SAND LAKE/CAÑON CANAL
LEVEL II FEASIBILITY STUDY
FINAL REPORT

SAND LAKE DAM

CAÑON CANAL AND SLIDE

PREPARED FOR:
WYOMING WATER DEVELOPMENT COMMISSION
AND IRIGATION DISTRICT

1997

INBERG-MILLER ENGINEERS
1120 East "C" Street
Casper, Wyoming
FINAL REPORT
SAND LAKE/CAÑON CANAL
LEVEL II FEASIBILITY STUDY

October 31, 1997

For
Wyoming Water Development Commission
Herschler Building, 4th Floor West Wing
122 West 25th Street
Cheyenne, WY 82002

INBERG-MILLER ENGINEERS
1120 East "C" Street
Casper, WY 82601
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INTRODUCTION

A. History of the Existing System

The Cañon Canal and Sand Lake Dam are a portion of the irrigation water collection and distribution system of the Wheatland Irrigation District which serves approximately 911 water users with 55,284 acres of irrigable lands. Recent conversations with Mr. Don Britton, manager of the District, indicated that the average water yield to the water users during the last 10 years is 1.1 acre-feet per acre which is equivalent to an average total water delivery of 60,800 acre-feet. The existing assessment levied by the District is $9.50 per acre.

A portion of the existing irrigation water supply is provided by water stored in Sand Lake along with diversions from Rock Creek into the Cañon Canal. Sand Lake provides a storage capacity of approximately 1,105 acre-feet with a 1953 priority date. The outlet works for Sand Lake Reservoir are typically left open through the fall, winter and early spring seasons. In late spring, the outlet works are closed to capture runoff and fill the reservoir. The water is then released into Rock Creek through the summer months. A map showing the location of Sand Lake is included as Figure 1.

Presently, Cañon Canal diverts and conveys water associated with the following water rights in Rock Creek:

<table>
<thead>
<tr>
<th>Priority Date</th>
<th>Quantity (cfs)</th>
<th>Comment/Ownership</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spring 1882</td>
<td>3.6</td>
<td>District</td>
</tr>
<tr>
<td>Summer 1883</td>
<td>0.35</td>
<td>District</td>
</tr>
<tr>
<td>Fall 1883</td>
<td>0.93</td>
<td>District</td>
</tr>
<tr>
<td>Spring 1885</td>
<td>0.43</td>
<td>District</td>
</tr>
<tr>
<td>Spring 1885</td>
<td>0.14</td>
<td>District</td>
</tr>
<tr>
<td>Summer 1885</td>
<td>1.32</td>
<td>District</td>
</tr>
<tr>
<td>June 18, 1888</td>
<td>0.35</td>
<td>Ryberg Ditch, District</td>
</tr>
<tr>
<td>May 15, 1890</td>
<td>1.71</td>
<td>Brokaw</td>
</tr>
<tr>
<td>Season 1891</td>
<td>1.43</td>
<td>Pitchers</td>
</tr>
<tr>
<td>April 28, 1897</td>
<td>3.60</td>
<td>Brokaw</td>
</tr>
<tr>
<td>February 17, 1920</td>
<td>97.72</td>
<td>District</td>
</tr>
<tr>
<td>August 14, 1920</td>
<td>15.13</td>
<td>Brokaw(5.09 cfs), District</td>
</tr>
<tr>
<td>July 12, 1921</td>
<td>7.44</td>
<td>State of Wyoming</td>
</tr>
<tr>
<td>January 7, 1944</td>
<td>81.19</td>
<td>Lebeau(4.45 cfs), Brokaw(5.55 cfs), District</td>
</tr>
</tbody>
</table>
Source: U.S.G.S. Sand Lake Quadrangle, T17N., R79W
INTRODUCTION, Continued

A. History of the Existing System, Continued

The Rock Creek diversion totals 215.34 cfs with approximately 93 percent of the diversions (200.25 cfs) associated with the District. In addition to conveying the releases from Sand Lake, the Cañon Canal also conveys water diversions from other District water sources including One Mile Creek and Three Mile Creek. Conversations with the water hydrographer for Water Division Number 1, Mr. Rod Oliver, indicated that the average diversion from Rock Creek into the Cañon Ditch during the period from 1972 to 1995 was 7,520 acre-feet. Assuming a full reservoir, the average water volume delivered into the Cañon Canal and earmarked for the WID becomes 8,620 acre-feet. Consequently, the water provided from Rock Creek and Sand Lake through the Cañon Canal represents approximately 14 percent (or 0.15 acre-feet/acre) of the average annual water supply for the District. It is also important to note that without the diversion of Rock Creek into the Cañon Canal, the delivery of water diverted from One Mile Creek and Three Mile Creek is significantly diminished due to the conveyance losses within the canal. Therefore, the Cañon Canal and the water supplies either delivered or carried by the canal appear to be very important to the long-term operation of the District.

Much of the water conveyed by the Cañon Canal to lands within the District resulted from a water rights transfer where water tributary to the Medicine Bow River was diverted into the Laramie River. The transfer was granted subject to a condition that the diversion is limited to 50 percent of the basic appropriation of 1 cfs per 70 acres and 25 percent of excess water allotment.

B. Summary of Existing Problems

During the winter months, the emergency spillway structure of Sand Lake typically blows full of snow. In the past, the collection of snow and ice in the spillway structure has prevented the structure from performing adequately, resulting in filling the reservoir and overtopping of the dam. Previous overtopping events reportedly had not caused significant damage to the dam. Because of the isolated, high altitude location of the
INTRODUCTION, Continued

B. Summary of Existing Problems, Continued

reservoir, the Wheatland Irrigation District (WID) is unable to bring equipment in to clean the spillway structure. On June 22, 1995, the reservoir filled, the spillway structure was clogged and the reservoir was overtopped. The overtopping caused a breach in the dam next to the outlet structure. In its present condition with the breach, the Sand Lake Reservoir can store approximately 1,097 acre-feet of water.

The Cañon Canal is constructed at the base of the hillside near the Arlington area. The area has historically experienced landslides, especially during wet spring months. Previous slides that have been recently documented include June 1986 and July 13, 1995. The slope movement caused a breach of Cañon Canal. The WID rebuilt the canal and maintained it open during the irrigation season of 1995. Because of the unstable condition of the hillside, there exists a potential that further movement and damage to the canal could occur. Figure 2 includes a map of the approximate slide area. The area encompassed by the present slide is approximately 80 acres.

TASK 1. SCOPING MEETING

A scoping meeting was held on June 6, 1996, at the project site. The meeting was attended by representatives of the Wyoming Water Development Commission, Wheatland Irrigation District, Inberg-Miller Engineers, State Engineer's Office, and the University of Wyoming. The meeting attendees toured the Cañon Canal and slide area, discussing project direction and scheduling. Due to heavy snow cover, access to Sand Lake Reservoir at that time was not possible. Sand Lake Reservoir has been visited independently by members of the project team on several occasions since June 6, 1996.
FIGURE 2. - CANON CANAL SLIDE AREA MAP

Source: U.S.G.S. Arlington Quadrangle, T19N., R78W.
TASK 2. INVENTORY OF EXISTING SYSTEM

A. **Sand Lake Dam**

Sand Lake Dam was built in approximately 1955 for the purpose of storage of irrigation water. According to the Phase I Inspection Report performed by the United States Army Corps of Engineers as part of the National Dam Safety Program, the dam has a height of 22.5 feet and a maximum storage of 1,105 acre-feet. The dam is located on Deep Creek approximately 12 miles southwest of Arlington, Wyoming in the Medicine Bow National Forest. The drainage area above the dam is 3.26 square miles. The basin has a total length of 2.2 miles and an average width of about 1.5 miles. The topography of the area is steep and drainage patterns are well defined. Slopes along the main channel average about 190 feet per mile.

The embankment is a rolled earth fill structure approximately 860 feet long, 22.5 feet high at the maximum section and 12 feet wide at the crest. Crest elevation is 10,136.5 mean sea level (MSL), the downstream slope is 2H:1V while the upstream slope is 3H:1V and the entire upstream slope of the dam embankment is protected with riprap. The dam embankment is reportedly founded on an 8 foot wide cut-off trench that extends to bedrock.

The emergency spillway channel is an earth cut and fill structure at the left dam abutment. The trapezoidal spillway is slightly curved in plan and has 3 control sills placed across the spillway channel. The side slopes of the spillway channel vary from 2H:1V at upstream and 1.25H:1V at downstream sections. The spillway channel is approximately 800 feet long and varies from 22 to 42.5 feet wide.

The outlet works consist of a sloped concrete inlet structure, a welded steel conduit, and a natural plunge pool. The conduit is a 116 feet long, 30 inch I.D. welded steel pipe. The conduit has an inlet elevation of 10,117.2 and an outlet elevation of 10,114.0. The conduit is reportedly coated with asphalt and has 4 concrete seepage collars located on 20 foot centers. The concrete gate control structure is located near the center of the dam on the upstream crest of the embankment.
A. **Sand Lake Dam, Continued**

In the Corps of Engineers report, it was reported that the dam was overtopped in the Spring of 1973 as a result of a combination of 3 factors: 1) heavy snow melt runoff, 2) closed outlet gate, and 3) an emergency spillway that was completely blocked with snow.

On July 13, 1996, Steve Moldt of Inberg-Miller Engineers visited Sand Lake Dam. At the time of our site visit, the water level in the reservoir was approximately 7 feet below the crest of the dam. The dam is breached near approximately the middle of the dam length at the highest height and nearly adjacent to the outlet conduit. The overall dimensions of the breach is approximately 15 feet at the top of the widest point narrowing down to approximately 11 feet wide at the bottom. The bottom of the breach "steps" down from approximately 7 feet below the crest elevation at the upstream side to approximately 16 feet at the downstream side. Clear water was flowing through the riprap that had collapsed on the upstream slope and flowed over the concrete at the outlet.

The outlet pipe was under water. In addition to the major breach, there are several other areas along the dam crest that show minor erosion from water apparently going over the top of the dam.

The outlet channel is not a well defined channel. Instead, it appears to be a meandering boulder field in a relatively wide area downstream from the dam. After the spillway joins the channel, it is a little more well defined.

The spillway can be described as a cut-in channel around the left abutment in the dam, then swings around below the dam to intersect the outlet channel. When the spillway gets below the dam, it becomes predominately an above-grade structure built up with soil and rock. Approximately mid-way down the length of the spillway there appeared to be a breach in the downstream side of the spillway channel. The breach was approximately 30 feet wide by 5 feet deep. Because of the distance from the dam, the breach in the spillway appears unrelated to the problems experienced by the dam.
A. **Sand Lake Dam, Continued**

From rough measurements of the breach area, it appears that approximately 370 cubic yards of material were lost from the breach. The area immediately downstream of the dam does not show much as far as remnants of the material. However, within the first approximately ½ mile or so below the dam, there is evidence of sediment around low lying trees and rock. Beyond ½ mile, no evidence of sediment was noted. It is not known if normal runoff results in movement of material, because the sediment is also the predominate soil type in the area. Because of the relatively fine grained nature of the material that comprises the embankment, it is likely that transportation of the material could have travelled as far as ½ mile, and yet be present only in small quantities anywhere. It is probable that some of the material could have been carried further downstream and dissipated.

B. **Cañon Canal**

An integral part of the Phase I efforts include the completion of a field exploration of the existing facilities associated with the Cañon Canal and Dutton Ditch. The majority of the field work was completed during the time period extending from June 24 to July 3, 1996. During this period, the WID was not diverting water from either Rock Creek, One-Mile Creek or Three-Mile Creek. The absence of the irrigation diversions facilitated the field work required to assess the existing facilities. Diversions from the three water sources occurred during the latter part of July. At this time, seepage studies were conducted along the Cañon Canal in the vicinity of the recent land slides.

The focus of the field exploration of the Cañon Canal facilities was to: (a) inventory and assess the condition of the existing structures; (b) collect site-specific data for the Phase II effort to promote the analysis of channel hydraulics and the hydraulic capacity of existing structures as well as proposed improvements; and (c) perform a preliminary geologic study of the canal slide. Specific activities that were undertaken included:
B. Cañon Canal, Continued

1. assessment of the condition of the existing structures with respect to type of materials, associated maintenance items and remaining design life;

2. assessment of the hydraulic efficiency of the structures and the potential for debris blockage;

3. assessment of the stability of the canal;

4. perform test borings and install ground-water monitoring wells in and around the slide;

5. photographic documentation of the structures within each canal system;

6. collection of gaging information in the Cañon Canal in the vicinity of the land slide; and

7. identification of field survey data necessary for the hydraulic analysis and conceptual design efforts (Phase II work).

At the request of the WWDC, an exploration of the Dutton Ditch facilities was also completed. The purpose of this work was to: (a) assess the condition of the existing facilities; and (b) identify major deficiencies which may prevent, limit or reduce the diversion of irrigation water from the Cañon Canal into the Dutton Ditch. The information collected during the field work provided the basis for the development of conceptual improvements along with preliminary cost estimates. Compared to the work completed for the Cañon Canal system, this work was completed at a very preliminary level (Level I). The results of this work are intended to provide the WWDC and the WID with information necessary to proceed with a more detailed investigation (Level II) of the irrigation facilities associated with the Dutton Ditch.

Prior to, and in conjunction with the completion of the field work, additional data and information was collected and reviewed. This information included topographic mapping and aerial photographs of the project area, water rights tabulation data and diversion records, and notes/memoranda related to the historical operation and maintenance of the existing facilities. All field and inventory data, mapping and existing information was compiled, reviewed and evaluated. As a result of these efforts, a list of proposed improvements necessary to rehabilitate the canal facilities was developed.
B. Cañon Canal, Continued

Cañon Canal Facilities

The Cañon Canal originates at the diversion structure and headgate on Rock Creek near Arlington, Wyoming. The canal conveys water from Rock Creek in an easterly direction approximately 10.9 miles across Interstate Highway 80 and ultimately into King Reservoir No. 1. In addition to the diversion from Rock Creek, the Cañon Canal conveys water diverted from One Mile Creek and Three Mile Creek.

Information obtained from Mr. Rod Oliver indicates that a maximum diversion, including surplus water from Rock Creek, One Mile Creek, and Three Mile Creek is approximately 215 cfs, 68 cfs and 21 cfs, respectively. In addition, water stored in Sand Lake (maximum capacity of 1,105 acre-feet) is released into Rock Creek and ultimately diverted at the Cañon Canal headgate. A preliminary evaluation of the diversions into and out of the Cañon Canal provided the information necessary to develop a discharge profile along the canal. The discharge profile ranged from 215 cfs at the canal headgate to a maximum 280 cfs immediately downstream of Three Mile to approximately 230 cfs at the inlet to King Reservoir No. 1.

Several structures were identified during the inventory of the Cañon Canal. These structures included stream diversion structures, canal headgates, drop structures, check structures, canal crossing structures, road crossing structures, flume crossings, and a canal gaging structure. Each type of structure is described in the following paragraphs along with a summary of the existing condition and noted deficiencies.

Table 1 presents a summary of the inventory for the Cañon Canal. Plates 1 through 6 in Appendix A illustrate the location of the facilities which were identified and inventories during the field investigation.
B. Cañon Canal, Continued

**Canal Headgate and Diversion Structure (Station 0+00)**

This structure consists of a concrete diversion weir in Rock Creek along with a concrete headgate. The majority of the diversion structure is in good condition. Additional concrete has been placed along the crest of the diversion structure in the vicinity of the headgate. Rehabilitation of this portion of the diversion structure is warranted. The headgate is in fair condition with previous maintenance noted during the field work. The two 5-foot slide gates are operable and require limited maintenance to prevent seepage during periods when no diversions from Rock Creek are permitted. Erosion along the downstream apron of the headgate structure was noted; armor protection of the erosion at this location is recommended.

**Canal Gaging Station (Station 2+00)**

The gaging station consists of a concrete sill within Cañon Canal along with a stilling well/recording device. During the field work, flow measurements were taken along the concrete sill and compared to the discharge measured by the recording device. A discrepancy of 30 percent was noted. Based on recent conversations with Rod Oliver, a shift in the rating curve for the concrete sill has occurred and must be accounted for to ensure a more accurate reading. Given the steep canal gradient in this reach, accuracy of the flow measurements would be improved by installation of a flow control structure such as a cipoletti weir.

Cañon Canal

Overall, the Cañon Canal is in good condition and appears to have the capacity to convey the flow diverted from Rock Creek, One Mile Creek and Three Mile Creek. Erosion is occurring at several locations (i.e., where drainage enters the unlined portion of the canal, transitions between
Table 1. Summary of Structure Inventory for the Cañon Canal.

<table>
<thead>
<tr>
<th>Station</th>
<th>Description of Structure</th>
<th>Condition/Comments</th>
<th>Remaining Design Life</th>
</tr>
</thead>
<tbody>
<tr>
<td>0+00</td>
<td>Rock Creek Diversion Structure and</td>
<td>The main weir segment appears to be structurally sound. The angled weir segment near the headgate is in very poor condition. The headgate is in fair condition; the concrete exit apron is in fair to poor condition.</td>
<td>Diversion Structure: less than 5 years</td>
</tr>
<tr>
<td></td>
<td>Canal Headgate</td>
<td></td>
<td>Headgate: 5 to 15 years</td>
</tr>
<tr>
<td>2+00</td>
<td>Canal Gaging Station</td>
<td>Structural condition of the concrete sill is good but it is located approximately 50 feet downstream of instrument housing. A rating curve shift has been noted leading to erroneous discharge measurements.</td>
<td>15 to 25 years</td>
</tr>
<tr>
<td>35+00</td>
<td>Check and Turnout Structure</td>
<td>Check structure consists of large cobble material placed haphazardly across the canal; it is in poor condition. The turnout structure is in fair to good condition.</td>
<td>5 to 15 years</td>
</tr>
<tr>
<td>60+00 to</td>
<td>Earth-lined Canal Through Slide Area</td>
<td>The canal stability is highly compromised through this reach due to the instability of the up slope hillside and down slope toe.</td>
<td>less than 5 years</td>
</tr>
<tr>
<td>83+40</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>97+10</td>
<td>Bridge Crossing</td>
<td>The structure is in fair condition but the intermediate steel supports have apparently experienced erosion and are now suspended. Abutment stability is fair to good, but the right abutment will eventually be affected by the bank erosion associated with two local drains into the canal.</td>
<td>5 to 15 years</td>
</tr>
<tr>
<td>109+10</td>
<td>Turnout Structure</td>
<td>The turnout structure is in good condition.</td>
<td>15 to 25 years</td>
</tr>
<tr>
<td>109+40</td>
<td>One Mile Creek Diversion Structure</td>
<td>The diversion structure and headgate are temporary structures with the diversion consisting of a plastic-lined rock dam. The ditch which conveys One Mile Creek flows to the structure has limited capacity; it appears that it cannot convey moderate to high flows to the structure.</td>
<td>less than 5 years</td>
</tr>
<tr>
<td>109+40</td>
<td>One Mile Creek Flume Over Canal</td>
<td>The steel and wood flume is in fair condition but lacks capacity for conveying moderate to high flows. The concrete outlet box/diversion structure is in poor structural condition. The arch CMP and downstream grout protection are in fair to good condition. The upstream concrete rubble and grout bank protection is in poor to fair condition.</td>
<td>5 to 15 years</td>
</tr>
</tbody>
</table>
Table 1. Summary of Structure Inventory for the Cañon Canal (continued).

<table>
<thead>
<tr>
<th>Station</th>
<th>Description of Structure</th>
<th>Condition/Comments</th>
<th>Remaining Design Life (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>119+70</td>
<td>Bridge Crossing</td>
<td>The structure is in good condition. The canal banks downstream of the bridge are cantilevered and being undercut; this bank erosion may eventually impact the bridge abutment stability.</td>
<td>15 to 25 years</td>
</tr>
<tr>
<td>127+30</td>
<td>Interstate 80 Bridge Crossings</td>
<td>Both east and west bound bridges are three-span concrete structures in excellent condition. The canal banks are lined with cobble-filled gabions through the bridges. The gabions are in good to excellent condition, with the exception of the upstream end of the right bank gabion which is being undercut by the adjacent local drain into the canal. The local drain has failed and is eroding.</td>
<td>greater than 25 years</td>
</tr>
<tr>
<td>140+20</td>
<td>Turnout Structure</td>
<td>The turnout structure is in good condition, but its conveyance capacity is limited by sediment deposits and the establishment of vegetation at the entrance.</td>
<td>15 to 25 years</td>
</tr>
<tr>
<td>142+20</td>
<td>Check and Turnout Structure</td>
<td>The turnout structure and left wingwall of the check structure are in good to excellent condition. The sill of the check structure, the concrete rubble used for downstream protection, and the footbridge are all in poor condition.</td>
<td>less than 5 years</td>
</tr>
<tr>
<td>149+00</td>
<td>Check and Turnout Structure</td>
<td>The turnout structure is in fair condition. The check structure and footbridge are in poor condition.</td>
<td>less than 5 years</td>
</tr>
<tr>
<td>176+20</td>
<td>Check and Turnout Structure</td>
<td>The turnout structure is in good condition. The check structure and footbridge are in poor condition.</td>
<td>5 to 15 years</td>
</tr>
<tr>
<td>186+70</td>
<td>Check and Turnout Structure</td>
<td>The turnout structure is in excellent condition. The check structure is in very poor condition.</td>
<td>less than 5 years</td>
</tr>
<tr>
<td>212+60</td>
<td>Culvert Crossing</td>
<td>The culvert is in good to excellent condition. Local erosion at outlet is minimal.</td>
<td>15 to 25 years</td>
</tr>
<tr>
<td>226+40</td>
<td>Culvert Crossing</td>
<td>The culverts are in good to excellent condition. Local erosion at outlets was noted with a minor headcut downstream of left barrel.</td>
<td>15 to 25 years</td>
</tr>
</tbody>
</table>
Table 1. Summary of Structure Inventory for the Cañon Canal (continued).

<table>
<thead>
<tr>
<th>Station</th>
<th>Description of Structure</th>
<th>Condition/Comments</th>
<th>Remaining Design Life (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>249+80</td>
<td>Culvert Crossing</td>
<td>The culvert is in good to excellent condition. A large scour hole is present downstream of the flared end section.</td>
<td>5 to 15 years</td>
</tr>
<tr>
<td>209+10 to 272+60</td>
<td>Concrete Lining Along Interstate 80 (four segments)</td>
<td>The concrete is generally in good condition (with the exception of the downstream end of the fourth segment—see Station 272+60). Cracking of lining and erosion of adjacent earth channel was noted at the upstream end of each of the four segments.</td>
<td>15 to 25 years</td>
</tr>
<tr>
<td>271+10</td>
<td>Three Mile Creek Diversion Structure</td>
<td>The structure is in good to excellent condition with two exceptions: (1) the concrete seams between the structure and the box culvert under I-80 have separated; and (2) significant sediment deposits have accumulated in the structure and vegetation has established.</td>
<td>15 to 25 years</td>
</tr>
<tr>
<td>272+60</td>
<td>Downstream End of Concrete Lining Along Interstate 80</td>
<td>Approximately 100 feet of the concrete lining is in very poor condition; it is severely cracked, sediment has deposited and vegetation has established.</td>
<td>less than 5 years</td>
</tr>
<tr>
<td>295+20</td>
<td>Check and Turnout Structure</td>
<td>The turnout structure is in good condition but is partially obstructed with sediment deposits. The check structure is in good condition except that the downstream concrete apron is perched and in fair condition.</td>
<td>5 to 15 years</td>
</tr>
<tr>
<td>313+20</td>
<td>Check and Turnout Structure</td>
<td>The turnout structure is in very poor condition. The check structure is in poor condition.</td>
<td>less than 5 years</td>
</tr>
<tr>
<td>333+50</td>
<td>Bridge Crossing</td>
<td>Structurally, the bridge appears to be in fair condition. Its stability is considered poor to fair due to bank erosion.</td>
<td>less than 5 years</td>
</tr>
<tr>
<td>339+80</td>
<td>Check and Turnout Structure</td>
<td>Both the mainline Cañon Canal and diversion to Seepage Creek check/turnout structures are in fair condition, with the exception of the upstream and downstream concrete aprons which are in poor condition</td>
<td>5 to 15 years</td>
</tr>
<tr>
<td>346+90</td>
<td>Pipe Drop Structure</td>
<td>The CMP is in good condition, but the embankment is in poor condition with seepage and piping noted.</td>
<td>less than 5 years</td>
</tr>
</tbody>
</table>
Table 1. Summary of Structure Inventory for the Cañon Canal (continued).

<table>
<thead>
<tr>
<th>Station</th>
<th>Description of Structure</th>
<th>Condition/Comments</th>
<th>Remaining Design Life (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>354+30</td>
<td>Pipe Drop Structure</td>
<td>The CMP is in good condition, but the approach angle is very poor. The embankment</td>
<td>5 to 15 years</td>
</tr>
<tr>
<td></td>
<td></td>
<td>is in fair to poor condition with local erosion noted on the downstream face.</td>
<td></td>
</tr>
<tr>
<td>363+20</td>
<td>Pipe Drop Structure</td>
<td>The cast iron pipe is in good condition. The embankment is in good condition but</td>
<td>5 to 15 years</td>
</tr>
<tr>
<td></td>
<td></td>
<td>it appears to be low and could be overtopped.</td>
<td></td>
</tr>
<tr>
<td>388+00 to</td>
<td>Rock Drop Structures</td>
<td>The numerous rock drop structures consist of dumped cobbles and boulders. They are</td>
<td>less than 5 years</td>
</tr>
<tr>
<td>406+00</td>
<td></td>
<td>generally in fair condition, however 2 or 3 are in danger of being flanked.</td>
<td></td>
</tr>
<tr>
<td>417+70</td>
<td>Drop and Turnout Structure</td>
<td>The drop structure is in fair condition, but there is no ability to check flows.</td>
<td>5 to 15 years</td>
</tr>
<tr>
<td></td>
<td></td>
<td>It appears a diversion is manually graded to direct flows to the turnout. The</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>turnout structure is in fair condition.</td>
<td></td>
</tr>
<tr>
<td>425+50</td>
<td>Pipe Drop Structure</td>
<td>The cast iron pipe is in good condition. The embankment is in fair condition with</td>
<td>5 to 15 years</td>
</tr>
<tr>
<td></td>
<td></td>
<td>local erosion noted on the downstream face. It appears that the embankment is low</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>and could be overtopped.</td>
<td></td>
</tr>
<tr>
<td>485+50</td>
<td>Turnout Structure and Footbridge</td>
<td>The turnout structure is in fair condition but the adjacent banks are highly</td>
<td>Turnout &amp; Footbridge:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>unstable, consisting of pushed up bed material (gravel and sand), a few cobbles,</td>
<td>15 to 25 years</td>
</tr>
<tr>
<td></td>
<td></td>
<td>and other debris. The footbridge is in excellent condition.</td>
<td>Canal Banks:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>less than 5 years</td>
</tr>
<tr>
<td>491+80</td>
<td>Check, Drop and Turnout Structure</td>
<td>The entire structure is generally in good condition. The downstream channel has</td>
<td>15 to 25 years</td>
</tr>
<tr>
<td></td>
<td></td>
<td>been unstable, as evidenced by the cobble material and concrete rubble which have</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>been placed.</td>
<td></td>
</tr>
<tr>
<td>551+60</td>
<td>Culvert Road Crossing</td>
<td>The CMP and downstream embankment are both in very poor condition.</td>
<td>5 to 15 years</td>
</tr>
</tbody>
</table>
B. Cañon Canal, Continued

Concrete-lined sections and the earth sections, and deeply incised channel sections; however, annual maintenance and placement of additional rock riprap would tend to mitigate this erosion. Where the canal is lined with concrete, the lining is in relatively good condition with the exception of the reaches described below. Finally, the canal reach in the vicinity of the land slide is in need of rehabilitation due to the recent movement of the canal and the ongoing seepage problems. The following paragraphs specifically focus on the canal reaches requiring rehabilitation efforts.

1. Station 60+00 to 83+40

This reach of the canal is located adjacent to the recent land slide. Seepage through this area is excessive. Field measurements indicate that as much as 9 cfs is lost within the canal when approximately 30 cfs is diverted from Rock Creek. The field measurements also indicate that upslope seepage enters the canal at several locations along the southern canal bank. The land slide significantly altered the alignment, geometry and profile of the canal and adversely impacted canal stability throughout this reach. In general, the canal requires rehabilitation to limit the seepage losses, improve canal stability and ensure the conveyance of irrigation water. A geologic report for the Cañon Canal slide is included in Appendix C.

2. Station 271+50 to 272+60

This section of concrete-lined canal is located immediately downstream of the Three Mile Creek diversion structure. Severe erosion of the right bank is threatening to undermine the canal lining. Cracking and spalling of the existing lining is noted along with significant encroachment by willows and large shrubs. Scour of the canal bed is occurring at the end of the concrete lining. Replacement of this portion of the concrete lining is warranted.
3. **Station 493+00 to 531+00**

   This section of canal is deeply incised into the native bed materials with adjacent banks reaching heights in excess of 30 feet. Within the canal bed, headcuts are actively migrating upstream. At several locations, the canal has incised into bedrock while at other locations, manmade grade control structures are evident. Active erosion will continue to occur and the potential exists for massive bank failure at several locations along the canal. Due to the magnitude of the erosion problem along with the cost associated with rehabilitation, however, development of a plan for monitoring the erosion and canal stability is recommended.

4. **Stream Diversion Structures (Stations 109+40 and 271+10)**

   In addition to the diversion structure located on Rock Creek, diversion structures are also located on One Mile Creek (Station 109+40) and Three Mile Creek (Station 271+10). The diversion on One Mile Creek was recently constructed and can be considered a temporary structure given the nature of the construction materials. Earthen berms and rock have been placed within and along One Mile Creek to contain the flow and promote the diversion into the Cañon Canal. A maximum of 68 cfs can be potentially diverted from this location. To ensure a long-term diversion of irrigation water from One Mile Creek, a more permanent structure is recommended and should consist of a diversion structure, headgate and measuring device.
B. Cañon Canal, Continued

At Three Mile Creek (Station 271+10), a concrete flume, diversion structure and headgate is located to convey flow over the Cañon Canal and for diversion of irrigation water. This structure appears to be in good condition with two exceptions: (a) the two vertical joints between the box culvert under the interstate highway and the walls of the diversion structure have separated; and (b) sediment and debris have collected within the concrete flume and significantly obstruct the flow path. Remediation of the concrete joints and removal of the sediment/debris/vegetation within the flume is recommended.

5. Drop Structures

Drop structures were noted at several locations along the Cañon Canal including structures located at Stations 346+90, 354+30, 363+20, 417+70, and 425+50. Two of the drop structures (Stations 363+20 and 425+50) are constructed with 75-inch cast iron/steel pipe. These structures are in good condition with only limited scour noticeable at the outlet. To ensure long-term stability of the structures, placement of rock riprap at the outlet is recommended.

The drop structures at Stations 346+90 and 354+30 are constructed with 5-foot corrugated metal pipe. The structure at Station 354+30 is in good condition while piping is occurring through the embankment at the drop structure at Station 346+90. Noticeable erosion of the downstream embankment is occurring and loss of the corrugated metal headwall is imminent. Rehabilitation efforts are required to improve structure stability and may include compaction of the backfill around the corrugated metal pipe or replacement of the structure.
B. Cañon Canal, Continued

The drop structure located at Station 417+70 is composed of grouted rock and rock riprap. This structure is in relatively good condition with evidence of historic bank and bed erosion downstream of the structure.

6. Flume Crossing (Station 109+40)

A flume crossing exists at this location to convey flows within One Mile Creek over the canal. The irrigation water within the canal is conveyed beneath the flume in an arch CMP. At the downstream end of the flume, a concrete wall serves to divert water back into One Mile Creek or into a turnout structure. In general, the structure is in fair condition with only limited capacity to convey flows within One Mile Creek. It is recommended that this structure be replaced with a structure that will provide increased capacity and long-term stability.

7. Road Crossings (Stations 127+30 and 551+60)

Two crossings of the Cañon Canal were identified during the field investigation. These include the crossing of Interstate Highway 80 (Station 127+30) and Carbon County Road 15 (Station 551+60). At Interstate Highway 80, two 3-span bridges cross the canal with canal banks and bridge abutments protected by rock gabions. This structure is in excellent condition with the exception of local erosion occurring in the vicinity of a drainage ditch which flows into the canal. Rehabilitation of the local erosion problem is recommended.
B. Cañon Canal, Continued

The crossing of Carbon County Road 15 requires rehabilitation. This crossing consists of a 102-inch CMP to convey the irrigation flows along with stormwater captured by the upstream canal. The capacity of the pipe appears adequate to convey the irrigation flows along with significant stormwater inflows. The existing CMP lacks adequate cover and is presently deflecting along the crown of the pipe. At the outlet of the crossing, significant erosion of the canal bed has occurred; the invert of the CMP has lowered several feet at this location and ruptured a portion of the pipe. Recommended improvements include stabilization of the canal at the outlet of the CMP and potential replacement of the pipe to remedy the existing problems with inadequate cover.

8. Check Structures

Throughout the Cañon Canal, several check structures are located to promote the diversion of irrigation flows into individual turnout structures or lateral headgates (structure utilized to divert water for multiple users). While it is understood that the individual turnout structures are the responsibility of the landowners, the maintenance associated with the check structures was assumed to rest with the WID. During the field investigation, check structures were identified at the following locations:

- Station 142+20
- Station 149+00
- Station 176+20
- Station 186+70
- Station 295+20
- Station 313+20
- Station 339+80
- Station 491+80
B. **Cañon Canal, Continued**

The structures located at Stations 149+00, 176+20 and 186+70 are in poor condition and should be replaced. At Stations 142+20 and 313+20, the check structures are in fair to poor condition and replacement for these structures is also recommended. The structures at Stations 295+20, 339+80 and 491+80 are in fair to good condition and require placement of additional rock riprap to existing or potential erosion/stability problems.

9. **Canal Crossings**

Canal crossing structures are categorized as any structure which crosses over or under the canal. These structures include access bridges or culverts which convey flow from drainages which cross the canal. Canal crossing structures were located at:

- Station 97+10  Station 226+40
- Station 119+70  Station 249+80
- Station 212+60  Station 333+50

Bridge crossings of the canal occur at Stations 97+10, 119+70 and 333+50. In general, bridge crossings are in good condition with the exception of the bridge at Station 333+50. Minimal to moderate bank protection is warranted at all locations to stabilize existing bank erosion and ensure the long-term stability of the bridge crossings.
B. Cañon Canal, Continued

At Stations 212+60, 226+40 and 249+80, culverts are located to convey cross drainage beneath the canal. Overall, these crossings are in good condition with only minor rehabilitation of the culvert outlets required. It is recommended that the culvert outlets be stabilized with rock riprap to mitigate existing or potential scour at the outlets.

C. Dutton Ditch

A preliminary exploration/inventory of the facilities associated with the Dutton Ditch was completed at the request of the WWDC. These facilities included the outlet facilities and canal from King Reservoir No. 1, Dutton Creek Reservoir supply canal and outlet facilities, and the structures associated with Dutton Ditch. As indicated previously, the purpose of this work was to: (a) assess the condition of the existing facilities; and (b) identify major deficiencies which may prevent, limit or reduce the diversion of irrigation water conveyed by the Cañon Canal into the Dutton Ditch and ultimately into the Laramie River.

The water diverted into the Dutton Ditch is derived from several sources including: (a) Dutton Creek, (b) releases from King Reservoir No. 1, (c) releases from Dutton Creek Reservoir, and (d) water diverted from Cañon Canal into Seepage Ditch and into either Dutton Creek or Dutton Creek Reservoir. The Dutton Ditch originates at the diversion structure and headgate on Dutton Creek which is located in Section 10, Township 19 North, Range 76 West. From this location, the ditch conveys irrigation water in an easterly direction approximately 11 miles across U.S. Highway 287 and ultimately into the Laramie River.

Several structures were inventoried during the field investigation of the Dutton Ditch. King Reservoir No. 1 and Dutton Creek Reservoir. These structures included the following:
C. **Dutton Ditch**, Continued

1. King Reservoir outlet pipe and outlet canal;
2. Dutton Creek Reservoir supply canal and diversion structure;
3. Dutton Creek Reservoir outlet pipes and outlet channel;
4. Dutton Ditch diversion structure and headgate;
5. Dutton Ditch including concrete-lined and unlined portions of the ditch;
6. Dutton Ditch outfall pipe into the Laramie River;
7. two siphons within the Dutton Ditch;
8. two gaging stations and measuring devices along the Dutton Ditch;
9. two wasteway structures within Dutton Ditch;
10. eleven ditch crossing structures (siphons and culverts);
11. three access bridges crossing the Dutton Ditch; and
12. four stock crossing structures.

Table 2 presents a summary of the inventory results of the Dutton Ditch, King Reservoir No. 1 and Dutton Creek Reservoir. Plates 7 through 13 in Appendix B illustrate the location of the facilities which were identified and inventories during the field exploration.
Table 2. Summary of Structure Inventory for the Dutton Ditch.

<table>
<thead>
<tr>
<th>Station</th>
<th>Description of Structure</th>
<th>Condition/Comments</th>
<th>Remaining Design Life</th>
</tr>
</thead>
<tbody>
<tr>
<td>0+00</td>
<td>Dutton Creek Diversion Structure and Canal Headgate</td>
<td>The overall structure is in good condition. Dutton Creek sand and gravels deposited in structure.</td>
<td>15 to 25 years</td>
</tr>
<tr>
<td>6+50</td>
<td>Canal Gaging Station</td>
<td>The gage housing in fair condition. The concrete lining is in poor condition, especially left bank where slab failures have occurred.</td>
<td>less than 5 years</td>
</tr>
<tr>
<td>47+70</td>
<td>Culvert Crossing</td>
<td>The culvert crossing is in good condition. Minor pipe segment separation and erosion at outlet.</td>
<td>5 to 15 years</td>
</tr>
<tr>
<td>58+10</td>
<td>Bridge Crossing</td>
<td>The wooden structure is in good to excellent condition.</td>
<td>5 to 15 years</td>
</tr>
<tr>
<td>58+60</td>
<td>Stock Crossing</td>
<td>The stock crossing is in poor condition. Upstream and downstream head walls are cracked. Downstream headwall has failed and collapse is imminent.</td>
<td>less than 5 years</td>
</tr>
<tr>
<td>95+00 to 97+60</td>
<td>Concrete Lining Failure/Temporary Earth-Lined Ditch</td>
<td>The original concrete lining has failed. The temporary earth-lined channel is in fair condition.</td>
<td>less than 5 years</td>
</tr>
<tr>
<td>97+00</td>
<td>Culvert Crossing</td>
<td>The culvert crossing pipe is in good condition. Approximately 6 inches of sediment deposition throughout pipe.</td>
<td>5 to 15 years</td>
</tr>
<tr>
<td>111+10</td>
<td>Stock Crossing</td>
<td>The stock crossing is in fair condition. The headwalls are cracked and stable. Previous repairs still in place.</td>
<td>5 to 15 years</td>
</tr>
<tr>
<td>132+20</td>
<td>Culvert Crossing</td>
<td>The culvert is in excellent condition.</td>
<td>15 to 25 years</td>
</tr>
<tr>
<td>136+10</td>
<td>Stock Crossing</td>
<td>The stock crossing is in fair condition. The headwalls are cracked and stable.</td>
<td>5 to 15 years</td>
</tr>
<tr>
<td>137+20</td>
<td>Bridge Crossing</td>
<td>The wooden structure is in excellent condition.</td>
<td>5 to 15 years</td>
</tr>
<tr>
<td>172+50</td>
<td>Culvert Crossing</td>
<td>The RCP siphon is in good condition. The outlet is approximately 3/4 buried.</td>
<td>5 to 15 years</td>
</tr>
<tr>
<td>174+90</td>
<td>Stock Crossing</td>
<td>The stock crossing is in poor condition. Both headwalls are cracked. The downstream headwall has failed but not collapsed.</td>
<td>less than 5 years</td>
</tr>
</tbody>
</table>
Table 2. Summary of Structure Inventory for the Dutton Ditch (continued).

<table>
<thead>
<tr>
<th>Station</th>
<th>Description of Structure</th>
<th>Condition/Comments</th>
<th>Remaining Design Life</th>
</tr>
</thead>
<tbody>
<tr>
<td>190+70</td>
<td>Bridge Crossing</td>
<td>The wooden structure is in excellent condition.</td>
<td>5 to 15 years</td>
</tr>
<tr>
<td>204+60</td>
<td>Culvert Crossing</td>
<td>The culvert pipe is in good condition.</td>
<td>5 to 15 years</td>
</tr>
<tr>
<td>235+40</td>
<td>Stock Crossing</td>
<td>The stock crossing is in poor condition. The headwalls are cracked and leaning into</td>
<td>less than 5 years</td>
</tr>
<tr>
<td></td>
<td></td>
<td>the crossing. Water getting behind channel lining at headwalls may be promoting</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>downstream lining failures.</td>
<td></td>
</tr>
<tr>
<td>257+20</td>
<td>Siphon Inlet and Wasteway (Left)</td>
<td>The siphon and wasteway inlet are in excellent condition. The wasteway is in good</td>
<td>Siphon Inlet:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>condition. Wasteway channel and stilling basin contain sediment deposits and</td>
<td>15 to 25 years</td>
</tr>
<tr>
<td></td>
<td></td>
<td>vegetation. Wasteway stilling basin headwall concrete eroded with exposed rebar.</td>
<td>Wasteway:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5 to 15 years</td>
</tr>
<tr>
<td>262+70</td>
<td>Siphon Outlet</td>
<td>The concrete siphon outlet is in excellent condition. Minor downstream erosion.</td>
<td>15 to 25 years</td>
</tr>
<tr>
<td>305+90</td>
<td>Bridge Crossing</td>
<td>The wooden structure is in good condition. The abutments are unprotected. The left</td>
<td>less than 5 years</td>
</tr>
<tr>
<td></td>
<td></td>
<td>abutment has minimal overlap on earthen bank.</td>
<td></td>
</tr>
<tr>
<td>307+50</td>
<td>Culvert Crossing</td>
<td>The culvert crossing is in poor condition. The pipe outlet is completely</td>
<td>less than 5 years</td>
</tr>
<tr>
<td></td>
<td></td>
<td>obstructed with sediment. Possible overtopping flows have eroded downstream banks.</td>
<td></td>
</tr>
<tr>
<td>335+40</td>
<td>Culvert Crossing</td>
<td>The siphon structure is in poor condition. The 24&quot; CMP is completely plugged with</td>
<td>less than 5 years</td>
</tr>
<tr>
<td></td>
<td></td>
<td>sediment. Left canal bank eroding due culvert overflows.</td>
<td></td>
</tr>
<tr>
<td>351+00</td>
<td>Culvert Crossing</td>
<td>The siphon structure is in fair condition. Cross drainage banks vegetated and</td>
<td>5 to 15 years</td>
</tr>
<tr>
<td></td>
<td></td>
<td>stable, approximately 3 foot headcut noted 50 feet downstream of outlet.</td>
<td></td>
</tr>
<tr>
<td>365+50</td>
<td>Culvert Crossing</td>
<td>The siphon structure is in good condition. Minor erosion at inlet.</td>
<td>5 to 15 years</td>
</tr>
<tr>
<td>418+30</td>
<td>Culvert Crossing</td>
<td>The culvert structure is in good condition.</td>
<td>5 to 15 years</td>
</tr>
</tbody>
</table>
Table 2. Summary of Structure Inventory for the Dutton Ditch (continued).

<table>
<thead>
<tr>
<th>Station</th>
<th>Description of Structure</th>
<th>Condition/Comments</th>
<th>Remaining Design Life</th>
</tr>
</thead>
<tbody>
<tr>
<td>440+10</td>
<td>Culvert Crossing</td>
<td>The culvert structure is in good condition.</td>
<td>5 to 15 years</td>
</tr>
<tr>
<td>470+70</td>
<td>Bridge Crossing, Check Structure and Wasteway (Right)</td>
<td>The check and wasteway structures are in good condition. The wooden bridge and abutments are in good to poor condition. Structural integrity of bridge may be questionable.</td>
<td>Check and Wasteway: 15 to 25 years Bridge: less than 5 years</td>
</tr>
<tr>
<td>484+50</td>
<td>Siphon Inlet</td>
<td>The entrance box and trash rack are in good condition with only minor cracking of concrete.</td>
<td>15 to 25 years</td>
</tr>
<tr>
<td>492+40</td>
<td>Siphon Outlet</td>
<td>The concrete siphon outlet box is in good condition.</td>
<td>15 to 25 years</td>
</tr>
<tr>
<td>492+60 to 498+80</td>
<td>Concrete Lining Downstream of U.S. Highway 30</td>
<td>The lining is overall in good condition. The termination at 498+80 has erosion behind right bank slab and along downstream earthen banks.</td>
<td>less than 5 years</td>
</tr>
<tr>
<td>518+00</td>
<td>Stock Crossing</td>
<td>The stock crossing is in fair condition.</td>
<td>5 to 15 years</td>
</tr>
<tr>
<td>557+00</td>
<td>Stock Crossing</td>
<td>The stock crossing is in fair condition.</td>
<td>5 to 15 years</td>
</tr>
<tr>
<td>560+50 to 581+70</td>
<td>Concrete Lining Upstream of Laramie River</td>
<td>The lining is in good condition.</td>
<td>15 to 25 years</td>
</tr>
<tr>
<td>562+60</td>
<td>Gaging Station</td>
<td>The gaging station is in good condition.</td>
<td>15 to 25 years</td>
</tr>
<tr>
<td>581+80</td>
<td>Drop Pipe Inlet</td>
<td>The concrete inlet box is in excellent condition.</td>
<td>15 to 25 years</td>
</tr>
<tr>
<td>582+70</td>
<td>Drop Pipe Outlet</td>
<td>The 48&quot; CMP outlet pipe and concrete anchor weight are in good condition.</td>
<td>15 to 25 years</td>
</tr>
</tbody>
</table>
The following sections describe preliminary alternative plans for rehabilitating Sand Lake Dam and Cañon Canal. The estimated costs associated with each alternative plan are our opinion of probable preliminary construction costs with a 40 percent markup to allow for contingencies and engineering design costs.

A. **Sand Lake Dam**

   Based on our observations and the operational history of the dam and reservoir, it is our opinion that the existing dam and spillway configuration are probably adequate most of the time. When certain climatic conditions occur, the spillway is prone to blowing full of snow and if coupled with a significant snow melt and operational constraints (i.e. closed outlet gate), the spillway can malfunction and the reservoir can overtop. This overtopping occurred previously in 1973 and now again in 1995. While it does not appear to occur regularly, improvements to operational procedures should be implemented to prevent the reservoir from not being able to drain. Based on our preliminary review of the existing structures and the current problems, it does not appear to be practical to perform improvements to the existing emergency spillway to prevent it from becoming blocked with snow. We have developed the following alternatives for rehabilitation of the Sand Lake Dam that address other methods of preventing the reservoir from overtopping.

   The preliminary alternatives to the rehabilitation of Sand Lake Dam included the following:

   - Installation of a remote telemetry system to control the outflow from the reservoir. This alternative assumes repair of the existing breach location.
   - Construction of a new spillway within the dam embankment. Armoring protection may include roller compacted concrete (RCC), revetment blocks, or other revetment materials.
   - Stabilize the dam in the vicinity of the breach and reclaim the dam and outlet facilities.
A. Sand Lake Dam, Continued  

Alternative A-Installation of a Remote Telemetry System

This alternative involves the installation of a remote telemetry system to control the outflow from the reservoir. The installation includes the following items:

- Installation of all hardware and software necessary to monitor the water level in the reservoir and flow in the outlet pipe.
- Installation of a stilling well in the dam embankment to monitor the water level in the reservoir.
- Installation of a flow meter in the outlet pipe along with a gate valve and motor for operation of the gate. A housing unit will also be required for this equipment.
- Placement of a solar-powered energy source at Sand Lake along with a radio antenna.
- Repair of the existing dam breach.

Remote operation of the reservoir will continuously monitor the water level as it rises during the spring. As the water level rises to within a foot of the existing spillway invert, the gate valve could release up to 100 cfs through the outlet pipe or an equivalent of approximately 200 acre-feet per day. Since the recorded capacity of the existing reservoir is approximately 1,105 acre-feet, the potential release of 200 acre-feet in one day is considered reasonable. Should the energy source fail or mechanical failure occur, this information will be immediately obvious to the WID. Daily monitoring of the water level is possible via a computer in the office of the WID and should the water level rise during the weekend, a telephone alarm system would notify the responsible parties at WID. Given that the water level would need to rise 5 to 6 feet before breaching the dam embankment and assuming a day for the maintenance crews from WID to respond to the situation, either the valve could be manually operated or the remote system repaired. It
A. Sand Lake Dam, Continued

is considered unlikely that the reservoir water level would rise 5 to 6 feet before the WID could respond to the situation. The key to this system is that continuous monitoring of the water level in the reservoir will occur thereby providing ample response time for maintenance or manual operation of the gate valve before a dam breach occurs.

The estimated cost of the proposed improvements associated with Alternative A is itemized below.

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Installation of remote telemetry system</td>
<td>$30,000</td>
</tr>
<tr>
<td>Flow meter purchase and Installation</td>
<td>$5,000</td>
</tr>
<tr>
<td>Housing for valve/flow meter</td>
<td>$15,000</td>
</tr>
<tr>
<td>Repair of dam breach</td>
<td>$27,000</td>
</tr>
</tbody>
</table>

Subtotal $77,000

Installation of a remote telemetry system provides for continuous monitoring of the water level in the reservoir. In addition, releases from the reservoir can be easily measured and tabulated to improve the accounting procedures for both the WID and the State Engineer’s Office. The risk of overtopping or breaching the dam embankment is reduced by the continuous monitoring of the water level. Should a malfunction or mechanical failure occur in the system, response time to correct the malfunction can be determined to ensure that manual operation of the release valve is possible.

The disadvantage of solely installing the remote telemetry system is directly related to response time to correct potential malfunctions in the system. Should the WID be unable to travel to the site and manually operate the release valve prior to overtopping the dam embankment, failure or breach of the embankment will occur. Given the seasonal inflows to the reservoir during the months of May and June, however, coupled with the available storage above the invert of the emergency spillway (estimated to be in excess of 500 acre-feet), several days of inflow may be required before the dam embankment is overtopped.
A. Sand Lake Dam, Continued

Alternative B-Installation of a Remote Telemetry System with 36-inch Outlet Pipe

This alternative assumes installation of the remote telemetry system with replacement of the existing outlet pipe for the reservoir. Placement of a larger outlet pipe will increase the discharge through the pipe and release a greater volume of water in a day. Replacement of the existing 30-inch outlet pipe with a 36-inch pipe would increase the peak discharge from the reservoir from approximately 100 cfs to 140 cfs. The enlarged outlet pipe would increase the volume of water released from the reservoir from 200 acre-feet to 280 acre-feet during the first day of operation. Replacement of the outlet pipe will release more water through the reservoir during the first day and will reduce the risk of overtopping to a greater extent. Providing this reduction in risk will result in a $21,000 increase in project costs. Therefore, the total estimated cost for the Alternative B is $98,000.

Alternative C-Construct a Spillway in the Dam

This alternative involves constructing a spillway within the dam itself, most likely near the location of the existing breach. The purpose of a spillway channel within the dam would be to allow spillage of water from the reservoir under those conditions when the existing emergency spillway is blocked. The spillway could be constructed of cast-in-place concrete, roller compacted concrete (RCC), or armor block. Consideration should be given to constructing the spillway with dark or black materials, to encourage solar heat retention and promote melting of snow and ice.

The estimated cost of the proposed improvements associated with Alternative C is itemized below.

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Earthwork</td>
<td>$20,000</td>
</tr>
<tr>
<td>Construct Spillway</td>
<td></td>
</tr>
<tr>
<td>Concrete</td>
<td>$29,000</td>
</tr>
<tr>
<td>RCC</td>
<td>$65,000</td>
</tr>
<tr>
<td>Armor Block</td>
<td>$27,000</td>
</tr>
</tbody>
</table>

Subtotal $47,000 to $85,000
A. Sand Lake Dam, Continued

This alternative could be utilized with either Alternatives A or B, above, and would give additional safety in operation of the dam to prevent an overtopping event to occur. Such a spillway structure would be significantly easier to keep free of blown snow, primarily because of its relatively short flow length. A dark or black color would also encourage the melting of snow or ice that did accumulate. In addition, the construction of the spillway could coincide with the location of the existing breach, simplifying construction.

The disadvantage of an in-dam spillway is the added cost of construction. However, the long-term benefit of being able to spill more water and reduce the potential for overtopping the dam should provide an offset against the costs.

Alternative D-Stabilize the Breach and Abandon the Dam

This alternative includes abandoning the dam, and no longer using the reservoir for impoundment of irrigation water. In order to properly abandon the dam, the entire dam and spillway structure would need to be removed and the area returned to original conditions.

The estimated cost of this alternative is itemized below.

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Earthwork</td>
<td>$56,000</td>
</tr>
<tr>
<td>Seeding</td>
<td>$8,000</td>
</tr>
</tbody>
</table>

Subtotal $64,000

As can be seen, this is the least costly alternative, however, the additional impact of this alternative is a potential loss of irrigation water. Secondary losses include the loss of recreation opportunities.
B. Cañon Canal

The inventory of the Cañon Canal identified several deficiencies in the existing facilities from the headgate on Rock Creek to the inlet to King Reservoir No. 1. This discussion of alternative improvements is limited to the rehabilitation of the major deficiencies within the system. Alternative improvements to correct both major and minor deficiencies have been identified and are included in the list of improvements in Table 3.

1. Station 60+00 to 83+40 and Slide Area

This reach of canal is located adjacent to the slide area. Based on our subsurface exploration, a review of the geologic information available for the area and our observations, it appears that the Cañon Canal landslide is driven by a combination of factors and appears to consist of several discrete zones of movement. (A preliminary geologic report is enclosed in Appendix C). The upper slide appears to be the result of movement of a mass of soil on a highly plastic clay layer. The movement occurs when enough moisture infiltrates the subsurface and reduces the shear strength of the clay. The lack of moisture currently observed indicates that the upper slide is likely relatively stable at the present time. Repair of the slide should consider limiting future moisture into the clay zone and increasing the shear strength of the clay. The lower slide appears to be the result of plastic flow of the soils when saturated. The combination of regional groundwater and leakage from the canal appears to be enough to saturate the soils below the canal to a significant distance from the canal. Repair of the slide in this area should consider controlling leakage from the canal or providing some method of subsurface drainage thereby increasing the strength of the subsoils. With these conclusions in mind, we have developed the following preliminary rehabilitation alternatives.

a. Reshaping the existing alignment of Cañon Canal along with installation of a geomembrane liner to prevent seepage losses.

b. Reshaping the existing alignment of Cañon Canal along with installation of a clay liner to prevent seepage losses.

c. Replacement of the canal section with a pipe.
Table 3. Summary of Recommended Improvements for the Cañon Canal.

<table>
<thead>
<tr>
<th>Station</th>
<th>Description of Structure</th>
<th>Recommended Improvements</th>
<th>Estimated Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0+00</td>
<td>Rock Creek Diversion Structure and Canal Headgate</td>
<td>Replace the angled weir segment near the headgate. Replace the concrete exit apron with a structural concrete apron and provide downstream riprap bed protection.</td>
<td>15,000</td>
</tr>
<tr>
<td>2+00</td>
<td>Canal Gaging Station</td>
<td>Install a Cipoletti Weir at the existing concrete sill and relocate the instrument housing downstream at the weir.</td>
<td>15,000</td>
</tr>
<tr>
<td>60+00 to 83+40</td>
<td>Earth-lined Canal Through Slide Area</td>
<td>Four improvement options: (A) install a geomembrane liner; (B) install a clay liner; (C) replace the open channel with a transmission pipe; (D) re-align the canal; (E) subsurface drainage along canal; (F) stabilize upper slide with regrading; and (G) stabilize upper slide with chemicals.</td>
<td>(A) 235,000</td>
</tr>
<tr>
<td>97+10</td>
<td>Bridge Crossing</td>
<td>Re-grade the local drains away from the bridge and provide rock protection for the drain outfalls to the canal.</td>
<td>500</td>
</tr>
<tr>
<td>109+40</td>
<td>One Mile Creek Diversion Structure</td>
<td>Replace and re-locate the temporary diversion structure and headgate with a permanent structure to serve as a diversion, headgate, and to pass One Mile Creek over or under the canal.</td>
<td>44,000</td>
</tr>
<tr>
<td>109+40</td>
<td>One Mile Creek Flume Over Canal</td>
<td>Abandon and remove.</td>
<td>2,000</td>
</tr>
<tr>
<td>119+70</td>
<td>Bridge Crossing</td>
<td>Stabilize banks downstream of bridge.</td>
<td>4,000</td>
</tr>
<tr>
<td>127+30</td>
<td>Interstate 80 Bridge Crossings</td>
<td>Re-grade and a stabilize the local drain outfall to the canal on the right bank at the upstream end of the gabion bank protection.</td>
<td>1,000</td>
</tr>
<tr>
<td>140+20</td>
<td>Turnout Structure</td>
<td>Remove vegetation and sediment deposits at turnout entrance.</td>
<td>200</td>
</tr>
<tr>
<td>142+20</td>
<td>Check and Turnout Structure</td>
<td>Replace the check structure and footbridge.</td>
<td>5,000</td>
</tr>
<tr>
<td>149+00</td>
<td>Check and Turnout Structure</td>
<td>Replace the check structure and footbridge.</td>
<td>5,000</td>
</tr>
<tr>
<td>176+20</td>
<td>Check and Turnout Structure</td>
<td>Replace the check structure and footbridge.</td>
<td>5,000</td>
</tr>
</tbody>
</table>
Table 3. Summary of Recommended Improvements for the Cañon Canal (continued).

<table>
<thead>
<tr>
<th>Station</th>
<th>Description of Structure</th>
<th>Recommended Improvements</th>
<th>Estimated Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>186+70</td>
<td>Check and Turnout Structure</td>
<td>Replace the check structure.</td>
<td>5,000</td>
</tr>
<tr>
<td>226+40</td>
<td>Culvert Crossing</td>
<td>Install rock apron for protection at the culvert outlet.</td>
<td>2,000</td>
</tr>
<tr>
<td>249+80</td>
<td>Culvert Crossing</td>
<td>Re-form scour hole and lining with rock.</td>
<td>4,000</td>
</tr>
<tr>
<td>209+10 to 272+60</td>
<td>Concrete Lining Along Interstate 80 (four segments)</td>
<td>Place a rock apron and rock bank protection at the upstream and downstream end of each segment of concrete.</td>
<td>12,000</td>
</tr>
<tr>
<td>271+10</td>
<td>Three Mile Creek Diversion Structure</td>
<td>Seal the concrete seams between the structure and the box culvert under I-80. Remove the vegetation and sediment from the structure.</td>
<td>500</td>
</tr>
<tr>
<td>272+60</td>
<td>Downstream End of Concrete Lining Along Interstate 80</td>
<td>Remove approximately 100 feet of the failed concrete lining, re-shape the channel section, and install approximately 150 lineal feet of rock canal lining.</td>
<td>25,000</td>
</tr>
<tr>
<td>295+20</td>
<td>Check and Turnout Structure</td>
<td>Provide rock protection at the downstream end of the existing concrete apron. Remove sediment deposits from the entrance to the turnout structure.</td>
<td>500</td>
</tr>
<tr>
<td>313+20</td>
<td>Check and Turnout Structure</td>
<td>Replace both the check and turnout structures.</td>
<td>5,000</td>
</tr>
<tr>
<td>333+50</td>
<td>Bridge Crossing</td>
<td>Re-grade canal banks in the vicinity of the bridge and install rock bank protection.</td>
<td>2,000</td>
</tr>
<tr>
<td>339+80</td>
<td>Check and Turnout Structure</td>
<td>Install rock aprons at the upstream end of the concrete apron for both structures, and at the downstream end of the concrete apron for the turnout structure. Replace the sloping grouted apron downstream of the check structure with a sloping rock drop structure.</td>
<td>3,000</td>
</tr>
</tbody>
</table>
Table 3. Summary of Recommended Improvements for the Cañon Canal (continued).

<table>
<thead>
<tr>
<th>Station</th>
<th>Description of Structure</th>
<th>Recommended Improvements</th>
<th>Estimated Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>346+90</td>
<td>Pipe Drop Structure</td>
<td>Remove existing embankment and replace with a compacted, engineered embankment. Place rock protection on both the upstream and downstream faces of the embankment. Provide a rock apron at the downstream end of the pipe.</td>
<td>4,000</td>
</tr>
<tr>
<td>354+30</td>
<td>Pipe Drop Structure</td>
<td>Remove existing embankment and replace with a compacted, engineered embankment. Place rock protection on both the upstream and downstream faces of the embankment. Provide a rock apron at the downstream end of the pipe.</td>
<td>4,000</td>
</tr>
<tr>
<td>363+20</td>
<td>Pipe Drop Structure</td>
<td>Raise embankment and upstream canal banks. Place rock protection on the downstream face of the embankment.</td>
<td>3,000</td>
</tr>
<tr>
<td>388+00 to 406+00</td>
<td>Rock Drop Structures</td>
<td>Rehabilitate the 2 or 3 structures which are in danger of being flanked by keying them into the banks and locally stabilizing the banks.</td>
<td>6,000</td>
</tr>
<tr>
<td>417+70</td>
<td>Drop and Turnout Structure</td>
<td>Replace drop structure with a controllable check structure and sloping rock drop structure.</td>
<td>7,000</td>
</tr>
<tr>
<td>425+50</td>
<td>Pipe Drop Structure</td>
<td>Raise embankment and upstream canal banks. Place rock protection on the downstream face of the embankment.</td>
<td>3,000</td>
</tr>
<tr>
<td>485+50</td>
<td>Turnout Structure and Footbridge</td>
<td>Locally reconstruct the right bank with suitable compacted material and provide rock protection.</td>
<td>4,000</td>
</tr>
<tr>
<td>491+80</td>
<td>Check, Drop and Turnout Structure</td>
<td>Replace the existing concrete rubble bed protection downstream of the drop structure with engineered sloping rock drops and bed/bank protection.</td>
<td>10,000</td>
</tr>
<tr>
<td>551+60</td>
<td>Culvert Road Crossing</td>
<td>Replace the existing CMP, rehabilitate the downstream embankment, and provide rock bed and embankment protection downstream of the pipe.</td>
<td>50,000</td>
</tr>
</tbody>
</table>
B. Cañon Canal, Continued

d. Relocation of the existing canal.

e. Provide subsurface drainage adjacent to canal.

f. Stabilize upper slide zone with regrading.

g. Stabilize upper slide zone with chemicals.

Alternative A - Reshape Canal and Install Geomembrane Liner

This alternative includes reshaping or reconstruction of the Cañon Canal throughout the area of influence associated with the land slides. Earthwork associated with improving the canal geometry and profile will be completed. The earthwork will facilitate the placement of a geomembrane liner to prevent the seepage losses within the reach. The cost associated with construction of this alternative is itemized below.

| Earthwork       | $ 95,000 |
| Geomembrane Liner | $175,000 |

Subtotal $270,000

This alternative promotes canal stability by eliminating or reducing seepage losses from the canal. The flexible nature of the geomembrane liner will allow for minor movement of the underlying materials. The geomembrane liner will prevent encroachment by vegetation and will require less maintenance than a clay liner. Damage to the geotextile liner may occur if stock or wildlife access is allowed. Finally, this alternative is more costly to implement than alternatives which utilize clay lining materials.
B. Cañon Canal, Continued

Alternative B-Reshape Canal and Install Clay Liner

Similar to Alternative A, this alternative includes reshaping or reconstruction of the Cañon Canal throughout the area of influence associated with the recent land slides. Following the earthwork necessary to reshape the canal, a clay liner will be placed or clay material worked into the existing material to produce an relatively impervious canal section. Construction costs associated with the implementation of Alternative B are itemized below.

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Earthwork</td>
<td>$95,000</td>
</tr>
<tr>
<td>Placement of Clay Liner</td>
<td>$140,000</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td><strong>$235,000</strong></td>
</tr>
</tbody>
</table>

Similar to Alternative A, this alternative promotes canal stability by eliminating or reducing seepage losses from the canal. The clay liner also provides a degree of flexibility to allow for minor movement of the underlying materials. The cost of a clay liner is less than the geomembrane liner. The clay liner is less likely to be damaged by livestock or wildlife.

The geomembrane liner will prevent encroachment by vegetation and will require less maintenance than a clay liner. In addition, the clay liner is susceptible to cracking due to wetting and drying cycles and may require future replacement. Due to the increase in maintenance costs, the long-term cost of the clay liner may be equivalent or more than the long-term costs associated with placement of the geomembrane liner.
Alternative C- Replacement of the Canal Section with a Pipe

This alternative includes minor reshaping of the canal along with placement of a pipe(s) to convey the irrigation water and reduce the seepage. Due to the relatively flat gradient of the canal, the pipes required to convey the maximum diversion from Rock Creek were determined to be two 66-inch pipes. A flexible pipe is especially ideal for this project. Unfortunately, the commercial availability is limited for flexible pipe of this size with coupling devices that tightly seal the joints. Consequently, utilization of reinforced concrete pipe was assumed for this alternative. The cost associated with construction of this alternative is itemized below.

<table>
<thead>
<tr>
<th></th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Earthwork</td>
<td>$45,000</td>
</tr>
<tr>
<td>Transmission Pipe</td>
<td>$562,000</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td><strong>$607,000</strong></td>
</tr>
</tbody>
</table>

Similar to both Alternatives A and B, this alternative promotes canal stability by eliminating or reducing seepage losses from the canal. Maintenance costs associated with the pipe will be less than the liner alternatives. The rigid nature of the concrete pipe may lead to failure if significant movement of the foundation material occurs. With respect to construction cost, placement of concrete pipe is more expensive than either the geomembrane or clay liner alternative.

Alternative D-Relocation of the Existing Canal

This alternative involves realignment of a portion of the Cañon Canal from Station 73+00 to Station 90+00. The realigned canal will be initially directed to the south at Station 73+00 for approximately 500 feet. At this location, the realigned canal will be directed to the southeast to ultimately tie into the existing canal at Station

38
B. Cañon Canal, Continued

90+00. Upstream of Station 73+00, the canal will be reshaped and a geomembrane liner will be installed to reduce seepage as indicated by Alternative A. Due to the depth of the cut along the realigned canal, a liner may not be required and has not been included as part of this alternative. Construction costs associated with the implementation of Alternative D are presented below.

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Earthwork</td>
<td>$331,000</td>
</tr>
<tr>
<td>Geomembrane Liner</td>
<td>$98,000</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td><strong>$429,000</strong></td>
</tr>
</tbody>
</table>

The advantages and disadvantages of this alternative are similar to those listed for Alternative A. Unfortunately, the cost associated with the additional earthwork does not offset the reduction in lining costs. Consequently, Alternative D is more costly than Alternative A.

We also have initially evaluated the feasibility of relocating the canal completely out of the slide area. This is a desired alternative because of the anticipated difficulty and cost of stabilizing the slide. This relocation would possibly consist of relocating the canal from about Station 20+50 to about Station 120+50. However, several potential problems need to be resolved, including how to maintain gravity flow and how to pick up One Mile Creek diversion. We propose to evaluate this further under Phase II.

**Alternative E-Provide Subsurface Drainage Adjacent to Canal**

This alternative includes installing a subsurface drain to intercept ground-water flow below and adjacent to the canal. The subsurface drain would consist of a perforated PVC pipe installed adjacent to the canal on the downhill side. The drain would discharge to the surface at the east end of the slide. The estimated costs for this alternative are as follows.
This alternative would allow drainage of the toe area of the slide, thereby promoting stability of the soil mass. This alternative could be used in conjunction with one of the canal lining options above, or could be used with no lining improvements to the canal. Without other stabilization measures, the subsurface drainage may not adequately stabilize the canal itself from further movement.

Alternative F - Stabilize the Upper Slide Zone with Regrading
This alternative would attempt to reduce the potential for infiltration of precipitation into the head of the slide by regrading and closing the existing scarps and cracks. The estimated cost of regrading the heads of both the east and west slides is $25,000.

The effectiveness of this alternative is limited to reducing the potential for infiltration of surface water. It would not limit the recharge of the shear zone by other sources, such as from ground water. However, it is a relatively inexpensive alternative.

Alternative G - Stabilize the Upper Slide Zone with Chemicals
This alternative would involve adding chemicals, in this case hydrated, powdered lime, to the soils in the shear zone. Based on our preliminary geologic study of the slide, it appears that the upper slide is primarily moving on a highly plastic clay. Preliminary laboratory classification tests have shown that the clay may react to the addition of lime. While somewhat experimental, lime has been used successfully at other landslide sites. The clay soil-lime reaction causes a reduction in the soil plasticity, and an increase in shear strength.
B. Cañon Canal, Continued

Application of the lime is typically performed by a series of relatively closely spaced auger borings down to the shear zone, and loose dumping lime at that location. Based on the present information available for the slide, we anticipate that an area of approximately 500 feet by 400 feet on the eastern side and 250 feet by 250 feet on the western slide could be treated. The depth of the auger borings will likely range from 10 to 40 feet. The estimated cost of this alternative is $400,000.

While preliminary indications are that the shear zone clay will be reactive to a chemical such as lime, additional characterization of the clay is required to confirm that this alternative will be effective. This characterization includes determining the mineralogy of the clay and confirming the thickness and depth of the clay layer. Additional test borings can be used to confirm the thickness of the clay layer and a shallow seismic survey would be useful in confirming the depth of the clay. We would also propose to consult with others who have used these stabilization techniques to confirm the effectiveness of these methods for this particular slide.

Stream Diversion-Station 109+40

This improvement includes relocation and replacement of the existing diversion structure on One Mile Creek. The WID recently determined the value of the water available in One Mile Creek for diversion into the Cañon Canal. As much as 68 cfs is legally available for diversion by the WID. A temporary diversion structure and headgate presently diverts water from One Mile Creek and is not likely to remain intact during periods of high flows. The cost to install the stream diversion facilities is listed below.

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stream Diversion Structure</td>
<td>$25,000</td>
</tr>
<tr>
<td>Headgate</td>
<td>$19,000</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td><strong>$44,000</strong></td>
</tr>
</tbody>
</table>
B. Cañon Canal, Continued

Station 271+50 to 272+60

This improvement includes rehabilitation or replacement of the concrete lining immediately downstream of the Three Mile Diversion Structure (Station 271+10). The concrete lining is severely deteriorated and encroachment by willow and shrubs limits the capacity of the canal to convey irrigation water. Furthermore, erosion and scour adjacent to the canal threatens to undermine the integrity of the existing lining. The cost to replace/rehabilitate this section of the Cañon Canal are listed below.

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Removal of existing concrete</td>
<td>$3,000</td>
</tr>
<tr>
<td>Placement of a concrete liner</td>
<td>$22,000</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td><strong>$25,000</strong></td>
</tr>
</tbody>
</table>

Ringsby Ranch Transfer Gaging Station-Station 328+50

This improvements involves installation of a gaging station in the vicinity of the hydrologic divide at Station 328+50. The purpose of the gaging station will be to monitor/measure the transbasin transfer of water associated with the Ringsby Ranch Transfer. The costs associated with installation of the gaging station is presented below.

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete measuring device/weir</td>
<td>$8,000</td>
</tr>
<tr>
<td>Recording Device</td>
<td>$5,000</td>
</tr>
<tr>
<td>Housing/Stilling Well</td>
<td>$2,500</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td><strong>$15,500</strong></td>
</tr>
</tbody>
</table>

Drop Structure-Station 346+90

At Station 346+90, the existing pipe drop structure is in need of rehabilitation. Replacement/rehabilitation of the structure is warranted due to the piping and erosion problems that presently exist. Rehabilitation of the structure at Station 363+20 is recommended. The cost to rehabilitate the pipe drop structure is itemized below.
TASK 3. PRELIMINARY ALTERNATIVE PLANS, Continued

B. Cañon Canal, Continued

<table>
<thead>
<tr>
<th>Earthwork</th>
<th>$1,500</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pipe Materials</td>
<td>$2,500</td>
</tr>
</tbody>
</table>

Subtotal $4,000

Cañon Canal-Station 493+00 to 531+00

Within this reach of the canal, active erosion will continue to occur and the potential exists for massive bank failure at several locations along the canal. Immediately downstream of Station 493+00, installation of a grade control structure to ensure the long-term stability of the upstream canal, headgate and diversion structure is recommended. The costs associated with installation of the grade control structure are presented below.

- Earthwork/excavation $500
- Rock riprap $9,500

Subtotal $10,000

Cañon Canal-Station 551+60

At this location, Carbon County Road 15 crosses the Cañon Canal. Although it is understood that responsibility for replacement of this crossing does not rest with WID, potential loss of this structure would restrict the conveyance of water through the canal and into King Reservoir No. 1. Therefore, it is recommended that coordination with the Carbon County Highway Department be initiated to determine the time frame associated with rehabilitation of the crossing structure. The estimated costs for rehabilitation of this structure are presented below.

- Replacement of the 102-inch CMP $30,000
- Earthwork $10,000
- Rock riprap $10,000

Subtotal $50,000

INBERG-MILLER ENGINEERS
C. Dutton Creek

The inventory of the Dutton Ditch Facilities, King Reservoir No. 1 and Dutton Creek Reservoir was intended to identify major deficiencies which could potentially reduce or adversely impact the conveyance of water diverted by Cañon Canal into the Laramie River. The following paragraphs describe the major deficiencies associated with these facilities.

Outlet Pipe to Dutton Creek Reservoir

One of the existing outlet pipes for Dutton Creek Reservoir must be replaced. Until replacement of the outlet facilities occurs, the capability of the reservoir to store water will be limited. Rehabilitation of the outlet pipe may involve placement of a PVC or ductile-iron liner pipe within the existing clay pipe. The estimated cost of this rehabilitation effort is $15,000.

Dutton Ditch-Concrete Lining

Several sections of the concrete lining within Dutton Ditch are deteriorating. Failure of the concrete lining may lead to a canal breach at these locations. In general, several sections of the concrete lining should be replaced from Station 0+00 to Station 257+20. Although failure of these concrete-lined sections is not imminent, it is recommended that the concrete lining be replaced. The cost to replace the concrete lining is estimated to be $160,000.

TASK 4. PHASE I INTERIM REPORT AND MEETING

Based on our understanding of the estimated costs for implementing the preliminary alternative plans presented above, and our understanding of the needs of the WID, we have developed a prioritization of the alternatives. The prioritized list of alternatives recommended for rehabilitation of Sand Lake Dam are included in Table 4. The prioritized list of alternatives recommended for rehabilitation of Cañon Canal are included in Table 5.
Table 4. Prioritization of Recommended Improvements for Sand Lake Dam

<table>
<thead>
<tr>
<th>Item No.</th>
<th>Description of Structure</th>
<th>Recommended Improvements</th>
<th>Estimated Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Remote Sensing System</td>
<td>Install remote sensing system to monitor reservoir depths and control flow out of outlet pipe.</td>
<td>77,000</td>
</tr>
<tr>
<td>2</td>
<td>In-Dam Spillway</td>
<td>Construct a spillway in the dam to allow overflow through the spillway during times of high water levels.</td>
<td>47,000</td>
</tr>
<tr>
<td>3</td>
<td>Remote Sensing System with new 36&quot; Pipe</td>
<td>Install new 36&quot; outlet pipe to increase outlet capacity.</td>
<td>98,000</td>
</tr>
<tr>
<td>4</td>
<td>Abandon Dam</td>
<td>Stabilize existing breach and seed and riprap slopes for long term protection</td>
<td>16,000</td>
</tr>
<tr>
<td>Item No.</td>
<td>Station</td>
<td>Description of Structure</td>
<td>Recommended Improvements</td>
</tr>
<tr>
<td>---------</td>
<td>-----------</td>
<td>-----------------------------------------------------------------</td>
<td>------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>1</td>
<td>60+00 to 83+40</td>
<td>Line Canal Through Slide Area, Stabilize Slide</td>
<td>7 improvement options: (A) Install geomembrane liner; (F) Stabilize Upper Slide with Regrading; (G) Stabilize Upper Slide with Chemicals; (B) Subsurface drainage along canal; (D) Relocate canal; and (C) Pipe the canal.</td>
</tr>
<tr>
<td>2</td>
<td>109+40</td>
<td>One Mile Creek Diversion Structure</td>
<td>Replace and re-locate the temporary diversion structure and headgate with a permanent structure to serve as a diversion, headgate, and to pass One Mile Creek over or under the canal.</td>
</tr>
<tr>
<td>3</td>
<td>109+40</td>
<td>One Mile Creek Flume Over Canal</td>
<td>Abandon and remove</td>
</tr>
<tr>
<td>4</td>
<td>328+50</td>
<td>Ringsby Ranch Transfer Gaging Station</td>
<td>Construct Facility</td>
</tr>
<tr>
<td>5</td>
<td>491+80</td>
<td>Check, Drop and Turnout Structure</td>
<td>Replace the existing concrete rubble bed protection downstream of the drop structure with engineered sloping rock drops and bed/bank protection.</td>
</tr>
<tr>
<td>6</td>
<td>346+90</td>
<td>Pipe Drop Structure</td>
<td>Remove existing embankment and replace with a compacted, engineered embankment. Place rock protection on both the upstream and downstream faces of the embankment. Provide a rock apron at the downstream end of the pipe.</td>
</tr>
<tr>
<td>7</td>
<td>551+60</td>
<td>Culvert Road Crossing</td>
<td>Replace the existing CMP, rehabilitate the downstream embankment, and provide rock bed and embankment protection downstream of the pipe.</td>
</tr>
<tr>
<td>8</td>
<td>2+00</td>
<td>Downstream End of Concrete Lining Along Interstate 80</td>
<td>Remove approximately 100 feet of the failed concrete lining, reshape the channel section, and install approximately 150 lineal feet of rock canal lining.</td>
</tr>
<tr>
<td>9</td>
<td>2+00</td>
<td>Canal Gaging Station</td>
<td>Install a Cipoletti Weir at the existing concrete sill and relocate and instrument housing downstream at the weir.</td>
</tr>
<tr>
<td>Item No.</td>
<td>Station</td>
<td>Description of Structure</td>
<td>Recommended Improvements</td>
</tr>
<tr>
<td>---------</td>
<td>---------</td>
<td>--------------------------</td>
<td>--------------------------</td>
</tr>
<tr>
<td>9</td>
<td>0+00</td>
<td>Rock Creek Diversion Structure and Canal Headgate</td>
<td>Replace the angled weir segment near the headgate. Replace the concrete exit apron with a structural concrete apron and provide downstream riprap bed protection.</td>
</tr>
<tr>
<td>10</td>
<td>388+00 to 406+00</td>
<td>Rock Drop Structures</td>
<td>Rehabilitate the 2 or 3 structures which are in danger of being flanked by keying them into the banks and locally stabilizing the banks.</td>
</tr>
<tr>
<td>11</td>
<td>249+80</td>
<td>Culvert Crossing</td>
<td>Re-form scour hole and lining with rock.</td>
</tr>
<tr>
<td>12</td>
<td>339+80</td>
<td>Check and Turnout Structure</td>
<td>Install rock aprons at the upstream end of the concrete apron for both structures, and at the downstream end of the concrete apron for the turnout structure.</td>
</tr>
<tr>
<td>13</td>
<td>425+50</td>
<td>Pipe Drop Structure</td>
<td>Raise embankment and upstream canal banks. Place rock protection on the downstream face of the embankment.</td>
</tr>
<tr>
<td>14</td>
<td>354+30</td>
<td>Pipe Drop Structure</td>
<td>Remove existing embankment and replace with a compacted, engineered embankment. Place rock protection on both the upstream and downstream faces of the embankment. Provide a rock apron at the downstream end of the pipe.</td>
</tr>
<tr>
<td>15</td>
<td>209+10 to 272+60</td>
<td>Concrete Lining Along Interstate 80 (four segments)</td>
<td>Place a rock apron and rock bank protection at the upstream and downstream end of each segment of concrete.</td>
</tr>
</tbody>
</table>
A meeting was held on August 16, 1996 to review and discuss the Phase I Interim Report, that was dated August 16, 1996. In attendance at the meeting were representatives of the Project Sponsor, the Wheatland Irrigation District (WID), the WWDC, the Wyoming State Engineer's Office, the Wyoming Geological Survey and the Project Consultants. The meeting provided direction for the Phase II part of the project. In a letter dated August 23, 1996, the WWDC indicated that the Phase II Study should include:

Plans for Sand Lake Rehabilitation include;
1. Repair the dam breach,
2. Installation of an increased sized outlet structure,
3. Installation of an in-dam spillway, and
4. Installation of a remote sensing system.

Plans for Cañon Canal Slide Area Rehabilitation include;
1. Induced slide failure stabilization,
2. Slide surface regrading,
3. Channel realignment through slide area, considering;
   a. Open channel, and
   b. Pipe.

Plans for Cañon Canal Rehabilitation Include;
1. Cañon canal diversion,
2. One-Mile Creek diversion,
3. Ringsby Ranch transfer gaging station, and
TASK 5. GEOTECHNICAL ANALYSIS

A. Sand Lake Dam

1. Field Exploration

In our April 3, 1996 Proposal, we originally proposed to perform a total of 8 test borings in the vicinity of the dam; 4 along the existing dam embankment through the crest, and 4 in proposed borrow areas. This scope was developed in the Spring of 1996, before we could access the site to perform an initial reconnaissance. After our initial site visit in July of 1996, and discussion with the U.S. Forest Service, access by our drilling rigs to the dam was considered not possible. Because of the cultural importance of the area, the USFS is not allowing disturbance in the areas north of the dam and spillway, which effectively limits vehicular access to the dam. Access to the south side of the dam is limited to ATV access.

Because of limited access and concern over archeological disturbance, it was determined to limit the geotechnical study to collection of soil samples from the dam breach and from shallow hand auger borings in proposed borrow sites. In our opinion, the dam appears stable, and was breached from overtopping. Therefore, our analysis will concentrate on determining suitable materials to repair the breach. From the original design drawings of the dam, the borrow material used in the dam construction came from an excavation just west if the dam, on the upstream side.

On October 16, 1996, a total of 5 hand auger borings were performed in the previous borrow area to the west of the dam. The field work was performed in cooperation with the USFS to avoid areas designated as culturally important.

The soil samples were field classified by a geotechnical engineer, sealed in containers to prevent loss of moisture and returned to our laboratory. They were then re-inspected by the geotechnical engineer prior to the preparation of this report, and reclassified visually in accordance with ASTM D2487.
TASK 5. GEOTECHNICAL ANALYSIS, Continued

A. Sand Lake Dam, Continued

1. Field Exploration, Continued

A field log was prepared for each boring during hand augering. After the retrieved samples were checked in the laboratory, a Final Log for each boring was prepared which contained the work method, samples recovered and the indication of the presence of various soil types. Table 6 presents the logs of the hand auger borings. The transition between soil layers is typically gradual.

TABLE 6. LOGS OF HAND AUGER BORINGS - SAND LAKE DAM

<table>
<thead>
<tr>
<th>Boring No.</th>
<th>Depth</th>
<th>Soil Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>HA-1</td>
<td>0-14&quot;</td>
<td>Dark Brown Clayey SILT</td>
</tr>
<tr>
<td></td>
<td>14&quot;-30&quot;</td>
<td>Light Brown, Sandy CLAY, Some Gravel</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Auger refusal at 30&quot;</td>
</tr>
<tr>
<td>HA-2</td>
<td>0-17&quot;</td>
<td>Dark Brown, Clayey SILT, Occasional lenses of Light Brown, Silty, Fine Sand</td>
</tr>
<tr>
<td></td>
<td>17&quot;-23&quot;</td>
<td>Light Brown, Sandy CLAY, Some Gravel</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Auger refusal at 23&quot;</td>
</tr>
<tr>
<td>HA-3</td>
<td>0-16&quot;</td>
<td>Light Brown to Dark Brown, Silty SAND</td>
</tr>
<tr>
<td></td>
<td>16&quot;-23&quot;</td>
<td>Light Brown, Clayey SAND, Some Gravel</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Auger refusal at 23&quot;</td>
</tr>
<tr>
<td>HA-4</td>
<td>0-12&quot;</td>
<td>Dark Brown, Sandy SILT</td>
</tr>
<tr>
<td></td>
<td>12&quot;-20&quot;</td>
<td>Brown, Clayey SAND, Some Gravel</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Auger refusal at 20&quot;</td>
</tr>
<tr>
<td>HA-5</td>
<td>0-14&quot;</td>
<td>Dark Brown, Sandy SILT</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Auger refusal at 14&quot;</td>
</tr>
</tbody>
</table>

NOTE: Hand auger borings performed on October 15, 1996, by Inberg-Miller Engineers

2. Laboratory Testing Program

In order to classify the recovered samples and to determine their engineering properties, the following laboratory soil tests were performed:
A. **Sand Lake Dam.** Continued

2. **Laboratory Testing Program.** Continued

   1. Moisture Content (ASTM D2216)  
   2. Atterberg Limits (ASTM D4318)  
   3. Sieve Analysis (#4 to #200) (ASTM D422 and D1140)  
   4. Sieve Analysis (Hydrometer) (ASTM D1140)  
   5. Moisture-Density Analysis (ASTM D698)  
   6. Direct Shear Tests  
   7. Water Soluble Sulfate

The results of geotechnical engineering laboratory testing are presented in Table 7. The sieve and moisture density test results are included in Appendix F.

**TABLE 7. SUMMARY OF GEOTECHNICAL ENGINEERING LABORATORY TESTS - SAND LAKE DAM**

<table>
<thead>
<tr>
<th>Sample</th>
<th>Depth</th>
<th>W. %</th>
<th>LL</th>
<th>PL</th>
<th>PI</th>
<th>% #200</th>
<th>% Clay</th>
<th>WSS %</th>
<th>Max. D.D.</th>
<th>Opt. Moist.</th>
<th>c (psf)</th>
<th>φ (°)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HA-1-1</td>
<td>0-14&quot;</td>
<td>49.1</td>
<td>69</td>
<td>17</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HA-1-2</td>
<td>14-30&quot;</td>
<td>19.5</td>
<td>47</td>
<td>0.013</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HA-2-1</td>
<td>0-17&quot;</td>
<td>27.2</td>
<td>42</td>
<td>19</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HA-2-2</td>
<td>17-23&quot;</td>
<td>17.7</td>
<td>30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HA-3-1</td>
<td>16-23&quot;</td>
<td>11.7</td>
<td>30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HA-4-1</td>
<td>12-20&quot;</td>
<td>35.5</td>
<td>NP</td>
<td>43</td>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HA-5-1</td>
<td>0-14&quot;</td>
<td>41.5</td>
<td>NP</td>
<td>64</td>
<td>17</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spillway-1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dam-1</td>
<td>10.0'</td>
<td>28</td>
<td>10</td>
<td>41</td>
<td>18</td>
<td>119</td>
<td>10.0</td>
<td>1500</td>
<td>34.6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dam-2</td>
<td>12.5'</td>
<td>28</td>
<td>9</td>
<td>0.006</td>
<td>118.0</td>
<td>12.5</td>
<td>950</td>
<td>29.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3. **Soil Conditions-Dam**

The two samples of soil collected from the dam breach consist of a yellow and tan to brown, sandy clay. The measured Liquid Limit was 28 percent, and the plasticity index is 9 to 10 percent. The sandy clay has a minus 200 sieve fraction of 41 percent and a clay content of 18 percent. An SCS hydrometer test (performed without dispersing agents) performed on a sample of the sandy clay indicates that the sandy clay has a low dispersion potential.
A. **Sand Lake Dam, Continued**

4. **Soil Conditions-Borrow Area**

The soils revealed in the 5 hand auger holes revealed a surficial layer of sandy silt and clay overlying a sandy clay. The soils were underlain by similar materials, with numerous gravel and cobbles. The measured Liquid Limit ranged from 34 to 35 percent, and the plasticity index ranged from 10 to 12 percent. The sandy clay had a minus 200 sieve fraction of 42 percent and clay content of 19 percent.

5. **Stability Analysis**

A slope stability analysis was performed on the downstream slope of the Sand Lake Dam using Geo-Slope International's "SLOPE/W" stability analysis software. The stability analysis was performed using the "Modified Bishop's Method", assuming a circular failure surface. Both static and seismic stability analyses were performed. A seismic coefficient of 0.05g was used in the analyses, which, based on our review of existing seismic information, appears to be a reasonable coefficient for this site. The parameters for soils input for the dam and foundation materials were based on the information obtained from the subsurface exploration. The embankment is assumed to consist entirely of the yellow and tan to brown, sandy clay.

The stability analyses were performed for both high, overtopping and rapid draw-down water conditions. The high water elevation is the elevation of the existing emergency spillway, which results in a free-board of 5 feet. The overtopping water level simulates the condition that existed when the dam was overtopped in 1995. The rapid draw-down condition simulates what typically is the worse-case condition for an earthen dam, with high pore pressures and low strength.

The results of the stability analyses for the dam for both static and seismic conditions are tabulated below. Graphical results of the stability analyses are contained in Appendix G. The graphical results show the geometry of the models and the location of the slip surface for the minimum factors of safety.
A. Sand Lake Dam, Continued

<table>
<thead>
<tr>
<th>Ground-Water Conditions</th>
<th>Static Factor of Safety</th>
<th>Seismic Factor of Safety</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>4.4</td>
<td>3.9</td>
</tr>
<tr>
<td>Overtopping</td>
<td>3.8</td>
<td>3.4</td>
</tr>
<tr>
<td>Rapid Draw-down</td>
<td>4.9</td>
<td>4.1</td>
</tr>
</tbody>
</table>

B. Cañon Canal

A Geologic Study has been performed for the Cañon Canal Slide Area, summarized in a report dated August 16, 1996. A preliminary copy of the report was originally submitted as part of the Phase I Interim Report, and is included in this report in Appendix C.

1. Field Exploration
A total of ten (10) test borings were performed around the landslide using a truck-mounted drill rig on June 17 through 19, and June 26, 1996. A total of 7 ground-water monitoring wells were constructed in selected test borings, to monitor ground-water response. Additional details regarding the field exploration are included in the Geologic Report in Appendix C.

2. Laboratory Testing Program
Geotechnical engineering laboratory tests were performed on selected soil samples to classify the soils and provide engineering properties. The results of the testing are included in the Geologic Report in Appendix C.

3. Geologic Conditions
Please refer to the Geologic Report in Appendix C for a description of the geologic conditions at the slide site.
TASK 5. GEOTECHNICAL ANALYSIS, Continued

B. Cañon Canal

4. Stability Analysis

A slope stability analysis was performed in an attempt to simulate the forces acting in the slide zone. The analysis was performed using Geo-Slope International's "SLOPE/W" Stability analysis software. The analysis was performed by assuming the slope is 2 separate failures, a lower, rotational failure surface, and an upper, sliding block. The result of the analysis indicates that the slope is indeed unstable, based on the soil strength parameters selected. Graphical results of the stability analyses are contained in Appendix H.

TASK 6. SURVEYING

A. Sand Lake Dam

Surveying performed at Sand Lake Dam included a topographic survey of the existing dam, spillway and immediate vicinity. Cross-sections of the existing dam embankment and spillway were also measured. The results of the surveying are included on the Existing Conditions Drawings in Appendix D.

B. Cañon Canal

Surveying tasks performed at Cañon Canal included a centerline survey and cross-sections of the canal from the Rock Creek Diversion to Interstate 80. The base map of the slide area was generated from an existing aerial photograph by the Wyoming Department of Transportation and ground surveying. The results of the surveying are included in Appendix E.

TASK 7. CONCEPTUAL DESIGN

A. Sand Lake Dam

The conceptual design for Sand Lake Dam included evaluation of alternative materials for lining an in-dam spillway, research and selection of a remote sensing and control system to control the outlet gate, and develop design details. In addition, the Wyoming SEO Safety of Dams requested that a Dam Break analysis and Inundation Study be performed for Sand Lake Dam. The conceptual design was completed in sufficient detail to promote the estimation of unit costs and the development of total costs for the final design and construction of the project.
TASK 7. CONCEPTUAL DESIGN

A. Sand Lake Dam

Dam Break Analysis

A dam break analysis of Sand Lake was completed to support the conceptual design of the proposed improvements to the existing spillway and embankment. The analysis included the following: (a) determination/verification of the hazard classification associated with the existing structure; (b) determination of the capacity of the existing spillway structure; and (c) evaluation of alternative spillway improvements and their capability to meet the requirements promulgated by the State Engineer’s Office.

Hazard Classification

All water impounding structures in Wyoming are regulated by the State Engineer and Board of Control using rules set forth in “Rules and Regulations”. Currently the “Rules and Regulations” are under revision. A draft copy of Chapter 10, “Requirements for Dams and Diversion Systems Falling Under the Safety of Dams Law” (W.S. 41-3-307 through 41-3-318) obtained from the State Engineer’s Office was used for this analysis. The regulations in the aforementioned document will be referred to herein collectively as the “Dam Safety Rules” or “Rules”, and individually as a “Rule”.

The Rules define a dam as any artificial barrier, including appurtenant works, used to impound or divert water and which is or will be greater than twenty (20) feet in height or with an impounding capacity of fifty (50) acre-feet or greater. Based on the original design plans (Cole, 1955) the structure has a normal capacity of 1,105 acre-feet and therefore is considered a dam. The State Engineer’s Office has declared the Sand Lake Dam a Class I high hazard structure. No official hazard classification analysis has been completed on this structure. According to the Rules, a Class I dam is a dam for which loss of human life is expected in the event of failure of the dam. Loss of human life may be expected if the product of the average floodplain flow velocity and the depth of flooding is greater than seven.
A. Sand Lake Dam, Continued

**Dam Break Analysis, Continued**

An analysis was performed to determine the hazard classification of the Sand Lake Dam. There are three main steps to a hazard classification analysis:

1) Assume a dam failure scenario,
2) Determine the downstream terminal point of flood routing,
3) Perform the analytical flood modeling.

Typically a “sunny-day” failure is chosen for a hazard classification failure scenario. A “sunny-day” failure assumes the reservoir is at a normal pool level and receiving normal inflows. The failure mode may be an earthquake, structural weakness, piping, etc. The sunny-day failure for the Sand Lake Dam assumed a normal pool level at the crest of the emergency spillway, elevation of 10,131.5 feet above mean sea level (msl). Dam break and flood routing methods found in the United States Corps of Engineers (USACE) HEC-1 model were used to analyze the failure and subsequent flooding downstream. Flood routing was performed to a point approximately 12.5 miles downstream of the dam, terminating upstream of the Interstate 80 road embankment. This downstream limit includes the community of Arlington, Wyoming.

The reservoir stage-storage rating was obtained from a USACE (1979) analysis documented in the report entitled “Phase I Inspection Report Wheatland Reservoir”. Critical to any dam break analysis are the input parameters; time of failure and breach bottom width. Based on recommendations by Fread (1988) a failure time of 1.1 hours and a final breach bottom width of 62 feet were assumed. Additionally, 1 horizontal to 1 vertical side slopes were assumed for the breach opening.
A. Sand Lake Dam, Continued

**Dam Break Analysis, Continued**

Sand Lake released flows into Deep Creek which then confluences with Rock Creek approximately 4.8 miles downstream of the dam. Flows are then conveyed approximately 7.7 miles within Rock Creek into Arlington. The channel upstream of Arlington is contained within a narrow canyon in the Medicine Bow National Forest. Based on available mapping, aerial photos and field investigations (limited by access), there are no permanent structures upstream of Arlington. In Arlington, three habitable structures were identified as potentially impacted by Rock Creek flooding. Historic structures and/or uninhabitable structures were not considered in the hazard classification. Based on a surveyed cross section in Arlington and the results of the flood routing, one of these structures may be inundated by two or more feet during a “sunny day” failure. Average floodplain velocities in Arlington may be as high as 11.5 feet per second. Hazard Classification flood inundation limits in the vicinity of Arlington are shown in Figure 3. Based on these results and the information provided by the State Engineer’s Office, the Sand Lake Dam should continue to be classified as a Class I structure.

Under Rule Ch.10.3(e)(ii), Class I dams shall have spillways capable of passing, as a minimum, the inflow design flood (IDF) generated by the Probable Maximum Precipitation (PMP), unless an incremental damage/loss of life analysis (IDA) demonstrates a lesser IDF is applicable.

**Existing Spillway Capacity**

The existing Sand Lake Dam spillway consists of an 800-foot long earth channel. The channel was originally designed to be 40 feet in width with 3(H):1(V) side slopes. The channel is rock lined and three concrete cut-off walls have been installed to prevent erosion. The spillway and dam crests were originally designed to be at elevations of 10,131.5 ft, msl and 10,136.5 ft, msl respectively.
A. **Sand Lake Dam**, Continued

*Dam Break Analysis*, Continued

The existing spillway was analyzed by the USACE in their 1979 study. The results indicated a peak reservoir inflow of 7,699 cfs. The study utilized the stage-storage-discharge data shown in Table 8.

### TABLE 8. SAND LAKE STAGE-STORAGE-DISCHARGE DATA (USACE, 1979)

<table>
<thead>
<tr>
<th>Stage (feet, msl)</th>
<th>Storage (acres-feet)</th>
<th>Spillway Discharge (cfs)</th>
<th>Top Of Dam Discharge (cfs)</th>
<th>Note</th>
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</thead>
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<td>1,840.0</td>
<td>2,000.0</td>
<td>4,424.0</td>
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</tr>
</tbody>
</table>

Low Level Inlet At 10,117.2 ft, msl

Spillway Crest At 10,131.5 ft, msl

Dam Crest At 10,136.5 ft, msl

The results of the 1979 analysis indicate that approximately 70 percent of the Probable Maximum Flood (PMF) will pass the existing spillway before overtopping the dam.
To verify the 1979 results, an updated PMP was generated using methods found in HMR-55A (National Weather Service, 1988). The updated PMP was utilized in the HEC-1 model to generate a revised PMF with a 5-minute peak discharge of 8,441 cfs which was routed through the dam and existing spillway. Geometric input data for the dam were the same as those for the Hazard Classification. Stage-storage-discharge ratings used are shown in Table 8. The results indicate that the existing spillway can pass approximately 75 percent of the revised PMF.

Proposed Spillway Improvements

During repairs to the existing structure, an additional spillway will be constructed. The additional spillway is required for two purposes:

1. bring the structure into compliance with requirements to pass the full PMF, and
2. provide an alternate spillway to pass more frequent events when the existing spillway is blocked by ice and snow.

Due to the remote location of Sand Lake, the manually operated outlet facilities were assumed closed for this analysis. The proposed spillway was assumed to be located in the middle of the dam embankment. The crest of the proposed spillway was set at 10,131.5 ft, msl, similar to the crest of the existing spillway. Side slopes on the proposed spillway were assumed to be 1(H):1(V). Input parameters for the existing spillway and dam were the same as those used during analysis of the existing spillway.
A. Sand Lake Dam, Continued

Dam Break Analysis, Continued

The width of the proposed spillway was determined iteratively until the existing and proposed spillways could pass the PMF without overtopping the dam (maximum stage of 10,136.5 ft, msl). The analysis indicates a 40-foot wide spillway will provide the additional capacity to safely pass the PMF. The proposed 40-foot width could possibly be reduced by performing an Incremental Damage Analysis (IDA). The results of an IDA would indicate whether a reduction in spillway width coupled with the subsequent failure during the PMF would induce incrementally significant damages and loss-of-life downstream, when compared to the PMF routed downstream without a dam in place. Given the potential for blockage of the existing spillway by snow and ice, however, an IDA was not performed and it is recommended that the width of the proposed spillway be 40 feet.

Install 36-inch Diameter Outlet Pipe

As discussed in the Preliminary Alternative Plans, one alternative to increase discharge out of the reservoir in high runoff conditions involves replacing the existing 30-inch diameter outlet pipe with a new 36-inch diameter outlet pipe. Part of the economy in installing a new outlet pipe is the fact that the breach in the dam has already removed embankment materials almost down to the existing outlet pipe, so additional excavation will not be extensive. Details of the proposed 36-inch outlet pipe and appurtenances are included in Figures 4 and 5.

Install In-Dam Spillway

Another alternative developed in the Preliminary Alternative Plans includes constructing a spillway in the dam itself, near the location of the existing trench. The purpose of the in-dam spillway is to allow spillage of water from the reservoir under those conditions when the existing emergency spillway is blocked. Several alternative materials to line the
A. Sand Lake Dam, Continued

**Install In-Dam Spillway, Continued**

In-dam spillway were evaluated for protection provided to the embankment, ease of construction, and cost. Based on these criteria, we anticipate that the spillway can be lined with a cellular containment system, filled with concrete. A dark color should be included in the spillway design to encourage the melting of snow and ice that may accumulate. Details of the cellular containment system and the geometry of the in-dam spillway are included in Figures 4 and 5. In addition to installing an in-dam spillway, the crest of the dam should be leveled, and areas of downstream slope erosion should be repaired.

**Install Remote Sensing and Control System**

Another alternative developed in the Preliminary Alternative Plans involves installing a remote telemetry system to monitor the reservoir level and to control the outflow from the reservoir. The installation includes the following items:

- Installation of all hardware and software necessary to monitor the water level in the reservoir and flow in the outlet pipe.
- Installation of a stilling well in the dam embankment to monitor the water level in the reservoir.
- Installation of a flow meter in the outlet pipe along with a gate valve and motor for operation of the gate. A housing unit will also be required for this equipment.
- Placement of a solar-powered energy source at Sand Lake along with a radio antenna.
- Repair of the existing dam breach.

Remote operation of the reservoir will continuously monitor the water level as it rises during the spring. As the water level rises to within a foot of the existing spillway invert, the gate valve could release up to 100 cfs through the outlet pipe or an equivalent of
LEGENg

0 TP-1 TEST PITS PERFORMED BY INBERG-MILr
ENGINEERS ON OCTOBER 16, 1996.

INBERG-MILLER ENGINEERS
CONCEPTUAL DESIGN OF
IMPROVEMENTS SAND LAKE DAM

WYOMING WATER DEVELOPMENT COMMISSION
CONTRIBUTED BY BECKMANN, MILLER & COMPANY, INC.
TASK 7. CONCEPTUAL DESIGN, Continued

A. Sand Lake Dam, Continued

*Install Remote Sensing and Control System*, Continued

approximately 200 acre-feet per day. Since the maximum capacity of the existing reservoir is approximately 1,100 acre-feet, the potential release of 200 acre-feet in one day is considered reasonable. Should the energy source fail or mechanical failure occur, this information will be immediately obvious to the WID. Daily monitoring of the water level is possible via a computer in the office of the WID and should the water level rise during the weekend, a telephone alarm system would notify the responsible parties at WID. Given that the water level would need to rise 5 to 6 feet before breaching the dam embankment and assuming a day for the maintenance crews from WID to respond to the situation, either the valve could be manually operated or the remote system repaired. It is considered unlikely that the reservoir water level would rise 5 to 6 feet before the WID could respond to the situation. The key to this system is that continuous monitoring of the water level in the reservoir will occur thereby providing ample response time for maintenance or manual operation of the gate valve before a dam breach occurs.

B. Cañon Canal

Following the review of the information in the Phase I report, the District along with the WWDC provided direction for the conceptual design of selected improvements. The improvements selected for conceptual design can be divided into two areas: improvement of the canal through landslide and improvements to the canal in other areas.

Improvements to Cañon Canal through the landslide area, Stations 60+00 to 83+40, that have been identified include:

1. Induced slide failure,
2. Slide surface regrading,
3. Channel realignment through the side area using;
   a. Open Channel, and
   b. Pipe, and
4. Lining of the Canal.

65
B. Cañon Canal, Continued

In addition, given recent earthwork activities performed by the WID between the 1996 and 1997 irrigation seasons, we are considering lining the canal section through the landslide with a geomembrane liner.

**Induced Slide Failure**

This alternative was discussed during the Phase I meeting and includes attempting to cause the slide to fail, and when the sliding is completed, regrade the canal. The method to induce failure was considered to be water, which would be added to the upper reaches of the slopes toward the end of an irrigation season.

We have further evaluated the feasibility of inducing the landslide to fail, and generally must recommend against the approach. From an engineering viewpoint, the addition of large quantities of water on the slope may cause the slope to move. However, it may not. Furthermore, the movement of the slope may not be uniform in total movement or rate of movement. A basic concern is that by not having control over the movement, loss of property, and possibly personal injury, could occur. Therefore, we are not providing this as a viable alternative.

**Slide Surface Regrading**

The Geologic Report of the slide indicates that an increase in soil moisture likely caused a reduction in soil strength, which thereby failed under the weight of the slope. The soil movement has resulted in some sizeable cracks and scarps around the perimeter of the landslide. These cracks allow ready movement of infiltrating moisture from precipitation to enter the slope. This alternative includes regrading the areas of cracks and scarps in an attempt to reduce the potential for infiltration of water. Figure 6 illustrates the areas where this regrading would occur.
B. Cañon Canal, Continued

Slide Surface Regrading, Continued

The effectiveness of this alternative is limited to reducing the potential for infiltration of surface water on the upper reaches of the slope. It would not limit the recharge of the shear zone by other sources, such as from ground water or canal leakage.

Channel Realignment Through the Slide

Open Channel

This alternative involved relocating a portion of the canal. The section of canal that appears the most influenced by the landslide is from approximately Stations 75+00 to 86+00. Relocation of the canal to avoid this section would need to traverse through the hillside around which the canal currently passes, resulting in excavations of approximately 50 feet deep. Figure 7 shows the concept of cutting through the hill, and assumes final cut side slopes of 3H:1V. Additional geotechnical exploration will be required to determine subsurface conditions at those depths prior to final design of this alternative. Additional evaluation of slope stability of cut slopes as well as the influence of the landslide will also need to be performed.

Pipe

This alternative follows a similar route as the open channel alternative. This alternative includes 2, 66-inch diameter reinforced concrete pipes. Maximum final cover over the pipes is 25 feet. Figure 8 illustrates this alternative. As is the case with the open channel alternative, an additional geotechnical exploration and slope stability evaluation should be performed along the pipe alignment.
B. Cañon Canal, Continued

**Lining of the Canal**

This alternative includes the regrading of the canal from Station 60+00 to 80+00 and placing a geomembrane as a canal liner. The purpose of the liner is to reduce seepage of water out of the canal, which is considered an influence on the instability of the slope below the canal. A 40 mil HDPE liner is considered appropriate. The liner will be placed with intentional overlaps to allow built-in flexibility through future slope movements. A minimum of 1 foot cover of sandy gravel will be required to protect the liner. Figure 6 illustrates the stationing over which the canal should be lined, while Figure 9 shows a typical cross-section of the liner construction.

Improvements to Cañon Canal in other areas include the following:

1. Cañon Canal Diversion and Headgate Structure
2. Cañon Canal Gaging Station
3. One Mile Creek Diversion Structure
4. Ringsby Ranch Transfer Gaging Station
5. Cañon Canal Canyon Stabilization

The conceptual design for each improvement is discussed below.
FIGURE 9 LINER SECTION
STATION 60+00 TO 86+00
CAÑON CANAL

ANCHOR TRENCH (TYP.)

12" MIN SOIL COVER

40 mil. HDPE

INBERG-MILLER ENGINEERS
B. Cañon Canal, Continued

Cañon Canal Diversion and Headgate Structure (Station 0+00)

Rehabilitation of the existing diversion structure was limited to the angled portion of the weir located near the canal headgate. The upper one foot of concrete along this segment of the weir should be removed and replaced with a concrete cap. The concrete cap should be tied into the headwall/wingwall of the existing headgate structure. In addition, placement of large rock boulders at the proper location along the east bank of Rock Creek immediately upstream of the diversion structure is recommended. The rock boulders should direct the main flow path of Rock Creek to the center of the channel and existing weir. Finally, the canal section immediately downstream of the headgate structure should be lined with rock riprap to protect the canal bed and the concrete apron associated with the headgate. Figures 10, 11 and 12 provide details for the improvements to the Cañon Canal Diversion Structure.

Cañon Canal Gaging Station (Station 2+00)

A cipoletti weir will be installed at the same location as the existing gaging station. The improvements include: (a) a concrete weir section, (b) steel plate attached to the concrete weir, (c) rock riprap bed and bank protection, and (d) protective housing and all associated plumbing/piping requirements. Figure 13 provides conceptual details for the improvements to the gaging station.

One Mile Creek Diversion Structure (Station 109+40)

This structure is intended to divert a maximum of 68 cfs from One Mile Creek into the Cañon Canal. In addition, a headgate was integrated into the structure to serve a senior appropriator on One Mile Creek. A preliminary hydrologic analysis indicated that the 25-year peak discharge at this location is approximately 200 cfs. Consequently, the structure was designed to accommodate a design flow rate of 200 cfs.
FIGURE 10
ROCK CREEK HEADGATE AND DIVERSION STRUCTURE IMPROVEMENTS
PROPOSED CONCRETE WALL

EXISTING ABUTMENT AND WING WALL

EXISTING CONCRETE CAP

TOP EXISTING CONCRETE APRON

EXISTING CONCRETE WIER

REMOVE 1 - 2' OF EXISTING CONCRETE CAP

SECTION A-A

PLAN

FIGURE 11.
ROCK CREEK HEADGATE AND DIVERSION STRUCTURE IMPROVEMENTS - DETAILS

WATER RESOURCES AND ENVIRONMENTAL CONSULTANTS
SECTION B–B
NTS

SECTION C–C
NTS

FIGURE 12.
ROCK CREEK HEADGATE AND
DIVERSION STRUCTURE
IMPROVEMENTS - DETAILS
CONCRETE FOOTING ~ FOOTING ~ L1 ~
G WELL
PROPOSED CANAL CHANNEL SECTION (APPROX.)
13.4' 0', 44', <1', 1'

PLAN VIEW
N.T.S.

CONCRETE FOOTING
SHELTER/STILLING WELL

STEEL PLATE
PROPOSED CANAL CHANNEL SECTION (APPROX.)

WEIR SECTION
(LOOKING DOWNSTREAM)
N.T.S.

CHANNEL INVERT
3.0'
7.0'
1.0'

SECTION A-A'
N.T.S.

SHELTER/STILLING WELL
N.T.S.

FIGURE 13
GAGING STATION DETAILS
AT HEADGATE - STATION 2+00
CAÑON CANAL
B. Cañon Canal, Continued

Construction of this improvement will consist of: (a) removal of the existing diversion structure and headgate on One Mile Creek; (b) removal of the existing flume and culvert crossing on the Cañon Canal; (c) regrading of the diversion channel from One Mile Creek into the Cañon Canal; (d) channel improvements along One Mile Creek from the existing diversion structure to the Cañon Canal; (e) placement of a concrete chute over the Cañon Canal; and (f) placement of berms along the south bank of the Cañon Canal to capture the overbank flows from One Mile Creek; and (g) placement of rock riprap for channel stabilization immediately downstream of the structure. Figures 14 to 16 provide conceptual design details for the One Mile Creek Diversion Structure.

Ringsby Ranch Transfer Gaging Station (Station 328+50)

A cipolletti weir and gaging station will be installed at this location along the Cañon Canal. Similar to the improvements at Station 2+00, construction will include: (a) placement of a concrete weir section and steel plate attached to the concrete weir, (b) installation of rock riprap bed and bank protection, and (c) protective housing and all associated plumbing/piping requirements. Figure 17 provides conceptual details for the construction of the gaging station.

Cañon Canal Canyon Stabilization (Station 491+80)

The Phase I report initially recommended the placement of a rock riprap grade control structure(s) to ensure the long-term stability of the upstream canal, headgate and diversion structure. Following the collection of field survey data, the channel slope was determined to be very steep immediately below the existing structure. Given the steep gradient, placement of grouted rock structures is necessary to ensure long-term stability. Grouted rock structures, however, often incur higher operation and maintenance costs, especially in the severe weather conditions likely to exist in this area. In consideration of a design life of 35 to
NOTE: REHABILITATION OF EXISTING CHANNEL OF ONE MILE CREEK IS REQUIRED TO INCREASE CAPACITY AT SELECTED LOCATIONS FROM EXISTING DIVERSION STRUCTURE TO CANON CANAL.

LOCATION MAP
(NTS)

FIGURE 14
ONE MILE CREEK
DIVERSION STRUCTURE
CAÑON CANAL
FIGURE 15.
SECTIONS - ONE MILE CREEK
DIVERSION STRUCTURE
CAÑON CANAL
FIGURE 16.
SECTIONS - ONE MILE CREEK
DIVERSION STRUCTURE
CAÑON CANAL
EXTEND ROCK RIPRAP 6.5 VERTICAL FEET ABOVE CHANNEL INVERT ALONG CHANNEL BANKS

CLASS II RIPRAP

SHELTER/STILLING WELL

CONCRETE FOOTING

PLAN VIEW

PROPOSED CANAL CHANNEL SECTION (APPROX.)

WEIR SECTION (LOOKING DOWNSTREAM)

SECTION A-A'

CONCRETE FOOTING

CHANNEL INVERT

STEEL PLATE

1.0' 2.0' 3.0' 5.0'

SHELTER/STILLING WELL

N.T.S.

N.T.S.

N.T.S.

N.T.S.

N.T.S. (N.T.S.)

N.T.S.

N.T.S.

N.T.S.
**TASK 7. CONCEPTUAL DESIGN.** Continued

B. **Cañon Canal.** Continued

50 years along with a reduction in average operation and maintenance costs, a concrete structure was identified to dissipate the energy associated with the normal irrigation diversions. A rock apron is required immediately downstream of the proposed concrete structure to preserve the long-term integrity of the structure. Figure 18 presents the conceptual design details associated with these improvements.

**TASK 8. OPERATING PLANS**

The purpose of this task of the project is to develop operation, maintenance and rehabilitation plans for the operation of Sand Lake and Cañon Canal, providing for storage, diversions, flood control and system failures.

A. **Sand Lake Dam**

The typical operation of Sand Lake by WID is that the water level is maintained low (with the outlet pipe open) through the fall, winter and early spring seasons. In late spring, the outlet works are closed to capture runoff and fill the reservoir. The water is then released into Deep Creek and eventually Rock Creek through the summer months. Following the irrigation season, the outlet pipe is then opened.

The proposed improvements to Sand Lake Dam, specifically the construction of an in-dam spillway and remote sensing and operation of the outlet gate, should reduce the potential for the dam to overtop. Otherwise, the operation of water levels can be continued by the WID. We believe that the WID is in the best position to control the water level of Sand Lake to best suit its needs. With greater control through the remote sensing and control system, the WID may be able to improve on its existing management of Sand Lake.

B. **Cañon Canal**

Cañon Canal conveys water from Rock Creek, One Mile Creek and Three Mile Creek. The average diversion from Rock Creek into the Cañon Canal during the period 1972 to 1995 is 7,520 acre-feet.
FIGURE 18.
SPILLWAY AND STILLING BASIN
STATION 491+80
CAÑON CANAL
B. Cañon Canal, Continued

Following the reactivation of the landslide that includes Cañon Canal in 1995, the WID regraded the canal through the slide area and continued to convey water during the 1995 and 1996 seasons. Following the 1996 irrigation season, the WID completely regraded the canal through the slide zone, and conveyed water successfully through the 1997 irrigation season.

We recommend that the WID continue to operate Cañon Canal as needed to satisfy irrigation needs. In the event of additional movement of the slide, there exists a potential for complete breach of the canal, and inundation of lands below the canal. Since complete prevention of the slide to recur is not practical, the WID must operate the canal with the ability to turn off the diversion at Rock Creek within 12 hours notice. The normal operating procedure for operation of the canal should include daily inspection of the canal to identify cracks and/or movement of the canal embankment. Development of cracks should initiate a reduction and eventual termination of flows through the canal to reduce the potential for inundation of lands below the canal.

TASK 9. ENVIRONMENTAL ANALYSIS

The purpose of this task of the project is to identify environmental studies, activities, and mitigation that may be necessary prior to or as a condition of construction activities at the Sand Lake Dam or Cañon Canal. Various State and Federal agencies have been contacted regarding this project. Identified permits are discussed in Task 10. Permitting and Easements.

Since a permit is likely not required from the U.S. Corps of Engineers, specific permits from environmental agencies are not identified. However, approval from Wyoming Department of Environmental quality, Air Quality and Water Quality Divisions may be required dealing with protection of air and water quality during construction.

The USFS previously expressed concern over documenting the extent of material deposition downstream in Deep Creek from the breach. Our observations are documented in Task 2.A. (page 8) of this report. We anticipate that no further evaluation or mitigation of the deposition of materials from the breach will be required.

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TASK 10. PERMITTING AND EASEMENTS

The purpose of this task of the project is to identify permits or easements that will be required to implement the proposed improvements to Sand Lake and Cañon Canal. State and Federal agencies were contacted regarding potential permitting requirements and institutional constraints associated with construction of the improvements. The following information was generated during our evaluation of these requirements.

1. U.S. Forest Service

Sand Lake is located on U.S. Forest Service (USFS) land, in the Medicine Bow National Forest. As such, any construction at the dam will require review and approval by the USFS, and a Special Use Permit. The Permit will likely require a Fire Prevention Plan and a Road Use Permit. Of foremost concern of the USFS is identified historical resources near Sand Lake. Our meetings and correspondence with Mr. Don Carroll, District Manager and Mr. John Baumchen, both of the USFS, have indicated that if construction activity for reconstruction of the dam can be limited to the areas adjacent to the existing dam and previously disturbed areas, that restrictions on historical resource inventorying during construction should be reduced. The USFS will require review of the proposed construction by the Wyoming State Historical Preservation Office.

2. Wyoming State Historical Preservation Office (SHPO)

Formal approval by the State Historical Preservation Office will be required for this project. A soon as practical, the proposed construction plans should be submitted to SHPO to allow them to review the proposed limits of construction with the known areas of historic resources.

3. U.S. Corps of Engineers

The Corps of Engineers (COE) typically has jurisdiction over construction of dams. However, conversations with Mr. Thomas Johnson of the COE regional office in Cheyenne, Wyoming indicates that as long as the dam embankment does not change significantly in line or grade, the reservoir storage capacity does not change, or if wetlands are not excavated, then the repairs to the dam should be exempt from permitting.
Mr. Johnson suggested that as soon as conceptual drawings are complete, they should be submitted to his office with a request to review the planned construction to allow a determination of whether a permit would be required.

4. Wyoming State Engineer's Office (SEO)
Plans and specifications detailing the construction of the Sand Lake Dam repairs should be submitted with the SEO for review and comment. Dave Benner with Safety of Dams has requested a dam break analysis with flood inundation mapping be performed for the dam and Deep Creek below the dam. The result of this analysis is included in this report.

5. Land Ownership and Property Owners
Where applicable, permission should be negotiated for right-of-access for all construction activities associated with Sand Lake. Since the site and access roads are under the jurisdiction of the USFS, the permitting required by the USFS should be sufficient. For Cañon Canal and slide area, local land owners should be identified and conferred with regarding the proposed improvements and coordinated with during construction. Existing utilities should be identified prior to construction and easements obtained, as necessary.

TASK 11. COST ESTIMATES
Based on the conceptual design details provided in Task 7, detailed estimates for the construction improvements to Sand Lake Dam and Cañon Canal were developed. The construction components associated with each structure were identified and construction costs assigned to each component. Detailed cost estimates for each alternative are provided in Tables 8 through 10. The final cost estimate and repayment plan are provided in Tables 11 through 13. All final cost estimates include 10 percent for engineering services during construction and 15 percent for construction contingencies. All WWDC funding for the project is assumed to be in the form of a 50 percent grant and 50 percent loan.
<table>
<thead>
<tr>
<th>ITEM</th>
<th>TOTAL</th>
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</thead>
<tbody>
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<td>$54,400</td>
</tr>
<tr>
<td>a. Excavate and Remove Existing</td>
<td>$6,200</td>
</tr>
<tr>
<td>b. 36-inch Pipe with Seepage Collars</td>
<td>$17,250</td>
</tr>
<tr>
<td>c. Outlet</td>
<td>$2,500</td>
</tr>
<tr>
<td>d. New Gate and Controller</td>
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</tr>
<tr>
<td>e. Backfill</td>
<td>$8,450</td>
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<td>Subtotal</td>
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<tr>
<td>2. Construct in-dam Spillway</td>
<td>$28,200</td>
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<tr>
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<td>$1,000</td>
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<tr>
<td>b. Remove and Replace Riprap</td>
<td>$1,700</td>
</tr>
<tr>
<td>c. Construct Spillway</td>
<td>$25,000</td>
</tr>
<tr>
<td>d. Replace Riprap</td>
<td>$500</td>
</tr>
<tr>
<td>Subtotal</td>
<td>$28,200</td>
</tr>
<tr>
<td>3. Remote Sensing and Control System</td>
<td>$46,500 to $56,500</td>
</tr>
<tr>
<td>a. Equipment/Install at Sand Lake</td>
<td>$32,000</td>
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<tr>
<td>b. Shelter at Sand Lake</td>
<td>$2,500</td>
</tr>
<tr>
<td>c. Repeaters (2)</td>
<td>$12,000</td>
</tr>
<tr>
<td>d. Equipment/Install at Base Station</td>
<td>$10,000*</td>
</tr>
<tr>
<td>Subtotal</td>
<td>$46,500 to $56,500</td>
</tr>
</tbody>
</table>

*Will not be required if WID purchases base station equipment under another project.
### TABLE 9. OPINION OF PROBABLE COST FOR CANÓN CANAL SLIDE

<table>
<thead>
<tr>
<th>ITEM</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Slide Surface Regrading</strong></td>
<td></td>
</tr>
<tr>
<td>a. Earthwork</td>
<td>$34,000</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td>$34,000</td>
</tr>
<tr>
<td><strong>2. Channel Realignment</strong></td>
<td></td>
</tr>
<tr>
<td>a. Open Channel</td>
<td></td>
</tr>
<tr>
<td>i) Earthwork</td>
<td>$476,200</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td>$476,200</td>
</tr>
<tr>
<td>b. Pipe</td>
<td></td>
</tr>
<tr>
<td>i) Excavation</td>
<td>$250,000</td>
</tr>
<tr>
<td>ii) Pipe Construction</td>
<td>$463,000</td>
</tr>
<tr>
<td>iii) Backfill</td>
<td>$125,000</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td>$838,000</td>
</tr>
<tr>
<td><strong>3. Channel Lining</strong></td>
<td></td>
</tr>
<tr>
<td>a. Earthwork</td>
<td>$10,000</td>
</tr>
<tr>
<td>b. Liner Construction</td>
<td>$40,000</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td>$50,000</td>
</tr>
<tr>
<td>ITEM</td>
<td>TOTAL</td>
</tr>
<tr>
<td>------</td>
<td>-------</td>
</tr>
<tr>
<td><strong>1. Cañon Canal diversion and Headgate Structure</strong></td>
<td></td>
</tr>
<tr>
<td>a. Rock Riprap</td>
<td>$3,300</td>
</tr>
<tr>
<td>b. Boulder Jetty</td>
<td>$5,000</td>
</tr>
<tr>
<td>c. Concrete Weir Rehabilitation</td>
<td>$5,000</td>
</tr>
<tr>
<td>d. Concrete Apron Rehabilitation</td>
<td>$2,700</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td><strong>$16,000</strong></td>
</tr>
<tr>
<td><strong>2. Cañon Canal Gaging Station</strong></td>
<td></td>
</tr>
<tr>
<td>a. Reinforced Concrete/Steel Plate</td>
<td>$14,100</td>
</tr>
<tr>
<td>b. Riprap</td>
<td>$5,400</td>
</tr>
<tr>
<td>c. Earthwork</td>
<td>$2,800</td>
</tr>
<tr>
<td>d. Recording Device</td>
<td>$5,000</td>
</tr>
<tr>
<td>e. Shelter</td>
<td>$2,500</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td><strong>$29,800</strong></td>
</tr>
<tr>
<td><strong>3. One Mile Creek Diversion Structure</strong></td>
<td></td>
</tr>
<tr>
<td>a. Regrade Existing Diversion Canal</td>
<td>$1,000</td>
</tr>
<tr>
<td>b. Remove Existing Structures</td>
<td>$3,000</td>
</tr>
<tr>
<td>c. Rehabilitation of One Mile Creek</td>
<td>$5,000</td>
</tr>
<tr>
<td>d. Construction of Flume</td>
<td>$40,000</td>
</tr>
<tr>
<td>e. Rock Riprap</td>
<td>$4,500</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td><strong>$53,500</strong></td>
</tr>
<tr>
<td><strong>4. Ringsby Ranch Transfer Gaging Station</strong></td>
<td></td>
</tr>
<tr>
<td>a. Reinforced Concrete/Steel Plate</td>
<td>$16,300</td>
</tr>
<tr>
<td>b. Riprap</td>
<td>$6,600</td>
</tr>
<tr>
<td>c. Earthwork</td>
<td>$4,400</td>
</tr>
<tr>
<td>d. Recording Device</td>
<td>$5,000</td>
</tr>
<tr>
<td>e. Shelter</td>
<td>$2,500</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td><strong>$34,400</strong></td>
</tr>
<tr>
<td><strong>5. Cañon Canal Stabilization</strong></td>
<td></td>
</tr>
<tr>
<td>a. Reinforced Concrete</td>
<td>$35,500</td>
</tr>
<tr>
<td>b. Riprap</td>
<td>$5,400</td>
</tr>
<tr>
<td>c. Earthwork</td>
<td>$6,600</td>
</tr>
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<td><strong>Subtotal</strong></td>
<td><strong>$47,500</strong></td>
</tr>
<tr>
<td>ITEM</td>
<td>COST</td>
</tr>
<tr>
<td>-------------------------------------------</td>
<td>----------</td>
</tr>
<tr>
<td>New 36-inch Outlet Pipe</td>
<td>$ 54,500</td>
</tr>
<tr>
<td>In-Dam Spillway</td>
<td>$ 28,200</td>
</tr>
<tr>
<td>Remote Sensing</td>
<td>$ 56,500</td>
</tr>
<tr>
<td>COST OF PROJECT IMPROVEMENTS</td>
<td>$ 139,100</td>
</tr>
<tr>
<td>Engineering Costs (10%)</td>
<td>$ 14,000</td>
</tr>
<tr>
<td>SUBTOTAL</td>
<td>$ 153,100</td>
</tr>
<tr>
<td>Contingency (15%)</td>
<td>$ 23,000</td>
</tr>
<tr>
<td>TOTAL CONSTRUCTION</td>
<td>$ 176,100</td>
</tr>
<tr>
<td>Final Plan and Specifications</td>
<td>$ 17,600</td>
</tr>
<tr>
<td>Permitting and Mitigation</td>
<td>$ 10,000</td>
</tr>
<tr>
<td>Legal Fees</td>
<td>$ 1,000</td>
</tr>
<tr>
<td>Access and Right-of-Way</td>
<td>$ 2,500</td>
</tr>
<tr>
<td>TOTAL PROJECT COST</td>
<td>$ 207,200</td>
</tr>
<tr>
<td>50% Loan</td>
<td>$ 103,600</td>
</tr>
<tr>
<td>Repayment Factor (25 yrs @ 7.25%)</td>
<td>0.08775</td>
</tr>
<tr>
<td>ANNUAL PAYMENT</td>
<td>$ 9,090</td>
</tr>
<tr>
<td>ITEM</td>
<td>COST</td>
</tr>
<tr>
<td>-------------------------------------------</td>
<td>------------</td>
</tr>
<tr>
<td>Slide Surface Regrading</td>
<td>$ 34,000</td>
</tr>
<tr>
<td>Channel Lining</td>
<td>$ 50,000</td>
</tr>
<tr>
<td><strong>COST OF PROJECT IMPROVEMENTS</strong></td>
<td>$ 84,000</td>
</tr>
<tr>
<td>Engineering Costs (10%)</td>
<td>$ 8,400</td>
</tr>
<tr>
<td><strong>SUBTOTAL</strong></td>
<td>$ 92,400</td>
</tr>
<tr>
<td>Contingency (15%)</td>
<td>$ 13,860</td>
</tr>
<tr>
<td><strong>TOTAL CONSTRUCTION</strong></td>
<td>$ 106,260</td>
</tr>
<tr>
<td>Final Plan and Specifications</td>
<td>$ 10,600</td>
</tr>
<tr>
<td>Permitting and Mitigation</td>
<td>$ 500</td>
</tr>
<tr>
<td>Legal Fees</td>
<td>$ 500</td>
</tr>
<tr>
<td>Access and Right-of-Way</td>
<td>$ 1,000</td>
</tr>
<tr>
<td><strong>TOTAL PROJECT COST</strong></td>
<td>$ 118,860</td>
</tr>
<tr>
<td>50% Loan</td>
<td>$ 59,430</td>
</tr>
<tr>
<td>Repayment Factor (25 yrs @ 7.25%)</td>
<td>0.08775</td>
</tr>
<tr>
<td><strong>ANNUAL PAYMENT</strong></td>
<td>$ 5,215</td>
</tr>
</tbody>
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```markdown
<table>
<thead>
<tr>
<th>ITEM</th>
<th>COST</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cañon Canal Diversion and Headgate</td>
<td>$16,000</td>
</tr>
<tr>
<td>Cañon Canal Gaging Station</td>
<td>$29,800</td>
</tr>
<tr>
<td>One Mile Creek Diversion Structure</td>
<td>$53,500</td>
</tr>
<tr>
<td>Ringsby Ranch Transfer Gaging Station</td>
<td>$34,400</td>
</tr>
<tr>
<td>Cañon Canal Canyon Stabilization</td>
<td>$47,500</td>
</tr>
<tr>
<td><strong>COST OF PROJECT IMPROVEMENTS</strong></td>
<td><strong>$181,200</strong></td>
</tr>
<tr>
<td>Engineering Costs (10%)</td>
<td>$18,200</td>
</tr>
<tr>
<td><strong>SUBTOTAL</strong></td>
<td><strong>$199,400</strong></td>
</tr>
<tr>
<td>Contingency (15%)</td>
<td>$30,000</td>
</tr>
<tr>
<td><strong>TOTAL CONSTRUCTION</strong></td>
<td><strong>$229,400</strong></td>
</tr>
<tr>
<td>Final Plan and Specifications</td>
<td>$23,000</td>
</tr>
<tr>
<td>Permitting and Mitigation</td>
<td>$2,500</td>
</tr>
<tr>
<td>Legal Fees</td>
<td>$1,000</td>
</tr>
<tr>
<td>Access and Right-of-Way</td>
<td>$2,500</td>
</tr>
<tr>
<td><strong>TOTAL PROJECT COST</strong></td>
<td><strong>$258,400</strong></td>
</tr>
<tr>
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<tr>
<td>Repayment Factor (25 yrs @ 7.25%)</td>
<td>0.08775</td>
</tr>
<tr>
<td><strong>ANNUAL PAYMENT</strong></td>
<td><strong>$11,340</strong></td>
</tr>
</tbody>
</table>
```
TASK 12. ECONOMIC ANALYSES/ABILITY TO PAY

Tables 11 through 13 present our recommended alternatives for improvement to Sand Lake Dam, Cañon Canal Slide and Cañon Canal. We can prioritize alternatives for Cañon Canal, and recalculate the projects costs, if desired.

We understand that the WID serves approximately 911 water users with 55,284 acres of irrigable lands. The WID has an existing assessment of $9.50 per acre.

Table 14 summarizes the additional assessment required for each recommended improvement.

**TABLE 14. ADDITIONAL ASSESSMENT**

<table>
<thead>
<tr>
<th>ITEM</th>
<th>ASSESSMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand Lake Dam</td>
<td>$0.17</td>
</tr>
<tr>
<td>Cañon Canal Slide</td>
<td>$0.10</td>
</tr>
<tr>
<td>Cañon Canal</td>
<td>$0.21</td>
</tr>
</tbody>
</table>

Note: Assessments based on annual payments in Tables 11 through 13, over 55,284 acres.

CONCLUSIONS AND RECOMMENDATIONS

Based on the information provided in the previous chapters, the following conclusions and recommendations are provided.

1. We recommend that consideration be given to the suggested improvements to Sand Lake Dam. These improvements include a larger outlet pipe to pass greater flows, an in-dam spillway to allow additional flow during high water conditions, and remote sensing and control equipment to allow monitoring of reservoir water levels, flows, and to control the outlet gate remotely. All of these alternatives are designed to decrease the possibility of the events that caused the breach in 1995. The suggested improvements, based on the repayment plan, would result in an increased annual assessment of $0.17 per acre.
CONCLUSIONS AND RECOMMENDATIONS. Continued

2. As discussed under Phase I of this study, there are several things that can be done to decrease the instability of the landslide through which Cañon Canal passes. However, because of the economics of attempting to stabilize the entire slope, several alternatives were developed. As discussed in this report, we do not recommend that the landslide be caused to fail. Instead, we recommend that two contributory factors of the slope instability, moisture in the soil at the top of the slope and saturated conditions in the toe of the slope, be addressed. By closing off existing scarps and cracks on the slope, infiltration of precipitation into the slope can be reduced. We believe that lining the canal with a somewhat flexible liner will reduce canal seepage and thereby reduce the water in soils at the toe of the slide. Unfortunately, the slope may continue to move, and maintenance of the canal, liner and slopes, will likely continue. As a minimum, the condition of the slope should be periodically monitored for new movement. These suggested improvements would result in an increased annual assessment of $0.10 per acre. However, additional maintenance costs may continue.

3. Improvements to Cañon Canal structures have been identified, prioritized, and conceptual designs developed. Our recommended improvements result in an increased annual assessment of $0.21 per acre. These improvements can be re-evaluated based on revised needs of the WID, if necessary.

ADDENDUM TO RECOMMENDATIONS

Between the dates of the Phase I Report (August 16, 1996) and the preparation of this Final Report, the Wheatland Irrigation District (WID) has performed some of the recommended improvements to Cañon Canal and the Cañon Canal Slide area. Improvements performed to the Cañon Canal include:

1. Cañon Canal Gaging Station,
2. One Mile Creek Diversion Structure, and
3. Ringsby Ranch Transfer Gaging Station.

Improvements performed to the Cañon Canal Slide area included regrading of the canal through the slide zone, and regrading of slopes immediately above and below the canal.
APPENDIX A - CAÑON CANAL STRUCTURES
PLATE 2 STRUCTURE INVENTORY FOR THE CAÑON CANAL
PLATE 5 STRUCTURE INVENTORY FOR THE CAÑON CANAL
APPENDIX B - DUTTON DITCH STRUCTURES
INDEX OF PLATES FOR THE DUTTON DITCH INVENTORY
PLATE 7  STRUCTURE INVENTORY FOR THE DUTTON DITCH
STRUCTURE INVENTORY FOR THE DUTTON DITCH

- STA 95 + 00 to 97 + 60
  CONCRETE LINING FAILURE/TEMPORARY EARTH-LINED DITCH

- STA 111 + 10
  STOCK CROSSING

- STA 132 + 20
  CULVERT CROSSING

- STA 136 + 10
  STOCK CROSSING

- STA 137 + 20
  BRIDGE CROSSING

DUTTON CREEK

SCALE: 1" = 500'

PLATE 8
APPENDIX C - GEOLOGIC REPORT OF CAÑON CANAL SLIDE
GEOLOGIC STUDY
CAÑON CANAL LANDSLIDE
LEVEL II FEASIBILITY STUDY

September 25, 1997

For
Wyoming Water Development Commission
Herschler Building, 4th Floor West Wing
122 West 25th Street
Cheyenne, WY 82002

7246-HE

INBERG-MILLER ENGINEERS
1120 East "C" Street
Casper, WY 82601
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Hydrogeologic Conditions .......................................... 6
Conclusions ........................................................ 7
Recommendations .................................................... 8
Closure ............................................................. 8

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   Data Collection

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   Site Location Map
   Aerial Photographs
   USGS 1967 Geologic Map of Area and Exploration
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   Geologic Cross-Sections (Pocket)

APPENDIX C - TEST BORING INFORMATION
   Geologic Section Descriptions
   Test Boring Logs (YELLOW SHEETS)
   Monitor Well Installation Records
   General Notes
   Classification of Soils for Engineering Purposes

APPENDIX D - LABORATORY TEST RESULTS (GREEN SHEETS)
   Particle Size Analysis

APPENDIX E - WATER TABLE DATA
   Hydrographs
   Data Sheet

APPENDIX F - INFORMATION SOURCES

INBERG-MILLER ENGINEERS
SUMMARY

The Cañon Canal slide area has been moving for at least 50 years and will continue to migrate given the existing site conditions. The eastern most slide, in places, is more than 40 feet thick and is primarily sliding along a 5 to 8 foot thick zone between the overlying colluvium and underlying Hanna Formation. The eastern slide is approximately 52 acres in size. The western slide, also known as the Horseshoe slide, is approximately 5 acres in size and is separated from the eastern slide by a 100 foot wide unaffected bench.

Our calculations indicate that the Cañon Canal leaks at nearly 9 cfs through the slide area. During the initial start-up of the canal for the 1996 irrigation season, most of the downgradient soil within the slump was saturated within 6 days. During this time, the occurrence of new stress cracks and increased flow in springs over time indicate that the slump was destabilizing.

SCOPE OF SERVICES

The purpose of this portion of the project was to explore the geologic and hydrogeologic conditions in the vicinity of the Cañon Canal slide to determine what caused the slide and if future movement at the site is likely to occur. Our study included reviewing available background information, performing surface and subsurface geological exploration of the site, installing piezometers and monitoring the effect the operation of the canal has on ground-water conditions at the site.

BACKGROUND INFORMATION

The Cañon Canal, owned and operated by the Wheatland Irrigation District (WID), has been used for more than 50 years. We understand that from 1972 through 1995 the canal delivered an average of 8,620 acre-feet of water to the WID, which accounts for approximately 14 percent of the average water supply delivered to the District. The WID serves approximately 911 water users.
BACKGROUND INFORMATION, Continued

The Cañon Canal slide area is located approximately ½ mile southeast of Arlington, Wyoming. The slide area is comprised of 2 slumps, a smaller 5 acre slide to the west and a larger, 52 acre slide to the east. Historically, the slumps have caused limited problems for the canal, however, on July 13, 1995, after an abnormally wet spring, the slumps began to severely move. The eastern, larger slump, along its southeastern side, experienced over 12 feet of vertical movement over a 7 day period and breached the canal (Rod Oliver, 1995). The WID was able to maintain the canal open throughout the remainder of the irrigation season, however, due to the uncertainty of the stability of the slide, the WID, in conjunction with the Wyoming Water Development Commission (WWDC), decided to undertake this study.

Previous studies performed in the area include a United States Geological Survey (USGS) geologic map of the area by H.J. Hyden, J.S. King and R.S. Houston dated 1967, unpublished site visits by J.C. Case of the Wyoming Geological Survey dated June 17 and 30, 1986, and unpublished site notes by Rod Oliver, Wyoming State Engineer’s Office, 1995. We have included a photocopy of the 1967 USGS map of the area in Appendix B.

The study area was mapped in 1967 as the Dutton Creek Formation, however, J.D. Love and A.C. Christiansen's 1985, USGS geologic map of Wyoming updated the area as the Hanna Formation and described it as brown and gray sandstone, shale, conglomerate and coal with giant quartzite boulders near Medicine Bow Mountains. The 1967 map did not indicate the presence of the Cañon Canal slumps.

J.C. Case's notes on the slide area indicated that the slump likely consisted of colluvium, slope-wash and reworked landslide debris sliding on the Hanna Formation, which was estimated to be dipping 10 to 45 degrees north-northeast. Mr. Case also noted that the Arlington Fault is located directly southwest of the slump and could be a contributing factor. His report recommended: 1) allow the slide to stabilize naturally; 2) establish surface drainage; 3) determine the thickness of the slide and type of movement; and 4) establish subsurface drainage.

Rod Oliver's notes on the area pertain mainly to the amount of movement the large slide was experiencing during the July 1995 event in addition to his general observations.
BACKGROUND INFORMATION, Continued

In addition to these works, aerial photographs dated September 22, 1995, September 9, 1994, September 6, 1975 and June 16, 1947 were reviewed. The photographs indicate that the larger slide has been present since 1947 and both slides were visible by 1975. By 1994, the smaller slide had taken a very similar shape as it appears today. The outline of the larger slide is clear in the 1994 photograph, however, the 1995 movement resulted in many exposed scarps. Copies of the aerial photographs, excluding 1995, are included in Appendix B. The topographic/water table map generated for the site was based upon the 1995 aerial photograph and is located in Appendix B.

FIELD EXPLORATION

The field work was performed using a Mobile B-57 truck-mounted drilling rig at the site on June 17 through 19 and June 26, 1996. Ten (10) borings were advanced to depths ranging from 13.0 to 51.5 feet. Drilling was performed using 8.5-inch diameter hollow-shaft augers. The augers act as continuously advancing steel casing. The method prevents test holes from caving in above the levels to be tested. Sampling tools are lowered inside the hollow stem for testing into undisturbed soils.

Drilling and field sampling were performed according to the following standard specifications:


2. Sampling with a two-inch O.D. split-barrel (split-spoon) per ASTM D1586, "Penetration Test and Split-Barrel Sampling of Soils". Sixty-four (64) such tests were performed.

3. Sampling with a three-inch O.D. ring lined, split-barrel sampler, per ASTM D3550 "Ring Lined Barrel Sampling of Soils", driven with procedure and effort of ASTM D1586. Twenty-one (21) such samples were obtained.
FIELD EXPLORATION, Continued

The soil samples were field classified by a geologist, sealed in containers to prevent loss of moisture and returned to our laboratory. They were then reinspected by the geologist prior to the preparation of this report, and reclassified visually in accordance with ASTM D2487.

A field log was prepared for each boring during drilling. After the retrieved samples were checked in the laboratory, a Final Log for each boring was prepared which contained the work method, samples recovered and the indication of the presence of various soil types. The Logs are bound into Appendix C as YELLOW SHEETS.

The Final Logs contain both factual and interpretive information. We emphasize that our recommendations are based only on the Final Boring Logs. On the Final Logs, horizontal lines designating the interface between differing materials encountered represent approximate boundaries. The transition between soil layers is typically gradual.

LABORATORY TESTING PROGRAM

In order to classify the recovered samples and to determine their engineering properties, the following laboratory soil tests were performed:

<table>
<thead>
<tr>
<th>TESTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Moisture Content (ASTM D2216)</td>
</tr>
<tr>
<td>2. Atterberg Limits (ASTM D4318)</td>
</tr>
<tr>
<td>3. Sieve Analysis - #200 (ASTM D1140)</td>
</tr>
<tr>
<td>4. Sieve Analysis (#4 to #200) (ASTM D422 and D1140)</td>
</tr>
<tr>
<td>5. Sieve Analysis (Hydrometer) (ASTM D1140)</td>
</tr>
</tbody>
</table>

The sieve analyses are presented graphically in Appendix D (GREEN SHEETS). All other test results are arrayed on the Final Logs (YELLOW SHEETS).
GEOLOGIC CONDITIONS

Representatives of Inberg-Miller Engineers were at the site from June 17, 1996 through June 26, 1996 performing a geologic exploration of the slide area. A total of 10 sections were measured at outcrops on the slide and a total of 10 test borings were drilled both on and off the slide. Due to limited access, the primary focus of our work was on the larger slide. Appendix C contains the test boring logs, geologic section descriptions and the topographic water table map that identifies the locations of these data points.

The topography at the site slopes north-northeasterly at approximately 10 percent and has an overall change in elevation of 190 feet. The site and immediate vicinity consists of rolling hills. Due to the slumping, there are several areas with nearly vertical relief. There are also many stress cracks throughout the slide making traversing the slump dangerous. Due to the cracking, drainage would be considered very poor.

The measured sections and the test borings indicate that the geology at the site consists of colluvium overlying the Hanna Formation. Except for the undisturbed area between the two slides, colluvium typically consists of light gray to brown, silty clay with varying amounts of gravel. The area between the two slides is overlain by a colluvial material that consists of a dark reddish brown, silty clay with abundant mafic gravel clasts. The Hanna Formation, which dips from 18 to 34 degrees northeast, consists of brown, blocky and fractured, silty clay to sandy clay, fine grained sandstone, gray to black clay and coal.

The test borings and geologic sections indicate that the thickness of the slide varies from a wedge edge at the head to more than 40 feet in the middle of the slide. The toe of the slide exceeds more than 30 feet in places. Samples collected along the eastern side of the slide indicate that movement occurred within the Hanna Formation approximately 20 feet below the contact with the overlying colluvium, while the middle to western half of the slide the slippage occurred within a zone up to 5 feet above and to several feet below the colluvium/Hanna contact. In these areas, slippage was readily visible along clayey zones in the Hanna Formation, as well as polished gravel within the colluvium. Geologic cross-sections have been developed from the site and are included in Appendix B.
HYDROGEOLOGIC CONDITIONS

A total of 7 ground-water monitoring wells were installed at the site with monitoring wells MW7246-6A and B being completed as a monitoring well nest in a single test boring to determine vertical hydraulic gradients. The site is underlain by at least 2 different aquifers. There is an unconfined colluvial aquifer perched on top of the Hanna Formation and a semi-confined coal layer aquifer which was encountered in monitoring well MW7246-6A within the Hanna Formation. The unconfined colluvial perched water bearing zone is limited in extent (prior to operating the canal) to the western half of the slide and is also discontinuous in the uphill direction.

On July 9, 1996, the WID began using the Cañon Canal to transmit water. At that time Inberg-Miller Engineers began collecting water level data to determine the impact the canal was having on the ground-water system. Hydrographs and water table data are presented in Appendix D. As can be seen from the graphs, MW7246-1 measured a response almost immediately after the canal was filled with water. Monitoring wells MW7246-3, MW7246-4, and MW7246-5 began responding approximately 2000 minutes after the canal began filling. Monitoring well MW7246-6A (deep) did not respond until after 8000 minutes while monitoring well MW7246-6B (shallow) began responding between 4000 and 8000 minutes. Monitoring well MW7246-2, the upgradient monitoring well never did indicate a response to the water in the canal. A water table map generated for the last set of water table data is enclosed in Appendix B.

Based upon the response time we observed in the wells, we can determine the approximate hydraulic conductivity of the unconfined aquifer as well as an estimate of the amount of water the canal is losing to the subsurface. Based upon an estimated porosity of 30 percent, a reaction time of 141 minutes, and a gradient of 0.75 at monitoring well MW7246-1, the hydraulic conductivity is estimated to be $4.32 \times 10^{-2}$ cm/sec. At monitoring well MW7246-3, the porosity is again estimated at 30 percent, however, the gradient is 1.31 and the reaction time 1539 minutes. This translates into a hydraulic conductivity of $3.20 \times 10^{-3}$ cm/sec. By averaging the hydraulic conductivities adjacent to the canal and using Darey's Law, we can estimate the discharge over the length of the canal effected by the slumps. Based on a 2200 foot
HYDROGEOLOGY CONDITIONS, Continued

length approximately 10 feet wide and a gradient of 0.2667, we estimate that the canal is losing approximately 8.9 cubic feet per second across its length. In addition, our observations and calculations indicate that the canal is losing water much more quickly along the western half of the slide. In fact, a response was measured in MW7246-5 before one was measured in MW7246-3 indicating that the water in MW7246-5 is being recharged more from the west than from the area immediately uphill and closer to the canal.

Stability observations during this same time frame indicate that stress cracks were reappearing in the road adjacent to the canal. Also, flow within several springs seemed to increase as the monitoring period progressed, indicating that piping might be occurring.

CONCLUSIONS

Based upon our observations and calculations, the following conclusions have been developed.

1. In our opinion, the slumping at the site has been occurring slowly over a period of at least 50 years as indicated by the aerial photographs. However, due to a rare natural recharge event in the spring of 1995, the slumping increased. The resulting fissures and tension cracks likely compounded the problem allowing additional water to enter into the already wet ground. It is difficult to say what the role the canal had in compounding the problem. However, we know that the canal leaks and had caused the soil downgradient to become saturated which likely increased the magnitude of the large slide.

2. The ground-water data collected at the site indicates that the canal leaks fast enough to saturate all the soil in the slump downgradient of the canal in approximately 6 days. The result of this additional water tends to destabilize the lower portion of the slide. This was evident by the new stress cracks observed on the road adjacent to the canal. Also, we observed an apparent increase in velocity
CONCLUSIONS, Continued

of several springs during the operating time. Destabilization of the upper portion
of the slide was not observed during those 6 days. However, movement might
have occurred if the canal had operated long enough.

3. In our opinion, additional movement of the slide is likely to occur given the
existing conditions. The leaking canal in combination with the poor drainage
caused by the cracking increase the likelihood of movement. Also, due to the
poor drainage, movement could occur with less precipitation than in 1995.

RECOMMENDATIONS

Based upon our initial conclusions several options are available to reduce movement
within the slide. Since the movement appears to be related to both precipitation (recharge) and
leakage from the canal, the solution, in part, may be accomplished by reducing the amount of
water entering the subsurface. This could be accomplished by lining the canal and improving
the drainage on the slide. Infiltration on the slide can also be reduced by increasing vegetation
growth.

It is possible that reducing infiltration alone will not completely stop the movement from
occurring. Highly plastic clays within the Hanna Formation seem to be a compounding factor
to the slumping. Preliminary indications are that the plastic clay may be able to be stabilized by
the addition of chemicals. Further analysis is necessary to determine if chemical stabilization is
feasible method for this site. If it is determined that stabilizing the clay is necessary and/or
feasible, additional exploration of the slide would be required to more closely define the depth
and extent of the plastic clay. That exploration could include a seismic survey and testing.

CLOSURE

This report has been prepared for the exclusive use of our client, Wyoming Water
Development Commission, for evaluation of the site, design and construction planning purposes
of the described project. It may contain insufficient information for applications other than is
herein described.

8
CLOSURE. Continued

We appreciate participating in your project. Please call if you have any questions regarding this report.

Sincerely,

INBERG-MILLER ENGINEERS

Eric T. Graney, P.G.
Hydrogeologist

REVIEWED BY:

Steven F. Moldt, P.E.
Vice President

ETG:cag:rpt
APPENDIX A - GENERAL CONDITIONS
GENERAL CONDITIONS - DATA COLLECTION

Field-sampling techniques were employed in this investigation to obtain the data presented in the Final Boring Logs, and in the Report, in accordance with ASTM D420, D1452, D1586 (where applicable) and D1587 (where applicable).

The drilling method utilized in borings is a dry-process, machine rotary auger type, which advances hollow steel pipe surrounded by attached steel auger flights in 5 foot lengths. This method creates a continuously cased test hole that prevents the boring from caving in above each level of substrata to be tested. Sampling tools are lowered inside the hollow shaft for testing in the undisturbed soils below the lead auger. Occasionally, other drilling methods are utilized in order to obtain soil samples. The specific drilling methods are outlined within the Field Exploration section of the Report.

Samples were brought to the surface, examined by the drilling foreman and sealed in containers (or sealed in the tubes) to prevent loss of moisture. They were returned to our laboratory for final classification per ASTM D2487-69 methods. Some samples were subjected to tests as described in the text of the report.

A field log was prepared for each boring by the drilling foreman during on-site operations in order to record field occurrences, sampling intervals and ground-water observations. The field logs and laboratory test data sheets are available for inspection at the Engineer's office. They are not included in this report because they do not represent the Engineer's final opinions or interpretations.

A Final Log of each test pit or boring was prepared by the writer of the report or the Engineer's staff. Each Final Log contains the writer's interpretation of field conditions or changes in substrata between recovered samples based on the field data received along with the laboratory test data obtained following the field work or on subsequent site observations. The final logs were prepared by assembling and analyzing field and laboratory data. Therefore, the Final Logs contain both factual and interpretive information. Our opinions are based on the Final Logs, not the field logs.

The Final Logs list boring methods, sampling methods, depths sampled, amounts of recovery in sampling tools, indications of the presence of subsoil types and groundwater level observations. Results of some laboratory test are arrayed on the final logs at the appropriate depths below grade. The horizontal lines on the final logs which designate the interface between successive layers represent approximate boundaries. The transition between strata is typically gradual.
We caution that the Final Logs alone do not constitute the report, and as such they should not be excerpted from the other appendix exhibits nor from any of the written text. Without the written report it is possible to misinterpret the meaning of the information reported on the final logs. If the reports are to be reproduced for reference purposes, the entire numbered report and appendix exhibits should be bound together as a separate document or as a section of a specification booklet, including all maps.

Pocket penetration tests taken in the field or on samples examined in the laboratory are listed on the final boring logs in a column marked "pp". These tests were performed only to indicate relative stiffness in consistency between successive layers of cohesive soil. It is not recommended that the listed values be used to determine allowable bearing capacities. Bearing capacities of soils are determined by the engineer using test methods as described in the text of the report.

Groundwater observations were made with cloth-tape measurements in the open drill holes by field personnel at the times and dates stated on the final logs. It must be noted that fluctuations may occur in the groundwater level due to subsequent water level stabilization, variations in rainfall, temperature, nearby site improvements, underdrainage, wells, severity of winter frosts, overburden weights and the permeability of the subsoils. Because variations may be expected, final designs and construction planning should allow for the need to temporarily or permanently dewater excavations or subsoils.
APPENDIX B - SITE INFORMATION
Source: U.S.G.S. Arlington Quadrangle, T19N., R78W.
AERIAL PHOTOGRAPH

Project:  Sand Lake/Cañon Canal Rehabilitation  
Location:  Arlington, Wyoming  
June 16, 1947
AERIAL PHOTOGRAPH

Project: Sand Lake/Cañon Canal Rehabilitation

Location: Arlington, Wyoming

September 9, 1994
Modified from: Hyden et al., 1967.
APPENDIX C - TEST BORING INFORMATION
### Geologic Section Description

<table>
<thead>
<tr>
<th>Section</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0-10' - brown, block, fractured, weathered clay (Hanna); 10-14' - brown, sandy clay (Hanna); 14-15' - interbedded gray and brown clay; 15-17' - brown, fine grained sandstone.</td>
</tr>
<tr>
<td>2</td>
<td>0-14.5' - brown, silty clay with gravel (colluvium); 14.5-22' - brown, blocky, fractured, silty clay (Hanna) slicken-sides at 14.7'.</td>
</tr>
<tr>
<td>3</td>
<td>0-7' - brown, blocky, fractured, silty clay (Hanna); 7' - light brown, fine grained sandstone (Hanna)</td>
</tr>
<tr>
<td>4</td>
<td>0-2' - gray, sandy clay with abundant gravel (colluvium); 2-4' - brown, silty clay with sparse gravel (colluvium); 4-8' - light brown, sandy clay with abundant gravel (colluvium)</td>
</tr>
<tr>
<td>5</td>
<td>0-4' - reddish brown, sandy clay with sparse gravel (colluvium); 4-10' - dark gray clay (slip face), dip 31.5° northeast (Hanna)</td>
</tr>
<tr>
<td>6</td>
<td>0-15' - brown, silty clay with sparse gravel (colluvium)</td>
</tr>
<tr>
<td>7</td>
<td>0-2.8' - brown, blocky, fractured, silty clay (Hanna); 2.8-3.8' - gray clay with some sandstone concretions (Hanna); 3.8-14' - brown, silty clay with sandstone concretions from 11' to 12'</td>
</tr>
<tr>
<td>8</td>
<td>0-0.9' - dark brown, sandy clay with gravel (colluvium); 0.9-2.4' - gray, silty clay with gravel (colluvium); 2.4-10' - brown, silty clay with some gravel (colluvium); 10-11' - gray to black clay (paleosol?); 11-12' - gray clay, dip 34° north (Hanna)</td>
</tr>
<tr>
<td>9</td>
<td>0-3' - light brown, silty clay with gravel (colluvium); 3-4.5' - light brown, silty clay with some sandstone concretions (displaced Hanna); 4.5-5' - dark brown to gray clay (paleosol?); 5-6' - brown to gray, silty clay with gravel (displaced Hanna); 6-9' - gray clay with slicken-sides, sandstone concretion at 8.5'</td>
</tr>
<tr>
<td>10</td>
<td>0-13.7' - gray, fine to coarse sand with some gravel (colluvium); 13.7-15.8' - brown, silty, fine sand (Hanna); 15.8-16.0' - gray, silty clay (Hanna); 16.0' - black coal (Hanna)</td>
</tr>
<tr>
<td>DEPTH (FT)</td>
<td>SAMPLING TYPE - NO.</td>
</tr>
<tr>
<td>------------</td>
<td>---------------------</td>
</tr>
<tr>
<td>0</td>
<td>Soft to Medium, Moist, Dark Brown, Sandy CLAY with Some Gravel (Fill)</td>
</tr>
<tr>
<td>5</td>
<td>SS-1</td>
</tr>
<tr>
<td>10</td>
<td>SS-2</td>
</tr>
<tr>
<td>15</td>
<td>SS-3</td>
</tr>
<tr>
<td>20</td>
<td>SS-4</td>
</tr>
</tbody>
</table>

(Log Continued on Next Page)
**LOG OF TEST BORING NO. B7246-1**

**Project:** Cañon Canal  
**Location:** Arlington, Wyoming  
**Client:** Wyoming Water Development Commission

**Surface El. (Ft):** 7752.5  
**Benchmark/Datum (Ft):** Mean Sea Level

### DEPTH (FT) VS. SAMPLING TYPE & NO. RECOVERY (IN)

<table>
<thead>
<tr>
<th>DEPTH TYPE - NO. DEPTH (FT)</th>
<th>SOIL DESCRIPTION</th>
<th>USCS N BLOWS PER FT</th>
<th>qp (TSF)</th>
<th>W (%)</th>
<th>γm (PCF)</th>
<th>LL PI (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>SS-5 Medium Dense to Dense, Moist, Greenish Gray, Fine to Medium SAND with Some Gravel (Colluvium)</td>
<td>32</td>
<td>2.8</td>
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<td></td>
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<tr>
<td>30</td>
<td>SS-6 Very Dense, Wet, Dark Greenish Brown, Medium to Coarse SAND with Some Gravel (Colluvium)</td>
<td>72</td>
<td>7.3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>SS-8 Very Stiff to Hard, Moist, Interbedded, Varigated CLAYSTONE and Grayish Brown Siltstone (Hanna Formation)</td>
<td>17</td>
<td>16.8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>SS-9</td>
<td>35</td>
<td>15.7</td>
<td></td>
<td></td>
<td></td>
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**WATER LEVEL OBSERVATIONS**

<table>
<thead>
<tr>
<th>Initial Occurrence While Drilling (Ft)</th>
<th>29.0</th>
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<tbody>
<tr>
<td>Time After Drilling</td>
<td>12 hrs</td>
</tr>
<tr>
<td>Depth to Water (Ft)</td>
<td>26.96</td>
</tr>
<tr>
<td>Depth to Cave-In (Ft)</td>
<td>41.5</td>
</tr>
</tbody>
</table>

**DRILLING AND SAMPLING NOTES**

<table>
<thead>
<tr>
<th>Date Begun: 6/17/96</th>
<th>Comp. 6/17/96</th>
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</thead>
<tbody>
<tr>
<td>Crew REP/ETG</td>
<td>Rig CME-55</td>
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<tr>
<td>Method: 3.25&quot; HSA</td>
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</tr>
<tr>
<td>Termination Depth (Ft): 41.5</td>
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</tr>
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</table>

INBERG-MILLER ENGINEERS
### LOG OF TEST BORING NO. B7246-2

**Project:** Cañon Canal  
**Location:** Arlington, Wyoming  
**Job No.:** 7246-HE  
**Client:** Wyoming Water Development Commission  
**Surface El.(Ft):** 7754.3  
**Benchmark/Datum (Ft):** Mean Sea Level

<table>
<thead>
<tr>
<th>DEPTH (FT)</th>
<th>SAMPLING TYPE - NO. DEPTH (FT)</th>
<th>SOIL DESCRIPTION</th>
<th>USCS BLOWS PER FT</th>
<th>N</th>
<th>q_p (TSF)</th>
<th>W (%)</th>
<th>( \gamma_m ) (PCF)</th>
<th>LL</th>
<th>PL</th>
<th>PL OTHER TESTS</th>
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</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
<td>Moist, Dark Brown, Silty CLAY with Sand and Gravel (Fill)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>SS-1</td>
<td>10.0-11.5</td>
<td>7</td>
<td>4.8</td>
<td>48</td>
<td>7d PI</td>
<td>48</td>
<td>29</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>SS-2</td>
<td>15.0-16.5</td>
<td>6</td>
<td>6.9</td>
<td>Sieve</td>
<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>20</td>
<td>SS-3</td>
<td>20.0-21.5</td>
<td>17</td>
<td>10.7</td>
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(Log Continued on Next Page)
**LOG OF TEST BORING NO.**

**Project:** Cañon Canal  
**Location:** Arlington, Wyoming

**Client:** Wyoming Water Development Commission

**Surface El.(Ft):** 7754.3  
**Benchmark/Datum (Ft):** Mean Sea Level

<table>
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<tr>
<th>DEPTH (FT)</th>
<th>SAMPLING TYPE - NO.</th>
<th>DEPTH (FT)</th>
<th>DEPTH (IN)</th>
<th>SOIL DESCRIPTION</th>
<th>USCS N BLOWS PER FT</th>
<th>q_p (TSF)</th>
<th>W (%)</th>
<th>( \gamma_m ) (PCF)</th>
<th>LL PL PI (%)</th>
<th>OTHER TESTS</th>
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</thead>
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<td>25</td>
<td>SS-4</td>
<td>25.0-26.5</td>
<td>18</td>
<td>23.0</td>
<td>Very Stiff to Hard, Moist, Orangish Brown to Dark Brown CLAYSTONE with Interbedded Gray to Black, Organic-rich Claystone and Coal (Hanna Formation)</td>
<td>31</td>
<td>22.6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>SS-5</td>
<td>30.0-31.5</td>
<td>18</td>
<td></td>
<td>25</td>
<td>36.9</td>
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<td></td>
</tr>
<tr>
<td>35</td>
<td>SS-6</td>
<td>35.0-36.5</td>
<td>18</td>
<td>26</td>
<td>27.1</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>SS-7</td>
<td>40.0-41.5</td>
<td>18</td>
<td>57</td>
<td>18.0</td>
<td></td>
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(Log Continued on Next Page)
<table>
<thead>
<tr>
<th>Depth (FT)</th>
<th>Sampling</th>
<th>Soil Description</th>
<th>USCS B/Per FT</th>
<th>N (TSF)</th>
<th>V (%)</th>
<th>γ_m (PCF)</th>
<th>LL PL (%)</th>
<th>Other Tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>45</td>
<td>SS-8</td>
<td>Hard, Moist, Reddish Brown, Silty, Sandy CLAY with Some Wet, Medium Sand (Hanna Formation)</td>
<td>45.0</td>
<td>69</td>
<td>9.6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>SS-8</td>
<td></td>
<td>&gt;50/5</td>
<td>13.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>55</td>
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</tr>
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<td>60</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>65</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**WATER LEVEL OBSERVATIONS**

- Initial Occurrence While Drilling (Ft): 50.0
- Time After Drilling: 0.0 min
- Depth to Water (Ft): Dry
- Depth to Cave-In (Ft): 47.0

**DRILLING AND SAMPLING NOTES**

- Date Begun: 6/18/96
- Crew: REP/ETG/SFM
- Rig: CME-55
- Method: 3.25" HSA
- Termination Depth (Ft): 51.5
<table>
<thead>
<tr>
<th>DEPTH (FT)</th>
<th>SAMPLING TYPE - NO.</th>
<th>SOIL DESCRIPTION</th>
<th>USCS/BLOWS PER FT</th>
<th>N</th>
<th>q_p (TSF)</th>
<th>γm (PCF)</th>
<th>LL PL (%)</th>
<th>OTHER TESTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
<td>Very Stiff, Moist, Brown, Silty CLAY with Little Sand and Gravel (Colluvium)</td>
<td>0</td>
<td>0</td>
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<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>SS-1</td>
<td></td>
<td>18</td>
<td>18</td>
<td>10.0</td>
<td>24</td>
<td>21.2</td>
<td>50/5</td>
</tr>
<tr>
<td>10</td>
<td>SS-2</td>
<td>Easier drilling at 8.0'</td>
<td>10.5</td>
<td>10.5</td>
<td>24</td>
<td>21.2</td>
<td>50/5</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>SS-3</td>
<td>Very Stiff, Brown, Silty Clay (Slickensides) (Hanna Formation)</td>
<td>12.0</td>
<td>12.0</td>
<td>24</td>
<td>21.2</td>
<td>50/5</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>SS-4</td>
<td>Hard, Moist, Light Brown to Orangish Brown, Silty CLAY (Hanna Formation)</td>
<td>20.5</td>
<td>20.5</td>
<td>36/6</td>
<td>6.9</td>
<td>50/5</td>
<td></td>
</tr>
</tbody>
</table>

### WATER LEVEL OBSERVATIONS

<table>
<thead>
<tr>
<th>Initial Occurrence While Drilling (Ft)</th>
<th>Date Begun</th>
<th>Comp.</th>
<th>Time After Drilling</th>
<th>Crew</th>
<th>Rig</th>
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<tr>
<td>24 hrs</td>
<td>6/18/96</td>
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### DRILLING AND SAMPLING NOTES

<table>
<thead>
<tr>
<th>Depth to Water (Ft)</th>
<th>Depth to Cave-In (Ft)</th>
<th>Method</th>
<th>Termination Depth (Ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry</td>
<td>20.0</td>
<td>3.25&quot; HSA</td>
<td>20.5</td>
</tr>
</tbody>
</table>
### Project: Canon Canal
### Location: Arlington, Wyoming
### Job No.: 7246-HE
### Client: Wyoming Water Development Commission

- **Surface El. (Ft):** 7779.0
- **Benchmark/Datum (Ft):** Mean Sea Level

#### SAMPLING DEPTH

<table>
<thead>
<tr>
<th>DEPTH (FT)</th>
<th>TYPE · NO.</th>
<th>SOIL DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
<td>Hard, Moist, Brown, Silty CLAY with Some Sand and Gravel (Colluvium)</td>
</tr>
<tr>
<td>5</td>
<td>SS-1</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>SS-2</td>
<td>Hard, Moist, Gray CLAY with Slickensides (Hanna Formation)</td>
</tr>
<tr>
<td>15</td>
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<tr>
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#### WATER LEVEL OBSERVATIONS

<table>
<thead>
<tr>
<th>Initial Occurrence While Drilling (Ft)</th>
<th>Date Begun</th>
<th>Comp.</th>
</tr>
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<tbody>
<tr>
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#### DRILLING AND SAMPLING NOTES

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<th>Time After Drilling</th>
<th>Crew REP/ETG/SFM</th>
<th>Rig CME-55</th>
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<tr>
<td></td>
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</tr>
<tr>
<td>Depth to Water (Ft)</td>
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<tr>
<td>Depth to Cave-In (Ft)</td>
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<tr>
<td>Termination Depth (Ft)</td>
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**INBERG-MILLER ENGINEERS**
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<th>DEPTH (FT)</th>
<th>SAMPLING TYPE - NO.</th>
<th>DEPTH (FT)</th>
<th>RECOVERY (IN)</th>
<th>SOIL DESCRIPTION</th>
<th>USCS BLOWS (TSF)</th>
<th>q&lt;sub&gt;p&lt;/sub&gt; (PCF)</th>
<th>W (%)</th>
<th>γ&lt;sub&gt;m&lt;/sub&gt; (PSF)</th>
<th>LL (%)</th>
<th>PI (%)</th>
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<tbody>
<tr>
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<td>Dark Brown, Silty SAND and Gravel (Colluvium)</td>
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<td>2.5</td>
<td>Moist, Light Brown to Gray, Silty CLAY with Trace Sand (Weathered Hanna Formation)</td>
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<td>5.0-6.5</td>
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<td>Medium Dense, Moist, Light Brown, Silty, Fine SAND (Some Slickensides) (Weathered Hanna Formation)</td>
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<td>24</td>
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(Log Continued on Next Page)
**LOG OF TEST BORING NO.**

**Project:** Cañon Canal  
**Location:** Arlington, Wyoming  
**Job No.:** 7246-HE  
**Client:** Wyoming Water Development Commission  
**Surface El.(Ft):** 7793.8  
**Benchmark/Datum (Ft):** Mean Sea Level

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<th>DEPTH (FT)</th>
<th>DEPTH TYPE - NO.</th>
<th>DEPTH (FT)</th>
<th>SOIL DESCRIPTION</th>
<th>USCS BLOWS PER FT</th>
<th>N</th>
<th>qP (TSF)</th>
<th>W (%)</th>
<th>( \gamma_m ) (PCF)</th>
<th>PL (%)</th>
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<td>20.0-21.5</td>
<td>Medium, Moist, Gray CLAY with Slickensides (Hanna Formation)</td>
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<td></td>
<td>6.7</td>
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<tr>
<td>18</td>
<td>SS-9</td>
<td>21.5-23.0</td>
<td>Loose to Medium Dense, Moist, Light Orangish Brown, Silty SAND with Interbedded Black, Silty Sand and Gray Clay (Hanna Formation)</td>
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<td></td>
<td>11.0</td>
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<td>SS-11</td>
<td>25.0-26.5</td>
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**WATER LEVEL OBSERVATIONS**

<table>
<thead>
<tr>
<th>Initial Occurrence While Drilling (Ft)</th>
<th>Time After Drilling</th>
<th>Depth to Water (Ft)</th>
<th>Depth to Cave-In (Ft)</th>
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<tbody>
<tr>
<td></td>
<td>24 hrs</td>
<td>Dry</td>
<td>24.0</td>
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**DRILLING AND SAMPLING NOTES**

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<th>Comp.</th>
<th>Crew</th>
<th>Rig</th>
<th>Method</th>
<th>Termination Depth (Ft)</th>
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<tbody>
<tr>
<td>6/18/96</td>
<td>6/18/96</td>
<td>REP/ETG/SFM</td>
<td>CME-55</td>
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<td>DEPTH (FT)</td>
<td>SAMPLING NO.</td>
<td>SOIL DESCRIPTION</td>
<td>USCS N BLOWS PER FT</td>
<td>qp (TSF)</td>
<td>W (%)</td>
</tr>
<tr>
<td>------------</td>
<td>--------------</td>
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<td>----------</td>
<td>------</td>
</tr>
<tr>
<td>0</td>
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<td>Dry, Brown, Silty CLAY with Gravel (Colluvium)</td>
<td>1.0</td>
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<tr>
<td></td>
<td></td>
<td>Stiff, Moist, Dark Orangish Brown, Silty CLAY with Some Sand (Colluvium)</td>
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</tr>
<tr>
<td>5</td>
<td>SS-1</td>
<td>Very Stiff, Moist, Brown, Silty CLAY with Gravel (Colluvium)</td>
<td>7.5</td>
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<tr>
<td>10</td>
<td>SS-2</td>
<td>More gravel at 15.0'</td>
<td>18</td>
<td>10.8</td>
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<tr>
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<td>Very Stiff, Moist, Brown, Silty CLAY (Hanna Formation)</td>
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<td>Very Stiff, Moist, Brown, Silty CLAY (Hanna Formation)</td>
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(Log Continued on Next Page)
<table>
<thead>
<tr>
<th>DEPTH (FT)</th>
<th>SAMPLING TYPE • NO.</th>
<th>DEPTH (FT)</th>
<th>SOIL DESCRIPTION</th>
<th>USCS BLOWS/PER FT</th>
<th>N'</th>
<th>q_p (TSF)</th>
<th>W (%)</th>
<th>I_m (PCF)</th>
<th>LL PL</th>
<th>OTHER TESTS</th>
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<tbody>
<tr>
<td>25</td>
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<td>25.0-26.5</td>
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<tr>
<td>30</td>
<td>SS-7</td>
<td>30.0-31.5</td>
<td>Very Dense, Moist, Orangish Brown, Fine SAND (Hanna Formation)</td>
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<tr>
<td>35</td>
<td>SS-8</td>
<td>35.0-36.5</td>
<td>Hard, Moist, Orangish Brown, Fractured CLAY (Hanna Formation)</td>
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</tr>
<tr>
<td>40</td>
<td>SS-9</td>
<td>40.0-41.5</td>
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**WATER LEVEL OBSERVATIONS**

<table>
<thead>
<tr>
<th>Initial Occurrence While Drilling (Ft)</th>
<th>Time After Drilling</th>
<th>Depth to Water (Ft)</th>
<th>Depth to Cave-In (Ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N/A</td>
<td>Dry</td>
<td>38.9</td>
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**DRILLING AND SAMPLING NOTES**

<table>
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<th>Comp.</th>
<th>Crew</th>
<th>Rig</th>
<th>Method</th>
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<td>CME-55</td>
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**LOG OF TEST BORING NO.**

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**Project:** Cañon Canal  
**Location:** Arlington, Wyoming  
**Job No.:** 7246-HE  
**Client:** Wyoming Water Development Commission  
**Surface El. (Ft):** 7914.3  
**Benchmark/Datum (Ft):** Mean Sea Level

### Sampling and Soil Description

<table>
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<th>Depth (FT)</th>
<th>Sampling Type - No.</th>
<th>Depth (FT) Recovery (IN)</th>
<th>Soil Description</th>
<th>USCS N Bows/Per FT</th>
<th>InSab</th>
<th>W (%)</th>
<th>Ym (PCF)</th>
<th>LL PL PI %</th>
<th>Other Tests</th>
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</tr>
<tr>
<td>5</td>
<td>SS-1</td>
<td>5.0-6.5 10</td>
<td>Medium Dense, Grayish Brown, Fine to Coarse SAND with Some Gravel (Colluvium)</td>
<td>22</td>
<td>0.4</td>
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<tr>
<td>10</td>
<td>DM-2</td>
<td>10.0-11.5 18</td>
<td>Dense, Light Brown to Gray, Silty SAND (Hanna Formation)</td>
<td>35</td>
<td>6.3</td>
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</tr>
<tr>
<td>15</td>
<td>DM-3</td>
<td>12.0-13.5 12</td>
<td>Hard, Brown, Interbedded CLAYSTONE and Black Coal (Hanna Formation)</td>
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<td>53.0</td>
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<td>20</td>
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<td>20.0-21.5 3</td>
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<td>&gt;50/3&quot;</td>
<td>7.3</td>
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### Water Level Observations

- **Initial Occurrence While Drilling (Ft):**
- **Time After Drilling:** 10 min
- **Depth to Water (Ft):** Dry
- **Depth to Cave-In (Ft):** 16.0

### Drilling and Sampling Notes

- **Date Begun:** 6/19/96  
- **Comp:** 6/19/96  
- **Crew:** REP/ETG/SFM  
- **Rig:** CME-55  
- **Method:** 3.25" HSA  
- **Termination Depth (Ft):** 20.8

---

**INBERG-MILLER ENGINEERS**
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<tr>
<th>DEPTH (FT)</th>
<th>SAMPLING TYPE - NO.</th>
<th>DEPTH (FT)</th>
<th>RECOVERY (IN)</th>
<th>SOIL DESCRIPTION</th>
<th>USCS BLOWS/PER FT (TSF)</th>
<th>q_p (TSF)</th>
<th>W (%)</th>
<th>( \gamma_m ) (PCF)</th>
<th>LL PL (%)</th>
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<td>Brown, Silty CLAY with Some Coarse Sand</td>
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<tr>
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<td>DM-1</td>
<td>5.0-6.5</td>
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<td>Medium Dense, Light Brown, Clayey, Fine to Coarse SAND with Some Gravel (Colluvium)</td>
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<td>DM-3</td>
<td>8.0-9.5</td>
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<td>DM-5</td>
<td>11.0-12.5</td>
<td>12.5</td>
<td>Medium Dense to Very Dense, Brown to Dark Gray, Silty, Fine to Coarse SAND and Gravel (Colluvium)</td>
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<td>Darker gray in color at 21.0'</td>
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<td>3.4</td>
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# LOG OF TEST BORING NO. B7246-7

**Project:** Cañon Canal  
**Location:** Arlington, Wyoming  
**Client:** Wyoming Water Development Commission  
**Job No.:** 7246-HE

**Surface El. (Ft):** 7791.0  
**Benchmark/Datum (Ft):** Mean Sea Level

<table>
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<th>DEPTH (FT)</th>
<th>SAMPLING TYPE - NO.</th>
<th>DEPTH (FT)</th>
<th>RECOVERY (IN)</th>
<th>SOIL DESCRIPTION</th>
<th>N USCS/BLOWS/PER FT</th>
<th>$q_p$ (TSF)</th>
<th>W (%)</th>
<th>$\gamma_m$ (PCF)</th>
<th>LL PL (%)</th>
<th>OTHER TESTS</th>
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<td>18</td>
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<td>6.4</td>
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<td>29.0-30.5</td>
<td>DM-18</td>
<td>30</td>
<td>18</td>
<td></td>
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<td>49</td>
<td>6.4</td>
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<tr>
<td>30.0-32.0</td>
<td>DM-19</td>
<td>30</td>
<td>18</td>
<td>Hard, Wet, Light Brown, Silty CLAY, 1&quot; Coal Seam and 8&quot; Black Clay at 32.5' (Hanna Formation)</td>
<td>20</td>
<td>8.4</td>
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**WATER LEVEL OBSERVATIONS**

<table>
<thead>
<tr>
<th>Initial Occurrence While Drilling (Ft)</th>
<th>29.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time After Drilling</td>
<td></td>
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<tr>
<td>Depth to Water (Ft)</td>
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</tr>
<tr>
<td>Depth to Cave-In (Ft)</td>
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**DRILLING AND SAMPLING NOTES**

<table>
<thead>
<tr>
<th>Date Begun</th>
<th>Comp.</th>
<th>Crew</th>
<th>Rig</th>
<th>Method</th>
<th>Termination Depth (Ft)</th>
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<tbody>
<tr>
<td>6/19/96</td>
<td>6/19/96</td>
<td>REP/ETG/SFM</td>
<td>CME-55</td>
<td>3.25&quot; HSA</td>
<td>35.0</td>
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### LOG OF TEST BORING NO. B7246-8

**Project:** Cañon Canal  
**Location:** Arlington, Wyoming  
**Job No.:** 7246-HE  
**Client:** Wyoming Water Development Commission

**Surface El.(Ft):** 7719.5  
**Benchmark/Datum (Ft):** Mean Sea Level

<table>
<thead>
<tr>
<th>DEPTH (FT)</th>
<th>SAMPLING TYPE - NO.</th>
<th>DEPTH (FT)</th>
<th>RECOVERY (IN)</th>
<th>SOIL DESCRIPTION</th>
<th>USCS BLOWS PER FT</th>
<th>Nq</th>
<th>W (%)</th>
<th>Dr (PCF)</th>
<th>LL PL (%)</th>
<th>OTHER TESTS</th>
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<tbody>
<tr>
<td>0</td>
<td>SS-1</td>
<td>5.0-6.5</td>
<td>18</td>
<td>Medium to Stiff, Moist, Brown, Silty CLAY (Colluvium)</td>
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<td></td>
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<td>5</td>
<td>SS-2</td>
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<td>10.0-11.5</td>
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<td>Loose, Moist, Light Brown, Clayey, Fine to Medium SAND (Colluvium)</td>
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<td>13.5</td>
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<td>10</td>
<td>SS-3</td>
<td>15.0-16.5</td>
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<tr>
<td></td>
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<td></td>
<td></td>
<td>Medium Dense, Wet, Brown, Medium to Coarse, Clayey SAND with Gravel (Colluvium)</td>
<td></td>
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<td>19.0</td>
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</tr>
<tr>
<td>15</td>
<td>SS-4</td>
<td>20.0-21.5</td>
<td>18</td>
<td></td>
<td>10</td>
<td>7.7</td>
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</table>

(Log Continued on Next Page)
**LOG OF TEST BORING NO.**

**Project:** Cañon Canal  
**Location:** Arlington, Wyoming  
**Job No.:** 7246-HE  
**Client:** Wyoming Water Development Commission

**Surface El. (Ft):** 7719.5  
**Benchmark/Datum (Ft):** Mean Sea Level

<table>
<thead>
<tr>
<th>DEPTH (FT)</th>
<th>SAMPLING TYPE - NO.</th>
<th>DEPTH (FT)</th>
<th>RECOVERY (IN)</th>
<th>SOIL DESCRIPTION</th>
<th>USCS BLOWS/PER FT</th>
<th>N (TSF)</th>
<th>q_p (%</th>
<th>d_m (PCF)</th>
<th>LL PL PI (%)</th>
<th>OTHER TESTS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SS-5</td>
<td>25.0-26.5</td>
<td>18</td>
<td>Medium Dense, Wet, Brown, Medium to Coarse, Clayey SAND with Gravel (Colluvium)</td>
<td>18</td>
<td>8.8</td>
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<td></td>
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<tr>
<td></td>
<td>SS-6</td>
<td>30.0-31.5</td>
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<td>Very Stiff, Moist, Brown to Gray CLAY (Hanna Formation)</td>
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<td>17.0</td>
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</tbody>
</table>

**WATER LEVEL OBSERVATIONS**

| Initial Occurrence While Drilling (Ft) | 19.0 |
| Time After Drilling | 6/26/96 |
| Depth to Water (Ft) | 6/26/96 |
| Depth to Cave-In (Ft) | 31.5 |

**DRILLING AND SAMPLING NOTES**

| Date Begun | 6/26/96 |
| Crew | REP/ETG |
| Method | 3.25" HSA |
| Rig | CME-55 |

***INBERG-MILLER ENGINEERS***
# Log of Test Boring No. B7246-9

**Project:** Cañon Canal  
**Location:** Arlington, Wyoming  
**Job No.:** 7246-HE  
**Client:** Wyoming Water Development Commission

**Surface El.(Ft):** 7711.0  
**Benchmark/Datum (Ft):** Mean Sea Level

<table>
<thead>
<tr>
<th>DEPTH (FT)</th>
<th>SAMPLING TYPE - NO.</th>
<th>DEPTH (FT)</th>
<th>SOIL DESCRIPTION</th>
<th>USCS/BLOWS N</th>
<th>q_p (TSF)</th>
<th>W (%)</th>
<th>( \gamma_m ) (PCF)</th>
<th>LL PL</th>
<th>OTHER TESTS</th>
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<tr>
<td>5</td>
<td>SS-1</td>
<td>5.0-6.5</td>
<td>Soft, Moist, Dark Brown, Silty CLAY</td>
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<td>22.2</td>
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<tr>
<td>10</td>
<td>SS-2</td>
<td>10.0-11.5</td>
<td>Very Dense, Wet, Brown, Fine SAND</td>
<td>&gt;50/4&quot;</td>
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</tr>
<tr>
<td>15</td>
<td>SS-3</td>
<td>15.0-16.5</td>
<td>&gt;50/5&quot;</td>
<td>23.4</td>
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<td>Sieve</td>
</tr>
<tr>
<td>20</td>
<td>SS-4</td>
<td>20.0-21.5</td>
<td>Very Stiff, Moist, Orangish Brown, Fractured CLAYSTONE (Hanna Formation)</td>
<td>34.8</td>
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</tbody>
</table>

**WATER LEVEL OBSERVATIONS**

- **Initial Occurrence While Drilling (Ft):** 9.0  
- **Time After Drilling:** 1 hr  
- **Depth to Water (Ft):** 7.19  
- **Depth to Cave-In (Ft):**

**DRILLING AND SAMPLING NOTES**

- **Date Begun:** 6/26/96  
- **Comp.:** 6/26/96  
- **Crew:** REP/ETG  
- **Rig:** CME-55  
- **Method:** 3.25" HSA  
- **Termination Depth (Ft):** 21.5

INBERG-MILLER ENGINEERS
<table>
<thead>
<tr>
<th>DEPTH</th>
<th>SAMPLING</th>
<th>SOIL DESCRIPTION</th>
<th>N</th>
<th>q_p</th>
<th>Td</th>
<th>LL</th>
<th>OTHER T</th>
<th>PER FT</th>
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</thead>
<tbody>
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<td>Medium Dense, Moist, Brown, Fine SAND (Hanna Formation)</td>
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<td>5</td>
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<td>Hard, Moist, Brown, Slightly Fractured CLAYSTONE</td>
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<td>(Hanna Formation)</td>
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<td>10</td>
<td>SS-2</td>
<td>Grades to Black Organic-rich Claystone to Coal at 12.0'</td>
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<td>10.0-11.5</td>
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<tr>
<td>15</td>
<td>SS-3</td>
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<td>15.0-16.5</td>
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<td>31.4</td>
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(Log Continued on Next Page)
## LOG OF TEST BORING NO. B7246-10

**Project:** Canón Canal  
**Location:** Arlington, Wyoming  
**Job No.:** 7246-HE  
**Client:** Wyoming Water Development Commission

<table>
<thead>
<tr>
<th>Surface El. (Ft):</th>
<th>7679.5</th>
<th>Benchmark/Datum (Ft): Mean Sea Level</th>
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</table>

<table>
<thead>
<tr>
<th>DEPTH (FT)</th>
<th>SAMPLING TYPE - NO. DEPTH (FT)</th>
<th>RECOVERY (IN)</th>
<th>SOIL DESCRIPTION</th>
<th>USCS/N BLOWS PER FT</th>
<th>q_p (TSF)</th>
<th>W (%)</th>
<th>γ_m (PCF)</th>
<th>LL PI (%)</th>
<th>OTHER TESTS</th>
</tr>
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<tr>
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<td>25.0-26.5</td>
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</tbody>
</table>

### WATER LEVEL OBSERVATIONS

| Initial Occurrence While Drilling (Ft) | 24.0 |
| Time After Drilling | 2 min |
| Depth to Water (Ft) | 18.0 |
| Depth to Cave-In (Ft) | None |

### DRILLING AND SAMPLING NOTES

<table>
<thead>
<tr>
<th>Date Begun</th>
<th>6/26/96</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crew</td>
<td>REP/ETG</td>
</tr>
<tr>
<td>Rig</td>
<td>CME-55</td>
</tr>
<tr>
<td>Method</td>
<td>3.25&quot; HSA</td>
</tr>
<tr>
<td>Termination Depth (Ft)</td>
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</tr>
</tbody>
</table>

*INBERG-MILLER ENGINEERS*
**MONITOR WELL INSTALLATION RECORD**

**PROJECT:** Cañon Canal  
**LOCATION:** Arlington, Wyoming  
**BORING NO.:** B7246-1  
**CLIENT:** Wyoming Water Development Commission  
**MONITOR WELL NO.:** MW7246-1  

**CAP:** Flush-Mounted

**CASING**
- **DIAMETER:** 2.0 in.
- **MATERIAL:** PVC
- **GAUGE:** Sch 40
- **FROM (A):** 0.0 ft.
- **TO (J):** 35.0 ft.

**BLANK CASING**
- **FROM (A):** 0.0 ft.
- **TO (G):** 25.0 ft.

**FACTORY SLOTTED CASING (SCREEN)**
- **SLOT SIZE:** 0.02 in.
- **FROM (G):** 25.0 ft.
- **TO (H):** 35.0 ft.

**BLANK CASING**
- **FROM (H):** N/A ft.
- **TO (J):** N/A ft.

**PACKING**
- **CONCRETE**
  - **FROM (B):** 0.0 ft.
  - **TO (C):** 2.0 ft.

**BENTONITE PLUG**
- **FROM (C):** N/A ft.
- **TO (D):** N/A ft.

**BACKFILL:** Natural Soil
- **FROM (D):** 2.0 ft.
- **TO (E):** 23.0 ft.

**BENTONITE PLUG**
- **FROM (E):** N/A ft.
- **TO (F):** N/A ft.

**SAND:** 10-20 Silica Sand
- **FROM (F):** 23.0 ft.
- **TO (I):** 40.0 ft.

**NATURAL CAVE-IN**
- **FROM (I):** N/A ft.
- **TO (K):** N/A ft.

**TOTAL COMPLETED CASING DEPTH (J):** 35.0 ft.  
**TOTAL COMPLETED TEST BORING DEPTH (K):** 40.0 ft.

**NOTE:** All depths measured from existing ground surface

**ELEVATIONS**
- **COMPLETION DATE:** 6/17/96  
- **SURFACE ELEV.:** 7723.69 ft.  
- **CASING ELEV.:** 7753.87 ft.

**POTENTIOMETRIC SURFACE**
- **DATE:** 7/9/96  
  - **7723.69 ft.**
- **DATE:** 7/10/96  
  - **7744.69 ft.**
- **DATE:** 7/15/96  
  - **7745.14 ft.**

**INBERG-MILLER ENGINEERS**
**Monitor Well Installation Record**

**Project:** Canon Canal  
**Location:** Arlington, Wyoming  
**Boring No.:** B7246-7  
**Monitor Well No.:** MW7246-2  
**Client:** Wyoming Water Development Commission

**Cap:** Flush-Mounted

**Casing**
- **Diameter:** 2.0 in.  
- **Material:** PVC  
- **Gauge:** Sch 40  

**FROM (A):**
- **To (J):**

**Blank Casing**
- **FROM (A):** 0.0 ft.  
- **To (G):** 25.0 ft.  
- **To (H):** 35.0 ft.

**Factory Slotted Casing (Screen)**
- **Slot Size:** 0.02 in.  
- **FROM (G):** 25.0 ft.  
- **TO (H):** 35.0 ft.

**Blank Casing**
- **FROM (H):** N/A ft.  
- **To (J):** N/A ft.

**Packing**
- **Concrete**
  - **FROM (B):** 0.0 ft.  
  - **TO (C):** 2.0 ft.
- **Bentonite Plug**
  - **FROM (C):** N/A ft.  
  - **TO (D):** N/A ft.
- **Backfill:** Natural Soil  
  - **FROM (D):** 2.0 ft.  
  - **TO (E):** 23.0 ft.
- **Bentonite Plug**
  - **FROM (E):** N/A ft.  
  - **TO (F):** N/A ft.
- **Sand:** 10-20 Silica Sand  
  - **FROM (F):** 23.0 ft.  
  - **TO (I):** 35.5 ft.
- **Natural Cave-In**
  - **FROM (I):** N/A ft.  
  - **TO (K):** N/A ft.

**Total Completed Casing Depth (J):** 35.0 ft.  
**Total Completed Test Boring Depth (K):** 36.5 ft.

**Elevations**
- **Completion Date:** 6/19/96  
- **Surface Elev.:** ft.  
- **Casing Elev.:** 7790.82 ft.

**Potentiometric Surface**
- **Date:** 7/9/96  
- **7759.63 ft.**  
- **Date:** 7/10/96  
- **7759.62 ft.**  
- **Date:** 7/15/96  
- **7759.62 ft.**

**Note:** All depths measured from existing ground surface.

*Inberg-Miller Engineers*
MONITOR WELL INSTALLATION RECORD

PROJECT: Canon Canal
LOCATION: Arlington, Wyoming
BORING NO.: B7246-2

CAP: Flush-Mounted

CASING
DIAMETER: 2.0 in.
MATERIAL: PVC
GAUGE: Sch 40
FROM (A): 0.0 ft.
TO (J): 50.0 ft.

BLANK CASING
FROM (A): 0.0 ft.
TO (G): 30.0 ft.

FACTORY SLOTTED CASING (SCREEN)
SLT SIZE: 0.02 in.
FROM (G): 30.0 ft.
TO (H): 50.0 ft.

BLANK CASING
FROM (H): N/A ft.
TO (J): N/A ft.

PACKING
CONCRETE
FROM (B): 0.0 ft.
TO (C): 2.0 ft.

BENTONITE PLUG
FROM (C): N/A ft.
TO (D): N/A ft.

BACKFILL: Natural Soil
FROM (D): 2.0 ft.
TO (E): 28.0 ft.

BENTONITE PLUG
FROM (E): N/A ft.
TO (F): N/A ft.

SAND: 10-20 Silica Sand
FROM (F): 28.0 ft.
TO (I): 51.5 ft.

NATURAL CAVE-IN
FROM (I): N/A ft.
TO (K): N/A ft.

TOTAL COMPLETED CASING DEPTH (J): 50.0 ft.
TOTAL COMPLETED TEST BORING DEPTH (K): 51.5 ft.

NOTE: All depths measured from existing ground surface
# Monitor Well Installation Record

**Project:** Cañon Canal  
**Location:** Arlington, Wyoming

**Boring No.:** B7246-8  
**Cap:** Flush-Mounted

**Casing**
- **Diameter:** 2.0 in.  
- **Material:** PVC  
- **Gauge:** Sch 40

**Blank Casing**
- **From (A):** 0.0 ft.  
- **To (J):** 30.0 ft.

**Factory Slotted Casing (Screen)**
- **Slot Size:** 0.02 in.  
- **From (G):** 15.0 ft.  
- **To (H):** 30.0 ft.

**Blank Casing**
- **From (H):** N/A ft.  
- **To (J):** N/A ft.

**Packing**
- **Concrete**
  - **From (B):** 0.0 ft.  
  - **To (C):** 2.0 ft.

**Bentonite Plug**
- **From (C):** N/A ft.  
- **To (D):** N/A ft.

**Backfill:** Natural Soil
- **From (D):** 2.0 ft.  
- **To (E):** 10.0 ft.

**Bentonite Plug**
- **From (E):** N/A ft.  
- **To (F):** N/A ft.

**Sand:** 10-20 Silica Sand
- **From (F):** 10.0 ft.  
- **To (I):** 30.0 ft.

**Natural Cave-In**
- **From (I):** N/A ft.  
- **To (K):** N/A ft.

**Total Completed Casing Depth (J):** 30.0 ft.  
**Total Completed Test Boring Depth (K):** 31.5 ft.

---

**Elevations**
- **Completion Date:** 6/26/96  
- **Surface Elev.:** N/A ft.  
- **Casing Elev.:** 7719.18 ft.

**Potentiometric Surface**
- **Date:** 7/9/96  
- **Elev.:** 7697.73 ft.  
- **Date:** 7/10/96  
- **Elev.:** 7703.21 ft.  
- **Date:** 7/15/96  
- **Elev.:** 7716.06 ft.

---

**Note:** All depths measured from existing ground surface

---

**Client:** Wyoming Water Development Commission

---

**Monitor Well No.:** MW7246-4

---

**Inberg-Miller Engineers**
MONITOR WELL INSTALLATION RECORD

PROJECT: Cañon Canal
LOCATION: Arlington, Wyoming
BORING NO.: B7246-9
CLIENT: Wyoming Water Development Commission
MONITOR WELL NO.: MW7246-5
JOB NO.: 7246-HE

CAP: Locking Steel

CASING
- DIAMETER: 2.0 in.
- MATERIAL: PVC
- GAUGE: Sch 40
  - FROM (A): 0.0 ft.
  - TO (J): 20.0 ft.

BLANK CASING
- FROM (A): 0.0 ft.
- TO (G): 5.0 ft.

FACTORY SLOTTED CASING (SCREEN)
- SLOT SIZE: 0.02 in.
  - FROM (G): 5.0 ft.
  - TO (H): 20.0 ft.

BLANK CASING
- FROM (H): N/A ft.
- TO (J): N/A ft.

PACKING
- CONCRETE
  - FROM (B): 0.0 ft.
  - TO (C): 2.0 ft.

BENTONITE PLUG
- FROM (C): N/A ft.
- TO (D): N/A ft.

BACKFILL: Natural Soil
- FROM (D): 2.0 ft.
- TO (E): 4.0 ft.

BENTONITE PLUG
- FROM (E): N/A ft.
- TO (F): N/A ft.

SAND: 10-20 Silica Sand
- FROM (F): 4.0 ft.
- TO (I): 20.0 ft.

NATURAL CAVE-IN
- FROM (I): N/A ft.
- TO (K): N/A ft.

TOTAL COMPLETED CASING DEPTH (J): 20.0 ft.
TOTAL COMPLETED TEST BORING DEPTH (K): 21.5 ft.

ELEVATIONS
- COMPLETION DATE: 6/26/96
- SURFACE ELEV.: __ ft.
- CASING ELEV.: 7711.47 ft.

POTENTIOMETRIC SURFACE
- DATE: 7/9/96 7703.94 ft.
- DATE: 7/10/96 7706.37 ft.
- DATE: 7/15/96 7711.05 ft.

NOTE: All depths measured from existing ground surface

INBERG-MILLER ENGINEERS
**MONITOR WELL INSTALLATION RECORD**

**PROJECT:** Cañon Canal  
**LOCATION:** Arlington, Wyoming  
**BORING NO.:** B7246-10  
**CLIENT:** Wyoming Water Development Commission  
**JOB NO.:** 7246-HE  
**MONITOR WELL NO.:** MW7246-6A

**CAP:** Locking Steel

**CASING**
- **DIAMETER:** 2.0 in.  
- **MATERIAL:** PVC  
- **GAUGE:** Sch 40
  - **FROM (A):** 0.0 ft.  
  - **TO (J):** 25.0 ft.

**BLANK CASING**
- **FROM (A):** 0.0 ft.  
- **TO (G):** 20.0 ft.

**FACTORY SLOTTED CASING (SCREEN)**
- **SLOT SIZE:** 0.02 in.
  - **FROM (G):** 20.0 ft.  
  - **TO (H):** 25.0 ft.

**BLANK CASING**
- **FROM (H):** N/A ft.  
- **TO (J):** N/A ft.

**PACKING**
- **CONCRETE**
  - **FROM (B):** 0.0 ft.  
  - **TO (C):** 2.0 ft.

**BENTONITE PLUG**
- **FROM (C):** N/A ft.  
- **TO (D):** N/A ft.

**BACKFILL:**
- **FROM (D):** N/A ft.  
- **TO (E):** N/A ft.

**BENTONITE PLUG**
- **FROM (E):** 15.0 ft.  
- **TO (F):** 20.0 ft.

**SAND:** 10-20 Silica Sand
  - **FROM (F):** 20.0 ft.  
  - **TO (I):** 25.0 ft.

**NATURAL CAVE-IN**
- **FROM (I):** N/A ft.  
- **TO (K):** N/A ft.

**TOTAL COMPLETED CASING DEPTH (J):** 25.0 ft.  
**TOTAL COMPLETED TEST BORING DEPTH (K):** 26.5 ft.

**ELEVATIONS**
- **COMPLETION DATE:** 6/26/96  
- **SURFACE ELEV.:** 7679.55 ft.

**POTENTIOMETRIC SURFACE**
- **DATE:** 7/9/96  
  - **ELEV.:** 7671.19 ft.
- **DATE:** 7/10/96  
  - **ELEV.:** 7671.17 ft.
- **DATE:** 7/15/96  
  - **ELEV.:** 7672.81 ft.

**NOTE:** All depths measured from existing ground surface.

INBERG-MILLER ENGINEERS
### MONITOR WELL INSTALLATION RECORD

**PROJECT:** Canon Canal  
**LOCATION:** Arlington, Wyoming  
**BORING NO.:** B7246-10  
**CLIENT:** Wyoming Water Development Commission  
**JOB NO.:** 7246-HE  
**MONITOR WELL NO.:** MW7246-6B

**CAP:** Locking Steel

**CASING**
- **DIAMETER:** 2.0 in.  
- **MATERIAL:** PVC  
- **GAUGE:** Sch 40  
  - FROM (A): 0.0 ft.  
  - TO (J): 15.0 ft.

**BLANK CASING**
- FROM (A): 0.0 ft.  
- TO (G): 0.0 ft.

**FACTORY SLOTTED CASING (SCREEN)**
- **SLOT SIZE:** 0.02 in.  
  - FROM (G): 5.0 ft.  
  - TO (H): 15.0 ft.

**BLANK CASING**
- FROM (H): N/A ft.  
- TO (J): N/A ft.

**PACKING**
- **CONCRETE**  
  - FROM (B): 0.0 ft.  
  - TO (C): 2.0 ft.

**BENTONITE PLUG**
- FROM (C): 2.0 ft.  
- TO (D): 4.5 ft.

**BACKFILL:**
- FROM (D): N/A ft.  
- TO (E): N/A ft.

**BENTONITE PLUG**
- FROM (E): 4.5 ft.  
- TO (F): 5.0 ft.

**SAND:** 10-20 Silica Sand
- FROM (F): 5.0 ft.  
- TO (I): 15.0 ft.

**NATURAL CAVE-IN**
- FROM (I): N/A ft.  
- TO (K): N/A ft.

**TOTAL COMPLETED CASING DEPTH (J):** 15.0 ft.  
**TOTAL COMPLETED TEST BORING DEPTH (K):** 26.5 ft.

### ELEVATIONS
- **COMPLETION DATE:** 6/26/96  
- **SURFACE ELEV.:** ft.  
- **CASING ELEV.:** 7679.49 ft.

### POTENTIOMETRIC SURFACE
- **DATE:** 7/9/96  
  - **ELEV.:** 7667.58 ft.
- **DATE:** 7/10/96  
  - **ELEV.:** 7667.52 ft.
- **DATE:** 7/15/96  
  - **ELEV.:** 7670.91 ft.

**NOTE:** All depths measured from existing ground surface

---

_INBERG-MILLER ENGINEERS_
LOG OF TEST BORING/TEST PIT - GENERAL NOTES

DESCRIPTIVE SOIL CLASSIFICATION

Grain Size Terminology

<table>
<thead>
<tr>
<th>Soil Fraction</th>
<th>Particle Size</th>
<th>U. S. Standard</th>
<th>Sieve Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boulders</td>
<td>Larger than 12&quot;</td>
<td>Larger than 12&quot;</td>
<td>3&quot; to 12&quot;</td>
</tr>
<tr>
<td>Cobbles</td>
<td>3&quot; to 12&quot;</td>
<td>3&quot; to 12&quot;</td>
<td></td>
</tr>
<tr>
<td>Gravel: Coarse</td>
<td>3/4&quot; to 3&quot;</td>
<td>3/4&quot; to 3&quot;</td>
<td></td>
</tr>
<tr>
<td>Fine</td>
<td>4.76mm to 3/4&quot;</td>
<td>#4 to 3/4&quot;</td>
<td></td>
</tr>
<tr>
<td>Sand: Coarse</td>
<td>2.00mm to 4.76mm</td>
<td>#10 to #4</td>
<td></td>
</tr>
<tr>
<td>Medium</td>
<td>0.42mm to 2.00mm</td>
<td>#40 to #10</td>
<td></td>
</tr>
<tr>
<td>Fine</td>
<td>0.074mm to 0.42mm</td>
<td>#200 to #40</td>
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<tr>
<td>Silt</td>
<td>0.005mm to 0.074mm</td>
<td>Smaller than #200</td>
<td></td>
</tr>
<tr>
<td>Clay</td>
<td>Smaller than 0.005mm</td>
<td>Smaller than #200</td>
<td></td>
</tr>
</tbody>
</table>

Plasticity characteristics differentiate between silt & clay

Relative Density | "n" Value* | Consistency | 9-ton/sq.ft. |
<table>
<thead>
<tr>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Loose</td>
<td>.0-4</td>
<td>Very Soft</td>
<td>.0 to 0.25</td>
</tr>
<tr>
<td>Loose</td>
<td>.4-10</td>
<td>Soft</td>
<td>.25 to 0.5</td>
</tr>
<tr>
<td>Medium Dense</td>
<td>10-30</td>
<td>Firm</td>
<td>.5 to 1.0</td>
</tr>
<tr>
<td>Dense</td>
<td>30-50</td>
<td>Stiff</td>
<td>1.0 to 2.0</td>
</tr>
<tr>
<td>Very Dense</td>
<td>Over 50</td>
<td>Very Stiff</td>
<td>2.0 to 4.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hard</td>
<td>Over 4.0</td>
</tr>
</tbody>
</table>

*NOTE: The penetration number, N, is the summation of blows required to affect two successive 6" penetrations of the 2" split-barrel sampler. The sampler is driven with a 140-lb. weight falling 30" and is seated to a depth of 6" before commencing the standard penetration test.

DESCRIPTIVE ROCK CLASSIFICATION

Engineering Hardness Description of Rock
(not to be confused with MOH's scale for minerals)

Very Soft: Can be carved with knife. Can be excavated readily with point of pick. Pieces one inch or more in thickness can be broken with finger pressure. Can be scratched readily by fingernail.

Soft: Can be gouged or grooved readily with knife or pick point. Can be excavated in chips to pieces several inches in size by moderate blows of a pick point. Small thin pieces can be broken by finger pressure.

Medium Soft: Can be gouged or gouged 1/16-inch deep by firm pressure on knife or pick point. Can be excavated in small chips to pieces about one-inch-maximum size by hard blows of the point of a geologist's pick.

Medium Hard: Can be scratched with knife or pick. Gouges or grooves to 1/4-inch deep can be excavated by hard blow of a geologist's pick. Hand specimens can be detached by moderate blow.

Hard: Can be scratched with knife or pick only with difficulty. Hard blow of hammer required to detach hand specimen.

Very Hard: Cannot be scratched with knife or sharp pick. Breaking of hand specimens requires several hard blows of geologist's pick.

NOMENCLATURE

Drilling and Sampling

SS - Split Barrel (spoon) sample
N - Standard Penetration Test No. (ASTM D1586), blows per foot
ST - Thin-walled Tube (Shelby Tube) sample (ASTM D1587)
DC - Drive Cylinder - Thick-wall drive sampler with stainless steel liner (O.D. = 3-1/8", I.D. = 2-1/2"); Sampler driven with ASTM D1586 effort.
A - Auger Sample (disturbed)
D - Disturbed Sample (backhoe, shovel, etc.)

Laboratory Tests

USCS - Unified Soil Classification System - Soil Type
W - Water Content, %
LL - Liquid Limit, %
PL - Plastic Limit, %
PS - Plasticity Index (LL-PL), %
q_u - Unconfined Strength, TSF
q_p - Penetrometer Reading (estimate of unconfined strength), TSF
γ_m - Moist Unit Weight, PCF
γ_d - Dry Unit Weight, PCF
WSS - Water Soluble Sulfate, %
Ø - Angle of Internal Friction, degrees
c - Soil Cohesion, TSF
SG - Specific gravity of soil solids
S - Degree of Saturation, %
e - Void Ratio
n - Porosity
k - Permeability, cm/sec.

Water Level Measurement

Y - Water Level at Time Shown

Note: Water level measurements shown on the boring logs represent conditions at the time indicated and may not reflect static levels, especially in cohesive soils. The available water level information is given at the bottom of each log.
CLASSIFICATION OF SOILS FOR ENGINEERING PURPOSES

ASTM Designation: D2487 -69 and D2488 - 69
(Unified Classification System)

<table>
<thead>
<tr>
<th>Major Divisions</th>
<th>Group Symbols</th>
<th>Typical Names</th>
<th>Laboratory Classification Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coarse-grained soils</td>
<td>GW</td>
<td>Well-graded gravels, gravel-sand mixtures, little or no fines</td>
<td>( C_L = \frac{D_{60}}{D_{10}} ) greater than 4; ( C_F = \frac{(D_{30})^2}{D_{10} \times D_{60}} ) between 1 and 3</td>
</tr>
<tr>
<td>(more than half of material is larger than No. 200 sieve size)</td>
<td>GP</td>
<td>Poorly graded gravels, gravel-sand mixtures, little or no fines</td>
<td>Not meeting all gradation requirements for GW</td>
</tr>
<tr>
<td></td>
<td>GM</td>
<td>Silty gravels, gravel-sand-silt mixtures</td>
<td>Atterberg limits below &quot;A&quot; line or P.I. less than 4</td>
</tr>
<tr>
<td></td>
<td>GC</td>
<td>Clayey gravels, gravel-sand-clay mixtures</td>
<td>Atterberg limits below &quot;A&quot; line with P.I. greater than 7</td>
</tr>
<tr>
<td></td>
<td>SW</td>
<td>Well-graded sands, gravelly sands, little or no fines</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SP</td>
<td>Poorly graded sands, gravelly sands, little or no fines</td>
<td>Not meeting all gradation requirements for SW</td>
</tr>
<tr>
<td></td>
<td>SM</td>
<td>Silty sands, sand-silt mixtures</td>
<td>Atterberg limits above &quot;A&quot; line or P.I. less than 4</td>
</tr>
<tr>
<td></td>
<td>SC</td>
<td>Clayey sands, sand-clay mixtures</td>
<td>Atterberg limits above &quot;A&quot; line with P.I. greater than 7</td>
</tr>
<tr>
<td></td>
<td>ML</td>
<td>Inorganic silts and very fine sands, rock flour, silty or clayey fine sands, or clayey silts with slight plasticity</td>
<td>Limits plotting in hatched zone with P.I. between 4 and 7 are borderline cases requiring use of dual symbols</td>
</tr>
<tr>
<td></td>
<td>CL</td>
<td>Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays</td>
<td></td>
</tr>
<tr>
<td></td>
<td>OL</td>
<td>Organic silts and organic silty clays of low plasticity</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MH</td>
<td>Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CH</td>
<td>Inorganic clays of high plasticity, fat clays</td>
<td></td>
</tr>
<tr>
<td></td>
<td>OH</td>
<td>Organic clays of medium to high plasticity, organic silts</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pt</td>
<td>Peat and other highly organic soils</td>
<td></td>
</tr>
</tbody>
</table>

Note: Division of GM and SM groups into subdivisions of d and u are for roads and airfields only. Subdivision is based on Atterberg limits; suffix d used when L.L. is 28 or less and the P.I. is 6 or less, the suffix u used when L.L. is greater than 28.

Borderline classifications, used for soils possessing characteristics of two groups, are designated by combinations of group symbols. For example, GW-GC, well-graded gravel-sand mixture with clay binder.

Plasticity Chart

INBERG-MILLER ENGINEERS
PARTICLE SIZE ANALYSIS

PROJECT: Cañon Canal
JOB NO.: 7246-HE
TEST DATE: 8/7/96
TESTED BY: ASC
TEST METHOD: ASTM D422

U.S. STANDARD SIEVE OPENINGS
(inches) (numbers)

1 1/2 4 8 16 40 100 200

100 75 50 25 0

PERCENT FINER BY WEIGHT

100 10 1 0.1 0.01

GRAIN SIZE IN MILLIMETERS

COBBLES COARSE GRAVEL FINE GRAVEL COARSE SAND MEDIUM SAND FINE SAND SILT CLAY

SOIL DESCRIPTION: Gray, Coarse Sand
SAMPLE NO.: B-1-7
SAMPLED BY: ETG
SOURCE: Test Boring B7246-1
DEPTH: 32.00

LIQUID LIMIT: 
PERCENT GRAVEL: 10.6
PLASTIC LIMIT: 
PERCENT SAND: 70.3
PLASTICITY INDEX: 
PERCENT SILT & CLAY: 19.1

INBERG-MILLER ENGINEERS
PARTICLE SIZE ANALYSIS

PROJECT: Cañon Canal
JOB NO.: 7246-HE
TEST DATE: 8/7/96
TESTED BY: ASC
TEST METHOD: ASTM D422

U.S. STANDARD SIEVE OPENINGS (inches) (numbers)

<p>| | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>2</td>
<td>1</td>
<td>1/2</td>
<td>4</td>
<td>8</td>
<td>16</td>
</tr>
<tr>
<td>40</td>
<td>100</td>
<td>200</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

HYDROMETER

GRAIN SIZE IN MILLIMETERS

<table>
<thead>
<tr>
<th>COBBLES</th>
<th>COARSE GRAVEL</th>
<th>FINE GRAVEL</th>
<th>COARSE SAND</th>
<th>MEDIUM SAND</th>
<th>FINE SAND</th>
<th>SILT</th>
<th>CLAY</th>
</tr>
</thead>
</table>

SOIL DESCRIPTION: Tan, Clayey Sand
SAMPLE NO.: B-2-2
SAMPLED BY: ETG
DEPTH: 15.00

LIQUID LIMIT: 
PLASTIC LIMIT: 
PLASTICITY INDEX: 

PERCENT GRAVEL: 0.1
PERCENT SAND: 77.3
PERCENT SILT & CLAY: 22.6
PARTICLE SIZE ANALYSIS

PROJECT: Cañon Canal  TEST DATE: 8/9/96
JOB NO.: 7246-HE  TESTED BY: ASC
CLIENT: Wyo. Water Development Comm.  TEST METHOD: ASTM D422

U.S. STANDARD SIEVE OPENINGS
(inches) (numbers) HYDROMETER

| HYDROMETER |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| 3   | 2   | 1   | 1/2 | 4   | 8   | 16  | 40  | 100  | 200 |

GRAIN SIZE IN MILLIMETERS

| 100 | 10  | 1   | 0.1 | 0.01 | 0.001 |

PERCENT FINER BY WEIGHT

| 100 | 75  | 50  | 25  | 0    |

COBBLES  COARSE GRAVEL  FINE GRAVEL  COARSE SAND  MEDIUM SAND  FINE SAND  SILT  CLAY

SOIL DESCRIPTION: Light Brown to Orangish Brown, Silty Clay
SOURCE: Test Boring B7246-3A
SAMPLE NO.: B-3-2
SAMPLED BY: ETG
DEPTH: 15.00

LIQUID LIMIT:  PERCENT GRAVEL: 0.0
PLASTIC LIMIT:  PERCENT SAND: 37.3
PLASTICITY INDEX:  PERCENT SILT & CLAY: 62.7
PARTICLE SIZE ANALYSIS

PROJECT: Cañon Canal
JOB NO.: 7246-HE
TEST DATE: 8/7/96
TESTED BY: ASC

TEST METHOD: ASTM D422

U.S. STANDARD SIEVE OPENINGS
( inches) (numbers)
3 2 1 1/2 4 8 16 40 100 200

PERCENT FINER BY WEIGHT
100 75 50 25 0

GRAIN SIZE IN MILLIMETERS
100 10 1 0.1 0.01 0.001

SOIL DESCRIPTION: Tan to Brown, Clayey Sand
SOURCE: Test Boring B7246-7
SAMPLE NO.: B-7-17
SAMPLED BY: ETG
DEPTH: 29.00

LIQUID LIMIT: NP
PLASTIC LIMIT: NP
PLASTICITY INDEX: NP
PERCENT GRAVEL: 20.2
PERCENT SAND: 71.6
PERCENT SILT & CLAY: 8.2

INBERG-MILLER ENGINEERS
PARTICLE SIZE ANALYSIS

PROJECT: Cañon Canal
JOB NO.: 7246-HE
TEST DATE: 8/7/96
TESTED BY: REP
TEST METHOD: ASTM D422

U.S. STANDARD SIEVE OPENINGS

<table>
<thead>
<tr>
<th>(inches)</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>1/2</th>
<th>4</th>
<th>8</th>
<th>16</th>
<th>40</th>
<th>100</th>
<th>200</th>
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<tbody>
<tr>
<td>(numbers)</td>
<td>8</td>
<td>16</td>
<td>40</td>
<td>100</td>
<td>200</td>
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<td></td>
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</tbody>
</table>

HYDROMETER

SOIL DESCRIPTION: Light Brown, Silty Clay
SAMPLE NO.: B-7-19
SAMPLED BY: ETG
SOURCE: Test Boring B7246-7
DEPTH: 32.00

LIQUID LIMIT: 80
PLASTIC LIMIT: 41
PLASTICITY INDEX: 39
PERCENT GRAVEL: 0.0
PERCENT SAND: 14.9
PERCENT SILT & CLAY: 85.1
## PARTICLE SIZE ANALYSIS

**PROJECT:** Cañon Canal  
**JOB NO.:** 7246-HE  
**CLIENT:** Wyo. Water Development Comm.  
**TEST DATE:** 8/7/96  
**TESTED BY:** ASC  
**TEST METHOD:** ASTM D422

### U.S. STANDARD SIEVE OPENINGS

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<thead>
<tr>
<th>Inches</th>
<th>Numbers</th>
</tr>
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<tbody>
<tr>
<td>3</td>
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<tr>
<td>2</td>
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<tr>
<td>1</td>
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<tr>
<td>100</td>
<td></td>
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<tr>
<td>200</td>
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</table>

### HYDROMETER

![Hydrometer Graph]

### GRAIN SIZE IN MILLIMETERS

<table>
<thead>
<tr>
<th>COBBLES</th>
<th>COARSE GRAVEL</th>
<th>FINE GRAVEL</th>
<th>COARSE SAND</th>
<th>MEDIUM SAND</th>
<th>FINE SAND</th>
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### SOIL DESCRIPTION:
- Tan to Light Brown, Clayey Sand

### SOURCE:
- Test Boring B7246-9

### SAMPLE NO.:
- B-9-3

### SAMPLED BY:
- ETG

### DEPTH:
- 15.00

### LIQUID LIMIT:

### PLASTIC LIMIT:

### PLASTICITY INDEX:

### PERCENT GRAVEL:
- 0.1

### PERCENT SAND:
- 77.8

### PERCENT SILT & CLAY:
- 22.1
APPENDIX E - WATER TABLE DATA
WATER LEVEL ELEVATIONS FOR MW-1

Cañon Canal

Graph showing water level elevations with elapsed time in minutes on the x-axis and elevation in feet on the y-axis.
WATER LEVEL ELEVATIONS FOR MW-1
Cañon Canal

Elapsed Time, min

Elapsed Time, min

Elevation, ft
WATER LEVEL ELEVATIONS FOR MW-2
Cañon Canal

Elapsed Time, min

Elevation, ft
WATER LEVEL ELEVATIONS FOR MW-3

Cañon Canal
WATER LEVEL ELEVATIONS FOR MW-4
Cañon Canal

Graph showing water level elevations over elapsed time.
WATER LEVEL ELEVATIONS FOR MW-5
Cafón Canal

Elaborated Time, min

Elapsed Time, min

Elevation, ft
WATER LEVEL ELEVATIONS FOR MW-6A & 6B
Cañon Canal

Elapsed Time, min

Elevation, ft

- MW-6A
- MW-6B
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**Wyoming Water Development Commission**

**Sand Lake/Cañon Canal Rehabilitation Project**

**7246-HE**

**Water Level Elevations Table**
APPENDIX F - INFORMATION SOURCES
INFORMATION SOURCES

Information presented in this report is based partially upon the following sources.

Aerial Photographs


Maps

USGS Topographic Map - Arlington Quadrangle
USGS Geologic Map - Arlington Quadrangle

References

Case, J.C., 1986; Draft notes on Cañon Canal slide area; Wyoming Geological Survey.


Love, J.D. and Christiansen, A.C., 1985; Geologic map of Wyoming; United States Geologic Survey.

Oliver, Rod, 1995; Personal notes on Cañon Canal slide; Wyoming State Engineer's Office.
APPENDIX D - EXISTING CONDITIONS - SAND LAKE DAM
EXISTING CONDITIONS
SAND LAKE DAM

PROFILE ALONG CENTERLINE OF DAM CREST

LEGEND
- TP-1 TEST PITS PERFORMED BY INBERG-MILLER ENGINEERS ON OCTOBER 16, 1996.

INBERG-MILLER ENGINEERS

EXBISTING EMERGENCY SPILLWAY

PROFILE ALONG CENTERLINE OF DAM CREST
APPENDIX E - EXISTING CONDITIONS - CAÑON CANAL
APPENDIX F - LABORATORY TEST RESULTS - SAND LAKE DAM
PARTICLE SIZE ANALYSIS

PROJECT: Cañon Canal
JOB NO.: 7246-HE
TEST DATE: 10/2/96
TESTED BY: RDB
TEST METHOD: ASTM D422

U.S. STANDARD SIEVE OPENINGS

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PERCENT FINER BY WEIGHT

GRAIN SIZE IN MILLIMETERS

SOIL DESCRIPTION: Yellow to Brown, Sandy
SAMPLE NO.: Dam-1
SAMPLED BY: CLNT
SOURCE: Dam 1
DEPTH: 0.00

LIQUID LIMIT: 28
PERCENT GRAVEL: 18.7
PLASTIC LIMIT: 18
PERCENT SAND: 40.4
PLASTICITY INDEX: 10
PERCENT SILT & CLAY: 40.9

INBERG-MILLER ENGINEERS
PARTICLE SIZE ANALYSIS

PROJECT: Cañon Canal  TEST DATE: 1/9/97
JOB NO.: 7246-HE  TESTED BY: RDB
CLIENT: Wyo. Water Development Comm.  TEST METHOD: ASTM D422

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GRAIN SIZE IN MILLIMETERS

PERCENT FINER BY WEIGHT

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<th>FINE GRAVEL</th>
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<th>MEDIUM SAND</th>
<th>FINE SAND</th>
<th>SILT</th>
<th>CLAY</th>
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SOIL DESCRIPTION: Tan to Brown, Sandy Clay
SAMPLE NO.: Dam-2
SOURCE: (w/out dispersing agent)
DEPTH: 0.00

LIQUID LIMIT: 28
PLASTIC LIMIT: 19
PLASTICITY INDEX: 9

PERCENT GRAVEL: 8.0
PERCENT SAND: 42.7
PERCENT SILT & CLAY: 49.3

INBERG-MILLER ENGINEERS
PARTICLE SIZE ANALYSIS

PROJECT: Cañon Canal
JOB NO.: 7246-HE
TEST DATE: 1/9/97
TESTED BY: RDB
TEST METHOD: ASTM D422

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GRAIN SIZE IN MILLIMETERS

PERCENT FINE BY WEIGHT

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SOIL DESCRIPTION: Brown, Silty Clay

SAMPLE NO.: HA-1-1
SAMPLED BY: 
SOURCE: 
DEPTH: 0.00

LIQUID LIMIT: NP
PLASTIC LIMIT: NP
PLASTICITY INDEX: NP

PERCENT GRAVEL: 0.5
PERCENT SAND: 30.6
PERCENT SILT & CLAY: 68.9

INBERG-MILLER ENGINEERS
PARTICLE SIZE ANALYSIS

PROJECT: Cañon Canal
JOB NO.: 7246-HE
TEST DATE: 1/9/97
TESTED BY: RDB
TEST METHOD: ASTM D422

U.S. STANDARD SIEVE OPENINGS
(3 2 1 1/2 4 8 16 40 100 200) HYDROMETER

GRAIN SIZE IN MILLIMETERS

PERCENT FINE BY WEIGHT

COBBLES | COARSE GRAVEL | FINE GRAVEL | COARSE SAND | MEDIUM SAND | FINE SAND | SILT | CLAY

SOIL DESCRIPTION: Brown, Silty Clay
SAMPLE NO.: HA-1-1A
SOURCE: (w/out dispersing agent)
DEPTH: 0.00

LIQUID LIMIT: 
PERCENT GRAVEL: 0.5
PLASTIC LIMIT: 
PERCENT SAND: 48.2
PLASTICITY INDEX: 
PERCENT SILT & CLAY: 51.3

INBERG-MILLER ENGINEERS
PARTICLE SIZE ANALYSIS

PROJECT: Cañon Canal  TEST DATE: 1/9/97
JOB NO.: 7246-HE  TESTED BY: RDB
CLIENT: Wyo. Water Development Comm.  TEST METHOD: ASTM D422

U.S. STANDARD SIEVE OPENINGS

(inches)  (numbers)
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PERCENT FINER BY WEIGHT

GRAIN SIZE IN MILLIMETERS

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SOIL DESCRIPTION: Dark Brown, Clayey Sand
SAMPLE NO.: HA-2-1
SAGED SAMPLLY: _______________________
SOURCE: _______________________
DEPTH: 0.00

LIQUID LIMIT: NP
PERCENT GRAVEL: 1.9
PLASTIC LIMIT: NP
PERCENT SAND: 51.0
PLASTICITY INDEX: NP
PERCENT SILT & CLAY: 47.1

INBERG-MILLER ENGINEERS
PARTICLE SIZE ANALYSIS

PROJECT: Cañon Canal
JOB NO.: 7246-HE

TEST DATE: 1/9/97
TESTED BY: RDB

U.S. STANDARD SIEVE OPENINGS (inches) (numbers)

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GRAIN SIZE IN MILLIMETERS

COBBLES  COARSE GRAVEL  FINE GRAVEL  COARSE SAND  MEDIUM SAND  FINE SAND  SILT  CLAY

SOIL DESCRIPTION: Brown to Orange, Silty Sand
SOURCE: SAMPLE NO.: HA-2-2
SAMPLING BY: DEPTH: 17.00

LIQUID LIMIT: 35
PLASTIC LIMIT: 23
PLASTICITY INDEX: 12

PERCENT GRAVEL: 21.0
PERCENT SAND: 36.8
PERCENT SILT & CLAY: 42.2

INBERG-MILLER ENGINEERS
PARTICLE SIZE ANALYSIS

PROJECT: Cañon Canal
JOB NO.: 7246-HE
TEST DATE: 1/9/97
TESTED BY: RDB
TEST METHOD: ASTM D422

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COBBLES | COARSE GRAVEL | FINE GRAVEL | COARSE SAND | MEDIUM SAND | FINE SAND | SILT | CLAY
---|---------------|-------------|-------------|-------------|-----------|------|------

SOIL DESCRIPTION: Light Brown, Clayey Sand with Some Gravel
SAMPLE NO.: HA-3-1
SAMPLED BY: 
DEPTH: 16.00

LIQUID LIMIT: 
PERCENT GRAVEL: 11.0
PLASTIC LIMIT: 
PERCENT SAND: 59.2
PLASTICITY INDEX: 
PERCENT SILT & CLAY: 29.8

INBERG-MILLER ENGINEERS
PARTICLE SIZE ANALYSIS

PROJECT: Cañon Canal

TEST DATE: 1/9/97

JOB NO.: 7246-HE

TESTED BY: RDB


TEST METHOD: ASTM D422

U.S. STANDARD SIEVE OPENINGS
(inches) (numbers)

<table>
<thead>
<tr>
<th>3</th>
<th>2</th>
<th>1</th>
<th>1/2</th>
<th>4</th>
<th>8</th>
<th>16</th>
<th>40</th>
<th>100</th>
<th>200</th>
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<table>
<thead>
<tr>
<th>PERCENT FINER BY WEIGHT</th>
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<td>100</td>
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GRAN SIZE IN MILLIMETERS

COBBLES| COARSE GRAVEL| FINE GRAVEL| COARSE SAND| MEDIUM SAND| FINE SAND| SILT| CLAY

SOIL DESCRIPTION: Brown, Clayey Sand

SAMPLE NO.: HA-4-1

SAMPLED BY: ______________________

SOURCE: ______________________

DEPTH: 12.00

LIQUID LIMIT: NP

PERCENT GRAVEL: 0.4

PLASTIC LIMIT: NP

PERCENT SAND: 56.9

PLASTICITY INDEX: NP

PERCENT SILT & CLAY: 42.7

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METHOD:
U.S. STANDARD SIEVE OPENINGS (inches)
(numbers)

HYDROMETER

PERCENT FINER BY WEIGHT

GRAIN SIZE IN MILLIMETERS

COBBLES | COARSE GRAVEL | FINE GRAVEL | COARSE SAND | MEDIUM SAND | FINE SAND | SILT | CLAY

SOIL DESCRIPTION: Dark Brown, Sandy Silt
SAMPLE NO.: HA-5-1
SAMPLED BY:
SOURCE:
DEPTH: 0.00

LIQUID LIMIT: NP
PLASTIC LIMIT: NP
PLASTICITY INDEX: NP
PERCENT GRAVEL: 1.2
PERCENT SAND: 34.7
PERCENT SILT & CLAY: 64.1
PARTICLE SIZE ANALYSIS

PROJECT: Cañon Canal
JOB NO.: 7246-HE
TEST DATE: 10/2/96
TESTED BY: RDB
TEST METHOD: ASTM D422

U.S. STANDARD SIEVE OPENINGS
(inches) (numbers)

100 3 2 1 1/2 4 8 16 40 100 200

HYDROMETER

PERCENT FINER BY WEIGHT

50 25

GRAIN SIZE IN MILLIMETERS

100 10 1

G R A I N  S I Z E  I N  M I L L I M E T E R S

COBBLES COARSE GRAVEL FINE GRAVEL COARSE SAND MEDIUM SAND FINE SAND SILT CLAY

SOIL DESCRIPTION: Orange to Brown, Sandy Clay
SAMPLE NO.: Spill-1
SAMPLED BY: CLNT
SOURCE: Spillway 1
DEPTH: 0.00

LIQUID LIMIT: 25
PLASTIC LIMIT: 18
PLASTICITY INDEX: 7
PERCENT GRAVEL: 18.8
PERCENT SAND: 45.7
PERCENT SILT & CLAY: 35.5

INBERG-MILLER ENGINEERS
MOISTURE-DENSITY ANALYSIS

PROJECT: Cañon Canal
TEST DATE: 10/2/96

JOB NO.: 7246-HE
TESTED BY: RDB

TEST METHOD: ASTM D698-A

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WATER CONTENT (%)

DRIED DENSITY (pcf)

LINES OF 100% SATURATION

Gs = 2.80
Gs = 2.70
Gs = 2.60

SAMPLE NO.: Dam-1
SAMPLED BY: CLNT
DEPTH: 0.00

SOIL DESCRIPTION: Yellow to Brown, Sandy Clay
SOURCE: Dam 1

PASSING #200 SIEVE: 40.9 %
LIQUID LIMIT: 28
PLASTICITY INDEX: 10

OPTIMUM WATER CONTENT: 10.0 %
MAXIMUM DRY DENSITY: 119.0 pcf
Moisture-Density Analysis

Project: Cañon Canal
Test Date: 10/2/96

Job No.: 7246-HE
Tested by: RDB

Client: Wyo. Water Development Comm.
Test Method: ASTM D698-C

Sample No.: Dam-2
Sampled by: CLNT
Depth: 0.00

Soil Description: Yellow to Brown, Sandy Clay
Source: Dam 2

Passing #200 Sieve: __________ %
Liquid Limit: __________
Plasticity Index: __________
Optimum Water Content: 12.5 %
Maximum Dry Density: 118.0pcf

Lines of 100% Saturation
Gs = 2.80
Gs = 2.70
Gs = 2.60

Dry Density (pcf)

Water Content (%)
DIRECT SHEAR TEST
ASTM D3080

Project: Sand Lake Dam
Client: WWDC
Source of Sample: Dam 1
Description of Soil: Yellow to Brown Sandy Clay
Dry Density of Soil: 59.6 (pcf)

Shear Stress Versus Normal Stress

\[ C = 1500 \text{ psf}, \phi = 34.6^\circ \]

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DIRECT SHEAR TEST
ASTM D3080

Project: Sand Lake Dam
Client: WWDC
Source of Sample: Dam 2
Description of Soil: Yellow to Brown Sandy Clay
Dry Density of Soil: 59.6 (pcf)

Job No: 5969-HM
Date Received: 35411
Tested By: REP

Shear Stress Versus Normal Stress

\[ \tau = c + \sigma \tan \phi \]

\( c = 950 \), \( \phi = 29.5' \)

Shear Stress (psf) vs Normal Stress (psf)

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APPENDIX G - SLOPE STABILITY ANALYSIS - SAND LAKE DAM
Sand Lake
High Water Condition - Static Analysis
File Name 7246HE.SLP
Analysis Method Bishop
Seismic Coefficient 0

Minimum F of S = 4.393

Embankment
Unit Wt. = 125 pcf
Phi = 35
Cohesion = 1500 psf

Upper Foundation
Unit Wt. = 118 pcf
Phi = 30
Cohesion = 950 psf

Lower Foundation
Unit Wt. = 135 pcf
Phi = 35
Cohesion = 950

Horizontal Distance (ft)
Elevation (ft) (x 1000)
Water
Embankment
Upper Foundation
Lower Foundation
Bedrock
Sand Lake
High Water Condition - Seismic Analysis
File Name 7246HWS.SLP
Analysis Method Bishop
Seismic Coefficient 0.05

Minimum F of S = 3.857

Embankment
Unit Wt. = 125 pcf
Phi = 35
Cohesion = 1500 psf

Upper Foundation
Unit Wt. = 118 pcf
Phi = 30
Cohesion = 950 psf

Lower Foundation
Unit Wt. = 135 pcf
Phi = 35
Cohesion = 950 psf
Sand Lake
Water Overtopping Dam - Static Analysis
File Name 7246OT.SLP
Analysis Method Bishop
Seismic Coefficient 0

Minimum F of S = 3.803

Embankment
Unit Wt. = 125 pcf
Phi = 35
Cohesion = 1500 psf

Upper Foundation
Unit Wt. = 118 pcf
Phi = 30
Cohesion = 950 psf

Lower Foundation
Unit Wt. = 135 pcf
Phi = 35
Cohesion = 950 psf

Elevation (ft) (x 1000)

Horizontal Distance (ft)
Sand Lake
Water Overtopping Dam - Seismic Analysis
File Name 7246OTEQ.SLP
Analysis Method Bishop
Seismic Coefficient 0.05

Minimum F of S = 3.351

Embankment
Unit Wt. = 125 pcf
Phi = 35
Cohesion = 1500 psf

Upper Foundation
Unit Wt. = 118 pcf
Phi = 30
Cohesion = 950 psf

Lower Foundation
Unit Wt. = 135 pcf
Phi = 35
Cohesion = 950 psf

Horizontal Distance (ft)
Elevation (ft) (x 1000)

Bedrock
Lower Foundation
Embankment
Water
Upper Foundation
Lower Foundation
Bedrock
Sand Lake
Rapid Drawdown Condition - Static Analysis
File Name 7246RDST.SLP
Analysis Method Bishop
Seismic Coefficient 0

Minimum F of S = 4.893

Embankment
Unit Wt. = 125 pcf
Phi = 35
Cohesion = 1500 psf

Upper Foundation
Unit Wt. = 118 pcf
Phi = 30
Cohesion = 950 psf

Lower Foundation
Unit Wt. = 135 pcf
Phi = 35
Cohesion = 950 psf

Horizontal Distance (ft)

Elevation (ft) (x 1000)

Bedrock

Lower Foundation

Upper Foundation

Embankment
Sand Lake
Rapid Drawdown Condition - Seismic Analysis
File Name 7246RDEQ.SLP
Analysis Method Bishop
Seismic Coefficient 0.05

Minimum F of S = 4.145

Embarkment
Unit Wt. = 125 pcf
Phi = 35
Cohesion = 1500 psf

Upper Foundation
Unit Wt. = 118 pcf
Phi = 30
Cohesion = 950 psf

Lower Foundation
Unit Wt. = 135 pcf
Phi = 35
Cohesion = 950 psf
APPENDIX H - SLOPE STABILITY ANALYSIS - CAÑON CANAL SLIDE
RATIONAL

BASED ON THE GEOLOGIC CROSS-SECTION PREPARED
BY ETG, 2 LANDSLIDES ZONES (THE TOE AND SLOPE).
I SUSPECT THAT THE TOE FAILED FIRST, THEN THE
SLOPE FOLLOWED. THE TOE FAILURE WAS A RESULT
OF SATURATED CONDITIONS WITHIN THE TOE COMBINED
WITH THE EXTERNAL FORCE OF THE SLOPE "SURCHARGING"
THE TOE. ONCE THE TOE FAILED, THERE WAS
NO RESISTANCE TO HOLD BACK THE SLOPE AND
IT PROCEEDED TO FAIL. TO MODEL THIS
I HAVE DIVIDED THE MODEL INTO TWO
PARTS, 1) TOE WITH AN EXTERNAL SURCHARGE APPLIED
2) SLOPE WITH THE TOE REMOVED.

THE EXTERNAL SURCHARGE LOAD IMPOSED BY THE
SLOPE WAS DERIVED BY ASSUMING A BLOCK OF
SOIL 100 FT LONG, 30 FT TALL WITH UNIT THICKNESS,
HAVING A UNIT WT OF 135 PES BY LOOKING AT
THE SYSTEM AS A BLOCK ON AN INCLINED PLANE
AND LOOKING AT THE EFFECTS OF FRICTION AS SHOWN

\[
w = (1000 \times 30 \times 135) = 4.05 \times 10^6 \text{ *}
\]
\[
f = 0.8 \times 0 = 0.36
\]
\[
F_r = (0.36 \times 4.05 \times 10^6) (0 \times 90^\circ) = 1.46 \times 10^6 \text{ * *}
\]

THIS WOULD BE THE MAXIMUM AMOUNT, THEREFORE
I HAVE ATTACHED A GRAPH DEPICTING FACTOR OF
ERFOM VS. SURCHARGE LOAD. THE SURCHARGE
WAS APPLIED AS FOLLOWS.
Then if the slope is analyzed based on an infinite slope with no resistance at the toe, the slope fails.
Minimum F of S = 0.413

Slope Soils
Unit Wt. = 135 pcf
Phi = 25
Cohesion = 500 psf
Canon Canal
Canal Stability Analysis - Saturated Conditions
File Name CANON1.SLP
Analysis Method - Bishop
Seismic Coefficient 0
Line Pressure = 5000 psf

Minimum F of S = 0.413

Slope Soils
Unit Wt. = 135 pcf
Phi = 25
Cohesion = 500 psf

Horizontal Distance (ft) (x 1000)
Elevation (ft)
Minimum F of S = 0.433

Canon Canal
Slope Stability Analysis
File Name 7246CCSL.SLP
Analysis Method Bishop
Seismic Coefficient 0

Colluvium
- Unit Wt. = 130 pcf
- Phi = 25
- Cohesion = 1500 psf

Weak Layer
- Unit Wt. = 70 pcf
- Phi = 5
- Cohesion = 0 psf

Claystone
- Unit Wt. = 128 pcf
- Phi = 15
- Cohesion = 3000 psf
Canon Canal - Stability Analysis

Normal Pressure vs F of S

Factor of Safety vs Normal Pressure