals in surface water over a short-term and long-term time frame while complying with ARARs.

Effectiveness relates to the potential of an alternative to achieve the PRAOs considering the chemical and physical characteristics of the source and the site conditions. Potential impacts to human health and the environment during the construction and implementation phase and the reliability of the process with respect to the site conditions are also considered. For the purposes of this evaluation, effectiveness is considered as low, moderate, high, or uncertain.

Implementability Evaluation

During an evaluation of the implementability of a removal action alternative, the technical and administrative feasibility of constructing, operating, and maintaining the alternative is measured (US Environmental Protection Agency [EPA] 1993). Technical feasibility takes into account whether or not the removal action alternative is applicable to the site and can be properly constructed and operated at the site. The evaluation considers long-term operation, maintenance, and monitoring of the implemented alternative. Administrative feasibility considers regulatory approval and scheduling constraints, and the availability of disposal services, disposal locations, and the necessary construction expertise and equipment. For this evaluation, implementability is classed as easy, moderately difficult, or difficult.

Cost Evaluation

The types of costs that will be assessed include the following:

- Capital costs, including both direct and indirect costs
- Annual O&M costs, including long-term effectiveness monitoring cost
- Net present worth of capital, O&M costs, and periodic costs.

These engineering costs estimates are expected to be within plus 50 to minus 30 percent of the actual project cost (based on 2014 dollars). Changes in the cost elements are likely to occur as a result of new information and data collected during the removal action design. The present worth of each removal action alternative provides the basis for the cost comparison. The present worth cost represents the amount of money that, if invested in the initial year of the removal action at a given interest rate, would provide the funds required to make future payments to cover all costs associated with the removal action over its planned life.

For the O&M costs, it has been assumed that for Alternatives 3 through 6, the water treatment facility would require 24 hours per week of operator time for routine operations. Differences in labor costs between the different alternatives are due to differences in the amount of maintenance that are anticipated between the different alternative treatment processes. Heating costs were based on cost data provided by DEQ for similar treatment plants at the Zortman Landusky Site. Each active treatment alternative cost includes estimated costs for installing conveyance pipes for Lewis Coulee, French Coulee, Brodie Mine, and a collection trench for Coke Oven Flats.

The cost of delivered quicklime used for the estimates was $160/ton, while the cost of delivered hydrated lime used was $180/ton. Single and two-stage lime treatment costs are provided with and without filter press equipment and associated operation and maintenance costs because the underground injection disposal alternative would not require the filter press equipment, and because significant cost savings are realized without the equipment and maintenance.

The present worth analysis is performed on all removal action alternatives using a 3.5 percent discount rate (historical average) over 100 years. This was requested by DEQ instead of the typical EPA Feasibility Study cost guidance percentage rate of 7 percent and lifetime of 30 years. Inflation and depreciation were not considered in preparing the present worth costs.

The final step of this analysis is to conduct a comparative analysis of the removal action alternatives. The comparative analysis, presented in Section 9.0 will discuss each alternative's relative strengths and weaknesses with respect to each of the criteria. Once completed, the findings of the comparative analysis will be used to identify preferred removal action alternatives.

It should be noted that although the Water Treatment Assessment Report (Hydrometrics, Inc. 2012) included bench-scale testing results that contain useful information about the treated water quality and sludge generation using both hydrated lime and caustic soda to treat Belt water, because none of the alternatives evaluated in this EE/CA are exactly identical to the treatment processes that were previously evaluated, it is recommended that bench-scale testing be conducted on the preferred alternative both to confirm treated water quality and obtain more data on chemical dosages and water treatment residuals/sludges and to further develop required retention times for reaction tanks. Bench-scale testing to compare between the high density sludge (HDS) and non-HDS hydrated lime treatment processes would also be helpful to determine differences in removal efficiencies of contaminants between the two processes.

8.1 ALTERNATIVE 1: NO ACTION

Under the No Action alternative, there would be no treatment of MIW, so potential human health, ecological, and water quality impacts associated with MIW are assumed to remain unchanged. The No Action alternative is used as a baseline against which other removal action alternatives are compared. The No Action alternative will be retained through the detailed analysis of alternatives.

8.1.1 Effectiveness

The No Action alternative is considered to have low effectiveness for achieving PRAOs. This alternative would not mitigate metals concentrations in the flow of MIW from the mine sites; would provide no control of human or ecological exposure to MIW; no reduction in risk to human health or the environment; and ingestion, and dermal adsorption would not be reduced. Protection of human health and the environment would not be achieved under the No Action alternative.

A comprehensive list of federal and state ARAR for Belt is presented in Section 5.0. ARARs are divided into contaminant-specific, location-specific, and action-specific requirements. Under the No Action alternative, MIW would not be treated, so no location- or action-specific ARARs apply to the No Action alternative. MIW metal concentrations at the Belt Creek mines would continue to exceed water quality criteria; therefore, the No Action alternative would not comply with chemical-specific ARARs.

Under the No Action alternative, no controls or long-term measures would be implemented to control MIW at the site, so this alternative provides no long-term effectiveness and would not be effective at improving water quality. The No Action alternative would provide no reduction in toxicity, mobility, or volume of MIW at the site. In the short-term, the No Action alternative would pose no additional threats to the community or the environment than exist under the current site conditions.

8.1.2 Implementability

The No Action alternative would be readily implementable and administratively feasible. No permits would be required, and no services or materials would be needed.

8.1.3 Costs

There are no foreseen costs associated with the No Action alternative.

8.2 ALTERNATIVE 2: WATER-POWERED CALCIUM OXIDE ADDITION

Under this alternative, two water-powered CaO addition units would be installed at the two mine discharges with enough flow to operate them; the Anaconda Mine drain and the French Coulee collection system. The following sections discuss the details of the water treatment, discuss treatment sludge disposal, the effectiveness, implementability, and cost of this alternative.

8.2.1 Water Treatment Components

Under this alternative water from the Anaconda Mine Drain and the French Coulee collection system would be treated with CaO which would be added by a water-powered device, such as the Aquafix system. This alternative is similar to hydrated lime treatment although it uses CaO instead of hydrated lime because CaO reacts more quickly than hydrated lime in acidic MIW and because the pebble form of CaO is easier to feed into the Aquafix system. This treatment is typically not as efficient or effective as conventional hydrated lime treatment because the lime in granular and does not mix completely with the MIW, but the system requires no electricity and has relatively low capital costs for setup, operation, and maintenance.

The implementation of this alternative would raise the pH at discharges of MIW from the Anaconda Belt Mine and the French Coulee collection system, by adding CaO to the MIW. MIW from Lewis Coulee, Brodie Mine, and groundwater seepage from the Coke Oven Flats area would not be addressed in this alternative because the low flow rates from these sources are below the necessary (10 gpm) to operate a water-powered CaO addition system are not present year round. Raising the pH of the MIW discharges would precipitate metals from the MIW, producing sludge that would be captured in a sedimentation basin. The exact demand of CaO for the water-powered CaO addition systems and the water quality results achievable would need to be refined through pilot scale testing. For this evaluation, CaO consumption is conservatively estimated to be 150 percent of the actual chemical demand due to potential inefficiencies of the delivery system. Accordingly, sludge production is also estimated to be 150 percent of a single stage hydrated lime treatment sludge production.

To implement this alternative, the water-powered CaO addition units would be constructed near the mine drains on locations shown on Figure 8-1. The units would be constructed inside simple metal insulated buildings built on concrete slabs. Because the systems would be powered by constantly flowing water they would not freeze as long as they were sheltered from cold winds. At each site the CaO would be stored in a 90-ton capacity silo constructed next to the building. Two concrete sedimentation basins, each with a volume equal to a 36-hour retention time (24-hour retention time plus 50 percent volume for sludge precipitation), would be constructed in parallel downstream of the addition system to precipitate solids from the CaO addition. Once one basin accumulated enough sludge, flow would be diverted to the other basin while the sludge is allowed to dry. Once dry, the sludge would be excavated and disposed, either at the nearest landfill or on-site on land owned by DEQ. The two alternatives for sludge disposal are discussed further in Section 8.2.2.

Operation and maintenance of the systems would be relatively simple. After the systems were operational, monthly maintenance would be required. Monthly maintenance would include oversight of reloading the silos, general cleaning and maintenance of the pipes and the units, and excavation and disposal of sludge from the drying basin. Monthly maintenance of the units would be necessary, which would include:

- Loading CaO into the hoppers;
- Confirming that the units are operating correctly mechanically;
- Keeping conveyance ditch free of pebble lime;
- Removal of debris from the water inlet device;
- Monitoring the pH of the discharge and periodically adjusting flow through the unit to achieve desired pH;
- Quarterly or semi-annual water quality sampling.

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FIGURE 8-1
Location of Possible Water Treatment Facility Footprints

TETRA TECH

Annual maintenance would be a more in-depth monthly maintenance. Under the on-site sludge disposal alternative annual maintenance would include covering past sludge waste with cover soil and excavating adjacent areas for upcoming sludge disposal.

8.2.2 Sludge Disposal

Sludge from the CaO addition could be disposed of off-site or on-site. Off-site disposal would involve excavating the sludge from the precipitation basins, loading sludge into trucks and hauling it to a nearby Class II or Class IV Resource Conservation and Recovery Act (RCRA) facility for disposal. This alternative for off-site sludge disposal is the least costly of the disposal options as shown in Table 8-1. However, sludge disposal costs at a commercial facility has uncertainty associated with it such as cost increases, regulatory changes, and business model changes. This cost may not be applicable over the 100-year project life.

TABLE 8-1
WATER-POWERED CaO ADDITION TREATMENT COSTS WITH OFF-SITE DISPOSAL

Cost Item	Quantity	Units	Unit Cost	Total Cost
Capital Costs				
Aquafix Units	2	EA	$25,000.00	$50,000.00
Lime Silos	2	EA	$90,000.00	$180,000.00
Buildings	2	EA	$40,000.00	$80,000.00
Installation	2	EA	$20,000.00	$40,000.00
French Coulee Precipitation Basin	2	EA	$ 29,500.00	$59,000.00
Anaconda Mine Drain Precipitation Basin	2	EA	$177,000.00	$354,000.00
Subtotal Installation Costs				**$763,000.00**
Installation Contingencies	20% of Installation Cost			$152,600.00
EPCM	10% of Installation Costs			$76,300.00
Total Capital Costs				**$ 991,900.00**
Annual O&M Costs				
Annual Lime Costs	700	TON	$200.00	$140,000.00
Monthly Maintenance	12	EA	$1,691.00	$20,292.00
Annual Sludge Disposal	4000	TON	$15.00	$60,000.00
Annual Maintenance	1	EA	$6,097.00	$6,097.00
Subtotal O&M Costs				**$226,389.00**
Operational Contingencies	20% of Annual O&M			$45,277.80
Total Annual O&M Costs				**$271,666.80**
Present Worth of Annual O&M Costs Based on 100 Year Life		PF Factor = 27.7		$6,260,787.80
Total Present Worth				**$7,252,687.80**

Notes:
EPCM Engineering, Procurement, and Construction Management
EA Each
CY Cubic Yard
TON 2,000 pounds
O&M Operation and Maintenance
PF Present Worth Factor

The on-site alternative would involve the construction of a local waste disposal area on 88 acres owned by DEQ. For legal analysis of this alternative such as applicability of Beville Exclusion or other issues relative to applicability of RCRA, DEQ legal staff will evaluate this issue with input from AML program.

Based on well logs and the depth to bedrock, it appears that the disposal area could be excavated to a depth of approximately 15 feet. At this depth, and at the assumed sludge production rate of 5 tons per day (assumed to be 50% greater than sludge production of a lime treatment plant due to inefficiencies in mixing), the sludge disposal would use approximately 0.125 acre per year. This would give the disposal area a 546-year operational life. If sludge were dry enough to be geotechnically stable and piled above ground surface, it could extend the lifetime of the disposal area significantly. It is estimated that disposing of the sludge on-site is approximately $7,500 more expensive per year than off-site because of the higher maintenance costs of the Solid Waste Disposal Area (Table 8-2). It also has higher estimated capital costs than off-site disposal.

8.2.3 Effectiveness

The water-powered CaO addition system is considered to have low to moderate success in achieving PRAOs. This alternative would raise the pH and precipitate metals from the two MIW drainages with the largest flow (Anaconda Mine Drain and French Coulee Collection System). It would significantly improve the water quality from the two treated MIW sources, but, would not address MIW from the other three sources (Lewis Coulee, Brodie Mine, and Coke Oven Flats) where flow rates are too low. At the two drainages where this alternative would be used, geochemical modeling shows it is unlikely that this treatment technology would meet DEQ-7 WQS for trace metals such as thallium. Achievable post-treatment water quality would have to be further evaluated by pilot scale testing. Potential ingestion and dermal absorption by human receptors would be reduced, but not eliminated, by meeting DEQ-7 standards, so protection of human health and the environment would be improved, but not completely achieved under this alternative.

A comprehensive list of federal and state ARARs for Belt is presented in Section 5.0. ARARs are divided into contaminant-specific, location-specific, and action-specific requirements. Under this alternative, MIW from the two largest sources would be treated, but DEQ-7 WQS standards would not be met. MIW metal concentrations at the Belt Creek mines would continue to exceed water quality criteria, so the alternative would not comply with chemical-specific ARARs.

TABLE 8-2
WATER-POWERED CaO ADDITION TREATMENT COSTS WITH ON-SITE DISPOSAL

Cost Item	Quantity	Units	Unit Cost	Total Cost
Capital Costs				
Aquafix Units	2	EA	$25,000.00	$50,000.00
Silos	2	EA	$90,000.00	$180,000.00
Buildings	2	EA	$40,000.00	$80,000.00
Installation	2	EA	$20,000.00	$40,000.00
French Coulee Precipitation Basin	2	EA	$29,500.00	$59,000.00
Anaconda Mine Drain Precipitation Basin	2	EA	$177,000.00	$354,000.00
Sludge Disposal Area Construction	24,200	CY	$5.00	$121,000.00
Subtotal Installation Costs				**$884,000.00**
Installation Contingencies	20% of Installation Cost			$176,800.00
EPCM	10% of Installation Costs			$88,400.00
Total Capital Costs				**$1,149,200.00**
Annual O&M Costs				
Annual Lime Costs	700	TON	$200.00	$140,000.00
Monthly Maintenance	12	EA	$1,691.00	$20,292.00
Sludge Disposal	4000	CY	$7.00	$28,000.00
Annual Maintenance	1	EA	$6,097.00	$6,097.00
Solid Waste Disposal Area Quarterly Maintenance	4	EA	$6,000.00	$24,000.00
Solid Waste Disposal Area Annual Maintenance	1	EA	$15,500.00	$15,500.00
Subtotal Annual O&M Costs				**$233,889.00**
Operational Contingencies	20% of Annual O&M			$46,777.80
Total Annual O&M Costs				**$280,666.80**
Present Worth of Annual O&M Costs Based on 100 Year Life		PF Factor = 27.7		$6,468,200.30
Total Present Worth				**$7,617,400.30**

Notes:
EPCM Engineering, Procurement, and Construction Management
EA Each
CY Cubic Yard
TON 2,000 pounds
O&M Operation and Maintenance
PF Present Worth Factor

Under the alternative, long-term measures would be implemented to control MIW at the site. This alternative provides limited short and long-term effectiveness, so the alternative would be effective at improving water quality, but not achieving DEQ-7 WQS. The alternative would provide a reduction in toxicity and mobility of MIW at the site, but not eliminate them entirely.

8.2.4 Implementability

The water-powered CaO addition alternative would be implementable and administratively feasible. Construction requirements for buildings and ponds could be achieved by local contractors. Adequate land area is available for implementation of this alternative. Depending on the disposal option chosen, a solid waste disposal permit may be required. Implementation of this alternative would involve the procurement and construction of two water-powered CaO addition units, construction of channel and sedimentation basins, and a regular supply of CaO for treating the MIW. Administratively this alternative is feasible if the discharge meets DEQ-7 WQS or if the requirements for discharge are waived or modified (such as including a mixing zone) by DEQ.

8.2.5 Cost

The cost of the water-powered CaO addition with off-site sludge disposal over a 100-year period is estimated to be $7,262,875. The estimated costs are detailed in Table 8-1. The cost of the same alternative with on-site sludge disposal is estimated to be $7,627,925. The estimated costs that include on-site disposal are in Table 8-2. The cost of this overall alternative assumes no replacement of the lime addition units and the lifetime of the units are not known. Several units are reported to have performed in the field for more than 20 years and are still operating. The replacement costs could be covered with the contingency funds estimated annually if necessary.

8.3 ALTERNATIVE 3: SINGLE-STAGE HYDRATED LIME TREATMENT

Alternative 3 is a single-stage hydrated lime treatment process for MIW received at a treatment facility in either a HDS process or as a conventional low density hydrated lime precipitation process. The water treatment processes in Alternative 3 involves treatment of raw water with hydrated lime to approximately pH 9.5, followed by sedimentation/clarification to remove the solids generated from treatment using hydrated lime. The effluent from the clarifier would then be filtered to further remove solids, followed by pH re-adjustment using carbonic acid to pH ~7 to precipitate aluminum. The water would then be treated through a zeolite media filter to remove thallium and also remove precipitated aluminum. A key assumption associated with Alternative 3 is based on previous bench-scale testing (Hydrometrics, Inc. 2012). This assumption is that the treated water in the clarifier overflow from the single-stage hydrated lime treatment process will contain higher than 0.087 mg/L of dissolved aluminum because of higher solubility of aluminum at pH 9–9.5 compared to pH 6.5–7. Bench-scale testing (Hydrometrics, Inc. 2012) using hydrated lime treatment to pH 9.5- 10 yielded dissolved aluminum concentrations exceeding both the chronic and acute aquatic life standards of 0.087 and 0.750 mg/L dissolved aluminum, respectively; treatment to pH ~9.5 or higher is necessary to precipitate and remove other metals to below DEQ-7 standards. However, by re-adjusting and lowering the pH with carbonic acid to approximately 7 after the first set of media filters prior to the zeolite filters, the trace amounts of aluminum will precipitate at circumneutral pH and be removed by the zeolite media. The zeolite media, which may be chabazite or clinoptilolite, has been used successfully to remove thallium at CR Kendall Mine, can be used to remove trace amounts of thallium that the hydrated lime process leaves in solution. The majority of the influent thallium is expected to be thallium(I). For the next phase of design, if thallium removal using zeolite is still considered a treatment option, it is suggested that bench-scale testing studies be conducted on the efficacy of thallium removal on representative influent water samples to the WTP to confirm that an additional treatment process would be necessary to remove thallium after the hydrated lime treatment process. If necessary, pilot testing would also be used to estimate the specificity of the various zeolites towards thallium(I), which would impact the expected life of zeolite media and replacement frequencies. Waste characterization of the spent zeolite from pilot testing can also be used to evaluate disposal requirements and costs.

Carbonic acid treatment for pH re-adjustment is proposed instead of using sulfuric acid because it is more safe to handle and also because sulfuric acid addition would add sulfate to the treated water. However, the specific reagent for pH re-adjustment would be evaluated more closely during detailed design.

Treatment processes are influenced by the disposal methods for generated sludge. The HDS process, compared to conventional hydrated lime treatment, is an adjustment on how hydrated lime is added to the process with a benefit of more efficient hydrated lime usage, a significant increase of clarifier underflow percent solids, solids that dewater more readily in a press, lower potential to scale post hydrated lime treatment, and potentially better water quality. The basis of the HDS step is that hydrated lime addition to underflow sludge changes the structure of the precipitate into a crystalline form that provides better seed material for precipitation growth, better dewatering characteristics and more stable solids for disposal (Aubé and Lee 2015).

A potential tradeoff associated with the HDS process is that the solids have less unreacted hydrated lime and a lower neutralization potential and therefore are possibly less attractive for a scenario of solids injected into the mine underground workings.

8.3.1 Water Treatment Components

The water treatment components for the single-stage hydrated lime treatment option are listed separately for HDS (Figure 8-1) versus conventional low density sludge (Figure 8-2) hydrated lime treatment.

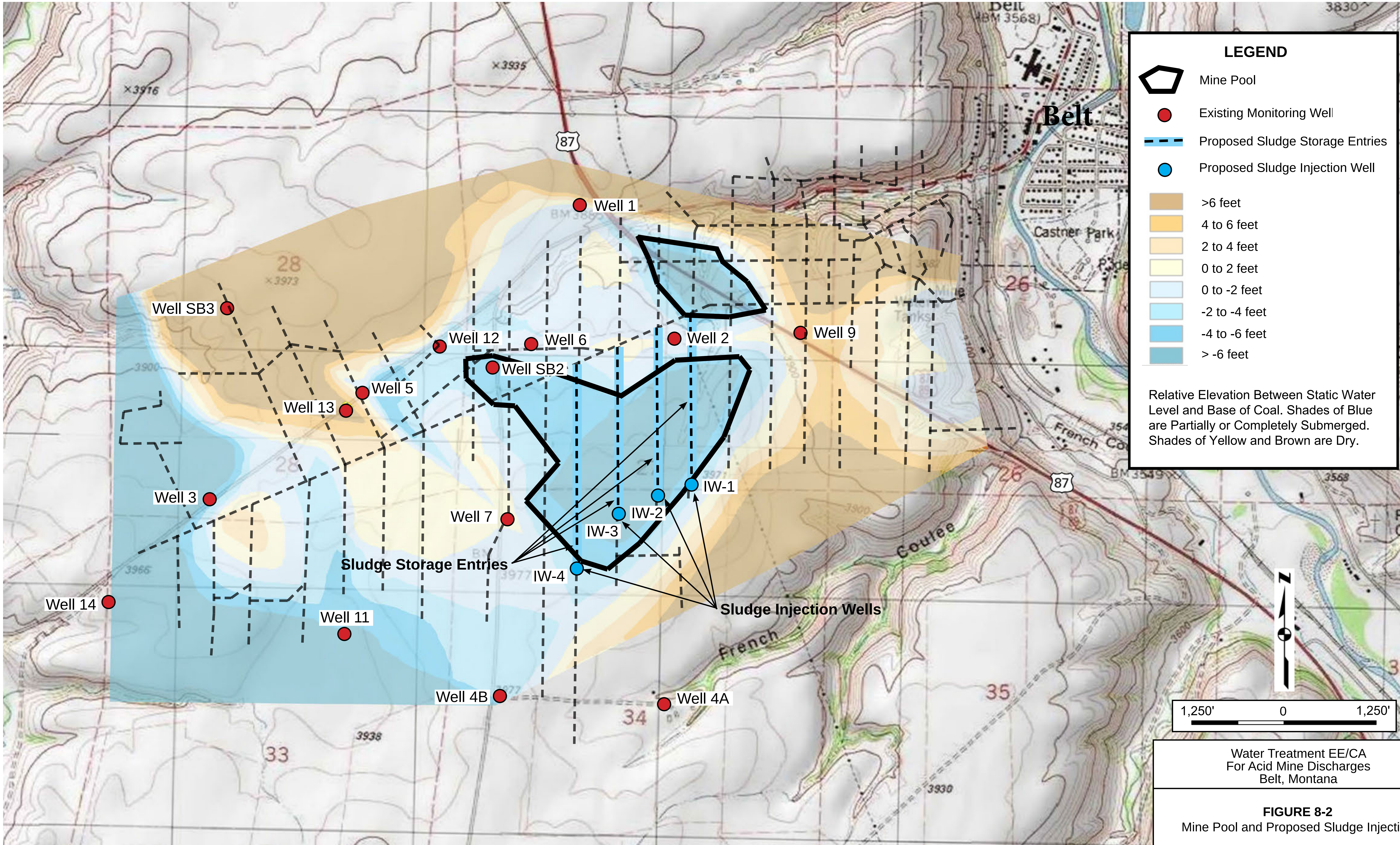

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FIGURE 8-2
Mine Pool and Proposed Sludge Injection

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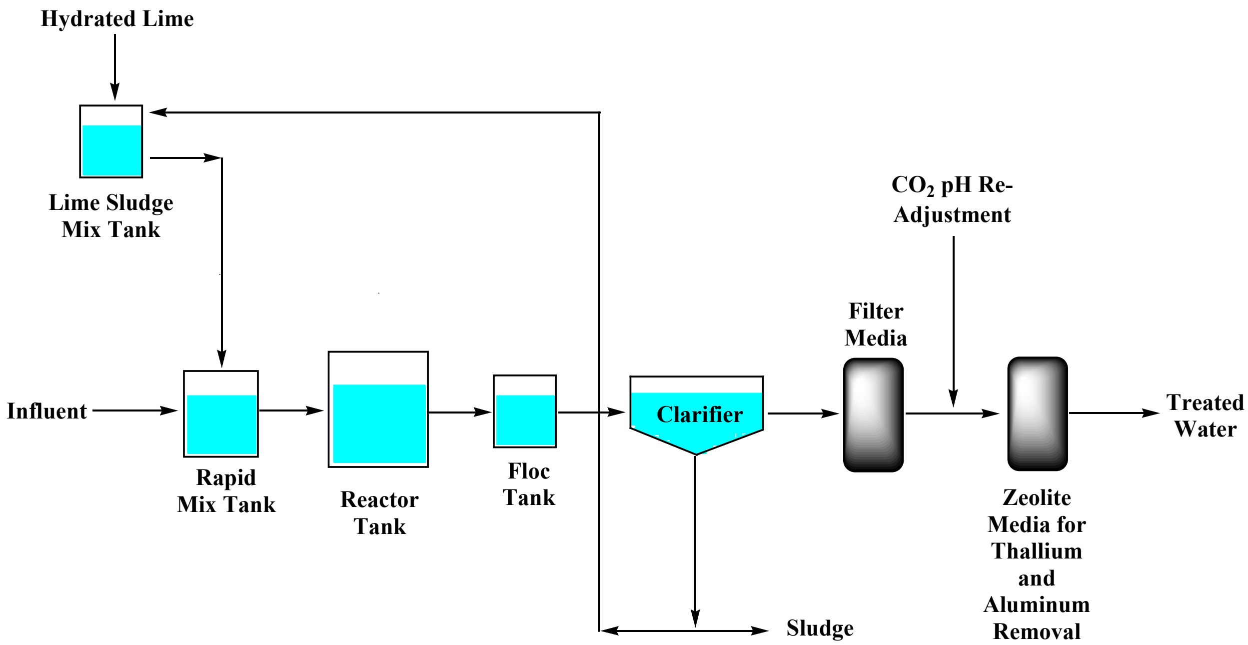
Source: Mine Pool Data from Gammons et.al., 2010

8.3.1.1 HDS Single-Stage Water Treatment Components

The standard HDS process flow diagram is presented below.



Process Flow Diagram 8-1: Single-step HDS hydrated lime treatment process depicting major equipment

MIW from Lewis Coulee is expected to be pumped from a collection sump to another collection sump at the Brodie Mine where a pump would convey the combined flow to the treatment plant. MIW discharges from the Anaconda Mine Drain and the French Coulee Collection System are expected to be gravity fed directly to the treatment plant.

MIW from Coke Oven Flats would be collected in a lined collection/barrier trench and pumped to the treatment plant. MIW is received in a small volume, high energy rapid mix tank where combined hydrated lime and recycled clarifier underflow is added for pH control. MIW then gravity flows to a Lime Reaction Tank with air diffusers in the tank bottom to promote oxidation of metals, especially iron (II) to iron (III) oxidation, and generation of metal hydroxides on the surface of the hydrated lime and recycled sludge mixture. The Lime Reaction Tank then overflows either into a Flocculation Tank or to a Clarifier/Thickener with a flocculating feed well. To more consistently meet effluent discharge standards for the metals such as cadmium that precipitate at high pH, Clarifier overflow can be pumped through media filtration prior to discharge. Underflow from the Clarifier is pumped to a small reaction tank where it is dosed with hydrated lime before adding to the Rapid Mix Tank. In this particular instance, because of the aluminum and thallium discharge standards dictated by DEQ-7, in addition to the first set of the filter media to filter water at high pH coming out of the clarifier overflow, another set of media filters using zeolites will also be employed for treating water after re-adjustment of the pH to remove remaining trace amounts of dissolved thallium and aluminum precipitated from lowering the pH from approximately 9.5 to 7. It is possible that precipitated aluminum may coat and shorten the life of the zeolite media for removing thallium, potentially requiring dual media filtration. Such considerations will need to be addressed during detailed design. Currently the filtration and zeolite processes are proposed to provide conservatism in the preliminary design to ensure consistent, adequate removal of trace COCs such as cadmium and thallium. It may be possible that through more extensive bench-scale testing or after installing a hydrated lime only treatment facility first, it is determined that these polishing processes may be unnecessary and that hydrated lime treatment alone would be adequate. Therefore, in the discussions about costs (Section 8.3.5), the capital and operating costs associated with the polishing steps are called out separately.

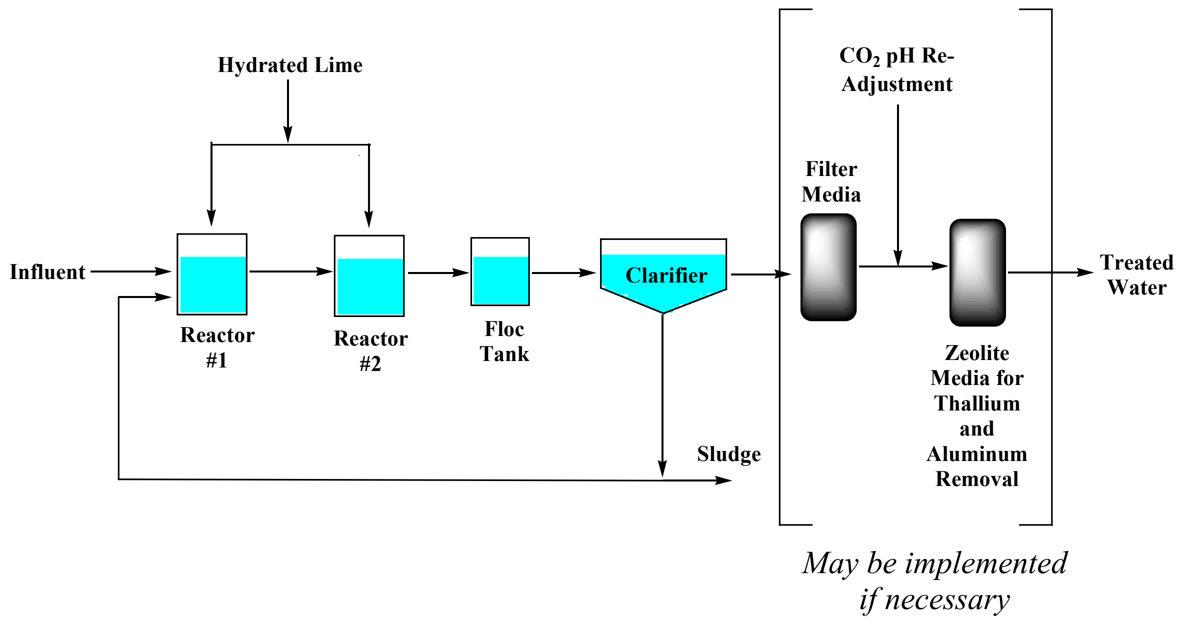
The retention time for the reactor tanks are as follows:

Description	Time (minutes)
Rapid Mix Tank	15
Reaction Tank	40
Lime Sludge Mix Tank	15

Ancillary equipment necessary to support unit processes includes Treated Water Tank and pumps to provide a source for filter backwash water, service water and reagent make-up water; Backwash Water Tank and pumps to receive filter backwash and bleed it back into the treatment process; air blowers; and reagent systems including bulk hydrated lime handling, polymer system and carbon dioxide (CO_2) system to lower the treated water discharge to near neutral pH. Polymer selection and dosage will be determined in the design phases and would also be based on avoiding potential aquatic toxicity issues. All process components in the treatment building, including the clarifier, will be located in a pre-engineered single story building.

8.3.1.2 Conventional Single-Stage Water Treatment Components

Conventional hydrated lime treatment is similar to HDS for process equipment. The standard conventional one-step hydrated lime treatment process flow diagram is presented below.



Process Flow Diagram 8-2: Single-step conventional hydrated lime treatment process depicting major equipment

MIW and hydrated lime and small amounts of recycled sludge are added together into Reactor Tank #1 for pH control. Sludge is pumped to the front of the process into Reactor Tank #1 to reduce the influence of variable influent water conditions, increase sludge density, and improve settling characteristics in the clarifier. Reactor Tank #1 gravity flows to Reactor Tank #2 to provide sufficient reaction time. Two reactors also allows for bypassing a reactor for cleaning, and hydrated lime can also be added to Reactor Tank #2. Air diffusers will be installed in Reactor Tanks #1 & 2 to promote complete oxidation of incoming metals for precipitation, especially for oxidizing iron(II) to iron(III) because iron(III) hydroxide precipitation occurs at a lower pH than iron(II) hydroxide precipitation, and the formation if iron(III) hydroxide removes iron from solution much better than the formation of iron(II) hydroxide. Aeration to oxidize iron(II) to iron(III) would improve treatment effectiveness because it provides more efficient iron removal compared to not oxidizing iron(II). Additionally, aeration is safer and more economical than other oxidants such as chlorine, permanganate, or ozone. Because the oxygen present in air is both thermodynamically and kinetically effective for oxidizing iron in water treatment processes, no other oxidants have been evaluated for this EE/CA. Reactor Tank #2 then overflows either into a Flocculation Tank or to a Clarifier/Thickener with a flocculating feed well. Typically, to meet on effluent discharge standards, Clarifier overflow is pumped through media filtration prior to discharge.

The retention time for the reactor tanks are as follows.

Description	Time (minutes)
Reaction Tank #1	30
Reaction Tank #2	30

The proposed combined retention time of 60 minutes in the two reactors is to provide sufficient reaction time for precipitation of various compounds, including gypsum, such that most of the precipitation will occur upstream of the clarifier. This way, the solids that are formed can be removed in the clarification process and not precipitate downstream of the clarifier and lead to premature blinding of the filter media. Details regarding the design retention time and the number of reaction tanks can be further explored during future phases of this project, where trade-offs between providing sufficient reaction time vs. lower cost smaller reactors can be evaluated. Furthermore, in future phase of this project, specific design parameters such as minimum design flow velocities in the sludge recycle and waste lines to mitigate gypsum and other scaling will need to be evaluated in greater detail. The preliminary design criterion for the clarifiers is a surface loading rate of 1 gpm/square foot (ft^2). The exact design surface loading rate and the resulting residence time in the clarifiers at the design flowrates will be further refined during detailed design.

Ancillary equipment necessary to support unit processes includes: Treated Water Tank and pumps to provide a source for filter backwash water, service water and reagent make-up water; Backwash Water Tank and pumps to receive filter backwash and bleed it back into the treatment process; air blowers; and reagent systems including bulk hydrated lime handling, polymer system and CO_2 system to lower the treated water discharge to near neutral pH. All process components within the treatment building, including the clarifier, will be installed within a single story pre-engineered building.

Under this alternative, the mass of sludge for disposal will vary slightly between HDS and conventional hydrated lime treatment because of increased hydrated lime efficiency. Volumetrically thickened sludge generated in a conventional hydrated lime pH adjust process is less than 10 percent solids whereas upwards of 25 percent solids can be generated from the HDS process. And, because of thickened sludge solids content and characteristics of solids following HDS process, pressing HDS sludge produces a higher solids content compared to conventional hydrated lime treatment.

Transportation and final storage requirements of this material typically dictate the level of degree that it must be dewatered. Thickened sludge is more suitable for landfill disposal than reinjection because it is more difficult to pump. Thickened sludge may be able to be pumped and reinjected, however, there is no reason to expend the capital costs pressing the sludge if reinjection is the preferred disposal alternative.

Belt filter presses and roll-off containers will be in a contained two-story structure. Liquid spills will report back to the treatment building sump system. HDS sludge pressing can generate a filter cake with up to 50 percent solids. Throughout the day, thickened sludge is collected in an agitated sludge storage tank suitable for 2 days storage total. Automatic pressing of the sludge will be performed during the day when operators are available to oversee any upset conditions, especially during dumping. Two belt filter presses, one operational, one on stand-by are recommended. Filter cake will be conveyed into a roll-off container that will be hauled to an on-site landfill for disposal. Roll-off containers will require dumping once every other day for a 20 cubic yard container.

For offsite handling and disposal of HDS or conventional sludge, it is recommended that dewatering of sludge be augmented with a filter-cake dryer. The maximum recommended final product should be 80 percent solids or less, above that, dust handling and mitigation becomes necessary.

Filter cake will discharge directly from either filter press into a bifurcated feed hopper. A single sludge dryer between the filters provides the alternative to discharging directly from filter presses into storage containers if the filter-cake dryer is off line. Dried filter cake is then screw-conveyed into a single container located outside. When full, the container is hauled to the disposal area.

8.3.3 Effectiveness

A single-stage hydrated lime treatment process in-and-of-itself would not be expected to consistently meet DEQ-7 standards for aluminum or thallium. Bench-scale testing done by TKT Consulting, LLC as described in Appendix D of the Water Treatment Assessment Report (Hydrometrics, Inc. 2012) showed that in a single-stage hydrated lime treatment process to either pH 9.5 or 10, the dissolved aluminum concentrations in the treated water after 24 hours of reaction time exceeded both the chronic and acute aquatic life standards of 0.087 and 0.750 mg/L dissolved aluminum, respectively. By adding a post-pH re-adjustment zeolite media process, aluminum and thallium are expected to meet DEQ-7 standards. Further bench-scale and pilot testing is recommended prior to the detailed design to confirm the viability of the proposed treatment process for consistently meeting all DEQ-7 standards. If thallium removal is not proven to be reliable with zeolite media, an oxidation process using a strong oxidant such as potassium permanganate can be added to the hydrated lime treatment step to oxidize and remove the residual thallium as thallium (III) hydroxide at high pH.

By adding in a pH re-adjustment process to improve aluminum removal, the overall treatment process has the flexibility to add hydrated lime to a higher pH than the currently assumed design pH of approximately 9.5 should future loadings of cadmium or nickel or other metals change and require higher pH hydrated lime treatment to meet DEQ-7 standards, since cadmium and nickel removal, both by precipitation as their hydroxides and by adsorption to ferric hydroxide, are known to be more effective at higher pH than 9.5. The pH 9 to 9.5 that has been (Hydrometrics, Inc. 2012) commonly used to treat MIW represents a compromise for removing both aluminum and other metals. The added pH re-adjustment filtration step will provide much better flexibility for maximizing aluminum and other metals removal without the capital and operating expenses of adding another clarifier.

8.3.4 Implementability

Alternative 3 is technically and administratively feasible. Design methods, construction practices, and engineering requirements for construction of the WTP building and major process equipment such as the clarifiers, hydrated lime storage and treatment systems, reactors, filter media, and piping are all well-documented and understood. Equipment, materials, and labor would all be available.

Because both hydrated lime treatment and filtration processes are well established for MIW treatment, long-term operation, maintenance, and monitoring of the performance of the Belt MIW WTP would be readily implementable. And because these are well-established treatment processes, Alternative 3 would be administratively feasible. Alternative 3 is rated as easy in terms of its implementability.

8.3.5 Costs

There are three sets of costs for Alternative 3. The estimated cost for conventional single-stage hydrated lime treatment geared towards generating sludge for underground disposal is $19.5M while the estimated cost for conventional hydrated lime treatment geared towards on-site or off-site disposal, without disposal costs, is $23.2M. The costs are summarized in Tables 8-3A and 8-3B, respectively. The reason for the higher costs for the latter option is because of the higher capital and operating costs involved for including the sludge dewatering equipment. Specifically, the higher capital costs include the belt filter presses, associated belt filter press wash and waste pumps, belt filter press cake handling conveyor, and an additional polymer system. The higher operating costs include higher polymer and electrical consumption and more labor and maintenance of equipment.

TABLE 8-3A
CONVENTIONAL LIME TREATMENT/ONE STAGE pH PROCESS, NO FILTER PRESS

Cost Item	Labor	Bulk Material	Equipment	Construction Equipment	Total
Capital Costs					
Tanks	$205,860.00		$491,530.67	$8,596.47	$705,987.14
Specialty (Chemical & Filtration)	$269,780.00		$634,067.00	$7,450.00	$911,297.00
Pumps / Blowers	$60,160.00		$149,021.89	$3,008.00	$212,189.89
Mixers	$7,520.00		$58,142.44	$188.00	$65,850.44
Ponds	$48,790.00	$131,600.00		$48,610.00	$229,000.00
Pipelines	$85,023.00	$55,731.16	$4,156.68		$144,910.84
Building	$443,615.00	$548,700.00	$317,627.00	$92,088.00	$1,402,030.00
Other Construction	$320,268.81	$545,517.00	$541,897.00	$10,827.00	$1,418,509.81
Sub-Total Installation Costs					**$5,089,775.13**
Installation Contingencies		30% of Installation and EPCM Costs			$2,058,300.00
EPCM					$1,771,585.92
Total Capital Costs					**$8,919,661.05**
Annual O&M Costs					
Annual Power Costs					$25,318.61
Annual Fuel Costs					$11,412.00
Annual Reagent Costs					$108,881.00
Annual Labor Costs					$165,313.00
Annual Equipment Maintenance / Replacement Costs					$57,685.49
Annual Filter Media Replacement Costs					$15,000.00
Total Annual O&M Costs					$383,610.10
Present Worth of Annual O&M Costs Based on 100 Year Life			PF Factor = 27.7		$10,608,737.27
Total Present Worth					**$19,528,398.32**

Notes: EPCM Engineering, Procurement, and Construction Management
O&M Operation and Maintenance
PF Present Worth Factor

TABLE 8-3B
CONVENTIONAL LIME TREATMENT/ONE STAGE pH PROCESS, WITH FILTER PRESS

Cost Item	Labor	Bulk Material	Equipment	Construction Equipment	Total
Capital Costs					
Tanks	$205,860.00		$491,530.67	$8,596.47	$705,987.14
Specialty (Chemical & Filtration)	$289,520.00		$681,767.00	$8,930.00	$980,217.00
Filter Presses	$110,920.00		$262,354.00	$5,546.00	$378,820.00
Pumps / Blowers	$83,660.00		$207,455.00	$3,878.00	$294,993.00
Mixers	$7,520.00		$58,142.44	$188.00	$65,850.44
Ponds	$48,790.00	$131,600.00		$48,610.00	$229,000.00
Pipelines	$85,023.00	$55,731.16	$4,156.68		$144,910.84
Building	$443,615.00	$548,700.00	$317,627.00	$92,088.00	$1,402,030.00
Other Construction	$408,959.00	$655,643.00	$661,036.00	$13,821.00	$1,739,459.00
Sub-Total Installation Costs					**$5,941,267.42**
Installation Contingencies		30% of Installation and EPCM Costs			$2,405,700.00
EPCM					$2,078,001.00
Total Capital Costs					**$10,424,968.42**
Annual O&M Costs					
Annual Power Costs					$26,626.00
Annual Fuel Costs					$11,412.00
Annual Reagent Costs					$117,635.00
Annual Labor Costs					$216,341.00
Annual Equipment Maintenance / Replacement Costs					$76,110.00
Annual Filter Media Replacement Costs					$15,000.00
Total Annual O&M Costs					$463,124.00
Present Worth of Annual O&M Costs Based on 100 Year Life			PF Factor = 27.7		$12,807,694.22
Total Present Worth					**$23,232,662.64**

Notes:
EPCM Engineering, Procurement, and Construction Management
O&M Operation and Maintenance
PF Present Worth Factor

The estimated cost for the single-stage HDS hydrated lime treatment system is \$22.6M. The costs are summarized in Table 8-4.

TABLE 8-4
HIGH DENSITY SLUDGE TREATMENT/ONE STAGE pH PROCESS, WITH FILTER PRESS

Cost Item	Labor	Bulk Material	Equipment	Construction Equipment	Total
Capital Costs					
Tanks	\$192,700.0		\$454,443.00	\$8,143.00	\$655,286.00
Specialty (Chemical & Filtration)	\$289,520.00		\$681,767.00	\$8,930.00	\$980,217.00
Filter Presses	\$110,920.00		\$262,354.00	\$5,546.00	\$378,820.00
Pumps / Blowers	\$89,300.00		\$221,050.00	\$4,583.00	\$314,933.00
Mixers	\$ 7,520.00		\$56,586.00	\$188.00	\$64,294.00
Ponds	\$ 48,790.00	\$131,600.00		\$48,610.00	\$229,000.00
Pipelines	\$85,023.00	\$55,731.16		\$4,157.00	\$144,911.16
Building	\$371,279.00	\$458,442.00	\$263,676.00	\$76,871.00	\$1,170,268.00
Other Construction	\$402,995.00	\$630,106.00	\$635,488.00	\$13,617.00	\$1,682,206.00
Sub-Total Installation Costs					**\$5,619,935.16**
Installation Contingencies		30% of Installation and EPCM Costs			\$2,277,000.00
EPCM					\$1,970,237.00
Total Capital Costs					**\$9,867,172.16**
Annual O&M Costs					
Annual Power Costs					\$26,209.00
Annual Fuel Costs					\$9,415.00
Annual Reagent Costs					\$117,635.00
Annual Labor Costs					\$214,993.00
Annual Equipment Maintenance / Replacement Costs					\$77,982.00
Annual Filter Media Replacement Costs					\$15,000.00
Total Annual O&M Costs					\$461,234.00
Present Worth of Annual O&M Costs Based on 100 Year Life			PF Factor = 27.7		\$12,755,426.27
Total Present Worth					**\$22,622,598.43**

Notes:
EPCM Engineering, Procurement, and Construction Management
O&M Operation and Maintenance
PF Present Worth Factor

For all of the options in Alternative 3, eliminating the filtration systems downstream of the hydrated lime process would save approximately \$100,000 in capital costs and approximately \$15,000 per year in media replacement costs. Because backwash from the filtration and zeolite media can be recycled to the front of the treatment process, handling of filter and zeolite media backwash waste is not expected to incur measurable extra operating costs on the overall treatment process.

8.4 ALTERNATIVE 4: TWO-STAGE HYDRATED LIME TREATMENT

Alternative 4 is a two-stage hydrated lime treatment for MIW received at a treatment facility. HDS process on the first pH stage can still be implemented. The inherent assumption associated with

Alternative 4 is that two steps are required to precipitate aluminum hydroxide well enough to meet DEQ-7 standards. The first step is adjusting the pH to the 6.5 to 7 range where aluminum hydroxide is typically least soluble. The next step adjusts the pH to approximately 9.5 or higher to precipitate and remove other metal hydroxides and also remove more sulfates. As discussed in section 8.3, having two sets of clarifiers just to remove aluminum is not necessary if filtration is done in a pH re-adjustment step after the hydrated lime treatment.

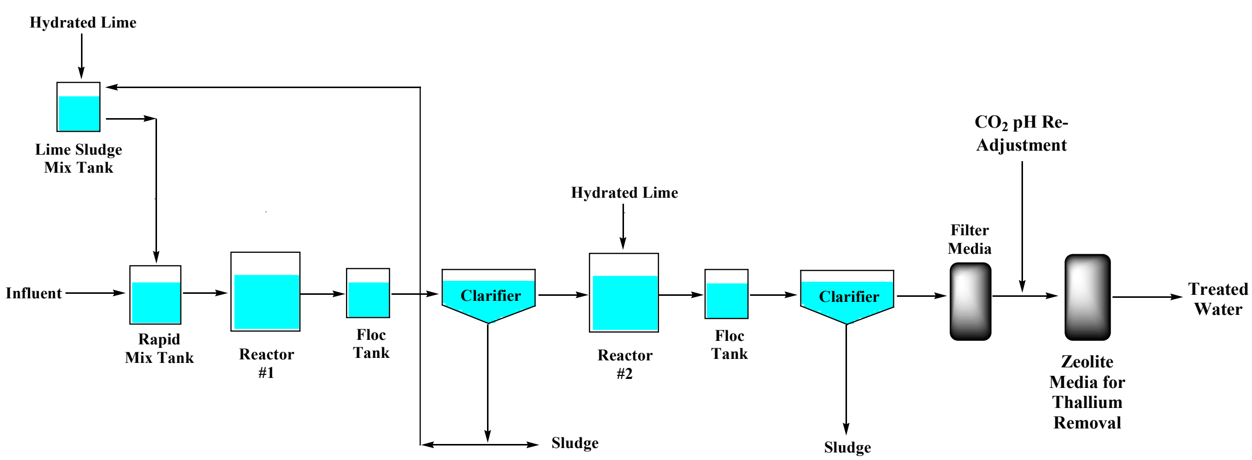
The HDS facilitates more efficient hydrated lime usage, a significant increase of clarifier underflow percent solids, lower potential to scale post hydrated lime treatment, better water quality and more stable solids that are less likely to leach contaminants. The potential tradeoff is that the solids have lower neutralization potential and more potential for clogging and therefore are possibly less attractive for the scenario of solids re-injected into the mine underground workings.

8.4.1 HDS Two-Stage Water Treatment Components

The water treatment components for the two-stage hydrated lime treatment option are listed separately for HDS versus conventional low density sludge hydrated lime treatment.

8.4.1.1 HDS Two-Stage Water Treatment Components

The standard HDS two-stage process flow diagram step is presented below.



Process Flow Diagram 8-3: Two-step HDS hydrated lime treatment process depicting major equipment

MIW is received in a small volume, high energy Rapid Mix Tank where combined hydrated lime and recycled clarifier underflow is added for pH control. MIW then gravity flows to a Reaction Tank #1 with air diffusers in the tank bottom to promote oxidation of metals and generation of metal hydroxides on the surface of the hydrated lime and recycled sludge mixture. The Reaction Tank #1 then overflows either into a Flocculation Tank or to a Clarifier/Thickener with a flocculating feed well.

HDS processes are most efficient with high influent dissolved solids. The HDS process will only be suitable for the first pH step followed by conventional hydrated lime treatment for the second, only trace metals will be removed in the second pH step. Following clarification from the first stage, water will gravity flow into Reactor Tank #2 where the pH is raised further to precipitate and remove additional metals. Discharge from Reactor Tank #2 gravity flows to at Flocculation Tank or to a second Clarifier/Thickener with a flocculating feed well. To more consistently meet effluent discharge standards for trace metals such as cadmium that are precipitated and removed at high pH, Clarifier overflow can be pumped through media filtration prior to discharge. For this process, it is anticipated that the zeolite media will remove thallium much better at circumneutral pH compared to high pH. Therefore, it is proposed that the zeolite media, if necessary to remove thallium, be placed downstream of the CO_2 pH re-adjustment step.

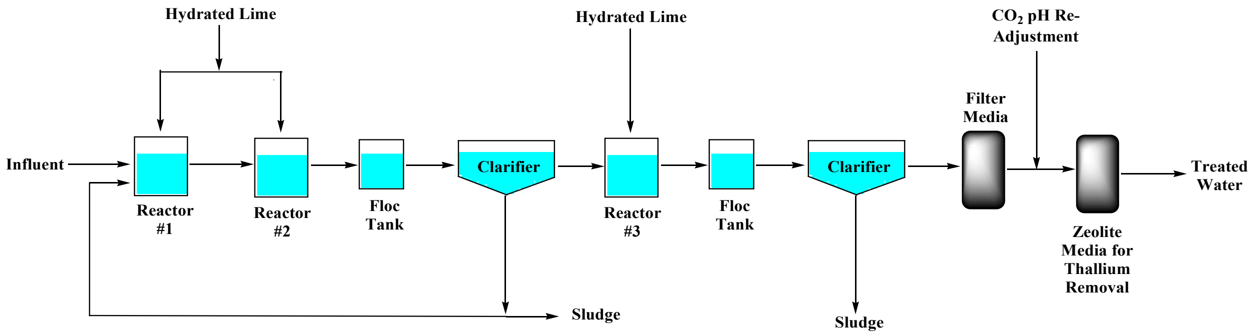
The retention time for the reactor tanks are as follows

Description	Time (minutes)
Reactor #1 Tank	30
Rapid Mix Tank	15
Reactor #2 Tank	40
Reactor #3 Tank	40

Ancillary equipment necessary to support unit processes includes Treated Water Tank and pumps to provide a source for filter backwash water, service water and reagent make-up water; Backwash Water Tank and pumps to receive filter backwash and bleed it back into the treatment process; air blowers; and reagent systems including bulk hydrated lime handling, polymer systems and CO_2 systems to lower the treated water discharge to near neutral pH. All process components in the treatment building, including the clarifiers, will be installed in a contained single story building.

8.4.1.2 Conventional Two-Stage Water Treatment Components

Conventional hydrated lime treatment is similar to HDS for process equipment with a slight modification on sequencing of where sludge and hydrated lime are added to the process. Conventional hydrated lime treatment is recommended for the second step. The standard conventional two-step hydrated lime treatment process flow diagram is presented below.



Process Flow Diagram 8-4: Two-step conventional hydrated lime treatment process depicting major equipment

MIW and hydrated lime are added together into Reactor Tank #1for pH control. Reactor Tank #1 gravity flows to Reactor Tank #2 for additional retention time to provide sufficient reaction time and to maintain pH control. Air diffusers will be installed in Reactor Tanks #1 and 2 to promote complete oxidation of incoming metals, especially iron(II), for precipitation. Reactor Tank #2 then overflows into a Flocculation Tank and then into a Clarifier. Following clarification from the first stage process, water will gravity flow into Reactor Tank #3 where hydrated lime is added to take the pH up to remove additional metals. Discharge from Reactor Tank #3 gravity flows to a second Flocculation Tank and then to the second Clarifier. To consistently meet effluent discharge standards for trace metals such as cadmium that are precipitated and removed at high pH, Clarifier overflow can be pumped through media filtration prior to discharge. For this process, it is anticipated that the zeolite media will remove thallium much better at circumneutral pH compared to high pH. Therefore, it is proposed that the zeolite media, if necessary for removing thallium, be placed downstream of the CO_2 pH re-adjustment step.

Sludge from the clarifiers is pumped to the front of the process step, into Reactor Tank #1 or Reactor #3, to reduce the influence of variable influent water conditions, increase sludge density and improve settling characteristics in the clarifier. The retention time for the reactor tanks are as follows.

Description	Time (minutes)
Reaction Tank #1	30
Reaction Tank #2	30
Reaction Tank #3	30

Ancillary equipment necessary to support unit processes includes Treated Water Tank and pumps to provide a source for filter backwash water, service water and reagent make-up water; Backwash Water Tank and pumps to receive filter backwash and bleed it back into the treatment process; air blowers; and reagent systems including bulk hydrated lime handling, polymer system and CO_2 system to lower the treated water effluent to near neutral pH. All process components within the treatment building will be installed in a contained single story building.

Under this alternative, the mass of sludge for disposal will vary slightly between HDS and conventional hydrated lime treatment because of increased hydrated lime efficiency. Volumetrically, as with the single-stage pH process, because the majority of metals loading is removed in the first stage, thickened sludge generated in a conventional hydrated lime pH adjust process in both the first and second stage is less than 10 percent solids, whereas upwards of 25 to 30 percent solids can be generated from the first stage in the two step HDS process. Transportation and final storage requirements of this material typically dictate the level of degree that it must be dewatered and is discussed below.

HDS sludge pressing can generate a filter cake up to 50 percent solids. Throughout the day, thickened sludge for both pH stages will be pumped to a common agitated sludge storage tank suitable for 2 days storage. Automatic pressing will be performed during the day when operations are available to oversee for any upset conditions, especially during dumping, in one operational and one on stand-by filter press arrangement. It is anticipated that sludge disposal options that require the use of filter presses for dewatering would require one more 8-hour day shift per week to operate and clean the filter press and associated equipment compared to sludge disposal options that do not require filter presses.

Filter cake will drop into a roll-off container that will be removed and hauled to an on-site landfill for dumping. Roll-off container will require dumping once every other day for a 20 cubic yard (yd^3) container.

Filter presses and roll-off containers will be in a contained two-story structure. Liquid spills will report back to the treatment building sump system.

8.4.2 Effectiveness

A two-stage hydrated lime treatment process along with a thallium removal polishing process is expected to meet all DEQ-7 standards, including for aluminum or thallium. Bench-scale and pilot testing is recommended prior to the detailed design to confirm the viability of the proposed treatment process for consistently meeting all DEQ-7 standards. If thallium removal is not proven to be reliable with zeolite media, an oxidation process using a strong oxidant such as potassium permanganate can be added to the high pH hydrated lime treatment step to oxidize and remove the residual thallium as thallium (III) hydroxide at high pH. Bench-scale testing can help determine whether a two-stage hydrated lime treatment process can meet the DEQ-7 standard for aluminum with clarification only and without filtration polishing. Alternatively, it may also be possible to design and build a hydrated lime treatment-only water treatment facility, whether HDS or conventional, and operate for a year and evaluate whether additional polishing steps are required.

8.4.3 Implementability

Alternative 4 is technically and administratively feasible. Design methods, construction practices, and engineering requirements for construction of the WTP building and major process equipment such as the clarifiers, hydrated lime storage and treatment systems, reactors, filter media, and piping are all well-documented and understood. Equipment, materials, and labor would all be available. Because hydrated lime treatment and filtration processes are well established for MIW treatment, long-term operation, maintenance, and monitoring of the performance of the Belt MIW WTP would be readily implementable. And because these are well-established treatment processes, Alternative 4 would be administratively feasible. Alternative 4 is rated as easy in terms of its implementability.

8.4.4 Costs

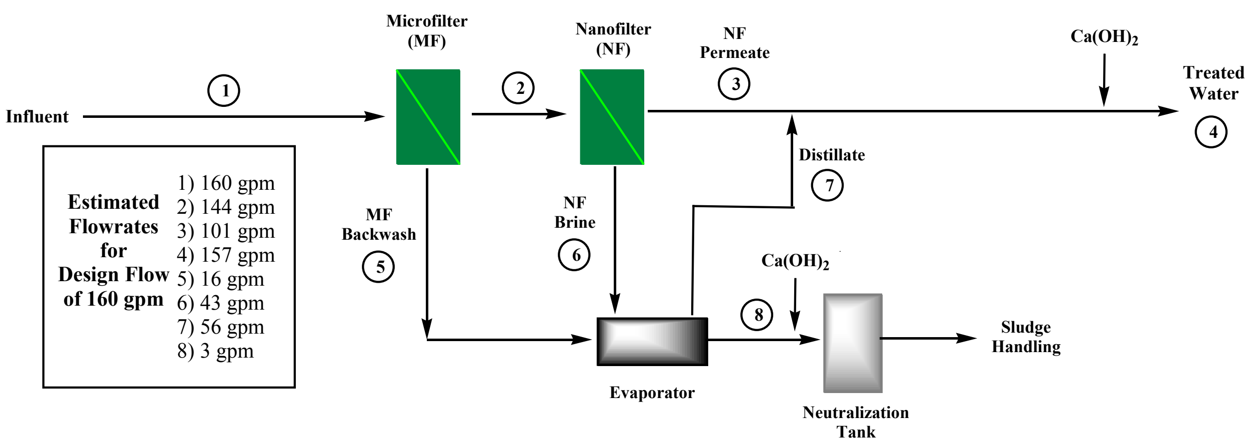
There are three sets of costs for Alternative 4. The estimated cost for conventional two stage hydrated lime treatment is \$23.1M for disposal of sludge underground (Table 8-5A), compared to \$26.8M for disposal of sludge on-site or off-site (Table 8-5B). The primary differences in costs between the two options are the capital and operating costs of the belt filter presses and associated equipment required for sludge disposal on- or off-site vs. pumping the sludge underground   Specifically, the higher capital costs include the belt filter presses, associated belt filter press wash and waste pumps, belt filter press cake handling conveyor, and an additional polymer system. The higher operating costs include higher polymer and electrical consumption and more labor and maintenance of equipment. The estimated cost for HDS lime treatment is $26M. The costs are summarized in Table 8-6.The HDS-treated sludge will be disposed on- or off-site and not underground.

For all of the options in Alternative 4, eliminating the filtration systems downstream of the hydrated lime process would save approximately $100,000 in capital costs and approximately $15,000 per year in media replacement costs if the water treatment facility is designed to remove the bulk of the contaminants in the Belt MIWs via hydrated lime treatment without polishing with the filtration systems (Tables 8-5A, 8-5B, and 8-6). Because backwash from the filtration and zeolite media can be recycled to the front of the treatment process, handling of filter and zeolite media backwash waste is not expected to incur measurable extra operating costs on the overall treatment process.

8.5 ALTERNATIVE 5: NANOFILTRATION WITH BRINE EVAPORATOR

8.5.1 Water Treatment Components

Alternative 4 is nanofiltration (NF) treatment of MIW without chemical pre-treatment followed by evaporation and neutralization of brine concentrate for disposal. The NF process flow diagram is provided below.



Process Flow Diagram 8-5: NF treatment process with brine evaporator – (Note: only major equipment depicted)

TABLE 8-5A
CONVENTIONAL LIME TREATMENT/TWO STAGE pH PROCESS, NO FILTER PRESS

Cost Item	Labor	Bulk Material	Equipment	Construction Equipment	Total
Capital Costs					
Tanks	$329,940.00		$786,296.00	$14,776.00	$1,131,012.00
Specialty (Chemical & Filtration)	$255,680.00		$600,532.00	$6,393.00	$ 862,605.00
Pumps / Blowers	$71,440.00		$176,211.00	$3,572.00	$251,223.00
Mixers	$9,400.00		$71,561.00	$235.00	$ 81,196.00
Ponds	$48,790.00	$131,600.00		$48,610.00	$229,000.00
Pipelines	$85,023.00	$55,731.16	$4,157.00		$144,911.16
Building	$608,955.00	$755,004.00	$440,943.00	$126,868.00	$1,931,770.00
Other Construction	$392,831.00	$676,985.00	$679,490.00	$13,279.00	$1,762,585.00
Sub-Total Installation Costs					**$6,394,302.16**
Installation Contingencies		30% of Installation and EPCM Costs			$2,585,100.00
EPCM					$2,222,906.00
Total Capital Costs					**$11,202,308.16**
Annual O&M Costs					
Annual Electrical Power Costs					$31,760.00
Annual Fuel Costs					$15,977.00
Annual Reagent Costs					$ 117,635.00
Annual Labor Costs					$ 181,554.00
Annual Equipment Maintenance / Replacement Costs					$65,947.00
Annual Filter Media Replacement Costs					$15,000.00
Total Annual O&M Costs					$427,873.00
Present Worth of Annual O&M Costs Based on 100 Year Life			PF Factor = 27.7		$11,832,827.82
Total Present Worth					**$23,035,135.98**

Notes:
EPCM Engineering, Procurement, and Construction Management
O&M Operation and Maintenance
PF Present Worth Factor

TABLE 8-5B
CONVENTIONAL LIME TREATMENT/TWO STAGE pH PROCESS, WITH FILTER PRESS

Cost Item	Labor	Bulk Material	Equipment	Construction Equipment	Total
Capital Costs					
Tanks	$329,940.00		$786,296.00	$14,776.00	$1,131,012.00
Specialty (Chemical & Filtration)	$275,420.00		$648,232.00	$7,873.00	$931,525.00
Filter Presses	$110,920.00		$262,354.00	$5,546.00	$378,820.00
Pumps / Blowers	$94,940.00		$234,645.00	$4,442.00	$334,027.00
Mixers	$9,400.00		$71,561.00	$235.00	$81,196.00
Ponds	$48,790.00	$131,600.00		$48,610.00	$229,000.00
Pipelines	$85,023.00	$55,731.16	$4,157.00		$144,911.16
Building	$608,955.00	$755,004.00	$440,943.00	$126,868.00	$1,931,770.00
Other Construction	$481,511.00	$ 787,111.00	$798,630.00	$16,273.00	$2,083,525.00
Sub-Total Installation Costs					**$7,245,786.16**
Installation Contingencies		30% of Installation and EPCM Costs			$2,932,500.00
EPCM					$2,529,322.00
Total Capital Costs					**$12,707,608.16**
Annual O&M Costs					
Annual Electrical Power Costs					$33,067.00
Annual Fuel Costs					$15,977.00
Annual Reagent Costs					$126,390.00
Annual Labor Costs					$232,582.00
Annual Equipment Maintenance / Replacement Costs					$84,371.00
Annual Filter Media Replacement Costs					$15,000.00
Total Annual O&M Costs					$507,387.00
Present Worth of Annual O&M Costs Based on 100 Year Life			PF Factor = 27.7		$14,031,787.49
Total Present Worth					**$26,739,395.65**

Notes:
EPCM Engineering, Procurement, and Construction Management
O&M Operation and Maintenance
PF Present Worth Factor

TABLE 8-6
HIGH DENSITY SLUDGE TREATMENT/TWO STAGE pH PROCESS, WITH FILTER PRESS

Cost Item	Labor	Bulk Material	Equipment	Construction Equipment	Total
Capital Costs					
Tanks	$319,600.00		$752,428.00	$14,423.00	$1,086,451.00
Specialty (Chemical & Filtration)	$275,420.00		$648,232.00	$7,873.00	$931,525.00
Filter Presses	$110,920.00		$262,354.00	$5,546.00	$378,820.00
Pumps / Blowers	$100,580.00		$248,239.00	$5,147.00	$353,966.00
Mixers	$9,400.00		$70,004.00	$235.00	$79,639.00
Ponds	$48,790.00	$131,600.00		$48,610.00	$229,000.00
Pipelines	$85,023.00	$55,731.16	$4,157.00		$144,911.16
Building	$522,840.00	$647,554.00	$376,716.00	$108,753.00	$1,655,863.00
Other Construction	$476,363.00	$759,097.00	$770,785.00	$16,096.00	$2,022,341.00
Sub-Total Installation Costs					**$6,882,516.16**
Installation Contingencies		30% of Installation and EPCM Costs			$2,787,000.00
EPCM					$2,407,937.00
Total Capital Costs					**$12,077,453.16**
Annual O&M Costs					
Annual Electrical Power Costs					$32,022.00
Annual Fuel Costs					$13,599.00
Annual Reagent Costs					$126,390.00
Annual Labor Costs					$231,407.00
Annual Equipment Maintenance / Replacement Costs					$84,295.00
Annual Filter Media Replacement Costs					$15,000.00
Total Annual O&M Costs					$502,713.00
Present Worth of Annual O&M Costs Based on 100 Year Life			PF Factor = 27.7		$13,902,528.02
Total Present Worth					**$25,979,981.18**

Notes:
EPCM Engineering, Procurement, and Construction Management
O&M Operation and Maintenance
PF Present Worth Factor

MIW is received in the treatment facility at a surge tank and then pumped into the microfiltration system. Permeate from the microfiltration is collected in another surge tank (not depicted in Process Flow Diagram 8-5) and then pumped through the NF system. Microfiltration is required to remove suspended solids to protect the nanofilter. NF permeate is then adjusted to pH neutral and collected in a treated water storage tank (not depicted in Process Flow Diagram 8-5) to provide retention time and sampling prior to discharge.

In many typical NF treatment processes, there is a chemical pretreatment step upstream of the NF process to reduce scale-forming constituents to reduce the scaling tendency of the brine and increase the water recovery of the NF process. Additionally, a scale inhibitor (antiscalant) is typically added upstream of the

NF process. Because the raw water at the WTP is already at a low pH of approximately 2–3, chemical modeling calculations show that scaling will not likely be an issue if no pH adjustment is made to the raw water prior to the NF process, especially if aeration/oxygenation of the water is minimized.

NF was selected for evaluation instead of RO because sulfate (SO_4^{2-}) constitutes most of the anions in the water. Because NF essentially rejects all divalent anions (such as sulfate), and because monovalent cations such as thallium (I) (Tl^{+}) will also be rejected by NF membranes due to the majority of the anions being divalent (because of the requirement to maintain net charge neutrality in the water), NF membranes would theoretically reject and thus remove thallium and other COCs such as cadmium as well as RO membranes for Belt MIW.

The advantage of not chemically pre-treating the raw water for the NF process is that a clarifier capable of treating up to the design flow rate of 160 gpm will be unnecessary, saving on capital costs for a clarifier of that size and saving space. One drawback of not chemically pre-treating the raw water and treating the acidic water with NF is that it would likely decrease the useful life of the NF membranes to approximately 50 percent of their typical lifespan, from approximately 3 years down to 1½ years. Another drawback to not chemically pre-treating the water is that the NF brine/reject stream will be highly acidic and would require chemical neutralization with a base such as hydrated lime to be considered non-hazardous waste.

Ancillary equipment necessary to support unit processes includes Treated Water Tank and pumps to provide a source for filter backwash water, service water and reagent make-up water; Backwash Water Tank and pumps to receive filter backwash and meter it into the concentrator; air blowers; and reagent systems including bulk hydrated lime handling and polymer system.

8.5.2 Effectiveness

Alternative 5 provides the cleanest treated water, with expected removals of >98 percent of all current COCs. Currently available data show an average thallium concentration in the combined streams that will feed the Belt MIW WTP at approximately 0.001 mg/L, with maximum values at approximately 0.005 mg/L. Assuming 98 percent removal, the NF process will be able to meet DEQ-7 human health standard of 0.00024 mg/L in the effluent. It is possible, though, that because DEQ-7 standard for human health for thallium is so low (0.00024 mg/L), Alternative 5 may not consistently meet DEQ-7 standards for thallium if the assumption of 98 percent removal does not hold true, and an additional thallium removal polishing step may be necessary for the NF permeate if the projected removal efficiency of >98 percent for all COCs does not hold for thallium based on bench-scale or pilot testing results or if thallium concentrations are much higher than the current data show. The exact removal efficiencies will need to be determined with bench-scale and/or pilot testing if this option were carried forward to detailed design. If Alternative 5 is carried forward, adding a zeolite thallium-removal step to the process can be evaluated. The treated water in Alternative 5 is also expected to be safe for fish and invertebrates because hydrated lime would be added to adjust the pH of the NF permeate before discharge, which in addition to neutralizing the permeate would also serve to remineralize the water to support aquatic life.

Despite possibly not meeting the thallium DEQ-7 standard without a thallium removal polishing step, Alternative 5 will provide the cleanest water of all of the alternatives explored in this EE/CA, so that it can provide the most contingency for potential future changes in ARARs and discharge standards at the site. As discussed in Sections 8.5.3 and 8.5.4, Alternative 5 also carries some major disadvantages in implementability and in capital and operating costs.

8.5.3 Implementability

Alternative 5 is technically and administratively feasible. Design methods, construction practices, and engineering requirements for construction of the WTP building and major process equipment such as the MF modules, NF modules, clarifier, brine evaporator, hydrated lime storage and treatment systems, reactors, filter media, and piping are all well-documented and understood. Equipment, materials, and labor would all be available.

Although MF and NF treatment processes are well-established, long-term operation, maintenance, and monitoring of the performance of Alternative 5 for the Belt MIW WTP would be moderately difficult to implement due to its increased operational complexity compared to standard hydrated lime treatment. Because of this and because of its high costs (Section 8.5.5), Alternative 5 may be administratively difficult to justify given that DEQ-7 standards do not require such pristine water from the Belt MIW WTP. Alternative 5 is rated as difficult in its implementability because it would be considerably more challenging to operate than hydrated lime MIW treatment processes and because of the potential administrative hurdles.

8.5.4 Costs

The costs associated with Alternative 5 are estimated to be $253M. These costs are summarized in Table 8-7. As seen in Table 8-7, the estimated annual fuel costs for operating the evaporator are more than $7 million, which contributes significantly to the Total Present Worth value. If the DEQ were to build wind turbines on-site and generate enough electricity to power the whole WTP, including an evaporator that uses electricity instead of propane, then the operating costs could be much lower. However, the capital costs of the wind turbines would need to be taken into account.

TABLE 8-7
MICROFILTER (MF)/NANOFILTER (NF) WITH BRINE EVAPORATOR

Cost Item	Labor	Bulk Material	Equipment	Construction Equipment	Total
Capital Costs					
Tanks	$109,980.00		$253,649.00	$4,280.00	$367,909.00
Specialty (MF/NF)	$2,605,680.00		$6,137,856.00	$65,142.00	$8,808,678.00
Pumps / Blowers	$45,120.00		$111,052.00	$2,256.00	$158,428.00
Mixers	$5,640.00		$44,724.00	$141.00	$50,505.00
Ponds	$48,790.00	$131,600.00		$48,610.00	$229,000.00
Pipelines	$85,023.00	$55,731.16	$4,157.00		$144,911.16
Building	$310,677.00	$391,883.00	$214,864.00	$63,456.00	$980,880.00
Other Construction	$1,574,834.00	$2,072,569.00	$2,189,644.00	$53,190.00	$5,890,237.00
				Sub-Total Installation Costs	**$16,630,548.16**
Installation Contingencies		30% of Installation and EPCM Costs			$6,771,000.00
EPCM					$5,939,843.00
Total Capital Costs					**$29,341,391.16**
Annual O&M Costs					
Annual Electrical Power Costs					$67,021.00
Annual Fuel Costs					$7,103,208.00
Annual Reagent Costs					$100,127.00
Annual Labor Costs					$477,096.00
Annual Equipment Maintenance / Replacement Costs					$320,710.00
Total Annual O&M Costs					$8,068,162.00
Present Worth of Annual O&M Costs Based on 100 Year Life			PF Factor = 27.7		$223,125,020.11
Total Present Worth					**$252,466,411.27**

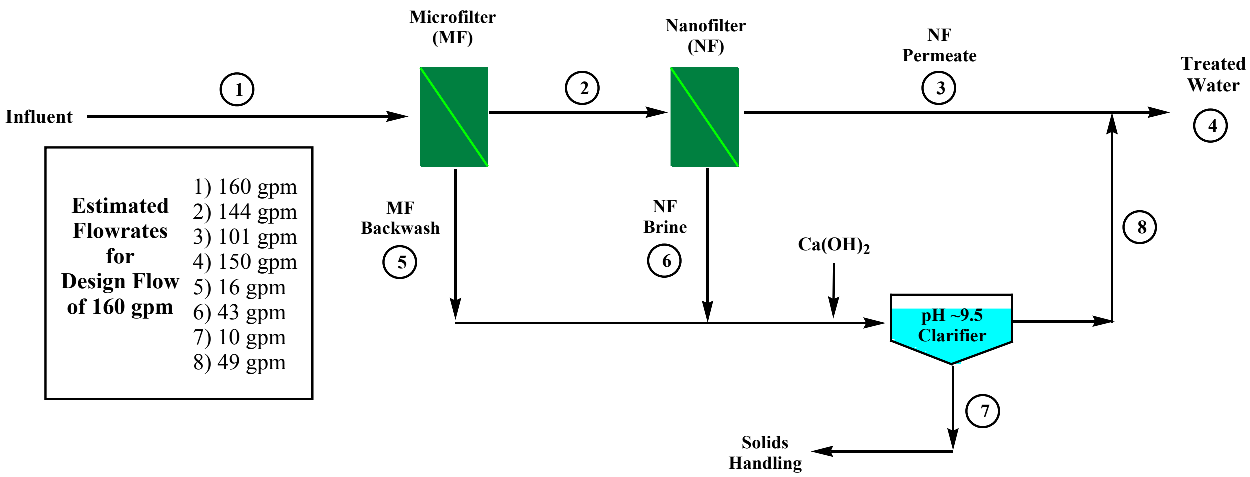
Notes:
EPCM Engineering, Procurement, and Construction Management
O&M Operation and Maintenance
PF Present Worth Factor

8.6 ALTERNATIVE 6: NANOFILTRATION COMBINED WITH CHEMICAL TREATMENT OF BRINE

8.6.1 Water Treatment Components

Alternative 6 is nanofiltration of MIW without chemical pre-treatment followed by single-step hydrated lime precipitation and neutralization of brine concentrate for clarification. The nanofiltration/ neutralization process flow diagram is below.

MIW is received in the treatment facility at a surge tank and pumped into the microfiltration system. Permeate from the microfiltration is collected in another surge tank and pumped through the NF system. Microfiltration is required to remove suspended solids to protect the nanofilter.



Process Flow Diagram 8-6: NF treatment process with chemical treatment of NF brine – (Note: Only major equipment depicted)

NF and microfilter backwash is collected in an agitated Backwash Tank where hydrated lime is added for single-step pH control. Backwash water is pumped through the clarifier and overflow is mixed with nanofilter permeate. Combining the low pH nanofilter permeate and high pH clarifier overflow will reach a near neutral state without requiring additional reagents.

A major advantage of the Alternative 6 process compared to the conventional hydrated lime treatment processes is that the treated water quality will be better, thus allowing for more contingency for future changes in the ARAR and discharge limits at the site. For example, even though there is currently no sulfate discharge standard, if one were to be implemented in the future, this process would allow for treating sulfate to below 600 mg/L compared to approximately 1,500–2,000 mg/L sulfate in the Alternative 3 and Alternative 4 hydrated lime treatment processes described in Sections 8.3 and 8.4. Analogously, Alternative 6 would also allow for future flexibility in treating COCs down to lower concentrations than possible using Alternative 3 or 4 because the NF will allow for better overall contaminant removal by concentrating the MIW stream prior to hydrated lime treatment. Also, because the clarifier for the hydrated lime treatment process will be for a concentrated flow (NF brine/reject) instead of the full flow, it will also be smaller, and the entire water treatment process will take up less space.

Ancillary equipment necessary to support unit processes includes Treated Water Tank and pumps to provide a source for filter backwash water, service water and reagent make-up water; Backwash Water Tank and pumps to receive filter backwash and meter it into the clarifier; air blowers; and reagent systems including bulk hydrated lime handling and polymer system. All process components within the treatment building will be installed in a contained single story building.

Lime sludge pressing can generate a filter cake up to 40 percent solids. Throughout the day, thickened sludge is collected in an agitated sludge storage tank suitable for 2 days storage total. Automatic pressing of the sludge will be performed during the day when operations are available to oversee for any upset conditions, especially during dumping. Two presses, one operational and one stand-by is recommended.

Filter cake will drop into a roll-off container that will be removed and hauled to an on-site landfill for dumping. Roll-off containers will require dumping once every other day for a 20 yd^3 container.

Filter presses and roll-off containers will be in a contained two-story structure.

8.6.2 Effectiveness

Alternative 6 provides the second cleanest water in terms of the overall treated water quality of all the examined alternatives because the NF process would concentrate the influent MIW stream and make metals precipitation and removal more efficient compared to an unconcentrated stream. Alternative 6 will likely not consistently meet DEQ-7 standards for thallium, and an additional thallium removal polishing step may be necessary for the re-blended stream prior to discharge. If Alternative 6 is carried forward, adding a zeolite thallium-removal step to the process can be evaluated.

Despite possibly not meeting the thallium DEQ-7 standard without zeolite polishing, however, Alternative 6 will provide cleaner overall water than Alternatives 3 and 4, so that it can provide more contingency for potential future changes in ARAR and discharge standards at the site.

8.6.3 Implementability

Alternative 6 is technically and administratively feasible. Design methods, construction practices, and engineering requirements for construction of the WTP building and major process equipment such as the MF modules, NF modules, clarifier, hydrated lime storage and treatment systems, reactors, filter media, and piping are all well-documented and understood. Equipment, materials, and labor would all be available.

Although MF and NF treatment processes are well-established, long-term operation, maintenance, and monitoring of the performance of Alternative 6 for the Belt MIW WTP would be moderately difficult to implement due to its increased operational complexity compared to standard hydrated lime treatment. Because of this, Alternative 6 may be administratively more difficult compared to Alternatives 3 and 4 given that DEQ-7 standards do not require sulfate removal at the Belt MIW WTP. Alternative 6 is rated as moderately difficult in its implementability because it would be more challenging to operate than hydrated lime MIW treatment processes alone and because of the possible administrative hurdles.

8.6.4 Costs

The costs associated with Alternative 6 are summarized in Table 8-8. The estimated cost for Microfilter/Nanofilter with brine treatment and clarifier is $31.4M.

TABLE 8-8
MICROFILTER (MF)/NANOFILTER (NF) WITH BRINE TREATMENT AND CLARIFIER

Cost Item	Labor	Bulk Material	Equipment	Construction Equipment	Total
Capital Costs					
Tanks	$168,260.00		$389,267.88	$7,520.63	$565,048.51
Specialty (Chemical & Filtration)	$1,034,940.00		$2,436,409.20	$25,873.50	$3,497,222.70
Pumps / Blowers	$ 67,680.00		$166,003.36	$3,384.00	$237,067.36
Mixers	$ 5,640.00		$40,254.66	$141.00	$46,035.66
Ponds	$48,790.00	$131,600.00		$48,610.00	$229,000.00
Pipelines	$85,023.00	$55,731.16	$4,156.68		$144,910.84
Building	$366,758.87	$463,671.96	$255,969.23	$75,119.94	$1,161,520.00
Other Construction	$ 729,261.13	$1,036,327.26	$1,071,210.89	$24,631.16	$2,861,430.44
Sub-Total Installation Costs					**$8,742,235.51**
Installation Contingencies		30% of Installation and EPCM Costs			$3,687,900.00
EPCM					$3,550,800.00
Total Capital Costs					**$15,387,176.76**
Annual O&M Costs					
Annual Power Costs					$69,652.55
Annual Fuel Costs					$9,129.00
Annual Reagent Costs					$101,002.00
Annual Labor Costs					$256,742.00
Annual Equipment Maintenance / Replacement Costs					$140,680.74
Total Annual O&M Costs					$577,206.29
Present Worth of Annual O&M Costs Based on 100 Year Life			PF Factor = 27.7		$15,962,639.96
Total Present Worth					**$31,349,816.71**

Notes:
EPCM Engineering, Procurement, and Construction Management
O&M Operation and Maintenance
PF Present Worth Factor

8.7 TREATMENT WASTE DISPOSAL ALTERNATIVE A: UNDERGROUND DISPOSAL

Underground sludge disposal is common in other coal mining regions in the United States. Waste sludge from single or two-stage hydrated lime treatment processes could be disposed of into the abandoned underground mine workings of the Anaconda Mine. Underground sludge disposal for nanofiltration wastes is not practical due to the solid nature of the treated brine or brine concentrate.

Sludge injection wells could be located within a mine pool or in an up dip portion of a dry part of the mine. The disposal area should be designed so that solids would flow away from the injection well and in an area where there is sufficient storage volume to provide a long life for the injection well. The distance that sludge flows away from an injection well would be affected by mine characteristics, such as slope of the mine entries, and potential obstructions in the mine. Because the mine is an old and abandoned, the potential obstructions are unknown, having multiple injection sites available would be needed to provide standby injection capacity when an injection well becomes full. Sludge characteristics, such as sludge density, viscosity and percent solids also affect the distance that sludge would flow from the injection well. Injection wells located in dry workings may use additional flush water to keep the well from plugging. The life of a sludge injection well can vary depending on the sludge generation rate, the available mine storage volume and conditions in the mine that could restrict flow. A sludge injection well could remain in service for more than 20 years where suitable conditions exist or as little as 1 year in areas where the mine workings have obstructions that restrict transport of solids.

This disposal method is a relatively low cost option because no sludge dewatering is required, transport/pumping costs are comparatively low, and disposal costs are not subject to solid waste tipping fees that can increase over time. The initial capital costs for sludge injection are higher, but the longer the performance period, the more cost effective sludge injection becomes. Other potential advantages of sludge injection may include an increase in the pH of the MIW discharge over time as the sludge buffers the MIW in situ, and reduce reagent usage rates of the MIW treatment facility. Using a pipeline to inject the sludge does not require truck hauling after initial construction, which decreases traffic and road damage and reduces the chances of transportation accidents. However, sludge injection can also have disadvantages. There is potential that it could increase the MIW flow rate from the mine workings, and that trace metals could be dissolved and remobilized by the injection.

A review of mine maps is the initial step in siting a sludge injection well. The Anaconda Belt Mine began operation in the 1870s and closed around the 1940s. A search for detailed mine maps was unsuccessful. A mine map was obtained from the Montana Natural Resource Information System but the map shows only a portion of the mine workings. The main entries are shown throughout the expected extent of the mine, including those sections of the mine where the detailed mine workings are not shown. The mine map was overlaid onto an aerial map of the mine site. Figure 8-2 shows the mine map with an outline of the underground mine pools. The total area of the underground mine workings, based on the mine map is estimated to be approximately 1,200 acres.

A general description of the Anaconda Belt Mine workings is provided in the report "Geochemistry and Stable Isotopes of Acid Mine Drainage in the Belt-Stockett Area, Montana" (Gammons et al., 2006). "Near Belt, the coal seams of the Great Falls Coal Fields are located several tens of meters above the regional water table. A perched water table of considerable lateral extent exists above the coal seams in permeable sandstone of the Kootenai Formation. This water slowly drains into the underlying mine workings, and serves as the main source of groundwater recharge to the mines. The mines followed a 1 to 4 meter thick coal seam with a shallow, undulating dip, and for this reason the mine workings are spread laterally over a huge area but have a limited vertical extent. Portions of the mines are now completely flooded with groundwater, other portions are partially flooded, and still others are freely draining to surface discharge points. Some of the larger mining complexes have extensive mine water pools whose elevations are controlled by spill-over points in the underground workings. The Anaconda Coal Mine in Belt is a good example of this pattern…."

Exploratory borings installed by MBMG provide information about the coal mine structure and static water levels in the mine pool. Table 8-9 is a summary of the MBMG exploratory monitoring well data. A map of mine structure and coal seam elevations developed from the borehole data is shown on Figure 8-3.

The criteria for siting injection wells are summarized as:

- Storage capacity in the mine voids is a primary factor in siting an injection well. The void space can be estimated based on mine maps but the actual void space available for sludge disposal can be significantly lower due to collapsed or blocked mine entries.
- Typically, sludge injection wells should connect to main entries or sub-main entries and particularly into track entries if possible. In general these mine entries would have the most stable roof conditions with greater potential for open passageways to be present. In the Belt Mine there was only one entry shown as the main and sub-main entry. If additional maps are located, design confidence would be improved.

TABLE 8-9
BELT ANACONDA MINE MONITORING WELLS

Well ID	Surface Elevation (feet amsl)	Bottom of Coal Elevation (feet amsl)	Static Water Elevation (feet amsl)	Coal Seam Height (feet)
SB3	3957	3745	Not Recorded	10
3	3939	3657	3675	6
13	3938	3678	Not Recorded	10
5	3924	3678	Not Recorded	6
12	3917	3651	3649	18
6	3922	3636	Not Recorded	6
1	3916	3701	3702	10
9	3895	3672	Not Recorded	5
2	3915	3619	3610	12
7	3978	3766	Not Recorded	6
11	3936	3668	Not Recorded	8
4B	3976	3691	3705	10
8	3994	3752	Not Recorded	2
15	3907	3679	Not Recorded	2

Source: Montana Bureau of Mining and Geology
Note: amsl = above mean sea level

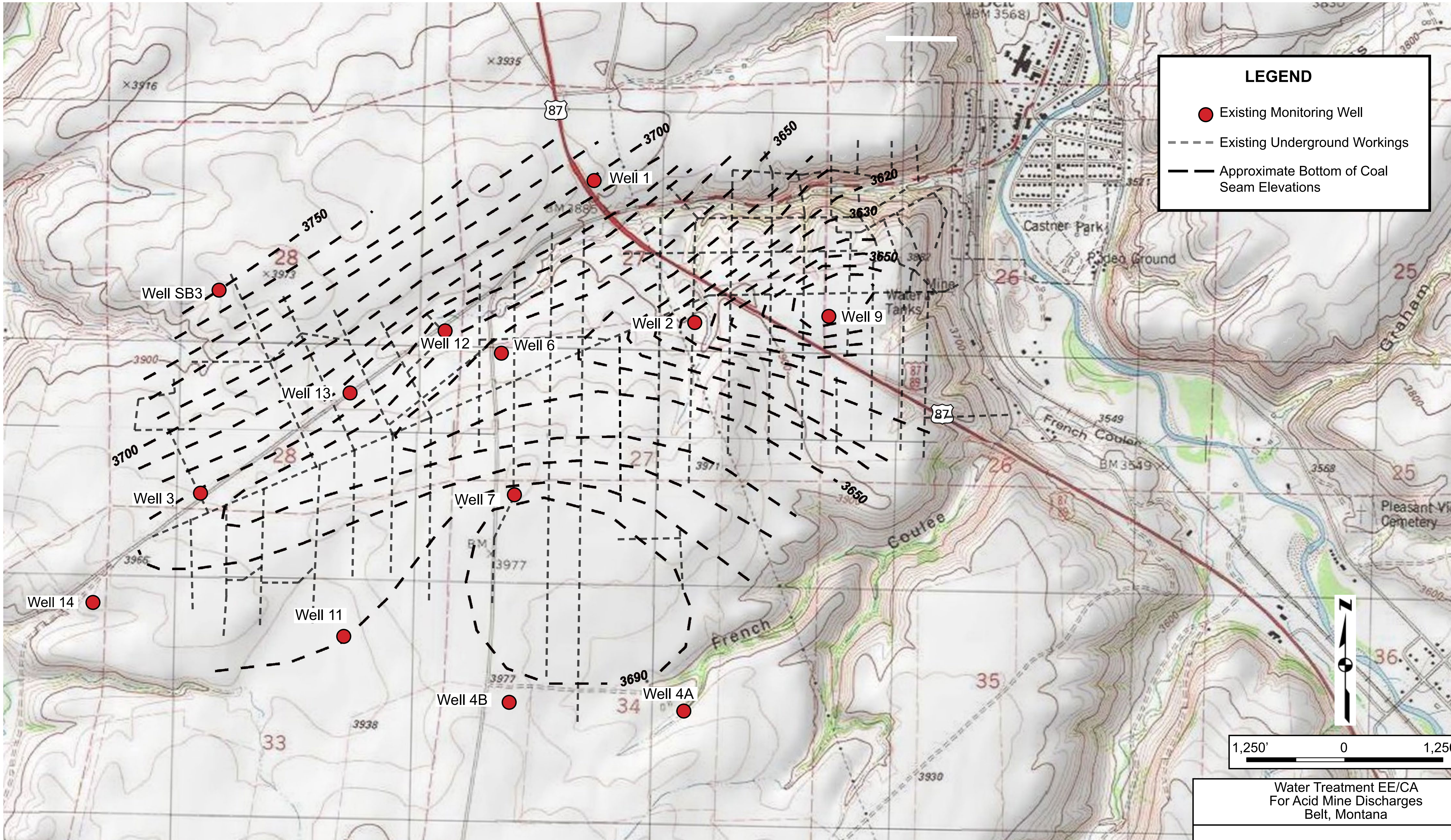
- Sludge should be deposited in flooded mine workings as a first option to allow solids to flow away from the injection well to lower the probability for plugging. Injecting sludge into dry workings is an acceptable alternative, but additional flush water may be required to flush solids away from the injection point.

- The injection well should be located so sludge can flow down-dip away from the well. The well should not be located at a low point in the mine pool. The dip direction in the Anaconda Mine is to the northeast.

- A minimum of two sludge injection wells are needed, one as a backup if the first should plug. Additional sludge injection wells should be planned for future installation. At least three locations for sludge injection should be identified at the design engineering phase of a treatment project.

- Exploratory drilling is needed to verify that sludge injection wells will enter mine voids. Where mine mapping is limited and the coal structure is not well-defined, the exploratory drilling program to locate injection wells will be more extensive. Use of downhole video and/or laser survey is recommended to determine the orientation of the workings and available void space.

- Property ownership is also a consideration in siting injection wells and wellheads, and sludge pipelines.



Water Treatment EE/CA
For Acid Mine Discharges
Belt, Montana

FIGURE 8-3

Coal Seam Elevations

TETRA TECH

8.7.1 Sludge Disposal Components

Preliminary sludge injection well locations were identified to estimate sludge storage volume capacity, the life of each injection well and the length of sludge pipelines. Figure 8-2 shows the location of four potential well locations. These locations were selected using the siting criteria described previously. The mine void space for each injection well is estimated based on the length of the main entries and the cross-sectional area of the mine entries. It is assumed that one main entry is available for sludge disposal in the set of sub-mains down dip of each injection well. This is a conservative estimate because it excludes cross-cuts and the entries alongside the main entry. The cross sectional area of the mine entry is based on an average seam height of 8 feet and assumed 12-foot width (average of the borings shown on Table 8-9) (as measured on the one available mine map). It is assumed that 50 percent of the volume is available for sludge disposal. The sludge generation rate, based on an average mine discharge flow rate of 154 gpm, is estimated to be approximately 20,000 gallons per day with a solids concentration of 5 percent by weight. The solids loading would thus be 1,050 pounds per day, or 0.53 tons/day. At a dry solids density of 80 pounds per cubic foot (lbs/ft^3), the volume of dry solids generated by the treatment system is estimated to be approximately 13 ft^3/day. The sludge storage volume for each of the sludge injection wells and the expected life of each well are summarized in Table 8-10.

TABLE 8-10
SLUDGE STORAGE CAPACITY

Injection Well	Cross-Sectional Area of Mine Entry (ft^2)	Total Length of Mine Entry (ft)	Total Volume of Mine Void in Main Entry (ft^3)	Available Storage Volume (50% of Void Space) (ft^3)	Estimated Injection Well Life (years)
IW-1	96	2,500	240,000	120,000	25
IW-2	96	2,500	240,000	120,000	25
IW-3	96	3,000	288,000	144,000	30
IW-4	96	3,000	288,000	144,000	30

Notes: % = percent, ft^3 = cubic feet,. ft^2 = square feet

Sludge waste generated from the treatment process would be pumped from the treatment plant by a positive displacement pump through a 4-inch diameter high density polyethylene (HDPE) buried pipe line connected to a sludge injection well. The sludge pump would have a 20 Hp motor and would operate at a rate of 100 gpm and 450 feet of total dynamic head.

Pipe line cleanouts would be spaced at intervals of 500 to 800 feet and access roadways would be needed for accessing the cleanouts. Figure 8-5 shows a proposed pipeline route from the MIW treatment plant to the farthest injection well, IW-4. Approximately 1 mile of pipeline would be constructed to wells IW-1 and IW-2 during the construction phase. The proposed pipeline route crosses under a railroad line and a road. Over the life of the MIW treatment plant, the pipeline would be extended to wells IW-3 and IW-4 as needed. The first ½ mile of pipeline would be constructed over state owned property and the remainder of the pipeline would be on private property. A permanent right-of-way agreement with the property owners would be required for the pipeline and the sludge injection wells. Alternative pipeline routes would be evaluated based on property ownership, and constructability concerns, such as topography, soil depth, and accessibility for maintenance.

Each sludge injection well would consist of an 8-inch Schedule 40 carbon steel casing grouted in a 12-inch borehole from the surface grade to the mine roof. A 12-inch surface casing would be installed through unconsolidated material from the surface grade to the top of solid rock, typically 20- to 30-foot depth. The pipe connection with a vent pipe will be housed in a pre-cast concrete pit. Figure 8-4 is a profile of a typical sludge injection well.

This estimated cost for installing four injection wells (Table 8-10) includes the cost of exploratory drilling (3 exploratory wells per injection well), mobilization and demobilization, construction of an access road, rotary air drilling, and installing a well casing pipe.

High Density Sludge

High density sludge is not ideal for underground disposal. The reasons why HDS is not recommended for underground disposal is:

1. It requires unnecessary capital costs for sludge concentrating equipment;
2. It has a higher potential for plugging the sludge injection pipelines and wells; and
3. HDS has less acid-neutralizing capacity than conventional sludge.

Based on these reasons conventional sludge is preferable for underground sludge disposal. Thus, underground sludge disposal was only evaluated in this document for the disposal of conventional sludge from single and two-stage hydrated lime treatment.

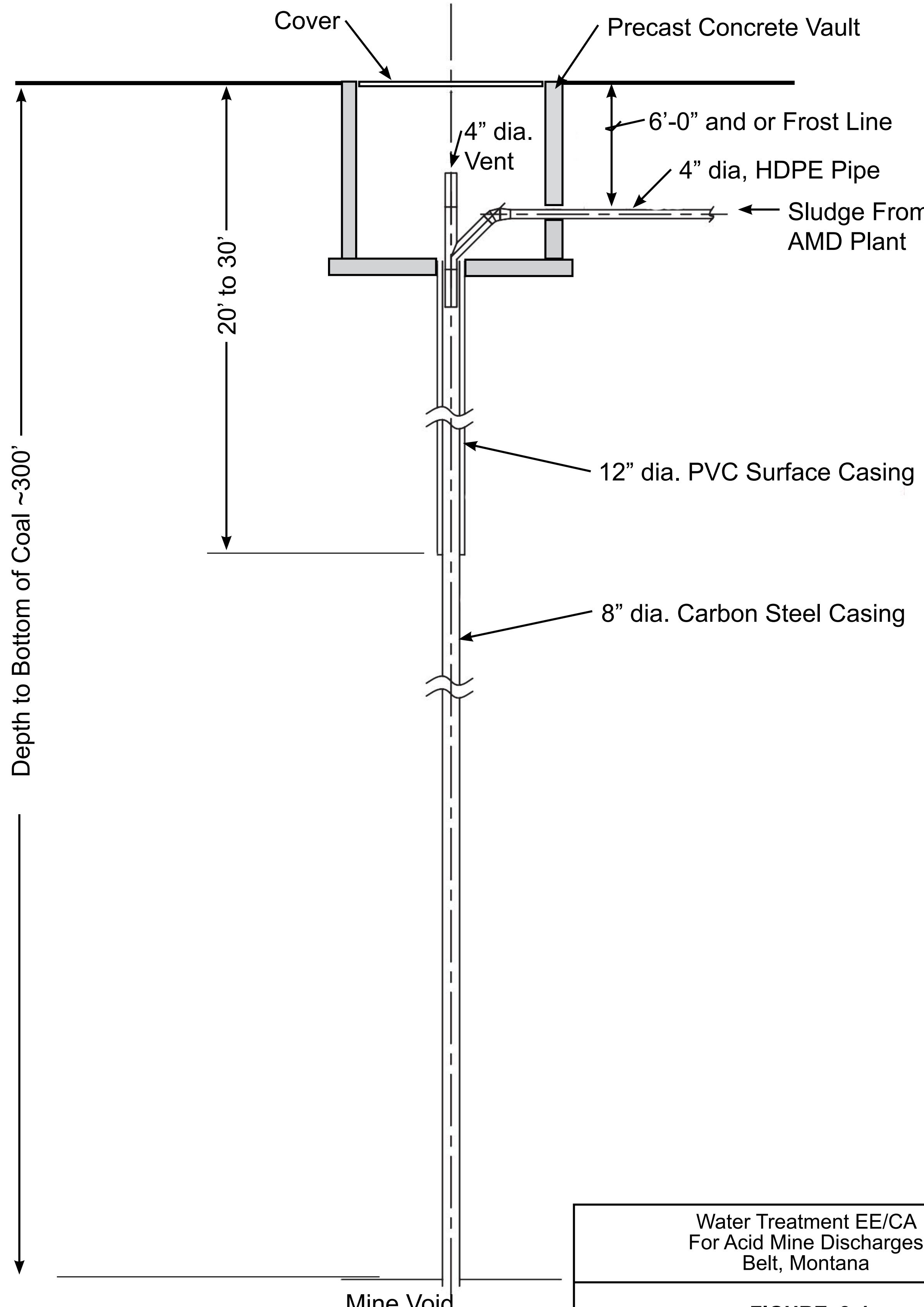


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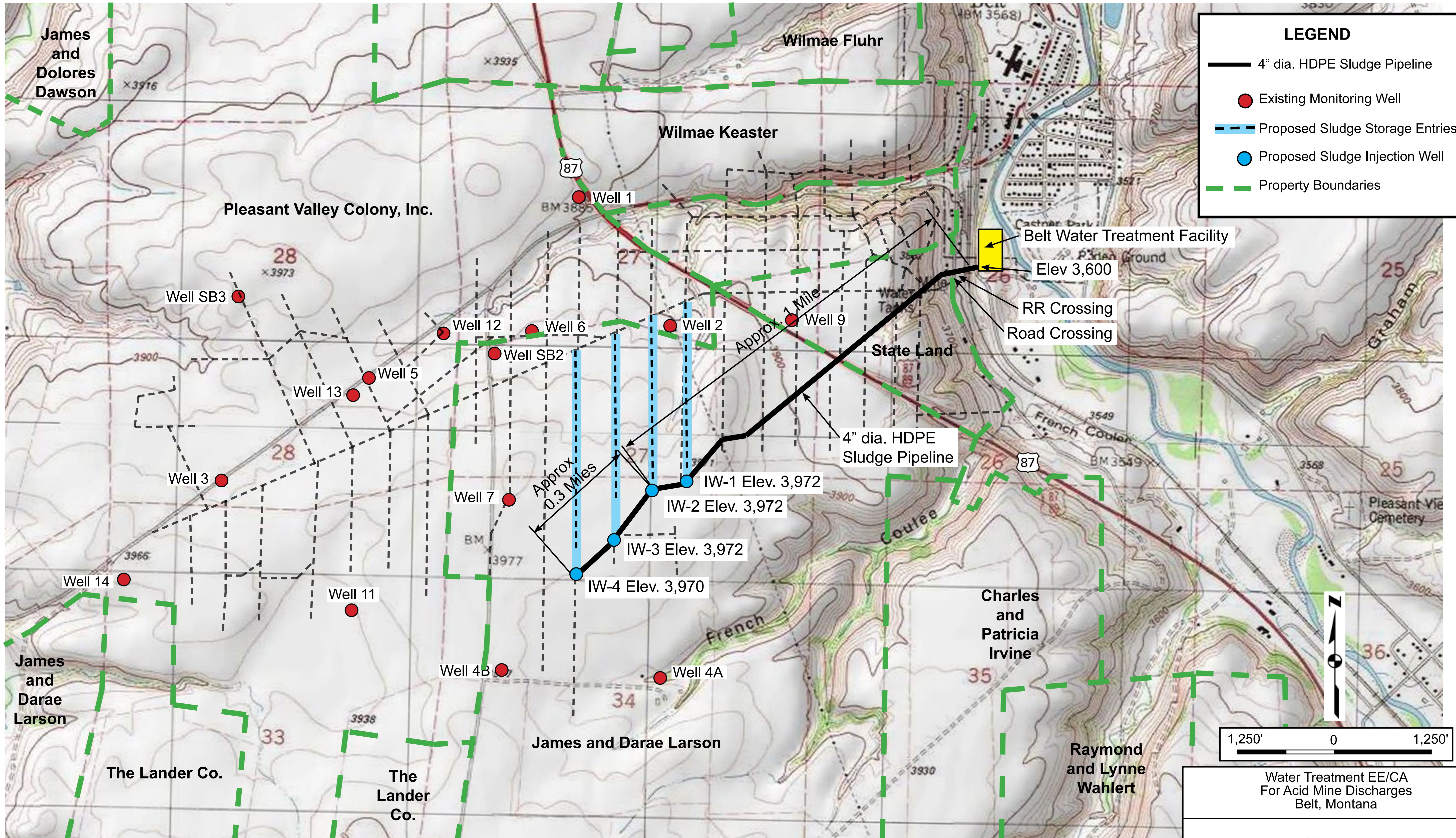
FIGURE 8-4
Sludge Injection Well Profile

TETRA TECH



Water Treatment EE/CA
For Acid Mine Discharges
Belt, Montana

FIGURE 8-5
Sludge Pipeline and Land Ownership

TETRA TECH

8.7.2 Effectiveness

Underground disposal is expected to be an effective means of disposing the sludge based on its use in other coal mining regions in the United States. This option is considered highly effective for the following reasons:

1. It has the potential to reduce or eliminate the volume of MIW draining from the mine by filling the workings with sludge.
2. It has the potential to increase the pH of the MIW inside the Anaconda Mine workings, decreasing the amount of hydrated lime (and associated capital costs) necessary to treat the MIW.
3. The acid neutralizing capacity of the sludge could also have a positive effect on groundwater in the vicinity of the Anaconda Mine workings. By neutralizing the MIW inside the mine, metals dissolved in the MIW would be precipitated before mobilizing to groundwater.
4. The sludge would be confined to a pipeline and pumped directly into the workings, so no loading or aboveground transportation of the sludge would be required except in cases of pipeline or pump failure.
5. It would not be exposed to surface receptors between quarterly covering events and would not be exposed to wind erosion.
6. It is projected to be the least expensive disposal alternative.

For these reasons, underground disposal of the sludge is expected to decrease the potential exposure of human and ecological receptors to the sludge. However, this alternative does have the potential to increase the amount of MIW discharging from the mine workings, and the potential additional volume should be taken into consideration when designing a treatment facility.

8.7.3 Implementability

This alternative is implementable. Construction of the sludge injection pipeline and wells is feasible with standard construction techniques and local supplies. Administratively, the alternative is feasible pending permission from private property owners to construct the pipeline across their land.

8.7.4 Cost

The net present value of the underground sludge disposal is estimated to cost $1.4M for both single-stage hydrated lime treatment and two-stage hydrated lime treatment. The detailed costs are shown in Table 8-11. Supporting cost estimate data is included in Appendix A. The installation capital costs are high for this alternative, but the long term operation and maintenance is lower than on-site disposal. Besides the installation capital costs and maintenance of the equipment, sludge injection significantly decreases treatment costs because it does not require filter press equipment and associated operation and maintenance. Filter press cost savings are estimated to be approximately $3.7M over the 100-year project life.

TABLE 8-11
UNDERGROUND DISPOSAL COSTS FOR CONVENTIONAL LIME TREATMENT

Cost Item	Quantity	Units	Unit Cost	Total Cost
Capital Costs				
Sludge Pumps	2	EA	$30,000.00	$60,000
Sludge Discharge Pipeline	1	EA	$248,000.00	$248,000
Sludge Injection Wells	4	EA	$86,375.00	$345,500
Subtotal Installation Costs				**$653,500**
Installation Contingencies	25% of Installation Cost			$163,375
EPCM	15% of Installation Costs			$98,025
Total Capital Costs				**$914,900**
Annual O&M Costs				**$14,000**
Operational Contingencies	20% of Annual O&M			$2,800.00
Total Annual O&M Costs				**$16,800**
Present Worth of Annual O&M Costs Based on 100 Year Life		PF Factor = 27.7		**$464,604**
Total Present Worth				**$1,379,504**

Notes: EPCM Engineering, Procurement, and Construction Management
EA Each
O&M Operation and Maintenance
PF Present Worth Factor

8.8 TREATMENT WASTE DISPOSAL ALTERNATIVE B: OFF-SITE SLUDGE DISPOSAL

Under this alternative, conventional sludge or HDS from single stage or two-stage hydrated lime treatment, or treated brine concentrate or crystalized brine waste from nanofiltration would be disposed of off-site at a permitted RCRA disposal facility. The sludge/waste would be loaded into haul trucks at the site and transported to High Plains Landfill north of Great Falls (70 miles from the site) or Schumaker's Class IV Landfill south of Great Falls (40 miles from the site). This disposal alternative is expected to meet all ARARs.

8.8.1 Disposal Components

Sludge/waste would be dried on-site until it could pass a paint-filter test. All sludge/waste would also require TCLP analysis for metals to be disposed of at a RCRA Subtitle D disposal facility. Sludge/waste that did not pass TCLP analysis would be treated on site with the necessary amount of hydrated lime to pass TCLP analysis. Dewatering and hydrated lime treatment equipment would be necessary for applicable treatments (these costs are included in the treatment costs). On-site loading equipment would be necessary to load the sludge/waste into haul trucks for transportation to the disposal facility. Cost items include loading costs, transportation costs, and landfill tipping fees.

8.8.2 Effectiveness

Off-site disposal is expected to be effective at preventing human and ecological receptor exposure to sludge or nanofiltration wastes. There are possibilities of accidental exposures during loading and transport. Exposure to human and ecological receptors is also possible via dermal exposure or inhalation during wind erosion when wastes are uncovered at the disposal facility. However, the disposal area would be fenced and the wastes would be covered quarterly by trained personnel so the exposure is expected to be minimal.

8.8.3 Cost

Off-Site sludge disposal costs are dependent on the amount of sludge or nanofiltration wastes produced. Off-site disposal is less expensive than the on-site disposal alternative for disposal of HDS from both single and two-stage hydrated lime treatment, and for disposal of waste from a nanofiltration brine concentrator. However, off-site disposal is more expensive than on-site disposal for the hydrated lime-treated nanofiltration brine. Off-site disposal costs are summarized in Table 8-12. Supporting cost estimating data is shown in Appendix A.

TABLE 8-12
DISPOSAL COSTS SUMMARY

Treatment Type	Disposal Type	Estimated 100-Year Sludge Disposal Cost
Lime Treatment (Single or Two Stage)	Off-Site	$1,631,700.00
	On-Site	$1,596,150.00
	Underground	$1,379,504.00
Lime Treatment with HDS (Single or Two Stage)	Off-Site	$1,126,755.00
	On-Site	$1,354,712.77
Nanofiltration with Brine Lime Treatment	Off-Site	$2,494,957.50
	On-Site	$1,911,440.05
Nanofiltration with Brine Concentrator	Off-Site	$748,487.25
	On-Site	$1,372,406.02

8.9 TREATMENT WASTE DISPOSAL ALTERNATIVE C: ON-SITE DISPOSAL

Under this alternative, sludge from hydrated lime treatment or nanofiltration wastes would be disposed of on-site at an 88-acre property owned by DEQ. The property has the capacity for more than 100 years of waste disposal for all treatment alternatives evaluated in this report.

8.9.1 Disposal Components

A waste disposal facility would be constructed on the property. The facility would either be permitted or meet all substantive permit requirements of an appropriate RCRA Subtitle D facility. The facility would consist of an unlined excavation into which the sludge or nanofiltration waste would be disposed. The facility would be excavated to a depth of approximately 15 feet (based on well-logs at the site). The facility would initially be constructed to contain the wastes produced for a year. Each year the facility would be expanded to accommodate the wastes for an additional year. It is assumed that the wastes would be track-compacted and covered with soil quarterly, although a permit may require these more frequently. No adverse impacts to groundwater from waste leaching are expected from lime treated waste, however treatment waste leaching potential should be evaluated in design.

As necessary, sludge or nanofiltration wastes would be loaded into a haul truck, transported to the disposal area and dumped into the excavation. This would require on-site loading equipment and a haul truck. Monthly, quarterly, and annual maintenance would require the use of a bulldozer or sheepsfoot to contour, track compact, and cover waste. An excavator and haul truck or a scraper would be necessary annually to excavate the next years' disposal cell.

8.9.2 Effectiveness

The goal of on-site disposal is expected to be effective at preventing human and ecological receptor exposure to the sludge or nanofiltration wastes. There are possibilities of accidental exposures during loading and transport. Exposure to human and ecological receptors is also possible via dermal exposure or inhalation during wind erosion when wastes are uncovered at the disposal facility. However, the wastes are covered quarterly by trained personnel and the exposure is expected to be minimal.

8.9.3 Cost

On-site disposal costs are dependent on sludge and waste amounts generated by MIW treatment. On-site disposal is only cost effective for very large amounts of waste. On-site disposal is only the least expensive alternative for disposal of hydrated lime-treated nanofiltration brine. On-Site disposal costs are summarized in Table 8-12. Supporting cost estimating data is shown in Appendix A.

9.0 COMPARATIVE ANALYSIS OF ALTERNATIVES

This section compares the treatment alternatives retained for detailed analysis for the MIW discharges in Belt. The comparison focuses on the effectiveness, implementability, and cost of each alternative. The following sections present the comparative analysis, a summary of analysis findings, and the recommended removal action alternative based on analysis findings.

9.1 COMPARATIVE ANALYSIS

The final step of an EE/CA is to conduct a comparative analysis of the removal action alternatives. The analysis will discuss each alternative's relative strengths and weaknesses with respect to each of the comparison criteria. Once completed, the analysis will be used to select the recommended removal action alternative(s).

The purpose of the analysis is to compare the relative effectiveness, implementability, and cost of the treatment alternatives in raising the pH and reducing the toxicity, mobility, and volume of dissolved metals in MIW at the five discharges in Belt. The effectiveness comparison will include consideration of the following criteria: (1) protectiveness of human health and the environment; (2) compliance with ARARs; (3) long-term effectiveness and permanence; (4) reduction of toxicity, mobility, and volume; (5) short-term effectiveness of each alternative; and (6) cost. The cost comparison will include consideration of the estimated total present worth cost of each alternative. The Comparative Analysis is summarized in Table 9-1. Costs are summarized in Table 9-2.

Supporting agency acceptance and community acceptance are additional criteria that will be addressed in the action memorandum after the state agency and the public review the evaluation process and the recommended removal action alternative.

TABLE 9-1
COMPARATIVE ANALYSIS OF ALTERNATIVES

Treatment Option	Protectiveness of Human Health and the Environment	Short-Term Effectiveness	Long-Term Effectiveness	Reduction of Toxicity, Mobility, and Volume	Implementable	ARAR Compliance	Cost
No Action	Not Protective	Not Effective	Not Effective	None	Yes	Not Compliant	No Cost
Water-Powered CaO Addition	Moderately Protective	Moderate	Moderate	Moderate	Yes	Not Compliant*	Low
Single Stage Lime Treatment	Highly Protective	Low	High**	High	Yes	Compliant**	Medium
Single Stage Lime Treatment with HDS	Highly Protective	Low	High**	High	Yes	Compliant**	Medium
Two Stage Lime Treatment	Highly Protective	Low	High	High	Yes	Compliant	Medium
Two Stage Lime Treatment with HDS	Highly Protective	Low	High	High	Yes	Compliant	Medium
Nanofiltration with Brine Concentrator	Highly Protective	Low	High	High	Yes	Compliant	High
Nanofiltration with Brine Treatment	Highly Protective	Low	High	High	Yes	Compliant	Medium
Sludge Disposal Option							
On-Site	Highly Protective	Moderate	Moderate	High	Yes	Compliant	Volume Dependent
Off-Site	Highly Protective	Moderate	Moderate	High	Yes	Compliant	Volume Dependent
Underground	Highly Protective	High	High	High	Yes	Compliant	Low

Notes:
HDS High Density Sludge
*Uncertainty due to lack of pilot testing
**Assumed meet DEQ-7 SW standards with zeolite treatment

TABLE 9-2
COST SUMMARY

Alt. No.	Treatment Type	Treatment Cost	Sludge Disposal Option	Estimated 100-Year Sludge Disposal Cost	Total Estimated 100-Year Treatment Cost with Disposal
1	No Action	**$ -**	**none**	**$ -**	**$ -**
2	Water-Powered Calcium Oxide Addition	$7,252,688	On-Site	$1,470,000	$7,252,688
			Off-Site	$1,803,127	$7,617,400
3A	Single Stage Lime Treatment (No Filter Press)	$19,528,398	Off-Site	$1,631,700	$21,160,098
			On-Site	$1,596,150	$21,124,548
			Underground	$1,379,504	$20,907,902
3B	Single Stage Lime Treatment	$23,232,663	Off-Site	$1,631,700	$24,864,363
			On-Site	$1,596,150	$24,828,813
			Underground	$1,379,504	$24,612,167
4	Single Stage Lime Treatment with High Density Sludge	$22,622,598	Off-Site	$1,126,755	$23,749,353
			On-Site	$1,354,713	$23,977,311
5A	Two Stage Lime Treatment (No Filter Press)	$23,035,136	Off-Site	$1,631,700	$24,666,836
			On-Site	$1,596,150	$24,631,286
			Underground	$1,379,504	$24,414,640
5B	Two Stage Lime Treatment with Filter Press	$26,739,396	Off-Site	$1,631,700	$28,371,096
			On-Site	$1,596,150	$28,335,546
			Underground	$1,379,504	$28,118,900
6	Two Stage Lime Treatment with High Density Sludge with Filter Press	$25,979,981	Off-Site	$1,126,755	$27,106,736
			On-Site	$1,354,713	$27,334,694
7	Nanofiltration with Brine Concentrator	$252,466,411	Off-Site	$748,487	$253,214,899
			On-Site	$1,372,406	$253,838,817
8	Nanofiltration with Brine Treatment	$31,349,817	Off-Site	$2,494,958	$33,844,774
			On-Site	$1,911,440	$33,261,257

9.2 SUMMARY OF FINDINGS

Baseline conditions at Belt as represented by Alternative 1, the No Action alternative, would allow continued flow of metals in MIW to the environment and therefore is not protective of human health and the environment.

All alternatives would raise the pH and reduce metals concentrations in MIW and would reduce human and ecological risk in Belt Creek by treating contaminated MIW from the five discharges. Alternative 2 would raise the pH and reduce the concentrations of metals in MIW and would reduce human and ecological risk by treating MIW from the two largest discharges at the site. However, it is not expected to achieve DEQ-7 water quality standards and is therefore not as effective as the active treatment alternatives. Alternatives 3, 4, 5, and 6 are considered more protective of human health and ecological receptors than Alternative 2 because they treat all five MIW discharges at the site and are all expected to meet DEQ-7 water quality standards. Of the disposal alternatives on-site and off-site each reduces human and ecological risk associated with exposure to the sludge produced from active treatment. However, underground disposal is considered the most effective because it will completely prevent human and ecological receptor exposure during all phases of disposal, where on-site and off-site disposal have potential for exposure during handling and disposal.

Alternatives 1and 2 would not comply with ARARs. Alternatives 3, 4, 5, and 6 would comply with ARARs by raising pH and reducing metals concentration in MIW through chemical precipitation and stabilization to eliminate contact with potential receptors. All disposal options would comply with ARARs.

Alternative 1, No Action, is not considered to have long-term effectiveness. All other alternatives would continue to treat MIW for metals and adjust pH indefinitely as long as the system components are adequately maintained. For all treatment alternatives the MIW transport and holding components would require periodic maintenance and clearing of debris to ensure proper flow. All disposal alternatives are considered to have long-term effectiveness.

Alternative 1 would not reduce or alter the volume, toxicity or mobility of metals in MIW, and therefore, is not considered to have long-term effectiveness. Alternative 2 would effectively raise the pH which would reduce the volume of MIW entering Belt Creek. It would also precipitate metals from the MIW in the form of metal oxides in a sludge, which would reduce the toxicity, mobility of the metals, but not to the degree of active treatment. Alternatives 3, 4, 5, and 6 would effectively raise the pH of the MIW reducing the concentration of metals entering Belt Creek and they would chemically precipitate metals from MIW more effectively and efficiently than Alternative 2. These alternatives are highly effective at reducing toxicity, mobility, and volume of the MIW at the site.

For disposal, on-site and off-site disposal are the most effective at reducing mobility because the sludge will be contained at a disposal facility, where underground disposal does not have clearly defined disposal areas within the mine workings. However, underground disposal is the only disposal alternative expected to reduce the toxicity in situ because it has the potential to increase the pH of the MIW inside the mine workings and precipitate metals prior to discharge from the mine workings. Underground disposal is also expected to be the most cost effective disposal alternative over the projected lifetime of the treatment plant.

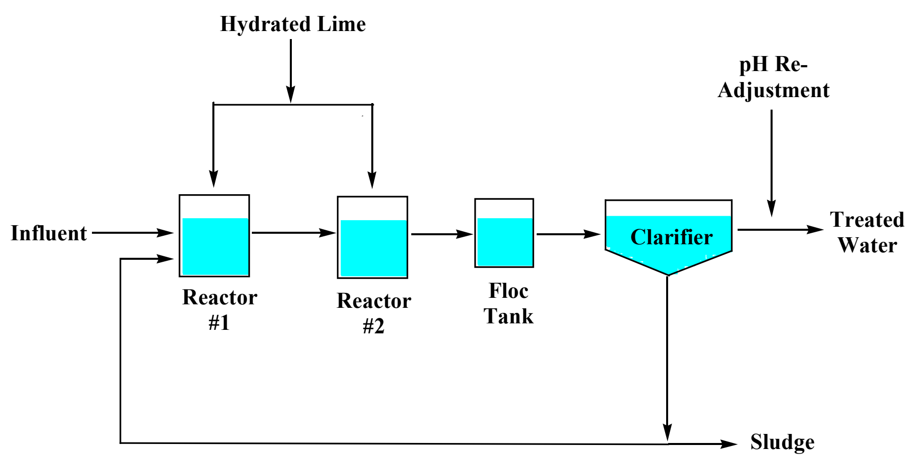
Alternative 1 is not considered to be effective in the short-term because it maintains the current site conditions. Alternative 2 is considered to have short-term effectiveness because it would be implemented in one field season. There are qualified contractors capable of accomplishing the construction and equipment and materials are commercially available for implementation. Short-term effects of construction would be minimized through application of water to construction surfaces and employment of adequate storm-water control measures at the treatment areas. There would be increased heavy traffic in the local area; however, appropriate traffic control would be used to minimize these effects. Alternatives 3, 4, 5, and 6 are expected to have low effectiveness in the short-term because the investigation for, and the design and construction of an active treatment plant could take several years. There are qualified contractors capable of accomplishing the construction and equipment and materials are commercially available for implementation. Short-term effects of construction would be minimized through dust suppression and employment of adequate storm-water control measures at the treatment areas. There would be increased heavy traffic in the local area; however, appropriate traffic control would be used to minimize these effects.

The costs of each treatment with the respective disposal option is shown in Table 9-2. Alternative 1 is the least expensive alternative as there is no cost incurred. For conventional sludge disposal, on-site disposal is the least expensive alternative for hydrated lime treatment (although the difference between underground and on-site disposal is not significant for a 100-year estimate). For nanofiltration with a brine concentrator, off-site disposal is the least expensive alternative. For nanofiltration with hydrated lime treatment of brine, on-site disposal is the least expensive. In compliance with the NCP feasibility study criteria these engineering costs are estimates that are expected to be within plus 50 percent to minus 30 percent of the actual project cost (based on year 2014 dollars). Changes in the cost elements are likely to occur as a result of new information and data collected during engineering design.

10.0 PREFERRED ALTERNATIVE IDENTIFICATION

The preferred treatment alternative is Alternative 3; single stage conventional lime treatment with pH readjustment. However, it is recommended that the configuration of the treatment train and the type of treatment (conventional or HDS) should be determined by the removal efficiencies determined during bench-scale testing. The alternative shown below is recommended based on the data available. The proposed sludge disposal method is Alternative A; underground disposal. The following section discusses the rationale for the selection of these alternatives.

Conventional lime treatment is selected because it is a reliable technology that meets the threshold criteria and is the most cost effective means of meeting ARARs. The process flow diagram for the preferred alternative, single-stage conventional hydrated lime treatment process, is presented below.



Process Flow Diagram 10-1: Preferred Alternative: Single-stage conventional hydrated lime treatment process depicting major equipment

As with Alternative 3 depicted in Section 8.3.1.2, in this preferred alternative, MIW and hydrated lime and small amounts of recycled sludge are added together into Reactor Tank #1 for pH control. Sludge is pumped to the front of the process into Reactor Tank #1 to reduce the influence of variable influent water conditions, increase sludge density, and improve settling characteristics in the clarifier. Reactor Tank #1 gravity flows to Reactor Tank #2 for additional retention time to provide sufficient reaction time. Having two reactors would also allow for bypassing a reactor for cleaning without shutting down the whole WTP, and hydrated lime can also be added to Reactor Tank #2. Air diffusers will be installed in Reactor Tanks #1 & 2 to promote complete oxidation of incoming metals for precipitation, especially for oxidizing iron(II) to iron(III) because iron(III) hydroxide precipitation occurs at a lower pH than iron(II) hydroxide precipitation, and the formation if iron(III) hydroxide removes iron from solution much better than the formation of iron(II) hydroxide. Aeration to oxidize iron(II) to iron(III) would improve treatment effectiveness because it would lead to better iron removal compared to not oxidizing iron(II). Additionally, because aeration is safer and more economical than other oxidants such as chlorine, permanganate, or ozone, and the oxygen in air is both thermodynamically and kinetically effective for oxidizing iron in water treatment processes, no other oxidants have been evaluated for this EE/CA. Reactor Tank #2 then overflows either into a Flocculation Tank or to a Clarifier with a flocculating feed well. All process equipment, including the clarifier, will be indoors.

The major difference between the preferred alternative and Alternative 3 presented in Section 8.3.1.2 is that the preferred alternative does not have polishing multimedia and zeolite filters downstream of the hydrated lime treatment process. It is recommended that further bench-scale testing be conducted to determine the levels of COC removal efficiencies that are expected with the preferred alternative treatment process. And a WTP to treat the MIW at Belt can be designed which allows for addition of polishing filters and zeolite media in the future, if necessary, after the WTP has run for a certain period to verify COC removal efficiencies at full-scale treatment capacity. It is also recommended that the existing wetlands at Belt be evaluated for use as polishing ponds to direct the effluent from the WTP for removing precipitated aluminum and for removing other metals. For further bench-scale testing investigations, although the preferred alternative is for non-HDS hydrated lime treatment, it is recommended that both non-HDS and HDS hydrated lime treatment be tested to determine differences in the removal efficiencies of trace metals removal between the two processes. The bench-scale testing should also include tests to estimate hydrated lime dosages, evaluate reaction times, and estimate the quantities of sludge that would be generated.

For sludge disposal, it is recommended that the sludge be reinjected for underground disposal to avoid both the capital and operating costs associated with sludge management equipment such as belt filter presses. Underground disposal is selected as the preferred alternative based primarily on cost. It is estimated to be the cheapest alternative at current market disposal prices (which will increase over time) and it offers substantial cost savings in treatment because it does not require filter press equipment and associated maintenance. In addition to equipment and maintenance cost savings, it may decrease lime consumption of the treatment plant over time by raising the pH of the water inside the Anaconda Mine workings. This could also result in cost savings. The feasibility of underground injection should be further evaluated by exploring the underground workings using sonic and/or visual methods.

11.0 AFFECTED ENVIRONMENT AND ENVIRONMENTAL CONSEQUENCES

This section addresses the potential impacts to physical and human environment resources for the Proposed Action to construct and operate a water treatment plant at Coke Oven Flats in Belt, Montana. The preferred water treatment alternative (Single-Stage Hydrated Lime Treatment) has been identified in this report, but not all specific details about the water treatment plant are known because construction-level details are not typically contained in an EE/CA or EA. Sludge will be generated from any of the water treatment alternatives evaluated in this EE/CA and will require proper disposal. However, the selection of the most effective, implementable, and cost appropriate sludge disposal alternative has not been finalized. The estimated daily wet-sludge volume would be approximately 20,000 gallons (at 5 percent sludge by weight) or the equivalent of about 1,050 pounds per day of dry-sludge solids. Because sludge would be generated by all action alternatives, sludge disposal alternatives were considered in the EE/CA and EA and evaluated in detail.

This EE/CA and EA also includes a conceptual analysis of wind-powered electricity generated from a turbine constructed on DEQ-owned property located on the terrace west of Coke Oven Flats. The wind-power analysis included a preliminary conceptual design for the site, a selection of a suitable wind turbine, and an estimated cost/benefit. No on-site studies or investigations were completed as part of the wind-power analysis. Similarly, there was no detailed analysis of potential environmental impacts to soils, vegetation, wildlife, birds and bats, noise, aesthetics, and other possible impacted resources because a wind-powered electricity generation was only considered but could be dismissed, and not require a detailed evaluation.

Table 11-1 provides a summary of the potential impact ratings for physical and human environmental resource areas along with brief descriptions of the potential resource impacts from the no action and proposed action alternatives.

TABLE 11-1
POTENTIAL ENVIRONMENTAL IMPACT RATING AND DESCRIPTION
FOR PHYSICAL AND HUMAN ENVIRONMENTAL RESOURCE AREAS

Resource Area	**Major**	**Moderate**	**Minor**	**None**	**Potential Resource Impact Description**
Physical Environmental Resources					
Terrestrial & Aquatic Life & Habitats			X		No Action would continue to impact terrestrial and aquatic life and habitats in French Coulee, Coke Oven Flats, and Belt Creek. The Proposed Action (during construction) would have minor impacts on terrestrial life but there is minimal habitat in Coke Oven Flats. The proposed water treatment plant would have long-term beneficial impacts on these resource areas.
Water Quality, Quantity, & Distribution	X (Beneficial)				No Action would continue to impact Belt Creek water quality. The proposed water treatment plant would have long-term beneficial impacts on these resource areas.
Geology & Soil Quality, Stability, & Moisture			X		No Action would continue to have minor impacts to soil quality and shallow groundwater in French Coulee and Coke Oven Flats. During construction, the Proposed Action would have minor impacts on soil stability. The proposed water treatment plant would have a long-term benefit to shallow groundwater by eliminating the flow of metal-contaminated surface water in Flat Creek.
Vegetation Cover, Quantity, & Quality			X		The No Action would have no impact to vegetation. The Proposed Action would slightly reduce the amount of vegetation in Coke Oven Flats with the building of the water treatment plant. Some areas disturbed during construction of the treatment plant site and pipelines would have temporary loss of vegetation but would be reseeded after construction.

TABLE 11-1
POTENTIAL ENVIRONMENTAL IMPACT RATING AND DESCRIPTION
FOR PHYSICAL AND HUMAN ENVIRONMENTAL RESOURCE AREAS

Resource Area	Major	Moderate	Minor	None	Potential Resource Impact Description
Aesthetics & Noise			X		The No Action would have no impact on aesthetics and noise. Current visual conditions reveal precipitated iron sludge from the mine drainage in Flat Creek, cascading into Belt Creek, and as slimy sludge in Belt Creek. During construction of the Proposed Action, there would be short-term increased noise. During operations, the Proposed Action would create minor audible noise from the Treatment Plant and the plant would be visible in the local area. The Proposed Action would result in beneficial improvements to the local area aesthetics by reducing the visible red and orange iron precipitates in Flat Creek and Belt Creek.
Air Quality			X		The No Action would have no impact on air quality. During construction of the Proposed Action, there would be minor impacts to air quality from construction equipment exhaust and potential fugitive dust emissions. Impacts could be mitigated to some extent through use of water spray to control dust and discontinuing major soil disturbing construction activities on very windy days. Long-term impacts to air quality from the Proposed Action would be from minor increases in exhausts from pumps and motors associated with the water treatment plant operations.
Unique, Endangered, Fragile, or Limited Environmental Resources				X	There would be no impacts to this resource area from either alternative.
Demands on Environmental Resources of Land, Water, Air, & Energy			X		The No Action would have no additional demands of Environmental Resources but would have a continued adverse impact on the flow of water across Coke Oven Flats and into Belt Creek. The Proposed Action would require the dedicated use of land for the water treatment plant. The Proposed Action would provide a new beneficial impact to water by providing good water for discharge to Belt Creek. There would be a minor increased demand for electricity and gas to power and heat the water treatment plant.

TABLE 11-1
POTENTIAL ENVIRONMENTAL IMPACT RATING AND DESCRIPTION
FOR PHYSICAL AND HUMAN ENVIRONMENTAL RESOURCE AREAS

Resource Area	Major	Moderate	Minor	None	Potential Resource Impact Description
Historical & Archaeological Sites				X	There would be no impacts to this resource area from either alternative.
Human Environmental Resources					
Social Structures & Mores				X	There would be no impacts to this resource area from either alternative.
Cultural Uniqueness & Diversity				X	There would be no impacts to this resource area from either alternative.
Local & State Tax Base & Tax Revenue			X		There would be no change or impacts to this resource area from the No Action. The Proposed Action (during construction) would provide short-term minor benefits to the local and state tax base and tax revenue by providing local jobs, wages and services associated with the construction activities. Long-term benefits to this resource area from operations of the plant would be minor but beneficial.
Agricultural or Industrial Production			X		There would be no impacts to this resource area from the No Action alternative. The Proposed Action would not impact industrial production in the Belt area. There could have a minor impact on the production of grass and alfalfa in the field above Coke Oven Flats if the area is used for sludge disposal or a wind-turbine is located in the field. However, if the treatment plant sludge is injected back into the underground mine workings and a wind-turbine not constructed for this project, there would be no impacts to agricultural production.
Human Health			X		The Proposed Action (during construction) could expose workers to unsafe conditions. During long-term operations of the water treatment plant, there would be minor increased risks to human health from exposures to mechanical and electrical equipment and to chemicals and waste products used for water treatment.to chemicals and waste products used for water treatment.

TABLE 11-1
POTENTIAL ENVIRONMENTAL IMPACT RATING AND DESCRIPTION
FOR PHYSICAL AND HUMAN ENVIRONMENTAL RESOURCE AREAS

Resource Area	Major	Moderate	Minor	None	Potential Resource Impact Description
Quantity & Distribution of Community & Personal Income			X		The Proposed Action (during construction) would provide short-term benefits by providing local jobs, wages, and construction services. Long-term minor benefits to the community and personal income would be from staff operating the water treatment plant and the purchase of chemicals and services.
Access to & Quality of Recreational & Wilderness Activities				X	There would be no impacts to this resource area from either alternative.
Quantity & Distribution of Employment			X		The Proposed Action (during construction) would provide multiple local construction jobs. The Proposed Action would require one to two full-time treatment plant operators (depends on plant complexity and automation).
Distribution & Density of Population & Housing				X	There would be no impacts to this resource area from either alternative.
Demands for Government Services			X		The Proposed Action would have a very minor beneficial impact on demand for government services. The treatment plant operator(s) may be State or contracted employee, and DEQ would need to provide some additional service to manage the site operations.
Industrial & Commercial Activity			X		The Proposed Action would have a very minor beneficial impact on activity in the Belt community by providing one or two jobs whose employees would contribute to local purchases and spending.
Demands for Energy			X		The No Action would have no additional demands for energy. The Proposed Action would result in an increased demand for electricity and gas to operate the treatment plant. The annual power consumption for the water treatment plant would be approximately 316,500 kWh. Annual energy costs at $0.08/kWh would be approximately $25,320. There would be an additional cost for gas to heat the water treatment plant building.

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APPENDIX A

COST SUPPORTING BACKUP

(Provided Electronically Only)