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EXECUTIVE SUMMARY

# CHEYENNE STAGE I PIPELINE REHABILITATION

# LEVEL II FEASIBILITY STUDY

**Prepared for the**

**Wyoming Water Development Commission**

**April 1993**

**Prepared by:**

**Civil Engineering Professionals, Inc. in association with CH2M Hill**
**355 N. Lincoln Street**
**Casper, WY 82601**

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# EXECUTIVE SUMMARY

This Executive Summary provides an overview of the results of the Cheyenne Stage I Pipeline Rehabilitation Level II Feasibility Study. The report provides an evaluation and cost estimates for the alternatives for rehabilitating the pipeline. The selected alternative is further evaluated and conceptual design concepts are presented along with an economic analysis and ability-to-pay evaluation.

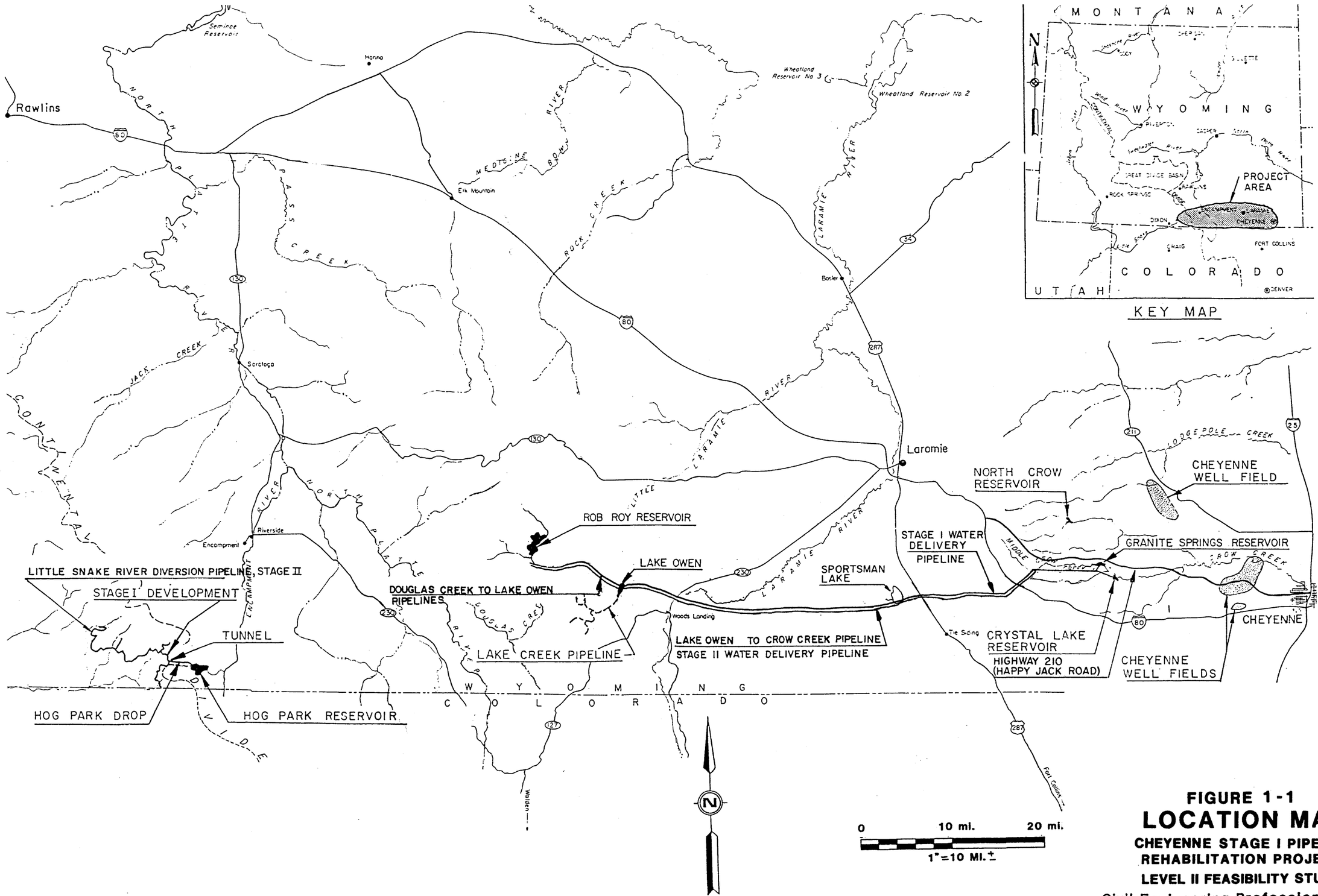
## SECTION 1 - INTRODUCTION

In 1960, the City of Cheyenne initiated a plan for developing a supplemental water supply system to bring water to Cheyenne from the North Platte River Drainage. The three-staged plan involved acquiring water from tributaries of the North Platte River located in the Medicine Bow Mountains west of Laramie. Because all the water rights to the North Platte River were appropriated, except when runoff is in excess, it was necessary to find replacement water. Cheyenne therefore acquired unappropriated water rights on the Little Snake River on the western slope of the Continental Divide in the Sierra Madre Mountains located approximately 200 miles west of Cheyenne. The Little Snake River is a tributary of the Yampa River and is in the Colorado River Drainage. Water collected on the western slope from the Colorado River drainage is transported through the Continental Divide and is used as replacement water for the water that Cheyenne diverts from the North Platte River drainage.

The location of the Stage I Pipeline project is shown in Figure 1-1. It is a very unique system which flows entirely by gravity without any pumping stations. It was intended to deliver approximately 7500 acre feet of water per year. The pipeline was constructed between 1962 and 1964, and consists of three pipeline segments, stream diversion and smaller collection structures, and three reservoirs. There are several inverted siphons along the alignment where the pipeline travels down through the mountain drainages and comes up the other side. Each pipeline segment is described below:

### Little Snake River Diversion Pipeline

The Little Snake River Diversion Pipeline is located in the mountains south of Encampment. This segment collects and diverts water from the North Fork of the Little Snake River and its tributaries, and carries it eastward through the Continental Divide in a 3480 feet long tunnel. The







KEY MAP

**FIGURE 1-1**

# LOCATION MAP

**CHEYENNE STAGE I PIPELINE REHABILITATION PROJECT**

**LEVEL II FEASIBILITY STUDY**

Civil Engineering Professionals, Inc.

pipeline on the west side of the tunnel is a 36-inch diameter concrete pipeline approximately 19,600 feet long, and includes four major inverted siphons. From the east portal of the tunnel, water is carried eastward in a 30-inch diameter concrete pipeline known as the Hog Park Drop. From there, it discharges into Hog Park Reservoir which was constructed as part of the Stage I Project. Water is then released from the reservoir into Hog Park Creek, a tributary of the Encampment River, which is a part of the North Platte River Drainage. The capacity of the pipeline ranges from 50 to 80 cubic feet per second (cfs).

## Douglas Creek to Lake Owen Pipeline

The second segment of the Stage I Pipeline is the Douglas Creek to Lake Owen Pipeline located in the Medicine Bow Mountains west of Laramie. The pipeline collects and diverts water from Douglas Creek and its tributaries and carries it eastward in a concrete pipeline for approximately 10 miles to Lake Owen. Rob Roy Reservoir was constructed at the head of the pipeline to store runoff from Douglas Creek and control the release of water into the pipeline. Lake Owen is used to store the water discharged by the pipeline and allow for control of releases into the third pipeline segment.

The pipeline flowing from Douglas Creek to Lake Owen is approximately 57,200 feet long and consists of 46,800 feet of 33-inch diameter concrete pipe and 10,400 feet of 24-inch diameter concrete pipe. There are 8 major inverted siphons along the alignment. The design capacity of the pipeline is approximately 18 cfs, an equivalent of 11.5 million gallons per day (mgd).

## Lake Owen to Crow Creek Pipeline

The third segment of the Stage I Pipeline is the Lake Owen to Crow Creek Pipeline which carries water released from Lake Owen eastward for approximately 40 miles across the Laramie Plains towards Cheyenne. The pipeline is a 26-inch diameter steel pipeline with coal tar enamel lining and exterior coal tar coating. A cathodic protection system is installed on the pipeline to protect it from external corrosion. The water is released from the pipeline into the Middle Fork of Crow Creek west of Cheyenne, and transported through the Crow Creek drainage where it is stored in Granite and Crystal Reservoirs. Water from these reservoirs ultimately flows to the Ray Scherard and Round Top Water Treatment Plants, where it is treated and pumped into Cheyenne's distribution system. The capacity of the steel pipeline is approximately 11.5 mgd and some operating pressures in the Laramie Plans area approach 650 pounds per square inch (psi).

Visual inspections of the concrete portions of the Stage I Pipeline by City Staff in 1987 indicated deterioration of the concrete interior. The deterioration was reported to be erosion of the pipe invert and roughening of the interior surface. Because of access difficulties, the interior condition of the steel pipeline was unknown although an increasing number of leaks were occurring. In 1991 the WWDC authorized a Level II Study to inventory the existing pipeline system, identify and describe those rehabilitation measures and/or recommendations for further analyses which may be necessary to ensure the efficient operation of the Cheyenne Stage I Pipeline system, and evaluate the cost of any needed improvements.

## SECTION 2 - PIPELINE EVALUATIONS

The pipeline evaluations consisted of water system data reviews, discussions with water operations personnel, pipe examinations and visual inspection, soil resistivity measurements, petrographic and laboratory analyses, electrical continuity and cathodic system evaluation and measurements, pipe coating evaluations and hydraulic analyses. Results of the inventory and evaluations are summarized below:

### Water Corrosivity

The raw water being carried in the pipeline has a pH in the range of 6.5 to 7. The water is undersaturated with calcium carbonate and has a negative Langelier's index. The water tends to be moderately to highly aggressive to concrete structures.

### Soil Corrosivity

In general, the soil conditions along the concrete pipeline segments are non-corrosive. The soil conditions along the steel pipeline segment range from non-corrosive to highly corrosive. There are 9.4 miles of the steel pipeline which are located in highly corrosive soils.

### Concrete Pipeline

Two types of concrete pipe were used in the Stage I concrete pipeline segments: (1) non-cylinder reinforced concrete pipe; and (2) reinforced concrete cylinder pipe. The non-cylinder pipe was installed in those areas where the pipeline flows are open channel, and in the upper portions of the siphons which have low head pressures of generally less than 100 feet. The non-

cylinder concrete pipe was manufactured in the Cheyenne area. The reinforced concrete cylinder pipe was installed in the lower portions of the siphons where the head pressures exceed 100 feet. The concrete cylinder piping was manufactured in Kansas.

Results of the field inventory for the concrete pipeline indicate that nearly all of the low head pressure piping is experiencing internal corrosion, predominantly in the lower half of the pipe. The corrosion is resulting in a rough internal surface with the pitting nearing 3/4 inch in depth. There are also a few areas experiencing longitudinal cracking and some minor structural damage. The higher head pressure piping used in the lower portions of the siphons is in relatively good condition.

Other concrete structures which are exposed to the water such as diversions and inlet boxes are also experiencing varying levels of corrosion.

Petrographic analyses were performed on cores taken from the non-cylinder reinforced concrete pipe and from fragments taken from damaged reinforced concrete cylinder pipe. Results of the analysis indicate the large aggregate used in the concrete for the non-cylinder reinforced concrete pipe is a fine grained limestone which is dissolved by the aggressive water. The cement mortar surrounding the aggregate is not significantly affected by the aggressive water. The dissolution of the limestone aggregate is leaving the internal surface of the concrete pipe pitted and very rough. The analysis also showed the reinforced concrete cylinder pipe was not composed of the same find grained limestone aggregate and is therefore not significantly affected by the aggressive water.

The corrosive action of the water on the non-cylinder reinforced concrete pipe is occurring at an overall rate of approximately .03 inches per year. If the corrosion goes unchecked, it is estimated that the steel reinforcing cage in the pipe will be exposed in 17 to 25 years. Exposure and subsequent corrosion of the rebar cage would lead to eventual structural failure of the pipeline.

The aggressive water has also caused the pipeline to lose its original hydraulic capacity during peak flow periods when the pipe is running full. The overall loss due to the increased roughness in the pipe is estimated at 30 to 35 percent of the original pipeline capacity.

## Steel Pipeline

The steel pipeline was constructed in 40-foot laying lengths and joined with flexible couplings. There are approximately 5,400 couplings on the pipeline. The pipeline is protected with a cathodic protection system designed to be electrically continuous through wire bonds across the couplings. The results of the steel pipeline evaluation indicate that the internal lining of the pipeline is in good condition. The majority of the problems occurring with the pipeline are related to corrosion caused leaks at the flexible couplings through failure of the coupling bolts. In addition, a shallow lake (Sportsman Lake) has developed over a 1.5 mile portion of the pipeline in the Laramie Plains area. This lake has made access to the pipeline difficult and costly.

The adequacy of the cathodic protection system that was originally installed during construction of the Stage I Pipeline was unknown until 1982 when it was found to be inadequate. Since 1987, the City has been upgrading and improving the system by installing additional cathodic protection stations, and replacing failed and unreliable joint bonds. The electrical continuity and repairs have been completed for 170 spans of the pipeline. There are still approximately 25 spans that are suspected of high resistance and may need repair.

The external coal tar enamel coating is in good condition for its age. The investigation of the internal lining also indicated the lining to be in good condition for its age. The underground piping associated with air relief valves, blow off valves, and buried meters have experienced varying degrees of external corrosion.

# SECTION 3 - DEFINING THE ALTERNATIVES

The alternatives for rehabilitating the Stage I Pipeline are defined in this section.

## Concrete Pipeline Rehabilitation Alternatives

The objectives in rehabilitating the concrete pipeline included protecting the internal concrete surfaces from further attack and deterioration from continued exposure to the aggressive water, and improving the hydraulic capacity of the pipeline. The alternatives that were determined to meet the criteria for further analysis are listed below:

| | | |
|---|---|---|
| Alternative No. 1 | – | No Action |
| Alternative No. 2 | – | Abandonment |
| Alternative No. 3 | – | Replacement |
| Alternative No. 4 | – | Rehabilitation |
| Alternative No. 4A | – | Cement–Mortar Lining |
| Alternative No. 4B | – | Epoxy Lining |
| Alternative No. 4C | – | Cement–Mortar/Polyurethane Lining |
| Alternative No. 4D | – | Sliplining |
| Alternative No. 4E | – | Insituform |

**Steel Pipeline Rehabilitation Alternatives**

Rehabilitation measures for the steel pipeline were either no action or rehabilitation. The rehabilitation needs for the pipeline were developed in terms or urgency of need and are discussed in terms of priorities.

| | | |
|---|---|---|
| Alternative No. 1 | – | No Action |
| Alternative No. 2 | – | Rehabilitation |
| Rehabilitation Priority No. 1 | – | Repair Known High Resistant Spans |
| Rehabilitation Priority No. 2 | – | Electrical Continuity Testing |
| Rehabilitation Priority No. 3 | – | Recoating ARV, BO and Meter Piping |
| Rehabilitation Priority No. 4 | – | Upgrade Steel Pipeline at Sportsman Lake |
| Rehabilitation Priority No. 5 | – | Rebonding Pipeline in Most Corrosive Soils |
| Rehabilitation Priority No. 6 | – | Rebonding Pipeline in Corrosive Soils |

## SECTION 4 - ALTERNATIVE ANALYSIS

The pipeline rehabilitation alternatives defined in Section 3 are further analyzed and ranked in this section. The criteria used to rank the alternatives for the concrete pipeline segments included capital cost, ability to improve hydraulic capacity, environmental impact, reliability/track record, maintenance/ease of repair and quality control. Adopting a no action alternative would result in

escalating O&M costs and an eventual need to replace the corroded portions of the pipeline. An abandonment alternative would mean abandoning 5,000 to 7,000 acre feet of water annually from Cheyenne's permitted water supply capacity. No action and abandonment were determined to be infeasible. Insituform was also determined to be infeasible because of its high cost and unsuitability for use in potable water applications.

The replacement and rehabilitation alternatives for the concrete pipeline segments were determined to be feasible solutions. In addition to cost comparisons, a matrix was used to develop a ranking for each alternative. The matrix assigned 10 possible points to each of the six criteria, with a total possible score of 60. The highest ranked alternative was determined to be sliplining with a score of 48, and a total estimated cost of $11.6 million.

The alternatives evaluated for the steel pipeline were no-action and rehabilitation. The no-action alternative was not considered to be feasible because of the already high costs associated with operation and maintenance of the pipeline. Without rehabilitation, these costs are expected to continue to escalate. Rehabilitation alternatives were limited to providing protection of the exterior pipe coating and couplings in an effort to reduce the maintenance costs created by corrosion related leaks in the pipeline. In addition to the rehabilitation alternatives for improving the electrical continuity, four different alignments were evaluated for realigning the pipeline around Sportsman Lake. The lowest cost alignment was No. 4 which routes the pipe to the south of Sportsman Lake. The exact location of the final alignment will depend in part, on the location of underground rock formations which will need to be identified through geotechnical field work.

## SECTION 5 - SELECTED ALTERNATIVE

This section presents a discussion of the selected alternative methods for rehabilitating the Stage I Pipeline and provides a refined cost estimate based upon a more detailed review of the design criteria.

### Concrete Pipeline

The selected alternative for rehabilitating the corroded portions of the concrete pipeline is Alternative No. 4, Sliplining. It was assumed the liner pipe would be high density polyurethane (HDPE), SDR 32.5. The pressure rating of the pipe is 50 psi which exceeds the pressure rating for the 100-foot concrete head pipe which is corroding. The HDPE pipe will be used to line the

corroded portions of the existing concrete pipeline and the upper portions of the inverted siphons. The 36-inch diameter concrete piping can be lined with a 34-inch diameter liner pipe which will restore the hydraulic capacity of the pipe to better than its original capacity. The 30-inch diameter pipeline known as the Hog Park Drop can be lined with a 26-inch diameter liner pipe which will nearly restore the pipeline to its original capacity, which is more than adequate to carry the original design flows. The 33-inch and 24-inch diameter piping on the Douglas Creek to Lake Owen Pipeline can be lined with 30-inch and 20-inch diameter liner pipe, respectively. These liner sizes will return the pipeline very near to its original capacity which is adequate to carry the original design flows.

The estimated cost of the sliplining alternative is $4.1 million for the Little Snake River Diversion Pipeline and includes sliplining approximately 3.52 miles of pipeline. The Douglas Creek to Lake Owen Pipeline is $6.4 million, and includes sliplining approximately 8.3 miles of pipeline. The quantities and associated cost estimates are provided in Tables 1 and 2.

Permits and/or permitting agencies which have been identified to be necessary to construct the project include the following:

U.S. Environmental Protection Agency
U.S. Forest Service
U.S. Army Corps of Engineers
Wyoming Department of Environmental Quality
Wyoming State Engineer

**Steel Pipeline**

The selected alternatives for rehabilitating the steel pipeline include Priorities No. 1 through No. 6 described in Section 4. Further evaluation was performed and refined cost estimates were prepared for each priority. The refined cost estimate is given in Table 3.

**REFINED COST ESTIMATE: LITTLE SNAKE DIVERSION – ALTERNATIVE 4D**
**SLIPLINING WITH HIGH DENSITY POLYETHYLENE PIPE**
**CHEYENNE STAGE I PIPELINE REHABILITATION PROJECT**

Abbreviations:

| | | |
|---|---|---|
| EA each | LF linear foot | MI mile |
| LS lump sum | SY square yard | CY cubic yard |

| ITEM DESCRIPTION | UNIT | UNIT COST (Dollars) | QUANTITY | ITEM TOTAL (Dollars) |
|---|---|---|---|---|
| Mobilization | EA | $200,000.00 | 1 | $200,000.00 |
| Rehabilitate intake structure (Little Snake) | EA | $85,000.00 | 1 | $85,000.00 |
| Rehabilitate other diversion structures | LS | $100,000.00 | 1 | $100,000.00 |
| Rehabilitate "D" structures | EA | $5,000.00 | 15 | $75,000.00 |
| Create access opening | EA | $5,000.00 | 38 | $190,000.00 |
| TV inspection (1 time) | LF | $1.50 | 18,800 | $28,200.00 |
| Sediment removal | CY | $560.00 | 10 | $5,600.00 |
| Modify prior repairs | EA | $450.00 | 20 | $9,000.00 |
| Repair holes with excavations | EA | $8,000.00 | 10 | $80,000.00 |
| Install liner | | | | |
| 30" | LF | $50.00 | 7,479 | $373,950.00 |
| 36" | LF | $70.00 | 11,126 | $778,820.00 |
| Pipe fittings | | | | |
| 30" | EA | $4,500.00 | 8 | $36,000.00 |
| 36" | EA | $6,000.00 | 15 | $90,000.00 |
| Clean and line manholes | EA | $1,500.00 | 10 | $15,000.00 |
| Install new RCP from structures | | | | |
| 12" | LF | $40.00 | 750 | $30,000.00 |
| 15" | LF | $45.00 | 2,700 | $121,500.00 |
| Grout annular space | CF | $75.00 | 1,500 | $112,500.00 |
| Connect inlets to main | EA | $5,000.00 | 15 | $75,000.00 |
| Test lined sections | EA | $500.00 | 30 | $15,000.00 |
| Surface restoration | SY | $2.00 | 30,000 | $60,000.00 |
| Forest service road maintenance | MI | $5,000.00 | 35 | $175,000.00 |
| Erosion control construction | SY | $3.00 | 30,000 | $90,000.00 |
| Demobilization | LS | $50,000.00 | 1 | $50,000.00 |
| SUBTOTAL CONSTRUCTION COST | | | | $2,795,570.00 |
| ENGINEERING DESIGN, PLANS, SPECIFICATIONS (10%) | | | | $279,557.00 |
| TV INSPECTION | | | | $50,000.00 |
| PERMITTING | | | | $75,000.00 |
| LEGAL FEES | | | | $50,000.00 |
| ENGINEERING DURING CONSTRUCTION (10%) | | | | $279,557.00 |
| SUBTOTAL PROJECT COST | | | | $3,529,684.00 |
| CONTINGENCY (15%) | | | | $529,452.60 |
| | | TOTAL PROJECT COST | | $4,059,136.60 |
| | | USE | | **$4,100,000.00** |

Table 2

| REFINED COST ESTIMATE: DOUGLAS CREEK – ALTERNATIVE 4D<br>SLIPLINING WITH HIGH DENSITY POLYETHYLENE PIPE<br>CHEYENNE STAGE I PIPELINE REHABILITATION PROJECT | | | | |
|---|---|---|---|---|
| Abbreviations:<br>EA each LF linear foot MI mile<br>LS lump sum SY square yard CY cubic yard | | | | |
| ITEM DESCRIPTION | UNIT | UNIT COST (Dollars) | QUANTITY | ITEM TOTAL (Dollars) |
| Mobilization | EA | $200,000.00 | 1 | $200,000.00 |
| Rehabilitate intake structure (Douglas Creek) | EA | $115,000.00 | 1 | $115,000.00 |
| Rehabilitate "D" structure | EA | $5,000.00 | 20 | $100,000.00 |
| Create access opening | EA | $5,000.00 | 61 | $305,000.00 |
| TV inspection (1 time) | LF | $1.50 | 45,600 | $68,400.00 |
| Sediment removal | CY | $560.00 | 25 | $14,000.00 |
| Modify prior repairs | EA | $450.00 | 20 | $9,000.00 |
| Repair holes with excavation | EA | $8,000.00 | 5 | $40,000.00 |
| Install liner | | | | |
| 24" | LF | $45.00 | 10,500 | $472,500.00 |
| 33" | LF | $60.00 | 33,360 | $2,001,600.00 |
| Pipe fittings | | | | |
| 24" | EA | $3,000.00 | 8 | $24,000.00 |
| 33" | EA | $4,000.00 | 8 | $32,000.00 |
| Clean and line manholes | EA | $1,500.00 | 32 | $48,000.00 |
| Grout annular space | CF | $75.00 | 4,500 | $337,500.00 |
| Connect inlets to main | EA | $5,000.00 | 20 | $100,000.00 |
| Replace 12" RCP from "D" structures | LF | $40.00 | 1,000 | $40,000.00 |
| Test lined sections | EA | $500.00 | 60 | $30,000.00 |
| Surface restoration | SY | $2.00 | 65,000 | $130,000.00 |
| Forest service road maintenance | MI | $5,000.00 | 25 | $125,000.00 |
| Erosion control construction | SY | $3.00 | 65,000 | $195,000.00 |
| Demobilization | LS | $50,000.00 | 1 | $50,000.00 |
| SUBTOTAL CONSTRUCTION COST | | | | $4,437,000.00 |
| ENGINEERING DESIGN, PLANS, SPECIFICATIONS (10%) | | | | $443,700.00 |
| TV INSPECTION | | | | $75,000.00 |
| PERMITTING | | | | $75,000.00 |
| LEGAL FEES | | | | $50,000.00 |
| ENGINEERING DURING CONSTRUCTION (10%) | | | | $443,700.00 |
| SUBTOTAL PROJECT COST | | | | $5,524,400.00 |
| CONTINGENCY (15%) | | | | $828,660.00 |
| | | TOTAL PROJECT COST | | $6,353,060.00 |
| | | USE | | $6,400,000.00 |

| TABLE 3<br>SUMMARY OF REFINED COSTS FOR STEEL PIPELINE REHABILITATION | | |
|---|---|---|
| **REHABILITATION PRIORITY** | | **ESTIMATED TOTAL PROJECT COST** |
| No. 1 | Repair High Resistant Spans | $120,000 |
| No. 2 | Electrical Continuity Testing | 80,000 |
| No. 3 | Recoat ARV's, BOs, Meters | 72,000 |
| No. 4B | Reroute Steel Pipeline at Sportsman Lake (Alternate Alignment No. 4) | 1,830,000 |
| No. 5 | Rebond Pipeline in Most Corrosive Soils (5.11 miles) | 220,000 |
| No. 6 | Rebond Pipeline in Corrosive Soils (3.39 miles) | 175,000 |
| | TOTAL | $2,497,000 |
| | **USE** | **$2,500,000** |

The major permits and landowners (for Sportsman Lake realignment) needed for rehabilitating the steel pipeline are listed below:

U.S. Army Corps of Engineers
Landowner – Booth Land and Livestock Co.
Wyoming Department of Environmental Quality

## Total Project Cost

The final refined project cost estimate for rehabilitating all three segments of the Stage I Pipeline, based on 1993/1994 dollars is $13 million.

## SECTION 6 - ECONOMIC ANALYSIS

An economic analysis was performed to determine the City of Cheyenne's ability-to-pay for the improvements. A benefit-cost analysis was performed and project repayment costs were developed to determine the cost to each user to retire the debt incurred in constructing the project. It was assumed that of the total $13 million estimated project cost, Cheyenne would obtain a grant of $6.5 million, and a loan of $6.5 million. The loan would be repaid at an annual interest rate of 4 percent over a 50-year period.

### Ability-to-Pay

The ability-to-pay analysis indicated that Cheyenne's water rates and per capita bonded indebtedness will be the second highest of the ten communities evaluated in the comparative analysis.

### Benefit-Cost Analysis

Two benefits will be realized by rehabilitating the Stage I Pipeline. The first benefit is a savings of 500 to 750 acre feet of water annually by improving the pipeline's hydraulics. Based on the cost of water from the Stage II Project, the current cost of 500 to 750 acre feet of water is $5.78 to $8.68 million. The second benefit is a reduction in the escalating O&M costs. The present value of the reductions is estimated to be $18.05 million over the 50 year period. The total present worth of benefits range from $23.83 to $26.73 million in comparison to the estimated cost of $13 million. The benefit cost ratio for the project ranges from 1.8:1 to 2:1.

### Project Repayment

The annual debt repayment for a $6.5 million loan at 4 percent interest over 50 years is approximately $302,900. Cheyenne currently assesses a $3.45 minimum monthly fee, and charges $1.55 per thousand gallons of water used. There are approximately 18,000 taps in the system. An increase of 5 percent in both fees would raise the monthly fee to $3.63 and the water sales charge to $1.63 per thousand gallons. This combined increase would generate $341,136 per year in added revenue, which would be adequate to meet the annual debt payments.