

NELSON TUNNEL
WATER MANAGEMENT FEASIBILITY STUDY
for the
WILLOW CREEK RECLAMATION COMMITTEE
CREEDE, COLORADO

January 24, 2006

The Willow Creek Reclamation Committee
c/o Kelley Thompson
PO Box 518
Creede, Colorado 81130

**RE: Letter of Transmittal/Summary
Nelson Tunnel Feasibility Study**

Committee Members:

Submitted attached is the Water Management Feasibility Study for overflow waters emanating from the Nelson Tunnel. The Nelson Tunnel flow is acid mine drainage – and is “responsible” for about 75% of the heavy metals contaminants in Willow Creek.

The study develops an optimum treatment system for this water, with estimates of capital and operating costs. A chemical precipitation process plant, located either near the Creede City Hall or the municipal wastewater treatment plant is recommended.

To partially offset the costs of treatment, the feasibility of using the water to generate hydropower and of using the inherent water inherent water temperature to recover heat was also evaluated. Although not necessary to finance/construct at the same time, both electrical generation and heat recovery are recommended. Present, and rising, energy costs will make these additions economically justifiable.


The recommended budget for the treatment facility, intake, and connecting pipeline is \$2,009,750.

The alternate of using the heat and energy to activate the fish hatching was found to be too expensive, primarily because of the capital requirements for the long transmission pipeline. We were impressed with the physical condition of the fish hatchery facilities, and believe that a local (deep) alluvial well probably would result in a less costly water supply.

We will be available to review the study with you.

Respectfully submitted,
McLaughlin Rincón, Ltd.


Ronald C. McLaughlin, P.E. & L.S.


Ronald J. McLaughlin, P.E.

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DRAWING. Location Map (at back of report)

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I. INTRODUCTION

BACKGROUND

The Nelson Tunnel collects water from a vast network of abandoned mine works north of the City of Creede, Colorado. The tunnel entrance is located on West Willow Creek, about 1.5 miles north of town. The collected water, approximately 200 gallons per minute, contains significant heavy metal contamination. Due to this contamination, Willow Creek cannot support a fishery and is detrimental to the valuable fishery in the Rio Grande River.

It has been estimated that the Nelson Tunnel discharge alone is responsible for 75% of the total inorganics (heavy metals) contamination in Willow Creek below the tunnel discharge. Since this single point source is responsible for such a large fraction of the contamination, the Willow Creek Reclamation Committee wishes to investigate the feasibility of capturing and treating this water – as well as the potential benefits and uses for the treated water.

SCOPE OF STUDY

The report will evaluate 3 proposals/goals and recommend a plan for implementation. These are:

- 1. Treatment of Nelson Tunnel Discharge.** While there a number of possible processes which could be used to treat the discharge from the Nelson Tunnel; e.g. Chemical, Electrical or Biological precipitation followed by separation has been identified as most likely feasible. Three precipitation methods will be evaluated and comparative preliminary cost estimates prepared. Potential sites for the treatment plant are at the tunnel adit, north edge of town, the Waste Water Treatment Plant site or the Fish Hatchery located south of town.
- 2. Recovery of Energy- Hydroelectric.** Once the discharge has been captured in a pipe and conveyed to a discharge point a potential to capture energy, as electricity, will exist. The available energy will depend on the elevation and location of the treatment site and discharge point. This energy could be used to offset power required for treatment, offset power required for municipal buildings

or sold to the electric utility. The value of this power will be used in the evaluation of possible plans.

3. **Recovery of Energy-Heat.** The temperature of the Nelson Tunnel discharge is fairly warm all year, approximately 57 to 63 degrees F during winter months. There are two potential uses for the heat contained in the discharge. The Town leases a fish hatchery from the State of Colorado. The hatchery is not presently in use due to inefficiency resulting from the lack of a warm water source, necessary for growth of fry. If the Nelson Tunnel discharge were sufficiently treated, the warm water could be used as the water supply for the hatchery. Alternatively, heat recovery, using water to air heat pumps, could be used to offset the cost of power used to heat municipal (or other) buildings.

4. **System Alternatives.** System design involves integrating the above proposals. Pipeline length and routing depends on selected facility location. Preliminary analyses indicated the practicality of evaluating alternate treatment plant sites:
 - a. Nelson Tunnel. (Although this would involve minimal pipeline costs, it was determined that winter access problems preclude the use of this site.)

 - b. Canyon. This site is north of Creede, near the canyon mouth.

 - c. North end of Creede. This site would be convenient for operations (near present City shops). Also, the demand for heat and electrical energy exists in this area.

 - d. Creede Wastewater Plant Site. The new facilities could be operated in conjunction with the municipal plant. There is a significant demand for electrical energy here.

 - e. Fish Hatchery. Demand for water, heat energy, and some electrical power here.

II. WATER TREATMENT

DESIGN CRITERIA

The Nelson Tunnel discharge has been sampled for quality and quantity numerous times between September 1999 and November 2002 by the Willow Creek Reclamation Committee. The results of this study were published in 2004 by the Committee. Tables 12 and 13, relating to the Nelson Tunnel, are attached to this report as Appendices A. For purposes of this report, the flow rate to be treated is assumed to be a maximum of 250 gpm (360,000 gpd), and the facilities designed to accommodate a possible expansion to 500 gpm.

The flow rates and water quality of the Tunnel discharge vary significantly. For estimation purposes the water quality will be assumed to be as listed in the following table (Major constituents, dissolved):

TABLE II-A
DESIGN RAW WATER CONTAMINANTS
(See Appendix A)

<u>Constituent</u>	<u>Concentration mg/l</u> <u>Dissolved</u>	<u>Load, lbs/day at</u> <u>250 gpm</u>	<u>TVS ug/l, from 2004</u> <u>Report, for</u> <u>Reference Only</u>
Calcium	250	750	
Magnesium	30	90	1.84
Cadmium	.5	1.5	7.12
Copper	.2	.6	
Iron	.2	.6	
Manganese	15	45	
Lead	1	3	1.88
Zinc	80	240	93.9
Aluminum	1.5	4.5	87.0

*These values are assumed to be yearly averages for operating cost estimation; however, the treatment system will be designed to be capable of treatment the constituents at the maximum levels anticipated.

TREATMENT OPTIONS

Biological Reduction

Biological treatment relies on the ability of microorganisms and plants to reduce sulfate to sulfide. The resulting sulfide combines with dissolved metals to form insoluble precipitates which then settle or are removed. Removal by plant uptake of metals is minor and not considered a factor.

This treatment is accomplished using constructed wetlands, ponds or flow through an organic media. These facilities may be combined with limestone pretreatment using beds or channels, for pH adjustment.

The results reported for this type of treatment are not consistent and highly variable. Most reports are from pilot studies with no data from long term full scale projects available. Area requirements are not well established, but loading rates for wetland have been reported at ½ acre per 1 gallon per minute. Since the rate of biological reactions is significantly affected by temperature and climate, it would be expected that area requirements at Creede would be greater than most reported conditions.

The successful pilot studies generally are treating water with much lower concentrations (where 50 to 75% removal is all that is required) of metals than the Nelson Tunnel discharge. In water with higher concentrations of metal, biological treatment has been suggested for pretreatment prior to mechanical/chemical treatment.

Long term success for biological treatment is doubtful for the Nelson Tunnel discharge due to the area required, temperature and metals loading. The zinc alone would produce 130,000 pounds per year of Zinc Sulfide (dry) sludge that would be retained in the treatment system. Ultimately this material would have to be removed, dried, stabilized and disposed of. Since it would not be practical to enclose a wetlands treatment system in a building, it is likely freezing would be a possibility and that biological reaction rate would be nearly zero. The beneficial use of effluent using heat recovery would also be eliminated.

Chemical/Physical Treatment

This treatment method consists of the addition of chemicals to react with dissolved metals, in a reactor vessel, to form a solid precipitate. This is followed by a solid/liquid separation process that produces a clarified effluent and a sludge waste. The effluent is typically pH adjusted and discharged. The sludge is dewatered, stabilized (if necessary) and disposed of. Disposal options may consist of municipal landfill or dedicated cell.

There are two basic reactions typically used to convert dissolved metals to a solid form, sulfide and hydroxide. In the first, sulfide ions are added, usually using a liquid Sodium sulfide solution or Hydrogen sulfide gas. The resulting reaction produces insoluble metal sulfides. The advantage of sulfide addition is that very low effluent concentrations, independent of pH, of dissolved metals are achievable. Sulfide precipitation is not commonly used because of the high chemical cost, precise dosing requirements, and potential for odor.

The far more common reaction used in the industry is the hydroxide addition method. The chemicals used are lime, caustic soda and soda ash. In some cases these may be used in combinations with each other. With the addition of hydroxide ions, metal hydroxide solids are formed. Lime is generally used in larger plants and with higher levels of dissolved metals due to the low relative cost. Lime is the most difficult of the commonly used chemicals to handle and feed to the raw water. Very large users may buy lime as Calcium oxide and prepare a slurry using slaking equipment. Since this is labor intensive, most plants purchase dry slaked lime.

Caustic soda is normally sold as a liquid solution. While it is a hazardous chemical, it is relatively easy to handle and feed. The scale formation and clogging associated with lime addition do not occur with caustic soda. The disadvantages of caustic soda are cost and the high water content of sludge produced. Caustic soda is a by product of Chlorine gas production. The cost varies with Chlorine demand, but averages about twice the cost of lime for an equivalent dose. As the demand for Chlorine for disinfection of drinking and wastewater decreases, it is expected that the cost for caustic soda will increase.

The sludge solids produced using caustic soda contain more water and therefore are greater in volume, requiring larger capacity dewatering equipment.

The Argo Tunnel plant, near Idaho Springs, was originally designed for caustic soda use. The plant is currently being converted to use lime as the primary chemical.

Soda ash can be used in some cases as a primary chemical, but is more likely to be used in combination with lime to produce solids that are more easily separated resulting in a clearer effluent, reduced sludge volume and sludge characteristics allowing dewatering to a solids content of 40-50% without heating. One process that uses this combination is the Heavy Metals Removal (HMR) process.

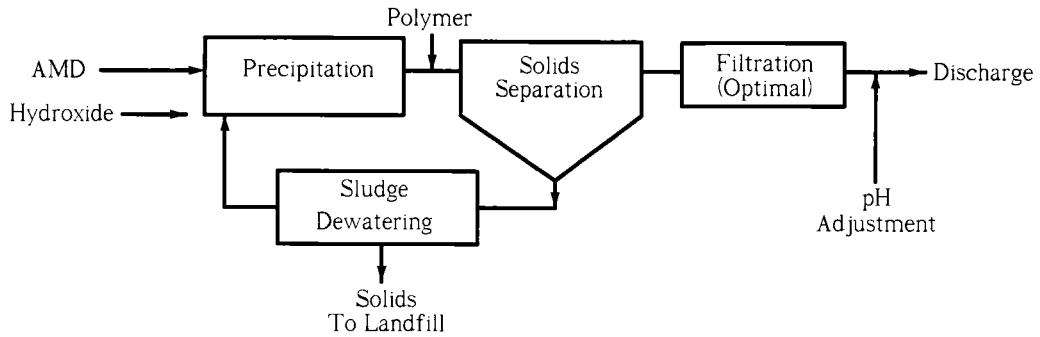
Sludge solids from the clarification process may be recycled to the plant influent to produce sludge that will settle and dewater better. This is referred to as a High Density Sludge (HDS) process. Schematic drawings of typical hydroxide removal processes are shown in Figure II-B.

After the reaction is completed, the formed solids and water are separated. A gravity clarifier is usually used. This may be followed by a filter if needed to meet the discharge standards. The sludge flow from the clarifier is sent to a dewatering facility. Plate and frame presses are the most common equipment used. Sludge must pass a stability test (TCLP) and a dryness test (Paint filter) prior to disposal.

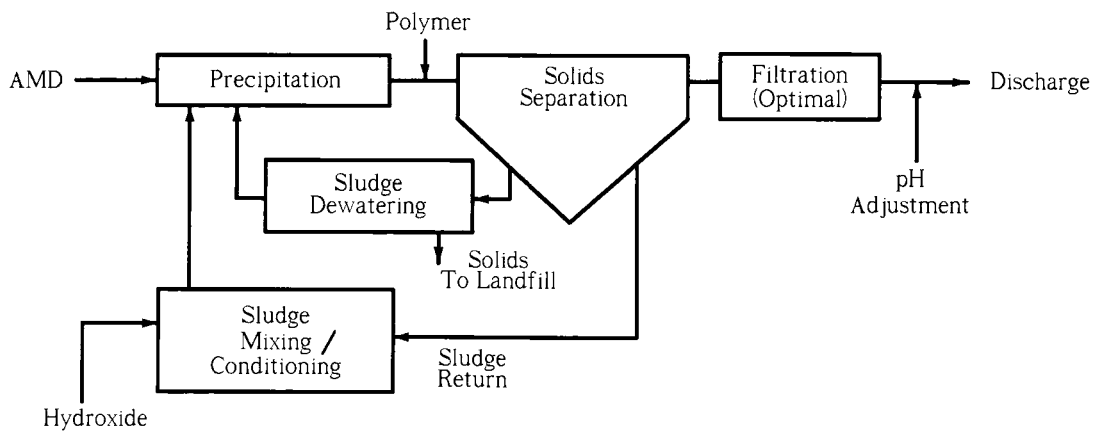
For treatment of the Nelson tunnel discharge, a process schematic using lime addition and reaction - followed by gravity clarifier - will be used for cost estimating. If hydroxide precipitation is selected as the preferred process, a plant using the HDS system with lime or an HMR system might be a viable alternative, and should be evaluated during final design phase.

The following table shows an estimate of Lime required for the Nelson Tunnel discharge.

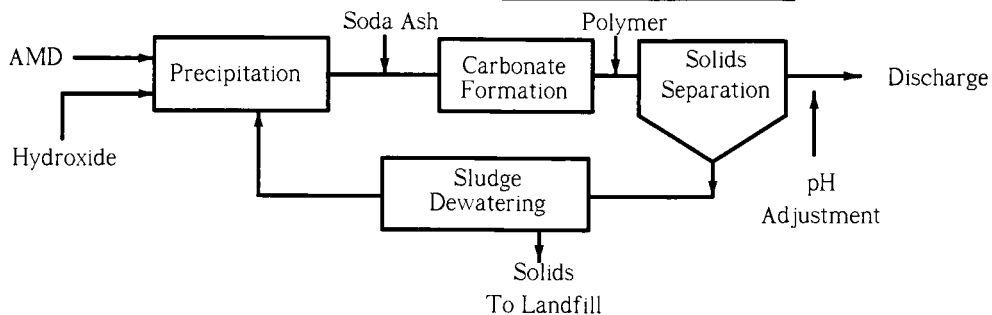
Figure II-B
Block Diagram Comparing Treatment Processes
Conventional Precipitation



High Density Sludge Process (HDS)



Heavy Metal Removal Process (HMR)



Notes

- Hydroxide source is generally lime or caustic.
- Oxidation options are not shown.

DESIGN: RJM
 DETAIL: RDL
 CHECK: RJM
 DATE: MAY, 2005

**Nelson Tunnel - Water
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<u>Constituent</u>	<u>Quantity (lbs/day)</u>	<u>Lime Required (lbs/day)</u>
Ph	---	150
Zinc	240	275
Mn	45	61
Pb	3	1
Fe	.6	1
Mg	90	140 (assume 50% removal)
Cd	1.5	1
Total	335	629

Acid quantity for final pH adjustment will be a function of the permit requirements. Assuming a discharge pH of 8, the plant would require approximately 80 pounds per day of hydrochloric acid. A polymer dose of 10 ppm would require 30 pounds per day. Total chemical demand for a 1 year period is summarized as follows:

- Lime - 115 tons per year
- Acid - 29,200 pounds per year (may not be required)
- Polymer - 11,000 pounds per year

Electrical/ Physical Treatment

Electrical treatment, or Electrocoagulation (EC) has been used for over 90 years, however the use is not widespread. Its use has been limited by cost and reliability issues. Recent improvements and technology have made the process more viable. The largest plant in Colorado is rated at 30 gpm and has been run at rates up to 42 gpm.

The process, as sold by Powell, passes water between a cathode and anode separated by metal plates, usually steel or aluminum. Dissolved contaminants are converted to solids and suspended solids are coagulated to form large floc particles which are separated from the water by settling. No chemical is used to accomplish this reaction. The metal plates are consumables and are replaced at regular intervals.

EC is effective at removing a wide range of contaminants from water, including heavy metals, hardness, silica, oils and some organics. The process is not selective, all contaminants treatable by EC will be removed.

Samples of Nelson Tunnel discharge were tested by Powell in June 2004 and February 2005. The samples in 2004 were tested for Cadmium, Manganese and Zinc. This test was not effective on the metals tested. In 2005, 3 new samples were tested for Zinc only. All tests showed complete removal to undetectable levels.

In addition to the metals removed, it is estimated that hardness was reduced by approximately 75 %, based on studies at other sites conducted by Powell. In the case of treatment at the Nelson Tunnel, this would be a disadvantage for two reasons. Hardness is a significant component of the discharge, approximately 840 pounds per day; for comparison, Zinc is the next largest load at 250 ppd, followed by Manganese at 45 ppd. Not only is removal of hardness not required, its removal increases the toxicity of heavy metals. The quantity of sludge produced due to the removal of hardness will exceed that of all other contaminants by a factor of about 2.

Since use of the EC process is not as extensive as the use of chemical processes, not as much data, information and experience are available to predict all the parameters required to thoroughly evaluate and design a system. Prior to final selection and design of an EC system, it is recommended that a pilot plant be operated for a period of time to evaluate performance on all constituents and quantify the production of sludge and maintenance requirements.

For purposes of evaluation we have used a power requirement of 7 kwh per 1,000 gallons treated and .2 pounds of sacrificial plates per 1000 gallons (about 72 lbs pounds per day), as provided by Frank Satterlee of Powell. The system requires an acid wash once or twice per day. Some ph adjustment may be required for discharge and acid neutralization.

Solid/liquid separation can be accomplished using conventional clarifiers and plate settlers. This is the same as the equipment used for chemical treatment. Powell has also used a vacuum type clarifier with success. For estimation, we have assumed a conventional clarifier because of simplicity, low operating cost and it is compatible with either chemical or EC systems. A schematic for this option is shown of Figure II-C.

Capital Cost Estimate

Table II-D is a summary of the preliminary cost estimate for both the EC and a Chemical Precipitation water treatment plans. This estimate does not include the cost for the electrical service. This item is included in the site evaluations, later in this report. Inlet and discharge structures and transmission pipelines are not included in this table.

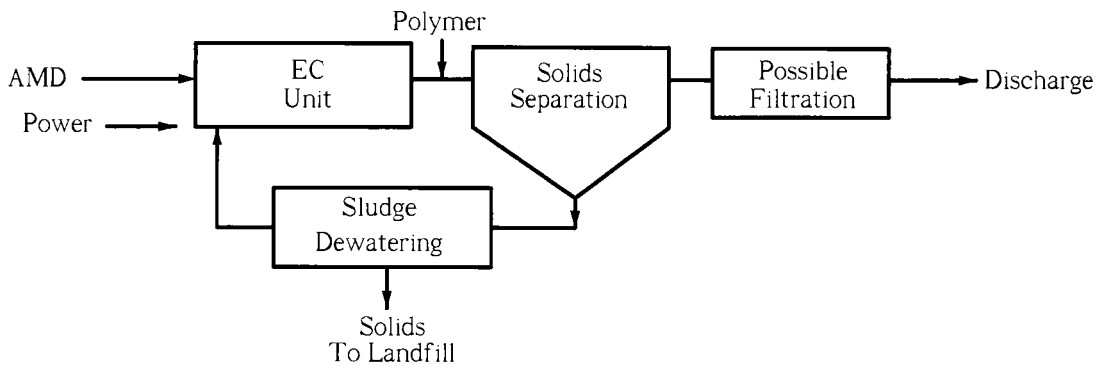
The estimate assumes both systems are fully enclosed and will require similar size buildings. Sludge dewatering equipment (plate and frame press) is included for both options.

A budget of \$1.728 million for the EC plant or \$1.48 million for the Chemical plant is appropriate for capital construction.

Operating Cost Estimates

Table II-E is a summary of operating costs for both type plants. The table indicates that the chemical plant, while more labor intensive, has a lower total operating cost. The EC plant operating cost is approximately \$.98 per 1000 gallons compared to \$.68 per 1000 gallons for the chemical plant. This is primarily due to the high cost of power compared to the cost of chemicals.

Figure II-C
Block Diagram
Electro Coagulation System



DESIGN: RJM
DETAIL: RDL
CHECK: RJM
DATE: MAY, 2005

Nelson Tunnel - Water
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FIGURE II-D

COMPARATIVE CAPITAL COST ESTIMATES

<u>ITEM</u>	<u>EC PLANT</u>	<u>CHEMICAL PLANT</u>
Building 60 x 100	\$150,000	\$150,000
Silo	---	\$60,000
Surge Tank	\$15,000	---
Lime Conveyor	---	\$22,000
Lime Feeder	---	\$17,000
EC Unit	\$340,000	---
Clarifier	\$235,000	\$235,000
Polymer System	---	\$12,000
Filter Press	\$270,000	\$270,000
Lime Reactor Tank with Mixer	---	\$70,000
HVAC	\$65,000	\$65,000
Controls/Meters	\$95,000	\$95,000
Electrical	\$130,000	\$75,000
Lab/Office	\$30,000	\$30,000
Piping/Valves	\$93,000	\$51,000
Acid Storage	\$10,000	\$20,000
<i>Total</i>	<i>\$1,383,000</i>	<i>\$1,187,000</i>
Recommended Budget	\$1,728,750	\$1,483,750

TABLE II-E

COMPARATIVE OPERATING COST ESTIMATES

(Does not include sludge disposal)

<u>ITEM</u>	<u>EC PLANT</u>	<u>CHEMICAL PLANT</u>
Lime \$150/ton	---	\$17,000
Polymer \$2/lb	---	\$22,000
Acid \$.20/lb	\$2,000	\$6,000
Power \$.09/kwh	\$89,000	\$7,000
Lab/Reporting	\$3,000	\$3,000
Labor \$20/hour	\$29,000	\$38,000
Plates	\$10,500	---
Maintenance	\$5,000	\$5,000
Total	\$138,500/yr	\$98,000/yr
<i>Unit Cost</i>	<i>\$1.02/1,000 gallons</i>	<i>\$.76/1,000 gallons</i>
Sludge Disposal & Hauling \$15/cy	\$6,500	\$6,500