This is a digital document from the collections of the Wyoming Water Resources Data System (WRDS) Library.

For additional information about this document and the document conversion process, please contact WRDS at wrds@uwyo.edu and include the phrase “Digital Documents” in your subject heading.

To view other documents please visit the WRDS Library online at: http://library.wrds.uwyo.edu

Mailing Address:
Water Resources Data System
University of Wyoming, Dept 3943
1000 E University Avenue
Laramie, WY 82071

Physical Address:
Wyoming Hall, Room 249
University of Wyoming
Laramie, WY 82071

Phone: (307) 766-6651
Fax: (307) 766-3785

Funding for WRDS and the creation of this electronic document was provided by the Wyoming Water Development Commission (http://wwdc.state.wy.us)
LEVEL II STUDY

PREPARED FOR:
The Wyoming Water Development Commission
AND
The City of Casper

October 1, 2001

Prepared By:
C.E.P.I
Civil Engineering Professionals, Inc.
Casper Zone II Supply Level II Study

Prepared For:
The Wyoming Water Development Commission
and the City of Casper

October 31, 2001

Prepared By:
Civil Engineering Professionals, Inc.
925 North Lincoln St. Casper, Wyoming 82601
(307) 268-4545 • (307) 268-0125 fax
# Table of Contents

## Section I

**Introduction**

Pages 1-1

## Section II

**Service Area & Demand Projections**

Pages 1-8

- **Service Area**
  - Pages 1-4
- **Population and Growth**
  - Pages 4-5
- **Water Use**
  - Pages 5-6
- **East Casper Zone 2 Demand and Growth**
  - Pages 6-8

## Section III

**Analysis of Existing Infrastructure**

Pages 11-11

- **Existing Water Works Facilities**
  - Pages 1-3
- **Hydraulic Model**
  - Pages 3-6
- **Flow Scenarios**
  - Pages 6-7
- **Analysis of Existing Water Works Facilities**
  - Pages 7-11

## Section IV

**Conceptual Design & Cost Estimates**

Pages 11-16

- **Water Storage Facilities**
  - Pages 1-7
- **Water Transmission Pipelines**
  - Pages 8-13
- **Cost Estimates**
  - Pages 14-15
- **Economic Analysis and Project Financing**
  - Pages 15-16

## Appendix A - Cost Estimates

## Appendix B - Subsurface Exploration and Geotechnical Engineering Report

## Figures

### Section II

- **II-1** Zone 2 - Service Area
- **II-2** Land Use Concept Plan
- **II-3** East Casper Zone 2 - Projected Development
- **II-4** Population Projections

### Section III

- **III-1** Zone 2 Water Systems
- **III-2** Link Node Description of Water System
- **III-3** Water Storage Requirements
- **III-4** Required vs. Available Storage 2001

### Section IV

- **IV-1** Zone 2 - Tank Sites
- **IV-2** Proposed Phase 1 and 2 Improvements
- **IV-3** Proposed Zone 2 Improvements
- **IV-4** Pipeline P-1 Profile
TABLE OF CONTENTS

TABLES

SECTION II
II-1 City of Casper Population Estimates
II-2 East Casper Population and Average Day Demand Estimates
II-3 East Casper Residential and Commercial Growth

SECTION III
III-1 Zone 2 Pump Stations
III-2 Zone 2 Water Storage Tanks
III-3 Modeled Pipe Roughnesses

SECTION IV
IV-1 Water Storage Sizing Recommendations
IV-2 Evaluation of Potential Tank Sites
IV-3 Cost Estimates
IV-4 Loan Calculations
IV-5 Loan Payment Effect on Average Water Bill

PICTURES

SECTION IV
Picture 1 - View from the southeast end of Wyoming Blvd
Picture 2 - View from Elkhorn Creek at south end of Elkhorn Dr
Picture 3 - View from Country Club Road and WY Blvd
Picture 4 - View from Casper Country Club Clubhouse
INTRODUCTION

The Wyoming Water Development Commission authorized and funded this Level II Study of the Casper Zone II Supply Project. The City of Casper has experienced significant growth in the eastern most regions of their system and the growth has strained their distribution and storage system. The purpose of this study was to analyze the existing water works facilities and their ability to meet the system demands, and to make recommendations for the needed transmission and storage improvements.

The study is divided into four sections; a brief description of each section is provided below followed by the project acknowledgements.

- **Section I - Introduction**
- **Section II - Service Area and Demand Projections:** this section addresses the service area for the study, Casper Zone 2, and presents the population projections for the service area. This section also addresses the demand projections for the service area including average day, peak day and peak hour demands.
- **Section III - Analysis of Existing Infrastructure:** this section identifies the water works infrastructure in the Casper Zone 2 system, defines the hydraulic model developed to analyze the system, presents the results of the system analysis, and identifies the system's ability to meet the 2001 water demands.
- **Section IV - Conceptual Design and Cost Estimates:** this section presents: the design alternatives for the 2020 and 2050 improvements, the conceptual design for the recommended improvements and provides cost estimates and an economic analysis for the improvements.

Acknowledgements

Several people assisted in the preparation and completion of this study. Below is a listing of the people who assisted with the analysis of the system and the completion of the work.

- Wyoming Water Development Commission: John Jackson for his assistance with the administration of the contract, cooperation and direction.
- City of Casper Public Utilities - David Hill, Tim Rail, Darren Mizokami and Clint Conner for their direction, knowledge and experience with the system aiding in our understanding and completion of the study.
This section of the study defines the service area and service population for Casper Zone 2; it also identifies the projected population and water demands for the system. Year 2001 population and water demand estimates are provided, followed by growth projections and associated population and demand projections over the next fifty years.

**Service Area**

The service area for the project is identified by the areas currently being provided water from the City of Casper’s Zone 2 system and areas of potential growth located in elevations served by Casper’s Zone 2. The Zone 2 service elevations range from 5220 feet to 5400 feet. Zone 1 serves areas below this elevation in Casper; areas above this elevation currently do not have water service available in east Casper. The western boundary for the study area, as defined during the scoping meeting for the project, is the 10 Million gallon City Reservoir. The northern and southern boundaries are defined by the topographic description of Zone 2. The eastern boundary is only limited by the potential growth in the system; as Zone 2 grows the system will expand to the east. Figure 11-1 identifies the current area served by Zone 2 and the future areas that can be readily served.

Anticipated land use in Zone 2 was based upon the Casper Area Comprehensive Plan, January 18, 2000, as prepared by Balloffet and Associates, Inc. The Comprehensive Plan identified current land uses and provided recommended land uses for the greater Casper area. The plan provides a road map for future development and land uses to best serve the Casper area. The results of the Comprehensive Plan are best defined by Panel 4 from the study. Panel 4 is provided in this report as Figure II-2.¹ Figure II-2 identifies the existing and future land uses for Casper. As identified in the figure, the majority of the future growth areas to be served by Zone 2 are planned to be moderate density single family residential.

The Comprehensive Plan is self-described as a living document, and one area of potential growth in the northeastern corner of the study area has recently changed. A cooperative effort between the City of Casper, Natrona County, the Wyoming Department of Transportation, the Casper Area Economic Development Alliance (CAEDA), local developers and landowners, and a local business partner, American

¹ *Casper Area Comprehensive Plan*, January 18, 2000, Balloffet and Associates, Inc.
Figure II-3
East Casper Zone 2 - Projected Development
LaFrance is planning the expansion of East Second Street to Hat Six. The extension of the roadway and public and private utilities will allow for the relocation of the American LaFrance facility near the intersection of East Second Street and Hat Six Road. The development of this site will undoubtedly pull development to the east along East Second Street. The enhancement of the infrastructure in this area will spur development and commercial growth. The American LaFrance Site is located in a Zone 1 service elevation; however, based upon the higher elevations to the west along East Second Street, and the water demands for fire service at the American LaFrance facility, Zone 2 service to the facility is recommended.

**POPULATION AND GROWTH**

There are several different opinions and estimates for population growth in central Wyoming. The Casper Long Range Transportation Plan estimated a 1.5 percent per year growth rate.\(^2\) The Casper Area Comprehensive Plan estimated the long-term growth rate at 0.70 percent per year\(^1\) based upon the State of Wyoming Department of Administration and Information. The recently completed US Census estimates identified 10 year growth rates of 8.9 percent and 8.7 percent for the State of Wyoming and Natrona County from 1990 to 2000. This equates to an annual growth rate of approximately 0.85 percent per year. The growth projections for the varying rates are summarized in Figure II-3. For the purpose of this study an annual growth rate of 1.0 percent was assumed.

---

Based upon the results of the 2000 US Census, the current population in the City of Casper is estimated to be 49,131. Using the 1.0 percent per year growth rate the subsequent population growth estimates for the next fifty years are summarized in the following table.

<table>
<thead>
<tr>
<th>Year</th>
<th>Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>49,131</td>
</tr>
<tr>
<td>2010</td>
<td>54,271</td>
</tr>
<tr>
<td>2020</td>
<td>59,947</td>
</tr>
<tr>
<td>2030</td>
<td>66,218</td>
</tr>
<tr>
<td>2040</td>
<td>73,144</td>
</tr>
<tr>
<td>2050</td>
<td>80,795</td>
</tr>
</tbody>
</table>

**WATER USE**

After identifying system population and projecting growth rates, the next step in predicting water usage is to establish per capita water demands. Average per capita water usage is calculated by dividing the total water used in the system throughout a calendar year by the total service area population in the system. Historically, the average per capita water demand for the City of Casper is approximately 200 gallons per capita per day (gpcd). The 1997 Water Master Plan Update completed for the City of Casper assumed an average demand of 221 gpcd to allow for demand during dry years. The Natrona County Regional Water System Level II Study assumed an average demand of 220 gpcd. The City of Casper and the Central Wyoming Regional Water System have generally accepted a 220 gpcd water use for planning and design. Based upon the actual historical demands, information provided by the Casper Public Utilities Office, and the historical use, an average day water demand of 220 gpcd was assumed for this study.

There are two other water usage figures that are important in the design and analysis of water systems, peak day demand, and peak hour demand. Peak day demand is defined as the highest water usage experienced during a 24-hour period. Peak hour demand is

---

3 1997 Water Master Plan Update, February 1998, Black and Veatch LLP
4 Natrona County Regional Water Supply Project Level II Study, November 1994, CEPI
the peak water usage observed at a point in time due to diurnal (daily cyclical) demands. The peak day and peak hour demands do not necessarily occur on the same day. However, both generally occur in the summer when irrigation watering is at its peak. Peak day demands and peak hour demands have also been historically analyzed and calculated. Both of the studies cited above assumed a peak day demand of 3.0 times the average day demand (peak day demand ratio). A peak day demand ratio of 3.0 was assumed for this study also.

A peak hour demand ratio of 6.5 was assumed for this study (peak hour demand = 6.5 times average day demand). This figure is slightly higher than the 6.0 figure used for the Natrona County Regional Water System Study, and significantly higher than the 4.5 factor used for the 1997 Water Master Plan Update. The reasoning for this increase is based upon the projected land use for the service area. In general, residential areas observe greater peaking factors than commercial and industrial areas. This is primarily due to the diurnal demand fluctuations in residential areas and increased irrigation demands. The percentage of commercial and industrial property in Zone 2 is quite low and not anticipated to increase dramatically. The area is primarily residential and the lots are quite large; the majority of the growth projected to occur in Zone 2 is residential. The smaller commercial base and larger residential lot sizes will result in higher peak hour demands.

**EAST CASPER ZONE 2 DEMAND AND GROWTH**

The current, 2001 service area population for Casper Zone 2 from the City Reservoir to the east is estimated to be 14,300 people. The 2001 service area population estimate is based upon a physical count of the houses served in this area; it was assumed that each residence housed three people. The apartment complexes were assumed to be full with an average occupancy of 1.5 people per apartment. Apartment complex sizes were verified over the phone. The commercial water usage estimates were based upon actual billed water usage for a sampling of the commercial establishments in the area. Given the commercial establishment size (acreage) and average day water demand a per acreage commercial water figure was established. The average day water demand used for the commercial properties was assumed to be 1,700 gallons per acre/day (1.2 gpm per acre). The service area population coupled with the commercial use in this zone
of the system results in a 2001 average day water demand of 2,550 gallon per minute (gpm).

The east side of Casper is growing and developing faster than other areas in Casper. The vast majority of this area is served by Casper Zone 2. Based upon the average number of plats completed for the east side of town and conversations with the area developers this trend will probably continue. The east side of Casper is currently developing at a rate of 30 to 40 lots per year; this equates to 90 to 120 new residents per year. This number of new residents divided into the 2001 Zone 2 service population results in a growth rate of approximately 0.80 percent. This growth rate is very comparable to the historic growth rate for Natrona County. Given the historic growth and development rates for the area, it is assumed that Zone 2 will grow at the same rate as Natrona County and the City of Casper. A summary of the growth and demand projections is provided in Table II-2.

### Table II-2

<table>
<thead>
<tr>
<th>Year</th>
<th>Population</th>
<th>Commercial and Industrial Demand (gpm)</th>
<th>Average Day Demand (gpm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>14,300</td>
<td>365</td>
<td>2,550</td>
</tr>
<tr>
<td>2010</td>
<td>15,796</td>
<td>403</td>
<td>2,816</td>
</tr>
<tr>
<td>2020</td>
<td>17,449</td>
<td>445</td>
<td>3,111</td>
</tr>
<tr>
<td>2030</td>
<td>19,274</td>
<td>492</td>
<td>3,437</td>
</tr>
<tr>
<td>2040</td>
<td>21,291</td>
<td>543</td>
<td>3,796</td>
</tr>
<tr>
<td>2050</td>
<td>23,518</td>
<td>600</td>
<td>4,193</td>
</tr>
</tbody>
</table>

Subdivision and aerial maps were studied to calculate the average population density for current developments in east Casper. In general, lot sizes range from 8,000 square feet to 14,000 square feet. Based upon this lot sizing, subdivision layout, and the previously cited assumption of three people per household, an average population density of 10 people per acre was calculated. Combining the population projections for Zone 2 with the projected population density of 10 people per acre, estimated growth areas were established. The projected growth areas are presented in Table II-3. The areas present the total area of growth projected to occur over the identified period of time. The areas
presented are cumulative (i.e. the total area of growth projected for year 2020 includes the growth for 2010).

<table>
<thead>
<tr>
<th>Year</th>
<th>Cumulative Commercial and Industrial Growth (Acres)</th>
<th>Cumulative Residential Growth (Acres)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2010</td>
<td>32</td>
<td>174</td>
</tr>
<tr>
<td>2020</td>
<td>67</td>
<td>367</td>
</tr>
<tr>
<td>2030</td>
<td>106</td>
<td>580</td>
</tr>
<tr>
<td>2040</td>
<td>148</td>
<td>814</td>
</tr>
<tr>
<td>2050</td>
<td>196</td>
<td>1,074</td>
</tr>
</tbody>
</table>
This section of the study identifies the existing water works facilities in this region of Zone II, and presents the hydraulic modeling process and results. This section identifies the adequacy of the existing water system to meet the current 2001 water demands. The systems ability to meet future demands and recommended improvements are identified in Section 4 – Conceptual Design and Cost Estimates.

Existing Water Works Facilities

During the boom in the late 70's and early 80's the majority of the growth in the City of Casper occurred to the west. The water system master plans completed in the late 70’s and early 80's recommended significant transmission, pumping and storage improvements in several areas of the Casper system, but especially in the western regions of the system. The master plan improvements to the western and central regions of the system were prioritized over the eastern Zone 2 improvements. Millions of dollars were spent on major system improvements in the western and central regions of Casper’s water system. After the "bust" in the mid 80’s and during the recovery in the early 90’s growth in Casper began to occur to the east. This area of Casper has continued to grow over the last fifteen years. Since the mid 80's the Zone 2 water system has been in need of major improvements to the pumping, transmission and especially storage systems. The City has undertaken several projects in this region to improve transmission and pumping improvements, but numerous additional improvements are still needed.

The study area for Zone 2 is bounded on the west side by the 10 Million gallon City Reservoir, limited by elevation on the northern and southern boundaries and is continuing to grow towards the east as development occurs. This area is served by pipelines ranging in size from 6-inches to 24-inches in diameter, three pump stations and two welded steel water storage facilities. A summary of these components is provided below.

Pump Stations: there are three pump stations in this region of Zone 2. They include the Oakcrest Booster Station (also referred to as the Golf Course Pump Station), the Manor Heights Booster Station and the Pratt Booster Pump Station. The 1997 Water Master Plan Update recommended the replacement of the existing aging Oakcrest Booster
Station and retirement of the Manor Heights Booster Station. The City of Casper is currently designing the new Oakcrest Booster Station, and construction should be completed by the end of 2002. For this study it was assumed that the manor heights station was retired and the new Oakcrest Booster Station is completed. The pump sizing information for the Oakcrest Booster Station was taken directly from the Casper Zone 2 Water System Improvements Preliminary Design Report. The hydraulic modeling completed was based upon these assumptions. General pump station information is provided in Table III-1.

**TABLE III-1**  
**ZONE 2 PUMP STATIONS**

<table>
<thead>
<tr>
<th>Description</th>
<th>Installed Capacity (mgd)</th>
<th>Firm Capacity (mgd)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manor Heights Booster Station</td>
<td>3 @ 1.1 mgd</td>
<td>2.2 mgd</td>
</tr>
<tr>
<td>Oakcrest Booster Station 1</td>
<td>1 @ 2.2 mgd</td>
<td>2.2 mgd</td>
</tr>
<tr>
<td>Oakcrest Booster Station 2</td>
<td>1 @ 3.4 mgd</td>
<td></td>
</tr>
<tr>
<td>Oakcrest Booster Station 3</td>
<td>3 @ 4.0</td>
<td>8.0 mgd</td>
</tr>
<tr>
<td>Pratt Booster Station</td>
<td>3 @ 3.4 mgd</td>
<td>6.8 mgd</td>
</tr>
</tbody>
</table>

1 To be retired  
2 Old pump station capacity to be replaced  
3 Proposed pump station capacity

**Water Storage Tanks**: there are currently two water storage tanks in the study area of Zone 2. Both of these tanks are welded steel tanks and are filled by the above cited booster pump stations. In general, the Pratt Booster fills the Manor Heights Tank, and the Oakcrest Booster fills the Golf Course Tank. Both water storage tanks have overflow elevations of 5500 feet. A summary of the water storage tanks is provided in Table III-2 below.

**TABLE III-2**  
**ZONE 2 WATER STORAGE TANKS**

<table>
<thead>
<tr>
<th>Description</th>
<th>Height (ft)</th>
<th>Diameter (ft)</th>
<th>Volume (gallons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manor Heights Tank</td>
<td>48</td>
<td>46</td>
<td>600,000</td>
</tr>
<tr>
<td>Golf Course Tank</td>
<td>48</td>
<td>46</td>
<td>600,000</td>
</tr>
</tbody>
</table>

1 *1997 Water Master Plan Update*, February 1998, Black and Veatch LLP  
Transmission and Distribution System: The current Zone 2 transmission and distribution system consists of pipelines ranging in size from 6-inches to 24-inches in diameter. The pipeline materials include: Ductile Iron Pipe (DIP), Cast Iron Pipe (CIP), Asbestos Cement Pipe (AC) and Polyvinyl Chloride Pipe (PVC). Zone 2 serves ground elevations ranging from 5220 feet to 5400 feet. Figure III-1 identifies the pipe configuration and sizing for Zone 2.

Hydraulic Model
In order to analyze the current operation of the Zone 2 water system a hydraulic model was developed. The model developed was based upon the hydraulic model prepared by Black and Veatch for the 1997 Water System Master Plan. The model was enhanced to include all of the pipes in the zone and the demands were modified to reflect the growth in the system since the preparation of the original model.

Cybernet: the hydraulic model prepared utilizes the Cybernet hydraulic modeling software as developed by Haestad Methods, Inc. The Cybernet model utilizes either the Hazen and Williams or Darcy-Weisbach equations for analyzing and solving the pipe network system. The Cybernet model uses a "link-node" description of a water system to develop a skeletal layout of the water system. The links represent pipelines and in general, the nodes represent junctions along the pipelines or water storage tanks. Links can also contain pumps or control valves (pressure sustaining, pressure reducing, altitude, etc.). Nodes occur at tees, crosses, transitions, and at water storage facilities (tanks or reservoirs). Nodes have defined elevations and demands in the system are identified at nodes; these demands can be associated with residential or commercial use or fire flow demands. Figure III-2 illustrates a generic link node description for simple water system components. The 2001 Zone 2 model includes every pipe in the
system and all of the isolation valves that separate Zone 2 from Zone 1. The closed isolation valves are modeled as links that are "closed". The hydraulic model skeleton for the 2001 Zone 2 system is provided in Figure III-1; the varying colors represent the different pipe sizes in the system.

Demand Distribution: The distribution of the water demands throughout the water system for the 2001 hydraulic model was completed in two manners:

- *Domestic Demands* were distributed based upon a physical count of residences in the area. Apartment complexes were allocated demands based upon the number of apartments. Specific demands for each residence were identified in Section II of this study.
- *Commercial Demands* were based upon actual billings for specific commercial establishments and schools.

Model Verification: In order to improve the accuracy of the hydraulic model a comprehensive model verification for the 2001 model was performed. The verification was performed in two steps: 1) all of the pipeline sizes and materials of construction were crosschecked against the current City of Casper atlas sheets and node elevations were verified, and 2) the demands allocation for all of the nodes were verified against aerial maps for the Zone 2 service area and billing records for the commercial customers. Model verification ensures that the skeletal representation of the actual physical water system is accurate.

Model Calibration: A limited hydraulic model calibration was completed for the 2001 Zone 2 model. Using the verified model information the model was performed for various average day scenarios. The initial model runs provided modeled system pressures at the nodes. These modeled system pressures were compared to actual gauged pressures at numerous fire hydrants throughout the existing Zone 2 water system. The modeled pipe roughnesses were adjusted for the different materials of construction to better match modeled system pressures to measured gauge pressures at fire hydrants. The pipe roughness factors used in the final model are identified in Table III-3 below. The modeled C values are lower than the typical values because no minor losses were used for fittings and valves in the pipe network. The modeled C values include the minor losses and the pipe friction losses. The majority of the modeled
pressures were within three to five pounds per square inch (psi) of the measured pressures.

<table>
<thead>
<tr>
<th>MODELED PIPE ROUGHNESSES</th>
</tr>
</thead>
</table>
| Pipe Material             | Hydraulic Model Hazen Williams C Value | Typical Hazen Williams C Values
| Cast Iron                 | 110                                      | 80 – 150                   |
| Ductile Iron              | 120                                      | 140                        |
| Asbestos Cement           | 130                                      | 140 – 160                  |
| PVC                       | 135                                      | 140 – 160                  |

Flow Scenarios

Numerous different flow scenarios are utilized to analyze a water system. The flow scenarios parallel the demand projections: average day, peak day and peak hour. Additionally, low flow periods are analyzed to address water storage tank replenishment. In general, the following rules apply for flow scenarios and their associated use:

- **Average Day Demand** – used to analyze system balance for the distribution, storage and pumping systems. Average day scenarios are used to identify competing components in the water distribution system including water storage and pumping systems and balance the system by modifying system operation or configuration. This scenario is also analyzed to evaluate tank replenishment.

- **Peak Day Demand** – used to size pumping facilities. In general, pumping stations are sized to meet peak day demands. Additionally, fire flow analyses are conducted during peak day demands. Most water system design standards, including AWWA, and the Wyoming Department of Environmental Quality rules require system pressures greater than 20 psi during fire flow conditions occurring during peak day demands.  

- **Peak Hour Demand** – used to size distribution and transmission mains. Most water system design standards, including AWWA, and the Wyoming Department of Environmental Quality rules require system pressures greater than 35 psi during normal operating conditions.  

---

3 Cameron Hydraulic Data, 1988, Ingersoll-Rand
4 Water Quality Rules and Regulations Chapter 12, May 1985, Wyoming Department of Environmental Quality – Water Quality Division
consideration for line sizing and service areas in a water system. Peak hour demands are also critical for designing equalization storage volumes for water storage facilities. Keeping in mind that pump stations are designed to meet peak day demands.

**Fire Flows:** Fire flow scenarios were completed for all nodes in the 2001 modeled water system. The fire flow requirements were obtained from the City of Casper Fire Department. The fire flow requirements assumed for the study are summarized as follows: Residential – 1,000 gpm fire flow rate required during peak day demands, Commercial – 3,000 gpm fire flow rate required during peak day demands. The commercial flow requirement may be lower if the building is equipped with a fire suppression sprinkler system; however, the required fire flow at the hydrant coupled with the demand of the sprinkler system is normally close to 3,000 gpm.

**Analysis of Existing Water Works Facilities**

The existing pumping, storage and distribution components of the Casper Zone 2 system and their ability to meet the current system demands were thoroughly analyzed and studied. The analysis was completed with the assistance of the 2001 hydraulic model developed for the system. Additionally, the system operation was discussed with the operations staff to identify operational challenges, problems and historic operational approaches. The results of the analyses of the pumping, storage and distribution systems and these systems ability to meet the 2001 demands are summarized in the following three sections.

**Pumping Stations:** As identified in the beginning of this chapter the pumping facilities have been thoroughly studied and the City is currently completing the design of the new Oakcrest Booster Station. The pump stations available to meet the 2001 demands in Zone 2 will include: a new Oakcrest Booster Station with a total capacity of 12 mgd and a firm capacity of 8 mgd, and the Pratt Booster Station with a total capacity of 10.2 mgd and a firm capacity of 6.8 mgd. The Manor Heights Booster Station will be retired. This equates to a total firm pumping capacity of 14.8 mgd, or 10,300 gpm.

The current peak day demand for east Casper Zone 2 is approximately 7,650 gpm (three times the average day demand of 2,550 gpm). Firm pumping station capacity should be
matched to the peak day demands for the system. With the existing Pratt Station capacity and the eventual construction of the Oakcrest Booster Station the east Casper Zone 2 system has an excess pumping capacity of approximately 35 percent. This available capacity will meet the projected system growth for the next 40 years. The City has done an excellent job of planning and constructing the needed Booster station improvements for Zone 2. No improvements are currently needed to the pumping stations in east Casper Zone 2.

**Water Storage Tanks:** Water storage facilities are designed to provide water storage for varying water system demands and allow for the cyclical operation of the pumping facilities. In general, pumping facilities fill the water storage facilities and then the system "floats" off the water in the tanks. The sizing of water storage tanks includes three components: emergency storage, equalization storage and fire flow storage. The sizing recommendations for each of these components are summarized as follows:

- **Emergency Storage** - is provided for emergency situations, e.g. power outages, treatment plant failures, transmission line breaks, natural disasters, etc. The amount of emergency storage required is based on several criteria and the system's level of risk. The criteria include: age of transmission piping, susceptibility of system to damage, system redundancy, standby power and several other risk factors. The City of Casper generally provides some level of standby service at their pumping stations and the stations are designed with spare pumps. Additionally, the water distribution system piping is relatively new and does not experience

---

frequent leaks. Based upon these criteria an emergency storage allowance of 100,000 gallons is recommended. This emergency storage should be provided for all water storage tanks.

- Fire Storage – is provided to fight fires in the zone. The amount of storage is dependent upon the types of structures in the zone (commercial, residential, industrial, high-rise, etc.), standby power/pumping capacities at the pump stations, and Insurance Service Office (ISO) requirements. The ISO requirements for Zone 2 identify storage for 3,000 gpm fire flows for a three-hour duration, or 540,000 gallons.

- Equalization Storage – is used to simplify system operation and to meet peak hour demands, keeping in mind that pump stations are design to meet peak day demands, with pipelines and tanks sized to meet peak hour demands. Equalization storage provides storage for diurnal demand cycles; at night demands are low then rise in the morning level off around noon and then peak in the early evening. Equalization storage provides storage to match the peak demand periods to the low periods. Equalization storage requirements are based upon three factors: the available pumping capacity, the peak day demand and the peak hour demand. To meet the equalization storage requirements in the evening, three hours of peak hour storage less the firm pumping capacity at the two pump stations is recommended. The recommended equalization storage is summarized on the following formula:

<table>
<thead>
<tr>
<th>2001 Peak Hour Demand</th>
<th>Firm Pumping Rate at Boosters</th>
<th>Required Equalization Storage (3 hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>16,500 gpm</td>
<td>LESS 10,300 gpm</td>
<td>EQUALS 6,200 gpm (1.12 Million Gallons)</td>
</tr>
</tbody>
</table>

The combined storage requirements of the emergency storage, fire flow storage and equalization storage for the 2001 demands are summarized in the Figure III-4. The figure also addresses the current available water storage in the system. As identified in the table there is a significant shortage of water storage in Zone 2 to meet the current demands. The system undoubtedly needs additionally storage. The shortage is somewhat offset by the excess pumping capacity and the standby power/pumping available, but additional storage is still needed to address existing demands.
Transmission and Distribution System: the transmission and distribution piping is evaluated in two manners: the system's ability to provide adequate fire flows without dropping system pressures below 20 psi, and the ability of the piping to deliver peak hour flows without excessive pipeline velocities and maintaining a 35 psi minimum operating pressure.

The east Casper Zone 2 System is generally divided into three regions. These regions have very well networked distribution systems, but are only connected to the other regions by one or two pipelines. In general, the connectivity and transmission between the regions needs to be improved. The three regions are defined and briefly described as follows:

- **Golf Course Region**: this area is located east of the Golf Course and west of Missouri Street; it contains about 40 percent of the 2001 study area Zone 2 population.
- **Kelly Walsh Region**: this area is located east Missouri Street and west of Wyoming Boulevard; it contains about 40 percent of the 2001 study area Zone 2 population.
- **Eastgate Region**: this area is located east of Wyoming Boulevard; it contains about 20 percent of the 2001 study area Zone 2 population. This area includes the Eastridge Mall.

The vast majority of the pipelines in the distribution system experience velocities below two to four feet per second during 2001 peak hour flows. However, there are several pipelines that experience moderate velocities during 2001 peak hour demands. In general, these pipelines are the interconnections between the three regions. The capacity of these pipelines should be augmented with new redundant
pipelines in undeveloped areas to better connect the three regions of the system. Additionally, there are several 6-inch diameter mains in the Golf Course region that should be upsized to 8-inches in diameter as part of the City’s waterline replacement projects.

The pipelines which supply both of the water storage tanks in this region, the Manor Heights and the Golf Course, experience velocities in excess of 10 feet per second during 2001 peak hour periods. The addition of new water storage to the system would partially address this issue; however, redundant pipelines should be added the tanks to reduce pipeline velocities and improve service.

All of the residential areas in east Casper Zone 2 have available fire flows in excess of 1,000 gpm, and the commercial areas can be provided 3,000 gpm fire flows. However, the velocities in the pipelines interconnecting the regions exceed 10 feet per second to meet many of the fire flows. Fire flows can be met, but redundancy of the major interconnecting pipelines should be improved to provide redundant links between the cells and to reduce pipeline velocities.
This section of the study addresses: the ability of the Zone 2 water system to meet the 20 and 50 year demand projections, the design alternatives for the improvements to the Zone 2 water system, the conceptual design for the proposed improvements and the cost estimates for the improvements.

The transmission, distribution and storage systems in the Zone 2 water system are in need of improvements to better serve the existing customers and the future customers. The proposed improvements presented in this study are limited to the transmission pipelines and storage facilities. For example, Section II identified that several 6-inch diameter pipelines should be upsized to 8-inches in diameter; these improvements are not addressed in this section. They were intentionally left out of the recommended improvements because the Wyoming Water Development Commission only funds transmission pipelines and storage facilities for water systems. Additionally, the pump station improvements required to meet the next 20-year growth projections are currently being designed and planned for construction next year. No preliminary design or conceptual design recommendations are required for the pumping stations in Zone 2 beyond the improvements currently being made.

Water Storage Facilities
As discussed and detailed in Section III, there are three criteria used to calculate water storage requirements: emergency storage, fire storage and equalization storage. The recommended storage volumes for the existing and future storage requirements are summarized in Table IV-1. The recommended volumes for each storage criteria are summarized as follows:

- Emergency Storage – 100,000 gallons for each tank in the system.
- Fire Flow Storage – Storage for a 3,000 gpm fire flow rate for a duration of three hours (540,000 gallons).
- Equalization Storage – three hours of peak hour storage less the firm pumping capacity in the zone.

The proposed water storage improvements are recommended to be sized for the twenty-year projections. The site should allow for the addition of future tanks, but installing too much storage can be as problematic as having too little storage. Water quality is a very important concern for a water utility and excessive storage can result in stagnant water,
difficulties maintaining chlorine residuals, and re-growth of bacteria in the system. For these reasons sizing of the tanks should be carefully considered and 40 or 50 year projections planned for but not constructed.

Table IV-1
Water Storage Sizing Recommendations

<table>
<thead>
<tr>
<th>Year</th>
<th>Recommended Volumes (gallons)</th>
<th>Total Additional Storage Required (gallons)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Emergency Storage</td>
<td>Fire Flow Storage</td>
</tr>
<tr>
<td>2001</td>
<td>300,000&lt;sup&gt;1&lt;/sup&gt;</td>
<td>540,000</td>
</tr>
<tr>
<td>2020</td>
<td>300,000&lt;sup&gt;1&lt;/sup&gt;</td>
<td>540,000</td>
</tr>
<tr>
<td>2050</td>
<td>300,000&lt;sup&gt;1&lt;/sup&gt;</td>
<td>540,000</td>
</tr>
</tbody>
</table>

<sup>1</sup> Assumes the construction of one new tank; a total of three tanks with 100,000 gal emergency storage each.

In order to meet the 2020 projections an additional 1.4 million gallons of storage is required. Three tanks sites were considered for the additional Zone 2 storage. The three sites are identified on Figure IV-1. The sites selected were in a region with elevations ranging from 5340 feet to 5370 feet. This allows for the construction of a fairly short and larger diameter tank (30 to 60 feet tall), which provides the maximum amount of usable storage. An analysis of the three tank sites is provided in Table IV-2. The analysis includes the advantages and disadvantages of each site.

Table IV-2
Evaluation of Potential Tank Sites

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Manor Heights Site</th>
<th>Blackmore Road Site</th>
<th>Hat Six Site</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topography</td>
<td>Good topography near existing tank, small amount of earthwork required.</td>
<td>Good topography, some earthwork required.</td>
<td>Excellent topography, little earthwork required.</td>
</tr>
<tr>
<td>Visibility</td>
<td>Low, adjacent to existing tank site, topography to the south tank hides tank silhouette.</td>
<td>Low, site is in the saddle of the hill, silhouette of tank hidden by topography to the south and north.</td>
<td>Moderate, Site is on a ridge and relatively visible.</td>
</tr>
<tr>
<td>Transmission Pipeline</td>
<td>Relatively short transmission pipeline, but location towards the middle of the zone increases the size of transmission pipelines to the east.</td>
<td>Relatively long transmission pipeline, but location to the east reduces other transmission pipeline sizes.</td>
<td>Long transmission pipeline which increases size and cost.</td>
</tr>
<tr>
<td>Access</td>
<td>Excellent, existing access road and gates.</td>
<td>Good, new access road will need to be constructed along the pipeline alignment.</td>
<td>Poor, access easement will have to be obtained or constructed along the pipeline.</td>
</tr>
<tr>
<td>Cost</td>
<td>Moderate – cost of larger transmission pipelines offsets the site closest to the existing infrastructure.</td>
<td>Moderate – relatively long transmission pipeline and access road increases cost.</td>
<td>High – long transmission pipeline and access road.</td>
</tr>
<tr>
<td>Final Rank</td>
<td>Second</td>
<td>First</td>
<td>Third</td>
</tr>
</tbody>
</table>
Figure IV-1
Zone 2 - Tank Sites
The Manor Heights water storage tank was originally on the eastern edge of Zone 2. However, as growth continued to occur the tank became more centrally located. As growth continues to occur to the east the Manor Heights tank will become even more centrally located in the zone. Additional storage is needed in Zone 2 and the logical location is further to the east. Once a new tank is constructed some demand will be taken off of the Manor Heights tank. Keeping in mind the layout of the distribution system with three regions; a new eastern water storage tank will provide each region with its own water storage: golf course, manor heights and eastgate. The Manor heights will be the central tank in the zone and will serve the greatest area and demand.

Based upon the results of the analysis in Table IV-2, the construction of a new tank at the Blackmore Road site is recommended. However, all of the additional storage recommended in Zone 2 should not be added to the eastern most region. A second tank should be added at the Manor Heights site with the additional storage roughly split between the two sites. For esthetic and operational reasons, the second tank at Manor Heights is recommended to have the same dimensions as the existing tank, 600,000 gallons, 46-feet in diameter, 48-feet tall. The proposed tank at the Blackmore Road site will have an operational capacity of 800,000 gallons. The Blackmore Road tank will be approximately 52-feet in diameter and 50-feet tall; the tank will have a base elevation of approximately 5450 feet.

The existing tank site at the Manor Heights location is not large enough to allow for the construction of a second tank on the existing site. However, the topography of the site is well suited for an additional tank directly to the east of the existing tank. Additionally property will have to be obtained to allow for the construction of the second tank.

The affected property owners for the Blackmore Road site were all contacted and the proposed improvements were discussed. None of the property owners were against the improvements, but several had questions regarding possible water taps on the line and the construction of an access road to the site to provide them with a second, and possibly improved access road to their properties. The landowners were instructed that an access road to the tank would be constructed. They were also informed that they should contact the City to request a tap on the pipeline if and when it is constructed.
The visual impact of the proposed tank on the area and its possible impact on the Casper skyline were carefully considered. On September 28, 2001, a "bucket-truck" was mobilized to the proposed site. The bucket was raised to an elevation equal to the top elevation of the proposed tanks. Pictures were taken from the bucket to determine the areas of town from which the tank would be visible. Following this process, numerous pictures were taken from different sites along the east side of Casper to determine the visual impact of the proposed tanks. Four of these pictures were selected for inclusion in this study; the pictures are shown on the following two pages. A water storage tank has been superimposed on the pictures. The visual size of the tank was estimated and may not be exact. It is important to note that only two of the pictures show how the tank will look with the naked eye. The other two pictures were taken with a zoom lens; the magnification is identified on the photo titles. The superimposed tank image has a "cartoon" type appearance and does not look natural. Painting the tank to match the surrounding area will be very important. A natural tan color should best hide the tank. This color has been used on several tanks throughout the City of Casper.

**Future Water Storage Facilities:** as the east side of Casper continues to grow and develop to the east the Manor Heights tank will become more and more important. The Manor Heights tank will become the central tank for the zone supplying water to the east and the west. This tank will be much like the 10 Million gallon City reservoir is to Zone 1. When the growth in east Casper Zone 2 exceeds the 20-year projections additional storage will probably first be needed at the Manor Heights site and eventually at the Blackmore Road site.
Picture 1 – View from the southeast end of Wyoming Boulevard (8X Zoom)

Picture 2 – View from Elkhorn Creek at south end of Elkhorn Drive (4X Zoom)
Water Transmission Pipelines

Following the development of the base model for 2001 Zone 2 hydraulic model, as described in Section III of this study, the model was expanded to include the projected growth in the zone (Section II of this study). The vast majority of the growth is anticipated to occur to the east. Approximately 20-percent of the growth in east Casper Zone 2 was projected to occur in the central areas to the south. The remaining growth was projected to occur to the east. All of the commercial and industrial development was anticipated to occur to the east. East Second Street is currently planned to be developed to the east to Hat Six Road as part of an economic development project funded locally and by the state. This development will draw commercial and industrial development to the east and spur growth in this area. The proposed water transmission pipeline for this development is identified on Figure IV-2 detailing the proposed transmission pipeline improvements.

As the model was developed for the 20 and 50-year growth projections the same weaknesses in the zone were observed which currently exist. East Casper Zone 2 is split into three separate regions, as described in Section II, and the regions are only interconnected one or two transmission pipelines. Additionally, the pipelines feeding the existing water storage reservoirs are too small (12-inches in diameter). As Casper continues to grow to the east these weaknesses must be addressed to provide a reliable transmission system for the City of Casper.

The proposed transmission pipeline improvements are identified in Figure IV-2 and IV-3. Figure IV-2 identifies the Phase 1 and Phase 2 improvements. These improvements are recommended to meet the 20-year growth projections. The improvements were phased to allow for funding and timing the improvements. Figure IV-3 identifies the Phase 1 and 2 improvements as well as future transmission improvements that will be needed as the area grows, and transmission improvements that are part of the existing City of Casper infrastructure. The figures also show the existing pipelines, color-coded for size. It is important to note that the Phase 1 and 2 pipelines are located to meet the 20-year projections, but sized to meet the 50-year demand projections. Below each pipeline has been briefly identified and described. The pipelines were given an indicator number ranging from P-1 to P-8.
FIGURE IV-3
PROPOSED ZONE 2 IMPROVEMENTS
Pipeline P-1: This pipeline is needed to convey water to and from the proposed Blackmore Road water storage tank. A plan and profile sheet for the pipeline is provided in Figure IV-4. The pipeline is located to allow for access and reduce the number of air release valves. The pipeline is also routed around irrigated lands at the north end. It connects the proposed water storage tanks to a 16-inch diameter transmission pipeline at the east end of 21st Street.

Pipeline P-2: This pipeline is needed to convey water to and from the new Blackmore Road water storage tank. The pipeline interconnects two existing transmission pipelines in 15th Street and 21st Street; it is a portion of the transmission pipeline serving the new tank. The pipeline also serves as a second transmission pipeline into the Eastgate subdivisions. The pipeline is located in undeveloped property. Earthwork and drainage improvements are recommended to "rough-in" the roadway. The proposed pipeline corridor is along a proposed roadway that interconnects 15th Street to 21st Street. The cost estimate for this pipeline includes costs to install a double box culvert at a major drainage crossing and earthwork to rough-grade the proposed roadway. This area is currently planned for development and if the pipeline is simply placed 5.5 feet below grade over half of it will have to be removed and replaced when the roadway is graded in the next few years.

Pipeline P-3: This pipeline is needed to reduce velocities in the transmission pipeline connecting the Manor Heights tank. Velocities in this pipeline currently exceed 10 feet per second during peak hour flows. This pipeline will also improve service to the residents in the Country Club Road area. The proposed pipeline is located in Kingsbury Drive between 18th Street and Country Club Road. The pipeline will connect with P-5 at the north and P-4 at the south end.

Pipeline P-4: This pipeline is needed to reduce velocities in the transmission pipeline at the Manor Heights tank. Velocities in this pipeline currently exceed 10 feet per second during peak hour flows. This pipeline will also provide a critical interconnection between the Pratt Booster and the Manor Heights tank. The proposed pipeline is located in undeveloped property along Country Club Road and Wyoming Boulevard. The pipeline will connect with P-3 at the south and the 24-inch main in 15th Street at the north end.
Pipeline P-5: This pipeline is needed as a second transmission connection between the Golf Course region and the Kelly Walsh region. The pipeline is located in an undeveloped area behind Manor Heights School. The alignment of the pipeline was selected to follow future roadways in the area. Some earthwork is anticipated for this pipeline to "rough-in" the future roadway alignment. This will eliminate the need to relocate or replace this pipeline when the area is developed.

Pipeline P-6: This pipeline is needed to complete an east west transmission pipeline in the central region of Zone 2. The pipeline is located in Wilson Street and Eastbrook Avenue. It will connect a 12-inch and 20-inch pipeline at its northern end with a 16-inch transmission pipeline at the southern end. The pipeline is needed to reduce velocities in the adjacent distribution system and to better connect the Golf Course region to the Kelly Walsh region.

Pipeline P-7: This pipeline is needed to complete an east west transmission pipeline in the eastern region of Zone 2. The pipeline is located in 15th Street between Kingsbury Drive and Nottingham Street. It will complete the 20-inch transmission pipeline in 15th Street. The pipeline is needed to connect the Golf Course region to the Kelly Walsh region.

Pipeline P-8: This pipeline is needed to provide redundant connections for the 8-inch pipeline around the Eastridge Mall and the 12-inch transmission pipeline in Landmark Lane. This pipeline is also essential to provide service for the commercial development of East Second Street to Hat Six Road. The pipeline is located in the parking lot of the mall and between the lots along the west side of Landmark Lane.
Cost Estimates

Cost Estimates for the proposed Phase 1 and Phase 2 components are summarized in Table IV-3 below. Detailed estimates for the individual pipelines and tanks are provided in Appendix A to this study. Access and Right-of-Way costs were estimated at $2.00 per linear foot; land acquisition for the tank site was estimated to be $10,000. The legal fees were assumed to be 20 percent of the right-of-way cost.

Table IV-3
Cost Estimates

<table>
<thead>
<tr>
<th>Description</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preparation of Final Design and Specifications</td>
<td>$229,900.00</td>
</tr>
<tr>
<td>Permitting and Mitigation</td>
<td>$15,000.00</td>
</tr>
<tr>
<td>Legal Fees</td>
<td>$6,000.00</td>
</tr>
<tr>
<td>Acquisition of Access and Right-of-Way</td>
<td>$29,000.00</td>
</tr>
</tbody>
</table>

**Phase 1 Components**

<table>
<thead>
<tr>
<th>Description</th>
<th>Subtotal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pipeline P-1</td>
<td>$809,220.00</td>
</tr>
<tr>
<td>Pipeline P-2</td>
<td>$564,690.00</td>
</tr>
<tr>
<td>Water Storage Tanks</td>
<td>$778,000.00</td>
</tr>
<tr>
<td>Subtotal Construction Cost</td>
<td>$2,151,910.00</td>
</tr>
<tr>
<td>Inflated Costs for Year 2003 Construction</td>
<td>$2,298,800.00</td>
</tr>
<tr>
<td>Construction Cost Subtotal No. 1 (CCS#1)</td>
<td>$2,298,800.00</td>
</tr>
<tr>
<td>Engineering Cost (10% of CCS#1)</td>
<td>$229,900.00</td>
</tr>
<tr>
<td>Construction Cost Subtotal #2 (CCS#2)</td>
<td>$2,528,700.00</td>
</tr>
<tr>
<td>Contingency (15% of CCS#2)</td>
<td>$379,400.00</td>
</tr>
<tr>
<td>Construction Cost Total</td>
<td>$2,908,100.00</td>
</tr>
</tbody>
</table>

**Phase 1 - Total Project Cost**

<table>
<thead>
<tr>
<th>Description</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$3,188,000.00</td>
</tr>
</tbody>
</table>
### Economic Analysis and Project Financing

All of the components identified in this section of the study are either transmission or storage related. Additionally, all of the components are new construction items. The Economic Analysis provided assumed:

- 50 percent Grant Funding
- 50 percent Loan Funding; interest rate = 7.5 percent, term = 30 years

The total project cost estimate for Phase I is $3,188,000; the total project cost estimate for Phase 2 is $2,332,800. The loan payments and calculations for each phase are summarized in Table IV-4.
### TABLE IV-4  
**LOAN CALCULATIONS**

<table>
<thead>
<tr>
<th>Description</th>
<th>Phase 1 Improvements</th>
<th>Phase 2 Improvements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interest rate</td>
<td>7.25%</td>
<td>7.25%</td>
</tr>
<tr>
<td>Term</td>
<td>30 Years</td>
<td>30 Years</td>
</tr>
<tr>
<td>Amount of Loan</td>
<td>$1,594,000</td>
<td>$1,166,400</td>
</tr>
<tr>
<td>Annual Loan Payments</td>
<td>$131,695</td>
<td>$96,367</td>
</tr>
<tr>
<td>Total of Payments</td>
<td>$3,950,870</td>
<td>$2,891,025</td>
</tr>
<tr>
<td>Total Interest</td>
<td>$2,356,870</td>
<td>$1,724,626</td>
</tr>
</tbody>
</table>

The City of Casper currently uses about four Trillion gallons of water every year; based off the Central Wyoming Regional Water System billing for the past four years. This equates to a bimonthly average of approximately 667 Million gallons. The loan payment divided into the yearly water usage equates to a projected increase in the cost of water per 1,000 gallons. The City currently has approximately 18,500 water accounts. If the water usage for all of these accounts were assumed to be equal, the average bi-monthly water bill would increase approximately $2.06 to service the debt on the proposed loan for both the Phase 1 and Phase 2 improvements. The effect on the cost of providing water and the average bi-monthly bill for both phases is summarized in Table IV-5 below.

### TABLE IV-5  
**LOAN PAYMENT EFFECT ON AVERAGE WATER BILL**

<table>
<thead>
<tr>
<th>Description</th>
<th>Phase 1 Improvements</th>
<th>Phase 2 Improvements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increase in Cost of Water per 1,000 gallons</td>
<td>$0.033</td>
<td>$0.024</td>
</tr>
<tr>
<td>Increase in Average Water Bill ($ bi-monthly)</td>
<td>$1.19</td>
<td>$0.87</td>
</tr>
<tr>
<td><strong>Total Cost of Phase 1 and 2 Improvements on bi-monthly Water Bill</strong></td>
<td></td>
<td>$2.06</td>
</tr>
</tbody>
</table>
Line Designation
P-1 (20")
Description
20" Line from 21st Street to the Proposed Elkhorn Tank

<table>
<thead>
<tr>
<th>Item No.</th>
<th>Description</th>
<th>Unit</th>
<th>Quantity</th>
<th>Unit Price</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Mobilization</td>
<td>LS</td>
<td>1</td>
<td>$165,000.00</td>
<td>$165,000.00</td>
</tr>
<tr>
<td>2</td>
<td>Connection to Mains</td>
<td>EA</td>
<td>1</td>
<td>$4,000.00</td>
<td>$4,000.00</td>
</tr>
<tr>
<td>3</td>
<td>20-inch PVC Pipeline</td>
<td>LF</td>
<td>6210</td>
<td>$80.00</td>
<td>$496,800.00</td>
</tr>
<tr>
<td>4</td>
<td>20-inch Valves</td>
<td>EA</td>
<td>4</td>
<td>$7,500.00</td>
<td>$30,000.00</td>
</tr>
<tr>
<td>5</td>
<td>20-inch Fittings</td>
<td>EA</td>
<td>8</td>
<td>$3,500.00</td>
<td>$28,000.00</td>
</tr>
<tr>
<td>6</td>
<td>Fire Hydrant</td>
<td>EA</td>
<td>4</td>
<td>$3,500.00</td>
<td>$14,000.00</td>
</tr>
<tr>
<td>7</td>
<td>Select Material</td>
<td>CY</td>
<td>400</td>
<td>$25.00</td>
<td>$10,000.00</td>
</tr>
<tr>
<td>8</td>
<td>Foundation Material</td>
<td>CY</td>
<td>200</td>
<td>$35.00</td>
<td>$7,000.00</td>
</tr>
<tr>
<td>9</td>
<td>Seeding</td>
<td>LF</td>
<td>6210</td>
<td>$2.00</td>
<td>$12,420.00</td>
</tr>
<tr>
<td>10</td>
<td>Gravel Road</td>
<td>Ton</td>
<td>2100</td>
<td>$20.00</td>
<td>$42,000.00</td>
</tr>
<tr>
<td></td>
<td><strong>Total Construction Cost</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>$809,220.00</strong></td>
</tr>
</tbody>
</table>
Line Designation
P-2 (16")
Description
20" Line along proposed 15th/21st Street

<table>
<thead>
<tr>
<th>Item No.</th>
<th>Description</th>
<th>Unit</th>
<th>Quantity</th>
<th>Unit Price</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Mobilization</td>
<td>LS</td>
<td>1</td>
<td>$50,000.00</td>
<td>$50,000.00</td>
</tr>
<tr>
<td>2</td>
<td>Connection to Mains</td>
<td>EA</td>
<td>2</td>
<td>$4,000.00</td>
<td>$8,000.00</td>
</tr>
<tr>
<td>3</td>
<td>Earthwork for Drainages</td>
<td>LS</td>
<td>1</td>
<td>$50,000.00</td>
<td>$50,000.00</td>
</tr>
<tr>
<td>4</td>
<td>Drainage Improvements</td>
<td>LS</td>
<td>1</td>
<td>$150,000.00</td>
<td>$150,000.00</td>
</tr>
<tr>
<td>5</td>
<td>20-inch PVC Pipeline</td>
<td>LF</td>
<td>3170</td>
<td>$80.00</td>
<td>$253,600.00</td>
</tr>
<tr>
<td>6</td>
<td>20-inch Valves</td>
<td>EA</td>
<td>3</td>
<td>$7,500.00</td>
<td>$22,500.00</td>
</tr>
<tr>
<td>7</td>
<td>20-inch Fittings</td>
<td>EA</td>
<td>2</td>
<td>$3,500.00</td>
<td>$7,000.00</td>
</tr>
<tr>
<td>8</td>
<td>Fire Hydrant</td>
<td>EA</td>
<td>3</td>
<td>$3,500.00</td>
<td>$10,500.00</td>
</tr>
<tr>
<td>9</td>
<td>Select Material</td>
<td>CY</td>
<td>200</td>
<td>$25.00</td>
<td>$5,000.00</td>
</tr>
<tr>
<td>10</td>
<td>Foundation Material</td>
<td>CY</td>
<td>50</td>
<td>$35.00</td>
<td>$1,750.00</td>
</tr>
<tr>
<td>11</td>
<td>Seeding</td>
<td>LF</td>
<td>3170</td>
<td>$2.00</td>
<td>$6,340.00</td>
</tr>
</tbody>
</table>

Total Construction Cost $564,890.00
**Line Designation**  
**Tanks**  
**Description**  
600,000 Gallon tanks at Manor Heights and 800,000 gallon Blackmoore Road

<table>
<thead>
<tr>
<th>Item No.</th>
<th>Description</th>
<th>Unit</th>
<th>Quantity</th>
<th>Unit Price</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Mobilization</td>
<td>LS</td>
<td>1</td>
<td>$45,000.00</td>
<td>$45,000.00</td>
</tr>
<tr>
<td>2</td>
<td>600,000 gal Tank</td>
<td>EA</td>
<td>1</td>
<td>$250,000.00</td>
<td>$250,000.00</td>
</tr>
<tr>
<td>3</td>
<td>800,000 gal Tanks</td>
<td>EA</td>
<td>1</td>
<td>$350,000.00</td>
<td>$350,000.00</td>
</tr>
<tr>
<td>3</td>
<td>Electrical to Elkhorn Site</td>
<td>LS</td>
<td>1</td>
<td>$30,000.00</td>
<td>$30,000.00</td>
</tr>
<tr>
<td>4</td>
<td>SCADA and Control</td>
<td>LS</td>
<td>2</td>
<td>$10,000.00</td>
<td>$20,000.00</td>
</tr>
<tr>
<td>5</td>
<td>Site Piping</td>
<td>LS</td>
<td>1</td>
<td>$30,000.00</td>
<td>$30,000.00</td>
</tr>
<tr>
<td>6</td>
<td>Imported Fill</td>
<td>CY</td>
<td>1000</td>
<td>$25.00</td>
<td>$25,000.00</td>
</tr>
<tr>
<td>7</td>
<td>Valve Vaults</td>
<td>EA</td>
<td>2</td>
<td>$12,000.00</td>
<td>$24,000.00</td>
</tr>
<tr>
<td>8</td>
<td>Base Course</td>
<td>Ton</td>
<td>40</td>
<td>$25.00</td>
<td>$1,000.00</td>
</tr>
<tr>
<td>9</td>
<td>Seeding</td>
<td>Ac</td>
<td>1</td>
<td>$3,000.00</td>
<td>$3,000.00</td>
</tr>
</tbody>
</table>

**Total Construction Cost** $778,000.00
Line Designation
P-3 (16")
Description
16" Line on Kingsbury from 18th Street to Country Club Road

<table>
<thead>
<tr>
<th>Item No.</th>
<th>Description</th>
<th>Unit</th>
<th>Quantity</th>
<th>Unit Price</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Mobilization</td>
<td>LS</td>
<td>1</td>
<td>$45,000.00</td>
<td>$45,000.00</td>
</tr>
<tr>
<td>2</td>
<td>Connection to Mains</td>
<td>EA</td>
<td>7</td>
<td>$2,000.00</td>
<td>$14,000.00</td>
</tr>
<tr>
<td>3</td>
<td>8-inch PVC Waterline</td>
<td>LF</td>
<td>500</td>
<td>$30.00</td>
<td>$15,000.00</td>
</tr>
<tr>
<td>4</td>
<td>8-inch Valves</td>
<td>EA</td>
<td>5</td>
<td>$1,200.00</td>
<td>$6,000.00</td>
</tr>
<tr>
<td>5</td>
<td>16-inch PVC Pipeline</td>
<td>LF</td>
<td>3410</td>
<td>$65.00</td>
<td>$221,650.00</td>
</tr>
<tr>
<td>6</td>
<td>16-inch Valves</td>
<td>EA</td>
<td>5</td>
<td>$5,000.00</td>
<td>$25,000.00</td>
</tr>
<tr>
<td>7</td>
<td>16-inch Fittings</td>
<td>EA</td>
<td>5</td>
<td>$2,000.00</td>
<td>$10,000.00</td>
</tr>
<tr>
<td>8</td>
<td>Fire Hydrant</td>
<td>EA</td>
<td>5</td>
<td>$3,500.00</td>
<td>$17,500.00</td>
</tr>
<tr>
<td>9</td>
<td>Select Material</td>
<td>CY</td>
<td>500</td>
<td>$25.00</td>
<td>$12,500.00</td>
</tr>
<tr>
<td>10</td>
<td>Foundation Material</td>
<td>CY</td>
<td>50</td>
<td>$35.00</td>
<td>$1,750.00</td>
</tr>
<tr>
<td>11</td>
<td>Roadway Restoration</td>
<td>LF</td>
<td>3910</td>
<td>$50.00</td>
<td>$195,500.00</td>
</tr>
<tr>
<td>12</td>
<td>Traffic Control</td>
<td>LS</td>
<td>1</td>
<td>$10,000.00</td>
<td>$10,000.00</td>
</tr>
</tbody>
</table>

Total Construction Cost $573,900.00
Line Designation
P-4 (16")

Description
16" Line from Manor Heights Tank to Wyoming Boulevard and 15th Street

<table>
<thead>
<tr>
<th>Item No.</th>
<th>Description</th>
<th>Unit</th>
<th>Quantity</th>
<th>Unit Price</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Mobilization</td>
<td>LS</td>
<td>1</td>
<td>$55,000.00</td>
<td>$55,000.00</td>
</tr>
<tr>
<td>2</td>
<td>Connection to Mains</td>
<td>EA</td>
<td>2</td>
<td>$2,000.00</td>
<td>$4,000.00</td>
</tr>
<tr>
<td>3</td>
<td>24-inch PVC Waterline</td>
<td>LF</td>
<td>800</td>
<td>$30.00</td>
<td>$24,000.00</td>
</tr>
<tr>
<td>4</td>
<td>24-inch Valves</td>
<td>EA</td>
<td>1</td>
<td>$1,200.00</td>
<td>$1,200.00</td>
</tr>
<tr>
<td>5</td>
<td>16-inch PVC Pipeline</td>
<td>LF</td>
<td>6180</td>
<td>$65.00</td>
<td>$401,700.00</td>
</tr>
<tr>
<td>6</td>
<td>16-Inch Valves</td>
<td>EA</td>
<td>4</td>
<td>$5,000.00</td>
<td>$20,000.00</td>
</tr>
<tr>
<td>7</td>
<td>16-inch Fittings</td>
<td>EA</td>
<td>6</td>
<td>$2,000.00</td>
<td>$12,000.00</td>
</tr>
<tr>
<td>8</td>
<td>Fire Hydrant</td>
<td>EA</td>
<td>4</td>
<td>$3,500.00</td>
<td>$14,000.00</td>
</tr>
<tr>
<td>9</td>
<td>Select Material</td>
<td>CY</td>
<td>100</td>
<td>$25.00</td>
<td>$2,500.00</td>
</tr>
<tr>
<td>10</td>
<td>Highway Crossing</td>
<td>LF</td>
<td>150</td>
<td>$325.00</td>
<td>$48,750.00</td>
</tr>
<tr>
<td>11</td>
<td>Seeding</td>
<td>LF</td>
<td>7000</td>
<td>$2.00</td>
<td>$14,000.00</td>
</tr>
<tr>
<td>12</td>
<td>Traffic Control</td>
<td>LS</td>
<td>1</td>
<td>$5,000.00</td>
<td>$5,000.00</td>
</tr>
</tbody>
</table>

Total Construction Cost $602,150.00
**Line Designation**

*P-5 (16")*

**Description**

16" Line from Missouri Street to Kingsbury

<table>
<thead>
<tr>
<th>Item No.</th>
<th>Description</th>
<th>Unit</th>
<th>Quantity</th>
<th>Unit Price</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Mobilization</td>
<td>LS</td>
<td>1</td>
<td>$30,000.00</td>
<td>$30,000.00</td>
</tr>
<tr>
<td>2</td>
<td>Connection to Mains</td>
<td>EA</td>
<td>3</td>
<td>$2,000.00</td>
<td>$6,000.00</td>
</tr>
<tr>
<td>3</td>
<td>16-inch PVC Pipeline</td>
<td>LF</td>
<td>3950</td>
<td>$55.00</td>
<td>$217,250.00</td>
</tr>
<tr>
<td>4</td>
<td>16-inch Valves</td>
<td>EA</td>
<td>4</td>
<td>$5,000.00</td>
<td>$20,000.00</td>
</tr>
<tr>
<td>5</td>
<td>16-inch Fittings</td>
<td>EA</td>
<td>4</td>
<td>$2,000.00</td>
<td>$8,000.00</td>
</tr>
<tr>
<td>6</td>
<td>Fire Hydrant</td>
<td>EA</td>
<td>3</td>
<td>$3,500.00</td>
<td>$10,500.00</td>
</tr>
<tr>
<td>7</td>
<td>Select Material</td>
<td>CY</td>
<td>500</td>
<td>$25.00</td>
<td>$12,500.00</td>
</tr>
<tr>
<td>8</td>
<td>Foundation Material</td>
<td>CY</td>
<td>100</td>
<td>$35.00</td>
<td>$3,500.00</td>
</tr>
<tr>
<td>9</td>
<td>Roadway Restoration</td>
<td>LF</td>
<td>300</td>
<td>$50.00</td>
<td>$15,000.00</td>
</tr>
<tr>
<td>10</td>
<td>Seeding</td>
<td>LF</td>
<td>3650</td>
<td>$1.75</td>
<td>$6,387.50</td>
</tr>
</tbody>
</table>

**Total Construction Cost** = $329,137.50
### Line Designation
**P-6 (16")**

### Description
16" Line on Wilson and Eastbrook Ave from 17th Street to 21st Street

<table>
<thead>
<tr>
<th>Item No.</th>
<th>Description</th>
<th>Unit</th>
<th>Quantity</th>
<th>Unit Price</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Mobilization</td>
<td>LS</td>
<td>1</td>
<td>$45,000.00</td>
<td>$45,000.00</td>
</tr>
<tr>
<td>2</td>
<td>Connection to Mains</td>
<td>EA</td>
<td>15</td>
<td>$2,000.00</td>
<td>$30,000.00</td>
</tr>
<tr>
<td>3</td>
<td>8-inch PVC Waterline</td>
<td>LF</td>
<td>1200</td>
<td>$30.00</td>
<td>$36,000.00</td>
</tr>
<tr>
<td>4</td>
<td>8-inch Valves</td>
<td>EA</td>
<td>12</td>
<td>$1,200.00</td>
<td>$14,400.00</td>
</tr>
<tr>
<td>5</td>
<td>16-inch PVC Pipeline</td>
<td>LF</td>
<td>1740</td>
<td>$65.00</td>
<td>$113,100.00</td>
</tr>
<tr>
<td>6</td>
<td>16-inch Valves</td>
<td>EA</td>
<td>3</td>
<td>$5,000.00</td>
<td>$15,000.00</td>
</tr>
<tr>
<td>7</td>
<td>16-inch Fittings</td>
<td>EA</td>
<td>14</td>
<td>$2,000.00</td>
<td>$28,000.00</td>
</tr>
<tr>
<td>8</td>
<td>Fire Hydrant</td>
<td>EA</td>
<td>2</td>
<td>$3,500.00</td>
<td>$7,000.00</td>
</tr>
<tr>
<td>9</td>
<td>Select Material</td>
<td>CY</td>
<td>750</td>
<td>$25.00</td>
<td>$18,750.00</td>
</tr>
<tr>
<td>10</td>
<td>Foundation Material</td>
<td>CY</td>
<td>100</td>
<td>$35.00</td>
<td>$3,500.00</td>
</tr>
<tr>
<td>11</td>
<td>Roadway Restoration</td>
<td>LF</td>
<td>3000</td>
<td>$50.00</td>
<td>$150,000.00</td>
</tr>
<tr>
<td>12</td>
<td>Traffic Control</td>
<td>LS</td>
<td>1</td>
<td>$20,000.00</td>
<td>$20,000.00</td>
</tr>
</tbody>
</table>

**Total Construction Cost** $480,750.00
Line Designation
P-7 (20")
Description
20" Line from Kingsbury to Nottingham

<table>
<thead>
<tr>
<th>Item No.</th>
<th>Description</th>
<th>Unit</th>
<th>Quantity</th>
<th>Unit Price</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Mobilization</td>
<td>LS</td>
<td>1</td>
<td>$25,000.00</td>
<td>$25,000.00</td>
</tr>
<tr>
<td>2</td>
<td>Connection to Mains</td>
<td>EA</td>
<td>8</td>
<td>$2,000.00</td>
<td>$16,000.00</td>
</tr>
<tr>
<td>3</td>
<td>8-inch PVC Waterline</td>
<td>LF</td>
<td>550</td>
<td>$30.00</td>
<td>$16,500.00</td>
</tr>
<tr>
<td>4</td>
<td>8-inch Valves</td>
<td>EA</td>
<td>5</td>
<td>$1,200.00</td>
<td>$6,000.00</td>
</tr>
<tr>
<td>5</td>
<td>20-inch PVC Pipeline</td>
<td>LF</td>
<td>900</td>
<td>$100.00</td>
<td>$90,000.00</td>
</tr>
<tr>
<td>6</td>
<td>20-inch Valves</td>
<td>EA</td>
<td>3</td>
<td>$6,500.00</td>
<td>$19,500.00</td>
</tr>
<tr>
<td>7</td>
<td>20-inch Fittings</td>
<td>EA</td>
<td>7</td>
<td>$3,500.00</td>
<td>$24,500.00</td>
</tr>
<tr>
<td>8</td>
<td>Fire Hydrant</td>
<td>EA</td>
<td>2</td>
<td>$3,500.00</td>
<td>$7,000.00</td>
</tr>
<tr>
<td>9</td>
<td>Select Material</td>
<td>CY</td>
<td>750</td>
<td>$25.00</td>
<td>$18,750.00</td>
</tr>
<tr>
<td>10</td>
<td>Foundation Material</td>
<td>CY</td>
<td>100</td>
<td>$35.00</td>
<td>$3,500.00</td>
</tr>
<tr>
<td>11</td>
<td>Roadway Restoration</td>
<td>LF</td>
<td>1450</td>
<td>$50.00</td>
<td>$72,500.00</td>
</tr>
<tr>
<td>12</td>
<td>Traffic Control</td>
<td>LS</td>
<td>1</td>
<td>$15,000.00</td>
<td>$15,000.00</td>
</tr>
</tbody>
</table>

Total Construction Cost $314,250.00
# Line Designation

**P-B (12")**  
**Description**  
12" Line to the Mall from Landmark Lane

<table>
<thead>
<tr>
<th>Item No.</th>
<th>Description</th>
<th>Unit</th>
<th>Quantity</th>
<th>Unit Price</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Mobilization</td>
<td>LS</td>
<td>1</td>
<td>$45,000.00</td>
<td>$45,000.00</td>
</tr>
<tr>
<td>2</td>
<td>Connection to Mains</td>
<td>EA</td>
<td>2</td>
<td>$2,000.00</td>
<td>$4,000.00</td>
</tr>
<tr>
<td>3</td>
<td>12-inch PVC Pipeline</td>
<td>LF</td>
<td>960</td>
<td>$40.00</td>
<td>$38,400.00</td>
</tr>
<tr>
<td>4</td>
<td>12-inch Valves</td>
<td>EA</td>
<td>2</td>
<td>$1,500.00</td>
<td>$3,000.00</td>
</tr>
<tr>
<td>5</td>
<td>12-inch Fittings</td>
<td>EA</td>
<td>2</td>
<td>$1,000.00</td>
<td>$2,000.00</td>
</tr>
<tr>
<td>6</td>
<td>Fire Hydrant</td>
<td>EA</td>
<td>1</td>
<td>$3,500.00</td>
<td>$3,500.00</td>
</tr>
<tr>
<td>7</td>
<td>Select Material</td>
<td>CY</td>
<td>100</td>
<td>$25.00</td>
<td>$2,500.00</td>
</tr>
<tr>
<td>8</td>
<td>Foundation Material</td>
<td>CY</td>
<td>25</td>
<td>$35.00</td>
<td>$875.00</td>
</tr>
<tr>
<td>9</td>
<td>Roadway Restoration</td>
<td>LF</td>
<td>800</td>
<td>$50.00</td>
<td>$40,000.00</td>
</tr>
<tr>
<td>10</td>
<td>Traffic Control</td>
<td>LS</td>
<td>1</td>
<td>$5,000.00</td>
<td>$5,000.00</td>
</tr>
</tbody>
</table>

**Total Construction Cost**  
$144,275.00
<table>
<thead>
<tr>
<th>Description</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preparation of Final Design and Specifications</td>
<td>$229,900.00</td>
</tr>
<tr>
<td>Permitting and Mitigation</td>
<td>15,000.00</td>
</tr>
<tr>
<td>Legal Fees</td>
<td>6,000.00</td>
</tr>
<tr>
<td><strong>Acquisition of Access and Right-of-Way</strong></td>
<td>29,000.00</td>
</tr>
<tr>
<td><strong>Phase 1 Components</strong></td>
<td></td>
</tr>
<tr>
<td>Pipeline P-1</td>
<td>$809,220.00</td>
</tr>
<tr>
<td>Pipeline P-2</td>
<td>564,690.00</td>
</tr>
<tr>
<td>Water Storage Tanks</td>
<td>778,000.00</td>
</tr>
<tr>
<td>Subtotal Construction Cost</td>
<td>2,151,910.00</td>
</tr>
<tr>
<td>Inflated Costs for Year 2003 Construction</td>
<td>$2,298,800.00</td>
</tr>
<tr>
<td>Construction Cost Subtotal No. 1 (CCS#1)</td>
<td>$2,298,800.00</td>
</tr>
<tr>
<td>Engineering Cost (10% of CCS#1)</td>
<td>229,900.00</td>
</tr>
<tr>
<td>Construction Cost Subtotal #2 (CCS#2)</td>
<td>$2,528,700.00</td>
</tr>
<tr>
<td>Contingency (15% of CCS#2)</td>
<td>379,400.00</td>
</tr>
<tr>
<td><strong>Construction Cost Total</strong></td>
<td>$2,908,100.00</td>
</tr>
<tr>
<td><strong>Phase 1 - Total Project Cost</strong></td>
<td>$3,188,000.00</td>
</tr>
<tr>
<td><strong>Description</strong></td>
<td></td>
</tr>
<tr>
<td>Preparation of Final Design and Specifications</td>
<td>$168,100.00</td>
</tr>
<tr>
<td>Permitting and Mitigation</td>
<td>5,000.00</td>
</tr>
<tr>
<td>Legal Fees</td>
<td>6,000.00</td>
</tr>
<tr>
<td><strong>Acquisition of Access and Right-of-Way</strong></td>
<td>28,000.00</td>
</tr>
<tr>
<td><strong>Phase 2 Components</strong></td>
<td></td>
</tr>
<tr>
<td>Pipeline P-3</td>
<td>$573,900.00</td>
</tr>
<tr>
<td>Pipeline P-4</td>
<td>602,150.00</td>
</tr>
<tr>
<td>Pipeline P-5</td>
<td>329,137.50</td>
</tr>
<tr>
<td>Subtotal Construction Cost</td>
<td>1,505,187.50</td>
</tr>
<tr>
<td>Inflated Costs for Year 2004 Construction</td>
<td>$1,680,300.00</td>
</tr>
<tr>
<td>Construction Cost Subtotal No. 1 (CCS#1)</td>
<td>$1,680,300.00</td>
</tr>
<tr>
<td>Engineering Cost (10% of CCS#1)</td>
<td>168,100.00</td>
</tr>
<tr>
<td>Construction Cost Subtotal #2 (CCS#2)</td>
<td>$1,848,400.00</td>
</tr>
<tr>
<td>Contingency (15% of CCS#2)</td>
<td>277,300.00</td>
</tr>
<tr>
<td><strong>Construction Cost Total</strong></td>
<td>$2,125,700.00</td>
</tr>
<tr>
<td><strong>Phase 2 - Total Project Cost</strong></td>
<td>$2,332,800.00</td>
</tr>
</tbody>
</table>
SUBSURFACE EXPLORATION AND GEOTECHNICAL ENGINEERING REPORT
TWO 650,000-GALLON WATER TANKS
EAST WATER STORAGE TANKS
CASPER, WYOMING

October 15, 2001

For
Civil Engineering Professionals, Inc.
355 North Lincoln
Casper, WY 82601

9838-CX

INBERG-MILLER ENGINEERS
1120 East "C" Street
Casper, WY 82601
October 15, 2001

Civil Engineering Professionals, Inc.
355 North Lincoln
Casper, WY 82601

ATTENTION: TOM BRAUER AND JIM JONES

RE: SUBSURFACE EXPLORATION AND 
GEOTECHNICAL ENGINEERING REPORT 
TWO 650,000-GALLON WATER TANKS 
EAST WATER STORAGE TANKS 
CASPER, WYOMING

Gentlemen:

Enclosed are three copies of our Subsurface Exploration and Geotechnical Engineering report for the above-referenced project.

The work described in this report has been completed per our September 6, 2001 Proposal and Service Agreement.

It has been a pleasure participating in this project. We are available to provide additional services, at your request, to review plans, perform excavation observations and construction materials testing. If you have any questions or comments, please contact us.

Sincerely,

INBERG-MILLER ENGINEERS

Mark W. Blakley, P.E.
Geotechnical Engineer

Enclosures: As stated
# TABLE OF CONTENTS

Transmittal Letter ........................................................................................................... i
Table of Contents ............................................................................................................. ii
Summary ............................................................................................................................ 1
Scope of Services ............................................................................................................. 1
Project Information ......................................................................................................... 2
Field Exploration .............................................................................................................. 2
Laboratory Testing Program ............................................................................................ 3
Site Conditions ................................................................................................................ 3
Subsoil Conditions .......................................................................................................... 4
Ground-Water Conditions ............................................................................................... 4
Conclusions ....................................................................................................................... 4
Recommendations ............................................................................................................ 5
   I. Site Preparation and Fill ........................................................................................... 5
   II. Foundation Design .................................................................................................. 6
   III. Floors .................................................................................................................... 7
   IV. General .................................................................................................................. 7
Construction Considerations ......................................................................................... 9
Closure .............................................................................................................................. 9

APPENDIX A - GENERAL CONDITIONS
   Geotechnical Engineering Report
   Data Collection

APPENDIX B - SITE INFORMATION
   Site Location Map
   Site Observations
   Test Boring Location Plan

APPENDIX C - TEST BORING INFORMATION
   Test Boring Logs (YELLOW SHEETS)
   General Notes
   Classification of Soils for Engineering Purposes

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

APPENDIX E - ADDITIONAL INFORMATION
   Envelope A Gradation
   Important Information About Your Geotechnical Engineering Report
SUMMARY

Based on the subsurface conditions encountered at the site and the results of our laboratory analysis, it is our opinion that the site is suitable for the proposed water tanks. However, the location of the proposed tanks is approximately 75 feet to the north of the original location and has resulted in the tanks being located on a relatively steep slope. Our concerns with siting the tanks on the slope include placing the tanks on a uniform foundation, and the possibility of encountering difficulties in excavating into the slope. Therefore, depending on the final tank locations, it may be necessary to perform additional test borings to confirm subsurface conditions at the tank locations. Because of this, we strongly recommend that we be consulted on the final location of the tanks prior to final design and construction. The following conclusions and recommendations are provided for the subsurface conditions revealed in the 3 test borings performed. The subsoil encountered at the site generally consists of silty to sandy clay soils with some gravel overlying formational shale bedrock, which was encountered at depths ranging from 7.5 to 13 feet. Auger refusal was encountered in the shale bedrock in all three borings advanced at the site. The soils encountered at anticipated shallow foundation elevations are considered to have consistencies ranging from very stiff to hard and consist of both residual soils and formational bedrock. Ground water was not encountered at the time of our exploration. The result of our laboratory analysis indicates that the shale bedrock tested exhibits expansive characteristics when wetted and has the potential for consolidation under increased loading. Additionally, the clay soils and the shale bedrock have similar low plasticity characteristics, however the clay soils have appreciable amounts of sand and gravel. Therefore, we recommend that the water storage tanks be supported on shallow spread footing foundations that bear on a minimum of 2 feet of properly compacted fill in order to provide uniform support for the footings. Furthermore, we recommend that tank floors be supported on a minimum of 4 feet of properly compacted fill. Our recommendations also include selection and placement of fills and site drainage considerations. Additional comments and detailed recommendations follow.

SCOPE OF SERVICES

The purpose of this study was to explore subsurface conditions at the proposed water tank and to provide information on soil bearing capacity, ground-water conditions, consolidation-swell potential of foundation soils, and other pertinent foundation design recommendations.
PROJECT INFORMATION

Project information was furnished by Tom Brauer and Jim Jones of Civil Engineering Professionals Inc. It is our understanding that the original scope of the project included the design and construction of one, 1 to 2 million-gallon water storage tank. Following the performance of our field services, we understand that the project will now consist of designing and constructing two steel water tanks having storage capacities of 650,000-gallons each. We understand that the tanks will have diameters of approximately 45 feet and will be approximately 60 feet tall.

FIELD EXPLORATION

The field work was performed using a Mobile B-57 truck-mounted drilling rig at the site on September 12, 2001. Three (3) borings were advanced to depths ranging from 25.6 to 35.4 feet. Drilling was performed using 4.25-inch inside 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. Based on the original scope of services, the test borings were located at the location of the proposed water tank. With the revised project scope, the new proposed tank locations have been moved to the north.

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". Twenty-six (26) 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. One (1) such sample was obtained.

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

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:

1. Moisture Content (ASTM D2216) 27
2. Unit Weight Determination (ASTM D2937) 1
3. Atterberg Limits (ASTM D4318) 3
4. Pocket Penetrometer Test 21
5. Sieve Analysis - #200 (ASTM D1140) 2
6. Sieve Analysis (#4 to #200) (ASTM D422 and D1140) 5
7. Consolidation - Swell Test (ASTM D2435) 1
8. Water Soluble Sulfate 1

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

SITE CONDITIONS

The site is located in the NE¼ of SW¼ of Section 19, Township 33N, Range 78W. More generally, the site is located approximately 2 miles southeast of Casper, Wyoming. The topography at the site slopes down to the west at an inclination of about 10H: 1V or flatter with about 5 to 10 feet of topographic relief across the site. The site contains a ground cover of sagebrush and sparse native grasses.

A Site Location Map, a Site Observation Sheet and a Test Boring Location Plan in Appendix B describe the site in more detail.
SUBSOIL CONDITIONS

The subsoil classified in the three test borings performed at the site consists of silty to sandy clay with some gravel from the ground surface to depths ranging from 7.5 to 13 feet. At depths ranging from 7.5 to 13 feet, formational shale bedrock was encountered through the depths of the borings. The shale bedrock consists of silty clay and auger refusal was encountered in all of the borings at depths ranging from 25 to 35 feet. The silty to sandy clay soils are considered to have very stiff to hard consistencies and the shale bedrock is considered hard. The silty to sandy clay soils tested have low plasticity characteristics and appreciable amounts of sand and gravel. The shale bedrock tested exhibits low swelling pressures and associated low expansion potential when wetted and the potential for moderate consolidation under the anticipated structure loads. The shale bedrock also exhibits low plasticity characteristics with only a trace of sand.

GROUND-WATER CONDITIONS

Ground-water observations were made in each borehole at the completion of drilling. These data, along with cave-in depths of the drill holes, are recorded on the Final Logs (YELLOW SHEETS) in Appendix C.

Ground water was not observed in any of the borings during the drilling operations and was not measured in the open boreholes after the completion of drilling. However, ground water elevations may fluctuate seasonally with variations in precipitation, infiltration, and runoff. Ground water may be encountered in excavations and should be anticipated.

CONCLUSIONS

Based on our findings, it is our opinion that the site where the test borings were performed is suitable for the proposed water storage tanks. However, the location of the proposed tanks is approximately 75 feet to the north of the original location and has resulted in the tanks being located on a relatively steep slope. Our concerns with siting the tanks on the slope include placing the tanks on a uniform foundation, and the possibility of encountering difficulties in excavating into the slope. Therefore, depending on the final tank locations, it may be necessary to perform additional test borings to confirm subsurface conditions at the tank locations. Because of this, we strongly recommend that we be consulted on the final location of the tanks prior to final design and construction. The following conclusions and
CONCLUSIONS. Continued

recommendations are provided for the subsurface conditions revealed in the 3 test borings performed. The subsoil encountered in the test borings consists of both residual soils and formational shale bedrock, which are considered to have variable consistencies that range from very stiff to hard. Additionally, all of the fine-grained soils tested have low plasticity characteristics and the shale bedrock tested exhibits some expansion potential when wetted. Therefore, in order to provide uniform support for the structure, we recommend that the tanks be supported on spread footing foundations that bear on a minimum of 2 feet of properly compacted fill. Furthermore, we recommend that tank floors be supported on a minimum of 4 feet of properly compacted fill as discussed in this report. Detailed recommendations follow.

RECOMMENDATIONS

I. Site Preparation and Fill

A. Fill required to backfill the foundation or floor excavations or to revise site grades should consist of sands or gravel obtained from off-site sources. On-site soils are generally suitable for use as general landscaping only. We recommend that imported fills comply with Envelope A gradation included in Appendix E. Other material may be utilized if approved by the geotechnical engineer.

B. All fill soils used at the site should be placed in loose lifts, not exceeding 8 inches in thickness. Fill required to establish subgrade beneath the structure should be compacted to a minimum of 95 percent of Modified Proctor (ASTM D1557) maximum dry density at moisture contents ranging from 2 percent below to 2 percent above the optimum moisture content. In-place density and water content of the fill materials should be tested and approved prior to placement of subsequent lifts.

C. Prior to construction on the site, all vegetation and organic surface matter should be stripped from the site. Stripping depths on the order of 6 to 12 inches may be required. The limits of stripping should be at least 10 feet beyond the proposed construction limits.
RECOMMENDATIONS, Continued

I. Site Preparation and Fill, Continued

D. In fill areas, we recommend that the natural subgrade be proofrolled with a loaded triaxle dump truck or equivalent heavy construction equipment to compact surficial soils that may have been loosened from past frost action or stripping operations, and to allow identification of possible soft or loose zones. Proofrolling should be performed under the observation of a qualified geotechnical engineer to allow correct identification of soft or loose zones that may require improvement. Any soft or loose zones identified by the geotechnical engineer during the proofrolling process should be overexcavated and replaced with properly compacted fill as described in Items A and B, above.

E. If construction takes place during the colder months care should be taken to prevent construction on frozen soils. In addition, fill materials should not be placed in a frozen condition.

II. Foundation Design

A. Continuous strip or individual pad (spread) footings are recommended to support the proposed water tank. Footings should bear on a minimum of 24 inches of properly compacted fill as described in Section I. Site Preparation and Fill above. In addition, the bottom of footings should be at least 2 feet below existing grade. Exterior footings should be founded a minimum of 4.0 feet below final exterior grade for frost protection.

B. The over-excavations performed at the footing locations should extend horizontally on all sides of the footing a minimum distance equal to the depth of the over-excavation (24 inches minimum). We anticipate that this will require a minimum footing excavation, measured at the bottom of the excavation of 4 feet plus the width of the footing.

C. Footings founded as specified in this report should be designed based on a maximum net allowable bearing capacity of 2,500 pounds per square foot (psf). The footings should be designed with a minimum dead load of at least 1,000 pounds per square foot (psf).
RECOMMENDATIONS, Continued

II. Foundation Design, Continued

D. If the tanks are designed and constructed as recommended in this report, the total anticipated settlement is 2½ inches with differential settlement in the range of 1 to 1½ inches.

E. Footing subgrades should be observed by a qualified geotechnical engineer prior to concrete placement, to identify suitable bearing materials and to observe whether or not the foundation soils have been properly prepared. This is particularly important depending on the final location of the water tanks relative to the test borings.

III. Floors

A. In order to provide uniform support for the tank floors, the floors should be founded on a minimum of 4 feet of granular fill placed as specified in Section I. Site Preparation and Fill.

B. Tank floors for the structure should be underlain by a minimum of 4 inches of free-draining, well-graded sand and gravel devoid of fines to provide uniform floor support and to act as a capillary moisture break. The depth of this free draining soil layer can be included in the minimum 4 feet of compacted fill beneath floors.

IV. General

A. Based on the results of the water soluble sulfate test from sample B-2-3 of 0.69%, we recommend that Portland cement used in concrete in contact with site soils to consist of Type V.

B. Site surface drainage should be addressed during design and construction to help prevent water from infiltrating subgrade soils near structural foundations. We suggest a 10H:1V slope away from the structure for the first fifteen (15) feet.
RECOMMENDATIONS, Continued

IV. General, Continued

C. In order to reduce the potential for foundation soils to become wet, we suggest that landscaping near structures should consist of native vegetation that can sustain on seasonal precipitation. Irrigation systems should not be installed near structural foundations.

D. Backfill for utility trenches should be properly compacted to prevent surface water from infiltrating and migrating along the trenches. If backfill is not properly compacted, water may infiltrate foundation soils via loosely placed backfill. Backfill of utility trenches should be performed as discussed in Section I, Site Preparation and Fill.

E. The site is in Seismic Zone 1 as identified by the Uniform Building Code, 1991 Edition.

F. A Geotechnical Engineer should review final plans and specifications in order to determine whether the intent of our recommendations have been properly implemented. In addition, a qualified Geotechnical Engineer and Testing Laboratory should be retained during construction to provide the following services:

1. Observe all excavations to determine:
   a. Subsurface conditions revealed are consistent with those discovered in the exploration.
   b. Proper bearing stratum is exposed at proposed foundation excavation depths.
   c. Foundation excavations are properly prepared, cleaned, and dewatered prior to concrete placement.

2. Test materials for:
   a. Field density testing of compacted fills.
   b. Field and laboratory concrete testing.
CONSTRUCTION CONSIDERATIONS

Excavations performed at the site should be prevented from becoming wet during construction. Water should not be allowed to accumulate in excavation bottoms and infiltrate the exposed soils. We anticipate that it may be necessary to slope the outside of the excavations or provide drainage swales. Excavations may encounter minor difficulties with caving soils and should be performed in accordance with all Federal and OSHA guidelines. The on-site fill soils should be considered as OSHA Type A soils, with the exception of excavations into slopes, which should be considered type C.

Excavation into the underlying shale and sandstone may be difficult, especially if excavation in slopes is necessary. Depending on final excavation depths, ripping of the bedrock may be necessary to facilitate excavation.

CLOSURE

This report has been prepared for the exclusive use of our client, Civil Engineering Professionals, Inc., 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.

We appreciate participating in your project. We can offer services under a separate contract to review final tank siting, final plans and specifications, or to examine excavations and perform field and laboratory construction materials testing, as may be required. Please call if you have any questions regarding this report.

Sincerely,

INBERG-MILLER ENGINEERS

Mark W. Blakley, P.E.
Geotechnical Engineer

MWB:gm:\9838-cx\9838.rpt

REVIEWED BY:

Steven F. Moldt, P.E.
President
APPENDIX A - GENERAL CONDITIONS
This report has been prepared by Inberg-Miller Engineers, hereinafter referred to as “Engineer”, to evaluate this property for the intended use described herein. If any changes of the facility are planned, with respect to the design vertical position and/or horizontal location as outlined herein of the facility are planned, the conclusions and recommendations contained in this report shall not be considered valid unless such changes are reviewed and the conclusions of this report modified in writing by the Engineer.

The analyses and recommendations submitted in this report are our opinions based on the data obtained and subsurface conditions noted from the field Exploration. The locations of the Exploration are illustrated on the accompanying map and diagram. This report does not reflect any variations, which may occur between, beyond or below the depths of these test pits or borings. Excavations during the construction phases may reveal variations from our interpretation of subsurface conditions between borings or test pits. The nature and extent of such variations may not become evident until excavation and construction begins. If variations then appear evident, it will be necessary for a re-evaluation of the recommendations of this report to be made after performing on-site observations during the construction period and noting the characteristics of any variations.

This report may not be sufficient to prepare an accurate bid. Contractors wishing copies of the report may secure them from Inberg-Miller Engineers when authorized by our client, with the understanding that its scope is limited to considerations as stated herein.

The ENGINEER is responsible for the conclusions and opinions contained herein based on the supplied data relative only to the specific project and location outlined in this report. If conclusions or recommendations are made by others, such conclusions or recommendations are not the responsibility of the ENGINEER unless the ENGINEER has been given an opportunity to review and comment on such conclusions or recommendations in writing.

It is recommended the ENGINEER be provided the opportunity to review final designs, plans and specifications using the conclusions of this report, in order to determine whether any change in concept may have any affect on the validity of the recommendations contained in this document. If the ENGINEER is not accorded the privilege of this review, he can assume no responsibility of misinterpretation or misapplication of these recommendations or for their validity in the event changes have been made in his understanding of the project and/or design content. Review of the final design, plans and specifications will be noted in writing by the ENGINEER upon client’s request and will become a part of this report.
Variations in soil conditions may be encountered during construction. To permit correlation between soil data in this report and actual soil conditions encountered during construction, we recommend that the ENGINEER be retained to perform continuous construction review of the earthwork and foundation phases of the work. The ENGINEER assumes no responsibility for construction compliance with the design concepts, specifications or recommendations unless he has been retained to perform full-time on-site observations during construction.

As a part of the above review it is recommended that the ENGINEER review all areas where fills are to be placed, test and approve each class of fill material to be used according to the attached recommendation for compacted fill.

The presence of our field representative, if such services are requested by the client, will be for the sole purpose of providing record observations and field soils testing. Our work does not include supervision, management or direction of the actual work of the contractor, his employees or agents. The contractor for this project should be so advised. The contractor should also be informed that neither the presence of our field representative nor the observation and testing by our firm shall excuse him in any way for defects discovered in his work. It is understood that our firm will not be responsible for job or site safety on this project.

This report has been prepared in accordance with generally accepted soil and foundation engineering practices and makes no warranties, either expressed or implied, as to the professional advice provided under the terms of the agreement between the ENGINEER and his client, included in this report. The report has not been prepared for other uses or parties other than those specifically named, or for uses or applications other than those enumerated herein. The report may contain insufficient or inaccurate information for other purposes, applications, building sites or other uses.
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 test 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 filed data received along with the laboratory test data obtained following the filed 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 filed 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 soils. 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
SITE LOCATION MAP

Project: Water Storage Tanks
Location: Casper, Wyoming
Client: Civil Engineering Professionals, Inc.

Map is presented for geotechnical engineering purposes only.
### SITE OBSERVATIONS

**Project:** Water Storage Tanks  
**Location:** Casper, WY  
**Job No.:** 9838-CX  
**Client:** Civil Engineering Professionals, Inc.

1. **LOCATION OF SITE**  
   Approximately 2 miles southeast of Casper, WY

2. **SLOPE OF GROUND SURFACE**  
   4 to 5% DOWNHILL DIRECTION  
   West

3. **ESTIMATED CHANGE OF ELEVATION**  
   5 to 10 feet

4. **BODIES OF WATER NEARBY**  
   The Platte River is located approximately 4 miles north of the subject site

5. **TOPSOIL TYPE**  
   Sandy clay with some surface gravel

6. **VEGETATION**  
   Sparse grass and sage brush

7. **SITE SUBJECT TO FLOODING?**  
   No

8. **ROCK OUTCROPS**  
   None  
   ESTIMATED DEPTH TO BEDROCK  
   7.5 to 13 feet

9. **ARTIFICIAL FILLS?**  
   No

10. **NEARBY LAND FEATURES**  
    Casper Mountain is located 4 miles south of the site

11. **PRESENT SITE IMPROVEMENTS**  
    None

12. **BURIED UTILITIES ON SITE**  
    None

13. **NEARBY BUILDINGS**  
    None

14. **CONDITION OF NEARBY FOUNDATIONS**  
    N/A

15. **CONDITION OF NEARBY STREETS AND WALKS**  
    N/A

16. **BURIED OBSTRUCTIONS ENCOUNTERED**  
    None Encountered

17. **HISTORY OF LAND USE**  
    Range

18. **EXISTING DRAINAGE FEATURES**  
    The site is located on a north-south traversing ridge and surface water drains to the west

19. **OVERHEAD UTILITIES CROSSING SITE**  
    None

20. **GEOLOGIC DESCRIPTION OF SITE**  
    Sandy clay with gravel underlain by sedimentary bedrock of the Cody Shale Formation of the Mesaverde Group
Test Borings performed by Inberg-Miller Engineers on September 12, 2001.
APPENDIX C - TEST BORING INFORMATION
<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>SAMPLING TYPE - NO.</th>
<th>SOIL DESCRIPTION</th>
<th>USCS N BLOWS (FT)</th>
<th>q_p (TSF)</th>
<th>W (%)</th>
<th>γ_m (PCF)</th>
<th>LL PL (%)</th>
<th>OTHER TESTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>SS-1</td>
<td>Hard, Slightly Moist, Sandy CLAY with some Gravel</td>
<td>31</td>
<td>4.1</td>
<td></td>
<td></td>
<td></td>
<td>Sieve</td>
</tr>
<tr>
<td>0.0-1.5</td>
<td>8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.5-4.0</td>
<td>SS-2</td>
<td>Some Fine Gravel at 2.0 feet</td>
<td>31</td>
<td>4.5+</td>
<td>4.1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>SS-3</td>
<td>Grades Very Stiff</td>
<td>16</td>
<td>4.5+</td>
<td>6.7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.0-6.5</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7.5</td>
<td>SS-4</td>
<td>Hard, Moist, Brown, Silty CLAY with Sand (Weathered Formational Shale Bedrock)</td>
<td>33</td>
<td>11.8</td>
<td></td>
<td></td>
<td></td>
<td>Sieve</td>
</tr>
<tr>
<td>7.5-9.0</td>
<td>14</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>SS-5</td>
<td>Grades More Competent Bedrock</td>
<td>66</td>
<td>4.5+</td>
<td>13.1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10.0-11.5</td>
<td>15</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>SS-6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15.0-16.5</td>
<td>15</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Log Continued on Next Page)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

INBERG-MILLER ENGINEERS
<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>SOIL DESCRIPTION</th>
<th>USCS BLOWS PER FT</th>
<th>N</th>
<th>q_p (TSF)</th>
<th>γ_m (PCF)</th>
<th>γ_d (%)</th>
<th>LL</th>
<th>PL</th>
<th>PI</th>
<th>OTHER TESTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>Hard, Moist, Brown, Silty CLAY with Sand (Formational Shale Bedrock)</td>
<td>50/4&quot;</td>
<td>4.5+</td>
<td>11.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Difficult Drilling below 22.0 feet</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>Hollow Stem Auger Refusal at 25 feet</td>
<td>50/2&quot;</td>
<td></td>
<td>10.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**WATER LEVEL OBSERVATIONS**

- Initial Occurrence While Drilling (ft): -
- Time After Drilling: 0.1 hr
- Depth to Water (ft): -
- Depth to Cave-In (ft): 13.4

**DRILLING AND SAMPLING NOTES**

- Date Begun: 9/12/01
- Comp.: 9/12/01
- Crew: MKP/JAY
- Rig: Mobile B-57
- Method: 4 1/4" Hollow-Stem Auger
- Termination Depth (ft): 25.6

INBERG-MILLER ENGINEERS
<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</th>
<th>N BLOWS PER FT</th>
<th>qp</th>
<th>W (%)</th>
<th>( \gamma_m )</th>
<th>( \gamma_d ) (PCF)</th>
<th>LL PL (%)</th>
<th>OTHER TESTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>SS-1</td>
<td>0.0-1.5</td>
<td>12</td>
<td>Very Stiff, Slightly Moist, Brown, Sandy CLAY</td>
<td>17</td>
<td>4.5+</td>
<td>7.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>SS-2</td>
<td>2.5-4.0</td>
<td>8</td>
<td>Grades to White and Brown with trace Gravel</td>
<td>18</td>
<td>4.5+</td>
<td>8.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Sieve</td>
</tr>
<tr>
<td>5</td>
<td>SS-3</td>
<td>5.0-6.5</td>
<td>10</td>
<td></td>
<td>14</td>
<td>12.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>40</td>
<td>w.s.s. = 0.69 %</td>
</tr>
<tr>
<td>10</td>
<td>SS-4</td>
<td>7.5-9.0</td>
<td>6</td>
<td>Some Gravel at 8.0 feet</td>
<td>21</td>
<td>7.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>27</td>
<td>80.5% passing #200 sieve</td>
</tr>
<tr>
<td>10</td>
<td>SS-5</td>
<td>10.0-11.5</td>
<td>12</td>
<td>Grades to More Sand and Gravel</td>
<td>29</td>
<td>8.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>SS-6</td>
<td>15.0-16.5</td>
<td>14</td>
<td>Hard, Moist, Orange-Brown, Silty CLAY with Sand (Formational Shale Bedrock)</td>
<td>60</td>
<td>4.5+</td>
<td>12.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Sieve</td>
</tr>
</tbody>
</table>

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

### Project: Water Tank
### Location: Casper, WY
### Job No.: 9838-CX
### Client: Civil Engineering Professionals, Inc.
### Surface El. (Ft): 5445.4
### Benchmark/Datum (Ft): Survey Information from CEPI

<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>( \gamma'_d ) (PCF)</th>
<th>LL PL PI (%)</th>
<th>OTHER TESTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>SS-7</td>
<td>20.0-21.5</td>
<td>7</td>
<td>Hard, Moist, Orange-Brown, Silty CLAY with Sand (Formational Shale Bedrock)</td>
<td>50/5&quot;</td>
<td>4.5+</td>
<td>12.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>SS-8</td>
<td>25.0-26.5</td>
<td>8</td>
<td>Grades Gray and Brown at 25.0 feet</td>
<td>50/5&quot;</td>
<td>4.5+</td>
<td>11.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>SS-9</td>
<td>30.0-31.5</td>
<td>8</td>
<td>Grades to Orange Brown at 30.0 feet with very thin layers of Clayey SAND (Formational Sandstone Bedrock)</td>
<td>50/5&quot;</td>
<td>4.5+</td>
<td>11.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>33.0-34.5</td>
<td>SS-10</td>
<td></td>
<td></td>
<td>Hollow Stem Auger Refusal at 33.0 feet</td>
<td>50/5&quot;</td>
<td>4.5+</td>
<td>9.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>35</td>
<td></td>
<td></td>
<td></td>
<td>Grades to Gray at 33.5 feet</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### WATER LEVEL OBSERVATIONS

- **Initial Occurrence While Drilling (ft):** -
- **Time After Drilling:** 0.1 hr
- **Depth to Water (ft):** -
- **Depth to Cave-In (ft):** 22.0

### DRILLING AND SAMPLING NOTES

- **Date Begun:** 9/12/01
- **Comp.:** 9/12/01
- **Crew:** MKP/JAY
- **Rig:** Mobile B-57
- **Method:** 4 1/4" Hollow-Stem Auger
- **Termination Depth (ft):** 33.9

---

**INBERG-MILLER ENGINEERS**
**LOG OF TEST BORING NO.**  
**B-3**  
Page 1 of 2

- **Project:** Water Tank  
- **Location:** Casper, WY  
- **Surface El. (Ft):** 5443.9  
- **Benchmark/Datum (Ft):** Survey Information from CEPI  
- **Client:** Civil Engineering Professionals, Inc.

<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 BCS</th>
<th>N BLOWS PER Ft</th>
<th>q_p (TSF)</th>
<th>W (%)</th>
<th>( \gamma_m )</th>
<th>( \gamma_d ) (PCF)</th>
<th>LL PL PI (%)</th>
<th>OTHER TESTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td>Very Stiff, Slightly Moist, Brown, Silty CLAY with Sand</td>
<td></td>
<td>15</td>
<td>4.5+</td>
<td>9.5</td>
<td>38</td>
<td>11</td>
<td>27</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>SS-2</td>
<td>5.0-6.5</td>
<td>13</td>
<td>Grades to Brown, with some Medium SAND at 5.0 feet</td>
<td>CL</td>
<td>14</td>
<td>4.5+</td>
<td>13.7</td>
<td></td>
<td></td>
<td>Sieve</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>SS-4</td>
<td>10.0-11.5</td>
<td>6</td>
<td>Some Coarse SAND and Gravel below 10.0 feet</td>
<td></td>
<td>13</td>
<td>4.5+</td>
<td>7.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>DC-5</td>
<td>15.0-16.0</td>
<td>9</td>
<td>Grades to More Competent Bedrock</td>
<td>CL</td>
<td>4.5+</td>
<td>11.0</td>
<td>32</td>
<td>32</td>
<td>15</td>
<td>17</td>
<td>79.3% passing #200 sieve consol-swell</td>
</tr>
</tbody>
</table>

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

**Project:** Water Tank  
**Location:** Casper, WY  
**Client:** Civil Engineering Professionals, Inc.  
**Surface El. (Ft):** 5443.9  
**Benchmark/Datum (Ft):** Survey Information from CEPI

### SAMPLING

<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>TYPE - NO.</th>
<th>SOIL DESCRIPTION</th>
<th>USCS N BLOWS PER FT</th>
<th>qp (TSF)</th>
<th>W (%)</th>
<th>γ_m (PCF)</th>
<th>LL PL (%)</th>
<th>OTHER TESTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>SS-6</td>
<td>Hard, Moist, Orange-Brown, Silty CLAY with Sand (Formational Shale Bedrock)</td>
<td>91/10&quot; 4.5+</td>
<td>13.9</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>SS-7</td>
<td>Grades Gray-Brown at 25.0 feet</td>
<td>50/5&quot; 4.5+</td>
<td>13.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>SS-8</td>
<td>Grades to Brown at 30.5 feet</td>
<td>50/4&quot; 4.5+</td>
<td>11.9</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>SS-9</td>
<td>Hollow stem Auger refusal at 35.0 feet</td>
<td>50/5&quot; 4.5+</td>
<td>8.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Grades Dark Gray at 35 feet</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### WATER LEVEL OBSERVATIONS

- Initial Occurrence While Drilling (ft)  
- Time After Drilling 0.1 hr  
- Depth to Water (ft)  
- Depth to Cave-In (ft) 24.0

### DRILLING AND SAMPLING NOTES

- Date Begun: 9/12/01  
- Comp.: 9/12/01  
- Crew: MKP/JAY  
- Rig: Mobile B-57  
- Method: 4 1/4" Hollow-Stem Auger  
- Termination Depth (ft): 35.4

---

LOG OF TEST BORING NO. 6885-8PJ INBERG-MILLER GERT 10/13/01 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 Sieve Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boulders</td>
<td>Larger than 12&quot;</td>
<td>Larger than 12&quot;</td>
</tr>
<tr>
<td>Cobble</td>
<td>3&quot; to 12&quot;</td>
<td>3&quot; to 12&quot;</td>
</tr>
<tr>
<td>Gravel: Coarse</td>
<td>3/4&quot; to 3&quot;</td>
<td>3/4&quot; to 3&quot;</td>
</tr>
<tr>
<td>Fine</td>
<td>4.75mm to 3/4&quot;</td>
<td>#4 to 3/4&quot;</td>
</tr>
<tr>
<td>Sand: Coarse</td>
<td>2.00mm to 4.75mm</td>
<td>#10 to #4</td>
</tr>
<tr>
<td>Medium</td>
<td>0.42mm to 2.00mm</td>
<td>#40 to #10</td>
</tr>
<tr>
<td>Fine</td>
<td>0.074mm to 0.42mm</td>
<td>$200 to #40</td>
</tr>
<tr>
<td>Silt</td>
<td>0.005mm to 0.074mm</td>
<td>Smaller than #200</td>
</tr>
<tr>
<td>Clay</td>
<td>Smaller than 0.005mm</td>
<td>Smaller than #200</td>
</tr>
</tbody>
</table>

Plasticity characteristics differentiate between silt & clay

Relative Density

<table>
<thead>
<tr>
<th>Term</th>
<th>Consistency</th>
<th>&quot;N&quot; Value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Loose ...</td>
<td>Very Soft</td>
<td>.0 to .23</td>
</tr>
<tr>
<td>Loose</td>
<td>Soft</td>
<td>.25 to 0.5</td>
</tr>
<tr>
<td>Medium Dense</td>
<td>Firm</td>
<td>0.5 to 2.0</td>
</tr>
<tr>
<td>Dense</td>
<td>Stiff</td>
<td>1.0 to 2.0</td>
</tr>
<tr>
<td>Very Dense ...</td>
<td>Very Stiff</td>
<td>2.0 to 4.0</td>
</tr>
<tr>
<td>Over 50</td>
<td>Hard</td>
<td>Over 4.0</td>
</tr>
</tbody>
</table>

NOTE: The penetration number, N, is the summation of blows required to effect 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 small chips to pieces about one-inch-maximum size by hard blows of the point of a geologist’s pick.

Medium Soft Can be grooved 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 specimen 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, X
LL - Liquid Limit, X
PL - Plastic Limit, X
PI - Plasticity Index (LL-PL), X
q_u - Unconfined Strength, TSP
q_p - Penetrometer Reading (estimate of unconfined strength), TSP
γ_m - Moist Unit Weight, PCF
γ_d - Dry Unit Weight, PCF
WSS - Water Soluble Sulfate, X
Ø - Angle of Internal Friction, degrees
c - Soil Cohesion, TSP
SG - Specific gravity of soil solids
S - Degree of Saturation, X
e - Void Ratio
n - Porosity
k - Permeability, cm/sec.

Water Level Measurement

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 Designations: 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></td>
<td></td>
<td></td>
<td>C_{g} = \frac{D_{10}}{D_{60}} greater than 4; C_{p} = \frac{(D_{10})^2}{D_{60} \times D_{10}} between 1 and 3</td>
</tr>
<tr>
<td>Coarse-grained soils (More than half of material is larger than No. 200)</td>
<td>d</td>
<td>Silty gravels, gravel-silt mixtures</td>
<td>Not meeting all gradation requirements for GW</td>
</tr>
<tr>
<td></td>
<td>u</td>
<td>Clayey gravels, gravel-sand-clay mixtures</td>
<td></td>
</tr>
<tr>
<td></td>
<td>d</td>
<td>Silty sands, sand-silt mixtures</td>
<td></td>
</tr>
<tr>
<td></td>
<td>u</td>
<td>Clayey sands, sand-clay mixtures</td>
<td></td>
</tr>
<tr>
<td>Fine-grained soils (Liquid limit less than 50)</td>
<td>ML</td>
<td>Inorganic silt and very fine sands, clayey silt with slight plasticity</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CL</td>
<td>Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, lean clays</td>
<td></td>
</tr>
<tr>
<td></td>
<td>OL</td>
<td>Organic silt and organic silty clays of low plasticity</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MH</td>
<td>Inorganic silt, micaeous or diatomaceous fine sand or silty soils, elastic silt</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CH</td>
<td>Inorganic clays of high plasticity, fine clays</td>
<td></td>
</tr>
<tr>
<td></td>
<td>OH</td>
<td>Organic clays of medium to high plasticity, organic silt</td>
<td></td>
</tr>
<tr>
<td>Highly organic soils</td>
<td>Ps</td>
<td>Peat and other highly organic soils</td>
<td></td>
</tr>
</tbody>
</table>

Determination of soil type and grain size (from Table 1, 2, 3, or 4) and from Table 5. Coarse-grained soils requiring dual symbols:

- GW: Well-graded gravels, gravel-sand mixtures, little or no fines
- GP: Poorly graded gravels, gravel-sand mixtures, little or no fines

Above "A" line with P.I. greater than 7

Below "A" line with P.I. less than 4

Not meeting all gradation requirements for GW

Above "A" line with P.I. greater than 7

Below "A" line with P.I. less than 4

Not meeting all gradation requirements for SW

Below "A" line with P.I. less than 4

Above "A" line with P.I. greater than 7

Not meeting all gradation requirements for SW

Plasticity Chart

- C_{g} = \frac{D_{10}}{D_{60}} greater than 4; C_{p} = \frac{(D_{10})^2}{D_{60} \times D_{10}} between 1 and 3

INBERG - MILLER ENGINEERS

Footnotes:
- Division of GM and SM groups into subdivisions of d and u are for sands and air-fills only. Subdivision is based on Atterberg limits; suffix u used when L.L. is 26 or less and the P.I. is 5 or less; the suffix u used when L.L. is greater than 26.
- Borderline classifications, used for soils possessing characteristics of two groups, are designated by combinations of group symbols. For example: GM-GC, well-graded gravel-sand mixture with clay binder.
APPENDIX D - LABORATORY TEST RESULTS
CONSOLIDATION-SWELL TEST

Project: Water Tank
Job No.: 9838-CX
Client: Civil Engineering Professionals, Inc.
Test Date: 9/24/2001
Tested By: SFM/DJB
Sample No.: B-3-5 Depth: 15

Swell Pressure: +/- 1,600 psf Percent Swell: 0.8

Specimen Diameter: 2.418 in.
Specimen Height: 1 in.
Overburden Pres. (Po): 2 psf
Comp. Index (Cc): 0.030 (Cr): 0.017

Moisture Content: Initial 11.0 % Final 19.0 %
Void Ratio: 0.414 0.452
Saturation: 71.6 % 113.5 %
Dry Density (pcf): 119.2 116.1

Soil Description: Brown, Silty, Sandy Clay
PARTICLE SIZE ANALYSIS

PROJECT: Water Tank
JOB NO.: 9838-CX
CLIENT: Civil Engineering Professionals, Inc.
TEST DATE: 10/1/2001
TESTED BY: DJB
TEST METHOD: ASTM D422

U.S. STANDARD SIEVE OPENINGS

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

HYDROMETER

<table>
<thead>
<tr>
<th>GRAIN SIZE IN MILLIMETERS</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
</tr>
<tr>
<td>90</td>
</tr>
<tr>
<td>80</td>
</tr>
<tr>
<td>70</td>
</tr>
<tr>
<td>60</td>
</tr>
<tr>
<td>50</td>
</tr>
<tr>
<td>40</td>
</tr>
<tr>
<td>30</td>
</tr>
<tr>
<td>20</td>
</tr>
<tr>
<td>10</td>
</tr>
<tr>
<td>5</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>1</td>
</tr>
</tbody>
</table>

PERCENT FINER BY WEIGHT


SOIL DESCRIPTION: Brown, Clayey Sand with Gravel

SAMPLE NO.: 1
SAMPLED BY: JAY
SOURCE: Boring B-1
DEPTH: 0

LIQUID LIMIT:
PLASTIC LIMIT:
PLASTICITY INDEX:

PERCENT GRAVEL: 25.7
PERCENT SAND: 27.1
PERCENT SILT & CLAY: 47.2

INBERG-MILLER ENGINEERS
**PARTICLE SIZE ANALYSIS**

**PROJECT:** Water Tank  
**JOB NO.:** 9838-CX  
**CLIENT:** Civil Engineering Professionals, Inc.  
**TEST DATE:** 10/1/2001  
**TESTED BY:** DJB  
**TEST METHOD:** ASTM D422

### U.S. STANDARD SIEVE OPENINGS

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

### HYDROMETER

- **GRAIN SIZE IN MILLIukes (inches)**
- **PERCENT FINER BY WEIGHT**
- **COBBLES**
- **COARSE GRAVEL**
- **FINE GRAVEL**
- **COARSE SAND**
- **MEDIUM SAND**
- **FINE SAND**
- **SILT**
- **CLAY**

### Soil Description:
- **SOIL DESCRIPTION:** Brown, Silty Clay with Sand  
- **SAMPLE NO.:** 4  
- **SAMPLED BY:** JAY  
- **SOURCE:** Boring B-1  
- **DEPTH:** 7.5

### Laboratory Results:
- **LIQUID LIMIT:**  
- **PERCENT GRAVEL:** 0.0  
- **PLASTIC LIMIT:**  
- **PERCENT SAND:** 2.2  
- **PLASTICITY INDEX:**  
- **PERCENT SILT & CLAY:** 97.8

---

**INBERG-MILLER ENGINEERS**
**PARTICLE SIZE ANALYSIS**

PROJECT: Water Tank

JOB NO.: 9838-CX

CLIENT: Civil Engineering Professionals, Inc.

TEST DATE: 10/1/2001

TESTED BY: DJB

TEST METHOD: ASTM D422

---

**U.S. STANDARD SIEVE OPENINGS**

- (inches) 3 2 1 1/2 4 8 16 40

- (numbers) 100 200

**HYDROMETER**

---

**GRAIN SIZE IN MILLIMETERS**

- 100 10 1 0.1

**PERCENT FINER BY WEIGHT**

---

**COBLES** | **COARSE GRAVEL** | **FINE GRAVEL** | **COARSE SAND** | **MEDIUM SAND** | **FINE SAND** | **SILT** | **CLAY**
---|---|---|---|---|---|---|---

**SOIL DESCRIPTION:** Brown, Silty, Sandy Clay

**SAMPLE NO.:** 2

**SAMPLED BY:** JAY

**SOURCE:** Boring B-2

**DEPTH:** 2.5

**LIQUID LIMIT:**

**PERCENT GRAVEL:** 0.0

**PLASTIC LIMIT:**

**PERCENT SAND:** 30.1

**PLASTICITY INDEX:**

**PERCENT SILT & CLAY:** 69.9

---

INBERG-MILLER ENGINEERS
PARTICLE SIZE ANALYSIS

PROJECT: Water Tank
JOB NO.: 9838-CX
CLIENT: Civil Engineering Professionals, Inc.

TEST DATE: 10/1/2001
TESTED BY: DJB
TEST METHOD: ASTM D422

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

| 100 | 90 | 80 | 70 | 60 | 50 | 40 | 30 | 20 | 10 | 5 | 1 | 1/2 |

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 with Sand
SAMPLE NO.: 6
SAMPLED BY: JAY
SOURCE: Boring B-2
DEPTH: 15

LIQUID LIMIT:
PLASTIC LIMIT:
PLASTICITY INDEX:

PERCENT GRAVEL: 0.0
PERCENT SAND: 3.6
PERCENT SILT & CLAY: 96.4
PARTICLE SIZE ANALYSIS

PROJECT: Water Tank
JOB NO.: 9838-CX
CLIENT: Civil Engineering Professionals, Inc.

TEST DATE: 10/1/2001
TESTED BY: DJB
TEST METHOD: ASTM D422

U.S. STANDARD SIEVE OPENINGS
(numbers)

HYDROMETER

GRAIN SIZE IN MILLIMETERS

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

SOIL DESCRIPTION: Brown, Silty, Sandy Clay
SAMPLE NO.: 2
SAMPLED BY: JAY
SOURCE: Boring B-3
DEPTH: 5

LIQUID LIMIT:        PERCENT GRAVEL:  0.8
PLASTIC LIMIT:       PERCENT SAND:  25.7
PLASTICITY INDEX:    PERCENT SILT & CLAY: 73.5

INBERG-MILLER ENGINEERS
APPENDIX E - ADDITIONAL INFORMATION
GRADATION ENVELOPE A

PROJECT: Water Tank
JOB NO.: 9838-CX
CLIENT: Civil Engineering Professionals, Inc.

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

1 1/2 4 8 16 40 100 200

I I I I I I I I I I

3 2

100
90
80
70
60
50
40
30
20
10
0

GRAIN SIZE IN MILLIMETERS

HYDROMETER

PERCENT FINER BY WEIGHT

0 10 20 30 40 50 60 70 80 90 100

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

Material Description (Envelope A): GRANULAR FILL

Recommended Gradation:

<table>
<thead>
<tr>
<th>Sieve Designation</th>
<th>Specified Percent Finer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 1/2&quot;</td>
<td>100</td>
</tr>
<tr>
<td># 4</td>
<td>50 - 100</td>
</tr>
<tr>
<td># 10</td>
<td>30 - 90</td>
</tr>
<tr>
<td># 30</td>
<td>15 - 75</td>
</tr>
<tr>
<td># 40</td>
<td>10 - 70</td>
</tr>
<tr>
<td># 200</td>
<td>0 - 20</td>
</tr>
</tbody>
</table>
Geotechnical Services Are Performed for Specific Purposes, Persons, and Projects

Geotechnical engineers structure their services to meet the specific needs of their clients. A geotechnical engineering study conducted for a civil engineer may not fulfill the needs of a construction contractor or even another civil engineer. Because each geotechnical engineering study is unique, each geotechnical engineering report is unique, prepared solely for the client. No one except you should rely on your geotechnical engineering report without first conferring with the geotechnical engineer who prepared it. And no one—not even you—should apply the report for any purpose or project except the one originally contemplated.

Read the full report

Serious problems have occurred because those relying on a geotechnical engineering report did not read it all. Do not rely on an executive summary. Do not read selected elements only.

A Geotechnical Engineering Report Is Based on A Unique Set of Project-Specific Factors

Geotechnical engineers consider a number of unique, project-specific factors when establishing the scope of a study. Typical factors include: the client’s goals, objectives, and risk management preferences; the general nature of the structure involved, its size, and configuration; the location of the structure on the site; and other planned or existing site improvements, such as access roads, parking lots, and underground utilities. Unless the geotechnical engineer who conducted the study specifically indicates otherwise, do not rely on a geotechnical engineering report that was:

- not prepared for you,
- not prepared for your project,
- not prepared for the specific site explored, or
- completed before important project changes were made.

Typical changes that can erode the reliability of an existing geotechnical engineering report include those that affect:

- the function of the proposed structure, as when it’s changed from a parking garage to an office building, or from a light industrial plant to a refrigerated warehouse,
- elevation, configuration, location, orientation, or weight of the proposed structure,
- composition of the design team, or
- project ownership.

As a general rule, always inform your geotechnical engineer of project changes—even minor ones—and request an assessment of their impact. Geotechnical engineers cannot accept responsibility or liability for problems that occur because their reports do not consider developments of which they were not informed.

Subsurface Conditions Can Change

A geotechnical engineering report is based on conditions that existed at the time the study was performed. Do not rely on a geotechnical engineering report whose adequacy may have been affected by: the passage of time; by man-made events, such as construction on or adjacent to the site; or by natural events, such as floods, earthquakes, or groundwater fluctuations. Always contact the geotechnical engineer before applying the report to determine if it is still reliable. A minor amount of additional testing or analysis could prevent major problems.

Most Geotechnical Findings Are Professional Opinions

Site exploration identifies subsurface conditions only at those points where subsurface tests are conducted or samples are taken. Geotechnical engineers review field and laboratory data and then apply their professional judgment to render an opinion about subsurface conditions throughout the site. Actual subsurface conditions may differ—sometimes significantly—from those indicated in your report. Retaining the geotechnical engineer who developed your report to provide construction observation is the most effective method of managing the risks associated with unanticipated conditions.