FEASIBILITY STUDY
ON
SUPPLEMENTARY
GROUND WATER SUPPLY
FOR
TOWN OF GREYBULL, WYOMING
June, 1982
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FOR
TOWN OF GREYBULL, WYOMING

June, 1982
Honorable Mayor and Town Council
Town of Greybull
24 South 5th St.
Greybull, Wyoming 82426

Gentlemen:

The following is our Feasibility Study on upgrading your municipal water supply system.

Augmentation of Greybull's present water supply system should be given serious consideration. This study shows that Greybull's water rights on Shell Creek and from Shell Reservoir will likely be inadequate by the year 1986 if the Town's population grows at a modest 2½% annually.

The Town's existing 14" diameter asbestos cement water transmission pipeline should deliver sufficient water to Town to handle projected population increases for the next 30 years. What is needed is an expanded supply source with dependable water rights.

The project geologist and engineer both feel that such a source can be found in the Madison limestone aquifer in the areas recommended within this report. Water quality should be excellent, flow volumes should be more than adequate and artesian pressures should be sufficient to deliver water into town without pumping.

Since it is hoped that construction of the proposed well improvements can be completed this year, time is of the essence. You will therefore want to review the CONCLUSIONS AND RECOMMENDATIONS section of this report in order to secure project funding and reviewing agency approval.

We look forward to moving ahead with you on this project in order to bring it to a rapid completion.

Respectfully yours,

JOHN W. DONNELL & ASSOCIATES, INC.

LaVerne M. Nelson, P.E.
Project Engineer
Registration No. 1106
# TABLE OF CONTENTS

I. INTRODUCTION ................................................................. 1 - 2

II. AREA TO BE SERVED AND POPULATION ..................................... 3 - 4

III. EXISTING FACILITIES ........................................................ 5 - 9
1. General ................................................................. 5 - 6
2. Water Usage ............................................................ 7 - 8
3. Water Supply ............................................................. 8
4. Water Rights .............................................................. 8 - 9
5. Water Quality ............................................................. 9 - 11

IV. ESTABLISHMENT OF WATER REQUIREMENTS .............................. 12 - 21
1. General ................................................................. 12 - 13
2. Historical and Projected Service Population ......................... 13 - 14
3. Projected Water Demands of Town of Greybull ....................... 14 - 18
4. Projected Demands of Shell Valley Watershed Improvement District . 18 - 20
5. Combined Projected Demands of Town of Greybull and Shell Valley Improvement District . 20 - 21

V. ALTERNATIVE SOURCES FOR MUNICIPAL WATER ........................ 22 - 24
1. General ................................................................. 22
2. Shell Creek ............................................................. 22 - 23
3. Big Horn River .......................................................... 23
4. Ground Water ............................................................ 23 - 24

VI. AQUIFER EVALUATION AND PRELIMINARY WELL LOCATION .......... 25 - 32
1. General ................................................................. 25
2. Evaluation of Aquifers .................................................. 25 - 28
3. Selection of Well Size ................................................. 28 - 29
4. Selection of Well Location ............................................ 29 - 32

VII. WELL DESIGN AND COST ESTIMATES ..................................... 33 - 35
1. Well Design ............................................................. 33
2. Construction Costs for Wells of Various Sizes ...................... 33
3. Test Well ............................................................... 33 - 35

VIII. REVIEWING AUTHORITIES .................................................. 36 -
1. Wyoming Water Development Commission (WWDC) .................. 36
2. Wyoming Department of Environmental Quality (DEQ) ............ 36 - 37
3. Wyoming State Engineer ............................................... 37

IX. AVAILABLE FINANCING ..................................................... 38 - 39
1. General ................................................................. 38
2. Wyoming Farm Loan Board (FLB) .................................... 38
3. U.S. Farmers Home Administration (FmHA) ......................... 38 - 39

X. ENVIRONMENTAL IMPACT STATEMENT .................................... 40

IX. CONCLUSIONS AND RECOMMENDATIONS ................................ 41
LIST OF TABLES

Table 1 - Classes of Municipal Water Users ........ 7
Table 2 - Historical Water Usage .................. 8
Table 3 - Present Water Quality .................... 10
Table 4 - Radionuclide Concentrations ............... 10
Table 5 - Historical Population Densities and Growth Rates .......... 13
Table 6 - Projected Service Population ............... 14
Table 7 - Projected Annual Water Usage, Town of Greybull .......... 15
Table 8 - Projected Summer Water Usage, Town of Greybull .......... 16
Table 9 - Projected Reservoir Withdrawal Rates, SVWID .......... 19
Table 10 - Required Reservoir Supply Rates, SVWID ......... 20
Table 11 - Well Casing Head Loss Calculations .......... 27
Table 12 - Well Depth to Top of Madison ............... 30
Table 13 - Estimated Formation Thicknesses ........... 31
Table 14 - Estimated Size and Cost of Conveyance Pipelines .......... 32
Table 15 - Estimated Well Construction Costs .......... 34

LIST OF EXHIBITS

EXHIBIT "A" - Request of Shell Valley Watershed Improvement District .......... 42
EXHIBIT "B" - Present Municipal Water Supply Facilities .......... 43
EXHIBIT "C" - Potential Ground Water Development Sites .......... 44
EXHIBIT "D" - Proposed Well Construction Detail .......... 45
EXHIBIT "E" - Source Development Standards .......... 46 - 61
APPENDICES


APPENDIX "B" - Letter of March 31, 1982 from L.E. Harris to Town of Greybull
INTRODUCTION

Municipal water for the Town of Greybull has been diverted from Shell Creek above the Town of Shell for many years. However, in recent years Town officials have become increasingly concerned with the quantity of water available from Shell Creek.

The problem is one of water rights. The town has an adjudicated water right (Permit No. 430) from Shell Creek for 595 gallons per minute (gpm) with a priority date of March 7, 1893. Additionally, the Town owns 375 acre-feet of storage capacity in Shell Reservoir (Permit No. 2200R), with a priority date of October 10, 1911. However, transportation losses from Shell Reservoir downstream some 15 miles to the point of diversion leave only 206 acre-feet of reservoir water available for the Town's use.

During dry winters and warm dry summers, there are great demands placed upon waters from Shell Creek, both by the Town of Greybull and by farmers and ranchers throughout the Shell Valley. Estimates show that the Town's demands will exceed its Shell Creek and Shell Reservoir water rights by the year 1986. For this reason, either a new source of supply will be needed or additional older rights having an acceptably early priority will have to be acquired, if the Town of Greybull is to have sufficient water for the development and expansion of its municipal system that will be necessitated due to anticipated population increases.

In 1972 an engineering study was made for Greybull on its then deficient water transmission pipeline. The 12 inch steel pipeline from Shell Creek to Greybull was then leaking badly and
delivering less than 1,000 gallons per minute. The report recom­
manded that a new 14 inch diameter asbestos cement pipeline be installed to replace the deteriorated steel pipe. That was
done in 1973 and 1974, and the new system proved capable of de-
delivering over 2,000 gpm, or 2.9 million gallons per day (mgd),
to Greybull's water users. Flows of this magnitude will handle
the Town's projected water needs at least until the year 2010.

This report will provide information on the feasibility of
developing an additional source of ground water from the Madison
formation that can serve the present 14 inch diameter transmission
pipeline with minimal cost. Further, the desire of the Shell Valley
Watershed Improvement District (SVWID) to develop some 1,187 acre-
feet of storage for irrigation purposes is addressed, along with
the possibility of the Town of Greybull and SVWID joining together
in a joint venture arrangement to satisfy their future water needs.
II

AREA TO BE SERVED AND POPULATION

Greybull's municipal water supply serves all 2277 people (1980 census) within the Town's corporate limits, plus an estimated 350 people throughout the Shell Valley and within the Town of Shell.

Additionally, another 94 users (residences) throughout the Shell Valley area have requested service from Greybull's transmission facilities. Greybull has refused service to these out-of-town families at the present time due to the Town's concern about an inadequate source of supply for the needs of future demands within the Town's corporate limits. However, if Town officials were convinced that Greybull had an adequate source of water for supplying both the in-town and out-of-town users with future needs, there would be less of a problem with providing the out-of-town users with service at the present time.

Finally, as mentioned in the INTRODUCTION, irrigators comprising the Shell Valley Watershed Improvement District (SVWID) are hopeful that, through some kind of joint venture arrangement with the Town of Greybull, they can obtain water for some 1,187 acre-feet of storage reservoirs (See Exhibit "A"). A 460 acre-foot reservoir is proposed for Collingwood Draw in the SW\(\text{SE}_{1}\) of Section 6, T. 52 N., R. 91 W.; and a 727 acre-foot reservoir is proposed at Fox Mountain in the SE\(\text{SE}_{1}\) of Section 2, T. 52 N., R. 92 W.

The SVWID hopes to utilize some 2,374 acre-feet of storage per year by filling and draining the two aforementioned reservoirs twice annually.
Exhibit "B", enclosed in the back of this report, shows the location and type of system components presently comprising the water supply, transmission and storage facilities owned by the Town of Greybull; whereas, Exhibit "C" delineates the likely ground water development sites.
III
EXISTING FACILITIES

1. General.

In order to properly evaluate the capability of a water system to meet present and potential water demands, it is necessary to analyze the record of past usage. In addition, such an analysis will serve as the basis for development of the design parameters required to properly estimate future water requirements and size proposed system improvements.

Water requirements for water systems are usually defined in terms of total annual, average day, maximum day, and maximum hour use rates. The total annual water use is significant because it identifies the quantity of raw water that must be supplied annually. The average day rate is the numerical value of total water use in a calendar year divided by the number of days in that year. This average day use rate is significant only because it is used as a plane of reference to express other relationships. When divided by population it is expressed in gallons per capita per day (gpcd) and when divided by the number of active water users it establishes the average number of gallons per user per day. These figures are used in conjunction with projected population levels to determine future water demands.

Since water shortages are normally greatest during the high usage summer months, water demands are critical during this time period. Accordingly, average day use rates for both the municipal needs of Greybull and the irrigation needs of the SVWID will be defined throughout the year and the critical summer months in order to arrive at total system supply requirements.
Maximum daily use is an actual use rate and is the maximum total amount of water used in any 24 hour day throughout the year.

The maximum day rate is used to determine the required capacity of raw water supply, transmission and treatment facilities. Good waterworks practice generally dictates that these facilities have reserve capacity in order to adequately provide for growth in water demands over a reasonable period of time in the future.

Municipal water systems commonly refer to water usage rates in terms of gallons per minute (gpm) or millions of gallons per day (mgd), and storage in terms of millions of gallons; whereas, irrigators refer to water usage rates in terms of cubic feet per second (cfs) or second feet, and storage is referred to in terms of acre-feet. For purposes of comparison, 449 gpm = 1 cfs and a flow rate of 226 gpm flowing for 24 hours will develop one acre-foot of storage (i.e. 325,829 gallons). Likewise, a storage reservoir containing 1,000,000 gallons of water contains 3.07 acre-feet.

It is also good waterworks practice, particularly for growing communities, to design system capacities to meet water demands which may be expected to occur during the warm summer months and dry weather conditions. Future water demands cannot be predicted precisely, but experience has shown that historical projection of water use trends, coupled with comparisons with water use in similar water systems, is a reasonably effective method of establishing waterworks facility design parameters.

Records of water used by the Town of Greybull have been kept for the years of 1975 thru 1978. Those records have been analyzed and the results are shown in the following subsection of this report.
2. **Water Usage.**

Annual water usage in Greybull's municipal water system has fluctuated with variation in climatic conditions and with changes in the number and type of active water users. Warm, dry summers result in higher water usage, whereas cooler summers with considerable precipitation result in relatively low domestic water use. Commercial and industrial users normally use far more water than domestic users.

The following table shows the breakdown, according to percentage, of the different types of users served by Greybull's municipal system:

<table>
<thead>
<tr>
<th>Class of Use</th>
<th>Percentage of Total Water Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industrial</td>
<td>1%</td>
</tr>
<tr>
<td>Public (Town)</td>
<td>5%</td>
</tr>
<tr>
<td>Commercial</td>
<td>10%*</td>
</tr>
<tr>
<td>Domestic</td>
<td>84%</td>
</tr>
</tbody>
</table>

*Includes school usage

The following figures represent actual water usage by the aforementioned water users during the years of 1975 through 1978, the latest dates of record:
TABLE 2
Historical Water Usage

<table>
<thead>
<tr>
<th>Year</th>
<th>Estimated Service Population</th>
<th>Total Annual Water Usage (Millions of Gallons)</th>
<th>Average Daily Usage Per Capita (gpcd)</th>
<th>Average July-Sept. Day Rate (mgd)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1975</td>
<td>2527</td>
<td>358.8</td>
<td>389</td>
<td>1.258</td>
</tr>
<tr>
<td>1976</td>
<td>2547</td>
<td>368.1</td>
<td>396</td>
<td>1.310</td>
</tr>
<tr>
<td>1977</td>
<td>2567</td>
<td>387.4</td>
<td>420</td>
<td>1.406</td>
</tr>
<tr>
<td>1978</td>
<td>2587</td>
<td>408.6</td>
<td>433</td>
<td>1.415</td>
</tr>
</tbody>
</table>


Greybull's sole source of potable water is Shell Creek approximately 3 miles above (east of) the Town of Shell. An infiltration gallery diverts water from the alluvial gravels below the stream and conveys it to Greybull via a 17 mile long 12"-14" diameter asbestos cement water transmission pipeline. A chlorinator is located near the diversion point and a single 1 million gallon storage tank is located at the lower end of the transmission pipeline on the east side of Greybull's city limits.

The location of the existing supply, treatment, transmission and storage facilities are shown on EXHIBIT "B".


The Town of Greybull is the owner of the following water permits issued to them by the State of Wyoming:

A. Permit No. 430 for the Greybull Pipeline from Shell Creek for municipal use in the amount of 1.326 cfs (595 gpm) with a priority date of March 7, 1893. This permit is adjudicated.

B. Permit No. 19279 for the Greybull Pipeline from Shell Creek for municipal use in the amount of 17.85 cfs (8,012 gpm) with a priority date of September 2, 1938. This permit is not adjudicated.
C. Additionally, the Town owns 375 acre-feet of storage capacity in the Shell Reservoir, Permit No. 2200R, which has a total storage capacity of 1949 acre-feet. Priority date for this permit is October 20, 1911. The reservoir is owned and operated by the Shell Creek Reservoir Company. Other space in the reservoir is owned by individual farmers in the Shell Creek Valley. Water is diverted from Shell Creek to storage in the reservoir when there is surplus water in the stream and released from the reservoir to the stream when runoff is deficient. The cycle is usually completed once each year.

5. Water Quality.

Water from Greybull's municipal system has been tested for contaminating constituents on a regular basis. Bacteriological tests have been taken monthly and have been negative. Chlorination near the source of supply on Shell Creek has undoubtedly been of value in providing a sanitary supply at all times.

Additionally, the State Chemist for the Wyoming Department of Agriculture tested water from Greybull's municipal system during March of 1978 and October of 1980. Those tests for inorganic chemicals, metals, nitrates and fluoride, found the following concentrations present, as shown on laboratory report numbers 1-1703 and 8-2890.
### TABLE 3
Present Water Quality

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Concentration Found (Mg/l)</th>
<th>EPA Maximum Contaminant Levels (Mg/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flouride</td>
<td>0.2</td>
<td>2.4</td>
</tr>
<tr>
<td>Nitrate (as N)</td>
<td>0.1 to 0.21</td>
<td>10.4</td>
</tr>
<tr>
<td>Arsenic</td>
<td>Less than 0.01</td>
<td>0.05</td>
</tr>
<tr>
<td>Salenium</td>
<td>Less than 0.005</td>
<td>0.01</td>
</tr>
<tr>
<td>Mercury</td>
<td>Less than 0.001</td>
<td>0.002</td>
</tr>
<tr>
<td>Cadmium</td>
<td>Less than 0.005</td>
<td>0.01</td>
</tr>
<tr>
<td>Chromium</td>
<td>Less than 0.01</td>
<td>0.05</td>
</tr>
<tr>
<td>Lead</td>
<td>Less than 0.02</td>
<td>0.05</td>
</tr>
<tr>
<td>Silver</td>
<td>Less than 0.05</td>
<td>0.05</td>
</tr>
<tr>
<td>Barium</td>
<td>Less than 0.1</td>
<td>1.0</td>
</tr>
</tbody>
</table>

The foregoing water quality constituents satisfy all EPA requirements for a potable water supply system.

Additionally, radionuclide tests were conducted on Greybull's present water supply by CDM laboratories in Wheat Ridge, Colorado. Those tests (Report No. 703-9582-1), made on samples collected on February 13, 1980, found the following radionuclide concentrations:

### TABLE 4
Radionuclide Concentrations

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Concentration Found (Picocuries Per Liter)</th>
<th>EPA Maximum Contaminent Level (PCi/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gross Alpha</td>
<td>8.0±3.6</td>
<td>15</td>
</tr>
<tr>
<td>Radium - 226</td>
<td>0.0±0.3</td>
<td>5</td>
</tr>
</tbody>
</table>
From the foregoing table, it can be seen that radionuclide concentrations from Greybull's present municipal distribution system, having its source in Shell Creek, meet all present EPA requirements for potable water.
IV

ESTABLISHMENT OF WATER REQUIREMENTS

1. General.

If the Town of Greybull is to continue to grow and encourage businesses and industries to locate within its corporate limits, it will need an assured source of quality water for its municipal system. That water source should be adequate to handle the community's needs for no less than 30 years, and more desirably for the next 50 years.

Greybull is already wisely planning for such development. A 200 acre tract of land on the southwest edge of town is now in the process of being cleared for development. The tract, owned by the Town, has been served with a 12" water main for residential-commercial-industrial usage, and funds have been allocated for clearing the area of abandoned refinery site structures preparatory to development. Considerable planning has already gone into the water system, street system, sewer system, zoning and lot layout for the contemplated improvements. When completed, the 200 acre tract will provide the homes and jobs for an additional 1,500-2,000 residents.

As mentioned previously, the Shell Valley Watershed Improvement District is also in need of additional water for irrigation purposes. The quantity of water desired by the SVWID is addressed herein.

Additionally, there are some 94 requests for water service by property owners throughout the Shell Valley. Town officials
have, up to the present time, declined service to these households due, primarily, to the present uncertainty of being able to handle future municipal water demands within the Town's corporate limits.

2. **Historical and Projected Service Population.**

The 1980 census established that Greybull had a population of 2277 people within its corporate limits. Additionally, there are some 100 water services outside of the Town's corporate limits, in the Town of Shell and throughout the Shell Valley, that add an additional 350 people to the service population of Greybull's water system.

The following table shows the historical population trends of the Town of Greybull:

<table>
<thead>
<tr>
<th>Year</th>
<th>Census Population</th>
<th>Annual Compound Growth Rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1910</td>
<td>258</td>
<td>---</td>
</tr>
<tr>
<td>1920</td>
<td>2692</td>
<td>26.43</td>
</tr>
<tr>
<td>1930</td>
<td>1806</td>
<td>(3.91)</td>
</tr>
<tr>
<td>1940</td>
<td>1828</td>
<td>0.12</td>
</tr>
<tr>
<td>1950</td>
<td>2262</td>
<td>2.15</td>
</tr>
<tr>
<td>1960</td>
<td>2286</td>
<td>0.11</td>
</tr>
<tr>
<td>1970</td>
<td>1953</td>
<td>(1.56)</td>
</tr>
<tr>
<td>1980</td>
<td>2277</td>
<td>1.55</td>
</tr>
</tbody>
</table>

From the foregoing figures it can be seen that past population trends in Greybull have been quite erratic. The average annual compound growth rate in the 70 year period between 1910 and
1980 has been 3.32 percent. The growth rate in the 70's has been a positive 1.55 percent. This pattern of a healthy positive growth is expected to continue in future years.

According to the Bureau of Economic Analysis (BEA), the State of Wyoming will increase in population at an annual rate of 2.8% until 1990, at which time the population increase will be 1.2%. Of course, population increases in Wyoming during the past 2 years have been approximately three times this predicted increase, due primarily to energy development. Greybull's growth will undoubtedly be affected by this energy development in future years, due primarily to the oil field development and abundant bentonite reserves in the area. Considering these factors, a modest 2.5% annual compound growth rate is predicted for the service population of Greybull's municipal water system in future years.

### TABLE 6

<table>
<thead>
<tr>
<th>Year</th>
<th>Annual Compound Growth Rate (%)</th>
<th>Projected Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>1980</td>
<td>1.55</td>
<td>2627*</td>
</tr>
<tr>
<td>1990</td>
<td>2.50</td>
<td>3265</td>
</tr>
<tr>
<td>2000</td>
<td>2.50</td>
<td>4080</td>
</tr>
<tr>
<td>2010</td>
<td>2.50</td>
<td>5125</td>
</tr>
<tr>
<td>2020</td>
<td>2.50</td>
<td>6460</td>
</tr>
<tr>
<td>2030</td>
<td>2.50</td>
<td>8175</td>
</tr>
</tbody>
</table>

*Includes 350 people served by the Water System outside of the Town's corporate limits.

3. **Projected Water Demands of Town of Greybull.**

Greybull's municipal water system now provides an average of
1,300,000 gallons of water per day to its users during the three summer months of July, August and September when demands are the greatest and stored water from Shell Reservoir must be utilized. As shown in TABLE 2, average summer day demands have exceeded 1,400,000 gallons. Further, average annual usage per capita has approximated 410 gallons per day.

Assuming that water usage during the years of 1975 through 1978 is representative of usage trends that can be expected in the future, the following projections for annual usage can be made:

<table>
<thead>
<tr>
<th>Year</th>
<th>Estimated Service Population</th>
<th>Average Daily Usage Per Capita (gpcd)</th>
<th>Total Annual Usage (MG) (Acre-Ft.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1980</td>
<td>2627</td>
<td>400</td>
<td>383.5 1177.1</td>
</tr>
<tr>
<td>1990</td>
<td>3265</td>
<td>390</td>
<td>464.8 1426.3</td>
</tr>
<tr>
<td>2000</td>
<td>4080</td>
<td>380</td>
<td>565.9 1736.7</td>
</tr>
<tr>
<td>2010</td>
<td>5125</td>
<td>370</td>
<td>692.1 2124.1</td>
</tr>
<tr>
<td>2020</td>
<td>6460</td>
<td>360</td>
<td>848.8 2605.0</td>
</tr>
<tr>
<td>2030</td>
<td>8175</td>
<td>350</td>
<td>1044.4 3205.0</td>
</tr>
</tbody>
</table>

The foregoing projected water use rates are based upon the premise that all water users are served through individual self-recording meters.

Average day water use per capita, as shown on TABLE 7, has been trended downward from 400 gallons per capita per day (gpcd) in the year 1980 to 350 gpcd in the year 2030. This is a reasonable assumption for the following reasons: (1) As the
number of users increases, the average water use per user will
decrease, and (2) as water rates increase in future years, users
will become more aware of the need to conserve on water resources.

In order to determine the approximate time when Greybull's
present water rights are no longer adequate to supply the Town's
future needs, the expected water demands during the summer months
need to be analyzed. Accordingly, the following table has been
prepared.

<table>
<thead>
<tr>
<th>Year</th>
<th>Estimated Service Population</th>
<th>Maximum Day Rate</th>
<th>Average Summer Rate</th>
<th>Total Average July-September Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>(MGD)</td>
<td>(GPD)</td>
<td>(MGD) (Ac-Ft.)</td>
</tr>
<tr>
<td>1980</td>
<td>2627</td>
<td>1.50</td>
<td>570</td>
<td>1.40 126.0 386.7</td>
</tr>
<tr>
<td>1990</td>
<td>3265</td>
<td>1.86</td>
<td>570</td>
<td>1.74 156.6 480.7</td>
</tr>
<tr>
<td>2000</td>
<td>4080</td>
<td>2.33</td>
<td>570</td>
<td>2.17 195.3 599.4</td>
</tr>
<tr>
<td>2010</td>
<td>5125</td>
<td>2.92</td>
<td>570</td>
<td>2.73 245.7 754.0</td>
</tr>
<tr>
<td>2020</td>
<td>6460</td>
<td>3.68</td>
<td>570</td>
<td>3.44 309.6 950.3</td>
</tr>
<tr>
<td>2030</td>
<td>8175</td>
<td>4.66</td>
<td>570</td>
<td>4.35 391.5 1201.7</td>
</tr>
</tbody>
</table>

By comparing the foregoing projected water usage figures with
Greybull's water rights, it can be seen that Greybull will soon
have a problem obtaining the necessary quantity of water for their
municipal system unless they develop a supplementary source of
supply.

During dry winters followed by warm-dry summers, Greybull's
unadjudicated 1938 water right from Shell Creek has no value. Then
the Town must rely entirely upon Permit No. 430 for 595 gpm from
Shell Creek, and the 375 acre-feet (i.e. 122,200,000 gals) of storage water rights in Shell Reservoir. Unfortunately, there is a transportation loss in the 15± miles from Shell Reservoir to the diversion point of approximately 45%, due to infiltration, evaporation and other losses. Thus, only some 206 acre-feet (i.e. 67.12 MG) is available to the Town for use.

Since the adjudicated 1893 right only permits the diversion of 595 gpm (i.e. 857,000 gpd), and since summer day usage presently averages 972 gpm (i.e. 1,400,000 gpd), the Town presently draws on its storage water rights from Shell Reservoir at the rate of 543,000 gpd (i.e. 1.67± acre-feet per day) during summer months. In a 90 day period, between July and September, it will presently normally use 150 acre-feet of reservoir water, close to the 206 acre-feet available. Should warm-dry weather begin in May or early June, requiring lawn watering at an early date, the entire 206 acre-feet of reservoir water could be used up before the end of summer, leaving the town with an inadequate supply of water to satisfy its users needs. This becomes especially critical during years of below normal snowfall and runoff when agricultural water is in great demand.

Similarly, since the adjudicated 1893 water right from Shell Creek (Permit No. 430) only permits the diversion of 237 acre-feet during the critical 90 day summer period when agricultural diversions are at their peak, and only 206 acre-feet are available from Shell Reservoir, it can be shown from TABLE 8 that the Town of Greybull will be short of water by 1986 during an average summer use period with a projected population growth rate of 2½ percent per year.
A supplementary source of supply should be capable of providing Greybull with its water needs at least until the year 2010, when average summer usage will be 754 acre-feet (i.e. 245.7 MG). Since present water rights allow for withdrawals from Shell Creek of but 443 acre-feet during this 90 day time period, a supplementary source would be needed for the balance, or 311 acre-feet. This would require a supply capable of delivering a flow rate of 782 gallons per minute throughout the entire 3 month summer period. An extremely warm and dry summer could require 1000 gpm.

If Greybull were to depend entirely on the supplementary water source to satisfy all of its municipal needs by the year 2010, a maximum day usage of 2.92 million gallons would be required according to TABLE 8. This would require a supply capable of delivering 2030 gpm. Greybull's present transmission facilities should have no problem delivering this flow rate into town without pumping if a pipeline pressure gradient elevation of 4330 or higher is provided near the supply source. With higher pressure gradients, resulting from artesian pressures or pumps, Greybull's present 14" diameter transmission pipeline can deliver even larger flows, and provide for the Town's water needs beyond the year 2010.

4. Projected Water Demands of Shell Valley Watershed Improvement District (SVWID).

The SVWID has plans for two large reservoirs to serve their needs in future years. As stated in their letter of May 18, 1982 (See EXHIBIT "A"), "the optimum needs of the District in connection with an artesian well would be to fill the following proposed reservoirs twice each year:"
Proposed Collingwood Draw ............ 460 Acre-feet
Proposed Fox Mountain Reservoir ........ 727 Acre-feet
TOTAL PROPOSED ANNUAL STORAGE ........ 2,374 Acre-feet

"The District's Directors are hopeful that the above named reservoirs could be filled during the winter months, then emptied during the early irrigation season, prior to runoff, when irrigation needs are great and Shell Creek is low. They could then be refilled during the high water runoff when the creek supplies sufficient water for both domestic and irrigation requirements."

The proposed Collingwood Draw reservoir is located in the SW\4SE\ of Section 6, Township 52 North, Range 91 West, and has a dam altitude of 4,280 feet (See EXHIBIT "C").

The proposed Fox Mountain reservoir is located in the SE\4SE\ of Section 2, Township 52 North, Range 92 West, and has a dam altitude of 4,245 feet (See EXHIBIT "C").

Using the foregoing "optimum needs" of the SVWID, the following tabulation has been prepared showing the average withdrawal rates from the proposed reservoirs:

<table>
<thead>
<tr>
<th>Normal Dates</th>
<th>Number of Days</th>
<th>Average Flow Rate (GPM)</th>
<th>Average Flow Rate (CFS)</th>
<th>Total Withdrawal (MG)</th>
<th>Total Withdrawal (Acre-Ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>April 10-May 15</td>
<td>35</td>
<td>7675</td>
<td>17.1</td>
<td>386.8</td>
<td>1187</td>
</tr>
<tr>
<td>July 15-Sept. 15</td>
<td>60</td>
<td>4477</td>
<td>10.0</td>
<td>386.8</td>
<td>1187</td>
</tr>
</tbody>
</table>

Assuming that the reservoirs can be filling during the times in which irrigation waters are being withdrawn (i.e. different supply and withdrawal systems), and assuming a 10% loss of supply...
water due to evaporation and infiltration, the following table shows the required water supply rates:

**TABLE 10**  
Required Reservoir Supply Rates  
SVWID

<table>
<thead>
<tr>
<th>Dates</th>
<th>Item</th>
<th>Number of Days</th>
<th>Required Filling Flow Rate (GPM)</th>
<th>Total Flow (MG)(Acre-Ft.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>July 15-Sept. 15</td>
<td>Empty Reservoirs</td>
<td>60 )</td>
<td>1094 2.44</td>
<td>425.5 1306</td>
</tr>
<tr>
<td>Sept. 15-April 10</td>
<td>Fill Reservoirs</td>
<td>210 )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>April 10-May 15</td>
<td>Empty Reservoirs</td>
<td>35 )</td>
<td>3110 6.93</td>
<td>425.5 1306</td>
</tr>
<tr>
<td>May 15-July 15</td>
<td>Fill Reservoirs</td>
<td>60 )</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

From the foregoing table it can be seen that an average supply flow rate of 1094 gallons per minute will be required on a continuous basis during the 270 day period beginning with July 15 of each year in order to have the reservoirs full by April 10 of the following year. Likewise, an average supply flow rate of 3110 gallons per minute will be required on a continuous basis during the 95 day period beginning with April 10 of each year if the reservoirs are to be full by the following July 15. The latter is the critical supply rate since it is of the highest magnitude.

5. **Combined Projected Demands of Town of Greybull and Shell Valley Water Improvement District.**

There are four possible alternatives for use of the proposed new water source, each of which has different flow requirements to satisfy water needs to the year 2010:

A. It can be used strictly as a supplementary source to Greybull's present water supply from Shell Creek, in which case flows of 1,000 gpm will be required.
B. It can be used strictly by the Town of Greybull as Greybull's sole source of supply, in which case flows of 2,030 gpm will be required.

C. It can be used strictly by the SVWID to satisfy its optimum needs for 2,374 acre-feet of reservoir water per year, in which case flows of 3,110 gpm will be required.

D. It can be used jointly by Greybull and the SVWID, to satisfy Greybull's supplementary needs of 1,000 gpm and SVWID's total needs of 3,110 gpm, in which case flows of 4,110 gpm will be required.

E. It can be used jointly by Greybull and the SVWID, to satisfy Greybull's total water needs of 2,030 gpm and SVWID's total needs of 3,110 gpm, in which case flows of 5,140 gpm will be required.

Alternative C could provide Greybull with its supplementary water needs through the purchase of additional water rights of an early priority on Shell Creek, or such rights could be "exchanged" for any new ground water rights that Greybull may develop or assist in developing.
V

ALTERNATIVE SOURCES FOR MUNICIPAL WATER

1. General.

There are but three known potential sources of water for a satisfactory expansion of Greybull's present municipal water supply system. They are (1) Shell Creek, (2) Big Horn River, and (3) ground water.

2. Shell Creek.

Shell Creek waters are already heavily appropriated. The 1978 Tabulation of Adjudicated Water Rights for Water Division Number Three, compiled by the State Board of Control, identifies adjudicated rights on Shell Creek totaling more than 162 cubic feet per second (cfs). However, adjudicated rights for priorities earlier than Greybull's Permit No. 430, which has a priority of March 7, 1893, total less than 40 cfs. The earliest adjudicated right on Shell Creek has a priority of January 10, 1887, and the latest has a priority of December 24, 1970.

The U.S. Geological Survey's records of water flows for Shell Creek near the Town of Shell show that spring runoff normally occurs in June and, sometimes, early in July. However, flows in Shell Creek normally drop to 160 cfs early in July, and August flows average approximately 100 cfs. Thus, Greybull's municipal priority of March 7, 1893 should be secure, but a priority filed at this late date would be of little value.

Further, additional storage rights from Shell Reservoir would be much too expensive to develop at the present time, and it would likewise be much too expensive to purchase rights having an early priority on Shell Creek or within Shell Reservoir.
Because of the aforementioned reasons, it appears unlikely that additional water can be obtained from Shell Creek, unless the Town could develop a new ground water supply that could be exchanged for Shell Creek waters having an early priority.

3. Big Horn River.

Big Horn River waters are already heavily appropriated. Further, the general adjudication suit on Big Horn River water threatens the security of rights dating back to the early 1900's.

It's possible that the Town of Greybull could purchase Big Horn River water from the U.S. Bureau of Reclamation's Boysen Dam impoundment. However, this would pose some costly problems for Greybull.

First, there would be large transportation losses between Boysen Reservoir and the 75+ miles to Greybull. Second, the water is of very poor quality for a potable supply, being highly mineralized with salts and sulfates that are not removed in conventional treatment processes. Third, a treatment plant would be required. Such a plant would cost over $1,000,000 to construct and would cost at least $100,000 per year to operate and maintain. This is far too costly for Greybull, since they presently spend less than $5,000 per year for operation and maintenance of their existing Shell Creek supply and transmission facilities.

Thus, it can be seen that development of a supplementary water source from the Big Horn River is not a practical solution to Greybull's needs for additional water during the summer months.


Any ground water supply used by Greybull should be in close proximity to the town or to the Town's existing 14" transmission pipeline in order to keep conveyance costs to a minimum.
There are four aquifers that could serve as a source of supplemental water for Greybull's municipal water system. These four aquifers are discussed in detail in the geological report of Mr. Loy Harris, included within APPENDIX "A" and APPENDIX "B" of this feasibility study. The aquifers, listed in the order in which they occur (top to bottom) are (1) the Tensleep sandstone, (2) the Madison limestone, (3) the Big Horn dolomite and (4) the Flathead sandstone. There would be little problem with securing adequate water rights from these aquifers since they are almost completely undeveloped in Greybull's area of interest.

After careful study of all four aquifers, Mr. Harris recommends that the Town develop the Madison formation for its future water needs. His report found in APPENDIX "A", and his subsequent letter to the Town of Greybull dated March 31, 1982 (APPENDIX "B"), suggest locations for a well into the Madison to obtain the desired quantity and quality of water under the desired pressure. The aquifers are discussed in more detail in Section VI of this study.
VI
AQUIFER EVALUATION AND PRELIMINARY WELL LOCATION

1. General.

As mentioned, the Tensleep sandstone, Madison limestone, Big Horn dolomite and Flathead sandstone are all aquifers and are of interest in this study. A summary of their limnological characteristics follows.

2. Evaluation of Aquifers.

The Tensleep sandstone is the shallowest aquifer, and its quality is generally very good for potable use. However, it poses some problems. Wells developed into the Tensleep sandstone seldom flow over 500 gallons per minute and their artesian pressures are quite low, even though they could be expected to flow in the area of interest. It's doubtful that the Tensleep sandstone aquifer could provide the Town with the quantity of water it will need at the desired pressure.

The Madison limestone is an aquifer of high potential for quality water at high pressures. It is underlain by the Big Horn dolomite aquifer which also contains large volumes of quality potable water at high pressures. Worland's two Madison wells on the Paintrock Anticline midway between Manderson and Hyattville deliver 5300 gpm (9" casing), and 14,000 gpm (13" casing) under full-flow conditions. The wells have shut-in pressures of approximately 200 psi and enter the top of the Madison at approximately 2000 feet below the ground surface. They develop the top 300'± of the Madison formation.

The Town of Ten Sleep drilled a new well into the Madison formation within the Town's corporate limits in 1978. It entered
the Madison approximately 1000 feet below the ground surface, and delivered 3500 gpm through an 8 inch casing under full-flow conditions. The shut-in pressure of this well is 130 psi, and it is developed only into the top 80 feet of the Madison.

Obviously, the Madison formation is capable of delivering extremely large volumes of quality water under high pressures. A water quality analysis of Worland's Husky Well is found within APPENDIX "A". One further desirable feature of the Madison formation is the possibility of extending any Madison well into the Big Horn dolomite aquifer, immediately below the Madison, if that should ever become necessary to obtain additional quantities of quality water. This could be done during the time of well construction or, if necessary, at some future date by re-entry of the well. However, Mr. Harris points out in his report that the 600 foot thick Madison limestone will, on the average, contain 14,899 million gallons of water (45,693 acre-feet) in a square mile, so the probability of a Madison well providing inadequate volumes of water is unlikely, provided it is properly cased and developed. Thus, one square mile of the Madison formation should contain enough water for all of Greybull's projected water needs for the next 25 to 30 years. Of course, water in the Madison aquifer is being continuously replenished from precipitation falling on and flowing over the outcrop zone on the western flank of the Big Horn mountains.

The Flathead sandstone is a tremendous aquifer that is capable of delivering extremely large volumes of water under great pressures. However, it has several drawbacks for a municipal supply. First, it would cost much more to develop a well into the
Flathead aquifer due to its extreme depth and extreme pressures. The Flathead formation generally lies 2,000 feet deeper than the Madison formation. Secondly, Flathead waters generally contain excessive amounts of iron and manganese for municipal use unless they are treated.

The Madison-Big Horn aquifers have the greatest potential for providing quality potable water for Greybull's needs in the area of interest. As Mr. Harris' geological study points out, static well head pressures of 250-300 psi can be expected and flow delivery rates at the well head will be primarily dependent upon the size of production casing used in developing the well. The following table shows the head losses, in feet, that can be expected from different size casings and under the different flow alternatives (i.e. A, B, C, D & E) from page 20.

**TABLE 11**
Well Casing Head Loss Calculations

<table>
<thead>
<tr>
<th>Nominal Casing Size</th>
<th>Inside Diameter</th>
<th>Area (Ft²)</th>
<th>Flow (GPM)</th>
<th>Flow Velocity (CFS)</th>
<th>Friction Loss In 2500' of Lined Casing* (Ft/Ft)</th>
<th>Total (Ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7 5/8&quot;</td>
<td>6.969&quot;</td>
<td>0.265</td>
<td>1,000</td>
<td>2.228</td>
<td>0.031</td>
<td>78'</td>
</tr>
<tr>
<td>7 5/8&quot;</td>
<td>6.969&quot;</td>
<td>0.265</td>
<td>2,030</td>
<td>4.523</td>
<td>0.116</td>
<td>290'</td>
</tr>
<tr>
<td>9 5/8&quot;</td>
<td>8.835&quot;</td>
<td>0.426</td>
<td>2,030</td>
<td>4.523</td>
<td>0.036</td>
<td>91'</td>
</tr>
<tr>
<td>9 5/8&quot;</td>
<td>8.835&quot;</td>
<td>0.426</td>
<td>3,110</td>
<td>6.929</td>
<td>0.080</td>
<td>201'</td>
</tr>
<tr>
<td>13 3/8&quot;</td>
<td>12.515&quot;</td>
<td>0.854</td>
<td>4,110</td>
<td>9.157</td>
<td>0.025</td>
<td>62'</td>
</tr>
<tr>
<td>13 3/8&quot;</td>
<td>12.515&quot;</td>
<td>0.854</td>
<td>5,140</td>
<td>11.452</td>
<td>0.037</td>
<td>93'</td>
</tr>
</tbody>
</table>

*For Lined Casing C=140

From the foregoing Table it can be seen that high velocities in the production casing result in high head losses. As mentioned, shut-in pressures of a well developed into the Madison in the area
of interest will probably be in the range of 250-300 pounds per square inch. Thus, a maximum shut-in pressure gradient of approximately 4630 feet can be expected. An energy gradient of 4330 is required at entry to Greybull's existing transmission pipeline, and a minimum energy gradient of 4280 is required at the Collingwood Draw Reservoir. This allows for some 300 feet of head loss within the well and conveyance piping system at the maximum flow rate required. Since the head loss in the open hole can be equal to approximately 2/3 of the head loss in the casing, due primarily to the roughness of the open hole, it would be well to keep head losses in the casing to a maximum of 130 feet. Total head losses in the well would then be about 220 feet, leaving an additional 80 feet of head available for losses in the conveyance piping and valving system.

3. **Selection of Well Size.**

Considering the foregoing head loss criteria, a 7 5/8" well can reasonably accommodate flows up to 1,300 gpm, a 9 5/8" well can accommodate flows up to 2,400 gpm, and a 13 3/8" well can accommodate flows up to 6,000 gpm. This, of course, assumes that the aquifer can deliver these quantities of water on a sustained basis without excessive pressure loss in the formation.

Thus, if Greybull desires to provide only enough water to supplement its present supply on Shell Creek, a 7 5/8" well should handle its needs nicely (i.e. 1,300 gpm capacity vs. 1,000 gpm demand) until the year 2010. However, if the new ground water supply may be used to provide all of the water needs for Greybull's municipal system through the year 2010, a 9 5/8" well will be required (i.e. 2,400 gpm capacity vs. 2,030 gpm demand).
Further, any well used solely to provide the SVWID with its needs of 3,110 gpm should be 13 3/8" in size. A 13 3/8" well, with the capacity to flow 6,000 gpm (i.e. 13.4 cfs) without excessive head loss, should be capable of providing for the entire water needs of both Greybull and the SVWID (i.e. 2,030 gpm + 3,110 gpm = 5,140 gpm).

4. Selection of Well Location.

EXHIBIT "C" at the end of this report shows four potential Madison ground water development sites. The general areas recommended for development by the Harris report are also identified on this exhibit. A well located in or near area No. 3 could expect to flow with the highest volumetric output. However, as Mr. Harris cautions, it is best to limit the westerly location of any Madison wells to the axis of the Cherry anticline since hydrocarbon contamination is more likely to the west of this anticline.

There are several factors to be considered in the final selection of a well site:

A. Is the well to serve Greybull solely, or is it also to serve the SVWID? If the well is to serve only Greybull, it should be located as close as possible to Greybull's present transmission pipeline, since conveyance piping to connect to the transmission line will cost between $1,200 and $1,600 per 100 feet of pipe.

If the well is to serve both the Town and the SVWID, the cost of conveyance piping to Greybull's transmission line and to the two proposed reservoirs needs to be added to the well costs to determine the most economical location.

B. All-weather access should be available to the well at minimal cost.

C. A well site area of approximately 300'x300' (2.07 acres) will be needed to provide land sufficient for well drilling equipment, site grading, reserve pits, and storage of equipment and materials. However, a site of 100'x100' (0.23 acres) should be sufficient for permanent operation and maintenance usage.
D. The site should be reasonably level without excessive amounts of rock or surface water problems in order to keep site grading costs reasonable.

E. The well should be located in close proximity to a water course to allow for flow testing of the well without damage to adjoining lands.

F. The well should be located on undeveloped or marginally developed lands, if possible, to minimize land acquisition costs.

Estimated depth from ground surface to the top of the Madison formation varies from 2225' to 2555' for the four well sites shown on EXHIBIT "C". The following table gives pertinent data on each site:

<table>
<thead>
<tr>
<th>Well Site Number</th>
<th>Location</th>
<th>Ground Elevation</th>
<th>Contour on Top of Tensleep Sandstone</th>
<th>Depth to Top of Madison Limestone</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Flitner Corner</td>
<td>4080</td>
<td>1900</td>
<td>2555</td>
</tr>
<tr>
<td>II</td>
<td>Fox Mountain</td>
<td>4250</td>
<td>2150</td>
<td>2475</td>
</tr>
<tr>
<td>III</td>
<td>Collingwood Draw</td>
<td>4250</td>
<td>2400</td>
<td>2225</td>
</tr>
<tr>
<td>IV</td>
<td>Fish &amp; Game Station</td>
<td>4060</td>
<td>2000</td>
<td>2435</td>
</tr>
</tbody>
</table>

From the foregoing table it can be seen that there is little difference in depth to the top of the Madison formation at any of the four selected sites. Therefore, there would be little difference in cost of constructing a well at any of the sites selected.

The foregoing well depths are predicated primarily upon the geological structure logs taken on the Consolidated Oil & Gas, Inc. well in Section 27, T. 53 N., R. 92 W. Those formation thicknesses follow:
**TABLE 13**  
Estimated Formation Thicknesses

<table>
<thead>
<tr>
<th>Formation</th>
<th>Estimated Thickness (Feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermopolis</td>
<td>500</td>
</tr>
<tr>
<td>Cloverly*</td>
<td>260</td>
</tr>
<tr>
<td>Morrison</td>
<td>280</td>
</tr>
<tr>
<td>Sundance</td>
<td>310</td>
</tr>
<tr>
<td>Gypsum Springs</td>
<td>210</td>
</tr>
<tr>
<td>Chugwater</td>
<td>700</td>
</tr>
<tr>
<td>Dinwoody</td>
<td>20</td>
</tr>
<tr>
<td>Phosphoria</td>
<td>270</td>
</tr>
<tr>
<td>Tensleep</td>
<td>100</td>
</tr>
<tr>
<td>Amsden</td>
<td>200</td>
</tr>
<tr>
<td>Upper Mississipian</td>
<td>75</td>
</tr>
<tr>
<td>Madison*</td>
<td>650</td>
</tr>
<tr>
<td>Big Horn</td>
<td>350</td>
</tr>
</tbody>
</table>

*Top of Cloverly to Top of Madison = 2425' ±

As mentioned in the foregoing well location selection criteria, one of the foremost considerations for selection of the best site will be the cost of piping needed to connect the well to the points of use. To aid in determining the cost of such piping, valving, etc. the following table has been prepared:
TABLE 14
Estimated Size and Cost of Conveyance Piplines

<table>
<thead>
<tr>
<th>Flow Alternative</th>
<th>Flow (GPM)</th>
<th>Flow (CFS)</th>
<th>Pipe Diameter For Maximum Velocity of 6 Ft/Sec</th>
<th>Installed Cost* (Per Foot)</th>
<th>Installed Cost* (Per Mile)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1,000</td>
<td>2.228</td>
<td>10&quot;</td>
<td>$12.00</td>
<td>$ 64,000</td>
</tr>
<tr>
<td>B</td>
<td>2,030</td>
<td>4.523</td>
<td>12&quot;</td>
<td>16.00</td>
<td>85,000</td>
</tr>
<tr>
<td>C</td>
<td>3,110</td>
<td>6.929</td>
<td>15&quot;</td>
<td>25.00</td>
<td>132,000</td>
</tr>
<tr>
<td>D</td>
<td>4,110</td>
<td>9.157</td>
<td>18&quot;</td>
<td>30.00</td>
<td>158,000</td>
</tr>
<tr>
<td>E</td>
<td>5,140</td>
<td>11.452</td>
<td>20&quot;</td>
<td>34.00</td>
<td>179,500</td>
</tr>
</tbody>
</table>

*For 150 PSI Operating Pressure. Includes pressure reducing valve, line valve, air valves and blow-off assembly.

Using the foregoing well selection information, the Town of Greybull and the SVWID can, in consultation with their project geologist and engineer, select the best size and location for the proposed well. Of course, such a selection will depend to a large extent on any joint venture arrangement arrived at between Greybull and the SVWID.
1. **Well Design.**

The proposed well design is shown on EXHIBIT "D" at the end of this report. As mentioned in Section VI, the depth to the top of the Madison for the proposed well is estimated at 2500', and a 600' open hole is proposed into the Madison. Thus, total well depth (TD) is estimated at 3100' and the following cost estimates are predicated on this design.

2. **Construction Costs For Wells of Various Sizes.**

Table 15 follows. It shows the estimated well construction costs for a 7 5/8" well, a 9 5/8" well, and a 13 3/8" well.

The foregoing cost figures do not include any allowance for contingencies. Nor do they include any land costs, site development costs (i.e. roads, fencing, etc.), or engineering costs. Once a specific size of well is selected, along with the construction site, the engineer will prepare a total project cost estimate.

3. **Test Well.**

In order to test the Madison formation for water quality, flow volumes, and formation pressures, a test well would have to be cased and cemented into the top of the Madison. Further, the well casing should be of a size that would deliver the required flow without excessive head loss within the casing, for a well developed with a casing of lesser size could not provide the information needed to determine the flow capabilities of the formation at the drill site.
### TABLE 15

Estimated Well Construction Costs
(2500' Casing + 600' Open Hole)

<table>
<thead>
<tr>
<th>Construction Item</th>
<th>OUTSIDE DIAMETER OF PRODUCTION CASING</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>7 5/8&quot;</td>
</tr>
<tr>
<td>1. Mobilization &amp; Demobilization</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Extension ($)</td>
</tr>
<tr>
<td></td>
<td>$60,000 L.S.</td>
</tr>
<tr>
<td>2. Drill 40' deep hole for Surface Casing</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$70.00</td>
</tr>
<tr>
<td>3. Supply, Install &amp; Set 40' of Surface Casing</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$40.00</td>
</tr>
<tr>
<td>4. Drill 2500' Production Casing Hole</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$57.00</td>
</tr>
<tr>
<td>5. Supply &amp; Install 2500' of Production Casing</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$45.00</td>
</tr>
<tr>
<td>6. Cement Production Casing Total Depth</td>
<td></td>
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<tr>
<td></td>
<td>$10.00</td>
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<td>7. Supply &amp; Install Well Head Assembly</td>
<td></td>
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<tr>
<td></td>
<td>$10,000 L.S.</td>
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<tr>
<td>8. Drill 600' of Open Hole below Production Casing</td>
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<tr>
<td></td>
<td>$50.00</td>
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<tr>
<td>9. Well Development &amp; Testing</td>
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<td></td>
<td>6,000 L.S.</td>
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<tr>
<td>10. Site Rehabilitation &amp; Seeding</td>
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<td>5,000 L.S.</td>
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<tr>
<td><strong>TOTAL WELL COSTS</strong></td>
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<tr>
<td></td>
<td><strong>$395,400</strong></td>
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</table>
For the aforementioned reasons, the groundwater exploration program authorized by the Wyoming Water Development Commission (WWDC) should consist of drilling a full sized production well. Only if this is done can the well be put to beneficial use. Construction of a smaller well would cost nearly as much as a production well, and would require the drilling of still another well at great additional expense.
VIII
REVIEWING AUTHORITIES

1. **Wyoming Water Development Commission (WWDC).**

On November 24, 1981 the WWDC made a grant award in the amount of $200,000 to the Town of Greybull for groundwater exploration. Some $167,600 of that grant is available for well construction upon approval of this feasibility study by the WWDC. Additional requirements of the WWDC follow:

A. After completion of the study phase of this project, the Town of Greybull must submit to the Water Development Commission 15 copies of a complete report as defined in the attached Scope of Services, Hydrogeological Study. No further obligations or expenditures will be authorized by WWDC until the report has been received and approved by WWDC, and the Town has been notified in writing that the Town may proceed with the exploratory drilling portion of the program.

B. If the exploratory drilling portion of the program is authorized by WWDC, the Town of Greybull must, at the completion of the exploratory drilling, submit to WWDC 15 copies of a report as defined in the attached Scope of Services, Exploratory Drilling Program.

C. Any exploratory drilling program under this contract must be supervised by an individual or firm qualified to locate drilling sites, supervise well construction, and prepare the reports required by WWDC.

D. The appropriate permits from the State Engineer's Office must be obtained before any drilling occurs.

The WWDC will distribute copies of this feasibility study to all State reviewing agencies, including the Department of Economic Planning and Development (DEPAD), the Department of Environmental Quality (DEQ), and the State Engineer.

2. **Wyoming Department of Environmental Quality (DEQ).**

The Wyoming Department of Environmental Quality has issued a set of "Source Development Standards" for development of Wyoming's
ground waters (See EXHIBIT "E"). These standards must be met in the design of municipal well systems before a permit will be issued to construct such systems.

3. Wyoming State Engineer.

The State Engineer's approval will be needed for a ground water appropriation from the proposed new well.
IX
AVAILABLE FINANCING

1. General.

As previously mentioned, the Town of Greybull has a grant in the amount of $167,600 for the development of a new well, subject to the approval of this report by the WWDC.

However, as Table 15 shows, well construction costs, depending on the well size selected, are likely to be between $395,400 and $572,600. Thus, additional monies will be needed if the project is to proceed.

2. Wyoming Farm Loan Board (FLB).

The Farm Loan Board, through the Wyoming Commissioner of Public Lands and Farm Loans, administers a system of grants and loans for public water improvements throughout the State of Wyoming. The FLB meets twice a year to consider applications for grant fund requests.

Applications should be made to:

Mr. Oscar E. Swan
Commissioner of Public Lands and Farm Loans
2424 Pioneer Avenue
Pioneer Building
Cheyenne, Wyoming 82002

The interest rate on FLB loans is presently 8½ percent.

3. U.S. Farmers Home Administration (FmHA).

The U.S. Department of Agriculture, Farmers Home Administration, has a program of providing grants, loans or both for the installation, repair, improvement or expansion of rural water supply and distribution systems. Although rural towns having populations of up to 10,000 people qualify, priority is given
to rural towns, cooperatives and villages having populations of less than 5,500 people. Authorization for FmHA funding is contained within Section 306 of the Consolidated Farmers Home Administration Act of 1961.

The grant portion of the program provides for an outright grant or contribution for up to 50% of the total project cost. The amount of the grant is dependent upon a review made by the FmHA of the water rates paid in Greybull as compared to average rates paid by other comparable communities in the area. They will likely insist that Greybull's water rates be up to par with rates in other similar water systems in the area. Of course, all grant funding is dependent also upon the availability of funds at the time of application and their funding limitations.

The loan portion of the program provides that the FmHA will assist with financing, if funds are available, through the issuance of mortgage and promissory notes. Loans are available from the FmHA for a maximum term of 40 years at a 12 3/8% interest rate on the unpaid principal.

Requests for financial assistance from the FmHA should be made through Fred Brownlee, District Director, Farmers Home Administration, 2006 Big Horn Avenue, P.O. Box 159, Worland, Wyoming.
ENVIRONMENTAL IMPACT STATEMENT

No Environmental Impact Statement is planned for the proposed ground water improvements, since no significant adverse environmental effects are anticipated, and the improvements are not likely to be highly controversial.
XI

CONCLUSIONS AND RECOMMENDATIONS

This Feasibility Study should be reviewed by Greybull's governing body and the Shell Valley Watershed Improvement District.

After consultation with the consulting geologist and engineer, Town officials should then decide upon a well size and location. The engineer can then prepare a complete project cost estimate for the proposed well, including costs for land, site development, engineering and an appropriate contingency.

The engineer should then be directed to complete preparation of 20 copies of the approved Feasibility Study, 15 copies of which should be sent to the WWDC for State approval. Should additional funding be desired in the form of grants or loans, the Commissioner of Public Lands and Farm Loans, and/or the U.S. Farmers Home Administration should be contacted for application procedures.
EXHIBITS
Vern Nelson, P.E.
Box 638
Worland, WY 82401

Dear Mr. Nelson:

The Board of Directors of the Shell Valley Watershed Improvement District met in special session on Saturday, May 15th to determine (per your request) what needs actually are for supplemental irrigation water that may be derived from a joint venture between the Town of Greybull and the District, in the drilling of an artesian well.

It was determined that the optimum needs of the District in connection with an artesian well would be to fill the following proposed reservoirs twice each year:

- Proposed Collingwood Draw: 460 acre feet
- Proposed Fox Mountain reservoir: 727 acre feet

TOTAL PROPOSED ANNUAL STORAGE: 2,374 acre feet

The District's Directors are hopeful that the above named reservoirs could be filled during the winter months, then emptied during the early irrigation season, prior to runoff, when irrigation needs are great and Shell Creek is low. They could then be refilled during the high water runoff when the creek supplies sufficient water for both domestic and irrigation requirements.

In order that you may have data necessary to properly locate the proposed well site, I submit the following information on the reservoir sites:

- Collingwood Draw Reservoir Site
  - Acre feet of storage: 460
  - Dam location: SW\&SE\& Sec. 6, T. 52 N., R. 91 W.
  - Top of Dam altitude: 4,280

- Fox Mountain Reservoir Site
  - Acre feet of storage: 727
  - Dam location: SE\&SE\& Sec. 2, T. 52 N., R. 91 W.
  - Top of Dam altitude: 4,245

Should you need further information regarding the reservoir sites, please contact the SCS office in Greybull.

Respectfully submitted,

[Signature]

Marvin L. Hankins
Secretary Treasurer

cc. Bob Nielson, Mayor
Ben Minter, Councilman

EXHIBIT "A"
EXHIBIT "C"

POTENTIAL GROUNDWATER DEVELOPMENT SITES

TOWN OF GREYBULL
GREYBULL, WYOMING

JOHN W DONNELL & ASSOCIATES, INC
CONSULTING ENGINEERS
WORLAND, WYOMING
JUNE, 1982
EXHIBIT "D"
PROPOSED WELL
CONSTRUCTION DETAIL

TOWN OF GREYBULL
GREYBULL, WYOMING

APPROXIMATE TOP OF
MADISON LIMESTONE

APPROXIMATE BASE OF
MADISON LIMESTONE

JOHN W. DONELL & ASSOCIATES, INC.
CONSULTING ENGINEERS
WORLAND, WYOMING
JUNE, 1982
3.0 GENERAL

In selecting the source of water to be developed, the designing engineer must prove to the satisfaction of the reviewing authority that an adequate quantity of water will be available, and that the water which is to be delivered to the consumers will meet the current requirements of the reviewing authority with respect to microbiological, physical, chemical and radiological qualities. Each water supply should take its raw water from the best available source which is economically reasonable and technically possible.

3.1 SURFACE WATER

A surface water source includes all tributary streams and drainage basins, natural lakes and artificial reservoirs or impoundments above the point of water supply intake.

3.1.1 Quantity

The quantity of water at the source shall

a. be adequate to meet the projected water demand of the service area as shown by calculations based on the extreme drought of record,

b. provide a reasonable surplus for anticipated growth,

c. be adequate to compensate for all losses such as silting, evaporation, seepage, etc.

3.1.2 Quality

A sanitary survey and study shall be made of the factors, both natural and man made, which will affect quality. Such survey and study shall include, but not be limited to

a. determining possible future uses of impoundments or reservoirs,

b. determining degree of control of watershed by owner,

c. assessing degree of hazard to the supply by accidental spillage of materials that may be toxic, harmful or detrimental to treatment processes,

d. obtaining samples over a sufficient period of time to assess the microbiological, physical, chemical and radiological characteristics of the water,

e. assessing the capability of the proposed treatment process to reduce contaminants to applicable standards.

3.1.3 Structures

3.1.3.1 Design of intake structures

shall provide for
3.1.3.1 Design of intake structures (cont'd.)

a. withdrawal of water from more than one level if quality varies with depth,

b. separate facilities for release of less desirable water held in storage,

c. where frazil ice may be a problem, holding the velocity of flow into the intake structure to a minimum, generally not to exceed 0.5 feet per second,

d. inspection manholes every 1000 feet for pipe sizes large enough to permit visual inspection,

e. occasional cleaning of the inlet line,

f. adequate protection against rupture by dragging anchors, ice, etc.,

g. ports located above the bottom of the stream, lake or impoundment, but at sufficient depth to be kept submerged at low water levels,

h. where shore wells are not provided, a diversion device capable of keeping large quantities of fish or debris from entering an intake structure.

3.1.3.2 Shore wells

shall

a. have motors and electrical controls located above grade, and protected from flooding as required by the reviewing authority,

b. be accessible,

c. be designed against flotation,

d. be equipped with removable or traveling screens before the pump suction well,

e. provide for introduction of chlorine or other chemicals in the raw water transmission main if necessary for quality control,

f. have intake valves and provisions for backflushing or cleaning by a mechanical device and testing for leaks, where practical,

g. have provisions for withstanding surges where necessary.

3.1.3.3 An upground reservoir

is a facility into which water is pumped during periods of good quality and high stream flow for future release to treatment facilities. Upground reservoirs shall be constructed to assure that
3.1.3.3 An unground reservoir (cont'd.)

a. water quality is protected by controlling runoff into the reservoir,
b. dikes are structurally sound and protected against wind action and erosion,
c. intake structures and devices meet requirements of Section 3.1.3.1,
d. point of influent flow is separated from the point of withdrawal,
e. separate pipes are provided for influent to and effluent from the reservoir.

3.1.4 Impoundments and reservoirs

3.1.4.1 Site preparation

shall provide where applicable

a. removal of brush and trees to high water elevation,
b. protection from floods during construction,
c. abandonment of all wells which will be inundated, in accordance with requirements of the reviewing authority.

3.1.4.2 Construction

may require

a. approval from the appropriate regulatory agencies of the safety features for stability and spillway design,
b. a permit from an appropriate regulatory agency for controlling stream flow or installing a structure on the bed of a stream or interstate waterway.

3.2 GROUND WATER

A ground water source includes all water obtained from dug, drilled, bored or driven wells, and infiltration lines.

3.2.1 Quantity

3.2.1.1

The total developed ground water source capacity shall equal or exceed the design maximum day demand and equal or exceed the design average day demand with the largest producing well out of service.
3.2.1.2

A minimum of two sources of ground water shall be provided.

3.2.1.3 Auxiliary power

a. When power failure would result in cessation of minimum essential service, sufficient power shall be provided to meet average day demand through

1. connection to at least two independent public power sources, or

2. portable or in-place auxiliary power.

b. When automatic pre-lubrication of pump bearings is necessary, and an auxiliary power supply is provided, the pre-lubrication line shall be provided with a valved by-pass around the automatic control.

3.2.2 Quality

3.2.2.1 Microbiological quality

a. Disinfection of every new, modified or reconditioned ground water source

1. should be provided after completion of work, if a substantial period elapses prior to test pumping or placement of permanent pumping equipment, and

2. shall be provided after placement of permanent pumping equipment.

b. After disinfection, one or more water samples shall be submitted to a laboratory satisfactory to the reviewing authority for microbiological analysis with satisfactory results reported to such agency prior to placing the well into service.

3.2.2.2 Physical and chemical quality

a. Every new, modified or reconditioned ground water source shall be examined for applicable physical and chemical characteristics by tests of a representative sample in a laboratory satisfactory to the reviewing authority, with the results reported to such authority.

b. Samples shall be collected at the conclusion of the test pumping procedure and examined as soon as practical.

c. Field determinations of physical and chemical constituents or special sampling procedures may be required by the reviewing authority.
3.2.2.3 Radiological quality

Every new, modified or reconditioned ground water source shall be examined for radiological activity as required by the reviewing authority by tests of a representative sample in a laboratory satisfactory to the reviewing authority, with results reported to such agency.

3.2.3 Location

3.2.3.1 Well location

The reviewing authority shall be consulted prior to design and construction regarding a proposed well location as it relates to required separation between existing and potential sources of contamination and ground water development.

3.2.3.2 Continued protection

Continued protection of the well site from potential sources of contamination shall be provided either through ownership, zoning, easements, leasing or other means acceptable to the reviewing authority. Fencing of the site may be required by the reviewing authority.

3.2.4 Testing and Records

3.2.4.1 Yield and drawdown tests

shall

a. be performed on every production well after construction or subsequent treatment and prior to placement of the permanent pump,

b. have the test methods clearly indicated in specifications,

c. have a test pump capacity, at maximum anticipated drawdown, at least 1.5 times the quantity anticipated, and

d. provide for continuous pumping for at least 24 hours or until stabilized drawdown has continued for at least six hours when test pumped at 1.5 times the design pumping rate.

e. provide the following data:

1. test pump capacity-head characteristics,
2. static water level,
3. depth of test pump setting, and
4. time of starting and ending each test cycle.
3.2.4.1 Yield and drawdown tests (cont'd.)

f. provide recordings and graphic evaluation of the following at one hour intervals or less as may be required by the reviewing authority:

1. pumping rate,
2. pumping water level,
3. drawdown, and
4. water recovery rate and levels.

3.2.4.2 Plumbness and alignment requirements

a. Every well shall be tested for plumbness and alignment in accordance with AWWA standards.

b. The test method and allowable tolerance shall be clearly stated in the specifications.

c. If the well fails to meet the requirements, it may be accepted by the engineer if it does not interfere with the installation or operation of the pump or uniform placement of grout.

3.2.4.3 Geological data

shall

a. be determined from samples collected at 5-foot intervals and at each pronounced change in formation,

b. be recorded and samples submitted to the appropriate authority,

c. be supplemented with information on accurate record of drillhole diameters and depths, assembled order of size and length of casings and liners, grouting depths, formations penetrated, water levels, and location of any blast charges.

3.2.5 General well construction

3.2.5.1 Minimum Protected Depths

Minimum protected depths of drilled wells shall provide watertight construction to such depth as may be required by the reviewing authority, to

a. exclude contamination, and

b. seal off formations that are, or may be, contaminated or yield undesirable water.
3.2.5.2 Temporary steel casing

Temporary steel casing used for construction shall be capable of withstanding the structural load imposed during its installation and removal.

3.2.5.3 Permanent steel casing pipe

shall

a. be new pipe meeting ASTM or API specifications for water well construction,

b. have minimum weights and thickness indicated in Table I,

c. have additional thickness and weight if minimum thickness is not considered sufficient to assure reasonable life expectancy of a well,

d. be capable of withstanding forces to which it is subjected,

e. be equipped with a drive shoe when driven, and

f. have full circumferential welds or threaded coupling joints.

3.2.5.4 Nonferrous casing materials

a. Approval of the use of any nonferrous material as well casing shall be subject to special determination by the reviewing authority prior to submission of plans and specifications.

b. Nonferrous material proposed as a well casing must be resistant to the corrosiveness of the water and to the stresses to which it will be subjected during installation, grouting and operation.

3.2.5.5 Packers

Packers shall be of material that will not impart taste, odor, toxic substance or bacterial contamination to the well water.

3.2.5.6 Screens

shall

a. be constructed of materials resistant to damage by chemical action of ground water or cleaning operations,

b. have size of openings based on sieve analysis of formation and/or gravel pack materials,
3.2.5.6 Screens (cont'd.)

c. have sufficient diameter to provide adequate specific capacity and low aperture entrance velocity. Usually the entrance velocity should not exceed 0.1 feet per second,

d. be installed so that the pumping water level remains above the screen under all operating conditions,

e. where applicable, be designed and installed to permit removal or replacement without adversely affecting water-tight construction of the well, and

f. be provided with a bottom plate or washdown bottom fitting of the same material as the screen.

3.2.5.7 Grouting requirements

All permanent well casing, except driven Schedule 40 steel casing with the approval of the reviewing authority, shall be surrounded by a minimum of 1\% inches of grout to the depth required by the reviewing authority. All temporary construction casings should be removed, but shall be withdrawn at least five feet to insure grout contact with the native formation.

a. Neat cement grout

1. Cement conforming to ASTM standard C150 and water, with not more than six gallons of water per sack of cement, must be used for 1\% inch openings.

2. Additives may be used to increase fluidity subject to approval by the reviewing authority.

b. Concrete grout

1. Equal parts of cement conforming to ASTM Standard C150, and sand, with not more than six gallons of water per sack of cement may be used for openings larger than 1\% inches.

2. Where an annular opening larger than four inches is available, gravel not larger than one-half inch in size may be added.

c. Clay seal

Where an annular opening greater than six inches is available a clay seal of clean local clay mixed with at least 10 per cent swelling bentonite may be used when approved by the reviewing authority.
3.2.5.7 Grouting requirements (cont'd.)

d. Application

1. Sufficient annular opening shall be provided to permit a minimum of 1½ inches of grout around permanent casings, including couplings.

2. Prior to grouting, bentonite or similar materials may be added to the annular opening, in the manner indicated for grouting.

3. When the annular opening is less than four inches, grout shall be installed under pressure by means of a grout pump from the bottom of the annular opening upward in one continuous operation until the annular opening is filled.

4. When the annular opening is four or more inches and less than 100 feet in depth, and concrete grout is used, it may be placed by gravity through a grout pipe installed to the bottom of the annular opening in one continuous operation until the annular opening is filled.

5. When the annular opening exceeds six inches, is less than 100 feet in depth, and a clay seal is used, it may be placed by gravity.

6. After cement grouting is applied, work on the well shall be discontinued until the cement or concrete grout has properly set.

e. Guides

The casing must be provided with sufficient guides welded to the casing to permit unobstructed flow and uniform thickness of grout.

3.2.5.8 Upper terminal well construction

a. Permanent casing for all ground water sources shall project at least 12 inches above the pumphouse floor or concrete apron surface and at least 18 inches above final ground surface.

b. Where a well house is constructed, the floor surface shall be at least six inches above the final ground elevation.

c. Sites subject to flooding shall be provided with an earth berm surrounding the casing and terminating at an elevation at least two feet above the highest known flood elevation, or other suitable protection as determined by the reviewing authority.

d. The top of the well casing at sites subject to flooding shall terminate at least five feet above the highest known flood elevation or as the reviewing authority directs.
3.2.5.9 Development

a. Every well shall be developed to remove the native silts and clays, drilling mud and/or finer fraction of the gravel pack.

b. Development should continue until the maximum specific capacity is obtained from the completed well.

c. Where chemical conditioning is required, the specifications shall include provisions for the method, equipment, chemicals, testing for residual chemicals, and disposal of waste and inhibitors.

d. Where blasting procedures may be used, the specifications shall include the provisions for blasting and cleaning.

3.2.5.10 Capping requirements

a. A welded metal plate or a threaded cap is the preferred method for capping a well.

b. A properly fitted, firmly driven, solid wooden plug is the minimum acceptable method of capping a well until pumping equipment is installed.

c. At all times during the progress of work, the contractor shall provide protection to prevent tampering with the well or entrance of foreign materials.

3.2.5.11 Well abandonment

a. Test wells and ground water sources which are not in use shall be sealed by such methods as necessary to restore the controlling geological conditions which existed prior to construction or as directed by the appropriate regulatory agency.

b. Wells to be abandoned shall

1. be sealed to prevent undesirable exchange of water from one aquifer to another,

2. preferably be filled with neat cement grout,

3. have fill materials other than cement grout or concrete, disinfected and free of foreign materials, and

4. when filled with cement grout or concrete, these materials shall be applied to the well hole through a pipe, tremie, or bailer.
3.2.6 Aquifer types and construction methods—Special conditions

3.2.6.1 Sand or gravel wells

a. If clay or hard pan is encountered above the water bearing formation, the permanent casing and grout shall extend through such materials.

b. If a sand or gravel aquifer is overlaid only by permeable soils the permanent casing and grout shall extend to at least 20 feet below original or final ground elevation, whichever is lower.

c. If a temporary outer casing is used, it shall be completely withdrawn as grout is applied.

3.2.6.2 Gravel pack wells

a. Gravel pack shall be well rounded particles, 95 per cent siliceous material, that are smooth and uniform, free of foreign material, properly sized, washed and then disinfected immediately prior to or during placement.

b. Gravel pack shall be placed in one uniform continuous operation.

c. Gravel refill pipes, when used, shall be Schedule 40 steel pipe incorporated within the pump foundation and terminated with screwed or welded caps at least 12 inches above the pump house floor or concrete apron.

d. Gravel refill pipes located in the grouted annular opening shall be surrounded by a minimum of 1½ inches of grout.

e. Protection from leakage of grout into the gravel pack or screen shall be provided.

f. Permanent inner and outer casings shall meet requirements of Section 3.2.5.3.

g. Minimum casing and grouted depth shall be acceptable to the reviewing authority.

3.2.6.3 Radial water collector

a. Locations of all caisson construction joints and porthole assemblies shall be indicated.

b. The caisson wall shall be reinforced to withstand the forces to which it will be subjected.

c. Radial collectors shall be in areas and at depths approved by the reviewing authority.
### 3.2.6.3 Radial water collector (cont'd.)

**d.** Provisions shall be made to ensure that radial collectors are essentially horizontal.

**e.** The top of the caisson shall be covered with a watertight floor.

**f.** All openings in the floor shall be curbed and protected from entrance of foreign material.

**g.** The pump discharge piping shall not be placed through the caisson walls.

### 3.2.6.4 Infiltration lines

**a.** Infiltration lines may be considered only where geological conditions preclude the possibility of developing an acceptable drilled well.

**b.** The area around infiltration lines shall be under the control of the water purveyor for a distance acceptable to or required by the reviewing authority.

**c.** Flow in the lines shall be by gravity to the collecting well.

### 3.2.6.5 Dug wells

**a.** Dug wells may be considered only where geological conditions preclude the possibility of developing an acceptable drilled well.

**b.** A watertight cover shall be provided.

**c.** Minimum protective lining and grouted depth shall be at least ten feet below original or final ground elevation, whichever is lower.

**d.** Openings shall be curbed and protected from entrance of foreign material.

**e.** Pump discharge piping shall not be placed through the well casing or wall.

### 3.2.6.6 Limestone or sandstone wells

**a.** Where the depth of mantle is more than 50 feet, the permanent casing shall be firmly seated in uncreviced or unbroken rock. Grouting requirements shall be determined by the reviewing authority.

**b.** Where the depth of mantle is less than 50 feet, the depth of casing and grout shall be at least 50 feet or as determined by the reviewing authority.
3.2.6.7 Naturally flowing wells

a. Flow shall be controlled.

b. Permanent casing and grout shall be provided.

c. If erosion of the confining bed appears likely, special protective construction may be required by the reviewing authority.

3.2.7 Well pumps, discharge piping and appurtenances

3.2.7.1 Line shaft pumps

Wells equipped with line shaft pumps shall

a. have the casing firmly connected to the pump structure or have the casing inserted into a recess extending at least one-half inch into the pump base, and

b. have the pump foundation and base designed to prevent water from coming into contact with the joint.

3.2.7.2 Submersible pumps

Where a submersible pump is used

a. the top of the casing shall be effectively sealed against the entrance of water under all conditions of vibration or movement of conductors or cables, and

b. the electrical cable shall be firmly attached to the riser pipe at 20 foot intervals or less.

3.2.7.3 Discharge piping

a. The discharge piping shall

1. be designed so that the friction loss will be low,

2. have control valves and appurtenances located above the pumphouse floor when an above-ground discharge is provided,

3. be protected against the entrance of contamination,

4. be equipped with a check valve, a shutoff valve, a pressure gauge, a means of measuring flow, and a smooth nosed sampling tap located at a point where positive pressure is maintained,
3.2.7.3 Discharge piping (cont'd.)

5. where applicable, be equipped with an air release-vacuum relief valve located upstream from the check valve, with exhaust/relief piping terminating in a down-turned position at least 18 inches above the floor and covered with a 24 mesh corrosion resistant screen,

6. be valved to permit test pumping and control of each well,

7. have all exposed piping, valves and appurtenances protected against physical damage and freezing,

8. be properly anchored to prevent movement, and

9. be protected against surge or water hammer.

b. The discharge piping should be provided with a means of pumping to waste, but shall not be directly connected to a sewer.

3.2.7.4 Pitless well units

a. The reviewing authority must be contacted for approval of specific applications of pitless units.

b. Pitless units shall

1. be shop-fabricated from the point of connection with the well casing to the unit cap or cover,

2. be threaded or welded to the well casing,

3. be of watertight construction throughout,

4. be of materials and weight at least equivalent and compatible to the casing,

5. have field connection to the lateral discharge from the pitless unit of threaded, flanged or mechanical joint connection, and

6. terminate at least 18 inches above final ground elevation or five feet above highest known flood elevation or as the reviewing authority directs.

c. The design of the pitless unit shall make provision for

1. access to disinfect the well,
2. a properly constructed casing vent meeting the requirements of Section 3.2.7.5,

3. facilities to measure water levels in the well (see Section 3.2.7.6),

4. a cover at the upper terminal of the well that will prevent the entrance of contamination,

5. a contamination-proof entrance connection for electrical cable,

6. an inside diameter as great as that of the well casing, up to and including casing diameters of 12 inches, to facilitate work and repair on the well, pump, or well screen, and

7. at least one check valve within the well casing or in compliance with requirements of the reviewing authority.

d. If the connection to the casing is by field weld, the shop-assembled unit must be designed specifically for field welding to the casing. The only field welding permitted will be that needed to connect a pitless unit to the casing.

3.2.7.5 Casing vent

Provisions shall be made for venting the well casing to atmosphere. The vent shall terminate in a downturned position, at or above the top of the casing or pitless unit in a minimum 1½ inch diameter opening covered with a 24 mesh, corrosion resistant screen. The pipe connecting the casing to the vent shall be of adequate size to provide rapid venting of the casing.

3.2.7.6 Water level measurement

a. Provisions shall be made for periodic measurement of water levels in the completed well.

b. Installation of permanent water level measuring equipment shall be made using corrosion resistant materials attached firmly to the drop pipe or pump column and in such a manner as to prevent entrance of foreign materials.

3.2.7.7 Observation wells

shall be

a. constructed in accordance with the requirements for permanent wells if they are to remain in service after completion of a water supply well, and

b. protected at the upper terminal to preclude entrance of foreign materials.
Table I
STEEL PIPE*

<table>
<thead>
<tr>
<th>SIZE</th>
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<th>THICKNESS (inches)</th>
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*Abstracted from AWWA Standard for Deep Wells, AWWA A100
APPENDICES
TOWN OF

GREYBULL, WYOMING

WATER WELL PROJECT

Preliminary Geologic Report

by

L. E. Harris
Consulting Geologist
STRATIGRAPHY

and

SURFACE GEOLOGY
PRE - CAMBRIAN

The basement (Pre-Cambrian) rocks of the area of interest are thought to be gray to pinkish Felspathic granite of igneous origin. In some localities the Pre-Cambrian rocks consist of metamorphosed gneiss and schists. These dark metamorphic rocks may be seen near the tunnels at the southern end of the Wind River Canyon south of Thermopolis. However as they do not seem to be in evidence in the Shell Creek Canyon section, it is assumed they will not be present in the area of interest. Because of the lack of reservoir characteristics and the general impervious nature of these rocks, they will not be given further consideration in this study.

CAMBRIAN AGE

Uncomfortably overlying the basement rocks are approximately 1,500 feet of Upper Cambrian Age sediments. These sediments of Cambrian Age in the Big Horn Basin have been divided into three lithographic units or formations:

Flathead Sandstone Formation The lowermost of these three formations consists chiefly sandstone which grade upward into sandy glauconitic shales. At the base of this formation the sandstones are coarse arkosic and conglomeritic in nature. This basal sandstone from 50-150 feet thick is the best and most prolific aquifer in the Cambrian section.

Gros Ventre Formation The sandstone of the underlying Flathead grade upward into the greenish to purple sandy shales of the Gros Ventre. This formation contains some sandy and glauconitic limestones. It is within this formation that the flat pebble limestone conglomerates are found. Because of the high percentage of shale, this formation does not have the high porosity or other favorable criteria for reservoir rocks as the underlying Flathead Sandstone. However, wherever porosity is developed the Gros Ventre can, and often does, carry water.

Gallatin Formation This top member of the rocks of Cambrian Age is composed chiefly of sandy and pebbly glauconitic limestones with interbedded green and purple shales and thin limey and glauconitic sandstones. The most prominent bed of the Gallatin Formation is the 50-60 foot thick Gallatin Limestone. This bed is typical Cambrian being a rather tight, hard, glauconitic and sandy limestone.
ORDOVICIAN AGE

Big Horn Dolomite The next approximately 400 feet of sediments in an ascending order is the Big Horn Dolomite of Ordovician Age. These beds are limey, slightly sandy, granular dolomite and usually develop rather high porosity and permeability. These characteristics make this a very good aquifer which can be expected to contribute a substantial source of water to any well that penetrates these beds.

Locally a sandstone 20-30 feet thick exists at the base of the Big Horn Dolomite. This sandstone of Ordovician Age is also a potential source of water whenever it is encountered in a well.

DEVONIAN AGE

The sediments of Devonian Age are represented in the area of this study, by about 50 feet of thin grey dolomitic shales and interbedded light shaley dolomites. Rocks of this age are not considered to be a prime objective for water wells in this area. Any porosity encountered in a drilled well would be incidental and handled in connection with the underlying Big Horn Dolomite or with the overlying Madison Limestone of Mississippian Age.

MISSISSIPPIAN AGE

Madison Limestone Formation The primary objective of this study, for water producing potential, are the sediments of Mississippian Age that have been named the Madison Limestone. This formation should be about 600 feet thick throughout the study area.

The Madison Limestone is a light grey dolomitic and cherty limestone. It contains many cherty nodules and in places thin (5-10 feet) beds of grey chert.

Because the top of this formation is an unconformity, there are frequent cavities and caves. This porosity caused by surface erosion helps the percolating waters increase the dolomitization of the original limestone. It is this change of volume, due to the change in the crystals of limestone to dolomite and dolomitic limestone, that
creates the effective porosity and permeability. This dolomitization of the Madison Limestone has created zones and pods of vugs, cavities, and even caverns which gives this formation the excellent qualities for an aquifer of very high potential.

These factors will combine to make the Madison Formation a very favorable objective for a water well.

At any location within the study it is very possible that some sediments of Upper Mississippian Age will be present in the drilled section. These rocks will be white rather fine-grained limestones interbedded with fine light colored sandstone and thin grey shales. In most instances the first limestone encountered below the overlying Amsden is called Madison. The rocks of Upper Mississippian Age are also considered to be aquifers although not of the magnitude of the Madison immediately below.

PENNSYLVANIAN AGE

Amsden Formation The sediments of the Amsden Formation are deposited on the erosional surface of the Mississippian rocks. In places this erosional surface is covered by a thick massive to cross-bedded sandstone which seems to smooth over the rough spots of the erosional surface. This sandstone unit while not present everywhere has been measured up to about 100 feet thick and is known as the Darwin Sandstone.

Overlying this basal sandstone is the fine, slightly dolomitic, purple shale. This shale member is usually about 50+ feet thick. It is in turn overlain by about 50+ feet of interbedded limestone and dolomites. These carbonate beds are usually of a slightly pinkish cast.

Where these limestones and dolomites develop vugs and fractures, and where the basal (Darwin) sandstone is present, it is possible they both become important aquifers.

Tensleep Formation The approximately 150-200 feet of sandstone immediately above the Amsden Formation is called the Tensleep Sandstone. The lower half of this sandstone is flat-bedded and dolomitic. The upper half is massive to cross-bedded, fine to medium grained. It is this upper portion that makes the better reservoir for either water or oil in areas of the Big Horn Basin. The Tensleep Sandstone is a very important aquifer in the area under consideration.
PERMEAN AGE

Phosphoria Formation Overlying the slight unconformity at the top of the Tensleep Sandstone, are the beds of the Phosphoria Formation approximately 220 feet thick. The lower part of the Phosphoria in the study area are red anhydritic shales interbedded with thin anhydritic dolomites and slightly dolomitic anhydrites. The upper portion becomes progressively more limey in a westerly direction. Vugs and fine inter-crystalline porosity of this upper limestone section commonly carry either water or oil. However most of the waters from this horizon are dark grey and strong with sulphur odor and taste. This horizon is not considered a source of good water in the area covered by this project.

TRIASSIC AGE

Dinwoody Formation Like the Phosphoria below, the Dinwoody Formation undergoes a color change in an East-West direction due to facies change. At the Eastern part of the area under consideration the Dinwoody is composed of red to pinkish anhydritic shales, with interbedded thin impure shaley anhyrites. To the West these beds become green anhydritic shales with pyrite inclusions. The total thickness of the Dinwoody should be about 50-75 feet.

Chugwater Formation Lying conformable on the Dinwoody Formation are the red shales, red siltstones and red anhydritic shales of the Chugwater Formation. This formation known as the red beds is about 700' thick. Because of the high percentage of gypsum and anhydrite found in the red beds of the Chugwater Formation, water occasionally encountered is not suitable for drinking purposes.

JURASSIC AGE

Gypsum Spring Formation The pinkish to maroon anhydritic shales and massive anhydrites, consisting of about 150' of sediments, comprise the Gypsum Springs Formation. These beds are not considered to have any potential as an aquifer. This is because of lack of porosity and because of the high sulphate contents of the rocks.
Sundance Formation The sediments of the Sundance Formation (about 250-300 feet thick) are characterized by the relatively high amount of dark green glauconite found in the entire sequence. This glauconite gives the formation an olive green color which is characteristic. The lower part of the formation is comprised of thin bedded highly fossiliferous limestone. There are two of these beds that are usually oolitic. These oolites make a good marker for picking the base of the formation from samples. In the upper portion of the formation glauconitic sandstones predominate. These sandstones are inter-bedded with dull olive green glauconitic shales.

Morrison Formation These lacustrine or shallow water sediments are the varicolored (ocher, purple, green and grey) shales that overlie the Sundance. This section contains some white sandstones and thin impure limestones, all of a very lenticular character.

CRETACEOUS AGE

Cloverly Formation The shallow seas of Morrison time continued locally into the Cloverly. The result being that in many places it is impossible to pick a point of separation, especially from well cuttings. In certain localities the Cloverly Formation can be divided into roughly four parts.

The lower member is called the Lakota Sandstone. Where it is present it is rather coarse grained, conglomeritic sandstone. This is covered by the Fuson Shale. The Fuson is a series of varicolored (pink, maroon, grey) shales that are apt to be slightly sandy to very fine. The Fuson is overlain by the Dakota Sandstone. This sandstone, where present, is light, fine to medium-grained and can be a very good aquifer but not of sufficient volume or pressure of water to be important to the project under consideration. The Dakota Sandstone grades upward into the beds called the Cloverly Silt Zone. These are brownish, sideritic, sandy shales that top the Cloverly Formation.

Thermopolis Shale (Lower Thermopolis) About 200 feet of fine, dark grey to black fissile shale lies over the Cloverly Silt Zone. This shale is slightly bentonitic with thin beds of light colored bentonite, especially in the lower part of the section.

Muddy Sandstone As the name implies this is (usually) a silty bentonitic sandstone. It varies in thickness from nothing to slightly over 50 feet. Where the sand is absent the beds are usually slightly lighter in color, more bentonitic and finely silty and sandy.
Shell Creek Shale (Upper Thermopolis) This 200+ feet of dark grey to black, fine fissile shale overlies the Muddy Sandstone horizon. It is almost identical to the Lower Thermopolis in character. Formerly the unit was classed as one formation with the Muddy Sandstone member being located in the middle. Subsequent nomenclature changes have resulted as stated above.

Mowry Shale This thin bedded, hard siliceous shale rests on the black to dark grey Shell Creek. The Mowry, on the surface, is lighter grey and because of its higher resistance to weathering, forms high ridges over the softer dark shales below. Near the top of this formation are the bentonite beds of commercial importance.

Frontier Formation The series of sandstones overlying the Mowry Shale are called the Frontier Formation. The somewhat lenticular sands of this series have at the base a fairly consistent member known as the Peay Sandstone. It is a slightly glauconitic sand and in many places it is a good reservoir for oil, gas, and/or water. This water is usually brackish and not good for domestic use. Locally at the top of the formation is a sandstone named the Torchlight Sandstone. As stated above these sands in this formation are very lenticular in nature and correlation of any one sand for a distance is very difficult.

Cody Shale Deposited on top of the Frontier Sands are about 3000 feet of grey to dark shale. Only the lower few feet of this formation are exposed in the area of interest. As it is not present in the localities to be recommended for drilling, no further consideration will be given to it.
STRUCTURAL GEOLOGY
STRUCTURE

For the study area (T. 51-53 N., incl., Rs 89-93 W. incl.) Exhibit II shows the major structural features.

Exhibit II is compiled from U.S.G.S. Hydrologic Investigation Atlas HA 512, Sheet 1 of 2, and from U.S.G.S. Oil & Gas Investigation Map OM 182, supplemented by information from the files and maps from my own office.

The map drawn using 1000-foot contour intervals shows and major structural trends, but due to the scale does not show some of the minor features.

The large Cherry Creek Anticline trend is seen to be plunging in a northwestern direction from near the center of the South line of T. 52 N., R. 90 W., to near the southwest corner of T. 53 N., R. 92 W. Along this major trend are the Cherry Creek Anticline and the Devil's Kitchen Dome.

These two minor structures are enechelon with the much larger southern projection of Sheep Mountain Anticline (T. 53 N., R. 93 W.).

To the South may be seen the Lamb-Torchlight fields (T. 51 N., R. 92-93 W.). Again, enechelon with these fields is the Greybull Dome Field located in T. 52 N., R. 93 W.

In the southwest of T. 51 N., R. 93 W., the rapid narrowing of the spacing of the contour lines indicates the very steep dip into the Basin.
RESERVOIR CHARACTERISTICS
FLATHEAD SANDSTONE

The Flathead Sandstone of Cambrian Age is a coarse to medium-grained sand. Where the sand rests on the Pre-Cambrian erosional surface the sand is coarse, poorly cemented arkosic. The porosity of the non-shale part of this sandstone should be in the range of 25%. Wells drilled to this horizon confirm that it may be the most prolific water sand in the Basin. However, the water of the Flathead is a little high in minerals. It is a source of water that is suitable for domestic uses.

BIG HORN DOLOMITE

The Big Horn Dolomite of Ordovician Age is a granular dolomite with well developed vugs and cavities. This vugular porosity along with good inter-crystalline porosity make the Big Horn a very good aquifer. Cores from this horizon show the porosity to range from 2% to 25% with an average porosity of around 12%. This good porosity is enhanced by many cavities and fractures which provide almost unlimited permeability. The water quality of the Big Horn Dolomite is very good and quite close to the analysis of that of the overlying Madison Limestone. A well that did not yield sufficient quantities of water in the Madison Limestone should be drilled deeper to penetrate the Big Horn Dolomite to augment the quantity of water, without affecting the quality in an adverse manner.

MADISON LIMESTONE

The Madison Limestone, the prime objective of this study, is a known aquifer of high potential. Available analysis of cores from this horizon show the porosity to range from a low of 1.5% to about 26% for an average of about 11.9%. Vugs, cavities and fractures tend to increase the porosity and permeability. It is thought that a well drilled to penetrate this formation, if drilled in a favorable location will furnish sufficient water for the town.

Using the figures given above it can be shown that one square mile of Madison Limestone 600 feet thick can contain about 1.489^10 gallons or, expressed in whole numbers about 14,899,000,000 gallons of water in place in the formation. The availability of this water for use will depend upon the permeability or ease with which fluid can pass through the formation and the head of pressure to which the water is subjected. In the case of the Madison Limestone matrix
this permeability ranges from 0 to about 1460 millidarcys. This relatively high permeability is further augmented by numerous fractures, caves and crevices.

TEN SLEEP SANDSTONE

The Tensleep Sandstone is another aquifer that must be considered. Core analysis of the upper cross-bedded portion of this sand show a range of porosity of from 10% to 20%. The permeability ranges from near zero to well over one thousand millidarcys. Again, vugs and fractures increase these figures. At present the ability of the Tensleep Sandstone to supply sufficient water is not known. However this sand has produced several flowing water wells in the area of interest and should be given consideration as a supplemental source, in case of necessity.

Inasmuch as all of these potential reservoirs are known to contain oil and gas in structures deeper in the basin, it is felt that they should be explored for water potential as close to the eastern edge or outcrops as practical. The reason for this is that as the waters percolate through the formations they are susceptible to contamination the further they travel. The Tensleep Sandstone is known to produce rather strong sulphur water just south of the Town of Greybull.
PROJECT CRITERIA
Exhibit #3 is a chart showing two generalized cross sections and a composite prognosis section for the area of interest.

The cross section line A-A' shows the profile of the terrain in relation to the sub-surface formations. The line A-A' is from the Madison Limestone outcrop in Shell Creek Canyon (sec. 17, T. 53 N., R. 90 W.) to the Madison outcrop in the Big Horn River Canyon through Sheep Mountain (sec. 35, T. 54 N., R. 94 W.). The hydraulic gradient between these two outcrops is seen to be below the surface profile throughout most of the distance. Where the profile of the land is above the hydraulic gradient line, the chances for a flowing water well are very small. Thus it is seen that the relatively high ground North of the Shell Creek Valley is not considered as a good prospect for the location of the water well or wells of the Greybull Water Well Project.

Still considering Exhibit #3, the generalized cross section line A-B is immediately below the line A-A' on the exhibit. This cross section is from the outcrop of the Madison Limestone (sec. 17, T. 53 N., R. 90 W.) through the Ed Chase, Hinkley No. 1 Well. This well located in the NW NW SW sec. 27, T. 52 N., R. 93 W., penetrated 210 feet of the Madison Limestone. A drill stem test taken in this well determined the head of water from the Madison. This well was used because I was the geologist during the drilling and testing and am confident with the results (pressures and recovery) of the tests. The hydraulic gradient line from the outcrop to the elevation of the head of water is seen on the cross-section. From the relation of the gradient line to the profile of the surface it is seen that at almost any point along this line, where the ground elevation is not above 4,200', a flowing water well from the Madison Limestone should be the result of a well drilled to a depth sufficient to penetrate the Madison Limestone.

This 4,200' elevation contour opens up the whole Shell Creek Valley, West of the town of Shell, Wyoming. The further West the location for the well is made will provide that much more gathering area and slightly better pressures at the same elevation. However, it must be kept in mind that as the water percolates through the rocks it is subject to contamination, especially hydrocarbons. For this reason it is recommended that the area East of the axis of the Cherry Creek Anticline be given primary consideration.

Along this line of thought it should be pointed out that the Tensleep Sandstone, which produces good water for human consumption in the eastern portion of the study area, produced dark grey sulphur
water at a well just South of the town of Greybull. This is due to the fact the water has passed through the rocks in the anticlinal areas that are traps and reservoirs for hydrocarbons (oil and gas), where the water picked up the contamination.

PRESSURE

Exhibit #4 of this report is a pressure gradient map of the area of study. The contours or isobars on this map are in increments of one hundred pounds. The map is based chiefly on surface pressures calculated from shut-in pressures from drill stem tests of wells drilled for oil or gas that penetrated at least part of the Madison Limestone section.

In making this map the highest readings were used in order to eliminate short shut-in times and also low readings because of wall damage that might be present in the well. The resulting map shows pressures that are slightly higher than would be expected using the elevation of the outcrop of the Madison Limestone in Shell Creek Canyon as the recharge source.

This additional pressure encountered in Madison tests can be accounted for in either of two ways. The first would rely on the principal recharge area of the Madison Limestone at being higher in the mountains and not at the lower elevation of the lower outcrop in the Shell Creek Canyon. This condition would indicate there should be a slight discharge at the above-mentioned outcrop. Lack of close volume and water characteristics in the local area of the outcrop prevent definite conclusions. The second theory to help account for the slightly excessive pressures would be for the Madison pressures to be augmented by pressures from the deeper horizons. This could take place through faults or fractures. Inasmuch as the study area is relatively free of faults or very steep sharply folded structures, this second idea does not appeal to me as much as the first with the higher recharge source. However the fact that the pressure exists in the Madison enhances the prospect.

TEMPERATURE

The temperature of the water from the Madison Limestone horizon will be directly related to the depth required in any hole to test that formation. This depth will vary as to the location and will be controlled by both the elevation of the location and the structural position of the Madison. When a more definite location for the well is determined, the depth and hence the temperature can be estimated with some degree of accuracy.
WATER PURITY

In the eastern portion of the area of interest there is no information from wells drilled to the Madison to indicate the purity of water from that formation. What few wells that have penetrated the Madison were drilled in search of oil and gas, and the water was considered a nuisance to be eliminated as quickly and cheaply as possible. For this reason no analysis showing the characteristics of the water suitability (or lack thereof) are available.

Included with this report (with the exhibits) are the water analyses for both the Madison Formation and the Flathead Formation waters taken from the well drilled by the Husky Oil Compan (sec. 12, T. 44 N., R. 91 W.). This well is now being developed by the Town of Worland as a source of water for the town.

There are no known reasons why a well drilled at the recommended locations in the current study area should not produce water of very similar characteristics.
SUMMARY

and

RECOMMENDATIONS
Information and data assembled in this study indicates that a well drilled to penetrate the Madison Limestone nearly any place in the Shell Creek Valley with a surface elevation below 4,200\' should flow water.

Exhibit #5 is a plat showing three areas for possible drilling sites.

These three areas are numbered 1, 2, and 3, in the probable order of their volumetric output:

Area No. 1 - sec. 33, T. 53 N., R. 92 W.
Area No. 2 - sec. 30, T. 53 N., R. 91 W.
Area No. 3 - S\text{\textfrac{1}{2}} sec. 28, T. 53 N., R. 91 W.

Areas number 1 and 2 will be very similar and should differ chiefly in the size of the area that could be considered as contributing or the drainage area for the individual wells. Area number 3, being somewhat closer to the outcrop, would be expected to flow, but with a lower pressure and volume, and a somewhat smaller reservoir area.
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- **102 Bbl OPD 152 Bbl WPD**
- **4000 Bbl OPD**
- **195 Bbl OPD 1025 Bbl WPD**
- **DST 4180-4235 Rec 10' Oil & 200' NCO**
- **FP 16-184 SIP 1836 HP 2129**
- **DST 4283-4305 Rec 573' Mud**
- **FP 43-195# SIP 1849 HP 2201**
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<th>Surf.</th>
<th>Datum</th>
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<td>465' E</td>
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<td>Stonehenge Oil</td>
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<td>Pan-Am-Pet No. 1</td>
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<td>Kirk Oil Co. #10 Govt</td>
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No tests in Madison
Drilled and Abandoned
No test in Madison
Producing oil well
37 Bbl OPD & 15 Bbl. WPD

DST 4028-4085 Rec OCM
FP 63-178 SIP 1417 HP 2077
Temporarily abandoned

DST 4003-4084 Rec 234' 0 & WCM (1 hr
FP 0-100 SIP 1465 FHP 2155
DST 4073-4094 Rec 155' WCM
FP 0-125 SIP 1425 GO 2299

Madison - Producing well
No Madison tests
Tensleep and Madison - Producing
34 Bbl 0 & 121 Bbl WPD
## Compiled Data Sheet for T. 51 North

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<tr>
<th>Well Name</th>
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<th>Surf. of Head Water</th>
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**No Madison test**

**Tensleep Producer**

**No tests in Madison**

**Madison producing well**

**Flowed 126 Bbl W PH from acidized perf. 4077-80 & 4083-87**

**Plugged back - Phosphoria producing**

**DST 4050-4070 Rec 1385' water**

**FP 62-637 SIP1861 HP 2133**

**D & A**

**DST 3867-3900 Rec 5' Oil & 105' OCR**

**DST-3995-4069 Rec 3966' SHAW (1 hr)**

**FP 123-1763 SIP 798-1902 HP 1990**

**Madison producer**

**No tests in Madison**

**Madison producer**
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<th>Well Name &amp; Number</th>
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<th>Elev.</th>
<th>Datum</th>
<th>Surf.</th>
<th>Datum</th>
<th>Ft. of head water</th>
<th>Total of water at surf.</th>
<th>Depth</th>
<th>Head of Water</th>
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| Minerals Mgt 24-1 Govt. | SW SW | 990'S & 990' W | 24-5N-93W | 4154 | 3702 | 452 | 69 | 4313 | 159 | 4011 | 4169 | DST 3740-74 Rec 1430' SXCW FP 91-367 SIP 1659 HP 1692 BHT 104° 
<p>| True Oil | NE SE | 498'N 571'E | 33-5N-93W | 3945 | 12147 | -8202 | 12596 | No test in Madison BHT 190° |</p>
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<td>J.W. Osborn et al</td>
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*Calculated head & pressure*
** Wyoming Department of Agriculture  
Division of Laboratories  
P. O. Box 3228  
Laramie, WY 82071  

OWNER OR USER: John W. Donnell & Associates  

ADDRESS: 1701 Big Horn ave., P.O. Box 13, Worland, WY 82401  
SOURCE: Flathead  
DESCRIPTION: LOCATION sec. 12, T 49N, R 9W  

DATE COLLECTED: April 3, 1979  
DATE RECEIVED: April 5, 1979  

** CATIONS **  

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** ANIONS **  

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** Other Chemicals **  

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** Temperature:**  

\[ \text{Temp} = 104^\circ F \]

** Date:** April 13 1979  

** State Chemist or Director:**

** Laboratory Fee:** $89.00 (Paid)  
Charged-to be billed monthly  

Please make checks payable to:  
Wyoming Department of Agriculture  
2219 Carey Avenue  
Cheyenne, WY 82002  

E.P.A. Standards are maximum contaminant levels.  
U.S.P.H. Standards are recommended levels for public supply.
<table>
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<th>mg/l</th>
<th>ANIONS meq/l</th>
<th>mg/l</th>
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Date: April 20, 1979

Wyoming Department of Agriculture
Division of Laboratories
P.O. Box 228
Laramie, WY 82071

Address: Husky Well #2 Madison

Date Collected: March 27, 1979

Date Received: March 27, 1979

Interstate Fee $89.00 (Paid) (Charged-to-be billed monthly)
March 31, 1982.

Town of Greybull
Mr. Gary Hartman
Attorney
Greybull, Wyoming 82426.

Dear Mr. Hartman:

At the last meeting of the Greybull Town Council, that I attended, my report and recommendations were presented.

At this meeting the question was raised concerning the possibility and practicality of at least two other locations slightly outside the recommended area (as outlined in Exhibit No. 5) of my report.

When the work was started on this report there were no criteria as to pressure, volume or location were given. There was the request for three possible areas for drilling, with at least one area to be in Township 91 West. It was my understanding at the time that the locations should be as close to the existing water line for the town of Greybull as practical.

Much of the reasoning for the locations recommended in the report was based on the records from the Consolidated Oil & Gas Company, well drilled in the SE - NW, Sec. 27, T53N, R92W. As seen in the report (Compiled Data Sheet for 53N) the well drilled 32 feet into the top of the Madison Limestone. At this depth the weight of the drilling mud had to be maintained at 10.1 lbs/gal. If the weight became less the water pressure in the well started to flow. If the mud weight got higher than 10.1 lbs/gal., circulation was lost and the formation took fluid. Thus it is seen that the weight of the column of 10.1 lbs/gal. mud was very close or equal to the formation pressure.

Calculations show that the 2922 foot column of 10.1 lbs/gal. mud would be the equivalent of 3499 feet of water column. This would indicate the water would reach a point 577 feet above the surface, or an elevation of about 4645 feet. In turn this indicates a surface pressure of 249.9 lbs/sq.in. or well head pressure. From this it would seem that any well drilled at an elevation below 4400 feet would flow water with close to 150 lbs/sq.in. pressure. Using these figures it would be possible to recommend almost any location below 4400 feet in elevation. However there are many unknown variable factors that could negate these calculations. For this reason and to stay on the conservative side, I would not recommend any location over 4500 feet in elevation.

APPENDIX "B"
It is a recognized fact that the pressures in the Madison Limestone, in the study area, are slightly higher than would be normally expected. In view of this and the above mentioned calculations, I would not hesitate to recommend any location, below 4300 feet in elevation, within the study area. This added elevation would be at the sacrifice of some pressure, but the well should flow.

The two submitted additional locations were:

1. Near the center of Section 6, T52N, R91W.

2. Near the center of the East line of Section 2, T52N, R92W.

Locations at either or both of these areas would be expected to produce a flowing water well from the Madison Formation. Both of these locations will be slightly over one mile from the existing water line, and being slightly higher in elevation, a slight pressure loss would be expected.

It is hoped that this letter, along with the report, will aid you in making a decision as to the location for the proposed water well.

Please feel free to call on me if I can be of any further assistance.

Sincerely,

[Signature]

Loy E. Harris