DRILLING and AQUIFER TESTING
OF THE
ERICSON FORMATION
PHASE II
FOR THE
CITY OF ROCK SPRINGS, WYOMING

Prepared By

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In Association With
BISHOP, BROGDEN & RUMPH, INC.
AND
HAROLD MOSHER & Associates
April 14, 1986

City of Rock Springs
P. O. Box 1030
Rock Springs, WY 82902

Attention: Mr. Glenn Sugano
Director of Public Works

Re: Groundwater Study
JFCo File No. 1668-1084

Dear Mr. Sugano:

Transmitted herewith is our report entitled, "Drilling and Aquifer Testing of the Ericson Formation, Phase II". This report is the result of drilling and completing an observation well and a production test well, an aquifer pump test, computer groundwater modeling, and hydrological studies of the Little Bitter Creek drainage basin.

This study indicates that acceptable groundwater southwest of Rock Springs, to the south of Bitter Creek, could be developed to supplement the City's existing water supply. The results of this study are not as encouraging as first thought in that the initial water supply from groundwater is less than anticipated, but groundwater development in this area is still possible. Two excellent possibilities exist for future groundwater exploration and development: (1) the Lower Ericson, both north and south of Bitter Creek, and, (2) on the strike line north of the Paul J. Wataha Recreation Complex.

Sincerely,

JOHNSON-FERMELIA CO. INC.

Wayne E. Johnson, PE and LS
President

Enc.

cc: Wyoming Water Development Commission (35 copies)
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The Phase I Ericson Aquifer Testing Report recommended additional testing of the Ericson aquifer south of Bitter Creek. This Phase II report is the result of this testing.

Sealed bids for the drilling of an observation well, a production test well, and aquifer pump testing were accepted by the City of Rock Springs in July, 1985. The location of these wells is in the Southeast Quarter of Section 20, Township 18 North, Range 105 West, Sweetwater County, Wyoming. Well drilling was started in September, 1985, and after much difficulty completing both wells, the aquifer pump testing was completed in mid-January, 1986. Among the difficulties encountered was the forced abandonment of the original production test well and completion of a new well at an alternate location.

Actual depth to the top of the Ericson was approximately 300 feet deeper than the project depth. The dip of the Ericson at the drill site is 34°, as compared to the 15° to 17° dip of the surface formations.

The testing results and modeling indicate that the production test well is capable of producing 150 gpm for over 50 years without exceeding practical limitations on drawdown. This is true without recharge considerations.
Hydrology of the Little Bitter Creek drainage basin and Little Bitter Creek streamflow measurements indicate that there is some aquifer recharge. Total basin runoff is estimated at 1,000 acre feet per year, as compared to an estimated average annual requirement of 2,100 acre feet for the City of Rock Springs. This well, and others drilled in this area, could supplement the water needs of the City, but could not supply the total needs.

Water from the production well is of good quality and should improve over the years with pumping. Water quality comparisons between this well and the Paul J. Wataha Recreation Complex wells indicate that the better quality water is to the north of Bitter Creek.

Geology in the test well area is complex because of the numerous northeast to southwest trending faults. A well field cannot be designed because of these complexities and each new well would have to be assessed on an individual basis.

Transmissivity of the Ericson in this area is 928 gallons per day per foot (gpd/ft), as compared to about 2,000 gpd/ft at the Paul J. Wataha Recreation Complex to the north. Storage coefficient for this area is 0.00002, as compared to 0.000055 at the Complex.

The porosity and grain size of the Ericson aquifer decreases from north to south along the west flank of the Rock Springs Uplift. Water quality appears to follow this trend of better quality to the north to less desired quality to the south.
The geology of the area indicates that the Mesa Verde Formation, which includes the Ericson, was deposited from northwest to southeast with the source being the Hoback Mountains or the Wind River Mountains. As with any water borne material, the larger, heavier particles are deposited first and the smaller, lighter particles are carried further from the source. Groundwater exploration to the north of the Paul J. Wataha Recreation Complex wells would confirm the apparent northerly trend of larger particle size with the additional porosity and productivity.
An aquifer pump test of the Upper Ericson Formation was completed in March, 1984. This testing program was conducted using existing production wells at the Paul J. Wataha Recreation Complex and the Sweetwater County Fairgrounds, northwest of Rock Springs. Elsewhere in this report this testing is referred to as Phase I.

One of the recommendations to come from this initial study was a test well southwest of Rock Springs, about 4,000 feet to the west of Little Bitter Creek. The purpose of this study is to determine the effect to the Ericson Aquifer of the considerable faulting in this area, to attempt to quantify the potential recharge where Little Bitter Creek flows over the Ericson Outcrop, and to determine the potential for well field development south of Bitter Creek.

Hydrology of the Little Bitter Creek Basin was studied to determine the runoff available for possible direct recharge to the Ericson Aquifer. Little Bitter Creek streamflows were gauged in an effort to determine losses to bank storage or groundwater recharge.
This portion of the aquifer pump test is referred to as Phase II and includes:

1. Drilling and completion of a monitor well, drilling, completion and pump testing a production well.

2. Pump test data analysis and computer simulated groundwater models.

3. Water quality analyses.

4. Little Bitter Creek drainage basin hydrology.

5. Geologic study.
Specifications for the drilling and completion of the monitor well and drilling completion and testing of the production test well were completed in June of 1985. Sealed bids were solicited from well drilling contractors and through the newspaper media.

On Tuesday, July 30, 1985, five sealed bids were opened and read in the City of Rock Springs' Council Chambers. The contractors and their respective bids are tabulated below:

1. K P Drilling, Casper, WY $119,160.75
2. Parker Drilling, Vernal, UT 142,240.00
3. Nucor, Inc., Riverton, WY 152,900.00
4. Sargent Irrigation, Mills, WY 162,453.42
5. Thomas Drilling, Afton, WY 170,045.30

K P Drilling was the apparent low bidder. A review of their unit prices indicated that they had overlooked the price of the production well's 10" casing in their bid. They were contacted and asked about this omission. Their reply was that they would need an additional $13,502.40 for the casing installation. This additional amount increased the low bid to $132,610.39. Since this amount was still below the next lowest bid of $142,240.00, the City of Rock Springs awarded the contract to K P Drilling.
K P Drilling was instructed to submit performance and payment bonds. Upon receipt of the bonds the Contract was formalized.

This project was designed to require two wells; an observation well and one production well. The available geologic information indicated that the maximum depths for these wells would be approximately 1600 feet. However, because of an unanticipated degree of steepening of dip between the outcrops along Little Bitter Creek and the selected locations, drilling to approximately 1800 feet was required to secure adequate penetration of the Upper Ericson aquifer. This contributed to the unforeseen time for drilling and extra cost of the wells.

Also, a major portion of the drilling contractor's time was occupied with "fishing" with magnets, overshots and milling to attempt to clear the holes of twisted off pipe, iron and bits dropped or lost in the holes during drilling or reaming. These recurring mechanical problems plagued operations to the point that, instead of only two wells, the contractor was forced to abandon and plug the second, nearly completed well and drill a third well nearby. The time consumed by the general hole cleaning (milling, "fishing", etc.) moved the time frame of operations back into November and December of 1985. Recurring winter-type storms and extremely cold weather may have contributed in part to operational inefficiencies. It should be noted, however, that very little time was lost due to above ground mechanical problems with the drilling rig, which was maintained in excellent condition.
The drilling program outlined for both holes was simple and in conformance with the preferred methods of the drilling contractor. Small diameter pilot holes were drilled to casing depths and then reamed to the specified diameters to accommodate the casings and the cement seal. Most of the down-hole problems occurred during reaming.

Table 3-1 below summarizes the disposition of the drilling contractor's time for each operation (rounded off to full days):

<table>
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<th>Drilling &amp; Casing</th>
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<th>Fishing</th>
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<td>6 days</td>
<td>5 days</td>
<td>10 days</td>
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<tr>
<td>Production Well</td>
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<td></td>
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<tr>
<td>No. 1 (Abandoned)</td>
<td>8 days</td>
<td>5 days</td>
<td>21 days</td>
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<tr>
<td>Production Well</td>
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<td></td>
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<tr>
<td>No. 1-A</td>
<td>7 days</td>
<td>15 days</td>
<td>None</td>
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</tbody>
</table>

3 - 3
The objective of this project has been to determine the feasibility of using underground water from the Ericson Formation of the Mesaverde Group to augment existing water supplies of the City of Rock Springs. The Phase I program was initiated in late 1983 when the Ericson wells in the North Recreation Area (NRA) were used to test the productive capacity of the Upper Ericson aquifer in that area. Positive results from that initial study lead to recommendations for further testing and possible development in Ericson closer to the City of Rock Springs and to the south-southwest.

For reasons to be discussed in subsequent paragraphs, the current drilling and aquifer testing project was located south of Rock Springs. (Figures 4-1 & 4-2.) The results obtained from this latter effort were not as promising as had been anticipated, but have provided an excellent evaluation of the true aquifer potential both locally and for the intervening area closer to Rock Springs. Further, a water well capable of a sustained yield of 150 gpm has been installed and could be a "magnet" for some type of development in the area.

The following discussion of the stratigraphy and structure of the Rock Springs Uplift in general is reproduced from the report "Aquifer Testing of Ericson Formation for City of Rock Springs, Wyoming" by Johnson-Fermelia Co. Inc. and others, dated March 1984. This provides a brief explanation of the geology history of the Rock Springs Uplift area of Wyoming. It is followed by a discussion of geology in the immediate locality of the CRS water wells.
SURFACE GEOLOGIC MAP of ROCK SPRINGS UPLIFT

Scale: 1" = 4 miles

FIGURE 4-1
FIGURE 4-2

LOCATION MAP

CRS OBSERVATION WELL #1 ELEV. 1428' 1224'

CRS PRODUCTION (ABANDONED) ELEV. 6419

CRS PRODUCTION WELL #1-A ELEV. 6419

WELL LOCATIONS FOR CRS WELLS #1 AND #1-A AND CRS OBSERVATION WELL #1 SE 1/4, SEC. 20, T18N, R106W SWEETWATER COUNTY WYOMING
A. **Overview of the Structure and Stratigraphy of the Rock Springs Uplift**

The Rock Springs Uplift is geologically dominant in central southwestern Wyoming. In total, it is a roughly oval-shaped upwarp or anticline with numerous subsidiary anticlinal heights. Its long axis is approximately 60 miles in length and it is 35 miles wide. It is asymmetrical to the west with surface dips of $15^\circ$ common on the west flank and $5^\circ$ dips on the east flank.

The geological features discussed herein are displayed on Figure 4-1. This map does not show all of the cross faulting now known to be present, but it shows clearly the position and outcrop width variations of the Ericson Formation. The aerial extent of the Bishop Conglomerate is also hachured for emphasis. The original map is by Sears (1925) as modified by Hale (1950). Except for the omission of some minor faulting as noted above, subsequent mapping has been reviewed and field checking done in some areas, but no observations were made which would invalidate this map as presented.

The upper Cretaceous Baxter Formation (shale) is exposed in the center of the Uplift and the overlying Mesaverde Group series of formations and Ft. Union Formation are exposed on the flanks of the Uplift. Lower Eocene Wasatch and the interfingering Green River Beds overlying the Paleocene Ft. Union and Mesaverde Group with an approximate $10^\circ$ angular unconformity.

The geological conclusions reached by numerous authors who have studied these sediments and their structure lead to the following history. During Baxter time, the Rock Springs
Uplift was non-existent and the sea covered most of Wyoming. The seas then withdrew and western Wyoming became an area of shallow seas and swamps as evidenced by the coals, shales and sandstones of the lower formations of the Mesaverde Group, the Blair and Rock Springs Formations. The Ericson Formation is believed to represent alluvial fan material from sources to the north, possible from the present area of the Wind River Mountains. These sediments were deposited as deltas in a shallow sea and spread southward beyond the present area of the Uinta Mountains. The "Ericson Sea" then withdrew leaving an environment which fluctuated between swampy and shallow sea conditions, giving the shales, coals and thinner sandstones which are characteristic of the Almond Formation.

The next and last deep water transgression which buried the Mesaverde Group was the Lewis Sea. The Lewis shale is exposed only on the east flank of the Rock Springs Uplift. With the retreat of the Lewis Sea, the uplifting movements, which are generally called Laramide, began. This Laramide orogeny began uplifting the essentially flat-lying Mesaverde and older sediments. The uplifting was not purely vertical but also exerted forces which operated to cause some westward displacement of the uplift. This resulted in the complex and multiple tear faults which cut the flanks of the Uplift. It is also the reason why the dips of the pre-Ft. Union strata are steeper on the west flank than on the east flank of the Rock Springs Uplift. (It is one of the tear faults which constitutes the boundary which is about 2000 feet north of the CRS water wells.) After a pause at the end of Ft. Union time, shallow broadly oscillating seas, lakes and slowly continuing uplifting of the Rock Springs feature provided the environment which is
today reflected in the Eocene Wasatch and the interfinger members of the Green River Formation.

During the final stages of Rock Springs Uplift development, the Uinta Mountains began to be raised and this movement continued through the upper Eocene, through the Oligocene and well into Miocene time. These sediments, now referred to as the Bishop Conglomerate, overlie the upturned edges of the Wasatch/Green River beds as well as the Measverde Group formations. Remnants of the Bishop Conglomerate are concentrated at the higher elevations of the uplift 12 miles to 30 miles south of Rock Springs.

B. Surface Geology

The Rock Springs Uplift is an asymmetric anticline and, as with most structures of this type and magnitude, it exhibits an abundance of cross faults or tension fractures. The U.S. Geological Survey also maps a buried major reverse or thrust fault close and parallel to the Almond Formation outcrop on the west flank of the structure. This fault is concealed under Wasatch sediments and is known only from seismic records and in one instance where it was cut at 8800 feet by a drill hole.

The steepest dips, 10° to 15°, are on the west flank from about three miles south to 20 miles north of Rock Springs. Further to the south (T 16 and 17 N - R 105 W) the dips on the Ericson exposures flatten to 5° or less. This results in an outcrop width two to three times greater than that to the north. It should also be noted that a marked flattening also occurs on the north end of the uplift (T 22 and 23 N - R 103 W).
Although notable for its lack of tectonic complexity, the angular relationship of the flat lying Bishop Conglomerate to the underlying Ericson Formation is believed to result in the Bishop being a kind of sponge which can contribute recharge to the Ericson if and when some type of depletion occurs.

C. Mesaverde Group

As previously stated, the Mesaverde Group consists of the following formations in order as encountered by the drilling bit:

1. Almond
2. Ericson
3. Rock Springs
4. Blair

Of these, only the Ericson has sufficient formation thickness and an updip zone of good quality water of sufficient volume to make for feasible groundwater development. The CRS area wells were not designed to penetrate more than the upper Ericson. Therefore, the stratigraphy of the middle and lower Ericson in the CRS area is still a matter of conjecture.

In the vicinity of the North Recreation Area aquifer test (Section 10, T 20 N - R 105 W), a simple three part section has developed with nearly equal upper and lower zones separated by about 100 feet of shale and silty shale.

The Cities Service well log from about seven miles south-southeast of Rock Springs shows development of a massive 285 foot section of upper Ericson sandstone. The base of the Ericson is probably at the base of the double sandstone zones occurring in the interval between 2052 and 2137 feet.
It is not the purpose of this discussion to resolve the intricacies of Mesaverde Group sedimentation such as exactly delineating formation boundaries. However, the main portions of the Ericson Formation have been traced for about 45 miles and their thickness and aquifer potentials can be estimated for the formation where logging is available.

D. Bishop Conglomerate

It is beyond the scope of this report to discuss the details of the Bishop hydrogeology except to note that where the Bishop Conglomerate is in contact with Ericson outcrop it probably contributes recharge to the Ericson sandstones. This does not rule out development of the Bishop as a direct source of water for Rock Springs.

CRS AREA GEOLOGY

In the area of the CRS wells the geologic section consists of the Ericson formation topped by a wedge of eroded Almond formation which in turn is overlain by lower Ft. Union sediments. Because of lithologic similarities between the Almond and Ft. Union, interbedded sands, shales and some coals, the boundary between these formations cannot be designated with assurance. However, about three miles north, Roehler (1983) has assigned an approximate thickness of 210 feet above the Ericson to the Almond. This suggests a top for the Almond at 1312 feet in the CRS Observation Well. This is about 25 feet above the 10-12 foot coal which is one of the most consistent marker beds within the Almond Formation. The remainder of the section to the surface is then Ft. Union.
Between the outcrops of the Ericson along Little Bitter Creek and CRS wells, approximately one mile to the west there is a steepening of dips or flexure of the Ericson. In contrast to the 12° - 15° dips of the Ft. Union beds on the surface, the dip on the top of the Ericson, as computed from the three CRS wells is 34°. The strike is N 23° E. (see Figure 4-3). It is this change from the 17° dips in the Ericson along Little Bitter Creek that accounted for the drilling depths of the CRS wells being 300 feet deeper than originally estimated.

**POSSIBLE FUTURE DEVELOPMENT**

The results of the CRS water well test program are serving to confirm the geologic theories presented by various writers regarding the origin and variations in physical characteristics of the Ericson formation. Because of its continuous outcropping around all but the southern end of the Rock Springs Uplift a consistent increase in grain size has been observed from south to north. This in turn indicates the source of the Ericson formation was in the vicinity of the Wind River Mountains and on into the Hoback area farther northwest. This general increase in particle size provides for enhanced groundwater storage and transmissivity to wells completed within the formation. The implications of Table 4-1, below, are that by stepping out five or possibly ten miles north of the North Recreation Area, wells capable of between 300 and possibly even 500 gpm might be developed. It is estimated that five new wells at one mile intervals could supply 1.5 million gallons per day to a system connected to the City of Rock Springs.

A. Figure 4-4 indicates in a general schematic way the direction of the grain size variations. However, it must be noted that these changes are **gradational**.
THREE POINT SOLUTION
FOR DIP AND STRIKE
ON TOP OF
ERICSON FM. OBSERVATION #1
+4841

CITY OF ROCK SPRINGS
TEST WELL LOCATIONS
SEC. 20 T18N R105W
SWEETWATER COUNTY
WYOMING

FIGURE 4-3
H.C.M., W.G. 4-5-86
Schematic Map of Generalized Grain Size Distribution within the Ericson Fm. in Southwestern Wyoming

FIGURE 4-4
**TABLE 4-1**

**ERICSON FORMATION**

Parameters and Potentials

<table>
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<tr>
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<th>CRS AREA SOUTH OF ROCK SPRINGS</th>
<th>NRS AREA NORTH OF ROCK SPRINGS</th>
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<tr>
<td>Transmissivity</td>
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<td>2050</td>
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<tr>
<td>Storage Coefficient</td>
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<td>0.000055</td>
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<tr>
<td>Recommended Long-term Pumping Rate/Well</td>
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<td>200 GPM</td>
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SELECTED REFERENCES


SECTION 5

PHASE II

PUMPING TEST ANALYSES AND PROJECTED WELL DRAWDOWNS, ERICSON FORMATION, ROCK SPRINGS AREA, WYOMING

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PHASE II *
PUMPING TEST ANALYSES AND PROJECTED WELL DRAWDOWNS.
ERICSON FORMATION, ROCK SPRINGS AREA.
WYOMING

INTRODUCTION

Bishop, Brogden & Rumph was retained by Johnson-Fermelia and Crank, Inc., to analyze data from two phases of pumping tests of the upper sandstone member of the Ericson Formation on the west flank of the Rock Springs Uplift, and to determine the probable drawdowns of the potentiometric head of the aquifer at various times after the start of operation of proposed wells. The purpose of the study was to determine if the Ericson Formation in the vicinity of Rock Springs, Wyoming, can sustain the continuous operation of a well field that can produce water of suitable quality for a supply for Rock Springs. The first phase involved the analyses of two pumping tests of existing wells north and west of Rock Springs, and was completed in March, 1984. This second phase comprised construction of a production well and an observation well located about 5 miles southwest of Rock Springs, one pumping test, and the analysis of the results of the test. Phase II occurred in late 1985 and early 1986.

The basic data for this study is almost entirely from data provided by Johnson-Fermelia and Crank, Inc. and Harold Mosher, consulting geologist. The data consisted of records of the pump test results, well details, and a brief description of the hydrogeologic setting. No field data or site-specific published data were collected by Bishop, Brogden & Rumph, Inc.

SUMMARY

The Phase I testing program was centered about 1 mile west and 3-1/2 miles north of Rock Springs. The Upper Ericson aquifer in this area has a transmissivity of about 2000 gallons per day per foot and was determined

* Please Note: All references to "Bitter Creek" in this Section shall be read as "Little Bitter Creek".
to be capable of supporting a well field that would produce 600 gallons per minute.

The Phase II testing program was centered about 3 miles west and 4 miles south of Rock Springs. The geology in this area is more complex than that in the Phase I area. The transmissivity of the Upper Ericson aquifer in the Phase II area is about half of that in the Phase I area. The Phase II test well is capable of a long-term pumping rate of 150 gallons per minute, and it is possible but not certain that additional wells could be pumped in the vicinity. The overall potential yield of the Phase II area depends on available recharge to the outcrop zone. Geologic conditions in the Phase II area are so complex that further wells will have to be drilled and evaluated individually.

LOCATION

The area studied is on the west flank of the Rock Springs Uplift extending westward from the outcrop of the Ericson Formation, about 5 miles southwest of Rock Springs. The pumped and observation wells are located in the southeast quarter of Section 20, Township 18 North, Range 105 West, Sweetwater County, Wyoming. Figure 1 shows the well locations.

GENERAL HYDROGEOLOGIC CONDITIONS

The Ericson Formation dips westerly from its outcrop at a rate of about 17 degrees and is overlain by about 1500 feet of Cretaceous and Tertiary rocks in the area of the pumping test, about 5000 feet west of the outcrop. An electric log of an oil well, to the south of the pumping-test area in Section 7, T19N, R105W, shows the lower sandstone member of the Ericson Formation about 310 feet thick overlain by about 145 feet of shale overlain by the upper sandstone member about 310 feet thick. The section above and below the Ericson Formation includes numerous shale beds which create a confining layer. The log indicates that the upper and lower sandstone members of the Ericson Formation are similar lithologically.
The Ericson Formation in the study area is believed to be thinner than the thickness indicated by the oil well log. The pumped well was drilled through about 205 feet of Upper Ericson Formation and the observation was drilled through about 215 feet of Upper Ericson Formation. Probably neither hole penetrated the entire Upper Ericson Formation.

The upper sandstone member of the Ericson Formation in the pumping test well produces water of suitable quality for municipal use, approximately 800 parts per million of total dissolved solids. Farther to the west, the Ericson aquifers produce water of poor quality. It is considered likely that in places where the upper sandstone member contains water of good quality, the lower sandstone member will contain water of similar but slightly poorer quality. The quality of contained water in the Ericson aquifers is best near the outcrop and becomes poorer with distance from the outcrop.

Numerous faults are mapped in the general area encompassed by this study, and the effects of faulting were observed in the analysis of the pumping test data. Major faults appear to act as barrier boundaries to the aquifer.

From the static water level data of the pumping and observation wells in Section 20, the potentiometric surface of the upper Ericson aquifer appears to be nearly horizontal at an elevation of about 6300 feet. In this case, the water table in the upper Ericson aquifer also would be at 6300 feet elevation and would be located at about the elevation of Bitter Creek in the subcrop area in the valley of Bitter Creek. Bitter Creek probably is a recharge source for the Ericson Formation but the magnitude of the recharge is not known.

Figure 1 shows the assumed locations of several faults and the potential line of recharge from Bitter Creek.
PUMPING TEST ANALYSES

One pumping test was run in Section 20, Township 18 North, Range 105 West, in January 1986. A pumping well and an observation well were drilled for the purpose of the test.

Observation Well

The observation well was located in Section 20, 1224 feet west of the east section line and 1318 feet north of the south section line. It was started on September 12, 1985 and completed on October 4, 1985. The well was drilled to 1810 feet, cemented in to 1585 feet (top of Ericson Formation), and completed with slotted casing from 1585 to 1800 feet.

Production Test Well

Difficulties were encountered in drilling the first production test well which was started on October 6, 1985. This hole was eventually abandoned on November 16. A new hole was started on November 17, 1985, and completed the following month. Casing of 8-5/8 inch diameter was set to 1620 feet with a 5-1/2 inch open hole to 1810 feet. The final well location is in Section 20, 1398 feet west of the east section line and 1006 feet north of the south section line.

Test Equipment

Water levels in both production and observation wells were measured with "In-Situ" pressure-sensitive transducers with electronic recorders, and also with electric sounding lines. Discharge of the pumping well was controlled by a gate valve and flow was measured by a piezometer and orifice, supplemented by a totallizing-flow meter.
Test Operations

The test was started on January 3, 1986, with a step-drawdown test followed by recovery measurements. The results of this test indicated that 170 gallons per minute was a sustainable pumping rate for further testing. Readings of water levels were taken in both pumped and observation wells.

On January 7, 1986, a seven-day, constant-rate pumping test at 170 gallons per minute was started. Water levels were observed in both pumping and observation wells throughout the test and during the following recovery period. The pumping test continued until January 14, 1986, when the pumping was stopped. Water levels were measured until January 27, 1986.

During the test, weather conditions frequently were poor and considerable difficulty was encountered in maintaining the desired pumping rate. However, examination of the plotted drawdown curve of the pumped well shows that after the initial adjustment period, the pumping rate was maintained with no more than about a two-percent variation except for insignificant, short-term fluctuations.

Test Data

The test data obtained from the automatic transducers and from the electric sounding lines were integrated, stored in computer memory, and printed in the form of graphic drawdown curves. The data were internally consistent and formed a coherent pattern that could be reliably analyzed.

The constant rate pumping test data were excellent and defined the aquifer characteristics so well that no attempt was made to use the step drawdown test data, which is much less suitable for determining aquifer characteristics and boundaries.
Several methods of analysis were used for different purposes. As a beginning, the drawdown readings from both the “In-Situ” transducers and the electric sounding lines were placed on a common datum and stored in an IBM PC computer. At this time, the difference in length of the horizontal and slope (along the aquifer) distances between the pumped well and the observation well was determined to be insignificant.

As a second step, the field data were plotted by the computer on a log-log scale. The observation well data made a far simpler pattern than the pumped well data. As a consequence, the observation well data were analyzed first.

The observation well time-drawdown data were analyzed by means of a Dumble and Cullen model. This model utilizes the basic Theis method and image well theory. The program permits the rapid generation of theoretical time-drawdown data for a variety of T and S values and boundary conditions, and the ability to numerically or graphically compare these theoretical curves to the field-drawdown data curves on a print-out or monitor screen. The theoretical curves can be readily and rapidly adjusted by varying the input data to obtain a precise match with the field data curves. The ability of the computer system to quickly treat data gives the operator the capability to investigate a large number of field conditions, thereby affording a greater insight into the applicability of a solution.

The time-drawdown data from the observation well were very consistent and were readily matched with theoretical curves to determine aquifer parameters. These data defined a typical artesian drawdown curve, Figure 2, of the basic Theis type with one barrier boundary indicated. Aquifer characteristics were:
OBSERVATION WELL
PUMP TEST DATA

THEORETICAL DRAWDOWN CURVE FOR:
T=928 gpd/ft
S=0.0002
r=357 ft
WITH ONE AQUIFER BOUNDARY
AT 1750 FT

PLOTTED DIFFERENTIALS

FIELD DATA POINTS

THEIS CURVE WITHOUT
BOUNDARY (MATCH
INDICATES NO FURTHER
BOUNDARY EFFECTS)

DIFFERENTIAL DUE TO
EFFECT OF BOUNDARY

TIME IN MINUTES FROM BEGINNING OF TEST

FIGURE 5-2
The theoretical curve matched the field-data curve very closely with the boundary effect showing at about 300 minutes.

The aquifer characteristics from the observation well analysis were used as guidance in the analysis of the pumped well data. The pumped well data drawdown plot defines an artesian drawdown curve, Figure 3, showing early-time effects of casing storage (Popodopulas and Cooper curves) and late-time effects of the barrier boundary. Aquifer characteristics were:

- Transmissivity 928 gallons per day per foot
- Storage Coefficient 0.00002
- Distance to Boundary 2000 feet

The theoretical curve matched the field-data curve very closely when an effective well radius of 1.5 feet was used. The deviation of field data below the typical Theis curve in the first minute represents the effects of much or most of the water coming from the well casing and not the aquifer. The field data from 1 minute to 10 minutes shows the transition from casing storage being of major significance to the time casing storage effects become insignificant; minor adjustments of flow rate can also be seen. The effect of the barrier boundary can be seen beginning at about 2000 minutes.

The recharge data from both observation and pumping well were found to be in conformity with the aquifer characteristics determined from the drawdown data.

No other boundary effects or partial penetration effects could be seen on the field data plots. The effect of the water table in the Ericson Formation near Bitter Creek could not be observed because the water-table area is about a mile from the wells and the effect during the seven days of pumping would be so minor in comparison to the total drawdown that it would not be differentiated from other drawdown effects.
PRODUCTION WELL PUMP TEST DATA

THEORETICAL DRAWDOWN CURVE FOR:
- T = 928 gpd/ft
- S = 0.0002
- r = 1.5 ft

WITH ONE AQUIFER BOUNDARY AT 2000 FT

DIFFERENTIAL DUE TO EFFECT OF BOUNDARY

THEIS CURVE WITHOUT BOUNDARY

FIELD DATA POINTS

FIELD DATA PLOTS BELOW THEORETICAL CURVE BECAUSE OF CASING STORAGE EFFECT

TIME IN MINUTES FROM BEGINNING OF TEST

FIGURE 5-3
Geologic Implications of Test Results

A series of faults trending west-southwest are recognized in the Cretaceous and older beds to the east of Bitter Creek. These faults are not readily observed in the younger beds west of Bitter Creek, but their alignments can be inferred from geomorphic evidence.

A major fault of this type passes north of the wells, Figure 1, at a distance corresponding to the barrier boundary identified in the test data analyses, about 1750 to 2000 feet. This fault interrupts the Ericson Formation near the wells. Two similar probable faults pass south of the wells, a relatively minor one at about 3000 feet distance and a major one at about 5000 feet distance. These are so distant from the wells that they were not detected as barriers by the seven-day test.

A water table undoubtedly exists in the Ericson Formation in or near the Bitter Creek valley. This water table will have the effect of a recharge boundary under long continued pumping. The magnitude of the recharge effect will depend on whether Bitter Creek actively recharges the aquifer, as appears likely, or whether the effect is limited to the lesser effect of the coefficient of yield (0.15+/−) at the water table in contrast to the much smaller artesian storage coefficient (0.00002) elsewhere in the aquifer.

Modelling of Potential Drawdowns

In order to estimate future potentiometric head conditions in the aquifer, a modified Prickett-Lonnquist finite-difference model was used. Four sets of conditions were modelled. Under all conditions, the existing production well was modelled as pumping 150 gallons per minute, the fault about 1/3 mile north of the wells was modelled as a barrier, the Ericson Formation was modelled as extending about 19,000 feet west-southwest of the wells, aquifer characteristics were modelled as uniform throughout the aquifer and as shown from the test results, and a water table was modelled.

A-5 - 11
5000 feet east of the wells. The variable conditions modelled are: with and without recharge from Bitter Creek; and the southern boundary being the probable major fault about 5000 feet south of the wells or being an east-west line 14,000 feet south of the wells. Table 1 shows the variable conditions.

**TABLE 1**

<table>
<thead>
<tr>
<th>Model</th>
<th>Figures</th>
<th>Recharge From Bitter Creek</th>
<th>Southern Boundary</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>4 and 5</td>
<td>None</td>
<td>Fault</td>
</tr>
<tr>
<td>B</td>
<td>6 and 7</td>
<td>Maximum</td>
<td>Fault</td>
</tr>
<tr>
<td>C</td>
<td>8 and 9</td>
<td>None</td>
<td>14,000 Feet South</td>
</tr>
<tr>
<td>D</td>
<td>10 and 11</td>
<td>Maximum</td>
<td>14,000 Feet South</td>
</tr>
</tbody>
</table>

The results of the modelling of potential drawdowns after 20 and 50 years of continuous pumping are shown in Figures 4 through 11. The figures show the location of the existing production well, assumed boundaries, applicable contours of drawdowns of potentiometric head in the aquifer, the projected pumping level in the production well, and the projected drawdown at the western model boundary.

The model results are shown in Table 2. The pumping drawdown is the pumping water level in the pumped well assuming an "effective radius" of 1.5 feet as determined in the analysis of the pumping test.
MODEL A
50 YEARS OF PUMPING

FIGURE 5-5
MODEL B
20 YEARS OF PUMPING

FIGURE 5-6
MODEL B
50 YEARS OF PUMPING

FIGURE 5-7
MODEL D
20 YEARS OF PUMPING
MODEL D
50 YEARS OF PUMPING

FIGURE 5-11
<table>
<thead>
<tr>
<th>Model</th>
<th>Years of Pumping</th>
<th>Pumping Drawdown in Well Boundary (feet)</th>
<th>Drawdown at West Boundary (feet)</th>
<th>Approximate Inflow Ratio, East to West</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>20</td>
<td>694</td>
<td>405</td>
<td>7 to 1</td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>835</td>
<td>545</td>
<td>10 to 1</td>
</tr>
<tr>
<td>B</td>
<td>20</td>
<td>448</td>
<td>157</td>
<td>8 to 1</td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>452</td>
<td>167</td>
<td>10 to 1</td>
</tr>
<tr>
<td>C</td>
<td>20</td>
<td>464</td>
<td>56</td>
<td>4 to 1</td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>550</td>
<td>103</td>
<td>4 to 1</td>
</tr>
<tr>
<td>D</td>
<td>20</td>
<td>393</td>
<td>24</td>
<td>4 to 1</td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>394</td>
<td>25</td>
<td>4 to 1</td>
</tr>
</tbody>
</table>

Models A and B are considered to represent more realistic conditions than Models C and D. Models A and B are bounded on the north and south by faults; the effect of the fault to the north was noted during the pumping test and the fault boundary to the south is very likely considering the geologic aspect. The aquifer is modelled as extending about 3 miles to the west of the well; changing this extent would make little difference to the model results.

Model A - This model includes no recharge from Bitter Creek, but the coefficient of yield used (0.15) may be slightly high which would have the same effect as a very small amount of recharge. In this model, the large majority of the water pumped comes from dewatering the aquifer at the water table at the east boundary as the water table is lowered. As the water table is lowered, the water table moves down-dip and the model indicates a movement of about 200 feet downward and almost 1000 feet to the west in 50 years. After 50 years, the pumping water level is almost 850 feet below static water level; however, the available drawdown is
about 1500 feet. A second well could be installed about 3500 feet south of the production well, but in 50 years of pumping, the drawdowns at both wells would be very deep at about 1400 feet. Even in 20 years, drawdowns would be about 1100 feet with two wells.

**Model B** - This model is identical to Model A except that Bitter Creek is assumed to provide sufficient recharge to the aquifer to prevent lowering of the water table. This is considered to be an optimistic assumption and actual conditions are likely to fall somewhere between those of Model A and Model B. After 20 years of pumping, the pumping drawdown at the well is about 450 feet. There is very little change between 20 and 50 years because by 20 years almost all the water is coming from recharge from Bitter Creek, and aquifer conditions are essentially stable. If a second well were installed about 3500 feet south of the existing well, pumping drawdowns in each would be about 600 feet under modelled conditions.

Models C and D are identical, respectively, to Models A and B except that the southern fault boundary is removed and the aquifer extends uninterrupted 19,000 feet south of the pumping well, and the water table and recharge boundaries are extended the same distance southwest. This is considered unlikely in the geologic environment.

**Model C** - The pumping drawdowns at 20 and 50 years are about 2/3 of those of Model A. Under these conditions, additional wells could be added to the south at about 4,000-foot spacings but pumping drawdowns would reach about 1100 feet.

**Model D** - Considering the more favorable aquifer conditions of Model D, there is comparatively little reduction compared to the drawdowns of Model B. In Model D, additional wells could be added at 3,000-foot spacing to the south and pumping drawdowns would not be much more than 600 feet in 50 years.
**Water Quality**

The quality of water from the production well is satisfactory for municipal use. Table 2 shows that the ratio of water of good quality (from the outcrop area to the east) to the water of poor quality (from the west) varies from 10-to-1 to 4-to-1 as modelled. Thus, over the long term, water from the production well or wells will improve in quality.

**RECHARGE FROM BITTER CREEK**

The effects of recharge from Bitter Creek could not be observed during the pumping test because the distance was too great in relation to the time of pumping and interference effects from faulting. Some recharge is considered very likely and tests could be made to confirm this matter.

Various tests are possible including comparisons of streamflow measurements along the subcrop area of the Ericson Formation, response of the water table in the Ericson Formation (as measured in a shallow observation well) to changes in stream level, or a pumping test of a well in the Ericson Formation relatively near the stream. If the production well is put to use, a monitor well near Bitter Creek would indicate the presence or absence of recharge after a number of years.

If Bitter Creek is recharging the Ericson aquifer, the recharge effect could be increased by ponding water in the creek bed to prevent loss of the water downstream, to provide recharge water when the stream is dry, and to provide additional head on the recharging water. Such ponding can be done by installing check dams which could be normal surface dams or subsurface dams extending from the land surface to underlying bedrock. Subsurface dams have the advantage of minimizing evaporation and offering little or no impediment to surface flow. They can be constructed by means of a slurry trench, sheet piling or a buried concrete wall.
The outcrop zone of the Upper Ericson Formation is approximately as wide as the alluvial flood of Bitter Creek valley. Careful surface geologic mapping might show whether the Upper Ericson or the Lower Ericson or part of both under the alluvium of Bitter Creek. The actual position of the alluvium in relation to the members of the Ericson Formation has major significance to potential recharge from Bitter Creek.

RECOMMENDATIONS AND CONCLUSIONS

The test results indicate that the existing well can be pumped for over 50 years at a rate of about 150 gallons per minute without exceeding practical limitations on drawdown. This is true whether significant recharge occurs from Bitter Creek or not. However, recharge is an important consideration as to the potential for expansion of a well field in the area. Determination and quantification of recharge is recommended, as is enhancement of potential recharge from Bitter Creek.

From the existing well test data, it appears to be practical to install and operate additional wells in the general area of the test well. The area is geologically complex and each well must be drilled and evaluated on an individual basis. Wells drilled less than a mile away may be in a considerably different hydrogeologic environment.

The well test did not show any partial penetration effects, indicating that the test data is independent of any contribution from the Lower Ericson aquifer. The Lower Ericson is likely to yield amounts of water roughly equivalent to those that can be produced from the Upper Ericson, but a test of the Lower Ericson would be necessary to confirm the supposition. The quality of water in the Lower Ericson would have to be investigated, but probably is suitable for municipal use in the area east of the test well.
The water quality parameters of pH, conductance and temperature were measured and recorded during the pump testing with the use of portable meters. Water samples were taken from the pump discharge and measured.

The results have been tabulated in Table 6-1 and plotted in Figures 6-1, 6-2, and 6-3. A comparison of the field measurements to the water quality testing performed by the Western Wyoming Community College Laboratory indicate that the filed pH and conductivity values are consistently low. The comparison are listed below:

<table>
<thead>
<tr>
<th>Time</th>
<th>pH</th>
<th>pH</th>
<th>Cond.</th>
<th>Cond.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mid-Test</td>
<td>6.3</td>
<td>8.56</td>
<td>1100</td>
<td>1300</td>
</tr>
<tr>
<td>End of Test</td>
<td>6.7</td>
<td>8.58</td>
<td>900</td>
<td>1300</td>
</tr>
</tbody>
</table>

Ambient temperatures during the performance of the pump testing ranged from -18°C to 2°C. Specifications for the field meters indicate that their operating range is 0°C to 45°C. The cold ambient temperatures seem to have affected the accuracy of the instruments.

Table 6-2 lists the Environmental Protection Agency Maximum Contaminant Levels (MCL) and the Secondary Maximum Contaminant Levels (SMCL). Also included for
<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Time (hrs)</th>
<th>Temp. (°C)</th>
<th>pH</th>
<th>Cond.</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. 1</td>
<td>0.0</td>
<td>20°</td>
<td>5.9</td>
<td>1175</td>
</tr>
<tr>
<td>No. 2</td>
<td>2.0</td>
<td>22°</td>
<td>7.3</td>
<td>1050</td>
</tr>
<tr>
<td>No. 3</td>
<td>2.6</td>
<td>22°</td>
<td>7.5</td>
<td>1050</td>
</tr>
<tr>
<td>No. 4</td>
<td>4.0</td>
<td>23°</td>
<td>7.3</td>
<td>1200</td>
</tr>
<tr>
<td>No. 5</td>
<td>6.0</td>
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<td>7.5</td>
<td>1175</td>
</tr>
<tr>
<td>No. 6</td>
<td>8.0</td>
<td>22°</td>
<td>7.5</td>
<td>1200</td>
</tr>
<tr>
<td>No. 7</td>
<td>16.0</td>
<td>22°</td>
<td>6.4</td>
<td>1100</td>
</tr>
<tr>
<td>No. 8</td>
<td>24.0</td>
<td>---</td>
<td>---</td>
<td>----</td>
</tr>
<tr>
<td>No. 9</td>
<td>48.0</td>
<td>22°</td>
<td>6.4</td>
<td>1100</td>
</tr>
<tr>
<td>No. 10</td>
<td>72.0</td>
<td>22°</td>
<td>6.3</td>
<td>1100</td>
</tr>
<tr>
<td>No. 11</td>
<td>96.0</td>
<td>22°</td>
<td>6.5</td>
<td>1100</td>
</tr>
<tr>
<td>No. 12</td>
<td>120.0</td>
<td>21.4°</td>
<td>6.42</td>
<td>820</td>
</tr>
<tr>
<td>No. 13</td>
<td>144.0</td>
<td>21.4°</td>
<td>7.0</td>
<td>1075</td>
</tr>
<tr>
<td>No. 14</td>
<td>167.0</td>
<td>22°</td>
<td>6.7</td>
<td>900</td>
</tr>
</tbody>
</table>
PUMP TEST pH DATA
FIGURE 6-1
PUMP TEST CONDUCTANCE DATA

FIGURE 6-2

(HOURS OF TIME)

(MICROMHOS/CM)
PUMP TEST TEMPERATURE DATA

FIGURE 6-3
comparison purposes in Table 6-2 are the water quality testing results at the mid point of the 7 day pump test and at the end of the 7 day pump test.

Most all testing parameters are under the E.P.A. limits. There are two exceptions: pH and T.D.S. (total dissolved solids). As a point of reference, these two particular E.P.A. standards, among others, are SMCLs. These SMCLs were established as guidelines for the individual States with the intent that the States could establish higher or lower levels appropriate to their particular circumstances. Basically, the SMCL deals with aesthetic quality of the drinking water and at this time the State of Wyoming has no established SMCLs.

The pH values of the water is slightly higher than the E.P.A. recommended limit, 8.58 as compared to 8.5. The solubility of ions in water is strongly influenced by its pH value. As a general rule, water with low or acidic pH values tends to be corrosive or aggressive to certain materials while high pH values or basic water tends to be scale forming. There are many instances in Wyoming where water with a pH value of 8 to 9 has been used as potable supply and pH alone cannot be used as a judge of water quality because of the influence of other parameters.

The other parameter exceeding the SMCL is T.D.S.: 964 mg per liter as opposed to 500 mg per liter. This parameter is similar to pH in that it is an aesthetic quality and could affect the taste of the water. High T.D.S. levels in water generally exhibit excessive hardness, taste,
mineral deposition or corrosion. As with pH there are many instances of water with a comparable level of T.D.S. being used for human consumption.

Two other parameters of note for which no limits have been established are sodium (Na) and alkalinity. The sodium level is moderately high which may have some affect on people with hypertension and heart problems who are on a low sodium diet.

The other parameter is alkalinity, which is a measure of the water's buffering capacity. The alkalinity level is moderate. Waters with high alkalinity levels are generally unpalatable.

Water from this well appears to be of good quality, acceptable for human consumption. In fact, the Town of Wamsutter's municipal wells exhibit very similar testing parameters.

In comparison to the water produced from the Ericson Formation at the Paul J. Wataha Recreation Complex, some notable differences are evident. This groundwater does not have the iron or manganese problem as does the Recreation Complex groundwater. Conversely, the groundwater at the Recreation Complex is much lower in levels of sodium, bi-carbonate, alkalinity and pH.
## Table 6-2

**WATER QUALITY**

<table>
<thead>
<tr>
<th></th>
<th>CRS #1A MID-TEST</th>
<th>CRS #1A END OF TEST</th>
<th>E.P.A. MAXIMUM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mg/l</td>
<td>Mg/l</td>
<td>Mg/l</td>
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<tr>
<td><strong>CATIONS</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Na</td>
<td>380</td>
<td>380</td>
<td></td>
</tr>
<tr>
<td>K</td>
<td>5.9</td>
<td>5.9</td>
<td></td>
</tr>
<tr>
<td>Mg</td>
<td>0.7</td>
<td>1.9</td>
<td></td>
</tr>
<tr>
<td>Ca</td>
<td>3.9</td>
<td>2.8</td>
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</tr>
<tr>
<td><strong>ANIONS</strong></td>
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<tr>
<td>Cl</td>
<td>210</td>
<td>210</td>
<td>250</td>
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<tr>
<td>F</td>
<td>0.98</td>
<td>1.4 to 2.4</td>
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<tr>
<td>NO₃-N</td>
<td>0.10</td>
<td>10</td>
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<tr>
<td>SO₄²⁻</td>
<td>115</td>
<td>116</td>
<td>250</td>
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<tr>
<td>CO₃⁻</td>
<td>12</td>
<td>14</td>
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<tr>
<td>HCO₃⁻</td>
<td>440</td>
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<td><strong>TRACE ELEMENTS:</strong></td>
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<tr>
<td>As</td>
<td>L.T. 0.0005</td>
<td>0.05</td>
<td></td>
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</tr>
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<tr>
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<td>L.T. 0.05</td>
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<tr>
<td>Pb</td>
<td>L.T. 0.5</td>
<td>0.05</td>
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<td>L.T. 0.05</td>
<td>0.05</td>
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<tr>
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<td>L.T. 0.0005</td>
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<tr>
<td>Se</td>
<td>L.T. 0.0005</td>
<td>0.01</td>
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<td>SiO₂</td>
<td>11</td>
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<td>L.T. 0.05</td>
<td>0.05</td>
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</tr>
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<td>pH</td>
<td>8.56</td>
<td>8.50</td>
<td>6.5 to 8.5</td>
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<td>1300</td>
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</tr>
<tr>
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6 - 5
PHYSICAL SETTING

The Little Bitter Creek drainage basin is situated southwest of Rock Springs along the west flank of the Rock Springs Uplift. Prominent topographic features included in the basin are Quaking Aspen Mountain on the east side at an elevation of 3,600 feet and Miller Mountain at the south end with an elevation of 8,500 feet. Little Bitter Creek is an intermittent stream that flows from south to north, parallel to the formational strike.

The basin exhibits the following characteristics:

1. The basin's length of approximately 28 miles is almost five times the average width of 6 miles.

2. The basin area is approximately 147 square miles.

3. Elevations range from 6,100 feet at the confluence with Bitter Creek to 8,600 feet on Quaking Aspen Mountain. Mean elevation is approximately 7,300 feet.
4. One sub-basin of note is present within the total basin. Cedar Creek contributes approximately 21 square miles, or 14% of the total area. This sub-basin is located on the east side of the main basin. Elevations range from 6,500 feet at the mouth of the sub-basin to 8,600 feet on Quaking Aspen Mountain. Mean elevation is approximately 7,400 feet.

CLIMATE

The climate is arid to semi-arid and is typically of the climate in the southern half of the Green River Basin. An extreme range of temperatures throughout the year is prevalent. Bureau of Reclamation measurements of pan evaporation indicates that the gross evaporation in this area averages approximately 33 inches. Low relative humidity, ample sunshine and prevailing southwesterly winds contribute to the high rate of evaporation.

Figure 7-1 is the Average Annual Precipitation-Distribution Map of the Little Bitter Creek Basin. Also included on this map are average annual runoff rates. As indicated on the map, the precipitation ranges from about 8 inches at the lower northerly elevations to about 9 inches at the higher southerly and easterly elevations. Average annual runoff rates approximate 0.4 inches for the basin.
LEGEND

- **P** - AVERAGE ANNUAL PRECIPITATION RATE
- **R** - AVERAGE ANNUAL RUN-OFF RATE
- **G** - GAGING STATION
- **-** - LITTLE BITTER CR. DRAINAGE BASIN BDRY.

PRECIPITATION RUN-OFF MAP

FIGURE 7-1
Average monthly temperatures for the City of Green River at an elevation of 6089 feet, Rock Springs Airport at an elevation of 6741 feet, and the City of Kemmerer at an elevation of 6958 feet have been plotted on Figure No. 7-2. As can be noted, the plots indicate that in the spring the monthly average temperature is below freezing in March and above freezing in April. In the fall, the monthly average is above freezing in October and at or below freezing in November.

This data has been adapted from the National Oceanic and Atmospheric Administration.

STREAMFLOW MEASUREMENTS

The earlier aquifer pump test and report completed in March 1984, by Johnson-Fermelia and Crank, Inc. indicated that as Little Bitter Creek flows directly across the Ericson Formation direct groundwater recharge is a definite possibility. Four gauging stations were established along Little Bitter Creek in an effort to correlate stream flows and groundwater recharge or storage. These gauging stations are located on Figure 7-1.

The gauging stations were strategically located to monitor flows of Little Bitter Creek before flowing across the Ericson Outcrop, monitor contribution of Cedar Creek to Little Bitter Creek, and monitor flows after Little Bitter Creek leaves the Ericson Outcrop.
AVERAGE MONTHLY TEMPERATURES
ROCK SPRINGS—GREEN RIVER—KEMMERER

FIGURE 7-2
Gauging Station No. 4 was located in Section 4, Township 16 North, Range 105 West, upstream of the Ericson Outcrop. Gauging stations No. 2, 3, and 2C were located at the confluence of Little Bitter Creek and Cedar Creek in Section 21, Township 17 North, Range 105 West. Number 3 was located upstream of the junction on Little Bitter Creek. No. 2 downstream of the junction on Little Bitter Creek and No. 2C on Cedar Creek. Gauging stations No. 1 was located downstream of the point where Little Bitter Creek leaves the Ericson Outcrop in Section 9, Township 18 North, Range 105 West.

Stream flows were measured periodically from April 1985 through November 1985. At this time measurements were suspended because of stream freeze-up. Measurements were restarted in March 1986 and completed by April 1, 1986. Methodology of the streamflow measurements included the use of a "Teledyne Gurley" pygmy current meter to determine segmental cross-section velocities and horizontal and vertical measurements to determine the segmental cross-sectional areas of the streamflow.
STREAMFLOW ANALYSES

Stage-discharge relationships were plotted for each of the individual gauging stations. (Figures 7-3 through 7-6.) Curves were fitted to the field data by the use of a regression series. The $r^2$ value is an indication of how well the curve fits the data. The $r^2$ values range from 0.16 to 0.93, with one curve, Figure 7-5, exhibiting a particularly good fit. This stage-discharge relationship is for gauging station No. 3 and has an $r^2$ value of 0.93.

The other three curves have $r^2$ values that indicate a less positive curve fit. This is caused by shifting control, physical changes in the stream channel, or measurements taken in a different portion of the stream channel.

These curves typify a narrowly incised channel at low flows. At higher flows, approaching peak runoff, the width of the channel increases markedly.

The stream flows for Little Bitter Creek were measured for approximately a year on an intermittent basis. Generally accepted standards for streamflow records are a 5 year continuous record to establish average annual runoff and 10 years of continuous record to establish peak
Figure 7-3

GAGING STATION No.1 — STAGE DISCHARGE

\[
\begin{align*}
\text{Discharge in C.F.S.} & \quad \text{(Stage in ft.)} \\
0 & \quad 0 \\
1 & \quad 1 \\
2 & \quad 2 \\
3 & \quad 3 \\
4 & \quad 4 \\
5 & \quad 5 \\
6 & \quad 6 \\
7 & \quad 7 \\
8 & \quad 8 \\
9 & \quad 9
\end{align*}
\]

\[
\begin{align*}
r^2 & = 0.88 \\
a & = 5.73 \\
b & = 0.20
\end{align*}
\]
Figure 7-4

GAGING STATION No. 2  STAGE DISCHARGE

DISCHARGE IN C.F.S.

\[ r^2 = 0.16 \]
\[ a = 10.09 \]
\[ b = 0.09 \]
\[ r^2 = 0.93 \]
\[ a = 7.81 \]
\[ b = 0.31 \]

GAGING STATION No. 3  STAGE DISCHARGE

FIGURE 7-5
GAGING STATION No. 4 — STAGE DISCHARGE

FIGURE 7-6

\( r^2 = 0.53 \)
\( a = 8.25 \)
\( b = 0.15 \)
flow characteristics. The streamflow gauging does not fit this criteria. Analyses of the gauging have been made in an attempt to determine trends and characteristics of the drainage basin.

The adjusted stream gauging data is tabulated in Table No. 7-1. Little Bitter Creek has been divided into two reaches. Reach I is between Gauging Station No. 4 and Gauging Station No. 3. Reach II is between Gauging Station No. 2 and Gauging Station No. 1. These reaches are shown on Figure No. 7-1.

Flows from March through June of the water year through Reach I indicate that the stream is effluent, or in other words, the groundwater contributes to the stream flow. Through July and August this reach of stream becomes influent, in other words, the stream flow contributes to the groundwater. Reach I becomes effluent in late September and continues until it freezes in the winter.

Flows through Reach II approximate the effluent-influent cyclic nature of Reach I. There is some evidence that from October to freeze-up time stream flows are stabilized from the effluent-influent point of view.

Hydrographs have been constructed for each of the gauging stations. (Figures 7-7 through 7-11.) Each hydrograph exhibits the same shape and characteristics. Two peaks are evident, one in spring of the year, and


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<th>GS#3</th>
<th>Loss or Gain</th>
<th>GS#2C</th>
<th>GS#3 *2C</th>
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* Peak had not reached G.S. #1.
GAGING STATION No. 2—HYDROGRAPH

FIGURE 7-8
one in the late fall of the year. The spring peak is considerably larger than the fall peak, which indicates that the majority of the streamflow throughout the year is from snowmelt in the higher elevations of Little Bitter Creek Basin. The smaller peak in the fall is due mainly to rainstorm runoff. It can also be noted that spring runoff is of much longer duration than the fall.

As noted previously in the CLIMATE subsection, data developed from the National Weather Service indicates that the average annual runoff for the Little Bitter Creek Basin is approximately 0.4 inches. With the basin area of approximately 147 square miles and runoff of 0.4 inches, the average runoff for the stream would be about 3150 acre feet. This figure appears high when compared to the estimated Salt Wells Creek Basin average runoff of 2,000 to 3,000 acre feet per year. (1) Salt Wells Creek drains a basin of over 500 square miles that abuts on the south of the Little Bitter Creek Basin.

Calculations based on the streamflow measurements of Little Bitter Creek indicate that for the water year 1985, a total of 400 to 500 acre feet were

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discharged. Because of the intermittent measurements, undoubtedly the peak flows from snowmelt or hard rainstorms have been missed. With this in mind, it is estimated that the average annual runoff from Little Bitter Creek is in the neighborhood of 1000 acre feet. By way of comparison, the City of Rock Springs uses approximately 2100 acre feet per year consumptive use. This is over twice the estimated capacity of the Little Bitter Creek Drainage.

CONCLUSIONS

The data collected, because of its short duration and intermittent nature, does not afford the opportunity for complete analysis. Collected data was analyzed and reviewed to develop trends and characteristics of the Little Bitter Creek drainage basin.

Streamflow measurements indicate that there is definitely groundwater recharge or storage. It is not clear whether the recharge is bank storage (alluvium recharge) or direct recharge to the Ericson Formation.

With total Little Bitter Creek runoff projected as direct recharge to the Ericson, the total water supply would not satisfy the water needs of the City of Rock Springs. A water source could be developed that would supplement the water needs of the City of Rock Springs.
APPENDICES

A-1 THROUGH A-7
APPENDIX A-1

ARCHAEOLOGICAL CLEARANCE
July 24, 1985

Harold Mosher
Johnson-Fermelia & Crank, Inc.
1515 Ninth Street
Rock Springs, WY 82901

RE: 85-WWC-63

Dear Mr. Mosher:

Enclosed is our report dealing with the results of the recent cultural resource inventory for the proposed City of Rock Springs Water Wells in Section 20, T18N, R105W, Sweetwater County, Wyoming.

We have recommended that archaeological clearance be granted to your project with the stipulation that all impacts to the potentially eligible archaeological site (48SW6246) be avoided.

If we can be of further assistance, please give us a call. Thank you.

Sincerely,

Steven D. Creasman
Director

James A. Head
Staff Archaeologist

JAH:vf

Enclosure

CC: Carmel Swidler, BLM
Affidavit of Cultural Resource Inventories

Project Reference No.: 85-WMC-63

Report Date: July 24, 1985

Project Identification: Two observation water well locations and access roads for the City of Rock Springs through Johnson-Fermelia & Crank.

Project Location: Observation Water Well No. 1 is located in the SE1SE1SE1NW1SE1 of Section 20, T18N, R105W, Sweetwater County, Wyoming (Figure 1). Water Well No. 2 is in the NE1SE1NE1SW1SE1 of Section 20, T18N, R105W. Water Well No. 2A (alternate) is in the SE1NE1NE1SW1SE1 of Section 20, T18N, R105W. Access Road No. 1 begins at an existing service road for an overhead power line in the NW1NW1NE1SE1SE1 of Section 20, then travels westerly through the NW1NW1SE1SE1 and the SW1SW1NE1SE1 to the Observation Well No. 1 location. From here, the first proposed access travels to the south through the NE1NW1SW1SE1 of Section 20 to the originally proposed Water Well No. 2 location. Access Road No. 2 begins at the City of Rock Springs landfill in the E1SE1 of Section 20. The proposed route then travels through the S1SE1NE1SW1, the S1SW1NW1SE1, and the S1SE1NE1SE1 to the Water Well No. 1 location. Access Road No. 3 begins at the service road for the overhead power line in the NW1NW1SE1NE1SE1 of Section 20, then travels westerly through the SE1NW1NE1SE1 and the NW1SW1NE1SE1 to the proposed Water Well No. 1 location. All three proposed access roads will share the same corridor between the No. 1 and No. 2 locations. Lands in Section 20, T18N, R105W are public lands administered by the Bureau of Land Management, Rock Springs District, Salt Wells Resource Area.

Description of Undertaking: The proposed project will involve the drilling of two water wells to observe subsurface water flow. There will be minimal construction at the well locations; the surface flora and about 6 inches of soil will be removed to level the pad. Drilling will be done by a large truck-mounted drill with small cutting pits to be constructed at each location. These pad areas are expected to be less than 100 ft x 100 ft. An improved access road will be constructed to approach the water wells.

Field Crew: James Head

Date of Survey: July 17 and 18, 1985

File Search, A prehistoric and historic file search was conducted by Mary Hopkins of the Wyoming State Archives, Museum, and Historical Department, Cultural Records Section, on July 17, 1985. This file search disclosed that the following archaeological work has taken place in Section 20, T18N, R105W.

In 1975, the Bureau of Land Management recorded site 48SW5383, a small scatter of flakes and fire-cracked rock in a sand blowout. Legal
Figure 1. Map indicating the proposed City of Rock Springs developments in Sec. 20, T18N, R105W, Sweetwater County, Wyoming. The approximate location of the CRS Landfill (existing), an overhead power line and site 48SW6246 are also shown. This map is a portion of USGS Quad: Kanda, 7.5 min., dated 1961, photorevised 1978.
Eligibility is unknown for this small campsite.

In 1979, Archaeological Services-Western Wyoming College (AS-WWC) performed a Class II inventory of the East 1/4 of Section 20 for the Bureau of Land Management and Rock Springs-Kemmerer Expansion. Four prehistoric sites were recorded.

48SW1537 (Kanda 32) W1SE1, Section 20, T18N, R105W. This open camp consists of flakes, retouched flakes, core fragments, a biface, biface fragments, a possible projectile point fragment, and some fire-cracked rock. Soil is shallow and underlain by sandstone bedrock. The site is listed as not eligible to the National Register of Historic Places (NRHP).

48SW1538 (Kanda 33) NE1SE1SE1SE1 of Section 20, T18N, R105W. This small lithic scatter is composed of flakes and core reduction material of moss agate and red, gray, and brown quartzite. The site is washing out of a small dune located on the side of a gravel terrace. A recommendation of ineligible was given to the site.

48SW1539 (Kanda 34) NW1SE1NE1SE1 of Section 20, T18N, R105W. This open camp lies in a small dune area under a north-south power line about 1 mi east of Highway 373. It includes core reduction material with flakes of brown, gray, and green quartzite. There is wide staining (a probable coal seam) containing fire-cracked rock and core reduction material. The site was recommended as ineligible to the NRHP.

48SW1540 (Kanda 35) SE1NW1SE1NE1 of Section 20, T18N, R105W. This open camp is found in a drainage on the west slope of a prominent ridge. The site consists of red, gray, and white quartzite flakes, a reddish-brown quartzite core, and white, brown, black, and red chert flakes which are representative of all stages of chipped stone tool manufacture and maintenance. Widely scattered fire-cracked rock was also observed. Clearance was recommended for this ineligible site.

In 1981, Science Application examined the route of a proposed power line for Pacific Power and Light running north to south to the E1/4 of Section 20, T18N, R105W. They rerecorded 48SW1539 (Kanda 34) and found two isolates and an ineligible site (48SW350), a lithic scatter composed of two small artifact clusters. No further information was given.

Environment: The project area is located in the central portion of the Rock Springs Uplift. More specifically, all proposed development is found in an upland area consisting of a series of interfluvial ridges which trend to either the north or the west. These ridges are separated by a series of unnamed intermittent water courses which eventually empty into Bitter Creek.

Soils in the project area are regolithic, sandy silts atop sandstone bedrock. Eolian sand is present on the lee side of certain north trending ridges. Flora in the study area is part of the Upper...
Sonoran life zone. Observed vegetation includes juniper, sagebrush, rabbitbrush, four-wing saltbush, shadscale, hopsage, prickly pear cactus, wild buckwheat, winterfat, wheatgrass, and Indian ricegrass. Modern impacts in the area include an overhead power line running north to south just east of the project area and the City of Rock Springs landfill just to the west.

Survey Methods: On July 17, 1985, one archaeologist from AS-WCC was accompanied by Harold Mosher, a ground water consultant for Johnson-Fermelia & Crank. The archaeologist examined two of the proposed access roads and three proposed water well locations. All proposed developments were examined utilizing parallel transects spaced not over ten meters apart. The area inventoried for each of the proposed water well locations was approximately 200 ft x 200 ft. A similar methodology was used to examine Access Roads No. 1 and 2 (approximately 700 ft x 1600 ft long respectively) with one archaeologist walking the entire route for an access corridor approximately 100 ft wide. Access Road No. 3 was examined by two archaeologists on July 18 walking parallel sinuous transects along the flagged center line. A total of approximately 23.5 acres of public lands was examined at the Class III level.

Results: A single prehistoric site containing both historic and prehistoric components (48SW6264) was recorded during the examination of the proposed development.

Archaeological Site

Site Number: 48SW6246 (Kanda 53) Figure 2
Location: NE1/4 SW1/4 SE1 of Section 20, T18N, R105W
Site Type: Open camp
Elevation: 1966 m (6450 ft)
Vegetation: Vegetation observed at the site includes juniper, big sagebrush, rabbitbrush, spineless hopsage, snakeweed, prickly pear cactus, wild ryegrass, wheatgrass, and Indian ricegrass.
Description: This multicomponent site is found near the northern end of a wide interfluvial ridge among both the sandy portions atop the ridge and on the western slope around sandstone outcrops. The prehistoric portion of the site is marked by a wide scatter of flakes of various materials (Table 1), several inferred hearth locations, and large mammal (antelope?) bone. There are at least two flake concentration areas on the site, one bone concentration (Figure 2), and a general flake and bone scatter over the site.

The historic portion exhibits several pieces of bottle glass, some of which has been melted, some undiagnostic bottle bases, wire, buttons, a lard can, and at least one hearth.
Artifacts Observed and Collected: A single observational transect was performed at the site, and material types and reduction stages represented are listed in Table 1. As well, three artifacts were collected. These are Ka53.1, a Late
Figure 2. Plan and contour map of site 48SW6246 (Kanda 53). Small x indicates collected prehistoric artifact locations. Site datum is on the proposed center line stake for CRS No. 2. The alternate location (CRS No. 2a) is located to the north of the site boundaries. The flake concentrations (2) are denoted by angle lines.
Table 1. Material Types and reduction stage noted on transect of 48SW6246 (60 m long at 305° from datum).

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<th>Translucent Chert</th>
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<td>Tertiary Flake</td>
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<td>Tertiary Flake Fragment</td>
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<td>5</td>
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<td>Tertiary Microflake</td>
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<td>1</td>
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<td>4</td>
<td>1</td>
<td>2</td>
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<td>Bifacial Thinning Flake</td>
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<td></td>
<td>1</td>
<td>1</td>
<td>3</td>
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<td></td>
<td>8</td>
</tr>
<tr>
<td>Shatter/Chunks</td>
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<td>3</td>
<td></td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
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<tr>
<td>Totals</td>
<td>73</td>
<td>6</td>
<td>3</td>
<td>2</td>
<td>51</td>
<td>14</td>
<td>9</td>
<td>5</td>
<td>3</td>
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<td>166</td>
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</table>
A prehistoric projectile point of translucent chert, Ka53.2, a complete bifacial preform of opaque chert, and Ka53.3, a partial final biface of fine-grained quartzite. All three artifacts are illustrated in Figure 3. In addition, three final biface fragments (one each of translucent chert, opaque chert, and medium-grained quartzite) were noted but not collected. Both burned and unburned mammal bone was noted as well as several possible hearth locations.

A small historic trash scatter consisting of several broken bottles, wire, and a lard can was noted within the prehistoric site boundaries.

**Evaluation:** The site is recommended as being potentially eligible for nomination to the NRHP. This recommendation is based upon the potential for intact cultural deposits to be extant in the 60+ cm of natural eolian sand deposits at 48SW6246.

**Impacts:** Harold Mosher, upon being informed the site had been recommended as being potentially eligible to the NRHP, decided to relocate the proposed water well to the north and thereby avoid impacts to this potentially eligible property. Since this alternate location is outside the surface boundaries of the site (and off the interfluvial ridge) no adverse impacts are anticipated at 48SW6246.

**Summary:** A Class III archaeological inventory was performed on approximately 23.5 acres of public lands for two proposed water wells and three access roads by AS-WWC. A single prehistoric-historic archaeological site (48SW6246) was located during this examination. Since the archaeologist was accompanied by Harold Mosher, a ground water consultant, the proposed well location was relocated to avoid impacts to this potentially eligible site.

**Recommendations:** The proposed water well location (CRS No. 2) was moved well away from 48SW6246 and will have no effect on the site. No cultural items were found in the relocation area, the proposed location of CRS No. 1, or any of the three proposed access roads.

If the alternate well location is utilized to avoid impacts to 48SW6246 and all development can be restricted to examined areas, it is recommended that cultural resource clearance be granted for the project.

**Certification:** This project was conducted under Federal Cultural Resource Use Permit No. 010-WY-C084 and complies with Executive Order 11593 and other applicable historic preservation laws.

Steven D. Creasman  
Principal Investigator

James A. Head  
Staff Archaeologist
Figure 3. Potentially diagnostic artifacts collected during inventory of site 48SW6246. a. Ka53.1 - Late Prehistoric projectile point, b. Ka53.2 - Chert preform, c. Ka53.3 - Partial final biface. All artifacts are drawn to scale.
APPENDIX A-2

DRILL SAMPLE LOGS
DRILLING SAMPLE LOG
CRS Observation Well

Sweetwater County, Wyoming
September, 1985

20- 30 Sandstone, gray w/ white interstitial filling, soft scattered black grains, some brown limonite staining, very fine to silt size, angular to subangular

30- 40 As above

40- 50 As above, plus some medium grains.

50- 60 Sandstone, white, tan & gray, very fine to silt, some limonite stain w/ trace mica, pore filling white to yellow

60- 70 As above w/ some coal & trace of shale, greenish gray

70- 90 Clay, gray

90- 110 Clay, greenish gray, some coal

110- 160 Clay, silty, gray. Trace coal

160- 170 Clay as above, some siltstone, gray, trace coal

170- 180 Clay & Coal as above

180- 200 Shale, silty, hard, dark gray to green

200- 210 Shale, dark gray to green

210- 230 Sandstone, white to gray, fine to very fine w/ white (tripolitic) pore filling. Some coal & trace shale gray

230- 250 Siltstone to very fine sandstone, gray, trace coal

250- 300 Shale brownish gray. Some coal & streaks siltstone, light to dark, hard

300- 330 Sandstone, white to gray, very fine grained, soft. Some w/ minute laminae of coal. Some shale, silty bluish gray

330- 360 As above but s/ general tannish aspect

360- 380 Shale, silty, bentonitic

380- 390 Sand, clear to white, very fine to fine, micaceous, pyritic. Some shale, bluish-gray, soft

390- 400 Shale, bluish-gray, soft

400- 420 Shale, silty, gray. Trace coal

420- 430 Bentonite, light gray, slightly silty, very soft

430- 440 Same as above w/ much coal & trace fine sand

440- 460 Shale, greenish-gray, hard

460- 470 Shale as above w/ traces sandstone very fine

470- 480 Shaley silt, white to gray

480- 520 Sandstone, gray, very fine to fine, pyritic, angular to subangular

520- 530 Sandstone as above. Some siltstone brown, some clay, gray

530- 550 Mixture as above

550- 600 Siltstone, light to dark gray, pyritic, some sandstone, very fine, subangular to subrounded, trace siltly shale, gray and bentonite, white. (Appears to be sequence of thin bedded, alternating streaks of sandstone, siltstone & shale)

600- 620 Sandstone, white, pyritic, very fine to fine grained. Some slightly silty

620- 660 Interbedded siltstone, very fine sandstone and silt shale, gray. Traces of coal
660-700 Sandstone, light to dark gray, very fine, soft to medium soft, subangular to sub-rounded w/ trace calcite & pyrite
700-710 Bentonite, white, gummy w/ trace of coal
710-720 Sandstone, silty, white, very fine grained
720-740 Siltstone, shaley, light & dark gray w/ few plant re-
740-785 Sandstone, gray, very fine grained, very hard (twisted off)
785-795 Shale, slightly silty, light gray, soft
795-810 Coal w/ trace of shale, as above
810-830 Shale, gray, slightly silty w/ trace of bentonite, white
830-840 Sandstone, gray, very fine to silty, hard. Some shale as above
840-860 Interbedded shales as above and siltstones, gray, hard
860-910 Sandstone, very silty, gray. Trace shale, light to dark gray
910-920 Shale, slightly silty, gray
920-960 Sandstone, light gray, very fine to silty, hard
960-980 Interbedded siltstone, gray, some shale, dark gray, some sandstone as above
980-1000 Sandstone and siltstone and shale interbedded as above
1000-1010 Siltstone, gray, shaley. Some coal
1010-1040 Sandstone, silty, light gray "salt and pepper" w/ trace pyrite, hard
1040-1050 Sandstone, very fine to fine, gray
1050-1060 Sandstone, light gray to white, soft bentonitic
1060-1070 Sandstone, soft, salt & pepper, very fine to fine, angular to subangular, tripolitic pore filling, porosity poor
1070-1110 Sandstone as above. Some shale medium gray to brownish w/ carbonaceous plant casts & trace of coal
1110-1130 Shale & siltstone, all colors of gray to brownish & greenish
1130-1160 Siltstone, white to light gray, some sandstone, limonite stained, tan, soft, very fine-grained
1160-1170 Sandstone, white, salt & pepper, very fine grained. Some shale, brownish and trace coal
1170-1180 Sandstone, siltstone & shale in about equal parts
1180-1190 Sandstone, silty, gray, hard
1190-1200 Coal, shale & some sandstone as above
1200-1210 Shale, gray, light to dark, bentonitic
1210-1230 Sandstone, gray, very fine-grained, salt & pepper, sub-
angular, hard. Some shale, gray, silty, soft
1230-1250 Sandstone & shale as above
1250-1260 Sandstone as above
1260-1335 Siltstone, gray, soft to hard. Some shale, gray, soft
1280-1290 Siltstone, brown to gray, some free quartz grains, clear to white to tan, angular to rounded, very fine to medium-
grained
1290-1310 Siltstone, variegated w/ bentonite, some shale, gray to tan
1310-1330 Sandstone, siltstone & shale all light to dark gray, soft
1330-1345 Coal bed
1345-1380 Interbedded siltstones, gray & shales, dark gray. Trace sandstone, gray, salt & pepper
1380-1390 Sandstone, slightly silty, gray, salt & pepper, very hard
1390-1400 Shale, gray to dark brown, slightly silty
1400-1430 Shale, gray w/ interbedded siltstone, light gray
1430-1440 Shale, gray to brownish w/ streak coal
1440-1470 Shale, as above
1470-1480 Sandstone, gray, salt & pepper, very fine-grained, soft
1480-1500 Sandstone, some silty and some shale
1500-1510 Sandstone, as above
1510-1520 Shale, slightly silty, greenish-gray, soft
1520-1530 Sandstone, gray, very fine to fine, silty in part
1530-1560 Shale, gray, silty & some greenish, soft
1560-1585 Shale, very silty, greenish w/ some gray, soft
1585-1650 Sandstone, gray, salt & pepper, soft, very fine to fine-grained, angular to sub-angular, porosity and sorting poor to moderate w/ variable interstitial tripolite
Top Ericson fm.
1650-1750 Sandstone, as above
1750-1758 Sandstone, white, salt & pepper, very fine-grained, very hard, tightly cemented. Some siltstone, dark gray, very hard, slightly shaley
1758-1770 Siltstone, as above. Trace shale, silty, dark gray
1770-1800 Sandstone, gray, very fine to medium-grained, angular to rounded, sorting very poor, tightly cemented to few loose grains. Trace of residual tar in a few chips
1800-1810 Sandstone as above. Trace of shale, greenish to gray.

DRILLER’S TOTAL DEPTH: 1810’
LOG TOTAL DEPTH: 1805
<table>
<thead>
<tr>
<th>Interval</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>20---30</td>
<td>Sandstone, gray with white interstitial filling, soft scattered black grains, some brown limonite staining, very fine to silt size, angular to subangular.</td>
</tr>
<tr>
<td>30---40</td>
<td>As above.</td>
</tr>
<tr>
<td>40---50</td>
<td>As above, plus some medium grains.</td>
</tr>
<tr>
<td>50---60</td>
<td>Sandstone, white, tan and gray, very fine to silt, some limonite stain with trace mica, pore filling white to yellow.</td>
</tr>
<tr>
<td>60---70</td>
<td>As above with some coal and trace of shale, greenish gray.</td>
</tr>
<tr>
<td>80---90</td>
<td>Clay, gray.</td>
</tr>
<tr>
<td>90---100</td>
<td>Clay, greenish gray, some coal.</td>
</tr>
<tr>
<td>110-160</td>
<td>Clay, silty, gray. Trace coal..</td>
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<tr>
<td>160-170</td>
<td>Clay as above, some siltstone, gray, trace coal.</td>
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<tr>
<td>170-180</td>
<td>Clay and Coal as above.</td>
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<tr>
<td>180-200</td>
<td>Shale, silty, hard, dark gray to green.</td>
</tr>
<tr>
<td>200-210</td>
<td>Shale, dark gray to green.</td>
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<td>210-230</td>
<td>Sandstone, white to gray, fine to very fine with white (tripolitic) pore filling. Some coal and trace shale gray.</td>
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<tr>
<td>230-250</td>
<td>Siltstone to very fine sandstone, gray, trace coal.</td>
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<td>250-300</td>
<td>Shale brownish gray. Some coal and streaks siltstone, light to dark, hard.</td>
</tr>
<tr>
<td>300-330</td>
<td>Sandstone, white to gray, very fine grained, soft. Some with minute laminae of coal. Some shale, silty bluish gray.</td>
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<td>330-340</td>
<td>As above but some with general tannish aspect.</td>
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<td>340-350</td>
<td>Shale, light-dark gray, silty btc. (betonitic) Tr vf, soft sand.</td>
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<td>350-360</td>
<td>Sandstone, soft, s and p, pyritic, angular-subangular cl-frosted. Some shale, soft, gray, non-btc.</td>
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<td>360-370</td>
<td>Shale, gray to brownish-gray, silty, very carb (carbonaceous).</td>
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<tr>
<td>370-380</td>
<td>Coal and brownish carb shale.</td>
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<tr>
<td>380-390</td>
<td>Siltstone, gray, soft.</td>
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<td>390-410</td>
<td>Shale, light-dark gray. Some siltstone as above.</td>
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<td>410-420</td>
<td>As above with trace of coal.</td>
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<tr>
<td>420-430</td>
<td>Shale and siltstone as above, very btc.</td>
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<tr>
<td>430-440</td>
<td>As above with trace of sandstone, vfg (very fine grained), s &amp; p.</td>
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<td>440-470</td>
<td>Some coal, shale and siltstone as above.</td>
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<tr>
<td>470-480</td>
<td>Siltstone and vf sandstone, s &amp; p. Some shale, lt-dk gray.</td>
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<tr>
<td>480-490</td>
<td>Shale, dk gray to some lt. gray.</td>
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<tr>
<td>490-500</td>
<td>Shale as above with Tr coal.</td>
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<tr>
<td>500-510</td>
<td>Siltstone and some ss and vfg, abundant pyrite, Tr coal.</td>
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<tr>
<td>510-520</td>
<td>Siltstone and shale, btc, sli carb.</td>
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<td>520-550</td>
<td>Sandstone, gray, vfg. Some shale.</td>
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<td>550-560</td>
<td>Shale, gray, btc, silty. Tr. coal.</td>
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</table>
560-570  Shale, brownish, carb and some coal.
570-590  Shale, gray, sli silty v btc with Tr coal.
590-600  Shale as above, TR sandstone, vfg.
600-620  Shale, tannish to dk gray, hard.
620-630  Siltstone and Tr vf sandstone with Tr coal and silty shale, carb.
630-640  As above with incr vf sandstone.
640-650  As above.  Sandstone, v. pyritic.
650-660  Siltstone
660-670  Shale, gray, lt-dk, btc.  Some coal.
670-680  Shale as above.  Tr coal.
680-690  Shale as above.
690-700  Silt and shale, tannish, carb, Tr vf sandstone.
700-720  Shale, gray, carb with Tr silt.
720-730  Sandstone, soft, gray, s & p.
730-740  Sandstone, med-f, ang-subang, cl & frosted.
740-750  Siltstone and shaley silt, carb.
750-760  Shale, tannish, v carb.
790-800  Shale tannish, carb, sli btc.
800-820  Sandstone, hard, gray, vfg, some siltstone, pyr.
820-840  Shale, tannish, soft, v carb w/ coal part.
840-850  As above and some dk gray shale and coal.
850-880  Shale, lt-dk gray, soft to hard, some v btc.
880-900  Shale, dk gray, v carb w/ Tr coal.
900-910  Shale, lt tan, carb, btc.
910-920  As above becoming silty, btc.
920-930  Shale, gray w/ Tr coal.
930-940  Shale, gray, some silty.
940-950  Shale, gray, some tan, Tr coal.
950-960  Shale, tannish, v btc, soft.
960-980  Shale, gray, sli silty w/ Tr coal.
980-990  Shale as above, some siltstone Tr coal.
990-1000  Siltstone, soft, gray.  Some shale, gray btc.
1000-1030  Shale, gray, btc w/ Tr siltstone.
1030-1040  Siltstone and shale, gray.
1040-1050  Siltstone and shale, gray-tannish.  Some coal.
1050-1060  Shale, carb, Tr coal and siltstone, gray.
1060-1070  Siltstone w/ some sandstone, vfg.
1070-1080  Shale anc carb. siltstone.
1080-1090  Shale, grays, Tr siltstone.
1090-1100  Shale and siltstone, carb.
1100-1110  Silty shale, lt gray, v btc.
1110-1140  Sandstone, silty, lt gray, soft, sli s and p.
1150-1150  Shale, lt gray, moderately hard.
1150-1180  Siltstone, lt gray, v pyritic, sli carb.
1180-1190  Shaley silt, lt gray, carb.
1190-1200  Siltstone, lt gray, sli s and p.
1200-1210  Sandstone, white to gray, s and p, vf-silty, soft, porosity low.  Tr coal and shale, gray.
1210-1220  As above w/ some coal, Tr silty shale, gray.

A-2 -5
1220-1230 As above w/ some coal & btc strk (won't clean up).
1230-1260 Shale, some silty, gray to tan, carb.
1260-1270 Siltstone, lt gray, soft, carb. Some shale as above.
1270-1280 Shale as above, some siltstone as above.
1280-1300 Shale, gray, btc, w/ some coal and f silt.
1300-1310 Shale as above.
1310-1320 Shale, siltstone, carb, some coal.
1320-1330 Shale, gray to tannish w/ some coal.
1330-1340 Siltstone, gray, soft, carb, some shale as above.
1340-1350 Coal and shale, gray, soft.
1350-1360 Coal and shale and siltstone.
1360-1370 Shale, soft, tannish gray w/ Tr coal.
1370-1380 Siltstone, tannish gray w/ some coal.
1380-1390 Shale and siltstone, lt-dk gray, some coal.
1390-1410 As above w/ Tr pyrite.
1410-1420 Shale, tannish gray and coal.
1420-1430 Shale as above plus f siltstone, v hard.
1450-1460 Shale, siltstone and some coal.
1460-1470 As above w/ Tr sandstone, vfg, s and p.
1470-1480 Shale, v btc, Tr sandstone, vfg/
1480-1490 Shale, dk gray, soft.
1490-1500 Shale as above, some siltstone, carb.
1500-1520 Shale, hard, gray, some silty.
1520-1530 Sandstone, lt gray, vfg, soft, s and p, some silty and v hard.
1530-1540 Siltstone, soft, gray, btc, some shale, gray, Tr coal.
1540-1550 Siltstone and sandstone, carb, soft, btc. Some coal.
1550-1560 Shale, lt-dk (carb) gray. Some siltstone as above.
1560-1570 Siltstone, lt-dk gray, some shale as above.
1570-1580 Shale, lt-dk (carb) gray.
1580-1600 Shale and siltstone as above.
1600-1620 Sandstone, vfg, gray, s and p, ang-subang, soft.
1620-1640 As above w/ some dark carb shale and Tr coal.
1640-1650 Shale and siltstone, carb, Tr sandstone as above.
1650-1660 Sandstone as above w/ Tr coal.
1660-1680 Sandstone, lt gray, vfg to silt, s and p, ang-subang, much white pore filling.
1680-1690 Sandstone as above, but w/ few fg, v hard and soft. Porosity low.
1690-1770 Sand grains as above but loose; grains cl to sli milky qtz.

This well was abandoned with junk in the hole.
DRILLING SAMPLE LOG
CRS IA Production Well
Sweetwater County, Wyoming
September, 1985

20-  50 Sandstone, gray w/ white interstitial filling, soft scattered black grains, some brown limonite staining, very fine to silt size, angular to subangular
50- 100 Sandstone, white, tan & gray, very fine to silt, some limonite stain w/ trace mica, pore filling white to yellow
100- 120 Clay, greenish gray, some coal
120- 160 Clay, silty, gray. Trace coal
160- 180 Clay as above, some siltstone, gray, trace coal
180- 200 Shale, silty, hard, dark gray to green
200- 220 Shale, dark gray to green
220- 260 Sandstone, white to gray, fine to very fine w/ white (triplotic) pore filling. Interbedded w/ some coal & trace shale gray
260- 270 Siltstone to very fine sandstone, gray, trace coal
270- 290 Shale brownish gray. Some coal & streaks siltstone, light to dark, hard
290- 300 Sandstone, white to gray, very fine grained, soft. Some w/ minute laminae of coal. Shale, silty bluish gray
300- 320 Shale as above but w/ general tannish aspect
320- 380 Shale, silty, bentonitic
380- 390 Sand, clear to white, very fine to fine, micaceous, pyritic. Some shale, bluish-gray, soft
390- 410 Shale, bluish-gray, soft, silty
410- 420 Shale, silty, gray. Trace coal
420- 430 Silt, light gray, bentonitic, very soft
430- 450 Same as above w/ much coal & trace fine sand
450- 470 Shale, greenish-gray, hard, silty
470- 480 Shaley silt, white to gray, soft
480- 530 Sandstone, gray, very fine to fine, pyritic, angular to subangular. Some siltstone brown, some clay, gray
530- 610 Siltstone, light to dark gray, pyritic, some sandstone, very fine, subangular to subrounded, trace silty shale, gray and bentonite, white. (Appears to be sequence of thin bedded, alternating streaks of sandstone, siltstone & shale)
610- 650 Sandstone, white, pyritic, very fine to fine grained. Some slightly silty
650- 670 Interbedded siltstone, very fine sandstone and shale, silty, gray, soft. Traces of coal
670- 710 Sandstone, light to dark gray, very fine, soft to medium soft, subangular to sub-rounded w/ trace calcite & pyrite
710- 720 Sandstone, silty, white, very fine grained
720- 750 Siltstone, shaley, light & dark gray w/ few plant remains. Some shale, dark gray
750- 770 Shale, silty, light to dark gray w/ thin streaks, siltstone, gray and coal
770- 790 Sandstone, gray, very fine grained, very hard
790-810 Shale, slightly silty, light gray, soft
810-820 Coal w/ trace of shale, as above
820-840 Interbedded shale, gray, slightly silty w/ trace of bentonite, white. Sandstone, gray, very fine to silty, hard. Some shale as above
840-895 Interbedded shales as above and siltstones, gray, hard. Shale, slightly silty, light to dark gray
895-920 Sandstone, very silty, gray. Trace shale, light to dark gray
920-930 Shale, slightly silty, gray
930-970 Sandstone, light gray, very fine to silty, hard. Interbedded siltstone, gray, some shale, dark gray, some sandstone as above
970-1000 Sandstone and siltstone and shale interbedded as above
1000-1010 Siltstone, gray, shaley. Some coal
1010-1040 Sandstone, silty, light gray "salt and pepper" w/ trace pyrite, hard
? Sandstone, very fine to fine, gray
1040-1050 Shale, light gray to white, soft bentonitic
1050-1110 Sandstone, soft, salt & pepper, very fine to fine, angular to subangular, triplonitic pore filling, porosity poor. Some shale medium gray to brownish w/ carbonaceous plant casts & trace of coal
1110-1130 Shale & siltstone, all colors of gray to brownish & greenish
1130-1180 Siltstone, white to light gray, some sandstone, limonite stained, tan, soft, very fine-grained
1180-1210 Sandstone, white, salt & pepper, very fine grained. Some shale, brownish and trace coal
1210-1220 Shale, gray, light to dark, bentonitic
1220-1230 Sandstone, gray, very fine-grained, salt & pepper, subangular, hard. Some shale, gray, silty, soft
1230-1250 Sandstone & shale as above
1250-1290 Siltstone, gray, brown, soft to hard. Some shale, gray, soft. Some free quartz grains, clear to white to tan, angular to rounded, very fine to medium-grained
1290-1310 Siltstone, variegated w/ bentonite, some shale, gray to tan
1310-1350 Siltstone & shale all light to dark gray, soft
1350-1365 Coal bed
1365-1380 Shale, dark to light gray w/ trace coal. Trace sandstone, very fine-grained, gray to light tan.
1380-1390 Shale and coal, brownish soft silty shale
1390-1400 As above w/ very bentonitic material, gray
1400-1410 Sandstone, fine to very fine, gray, salt & pepper, some medium-grained
1410-1430 Shale as above, some brownish lignitic, trace coal. Streak bentonite. Some sandstone, very soft, very fine-grained
1430-1450 Sandstone as above. Some shale
1450-1490 Shale and silty shale, light to dark gray
1490-1500 Siltstone
1500-1520 Silty shale w/ some coal
1520-1540 Siltstone, gray w/ some shale. Trace coal
1540-1550 Silty sandstone, gray, soft, salt & pepper. Trace
coal

1580-1600 Silty shale, carbonaceous partings, light tan & gray to dark gray, soft shale, gray, bentonitic, some silt, slightly tan

1600 TOP OF ERICSON

1600-1620 Sandstone, gray, salt & pepper, subangular to sub-rounded, moderate porosity, some pyrite, very fine to medium-grained, sorting poor

1620-1630 As above

1630-1640 As above but w/ greater % fine to medium

DRILLER’S TOTAL DEPTH:

LOG TOTAL DEPTH: 1640’
APPENDIX A-3

ELECTRIC AND GAMMA RAY LOGS
APPENDIX A-4

DETAILED WELL HISTORY
<table>
<thead>
<tr>
<th>DAY</th>
<th>OBSERVATION WELL #1</th>
</tr>
</thead>
<tbody>
<tr>
<td>1985</td>
<td><strong>Showed K.P. Drilling Company prepared well locations. Surface conductor 12 1/4&quot; hole drilled and 8 5/8&quot; casing cemented at 22'.</strong></td>
</tr>
<tr>
<td>9/12</td>
<td>1</td>
</tr>
<tr>
<td>9/13</td>
<td><strong>Dug pits and miscellaneous rig-up activities. Drilled 5 5/8&quot; pilot hole to 320'.</strong></td>
</tr>
<tr>
<td>9/14</td>
<td>2</td>
</tr>
<tr>
<td>9/15</td>
<td><strong>Drilled to 783' and twisted off at top of bit. Started fishing.</strong></td>
</tr>
<tr>
<td>9/16</td>
<td>4</td>
</tr>
<tr>
<td>9/17</td>
<td><strong>Milled and pushing on junk, fishing with magnet and reached 809 feet.</strong></td>
</tr>
<tr>
<td>9/18</td>
<td>5</td>
</tr>
<tr>
<td>9/19</td>
<td><strong>Drilled to 1535 feet. Estimated Ericson Formation top at 1585 feet.</strong></td>
</tr>
<tr>
<td>9/20</td>
<td>6</td>
</tr>
<tr>
<td>9/21</td>
<td><strong>Drilled to 1740' at 1100 hours and shut down to wait on more drill pipe. Resumed drilling at 1900 hours and reached 1765' by 2400 hours.</strong></td>
</tr>
<tr>
<td>9/22</td>
<td>7</td>
</tr>
<tr>
<td>9/23</td>
<td><strong>Drilled to 1810 feet at 0830 hours started logging. Ran Resistivity S.P. and Density-Gamma Caliper logs. Completed logging at 1300 hours. Driller started reaming hole to 7 7/8&quot;.</strong></td>
</tr>
<tr>
<td>9/24</td>
<td>8</td>
</tr>
<tr>
<td>9/25</td>
<td><strong>Reaming at 520' at 1530 hours.</strong></td>
</tr>
<tr>
<td>9/26</td>
<td>9</td>
</tr>
<tr>
<td>9/27</td>
<td><strong>Reaming at 760' at 1000 hours. (Mosher left for Casper. JFC to monitor operations).</strong></td>
</tr>
<tr>
<td>9/28</td>
<td>10</td>
</tr>
<tr>
<td>9/29</td>
<td><strong>Reaming at 1000 feet at 1200 hours.</strong></td>
</tr>
<tr>
<td>9/30</td>
<td><strong>Reaming at 1400 feet at 1430 hours.</strong></td>
</tr>
<tr>
<td></td>
<td>11</td>
</tr>
<tr>
<td></td>
<td><strong>Dropped slip in hole while coming out for new bit. Old bit at 510 feet. Had to shoot off drill collars at 450 feet. Went in with overshot. (Mosher returned from Casper).</strong></td>
</tr>
<tr>
<td></td>
<td>12</td>
</tr>
<tr>
<td></td>
<td><strong>Fishing and milling on junk.</strong></td>
</tr>
<tr>
<td></td>
<td>13</td>
</tr>
<tr>
<td></td>
<td><strong>Fishing and milling on junk. Pushed junk to 1493 feet.</strong></td>
</tr>
<tr>
<td></td>
<td>14</td>
</tr>
<tr>
<td></td>
<td><strong>Milling and fishing with magnet. Still at 1493 feet.</strong></td>
</tr>
<tr>
<td></td>
<td>15</td>
</tr>
<tr>
<td></td>
<td><strong>Milling and fishing at 1510 feet.</strong></td>
</tr>
<tr>
<td></td>
<td>16</td>
</tr>
<tr>
<td></td>
<td><strong>Milling and fishing - still at 1510 feet. (Mosher to Casper. JFC to monitor operations).</strong></td>
</tr>
</tbody>
</table>
1985 DAY OBSERVATION WELL #1

9/30 19 Pushed junk down to 1600 feet.
10/01 20 Reaming at 1570 feet.
10/02 21 Milling at 1720 feet.
10/03 22 Reamed to 1760 feet.
10/04 23 Reamed to 1810 feet. Set and cemented 1799 feet 4 1/2" casing. Bottom 200 feet slotted. Commenced developing well with air.
10/05 24 Finished development, caught water samples. Released rig at 1430 hours.

END OF OBSERVATION WELL OPERATIONS.

1985 DAY PRODUCTION WELL #1 (ABANDONED)

10/06 25 Rig moved to Production Well #1 site (382' south). Observation Well static water level 124'.
10/07 - 10/10 Contractor shut down operations to give crews time off.
10/11 26 Contractor on site. Drilled set and cemented 40 feet of 16" surface casing.
10/12 27 Drilled plug at 1200 hours. Made 6 1/4" pilot hole to 200 feet at 1830 hours.
10/13 28 Drilling at 640' at 2145 hours.
10/14 29 Drilling at 900' at 1400 hours.
10/15 30 Drilling at 1350' at 1800 hours.
10/16 31 Drilling at 1550' at 1600 hours.
10/17 32 Drilled to 1820 feet, total depth ordered at 1420 hours. Ran Resistivity - S.P. and Density Gama-Caliper logs.
10/18 33 Completed logging at 0200 hours. Reamed with 12 1/4" bit to 200 feet at 1500 hours.
10/19 34 Reaming at 550 feet at 1400 hours.
10/20 35 Reaming at 750 feet at 0900 hours.
10/21 36 Reaming at 930 feet at 0730 hours. Shut down at 1020 feet, 1430 hours, for repairs to mud pump.
10/22 37 At 0800 hours, reaming at 1165'. Bit twisted off at about 1200 feet at 1530 hours called out Acme Tool for fishing tools.
10/23 38 On second trip fished bit out at 0330 hours. Reamed to 1250 feet at 1630 hours. Pulled bit, need replacement. None on site.
10/24 39 Reaming with 7 7/8" bit at 1590 feet.
1985    DAY    PRODUCTION WELL #1 (ABANDONED)

10/25    40    Reaming at 1370 feet.
10/26    41    At 1600 hours lost 7 7/8" pilot bit at 1450 feet. Started fishing.
10/27    42    Fishing. Reamed hole to 12 1/4" to top of bit at 1460 feet at 1430 hours.
10/28    43    Fishing at 1830 hours.
10/29    44    Milling and fishing at 1460 feet.
10/30    45    Milling and fishing at 1510 feet at 0800 hours.
10/31    46    Milling and fishing at 1510 feet. (0800 hour report.)

11/01    47    As above.
11/02    48    As above.
11/03    49    As above.
11/04    50    As above but "almost thru junk".
11/05    51    Milling and fishing at 1510 feet.
11/06    52    As above. Tried 7 7/8" overshot without success.

11/08    54    Preparing to "shoot". At 1047 hours fired shot. Shook rig, no mud blowout. At 2030 hours, fishing with magnet. No recovery except mill filings.
11/09    55    Tried 8" I.D. overshot. Failed to get fish.
11/10    56    Milling and fishing.
11/11    57    At 0200 hours recovered 6" sector of bit and large amount of filings. Pushed junk to 1550 feet.
11/12    58    Milled and pushed fish to 1560'. Felt piece of bit in wall at 1510 feet. Pushed it down to 1540 feet with 10" bit.
11/13    59    Set cement plug 1550-1450 feet. Completed cementing at 1545 hours.
11/14    60    At 1500 hours, waiting on cement.
11/15    61    At 1000 hours. Top of plug at 1460 feet. Drilled 2 feet of top of plug with 12 1/4" bit. Went in with 6 1/4" bit to attempt to side track hole around plug and junk. Drilled thru plug to fish at 1550 feet. Suspected cement had not set up sufficiently.
11/16    62    Driller to abandon hole. New location selected 65 feet east.
11/17    63    Used Rat Hole rig to drill 16" hole and set and cemented 40' of 14 inch surface casing.

A-4 - 3
11/18  64  Commenced drilling 6 1/4" pilot hole.
11/19  65  At 0800 hours drilling at 440 feet; 1500 hours at 660 feet.
11/20  66  At 0800 hours drilling at 910 feet.
11/21  67  At 0800 hours drilling at 1245 feet.
11/22  68  At 0800 hours drilling at 1245 feet.
11/23  69  Drilled to 1640 feet. Casing point to be 1620 feet with 20 feet of rat hole for cavings. Logged 6 1/4" hole with Resistivity - S.P. tools only. Top of Ericson at 1606 feet. Began reaming to 12 1/4" hole.
11/24  70  No report.
11/25  71  At 0800 hours, reaming at 540 feet.
11/26  72  At 0800 hours reaming at 710 feet.
11/27  73  At 0800 hours reaming at 820 feet.
11/28  74  No report.
11/29  75  No report.
11/30  76  At 1000 hours reaming at 1190 feet.
12/01  77  No report.
12/02  78  At 0800 hours reaming at 1380 feet.
12/03  79  At 0800 hours reaming at 1425 feet.
12/04  80  At 0800 hours reaming at 1480 feet. At 1500 hours reaming at 1510 feet.
12/05  81  At 0800 hours reaming at 1560 feet. At 1430 hours at 1573 feet.
12/06  82  At 0800 hours at 1600 feet with 12 1/4" hole. At 1620 foot total depth and tripped out of hole at 1320 hours. Casing crew rigged up at 1630 hours. Started running 8 5/8" casing at 1745 hours; completed at 2235 hours with bottom of casing at 1620 feet. Commenced cementing at 2400 hours.
12/07  83  Cementing 8 5/8" casing at 1620 feet completed at 0400 hours. Contractor cleaning up drill sites at 1500 hours. NOTE: Filled abandoned well bore with bentonite chips and poured 10 foot cement surface seal.
12/08  84  Waiting on cement.
12/09  85  At 0800 hours reaming 6 1/4" rat hole to 7 7/8" at 1735 feet.
12/10  86  At total depth of 1805 feet at 0400 hours. Started development with air between 800 and 1000 feet.
12/11 - 12/15  Waiting on cement and contractor days off.
12/16  87  At 1500 hours contractor on site working on equipment. Observation Well statid water level 125.6 feet. Production well 117.2 feet.
Cement bond log run to 1653 feet. Bottom of casing at 1620 feet. Pushed on chunk of cement at 1657 feet and chunk fell to bottom at 1800 feet. Released rig.

END OF CRS DRILLING AND COMPLETION OPERATIONS.
APPENDIX A-5

TEST PUMP CONFIGURATION
FIG. A-5.1 FUEL TANK & GENERATOR IN FOREGROUND
PRODUCTION TEST WELL IN BACKGROUND

FIG. A-5.2 PRODUCTION TEST WELL FOREGROUND
MONITOR WELL PAD AND ACCESS ROAD BACKGROUND
FIG. A-5.3 PRODUCTION TEST WELL FOREGROUND GENERATOR BACKGROUND

FIG. A-5.4 PRODUCTION TEST WELL
APPENDIX A-6

PUMP TEST OPERATIONS
PUMP TEST OPERATIONS

HISTORY OF CRS WELL PUMP TESTING

Engineer in Charge - Harry L. Moore, P.E. and L.S.
Johnson-Fermelia Co. Inc.
Rock Springs, Wyoming

Hydrogeologists - Harold C. Mosher
Martha Horn
Harold Mosher & Associates
Mills, Wyoming

Testing Contractor - Warco Pump Company
Rock Springs, Wyoming

Note: In addition to mechanical "M-Scope" water level measurements, "In-Situ" transducer/recording computer equipment loaned by the Wyoming Water Development Commission was used on both the pumped well and the observation well.

<table>
<thead>
<tr>
<th>Date</th>
<th>Day</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>12/31/85</td>
<td>1</td>
<td>Contractor set 75 HP, 6&quot; submersible pump and motor.</td>
</tr>
<tr>
<td>1/02/86</td>
<td>2</td>
<td>Generator arrived and electrical connections made, pump rotation checked.</td>
</tr>
</tbody>
</table>

A-6 - 1
<table>
<thead>
<tr>
<th>Date</th>
<th>Day</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/03/86</td>
<td>3</td>
<td>Commenced initial &quot;Step Test Pumping&quot; at 1210 hours at 235 gpm. After 30</td>
</tr>
<tr>
<td>(Clock Time</td>
<td></td>
<td>minutes excessive drawdown indicated so reduced flow rate to 200 gpm.</td>
</tr>
<tr>
<td>1210-1931</td>
<td></td>
<td>From 1400 hours, 110 minutes into test, until 1931 hours, when pump</td>
</tr>
<tr>
<td>hours)</td>
<td></td>
<td>was shut off, had difficulty controlling flow due to freezing to ice</td>
</tr>
<tr>
<td></td>
<td></td>
<td>of water in piezometer. Computer times and water levels were read out</td>
</tr>
<tr>
<td></td>
<td></td>
<td>and recorded manually from 56 minutes into test to 427 minutes, the shut</td>
</tr>
<tr>
<td></td>
<td></td>
<td>off time. In process of preparation for shifting to Recovery Phase,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>suspected lost computer recorded data so pulled transducer and ran in</td>
</tr>
<tr>
<td></td>
<td></td>
<td>spare M-Scope to read recovery water levels.</td>
</tr>
<tr>
<td>1931 hrs</td>
<td></td>
<td>Pump off, started recovery readings with M-Scope.</td>
</tr>
<tr>
<td>1/04/86</td>
<td>4</td>
<td>Took periodic water level recovery readings with M-Scope and checked</td>
</tr>
<tr>
<td>to</td>
<td>to</td>
<td>against computer readouts.</td>
</tr>
<tr>
<td>1/07/85</td>
<td>7</td>
<td></td>
</tr>
</tbody>
</table>

A-6 - 2
<table>
<thead>
<tr>
<th>Date</th>
<th>Day</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/07/86</td>
<td>7</td>
<td>Monitored 7-day drawdown test at 170 gpm. Took conductivity and pH measurements and collected water samples for analysis. Had problems reading and maintaining constant flow rate due to freezing of piezometer.</td>
</tr>
<tr>
<td>1/14/86</td>
<td>14</td>
<td>Pump shut off. Started recovery readings. Left equipment unattended JFCo personnel to check it daily. Picked up In-Situ equipment (1/27).</td>
</tr>
<tr>
<td>1/28/86</td>
<td>28</td>
<td>Delivered In-Situ equipment to WWDC offices in Cheyenne and made printouts of all test data.</td>
</tr>
</tbody>
</table>
APPENDIX A-7

CASING SCHEDULE
## CRS PRODUCTION WELL #1 - A

**Casing Schedule**

<table>
<thead>
<tr>
<th>Number</th>
<th>Length</th>
<th>Type of Casing</th>
<th>Depth to Bottom of Joint</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8.10</td>
<td>8 5/8&quot; 28.6# T &amp; C</td>
<td>8.1 feet</td>
</tr>
<tr>
<td>2</td>
<td>42.40</td>
<td>&quot;</td>
<td>50.50 &quot;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Centralizer</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>42.15</td>
<td>&quot;</td>
<td>92.65 &quot;</td>
</tr>
<tr>
<td>4</td>
<td>42.15</td>
<td>&quot;</td>
<td>134.80 &quot;</td>
</tr>
<tr>
<td>5</td>
<td>42.15</td>
<td>&quot;</td>
<td>176.95 &quot;</td>
</tr>
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<td>6</td>
<td>42.16</td>
<td>&quot;</td>
<td>219.11 &quot;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Centralizer</td>
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</tr>
<tr>
<td>7</td>
<td>42.15</td>
<td>&quot;</td>
<td>261.26 &quot;</td>
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<tr>
<td>8</td>
<td>42.18</td>
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<td>303.44 &quot;</td>
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<td>9</td>
<td>42.15</td>
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<td>345.59 &quot;</td>
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<td>41.21</td>
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<td>42.15</td>
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<td>1604.01 &quot;</td>
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<tr>
<td>40</td>
<td>17.18</td>
<td>&quot;</td>
<td>1621.19 &quot;</td>
</tr>
</tbody>
</table>

Total Casing 1,621.19 - 2.90 Stick Up = 1,618.29 Setting Depth.
WELL CAP ELEV. 6427

10" HOLE 8 5/8" O.D. STEEL CSG.

14" I.D. STEEL CSG. 16" HOLE ELEV. 6419

122' S.W.L. 113'

CEMENT TO SURFACE

4" I.D. SCH 40 STEEL CASING

1586' TOP OF ERICSON

1595' FLOAT COLLAR & CEMENT BASKET

CASING TO 1620'

7 7/8"

1/8" x 4" SLOTS ;
4 SLOTS PER 10'
200'

1805' TOTAL DEPTH

1800 TOTAL DEPTH

AS BUILT

OBSERVATION WELL

PRODUCTION TEST WELL

NOT TO SCALE

A-7 -2