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APPENDIX B
(11/03/78)

HYDROLOGIC EVALUATION

of

THE COLLINS DRAW RESEARCH AND DEVELOPMENT SITE

for

IN SITU URANIUM RECOVERY

by

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*(with Cleveland Cliffs Iron)

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1.0 SUMMARY AND CONCLUSIONS

The research and development project site is located adjacent to Collins Draw in the south-central part of the Powder River Basin on the boundary of section 35 and 36 of T43N, R76W.

The mineralized sand at the site lies in the Wasatch Formation which begins at the surface and attains a depth of over 1500 feet. The Wasatch Formation is the only unit which can be affected by the pilot project. Our studies have accordingly focused on the regional and local hydrology pertinent to this formation and site.

The Wasatch Formation in the Powder River Basin is very close to a balanced recharge-discharge system. Water levels therefore exhibit only minor seasonal fluctuations.

Using data available in the literature together with site specific measurements by Cliffs and others, a regional piezometric surface map for the basin was constructed. The gradient at the site from the regional map was computed to be .006 foot/foot. This compares very favorably with a gradient of .008 foot/foot calculated from the local piezometric surface obtained from wells at the site. The local gradient and hydrologic properties combine to yield a groundwater flow of 6.3 feet/year in a direction 19° west of north at the site. Local water levels over a period of 18 months fluctuate on the order of a few tenths of a foot.

Wells used in Cliffs' study have an average well efficiency of 80% and were thus in excellent condition for hydrologic testing. Seven pump tests were performed by the Cleveland Cliffs Iron Co. under the direction of Mr. Jerry Laman. Water level measurements were carried out using pressure transducers sensitive to ±.01 psi changes.

The aquifer has an average thickness of 52 feet and a porosity of 28% with the top of the sand 431 feet below the surface.

Assumptions used in analytic solutions to obtain the hydrologic properties of the aquifer were satisfied to a high degree of accuracy.

Average hydrologic properties over all wells for the Collins Draw Site were 192 gpd/ft. for transmissivity and 1.7×10^{-4} for storage coefficient. An impermeable boundary was detected at 240 feet from the pumped well running in a North-South direction. No recharge or discharge boundaries were detected.

Mean directional permeability using all wells in test 7 was found to be:

Major transmissivity 307 gpd/ft.

Minor transmissivity 111 gpd/ft.

Direction of major transmissivity E 31°S

The hydrologic tests conducted at Collins Draw had a radius of influence of 485 feet.

Overlying monitor well 230 was used to check for leakage. No measurable water level changes were detected during the tests. Furthermore, drawdown data were checked against Hantush's Leaky type curves. Matches were obtained only on the limiting non-leaky curve. This indicates the absence of leakage and good vertical confinement.

A small bleed stream of .6 gpm is inherent to the project and will serve to further protect against solution excursion. The drawdown at one year at a distance of 2000 feet from the R & D site will be only 1 foot thereby giving rise to a very minimal impact on regional groundwater as opposed to more conventional methods of extraction such as open pit and underground mining.

We conclude that the hydrologic conditions at the site are favorable for insitu uranium extraction.

2.0 INTRODUCTION

The purpose of our report is to analyze the regional and local hydrology pertinent to the Collins Draw Insitu Uranium Pilot Site. The site is located in the south-central part of the Powder River Basin on the boundary of section 35 and 36 in T43N, R76W.

Collins Draw is a research and development project and involves only several small isolated patterns. Its effects in a regional sense will therefore be negligible. For this reason our study concentrates mainly on site specific hydrology and correlates these findings with general regional features such as the piezometric surface or water level contours.

Regional hydrologic information was gathered from published literature and Cliff's baseline wells. Site specific data was obtained from a total of seven pump tests and one injection test. They were conducted on the Collins Draw Property by the Cleveland Cliffs Iron Company from December 20, 1975 to November 17, 1976 under the direction of Mr. Jerry Laman. Test 7 was the largest and consisted of a seven well interference tests designed to investigate layering effects as well as directional permeability.

3.0 PREVIOUS INVESTIGATION

The work of Hodson, Pearl and Druse (1973) describing the water resources of the Powder River Basin is fundamental to our regional study. They summarize their findings as well as unify the efforts of many previous investigators. We have used their data to construct a piezometric surface map of the Basin. While the data presented in the report of Hodson et al consists of measurements prior to 1973, interpolated contours through Collins Draw are in excellent agreement with the water level observations recorded by Cliffs personnel. This is mainly due to the balanced recharge-discharge in the basin which precludes large annual fluctuations.

Another regional study was conducted by Wyoming Mineral Corporation and the Nuclear Regulatory Commission (NRC) for a commercial application at Irigaray Ranch. The findings were issued in an overall environmental impact statement by the NRC. This site is only 20 miles N-NW of the Collins Draw project.

The NRC report relies to a great extent on the previous study of Hodson et al. However, new site specific hydrologic data particularly water level measurements are included. This information together with that gathered by Cliffs was used to provide increased definition to the water table in the vicinity of the project.

4.0 REGIONAL GROUNDWATER

4.1 Geologic Setting

The Collins Draw project is located in the south-central part of the Powder River Basin. The formation is part of an accumulation of fluvial sediments eroded from surrounding mountains and deposited in the Powder River Basin. The uppermost 2000 feet of deposition contain a number of red colored beds and have been designated as the Wasatch Formation. The Wasatch Formation is exposed at the surface across most of the central part of the Basin and all of the site with the possible exception of thin alluvial deposits in adjacent dry stream beds. Site surface drainage is to the Powder River.

The following information refers to regional characteristics and is not site specific unless designated as such.

4.2 Aquifer Characteristics

In the subsequent discussion we briefly dispense with alluvial aquifers and discuss to a greater extent the water bearing properties of the Wasatch Formation. The deeper Fort Union is not discussed since at least 1500 feet of multiple confining layers separate the mineralized sands at Collins Draw from this formation. The potential for migration of lixiviant to this unit during the short duration of the operation therefore is extremely remote.

4.2.1 Alluvial Aquifers

Alluvial aquifers in the basin are only important in the vicinity of major rivers, such as the Powder and Belle Fourche, none of which are located near the site. For this reason we will omit a discussion of these aquifers in the present study.

4.2.2 Wasatch Formation

In general, aquifer zones in the Wasatch Formation are confined, although local water table or unconfined aquifers may occur in a few near surface layers. Yield from wells is highly variable and ranges from a few gpm in the northern part of the Basin to as much as several hundred gpm in the southern Powder River Basin. Water produced is from lenticular sandstone beds which vary considerably in areal extent, and to a lesser amount from jointed coal and clinker beds.

4.2.2.1 Sources and Sinks

The Powder River Basin is a relatively independent groundwater system. Recharge is determined mainly by geology and precipitation. Recharge to the Wasatch is along the front of the Bighorn Mountains and in the Black Hills with additional influx from precipitation over the remainder of the Basin. Discharge is by evaporation, seepage to springs, streams and rivers and by transpiration as well as pumpage. Principal natural discharge of water is along the Powder River and Little Powder River valleys and tributaries.

4.2.2.2 Seasonal Variation

Most groundwater development has been for stock and domestic use. Wells are usually drilled and developed to satisfy only these requirements. Hence it is not surprising to find that groundwater levels exhibit only minor seasonal fluctuations. This indicates that recharge and discharge, unlike many portions of the United States are approximately in balance. This is further substantiated by the small local water level changes observed by Cliffs at Collins Draw which will be presented in a later section.

4.2.2.3 Piezometric Surface and Regional Flow

Figure 1 depicts the regional piezometric surface for groundwater in the Wasatch formation of the Powder River Basin. The area shown consists of 486 townships (R67W-R84W and T31N-T57N). The area covers approximately 14400 square miles. Water level data from 91 well locations were used in constructing the water table. Pertinent well data are presented in Table 1. Ground level elevations for all wells were obtained by interpolating between contours on the standard U.S.G.S. topographic qradrangle maps. The depth to water was then subtracted from this elevation resulting in a water elevation referred to mean sea level.

The area given in the map is certainly greater than that usually given for studies such as the present one. However, the map does provide additional insight into groundwater movement and a better comparison between site specific

or local data and regional trends.

As evidenced by the map, the Powder River with its tributaries is one of the major controlling factors in the regional movement of water in the Wasatch. The movement of water is generally northward toward these drainage ways. Locally, especially in near-surface aquifers, movement of water is controlled by other drainages such as the Belle Fourche River.

The location of the pilot site in the regional map is also marked in Figure 1.

5.0 LOCAL GROUNDWATER

5.1 Local Aquifer Description

A map indicating three cross sections (A-B, C-D, E-F) is given in Figure 2. Three major water bearing sands are given in cross section in Figures 3 (A-B), 4 (C-D), and 5 (E-F). The uranium host or No. 1 sand is at a depth of 425 feet with an average thickness of 52 feet. Above this intended production sand is the AB sand which is a coalescence of two sands. This upper sand is separated from the production or No. 1 sand by a claystone confining layer ranging in thickness from 1[illegible] to 52 feet. The C sand is nearest the ground surface and is separated from the AB sand by a 26-41 foot claystone confining layer.

Features to a depth of 113 feet below the production aquifer (No. 1 sand) have been explored. Below the production aquifer is another 10-16 foot claystone layer. The water bearing sandstones appear to have a very limited lateral extent and lack continuity. Continuous units such as those overlying the production sand do not appear to be present to the depth explored.

The production aquifer can be further subdivided into three differing layers. The top unit in this aquifer has been termed the 1c layer and is approximately 15 feet thick. The next layer below it is termed 1b (20-25 feet thick), while the lowermost is the 1a (15 feet thick). The 1c and 1a layers appear to be cleaner and exhibited fair to good

porosity and permeability while 1b layer is more shaley and clayey and possesses lower porosity and permeability.

Features such as vertical confinement will be treated in the section reporting test results from the production aquifer.

5.2 Local Piezometric Surface Map

The local piezometric surface is given in Figure 6. The coordinates are North-East system and are given in feet with the origin of coordinates having the value 100,000N, 100,000E at the northwest corner of section 30 in R74,T43.

Some deviation of wells from the surface on the order of a few tenths of a foot are evident. We attribute these deviations to minor surveying errors. The surface has been accordingly drawn as approximately planar, since it has been our experience that groundwater tables over a small area invariably result in a planar surface.

The local gradient is approximately .008 feet/foot in a direction which is 19^{o} West of North. This compares well with the regional gradient of .006 feet/foot computed from Figure 1. The direction of the local gradient is also in good agreement with the regional gradient at site in Figure 1.

5.3 Local Groundwater Flow

The well locations, water level data, and hydrologic properties (discussed in the next section) were input to a computer program. The program fits a least squares trend

surface through the data to obtain the local gradient as well as direction and magnitude of groundwater flow. The resulting values were .008 feet/foot with a flow of 6.3 feet/year in a direction of 18.9^{o} West of North. The flow is clearly negligible and will not cause any problems during the life of the insitu pilot field.

5.4 Local Water Level Fluctuations

Baseline water level fluctuation on several wells taken over a period of one and a half years is given in Figure 7. Water level changes are small and on the order of a few tenths of a foot, in agreement with previous statements regarding a balanced recharge-discharge system.

6.0 HYDROLOGIC TESTS OF THE LOCAL PRODUCTION AQUIFER

As mentioned in the introduction, a total of seven pumping tests and one injection test were conducted on the Collins Draw Property by Mr. Jerry Laman of the Cleveland Cliffs Iron Company. These were performed from December 20, 1975 to November 17, 1976. Test 7 involved the largest number of wells. Test 5 was run for the longest period. Accordingly, the bulk of our analysis concentrates on these tests. In the following we will discuss the well characteristics, test results, and vertical confinement.

6.1 Well Characteristics

All wells were drilled with mud down to the top of the production aquifer. Wells were then cased and cemented to the surface. After this the production aquifer was drilled. Extreme care was taken by the well drilling contractors and supervisory personnel to insure the least amount of formation wellbore damage from the drilling operation. To this end drilling in the production aquifer was done with foam to avoid mud infiltration and formation damage. The wells were developed by air jetting, and then left without screen to further minimize well losses.

It has been our experience that wells drilled in this manner have well efficiencies on the order of 80%. The majority of Cliffs wells exhibit well efficiencies of this magnitude.

Wells 139, 146 and 191 were cased with a light 6 5/8" steel casing. Well 190 was cased with 6" yellomine pipe. The remainder of the wells were completed with 5" yellomine casing.

All wells were completed through the entire production zone with the exception of wells 231 and 232. Wells 231 and 232 were completed in only the 1c or uppermost 15 feet of the production aquifer.

Relevant well data used in hydrologic testing are listed in Table 2. Well efficiencies are listed in Table 7.

6.2 Test Procedure and Instrumentation

An electrical conductance water level device with depth markings every 5 feet was used to measure initial water levels. The instrument is a simple battery operated device which can achieve excellent accuracy when properly used.

Pressure transducers were used to record water level during the various injection tests. The transducers are sensitive to pressure changes on the order of .01 psi. The transducer cables merge to a central switching box and digital readout meter. The pressure and hence water level in a given well is obtained by turning the switch to the well's transducer and recording its reading. The rapid nature of this mechanism allows collection of reliable data early in time when pressure changes were rapid.

Each transducer, switching box and digital meter were checked for reliability and sensitivity prior to commencing

the pump test.

Flow rate was measured by either a Badger or Carlin flow meter with an accuracy of $\pm$ 2%. Rates were held constant by manually adjusting a value to maintain a constant flow reading.

Since water levels decline rapidly during the initial stages of the test, water level readings were taken at short intervals. The time between readings increased gradually as pumping continued.

Collected drawdown data from earlier tests were plotted and analyzed. Preliminary tests and analyses provided the basis for determining the duration of the test to obtain the necessary radius of influence, to detect hydrologic boundaries near the test site.

6.3 Method of Analysis and Assumptions

Three methods were used to analyze the data. First the type curve method was used to check for leakage. Secondly, when we were assured no leakage was present the semi-log straight line method devised by Jacob was used. Jacob's method requires that the dimensionless parameter u given by

$$u = \frac{1.87\ r^2 s}{Tt}$$

be less than .01. In order to check this method we used Chow's technique which still allows a semi-log plot but is

not subject to any restriction on u. Hantush's partially penetrating type curves were used to examine the ratio of vertical to horizontal permeability in the deposit.

The following assumptions are made in the derivation of these solutions:

1. The formation is a confined aquifer.
2. The formation is homogeneous within the radius of influence.
3. The thickness of the aquifer is uniform.
4. The pumped well is of infinitesimal radius.
5. Water is derived simultaneously from storage with the change of pressure.

We made the following observations concerning the above assumptions in sequence. The assumption of confined condition was verified by water level measurements and well logs. The water levels are located at approximately 77 feet below the top of the surface (from water level measurements) and the top of the aquifer is located at approximately 431 feet below the ground surface (from well logs). The lack of measurable response in the overlying monitor well No. 230 in the AB sand further substantiate the existence of confining conditions.

A substantial number of tests and varying methods were applied to each well. The mean values for all tests applied to an individual well are given in Table 3. The average transmissivity is 192 gpd/ft. with maximum deviation of 15 to 18%. While some heterogeneity exists it does not appear to be of a nature which would prevent us from arriving at

good approximations for the hydrologic properties of the pilot site.

The assumption of uniform thickness is easily checked by referring to the list of thicknesses given in Table 2. From these values we obtain an average thickness of 52 feet with variation about the mean on the order of ± 10%. Fluctuations of this magnitude will not have more than a 10% effect on transmissivity values. This is because transmissivity is proportional to aquifer thickness.

With respect to assumption 4, the pumped well is obviously not of infinitesmal diameter. For our situation the drawdown in the pumped well is affected by the finite diameter of the well during the first 50 minutes of pumping (Papadopulos and Cooper 1967). Thereafter the finite well-bore diameter has negligible effect on the pumped well. No drawdown measurements were taken in the pumped well.

The effect of a pumped well having a finite well bore on an observation well has been examined by Wigley (1968). For our situation the error in an observation well 100 feet from the pumped well is approximately 2% after 5 minutes from the onset of pumping. For a well 50 feet from the pumped well at 5 minutes the percentage error between our solutions and the exact solution is a few hundredths of a percent. Errors due to the finite well bore radius of the pumped well are small and decline exponentially with increasing time. The effect of a finite well bore and well bore storage can therefore be safely neglected for observation wells used in

our study.

Assumption 5 that water is derived simultaneously from storage with a change in pressure is also satisfied. This is due to the fact that yielding of water from storage in a confined aquifer is an elastic phenomenon. As such the only delay that can occur in yielding water due to a pressure change at a given distance is the time for elastic equilibrium to occur. The time for this to occur is approximately 10 traversals of a stress wave over thickness of the aquifer. Calculating the bulk modulus from the storage coefficient results in a value of 3.2×10^5 psi. The resulting wave speed is therefore approximately 4000 feet per second. Hence the required equilibrium time is .13 second. The delay of approximately .1 second between an applied pressure change and yielding of water from storage can for all practical purposes be regarded as simultaneous or instantaneous.

We therefore conclude that all assumptions required in the analysis are satisfied to a good approximation.

6.4 Radius of Influence

Essential to proper evaluation of an aquifer is to determine the area for which the results are valid. This naturally leads to the concept of radius of influence and its definition. A number of formulas are given by Bear et al (1968) for determining the radius of influence due to pumping. We prefer the

the formula given on page 406 of Bear et al because it has a natural analytic definition and can be directly related to the well function. In the gallon-day-foot system, the equation for radius of influence is

$$r_e = (.3Tt/S)^{\frac{1}{2}}/2*$$

where S is the storage coefficient. The above equation is derived from the long time logarithmic approximation to the well formation by finding the radius at which the drawdown is zero. When the value for r_e is substituted into the exact well function the drawdown will not be zero but instead have a finite value. The value depends on the hydrologic properties of the aquifer. In the present case the drawdown at r_e for test 5 is approximately 7.6 feet. Test 5 had a radius of influence of 485 which was the largest value attained since this particular test was run for the longest period.

There did not appear to be any systematic change in transmissivity values with increasing area of influence. The values from test 5 are in agreement with values from other tests having lesser radii of influence.

We conclude that tests conducted by Cliffs yielded values representative out to a distance of 485 feet from the center of well 146. An impermeable boundary was detected within this radius indicating that our criteria for the radius of

* The factor of 2 is included to account for the ficticious image well used in the analysis of boundary effects.

influence was correct.

6.5 Data Analysis

As mentioned in an earlier section, a total of seven pumping tests and one injection test were conducted by Cleveland Cliffs Iron Company. Results of all tests are summarized on a test by test basis in Table 4 and on a well by well basis in Table 5.

The amount of data involved is substantial. We have therefore chosen to report only the resulting parameters and methods used for tests 1, 2, 3, and 4, and instead confine this report to a detailed discussion of tests 5, 6, and 7. These three tests delineate the significant hydrologic properties of the production aquifer. Test 5 was run the longest in order to detect boundary effects. Test 6 was performed to analyze layering effects and the ratio of vertical to horizontal permeability. Test 7 was conducted primarily to determine directional permeability.

Where possible, three different methods were applied to the data. In the majority of cases the value of transmissivity agreed within 10 to 15%. Storage coefficient is more sensitive to the particular technique used and accordingly varied more widely.

Average values for all tests on a well by well basis are given in Table 3. The average value obtained for transmissivity was 192 gpd/ft. while the average storage coefficient (excluding well 190WC) was 1.7×10^{-4}. Well 190 was excluded

for the storage coefficient since its value is an order of magnitude larger than the mean. If it were included, we would have obtained 4.1×10^{-4}. The difference between the two averages is not great considering the variability usually attending storage coefficient measurements. We would however prefer to use the value of 1.7×10^{-4} for the Collins Draw Pilot Site. We now turn to a more detailed analysis of tests 5, 6, 7, and discuss them in numerical sequence.

6.5.1 Test Five (Hydrologic Barrier)

Test five was run for the longest period with the intent of establishing a large radius of influence and detecting any hydrologic boundaries within this radius. The radius of influence of this test was 485 feet.

Drawdowns in the observation wells were plotted against time on semi-logarithmic paper in Figure 8. Values of transmissivity and storage coefficient were computed using the early straight line portions of the drawdown curve before the boundary affected the slope of the curve. After 1000 minutes of pumping the rate of drawdown in the observation wells increased indicating the presence of a hydrologic barrier. The barrier could be a pinchout of the sand or transition to a significantly lower permeability.

Image well theory is used to locate the barrier by constructing circles around each observation well. The

diameter is calculated by selecting a point at which the drawdown from the pumped well is equivalent to that due to the ficticious image well on the other side of the boundary. Ideally all three circles share a common intersection. The boundary is then half the distance between the pumped well and point of intersection. In our case only two of the circles intersected indicating a boundary at 240 feet and lying either east or west of the property. An impermeable boundary running in a north-south direction is certainly consistent with the direction of local groundwater flow discussed previously.

The tests have established the location of a hydrologic boundary. Its location will be determined by conducting a more precise hydrologic test in the near future.

6.5.2 Test Six (Layering Effects)

Test six consisted of three wells (231, 232, 233). Wells 231 and 232 were completed in the uppermost 10 feet of the production sand.

Well 231 was the observation well while 232 served as the pumped well. The time drawdown response and match to the type curve is given in Figure 9. The best match was achieved with a ratio of horizontal to vertical permeability of unity. If the ratio of horizontal to vertical permeability were unity then partial penetration effects would be absent a distance of 1.5 times the aquifer thickness from the pumped well. In this case observation well

No. 231 was 1.7 times the aquifer thickness from the pumped well. This would still be sufficient to allow detection of permeability ratios for horizontal to vertical permeability of 3 or less. We would therefore conclude that this ratio lies between 1 and 3.

6.5.3 Test Seven (Directional Permeability)

In test 7, water level changes in six observation wells were monitored. Well 139 was pumped at a constant rate of 20 gpm. Transient drawdown data were first analyzed using Jacob's, Chow's and Hantush's methods. The results from Jacob's and Chow's methods are displayed in Figures 10 - 16. Matches against Hantush's type curves are given in Figure 17. Results for these analyses are listed in Table 4.

Papadopulos' method was initially used to determine the directional permeability of the formation. Papadopulos' method requires a minimum of three observation wells in three different directions from the pumped wells. In a homogeneous anisotropic medium any combination of three observation wells should yield identical results. However, most formations exhibit some heterogeneity as well as anisotropy. In this case anisotropy may be due to smaller scale features such as braided stream channels which can give rise to contrasts in permeability. Depending on their spacing and angular distribution, various combinations of wells can give different results. Some wells may be drilled into a localized feature which is

not representative of the region as a whole. Such features may include local higher or lower permeability zones. It is also possible that a higher permeability stream channel directly connects the pumped well with an observation well. Some representative three well combinations are given in Table 6. There are a total of 20 possible three well combinations.

Using a computer program, all the data from observation wells in test 7 were analyzed simultaneously using a least squares technique to arrive at an average orientation and directional transmissivity values. The results are:

Major transmissivity 307 gpd/ft.

Minor transmissivity 111 gpd/ft.

Geometric mean transmissivity 185 gpd/ft.

Direction of major transmissivity E 31^{o}S

Storage coefficient 8.8 x 10^{-5}.

The geometric mean value of 185 gpd/ft. agrees within 4% of the previous single well average of 192 gpd/ft. Considering the variability in storage coefficient, this value is also in good agreement with the previous average of 1.7 x 10^{-4}.

6.5.4 <u>Transmissivity Contours</u>

To obtain a transmissivity distribution over the site the average values listed for each well in Table 3 were contoured. The results were given in Figure 18. The

variability of transmissivity is not large. However, there is a trend toward higher permeability at the center of the site.

6.5.5 Vertical Confinement

Well No. 230 was drilled into the sand overlying the production aquifer. No measurable drawdown was detected by Cliffs personnel. In addition to this, the results of test 7 were matched against Hantush's unsteady state type curve in Figure 17. No leakage was detected.

7.0 EFFECT OF BLEED STREAM

It is anticipated that a small bleed stream on the order of 200 to 900 gallons per day will be required during the operation of the pilot plant. This amounts to approximately .14 to .63 gallons per minute.

At one year the drawdown due to a 900 gpd withdrawal is 3 feet at 200 feet and only 1 foot at 2000 feet from the site. The impact is clearly negligible and much less than the drawdown which would be associated with alternative extraction methods such as open pit and underground mining.

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TABLES

46-78-18 dc	110	540	Provence Ranch	4525	4415
47-78-24 db	flowing (1 gpm)	235	Bowman Flats	4195	-
51-78-32 bb	200	344	Bear Draw	4325	4125
51-79-16 ba	30	164	Floate Draw	4020	3990
50-79-19 bc	165	600	Pine Gulch	4170	4005
48-79-29 ca	125	390	Brown Ranch	4555	4430
43-79-20 dac	49	103	Soldier Creek	4565	4516
43-79-9 dac	30	85	Sussex	4495	4465
43-79-2 dd	68	270	Sussex	4490	4422
45-80-1 dac	39	141	Elaine Draw	4545	4506
47-80-16 ba	66	220	Brown Ranch	4635	4569
49-80-23 ac	4	145	Crazy Woman Ranch	4280	4276
50-80-26 ac	15	215	Buffalo, SE	4620	4605
49-82-2 bb	6	318	Buffalo	5117	5111
36-72-29 ba	50	400	Highland Flats	5250	5200
36-72-9 dd	180	212	Bill	5420	5240
43-72-16 cc	305	345	Turnercrest	5180	4875
43-72-18 bd	165	261	Turnercrest	5215	5050
45-72-15 ba	20	145	Reno Junction	4855	4835
45-72-10 bc	20	145	North Star School	4860	4840
46-72-34 bd	25	205	North Star School	4855	4830
46-72-1 bcc	30	90	Eagle Rock	4695	4665
48-72-24 cd	15	40	The Gap, SW	4635	4620
48-72-13 aa	58	122	The Gap	4615	4557
50-72-5 aab	55	120	Gillette West	4600	4545
50-72-4 ab	133	387	Gillette West	4560	4427
51-72-35 dd	4	305	Gillette West	4500	4496
50-72-8 bbb	160	380	Gillette West	4405	4245
51-72-29 bdd	30	34	Gillette West	4320	4288
51-72-22 cb	32	100	Rawhide School	4265	4233
49-71-18 dcc	48	204	The Gap	4650	4602
50-71-29 dca	166	263	The Gap	4675	4509
47-71-11 bcc	110	180	Coyote Draw	4630	4520
49-71-34 cb	24	114	The Gap, SW	4505	4481
45-71-2 aa	100	155	Neil Butte	4740	4640
44-71-10 dd	95	124	Hilight	4830	4735
34-70-5 db	55	149	Clausen Ranch	5160	5105

TABLE 1

REGIONAL PIEZOMETRIC SURFACE DATA

Well Number *	Water Level (ft.)	Depth (ft.)	Quadrangle Name	Ground Elevation (ft.)	Water Elevation (ft.)
44-76-8 cdc	flowing (2 gpm)	760	Fort Reno, SE	4660	-
42-74-6 ac	185	225	South Butte	5370	5185
46-76-10 da	28	90	Savageton	4510	4482
47-76-26 cd	105	300	Bogie Draw	4810	4705
49-76-27 aaa	flowing (1 gpm)	1000	Morgan Draw	4170	-
46-75-9 bd	4	400	Savageton	4700	4696
47-75-13 bcc	34	355	Double Tanks	4730	4696
50-75-30 bd	150	400	Carr Draw	4340	4190
53-74-7 bcc	46	120	Truman Draw	4330	4284
50-74-31 cb	84	290	Jeffers Draw	4530	4446
49-74-13 db1	10	143	Four Bar J Ranch	4750	4740
46-74-9 cb	187	281	Savageton	4940	4753
40-74-21 ac	20	30	Coal Draw	5080	5060
38-74-13 db	40	160	Coal Draw	5175	5135
37-74-35 dc	70	118	Highland Flats	5400	5330
36-74-18 ca	27	35	Fifty Five Ranch	5870	5843
35-73-33 da	38	80	Gilbert Lake	5180	5142
36-73-27 bd	168	180	Highland Flats	5520	5352
38-73-17 ab	flowing (1 gpm)	515	Coal Draw	5120	-
39-73-24 caa	70	267	Coal Draw	4955	4885
43-74-25 da	30	177	Turnercrest	5125	5095
44-73-35 cc	45	205	North Star School	4910	4865
46-73-34 ccd	19	200	North Star School	4810	4791
46-73-6 ddd	22	233	North Star School	4900	4878
48-73-31 ad	79	305	Pleasantdale	4830	4751
52-73-25 dd	80	210	Rawhide School	4255	4175

* 1st numeral denotes township, 2nd numeral denotes range, 3rd numeral denotes section. Subdivisions within a section are labeled a,b,c, and d in a counterclockwise direction beginning in the northeast quarter (a - NE¼, b - NW¼, c - SW¼, d - SE¼). The first letter denotes the quarter section, the second letter, if shown denotes the quarter-quarter section,etc. A numeral n if shown indicates it is the nth well assigned a number in that quarter-quarter -...section.

TABLE [illegible] cont.

42-70-32 aaa	240	280	Teckla	4850	4610
42-70-5 ddd	110	233	Reno Reservoir	4780	4670
43-70-11 da	25	45	Piney Canyon, NW	4725	4700
44-70-28 cbc	110	261	Hilight	4865	4755
33-73-27 bdb	9	92	Orpha	5170	5161
57-79-25 cc	40	95	Box Elder Draw	4225	4185
55-79-30 bba2	150	200	Clearmont	4085	3935
53-79-7 bc	70	280	Julie Draw	3975	3905
52-79-12 cc	27	160	Floate Draw	4310	4283
52-80-1 ac	26	312	Julie Draw	4275	4249
53-80-18 ca2	46	143	Ucross	4083	4037
53-80-2 db	50	260	Julie Draw	4200	4150
54-80-24 bc	82	120	Clearmont	4060	3978
57-81-7 cb	80	510	Cedar Canyon	3700	3620
56-81-29 bd	190	378	Jones Draw	4080	3890
54-81-14 bc	47	110	ULM	4460	4413
52-81-13 db	12	246	Lake DeSmet East	4480	4468
54-82-29 ba	12	60	Buffalo Run Creek	4320	4308
56-82-35 aa	50	87	Jones Draw	3880	3830
54-83-3 bd	20	245	Buffalo Run Creek	4090	4070
53-83-7 dd	7	42	Story	5115	5108
54-84-11 ab	11	160	Big Horn	4130	4119
41-73-6 bb	40	120	Turnercrest	5020	4980
41-74-11 dd	0	-	Turnercrest	5090	5090
42-73-8 ca	180	450	Turnercrest	5240	5060
43-74-10 bd	150	290	Turnercrest	5160	5010
43-73-9 aa	110	152	Turnercrest	5080	4970
42-73-31 aa	65	210	Turnercrest	5120	5055

TABLE 2

Collins Draw Water Well Data
1-Sand
T43N R76W Sec. 35

Hole No.	Surface Coordinates N/S	Surface Coordinates E/W	Bottom Hole Coordinates N/S	Bottom Hole Coordinates E/W	Hole Depth (ft.)	Casing Depth (ft.)	Host Sand Top (ft.)	Host Sand Thickness (ft.)	Ground Elevation (ft.)	Top Casing Elevation (ft.)
139W	97300N	62000E	drift/5	36/max	485	430	426	52	4885.48	4886.73
146W	97300N	61965E	97297.39	61966.1	485	429	428	55	4883.03	4884.71
190WC	97300N	61975E	97301.6	61969.68	481	429.6	430	47	4883.41	4885.27
191WC	97359.5N	62017E	97369.67	62023.13	480	431	431	49	4883.08	4884.40
230W*	97275N	62050E	Not available		396	312	312	84	4890.06	4890.93
231W	97335N	62095E	97332.10	62085.68	488	438	438	50	4893.89	4894.78
232W	97240N	62110E	97243.34	62108.54	lc(457)	447	447	(10)	4899.63	4900.06
233W	97250N	62012E	97250.45	62010.46	487.5	429	426	52	4885.31	4887.34
234W	97260N	61960E	97263.95	61963.71	479.5	425	421	58.5	4880.15	4881.47

* Hole No. 230W is in the "A" sand.

TABLE 3

AVERAGE TRANSMISSIVITY AND STORAGE COEFFICIENT FOR EACH WELL

Well No.	Township-Range-Section	N/S Surface Coordinates	E/W Surface Coordinates	Average Transmissivity gpd/ft.	Average Storage Coefficient
139W	43 - 76 - 35	97300N	62000E	227	2×10^{-4}
146W	43 - 76 - 35	97300N	61965E	216	4.3×10^{-4}
190WC	43 - 76 - 35	97300N	61975E	187	2.1×10^{-3}
191WC	43 - 76 - 35	97359N	62017E	163	2.3×10^{-4}
231W	43 - 76 - 35	97335N	62095E	167	9.3×10^{-5}
232W	43 - 76 - 35	97240N	62110E	182	5.5×10^{-5}
233W	43 - 76 - 35	97250N	62012E	212	9.7×10^{-5}
234W	43 - 76 - 35	97260N	61960E	180	1.1×10^{-4}

Average transmissivity over all wells = 192 gpd/ft.

Average storage coefficient (excluding 190WC) = 1.7×10^{-4}

TABLE 4

History of pump tests, test by test

C[illegible]ns Draw, Wyoming

Date	Test No.	Well No.	Transmissivity(gpd/ft.)			Storage Coefficient			Discharge (gpm)
			Jacob's	Chow's	Hantush's	Jacob's	Chow's	Hantush's	
		146W	258						33.2
12/20/75		139W	270						48.0
		139W	270						
7/15/76	1	139W	225						35.0
		139W	225						
		146	210	209		$8.23x10^{-5}$	$8.24x10^{-5}$		
7/30/76	2	139W	258						40.0
		146	235	209	209	$1.20x10^{-4}$	$1.49x10^{-4}$	$1.49x10^{-4}$	
		190	216	190	181	$2.24x10^{-4}$	$1.52x10^{-4}$	$3.17x10^{-4}$	
		191	182	150	144	$2.48x10^{-4}$	$1.81x10^{-4}$	$2.76x10^{-4}$	
7/30/76	3	190	243						35.0
		139	231	212	192	$3.02x10^{-4}$	$2.01x10^{-4}$	$2.45x10^{-4}$	
		146	234	221	178	$1.61x10^{-3}$	$1.06x10^{-3}$	$1.49x10^{-3}$	
		191	176	161	132	$3.08x10^{-4}$	$2.05x10^{-4}$	$2.50x10^{-4}$	
8/5/76	4	139W	204						34.0
	Injection well	146	204	187		$1.37x10^{-4}$	$1.29x10^{-4}$		
		190	169	146		$5.53x10^{-3}$	$7.09x10^{-4}$		
		191	243	175		$9.12x10^{-5}$	$1.23x10^{-4}$		
8/23/76	5	146	189						25.61
		139	194	178	184	$1.34x10^{-4}$	$1.62x10^{-4}$	$1.61x10^{-4}$	
		190	188	172	178	$2.86x10^{-3}$	$3.53x10^{-3}$	$3.53x10^{-3}$	
		191	186	178	148	$1.06x10^{-4}$	$1.08x10^{-4}$	$1.44x10^{-4}$	
11/5/76	6	232	183						
		231	173		134	$4.36x10^{-5}$		$6.0x10^{-5}$	
		233	271		220	$5.66x10^{-5}$		$5.47x10^{-5}$	
11/17/76	7	139	269	267					20.07
		146	186	172	192	$1.75x10^{-4}$	$2.40x10^{-4}$	$1.36x10^{-4}$	
		191	139	104		$4.15x10^{-4}$	$5.59x10^{-4}$		
		231	183	170	173	$1.10x10^{-4}$	$1.24x10^{-4}$	$1.25x10^{-4}$	
		232	186	170	190	$5.31x10^{-5}$	$6.51x10^{-5}$	$5.18x10^{-5}$	
		233	191	176	204	$1.24x10^{-4}$	$1.47x10^{-4}$	$1.02x10^{-4}$	
		234	180	169	190	$1.11x10^{-4}$	$1.29x10^{-4}$	$8.90x10^{-5}$	

Table 5
History of pump tests, well by well
Collins Draw, Wyoming

Well No.	Date	Test No.	Transmissivity (gpd/ft.) Jacob's	Chow's	Hantush's	Storage Coefficient Jacob's	Chow's	Hantush's
139	12/20/75		270					
			270					
	7/15/76	1	225					
			225					
	7/30/76	2	258					
	7/30/76	3	231	212	192	$3.02x10^{-4}$	$2.01x10^{-4}$	$2.45x10^{-4}$
	8/5/76	4	204					
	8/23/76	5	194	178	184	$1.34x10^{-4}$	$1.62x10^{-4}$	$1.61x10^{-4}$
	11/17/76	7	269	267				
146			258					
	7/15/76	1	210	209		$8.23x10^{-5}$	$8.24x10^{-5}$	
	7/30/76	2	235	209	209	$1.20x10^{-4}$	$1.49x10^{-4}$	$1.49x10^{-4}$
	7/30/76	3	234	221	178	$1.61x10^{-3}$	$1.06x10^{-3}$	$1.49x10^{-3}$
	8/5/76	4	204	187		$1.37x10^{-4}$	$1.29x10^{-4}$	
	8/23/76	5	189					
	11/7/76	7	186	172	192	$1.75x10^{-4}$	$2.40x10^{-4}$	$1.36x10^{-4}$
190	7/30/76	2	216	190	181	$2.24x10^{-4}$	$1.52x10^{-4}$	$3.17x10^{-4}$
	7/30/76	3	243					
	8/5/76	4	169	146		$5.53x10^{-3}$	$7.09x10^{-4}$	
	8/23/76	5	188	172	178	$2.86x10^{-3}$	$3.53x10^{-3}$	$3.53x10^{-3}$
191	7/30/76	2	182	150	144	$2.48x10^{-4}$	$1.81x10^{-4}$	$2.76x10^{-4}$
	7/30/76	3	176	161	132	$3.08x10^{-4}$	$2.05x10^{-4}$	$2.60x10^{-4}$
	8/5/76	4	243	175		$9.12x10^{-5}$	$1.23x10^{-4}$	
	8/23/76	5	186	178	148	$1.06x10^{-4}$	$1.08x10^{-4}$	$1.44x10^{-4}$
	11/17/76	7	139	104	No match	$4.15x10^{-4}$	$5.59x10^{-4}$	
231	11/5/76	6	173		134	$4.36x10^{-5}$		$6.0x10^{-5}$
	11/17/76	7	183	170	173	$1.10x10^{-4}$	$1.24x10^{-4}$	$1.25x10^{-4}$
232	11/5/76	6	183					
	11/17/76	7	186	170	190	$5.31x10^{-5}$	$6.51x10^{-5}$	$5.18x10^{-5}$

Table 5 (Continued)
History of pump tests, well by well
Collins Draw, Wyoming

Well No.	Date	Test No.	Transmissivity (gpd/ft.) Jacob's	Chow's	Hantush's	Storage Coefficient Jacob's	Chow's	Hantush's
233	11/5/76	6	271		220	$5.66x10^{-5}$		$5.47x10^{-5}$
	11/17/76	7	191	176	204	$1.24x10^{-4}$	$1.47x10^{-4}$	$1.02x10^{-4}$
234	11/17/76	7	180	169	190	$1.11x10^{-4}$	$1.29x10^{-4}$	$8.90x10^{-5}$

Table 6

Summary of Results, Papadopulos' method
Test 7, Collins Draw, Wyoming

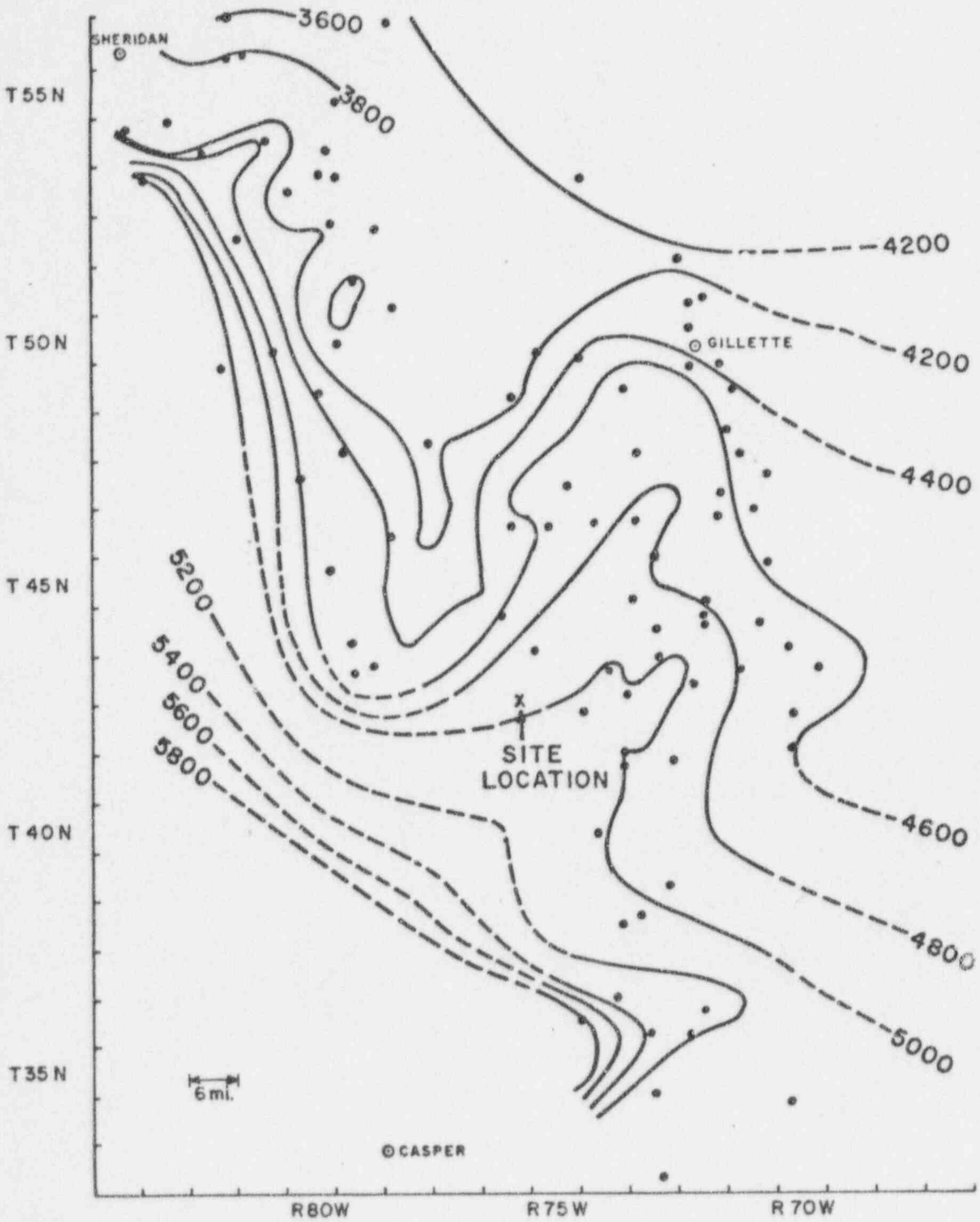
Well Nos.	Major Transmissivity (gpd/ft.)	Minor Transmissivity (gpd/ft.)	Direction of Major Transmissivity	Storage Coefficient
146,231,234	385	87	N 57°E	2.05×10^{-4}
146,231,233	600	58	N 30°E	7.61×10^{-5}
146,232,233	543	65	E 42°S	1.02×10^{-4}
231,232,233	329	106	E 26°S	9.39×10^{-5}
232,233,234	314	109	E 14°S	8.14×10^{-5}
146,233,234	260	132	N 19°E	1.35×10^{-4}
231,233,234	191	178	N 63°E	1.17×10^{-4}

Table 7

Well Efficiencies

Date	Test No.	Pumping Well	Discharge (gpm)	Time (minutes)	Observed Drawdown (ft.)	Theoretical Drawdown (ft.)	Well Efficiency
12/20/75		139	48	180	137	115.2	84%
7/15/76	1	139	35	120	114.9	73.5	64%
7/30/76	2	139	40	270	125	105	84%
11/7/76	7	139	20	470	74	59.5	80%
?		146	33.2	120	106.3	69.7	66%
8/23/76	5	146	25.6	1000	107	88.3	82%
7/30/76	3	190	35	181	160	147	92%

FIGURES



REGIONAL PIEZOMETRIC SURFACE

In-situ Consulting

PREPARED BY: R.S.	DATE: 9-27-78
CHECKED BY: C.R.M.	DATE: 9/28/78
DRAWN BY ZIMMERGRAPHICS	FIGURE NO 1

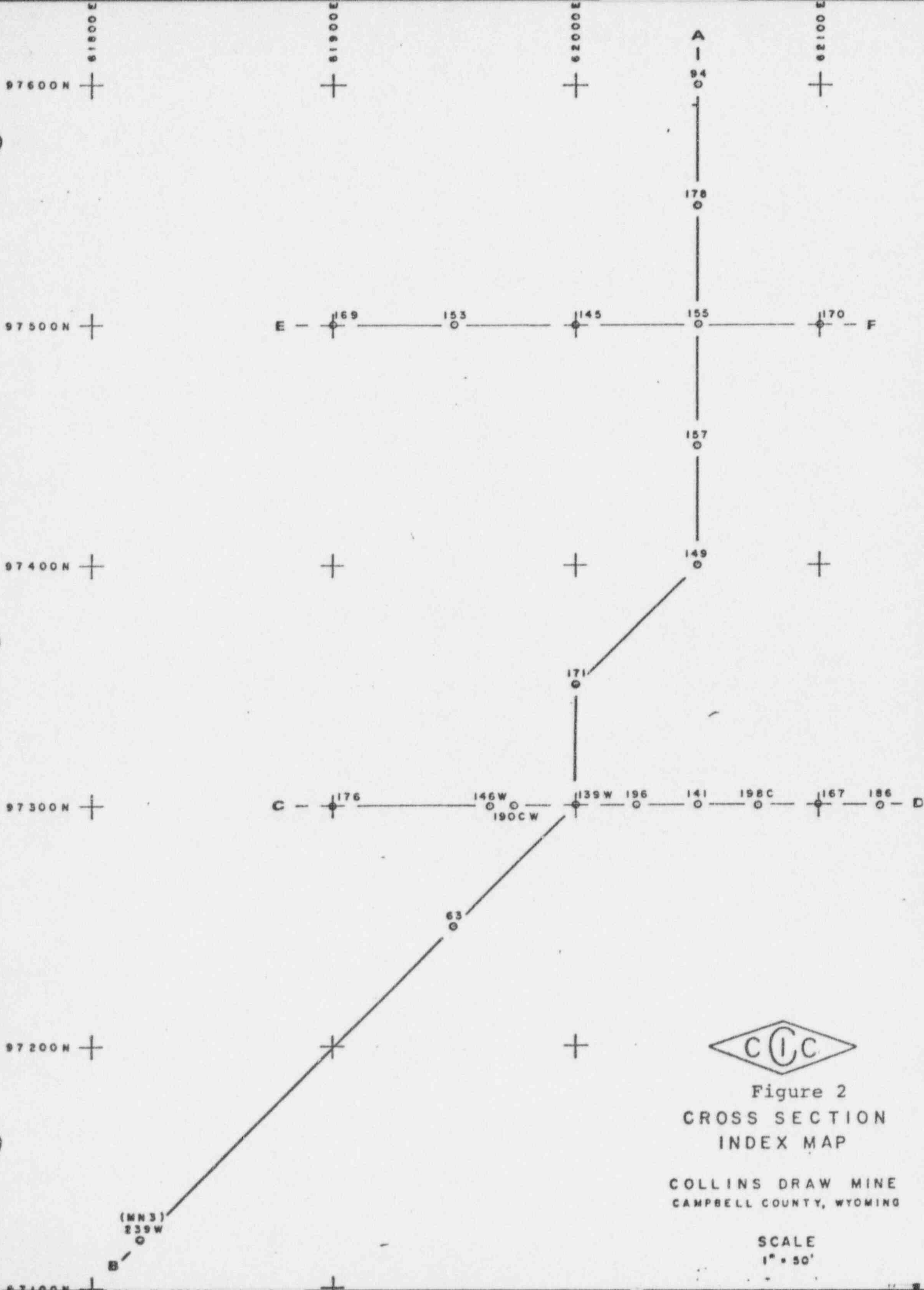
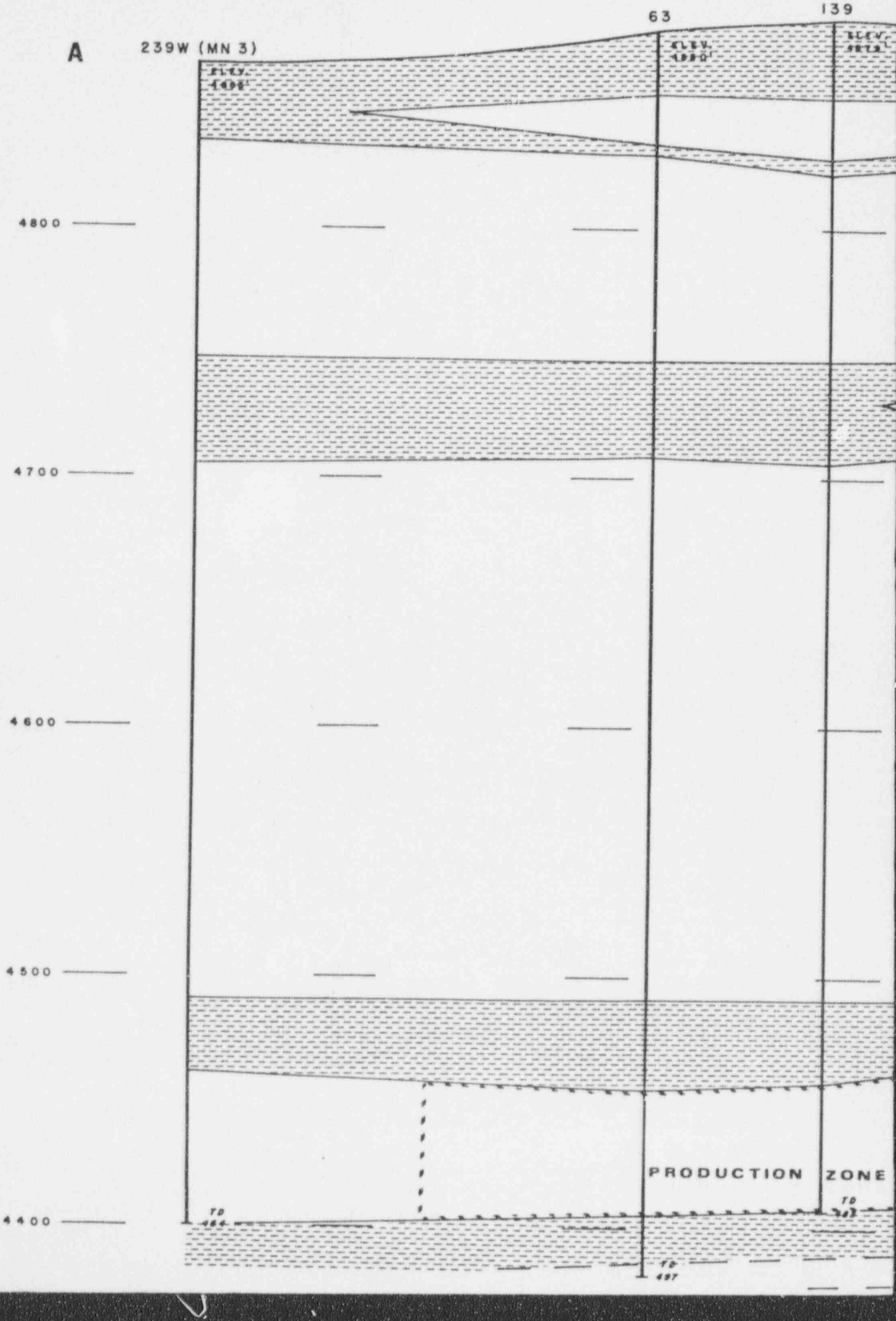
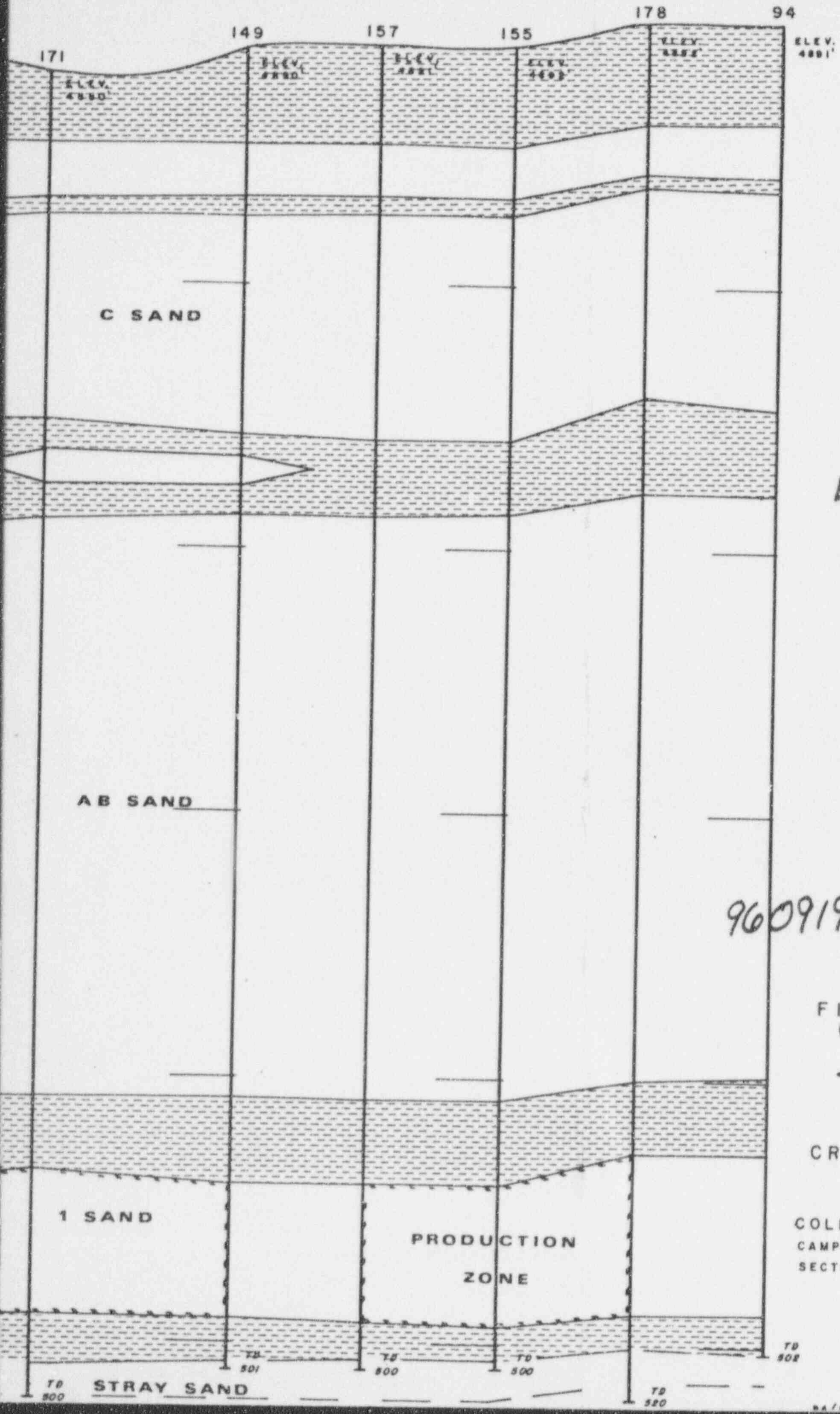


Figure 2
CROSS SECTION
INDEX MAP

COLLINS DRAW MINE
CAMPBELL COUNTY, WYOMING

SCALE
1" = 50'


A
239W (MN 3)
63
139
4800
4700
4600
4500
4400
PRODUCTION ZONE
TD
TD
TD



B

ANSTEC
APERTURE
CARD

Also Available on
Aperture Card

9609190260-1

FIGURE 3
(11/3/78)

CCIC

CROSS SECTION
A-B

COLLINS DRAW MINE
CAMPBELL COUNTY, WYOMING
SECTION 35, T.43N., R.76W.

SCALES
VERT. 1" = 500'
HORIZ. 1" = 500'

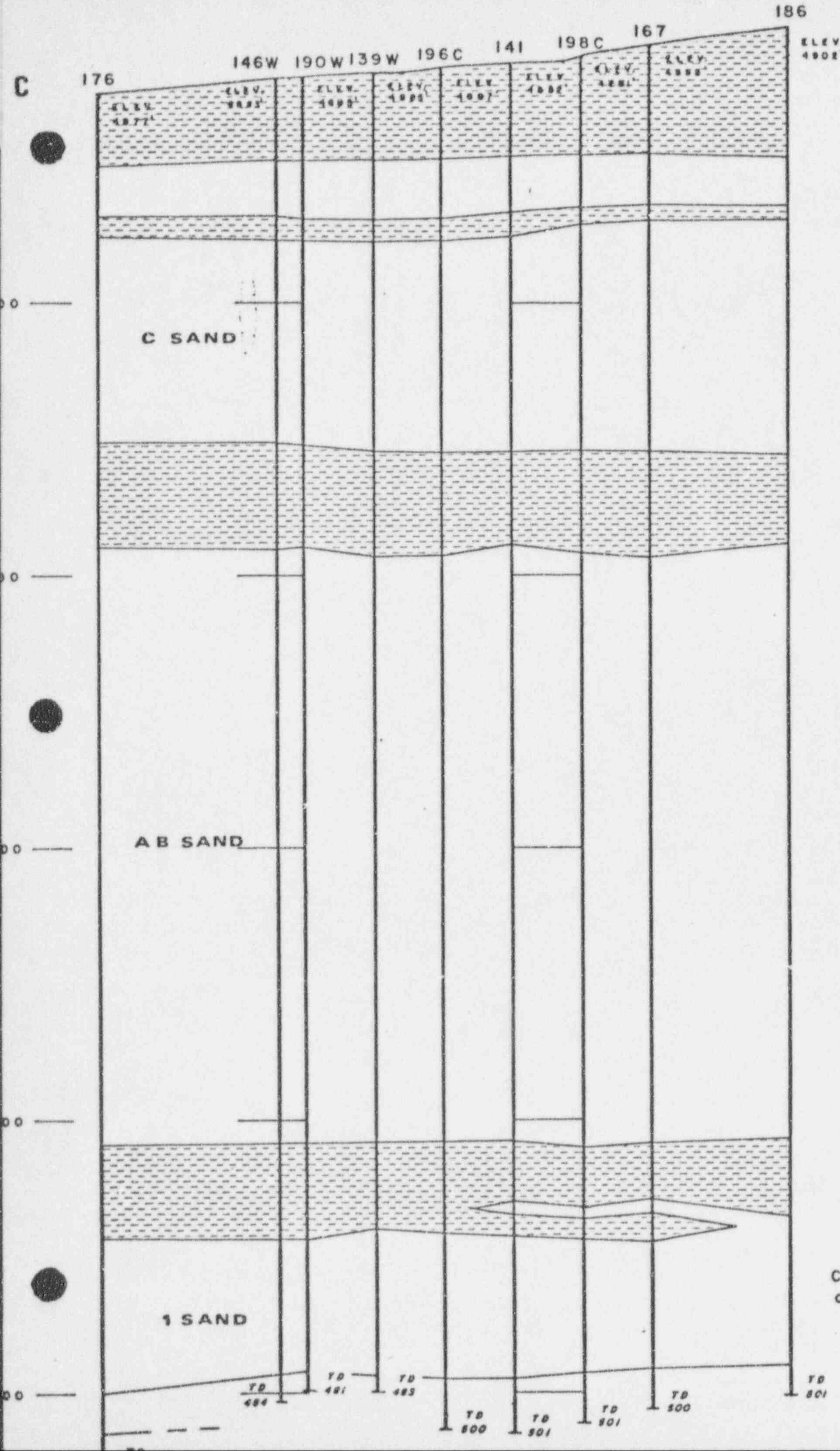


Figure 4

CROSS SECTION

C - D

COLLINS DRAW MINE

CAMPBELL COUNTY, WYOMING

SCALES

VERT. 1" = 500'

HORIZ. 1" = 500'

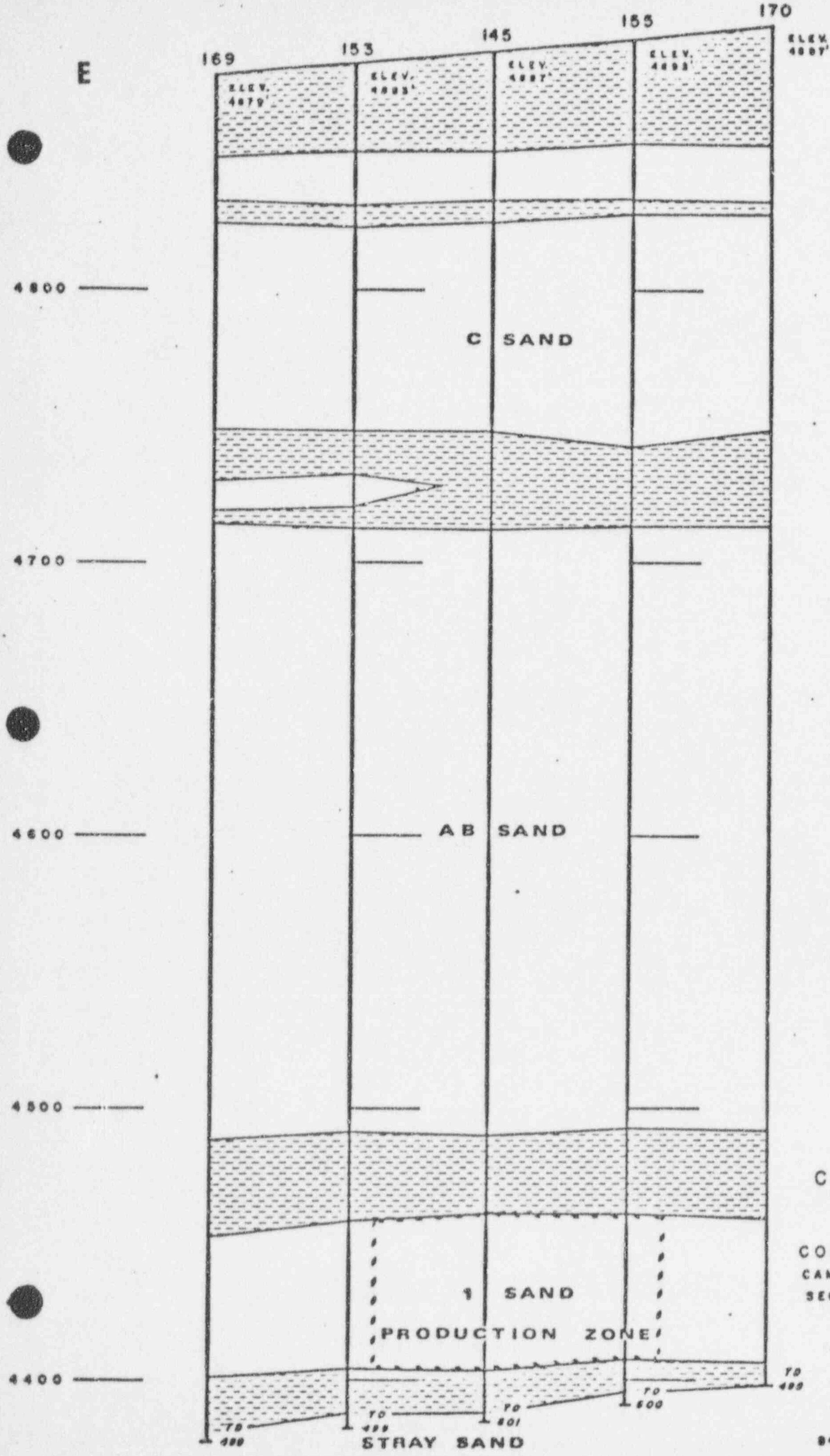


FIGURE 5

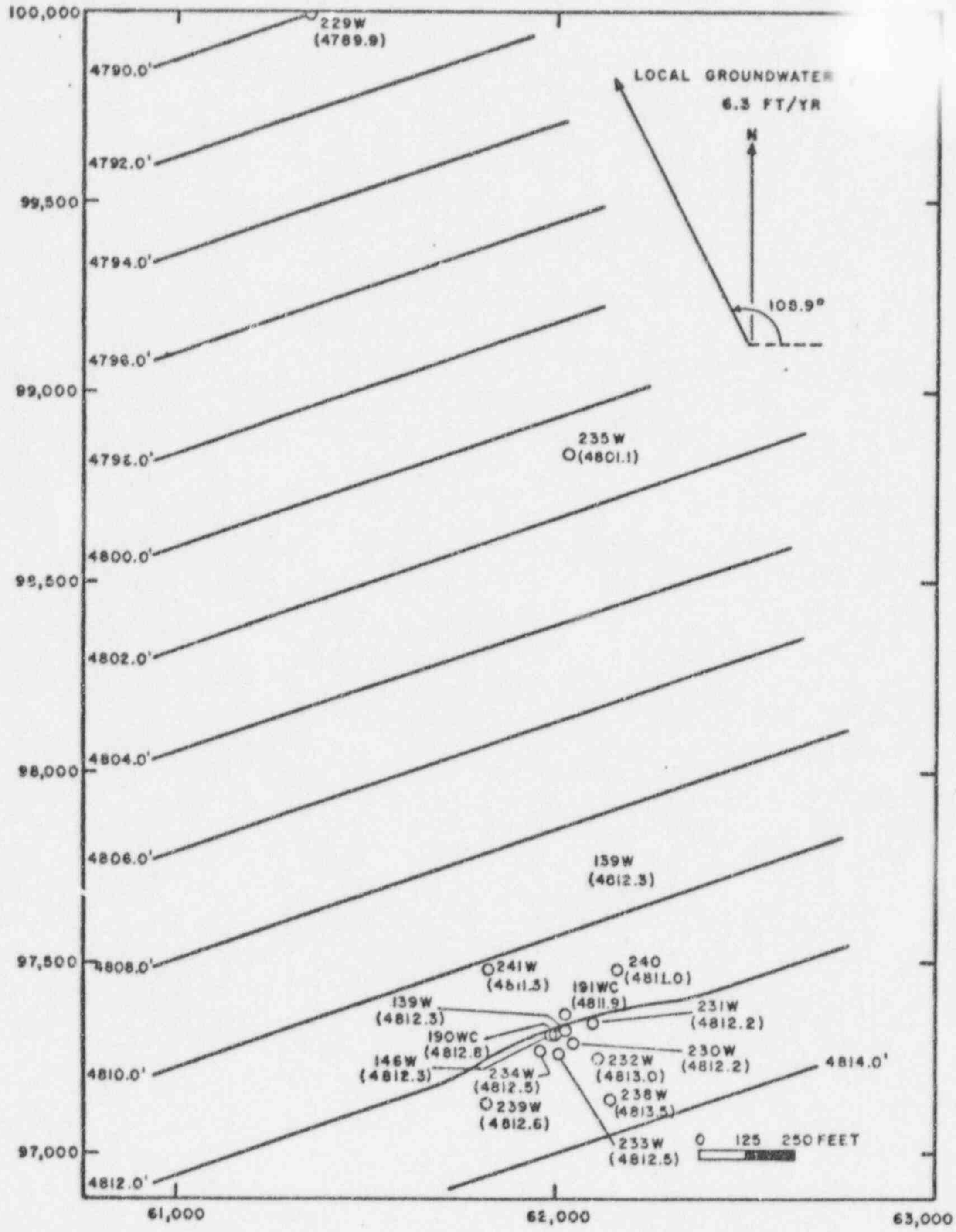
CIC

CROSS SECTION
E-F

COLLINS DRAW MINE
CAMPBELL COUNTY, WYOMING
SECTION 35, T.43N., R.76W.

SCALES
VERT. 1" = 500'
HORIZ. 1" = 500'

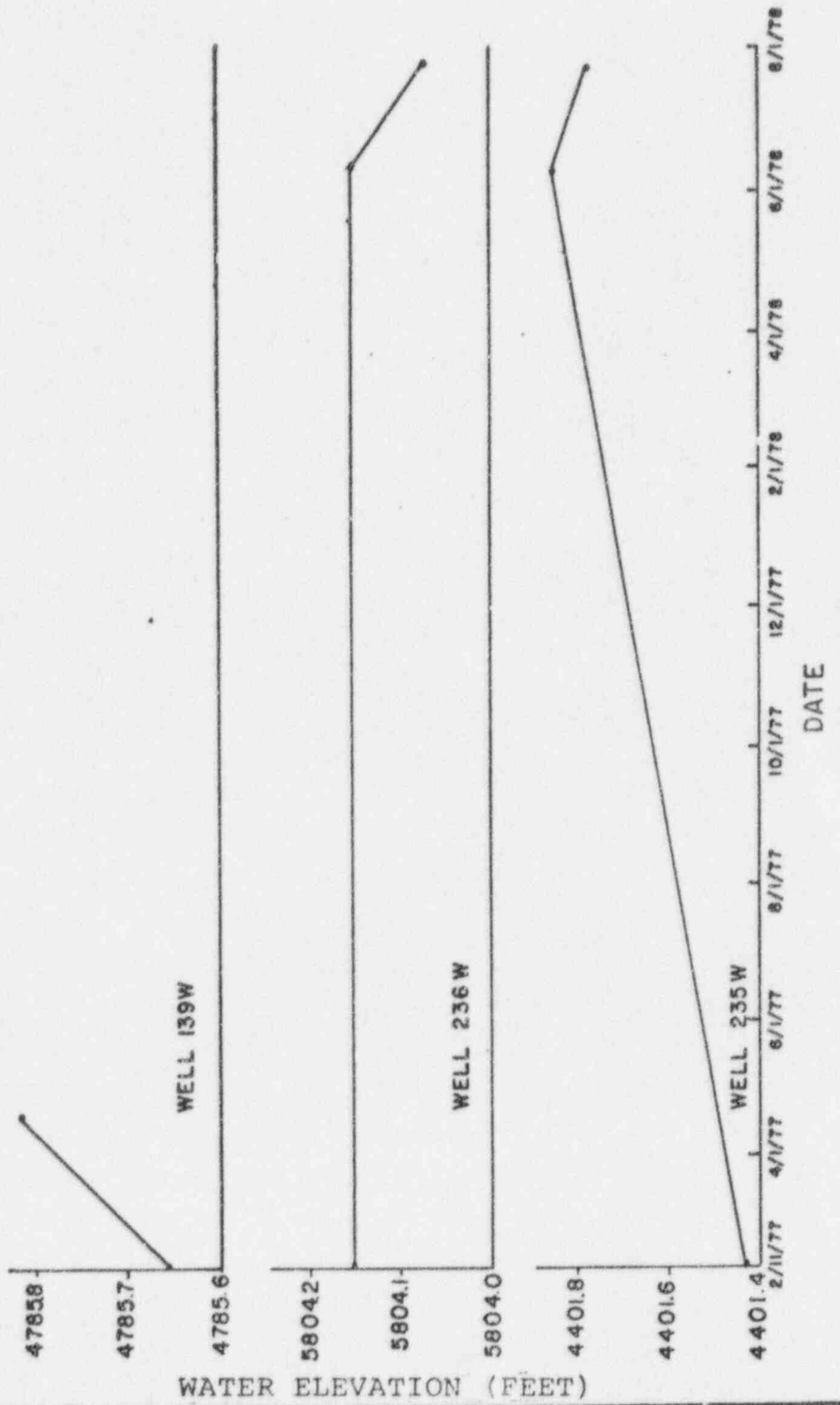
84/805/SV-LA-XX-8/8



PIEZOMETRIC SURFACE MAP

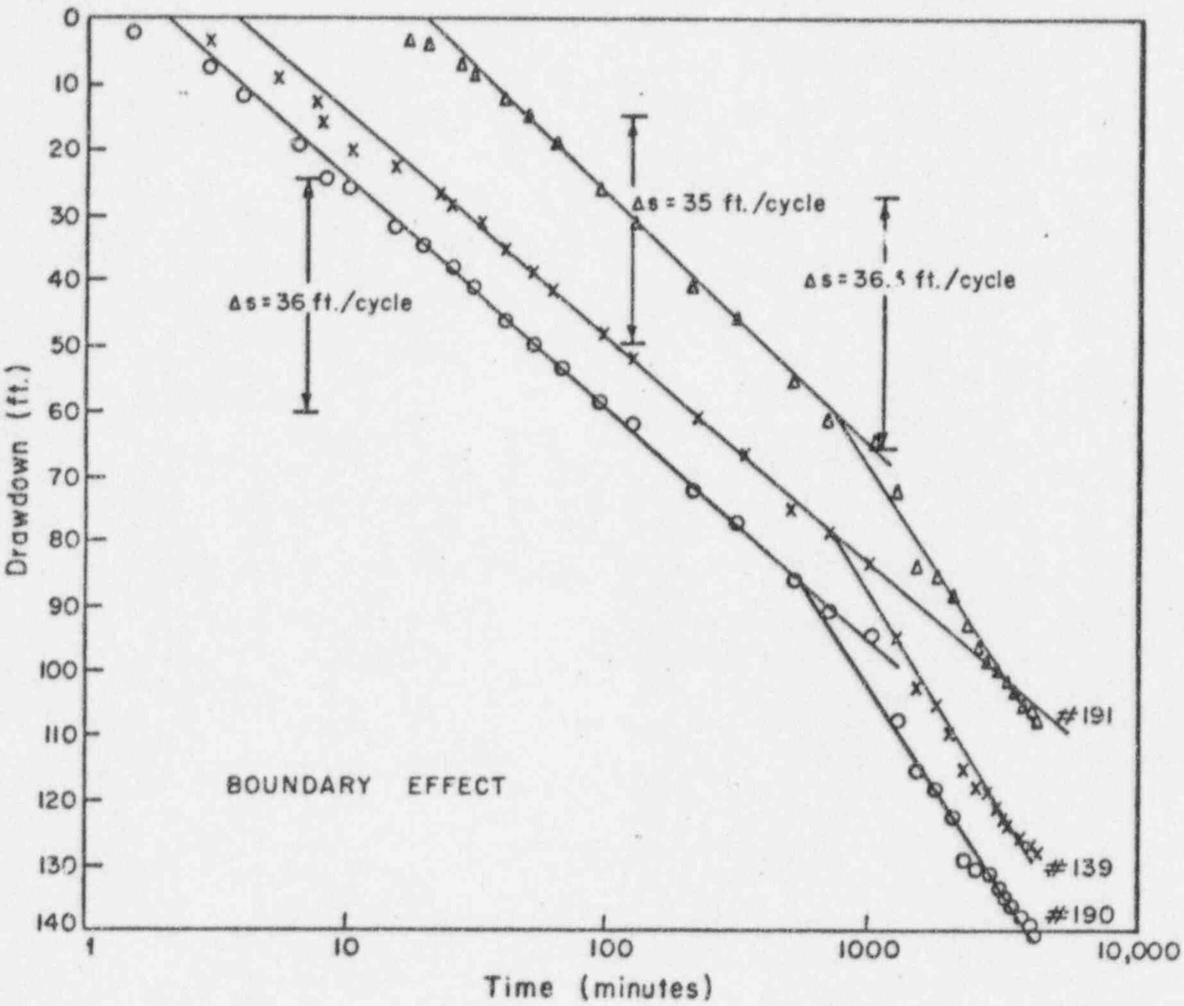
In-situ Consulting

PREPARED BY: R.S	DATE: 9-27-78
CHECKED BY: C.R.M	DATE: 9/28/78
DRAWN BY ZIMMERGRAPHICS	FIGURE NO. 6

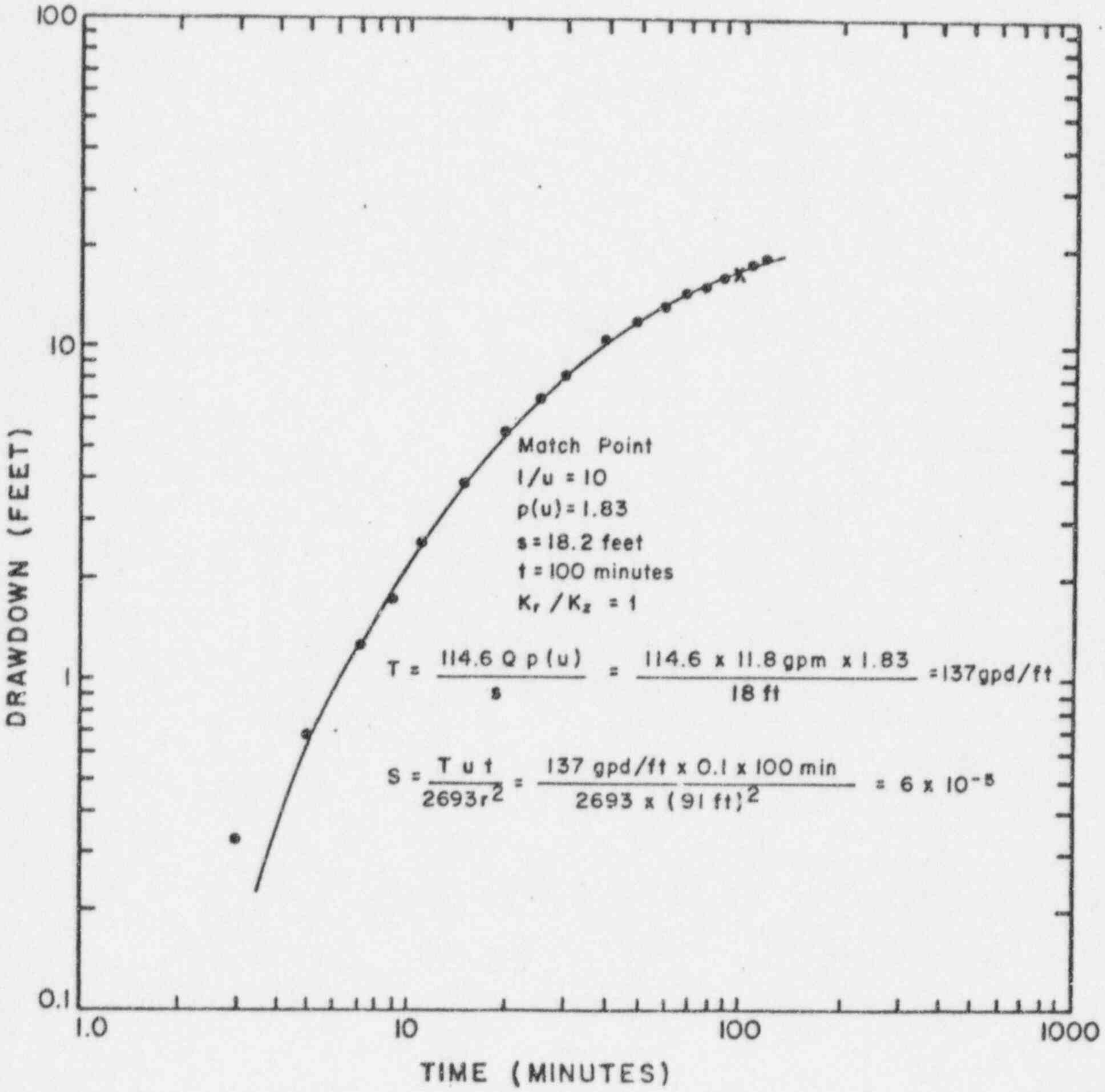


	WATER ELEVATION VS. TIME **COLLINS DRAW**

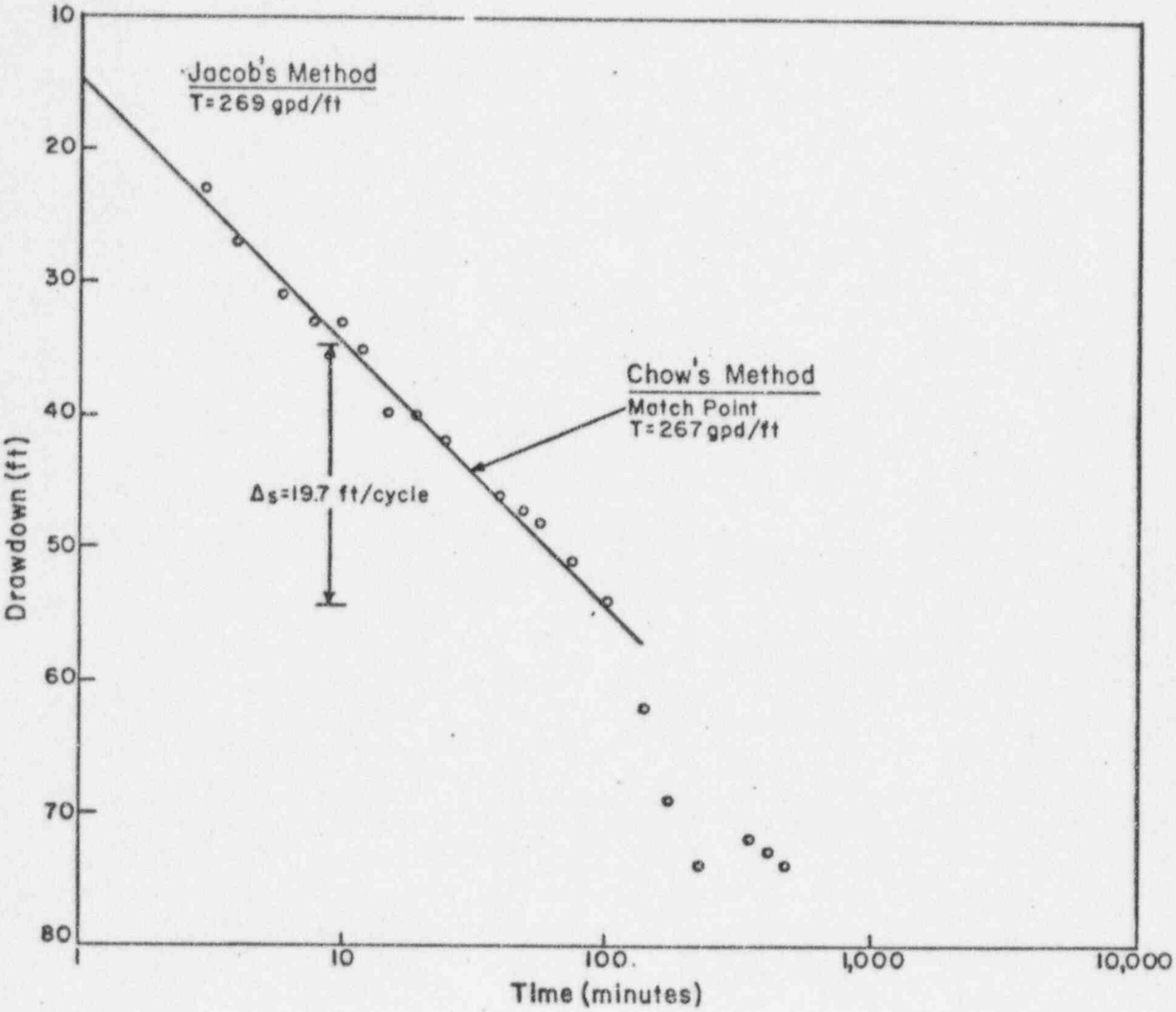
In·situ Consulting	PREPARED BY: R.S.	DATE: 9-27-78
	CHECKED BY: C.R.M.	DATE: 9/28/78
	DRAWN BY ZIMMERGRAPHICS	FIGURE NO. 7



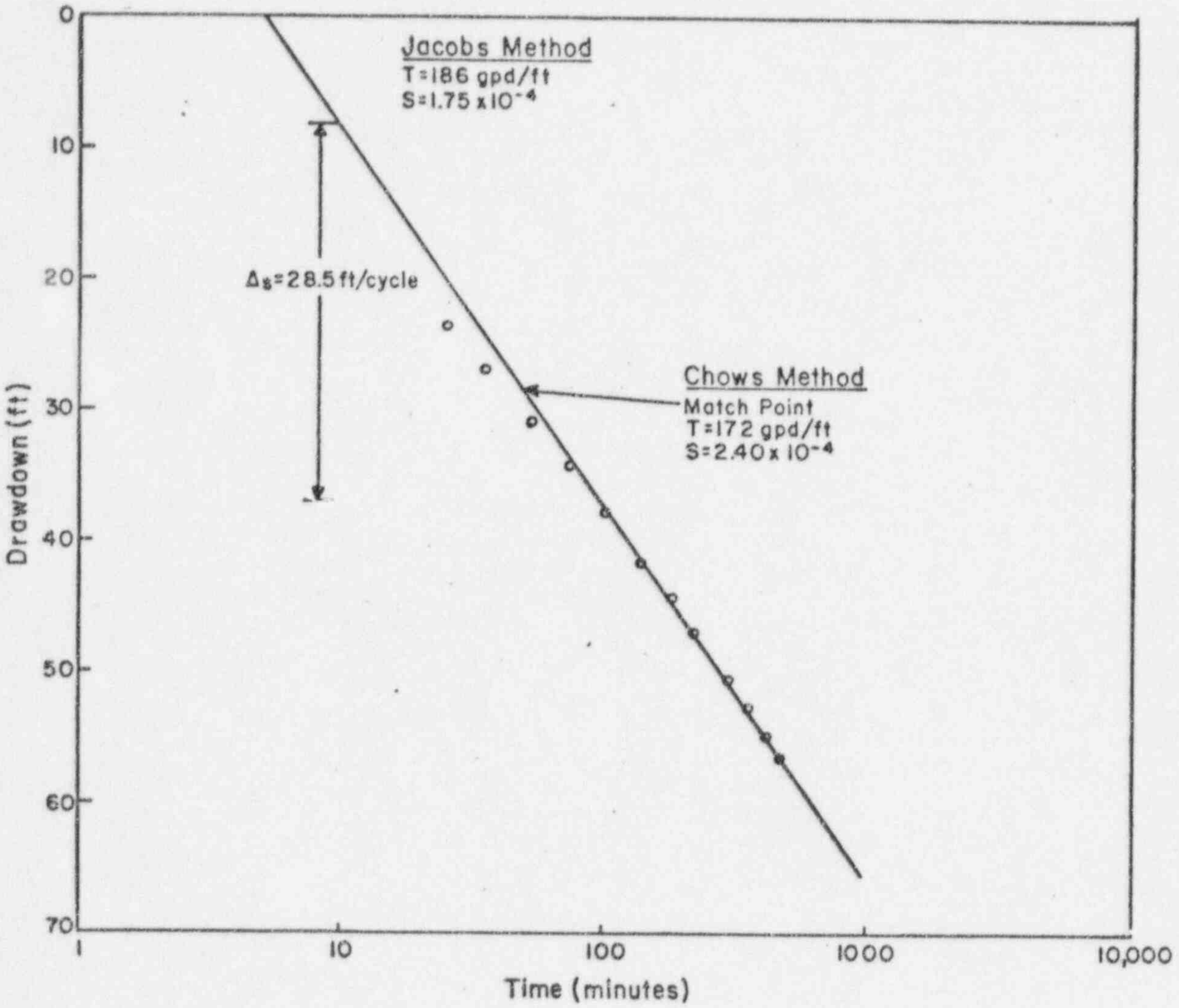
CLEVELAND CLIFFS IRON CO.	TEST 5 PUMPING WELL 146 Q = 25.6 gpm	
In-situ Consulting	PREPARED BY: T.W	DATE: 9-27-78
	CHECKED BY: C.R.M.	DATE: 9/28/78
	DRAWN BY ZIMMERGRAPHICS	FIGURE NO. 8



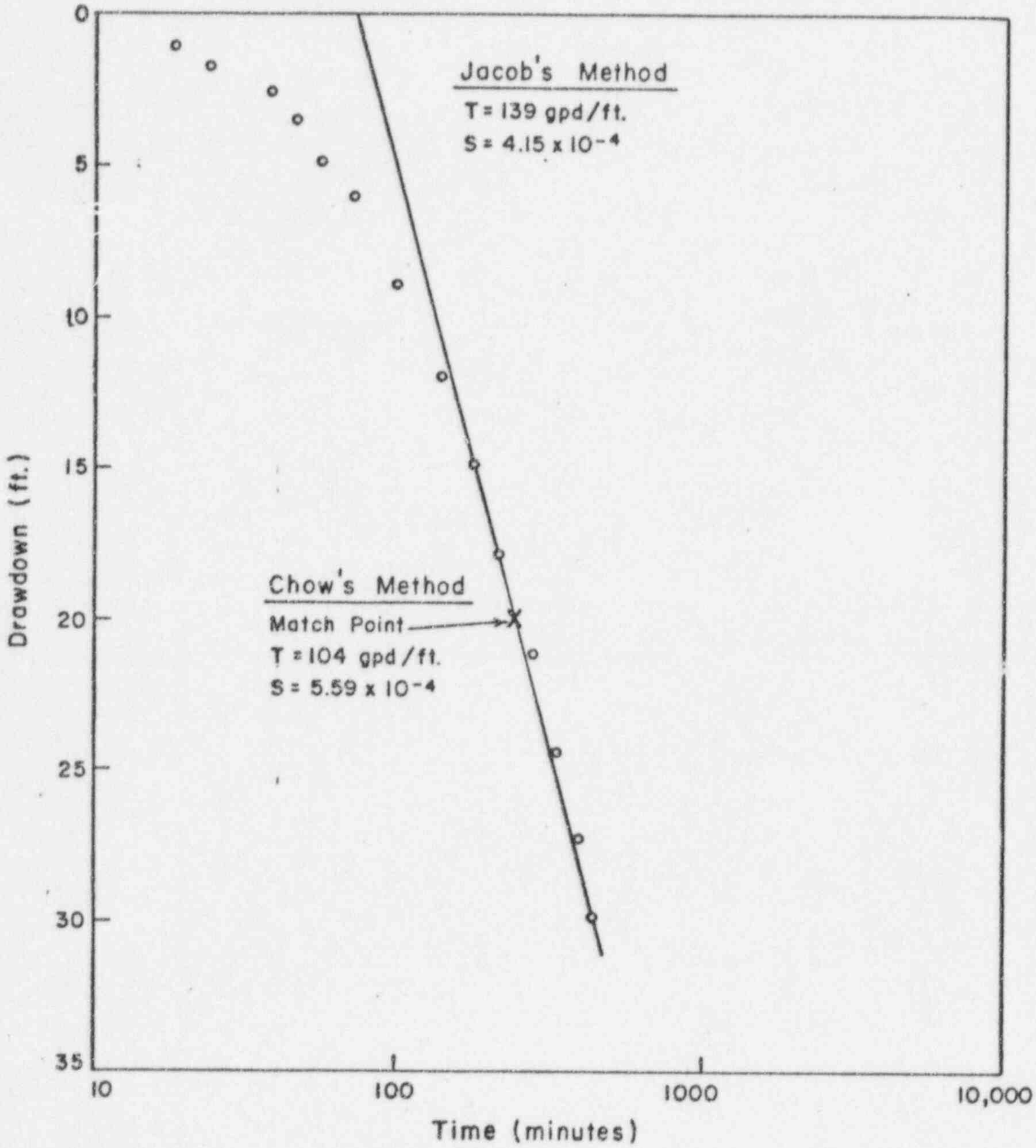
CLEVELAND CLIFFS IRON CO.	HANTUSH'S UNSTEADY STATE TYPE CURVE OBSERVATION WELL NO. 231 TEST 6	
In-situ Consulting	PREPARED BY: T. W.	DATE: 5-27-78
	CHECKED BY: C. R. M	DATE: 9/28/78
	DRAWN BY ZIMMERGRAPHICS	FIGURE NO. 9



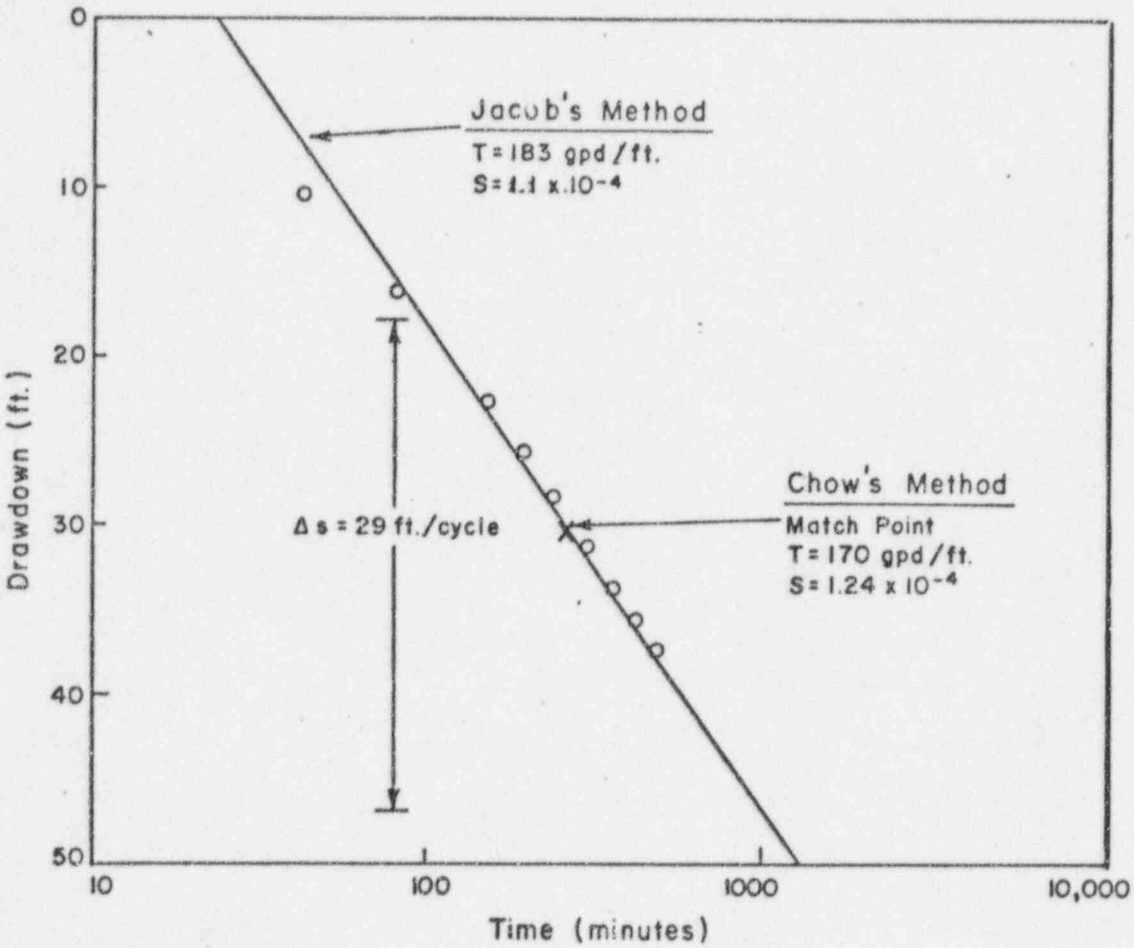
CLEVELAND CLIFFS IRON CO.	TEST 7 PUMPING WELL 139 Q=20 gpm
In·situ Consulting	PREPARED BY: T. W. — DATE: 9-27-78 CHECKED BY: C. R. M. — DATE: 9/28/78 DRAWN BY ZIMMERGRAPHICS — FIGURE NO. 10



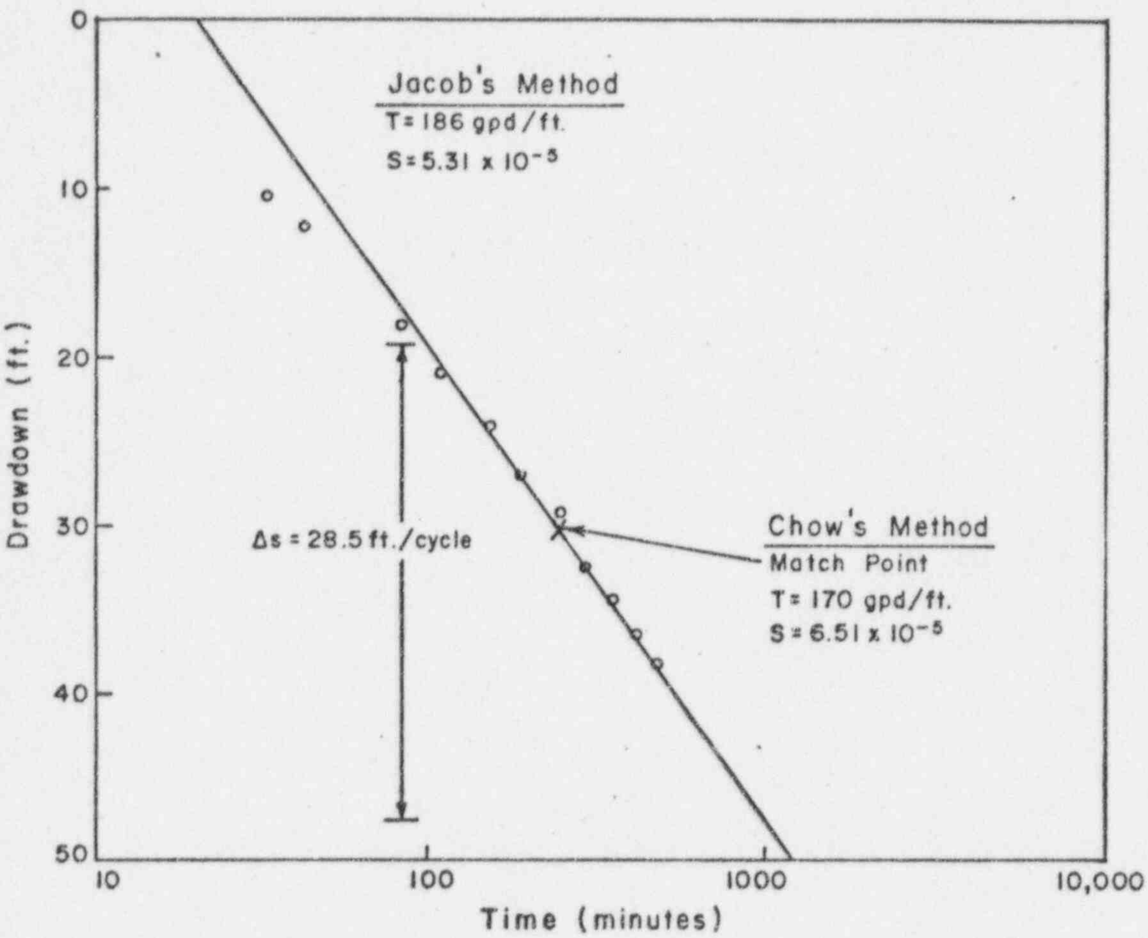
CLEVELAND CLIFFS IRON CO.	TEST 7 OBSERVATION WELL 146 PUMPING WELL 139 Q=20 gpm	
In·situ Consulting	PREPARED BY: T.W.	DATE: 9-27-78
	CHECKED BY: C.R.M	DATE: 9/28/78
	DRAWN BY ZIMMERGRAPHICS	FIGURE NO. 11



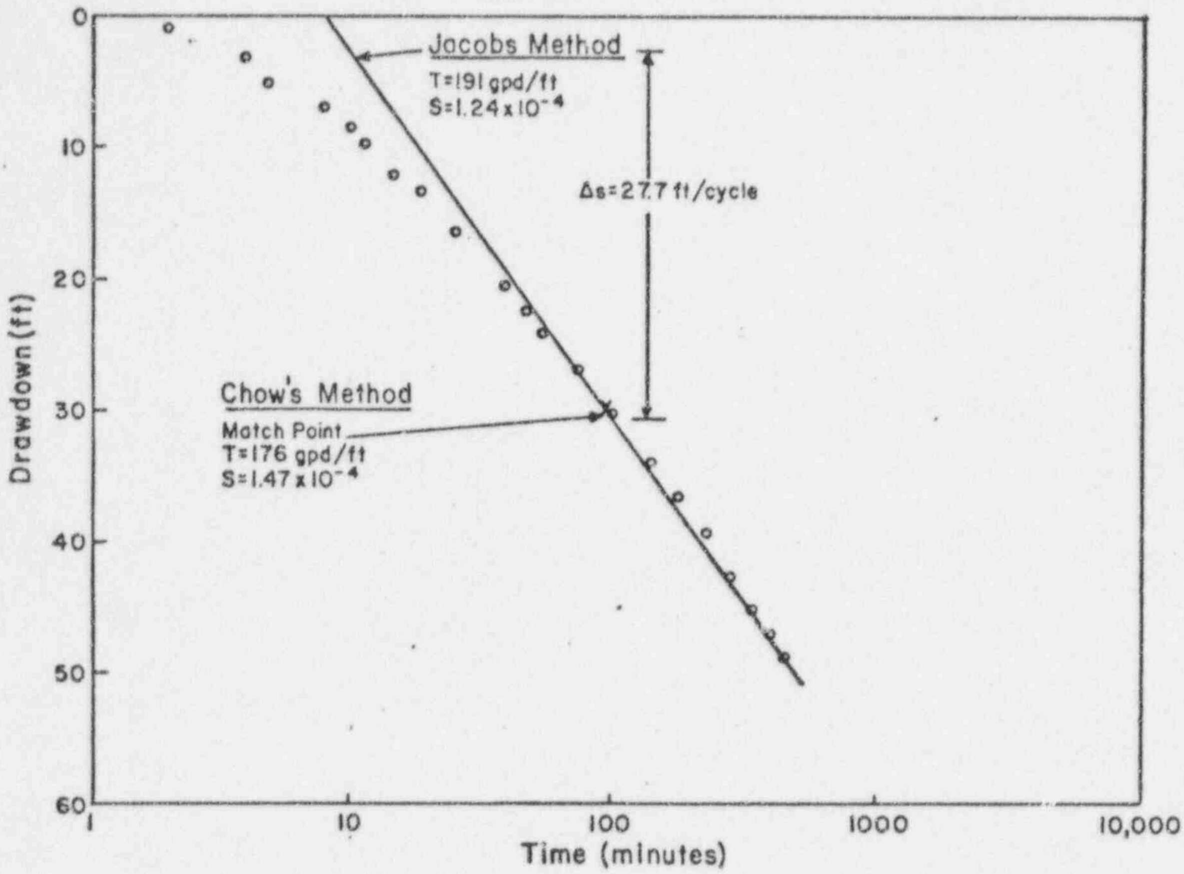
CLEVELAND CLIFFS IRON CO.	TEST 7 OBSERVATION WELL 191 PUMPING WELL 139	Q = 20 gpm
In-situ Consulting	PREPARED BY: T.W.	DATE: 9-27-78
	CHECKED BY: C.R.M.	DATE: 9/28/78
	DRAWN BY ZIMMERGRAPHICS	FIGURE NO. 12



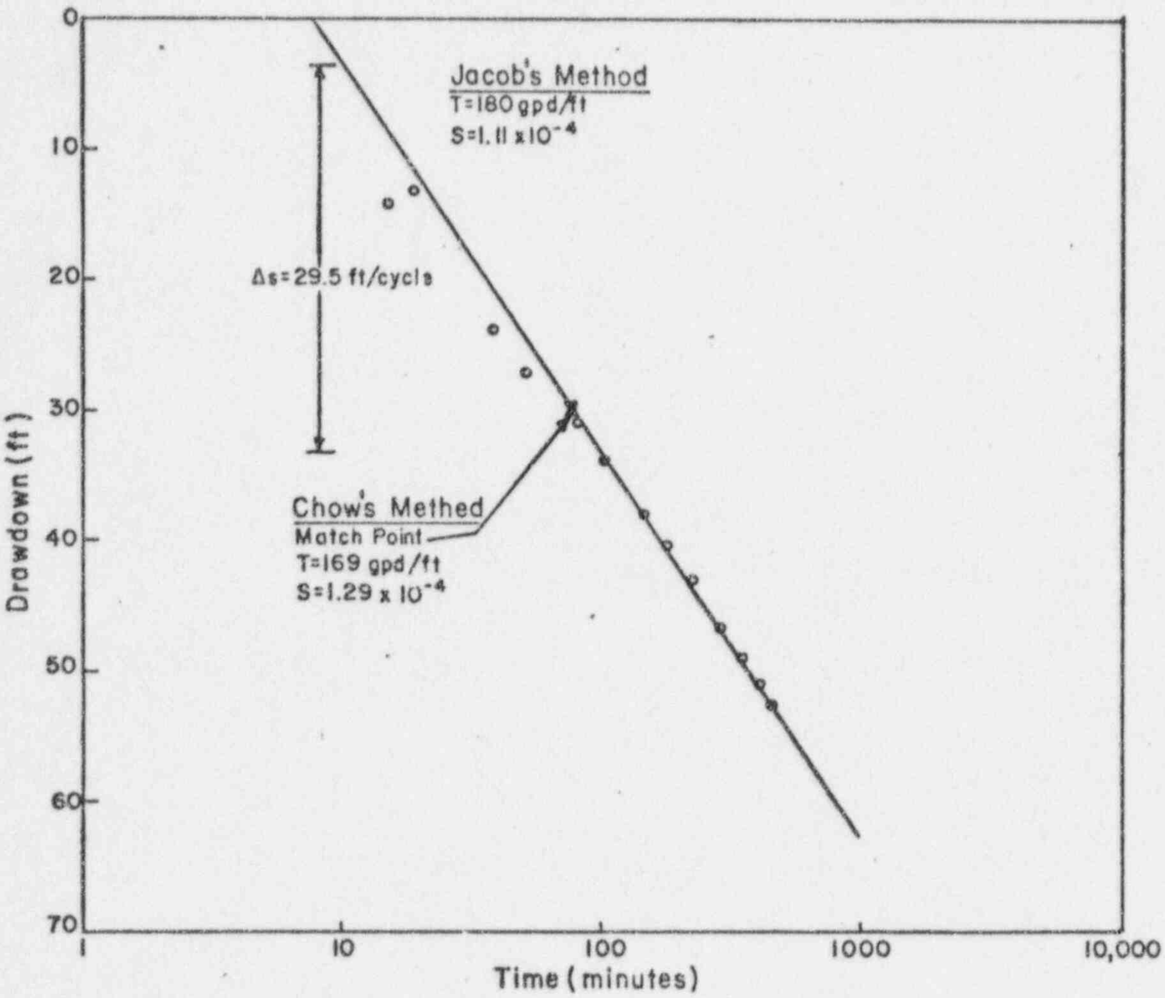
CLEVELAND CLIFFS IRON CO.	TEST 7 OBSERVATION WELL 231 PUMPING WELL 139 Q=20gpm
In·situ Consulting	PREPARED BY: TW — DATE: 9.27-78 CHECKED BY: C.R.M. — DATE: 9/28/78 DRAWN BY ZIMMERGRAPHICS — FIGURE NO. 13



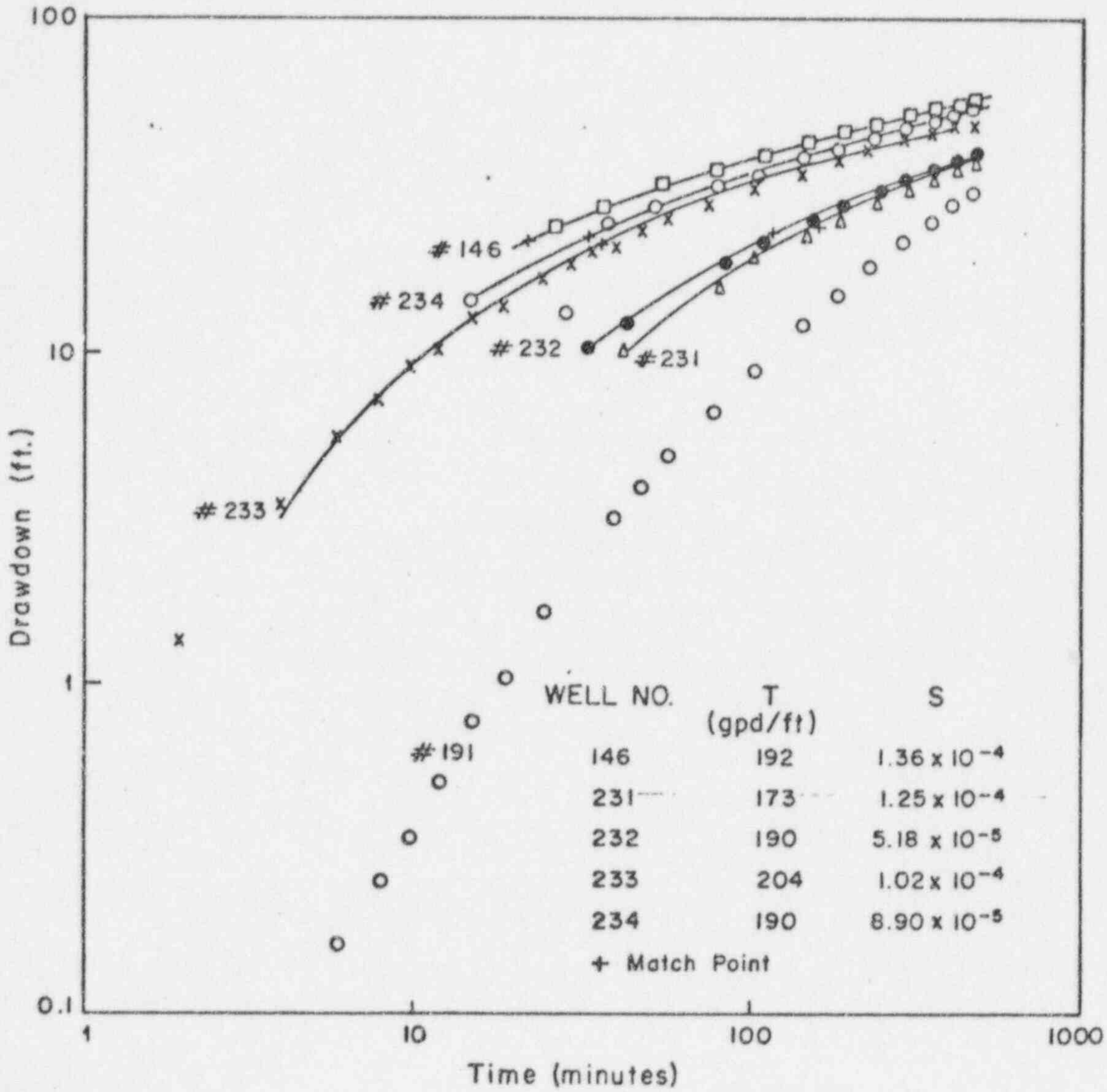
CLEVELAND CLIFFS IRON CO.	TEST 7 OBSERVATION WELL 232 PUMPING WELL 139 Q=20gpm	
In·situ Consulting	PREPARED BY: T.W.	DATE: 9-27-78
	CHECKED BY: C.R.M.	DATE: 9/28/80
	DRAWN BY ZIMMERGRAPHICS	FIGURE NO. 14



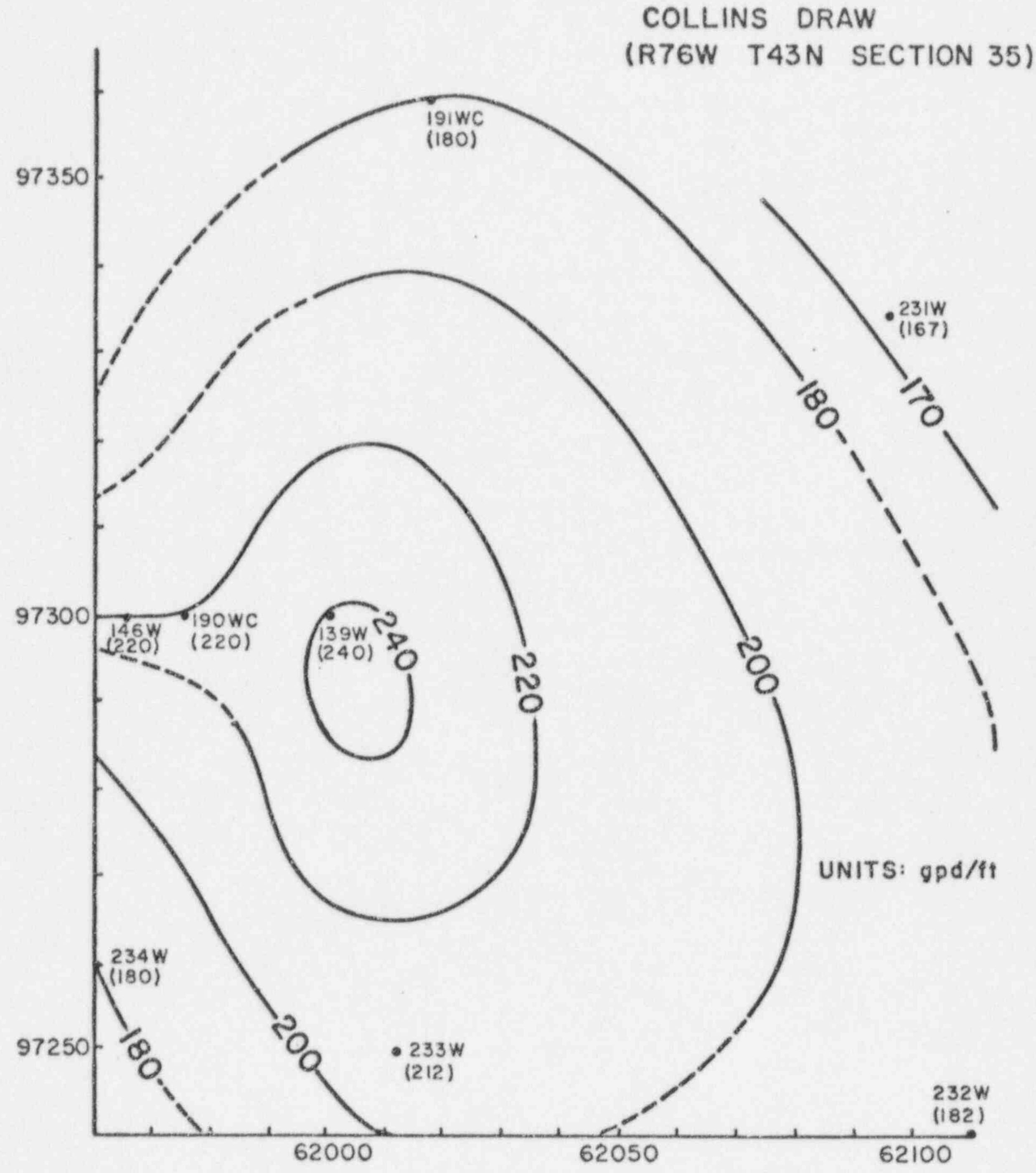
CLEVELAND CLIFFS IRON CO.	TEST 7 OBSERVATION WELL 233 PUMPING WELL 139 Q=20gpm
In-situ Consulting	PREPARED BY: T. W. — DATE: 9-27-78 CHECKED BY: G. R. M. — DATE: 9/28/78 DRAWN BY ZIMMERGRAPHICS — FIGURE NO. 15



CLEVELAND CLIFFS IRON CO.	TEST 7 OBSERVATION WELL 234 PUMPING WELL 139 Q=20 gpm
In-situ Consulting	PREPARED BY: T. W. — DATE: 9-27-78 CHECKED BY: C.R.M. — DATE: 9/28/80 DRAWN BY ZIMMERGRAPHICS — FIGURE NO. 16



CLEVELAND CLIFFS IRON CO.	HANTUSH'S UNSTEADY STATE LEAKY TYPE CURVE METHOD	
In·situ Consulting	PREPARED BY: T. W.	DATE: 9-27-78
	CHECKED BY: D. R. M.	DATE: 7-28-78
	DRAWN BY ZIMMERGRAPHICS	FIGURE NO. 17



TRANSMISSIVITY CONTOUR MAP

In·situ Consulting

PREPARED BY: T.W.	DATE: 9-27-78
CHECKED BY: C.R.M.	DATE: 9/28/78
DRAWN BY ZIMMERGRAPHICS	FIGURE NO 18

Computations Accompanying Figures in Text

FIGURE 8

JACOB'S METHOD

WELL # 191

$T = \frac{264Q}{\Delta s}$

$= \frac{264 \times 25.61\ gpm}{36.3\ ft}$

$= 186\ gpd/ft$

$S = \frac{Tt_0}{4790r^2}$

$= \frac{186\ gpd/ft \times 19.7\ min}{4790 \times (85.02\ ft)^2}$

$= 1.06 \times 10^{-4}$

WELL # 190

$T = \frac{264Q}{\Delta s}$

$= \frac{264 \times 25.61\ gpm}{36\ ft}$

$= 188\ gpd/ft$

$S = \frac{Tt_0}{4790r^2}$

$= \frac{188\ gpd/ft \times 2.05\ min}{4790 \times (5.3\ FT)^2}$

$= 2.86 \times 10^{-3}$

WELL # 139

$T = \frac{264Q}{\Delta s}$

$= \frac{264 \times 25.61\ gpm}{35\ ft}$

$= 194\ gpd/ft$

$S = \frac{Tt_0}{4790r^2}$

$= \frac{194\ gpd/ft \times 3.8\ min}{4790 \times (33.9\ FT)^2}$

$= 1.34 \times 10^{-4}$

CHOW'S METHOD

WELL # 191

AT MATCH POINT

$s = 35\ ft$

$t = 160\ min$

$F(u) = 35/35 = 1.0$

$W(u) = 2.11$

$u = 0.074$

$T = \frac{114.6\ Q\ W(u)}{s}$

$= \frac{114.6 \times 25.61\ gpm \times 2.11}{35\ FT}$

$= 178\ gpd/ft$

$S = \frac{Tut}{2693r^2}$

$= \frac{178\ gpd/ft \times 0.074 \times 160\ min}{2693 \times (85.02\ ft)^2}$

$= 108 \times 10^{-4}$

WELL # 190

AT MATCH POINT

$s = 36\ ft$

$t = 21\ min$

$F(u) = 35/35 = 1.0$

$W(u) = 2.11$

$u = 0.074$

$T = \frac{114.6\ Q\ W(u)}{s}$

$= \frac{114.6 \times 25.61\ gpm \times 2.11}{36\ FT}$

$= 172\ gpd/ft$

$S = \frac{Tut}{2693r^2}$

$= \frac{172\ gpd/ft \times 0.074 \times 21\ min}{2693 \times (5.3\ ft)^2}$

$= 3.53 \times 10^{-3}$

WELL # 139

AT MATCH POINT

$s = 35\ ft$

$t = 38\ min$

$F(u) = 35/35 = 1.0$

$W(u) = 2.11$

$u = 0.074$

$T = \frac{114.6\ Q\ W(u)}{s}$

$= \frac{114.6 \times 25.61\ gpm \times 2.11}{35\ ft}$

$= 178\ gpd/ft$

$S = \frac{Tut}{2693r^2}$

$= \frac{178\ gpd/ft \times 0.074 \times 38\ mi}{2693 \times (33.9\ ft)^2}$

$= 1.62 \times 10^{-4}$

FIGURE 10

JACOB'S METHOD

$T = \frac{264Q}{\Delta s}$

$= \frac{264 \times 20.07\ gpm}{19.7\ ft}$

$= 269\ gpd/ft$

CHOW'S METHOD

AT MATCH POINT

$s = 44\ ft$

$t = 30\ min$

$F(u) = 44/19.7 = 2.23$

$\Rightarrow w(u) = 5.1$

$u = 0.003$

$T = \frac{114.6\ Q\ w(u)}{s}$

$= \frac{114.6 \times 20.07\ gpm \times 5.1}{44\ ft}$

$= 267\ gpd/ft$

FIGURE 11

JACOB'S METHOD

$T = \frac{264Q}{\Delta s}$

$= \frac{264 \times 20.07\ gpm}{28.5\ ft}$

$= 186\ gpd/ft$

$S = \frac{Tt_0}{4790 r^2}$

$= \frac{186\ gpd/ft \times 5.2\ min}{4790 \times (34\ ft)^2}$

$= 1.75 \times 10{-}4$

CHOW'S METHOD

AT MATCH POINT

$s = 2.87\ ft$

$t = 62\ min$

$F(u) = 28.7/28.5 = 1.01$

$\Rightarrow W(u) = 2.15$

$u = 0.07$

$T = \frac{114.6\ Q\ w(u)}{s}$

$= \frac{114.6 \times 20.07\ gpm \times 2.15}{28.7\ ft}$

$= 172\ gpd/ft$

$S = \frac{Tut}{2693 r^2}$

$= \frac{172 \times 0.07 \times 62\ min}{2693 \times (34\ ft)^2}$

$= 2.40 \times 10^{-4}$

FIGURE 12

JACOB'S METHOD

$T = \frac{264Q}{\Delta s}$

$= \frac{264 \times 20.07\ gpm}{42.5ft - 4.3ft}$

$= 139\ gpd/ft$

$S = \frac{Tto}{4790r^2}$

$= \frac{139\ gpd/ft \times 77\ min}{4790 \times (73.41\ ft)^2}$

$= 4.15 \times 10^{-4}$

CHOW'S METHOD

AT MATCH POINT

$s = 20ft$

$t = 260\ min$

$F(u) = 20/38.2 = 0.52$

$\Rightarrow w(u) = 0.9$

$u = 0.3$

$T = \frac{114.6\ Q\ w(u)}{s}$

$= \frac{114.6 \times 20.07\ gpm \times 0.9}{20ft}$

$= 104\ gpd/ft$

$S = \frac{Tut}{2693r^2}$

$= \frac{104\ gpd/ft \times 0.3 \times 260\ min}{2693 \times (73.41\ ft)}$

$= 5.59 \times 10^{-4}$

FIGURE 13

JACOB'S METHOD

$T = \frac{264Q}{\Delta s}$

$= \frac{264 \times 20.07gpm}{29ft} = 183\ gpd/ft$

$S = \frac{Tto}{4790r^2}$

$= \frac{183gpd/ft \times 24.5\ min}{4790 \times (91.5ft)} = 1.1 \times 10^{-4}$

CHOW'S METHOD

AT MATCH POINT

$s = 30ft \quad t = 260min$

$F(u) = 30/29 = 1.034$

$\Rightarrow w(u) = 2.22 \quad u = 0.063$

$T = \frac{114.6Q\ w(u)}{s}$

$= \frac{114.6 \times (20.07gpm) \times 2.22}{30ft} = 170\ gpd/ft$

$S = \frac{Tut}{2693r^2}$

$= \frac{170\ gpd/ft \times 0.063 \times 260min}{2693 \times (91.5ft)^2}$

$= 1.24 \times 10^{-4}$

FIGURE 14

JACOB'S METHOD

$$T = \frac{264Q}{\Delta s}$$

$$= \frac{264 \times 20.07\,gpm}{28.5\,ft} = 186\,gpd/ft$$

$$S = \frac{Tt_0}{4790 r^2}$$

$$= \frac{186\,gpd/ft \times 20.5\,min}{4790 \times (122.44\,ft)^2} = 5.31 \times 10^{-5}$$

CHOW'S METHOD

AT MATCH POINT

$s = 30\,ft$

$t = 283\,min$

$F(u) = 30/28.5 = 1.05$

$\Rightarrow W(u) = 2.22$

$u = 0.065$

$$T = \frac{114.6\,Q\,W(u)}{s}$$

$$= \frac{114.6 \times 20.07\,gpm \times 2.22}{30\,ft} = 170\,gpd/ft$$

$$S = \frac{Tut}{2693 r^2}$$

$$= \frac{170\,gpd/ft \times 0.065 \times 283\,min}{2693 \times (122.44\,ft)^2}$$

$= 6.51 \times 10^{-5}$

FIGURE 15

JACOB'S METHOD

$$T = \frac{264Q}{\Delta s}$$

$$= \frac{264 \times 20.07\,gpm}{27.7\,ft}$$

$= 191\,gpd\,ft$

$$S = \frac{Tt_0}{4790 r^2}$$

$$= \frac{191\,gpd/ft \times 8\,min}{4790 \times (50.64\,ft)^2}$$

$= 1.24 \times 10^{-4}$

CHOW'S METHOD

AT MATCH POINT

$s = 30\,ft$

$t = 96\,min$

$F(u) = 30/27.7 = 1.083$

$\Rightarrow W(u) = 2.3$

$u = 0.06$

$$T = \frac{114.6\,Q\,W(u)}{s}$$

$$= \frac{114.6 \times 20.07\,gpm \times 2.3}{30\,ft}$$

$= 176\,gpd/ft$

$$S = \frac{Tut}{2693 r^2}$$

$$= \frac{176\,gpd/ft \times 0.06 \times 96\,min}{2693 \times (50.64\,ft)^2}$$

$= 1.47 \times 10^{-4}$

FIGURE 16

JACOB'S METHOD

$T = \frac{264Q}{\Delta s}$

$= \frac{264 \times 20.07 \text{ gpm}}{2.95 \text{ ft}}$

$= 180 \text{ gpd/ft}$

$S = \frac{T t_0}{4790 r^2}$

$= \frac{180 \text{ gpd/ft} \times 7.7 \text{ min}}{4790 \times (51.15 \text{ ft})^2}$

$= 1.11 \times 10^{-4}$

CHOW'S METHOD

AT MATCH POINT

$s = 30 \text{ ft}$

$t = 80 \text{ min}$

$F(u) = s/\Delta s = 30/29.5 = 1.02$

$\Rightarrow W(u) = 2.2$

$u = 0.067$

$T = \frac{114.6 Q W(u)}{s}$

$= \frac{114.6 \times 20.07 \text{ gpm} \times 2.2}{30 \text{ ft}}$

$= 169 \text{ gpd/ft}$

$S = \frac{T u t}{2693 r^2}$

$= \frac{169 \text{ gpd/ft} \times 0.067 \times 80 \text{ min}}{2693 \times (51.15 \text{ ft})^2}$

$= 1.29 \times 10^{-4}$

FIGURE 17

HANTUSH'S METHOD

AT ALL MATCH POINTS $u = 0.1$ $\frac{1}{u} = 10$ $w(u) = 1.8$

WELL # 146

$$T = \frac{114.6\ Q\,w(u)}{s}$$
$$= \frac{114.6 \times 20.07\text{ gpm} \times 1.8}{21.5\text{ ft}}$$
$$= 192\text{ gpd/ft}$$

$$S = \frac{Tut}{2693 r^2}$$
$$= \frac{192\text{ gpd/ft} \times 0.1 \times 22\text{ min}}{2693 \times (34\text{ ft})^2}$$
$$= 1.36 \times 10^{-4}$$

WELL # 231

$$T = \frac{114.6\ Q\,w(u)}{s}$$
$$= \frac{114.6 \times 20.07\text{ gpm} \times 1.8}{24\text{ ft}}$$
$$= 173\text{ gpd/ft}$$

$$S = \frac{Tut}{2693 r^2}$$
$$= \frac{173\text{ gpd/ft} \times 0.1 \times 163\text{ min}}{2693 \times (91.5\text{ ft})^2}$$
$$= 1.25 \times 10^{-4}$$

WELL # 232

$$T = \frac{114.6\ Q\,w(u)}{s}$$
$$= \frac{114.6 \times 20.07\text{ gpm} \times 1.8}{21.8\text{ ft}}$$
$$= 190\text{ gpd/ft}$$

$$S = \frac{Tut}{2693 r^2}$$
$$= \frac{190\text{ gpd/ft} \times 0.1 \times 110\text{ min}}{2693 \times (122.44\text{ ft})^2}$$
$$= 5.18 \times 10^{-5}$$

WELL # 233

$$T = \frac{114.6\ Q\,w(u)}{s}$$
$$= \frac{114.6 \times 20.07\text{ gpm} \times 1.8}{20.3\text{ ft}}$$
$$= 204\text{ gpd/ft}$$

$$S = \frac{Tut}{2693 r^2}$$
$$= \frac{204\text{ gpd/ft} \times 0.1 \times 34.5\text{ min}}{2693 \times (50.04\text{ ft})^2}$$
$$= 1.02 \times 10^{-4}$$

WELL # 234

$$T = \frac{114.6\ Q\,w(u)}{s}$$
$$= \frac{114.6 \times 20.07\text{ gpm} \times 1.8}{21.8\text{ ft}}$$
$$= 190\text{ gpd/ft}$$

$$S = \frac{Tut}{2693 r^2}$$
$$= \frac{190\text{ gpd/ft} \times 0.1 \times 33\text{ min}}{2693 \times (51.15\text{ ft})^2}$$
$$= 8.90 \times 10^{-5}$$

APPENDIX C
(1/16/79, Exhibit 1)

ANALYSIS of PUMP TEST CONDUCTED on WELL 237 and COMPLETED into STRAY SAND UNDER MINERALIZED AQUIFER

By

C. R. McKee
In-Situ Consulting

ESTIMATE of the TRANSMISSIVITY of Well 237

A slug test was conducted on Well 237W which is completed in an apparent stray sand member below the mineralized zone at Collins Draw on 5/15/78. Static water level was 60.3 feet below the top of the casing. The transducer was set at 281.5 feet or 221.2 feet below static water level. The pump was turned on for a period of 4.5 minutes at a rate of 45.9 gpm removing a total of 206.6 gal. and producing a drawdown of 218.2. However, since a check valve was not left in the pump the volume enclosed in the 2" pipe quickly drained into the well. This amounts to 49.85 gallons which drained from the pipe into the well bore, resulting in a net 156.78 gal. pumped from the well. The resulting decreases in water level due to the stray withdrawal is 165.5 feet. The data are given in Table 1. Water level is computed by subtracting the transducer level from the initial static level of 221.2 feet above the transducer. The value of H/H_o is plotted against the logarithm of the time and matched to the type curve given in Lohman (1972). From the match point, a value of 2.14 gpd/ft was obtained. The estimated sand thickness of 12 feet yielded rather low permeability of 10 millidarcies. The storage coefficient was found to be 7.9×10^{-6} which is consistent with a confined aquifer.

One can also estimate the value of transmissivity by using superposition theory and solving for the transmissivity. The recovery formula is (Ferris et al 1962).

$$s = \frac{114.6\ Q}{T} \ln \frac{t}{t'}$$

where t is the time since pumping began and t' is the time since pumping stopped. We chose the largest time possible to avoid early time effects since this equation is a long time approximation. Using the last point at 72 minutes with s = 150.2 feet from Table 1 and substitution in the previous equation we obtain another independent estimate for the transmissivity.

$$T = \frac{(114.6)(45.9)}{150.2} \ln \frac{(72)}{(72-4.5)} = 2.26 \text{ gpd/ft}$$

which is in excellent agreement with the value from type curve match of 2.14 gpd/ft. Since the well was drilled with foam and the other wells drilled by Cliffs have an average efficiency of 80%, we do not believe that well bore effects are interfering in our case. It is, therefore, our opinion that the lower sand is not capable of producing any significant quantities of water in view of its extremely low permeability, and should, therefore, be deleted from the monitoring program. Furthermore, the low value for the storage coefficient indicates this sand does not exhibit leakage.

References

Lohman S.W., Ground Water Hydraulics, Geol. Survey Prof. Pap. 708. U.S. Gov. Printing Office, 1972

Ferris J. G., Knowles D. B., Brown R. H., Stallman R. W., Theory of Aquifer Tests, Geol. Survey Water-Supply Paper 1536-E. U.S. Gov. Printing Office 1962

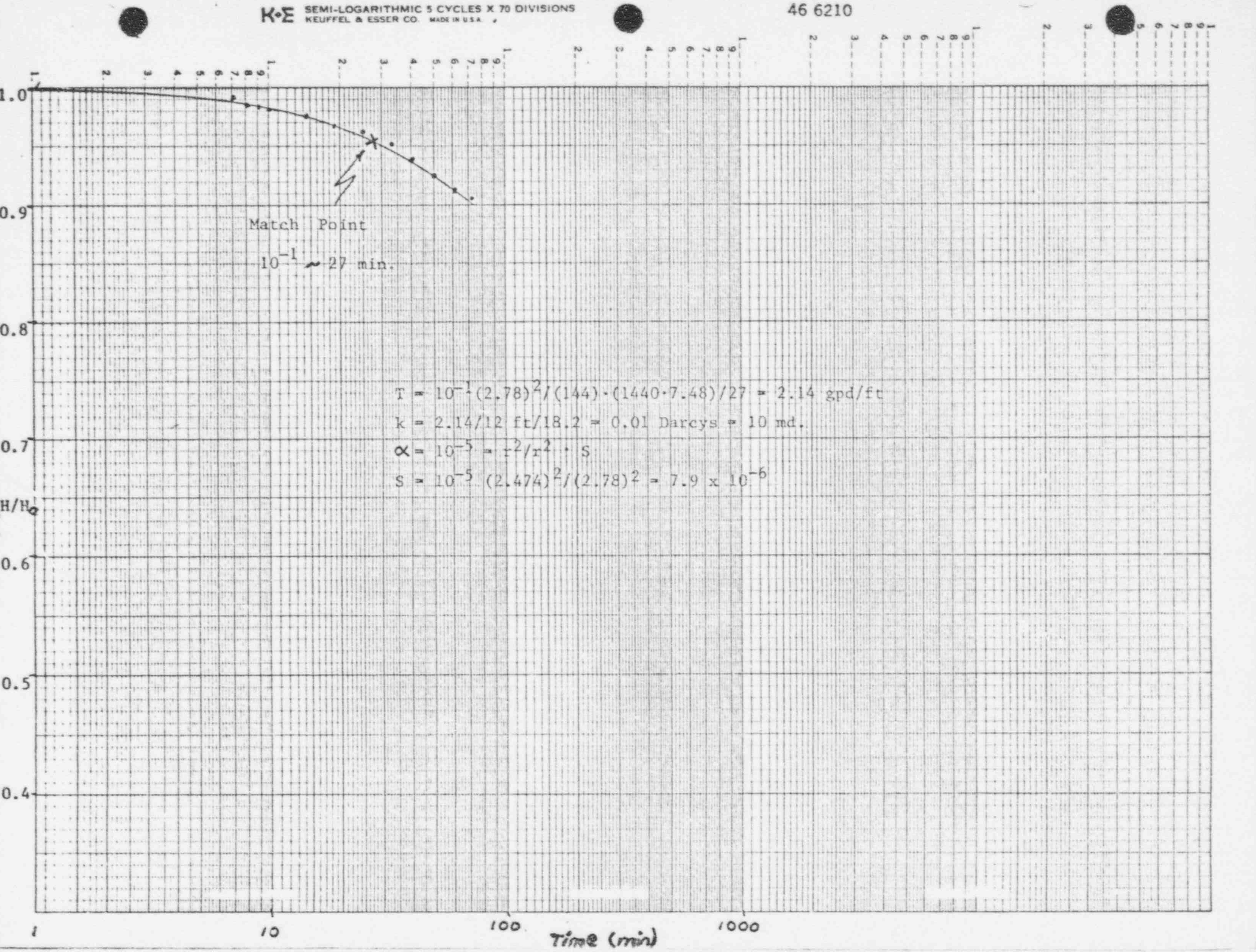

K•E SEMI-LOGARITHMIC 5 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 6210
Match Point
$10^{-1} \sim 27$ min.
$T = 10^{-1}(2.78)^2/(144)\cdot(1440\cdot7.48)/27 = 2.14$ gpd/ft
$k = 2.14/12$ ft$/18.2 = 0.01$ Darcys $= 10$ md.
$\alpha = 10^{-5} = r^2/r^2 \cdot S$
$S = 10^{-5}\ (2.474)^2/(2.78)^2 = 7.9 \times 10^{-6}$
H/Ho
Time (min)

TABLE 1 - FIELD DATA

Time (Min	Transducer Level	Water Level(H)	H/H_o
7	57	164.2	.992
8	58	163.2	.986
9	58.5	162.7	.983
10	59	162.2	.980
14	60	161.2	.974
18.5	61	160.2	.968
24.5	62	159.2	.962
31.5	64	157.2	.950
39	66	155.2	.938
50	68	153.2	.926
62	70	151.2	.914
72	71	150.2	.908