KANSAS GEOLOGICAL SURVEY
OPEN-FILE REPORT 82-3

A GEOLOGIC AND HYDROLOGIC INVESTIGATION OF A PROPOSED EXPANSION OF THE KIES INDUSTRIAL WASTE DISPOSAL FACILITY IN SEDGWICK COUNTY, KANSAS

for

The State Attorney and the Secretary of the
Kansas Department of Health and Environment

by

Members of the
Staff of the State Geological Survey

Coordinated by
Frank W. Wilson
Senior Geologist

Disclaimer

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May, 1981

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EXECUTIVE SUMMARY

Two water-bearing zones were found beneath the proposed site at depths which may affect its suitability as a hazardous waste disposal facility.

An upper aquifer at about elevation 1350 feet is associated with a soft limestone that marks the horizon of a dissolving gypsum bed. It is present except in the northeast quarter of the site.

A second layer at about elevation 1337 feet is associated with a series of gypsum, calcite, and dolomite layers. It is present beneath all of the site.

The aquifers occur also in shallow farm or residence wells in surrounding sections. The water is of poor quality, but it is being used at present for stock and domestic water purposes.

Water levels measured by geotechnical consultants for KIES in 1976 and 1979 are about five feet higher than those measured by us in closely adjacent wells during a period of drought in February and March, 1981. It is probable that the water level in the upper aquifer will be at about elevation 1355 during periods of more normal precipitation.

The elevation of the bottoms of the proposed disposal trenches is 1358-60 feet. The vertical separation between the usable aquifer and the waste material is probably less than the five foot minimum required by EPA and KDHE.

Our field tests and observations suggest that the permeability of the separating material is greater than that reported by the geotechnical consultant from laboratory tests.

We thus conclude that the site, as it is proposed to be designed and operated, does not meet present criteria of EPA and KDHE in that during periods of normal or above normal precipitation, there may not be five feet of 1×10^{-7} permeability material between the base of the proposed trenches and the historical high groundwater table.

Further, we consider present site evaluation techniques and criteria to be inadequate. New criteria should be developed for sites involving geologic materials such as shales and interbedded evaporites. Pressure testing of drill holes should be done with isolating packers. Large scale test pits should be dug, if necessary, to attain in-place block samples for determination of horizontal and vertical permeability and to confirm whether or not vertical joints or fractures are present.

Except for one hole at the southeast corner of the site, all of the test holes and an existing water well were reported to be dry by the site geotechnical consultant in 1979. Holes drilled by KGS closely adjacent to the consultant's test hole locations found water at levels above the elevation of the bottoms of the reportedly dry holes. We can think of no technical explanation for this apparent discrepency.

In the future, a KDHE geologist should be present at all times when site investigations are made.

Geotechnical reports for proposed sites should contain an analysis of regional as well as site geology and hydrology. In addition to present conditions, geologic and geomorphic processes that have affected the site should be considered. This part of the report should be prepared by a qualified geologist or hydrologist.

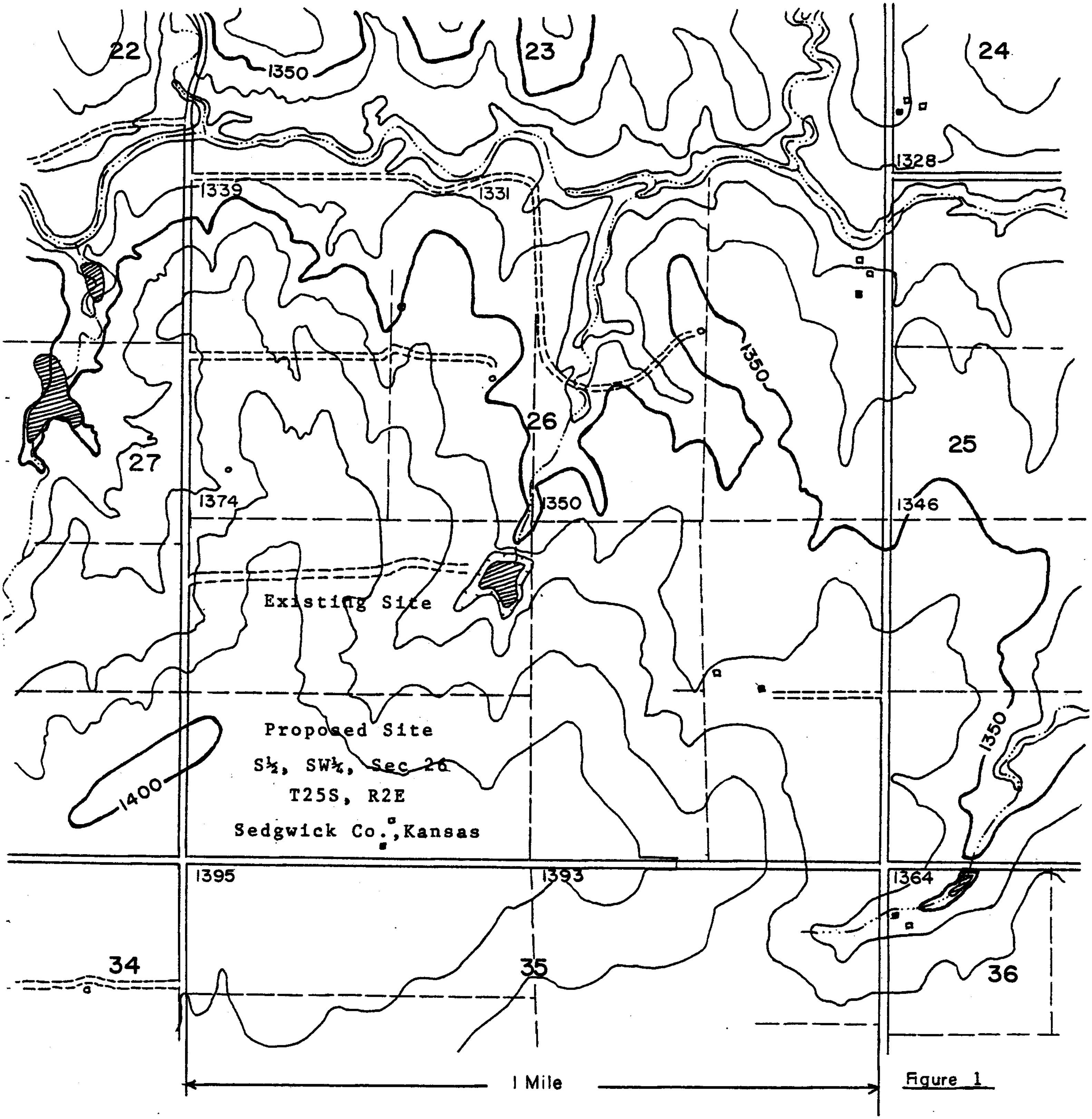
INTRODUCTION

The Kansas Geological Survey (KGS) was requested by the State Attorney General and the Secretary of Health and Environment (KDHE) to make an independent study of a proposed hazardous waste treatment and disposal site near Wichita.

Kansas Industrial Environmental Services, Inc. (KIES) has applied for a permit to expand their existing operations onto an adjacent 80 acres (see Figure 1). Local landowners and their geological consultant had objected to the site geotechnical report prepared by Haliburton Associates (HA), Stillwater, Oklahoma, stating that it did not fully address the geologic and hydrologic aspects of the site and surrounding areas.

JUSTIFICATION

The study was planned and conducted primarily to answer the above concerns, but because the project was financed entirely by the Kansas Geological Survey from its research funds, the director and staff agreed that the investigation should also be designed to develop methods and data that could be used to produce guidelines for the study and evaluation of future sites that might be proposed. This policy is in line with one of the principal objectives of the KGS, to conduct applied geologic and hydrologic research that will benefit the general public and assist other agencies in carrying out their legislative, administrative, and regulatory duties.



22
23
24
1350
1328
1339
1331
1350
26
25
27
1374
1350
1346
Existing Site
Proposed Site
S½, SW¼, Sec 26
T25S, R2E
Sedgwick Co., Kansas
1400
1350
1395
1393
1364
34
35
36
1 Mile

Figure 1

FIELD INVESTIGATIONS

DRILLING AND SAMPLING PROGRAM

Observation Wells

Eight observation wells were drilled at the four corners and near the center of the proposed site (see location map, Figure 2). KGS-1 was drilled to a depth of 134 feet to determine the subsurface stratigraphy. It was drilled using a Failing Holemaster 1250 core drill with a 6.5 inch diameter tri-cone bit and Wichita city water as circulating fluid. Cuttings were sampled and logged at approximate five-foot intervals or at changes in lithology. Samples were logged by Patrick Cobb, staff geologist-hydrologist.

The remaining holes were drilled dry with a CME power auger using mainly a 4-inch diameter continuous-flight auger. Cuttings were logged by Patrick Cobb or Frank Wilson, senior geologist. Samples were not saved except from KGS-2 where continuous push-tube samples were taken to refusal at 31 feet. These samples were taken with a standard USDA 42 mm inside diameter side-slotted sampler, pushed without rotation using the hydraulic draw-down on the auger rig. The hole was subsequently deepened to 51 feet with 4-inch auger. Push samples were boxed, labeled, and later logged in detail by Harold Dickey, staff soil scientist, and Jerome Welch, staff soil geochemist. Cuttings from this hole were bagged in plastic and analyzed in the laboratory.

The laboratory data for KGS-2 appear in Table 2, Appendix A, following the log of KGS-2. This well is near the location of boring No. 4 reported in the Geotechnical Engineering Report of this site. The results of field moisture density and grain size distribution in Table 2 are similar to results reported in Table 2 of the site Geotechnical Engineering Report by Haliburton Associates. Therefore, we would agree that the results for field moisture, density, Atterberg limits, grain size distribution, standard Proctor compaction, and permeability of compacted samples are reasonably representative of clay shale, except we considered the Wellington Formation at this site to be "soil-like" clay shale 1/.

All augered observation wells were drilled to an approximate depth of 50 feet. Holes were cased through the upper soil with 5 inch I.D. PVC pipe. Caps were glued on to prevent tampering and a one inch hole drilled in the side for venting and measuring. Water levels, if any, were checked upon (1) completion of drilling, (2) approximately 24 hours after drilling, (3) and periodically during the course of the field investigation.

Except for KGS-1, which was left open at the request of KDHE, casing was retrieved from all holes and they were plugged to the surface with dry drilling mud at the end of the field investigation.

1/ Underwood, Lloyd B., 1966, Classification and Identification of Shales, ASCE Water Resources Engineering Conference.

Locations of test holes, permeameters, and wells are shown on Figure 2. Detailed descriptions and logs of the stratigraphy hole and observation wells are included in Appendix A.

Permeameters

Field permeameters were used in an attempt to determine in-place permeabilities of the soils and shale into which the trenches are proposed to be dug. The permeameters are wells, either cased or partially cased to varying depths, into which water is pumped. Water levels were then measured periodically as water seeped into the material in the walls of the wells.

Three open-hole permeameters were drilled adjacent to observation wells at the southwest, southeast, and northeast corners of the proposed site. These were drilled dry with 6-inch continuous flight auger and cased to various depths with 5 inch inside diameter PVC pipe. The outside of the casing was sealed at the surface with tamped soil and dry bentonitic drilling mud. Caps were glued on to prevent tampering and a measuring/vent hole drilled in the side.

Two observation wells, KGS-5 near the center of the site and KGS-9 at the northwest corner, were subsequently converted to permeameters in attempt to determine the yield of a subsurface water-bearing zone (aquifer).

The permeameters were drilled to approximate depths of 40 feet. Except for KGS-5 and 9, cuttings were examined but not logged in detail.

The permeameters were charged to the ground surface with Wichita city water or with formation water pumped from the KGS-1 during the final test.

Permeameters were charged on February 5, 18, 26, and March 17, 1981. Except for KGS-9, water levels were measured once between the first and second fillings, twice between the second and third, four times after the third and at least seven times after the fourth and final fillings. Descriptions of the permeameters, date and time of fillings, and measuring are included in Appendix B; analyses of permeameter data are in Appendix C.

Well Sampling and Water Level Measurements

Water samples for laboratory chemical analyses by the KGS were taken from three water wells on the proposed expansion site (KGS-1-A, 1-B, and 5-A) and three of the seven observation wells (1, 2, and 7). All samples except those for 1 and 1-A were taken with a bailer. Samples from 1 and 1-A were taken after these wells had been pumped, and therefore are more representative of the water in the zones penetrated by the wells.

Water samples were also taken of the source springs for Prairie Creek to determine if these were fed by seepage from the two aquifers found beneath the proposed expansion site.

Twenty existing wells in Section 26 (not located on the present KIES site or the proposed KIES expansion site) and adjacent sections that were sampled for water quality by the KDHE were measured by the KGS for water-level elevations. These measurements were made after it became apparent that the chemical data of our wells did not correlate with data for most wells in sections sampled by the KDHE in September, 1980. We also measured the water-level elevation in an additional 14 wells in the area for which there were no chemical data available. In all, 34 wells were measured for water-level elevation. This information was then correlated with the chemical data from the water sampling to determine chemical variations in the water-bearing zones present in these sections and the wells located in the different aquifers.

The location of all wells and springs (not located on the existing or proposed KIES sites) along with water-level elevations above mean sea level-in feet, are shown in Appendix E, Figure E-1. Only 28 points are shown on the map because at six locations there were two closely spaced wells that had water at the same elevation. Records of wells that were measured for both water-level elevation and chemical quality, grouped according to the aquifer they are located in, are given in Table E-2. Corresponding chemical quality data for the wells, again grouped according to the aquifer they are located in, are given in Table E-3. Records of wells measured only for water-level elevation are given in Table E-1. To aid the reader in locating the wells shown on Figure E-1, an explanation of the well numbering system used in this report is shown on Figure E-2. A Piper diagram used in explaining changes and anomalies among the chemical data is shown on Figure E-3.

Pumping Tests

A four-hour pump test was run on KGS-1. The test was terminated because of heavy rain, nearby ground-striking lightning, and the report of a tornado on the ground near the site. During the period of pumping, a steady-state flow in excess of five gallons per minute was established. No drawdown of existing water well 1B was detected. This well is about 100 feet NW of KGS-1 and in the same aquifer.

A pumping test was twice attempted on existing water well 1A, but the capacity of the pump was too large to establish a steady-state flow. From water-level measurements taken during recovery periods, the capacity of the well was estimated to be approximately nine gallons per hour. No drawdown was detected in KGS-10 which was located 40 feet west of the well.

Stream Flow Measurements

Portable 90 degree V-notch weirs were installed on Prairie Creek near the SW corner of Sec. 23, T.25S., R.2E. and the NW 1/4, Sec. 25, T.25S., R.2E. The weirs were designed to measure the apparent increase in spring or seepage flow from contributing aquifers in that reach of the stream.

A flow of approximately 25 gpm was measured near the SW corner of Sec. 23 before the weir collapsed. It is not certain that a steady-state flow through the weir notch was established before it failed. The weir was located a short distance downstream from the point that Prairie Creek first begins to flow at the surface.

The weir near the NW corner of Sec. 25 failed twice because of water pressure and undermining by crayfish that attempted to burrow under the weir when stream flow was cut off.

RESULTS OF FIELD STUDIES

Observation Wells

Groundwater was found at a depths of approximately 45 and 60 feet in all of the observation wells except KGS-4A. This well apparently was stopped a few feet above water as indicated by recorded levels in test holes on the existing disposal site. Water was also present in the three abandoned water wells on the farmstead (see figures 2 through 8).

At least two aquifers are present at fairly shallow depths beneath the site, a semicontinuous zone at about elevation 1350 feet and an apparently continuous zone at about elevations 1332-1336 feet. The uppermost zone is associated with a thin layer of soft caliche-like limestone and several feet of underlying saturated fine clayey sand or silty clay. The latter bed probably marks the horizon of a gypsum layer which is being dissolved in the surficial zone of weathering of the Wellington Shale.

The second aquifer is associated with a series of gypsum, calcite and dolomite beds near the base of the weathered zone.

In KGS-3, 7, 9 and 10, free water was present immediately after completion of drilling into or through the upper zone. KGS-5 had water at the level of the upper aquifer within 24 hours, but had not stabilized at the water level of nearby water well 5-A before it was charged with water to convert it to a permeameter.

The existence of the upper aquifer in KGS-1 is inferred from loss of drilling water at that depth during initial drilling (see Figure 9) and the fact that swelling or caving of the hole at the same depth required reaming of the hole each time the drill stem was withdrawn or put back into the hole. Repeated reaming eventually sealed off the upper horizon and the water level stabilized at the elevation of the second aquifer after drilling fluid was bailed from the hole. KGS-8 was drilled through moist clay at the level of the upper zone, but did not contain free water until about 24 hours later when the level stabilized at the top of the lower horizon.

Permeameters

It is emphasized that there are at present no standard field or laboratory tests for determining the permeabilities of tight geologic formations such as weathered or near-surface shale beds or low per-

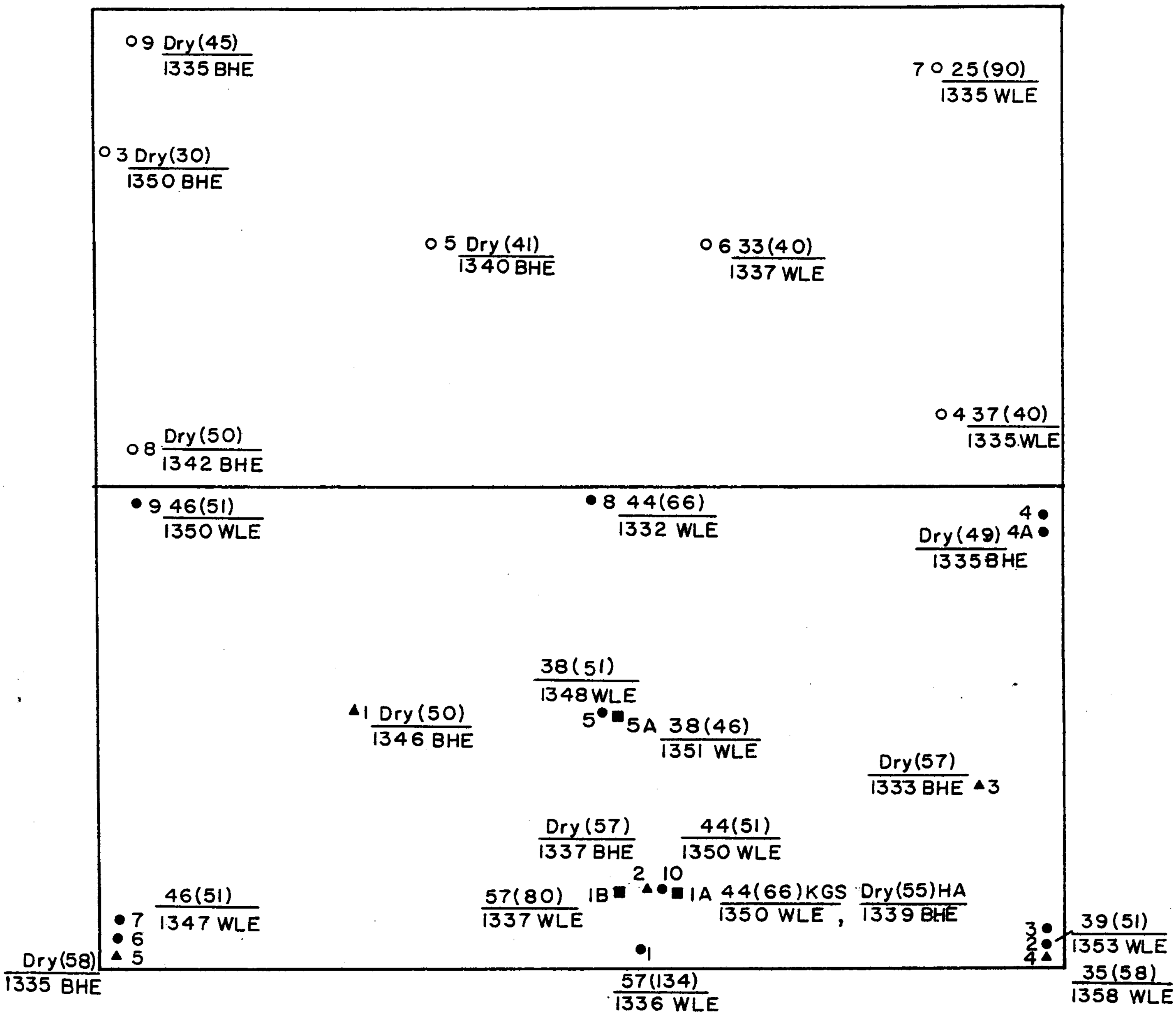


Figure 2

■ Existing Water Well

○ Standard Testing and Engineering Co. and identification number

▲ Haliburton Associates Well and identification number

● Kansas Geological Survey Well and identification number

Depth to water level below land surface (Depth of well)
Elevation of water level (WLE) or
Bottom Hole Elevation (BHE)

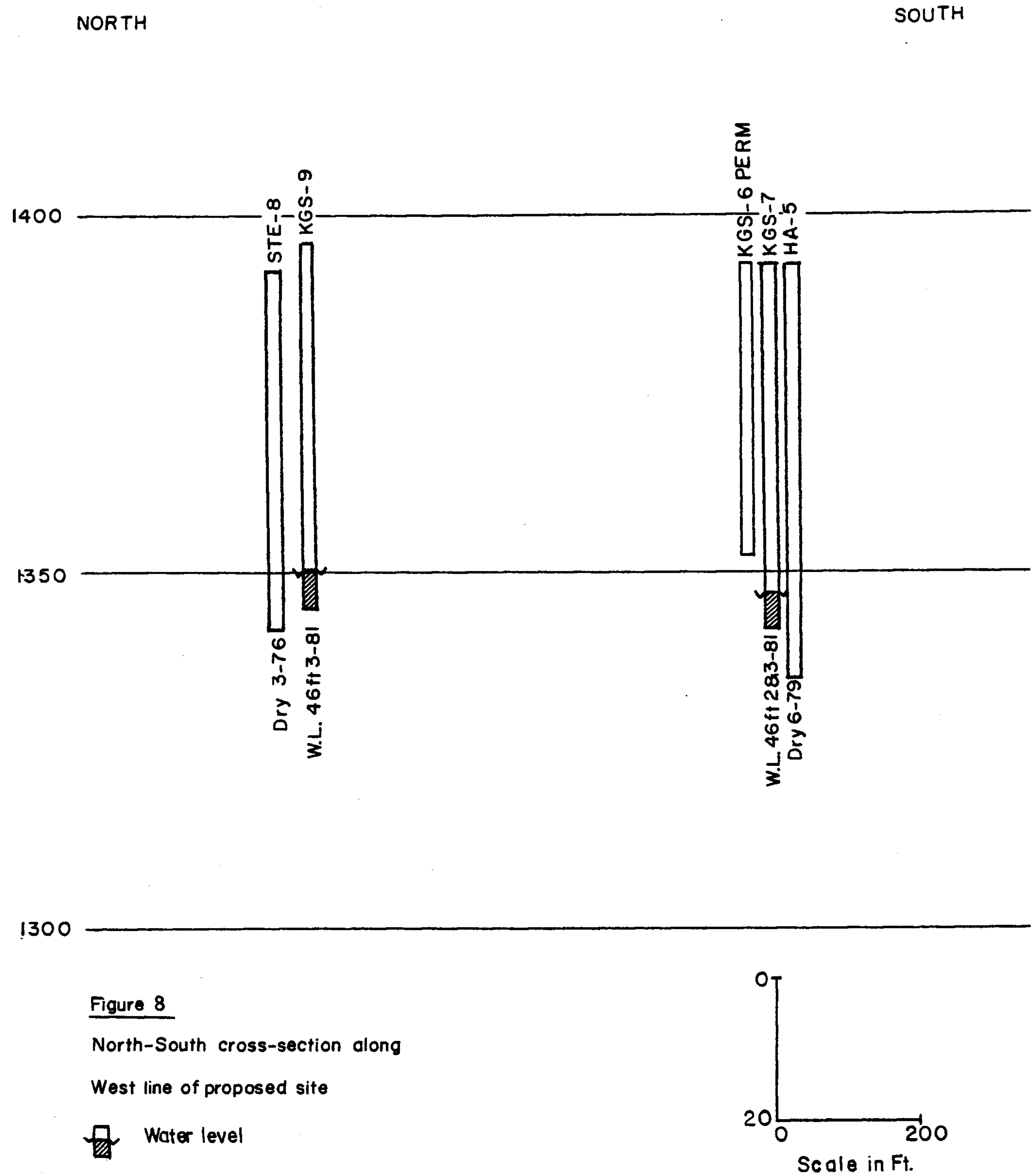


Figure 8

North-South cross-section along

West line of proposed site

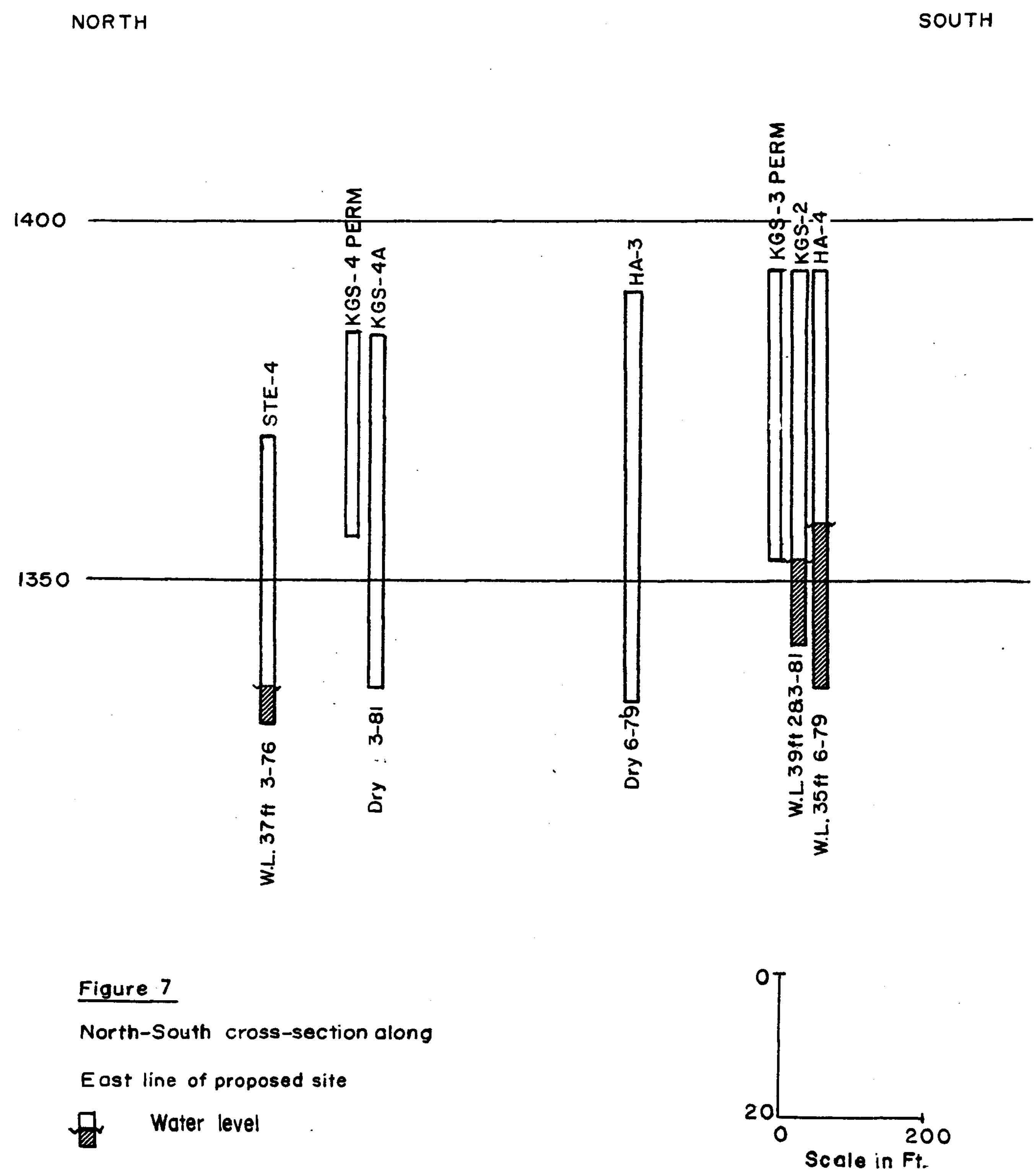


Figure 7

North-South cross-section along

East line of proposed site

Water level

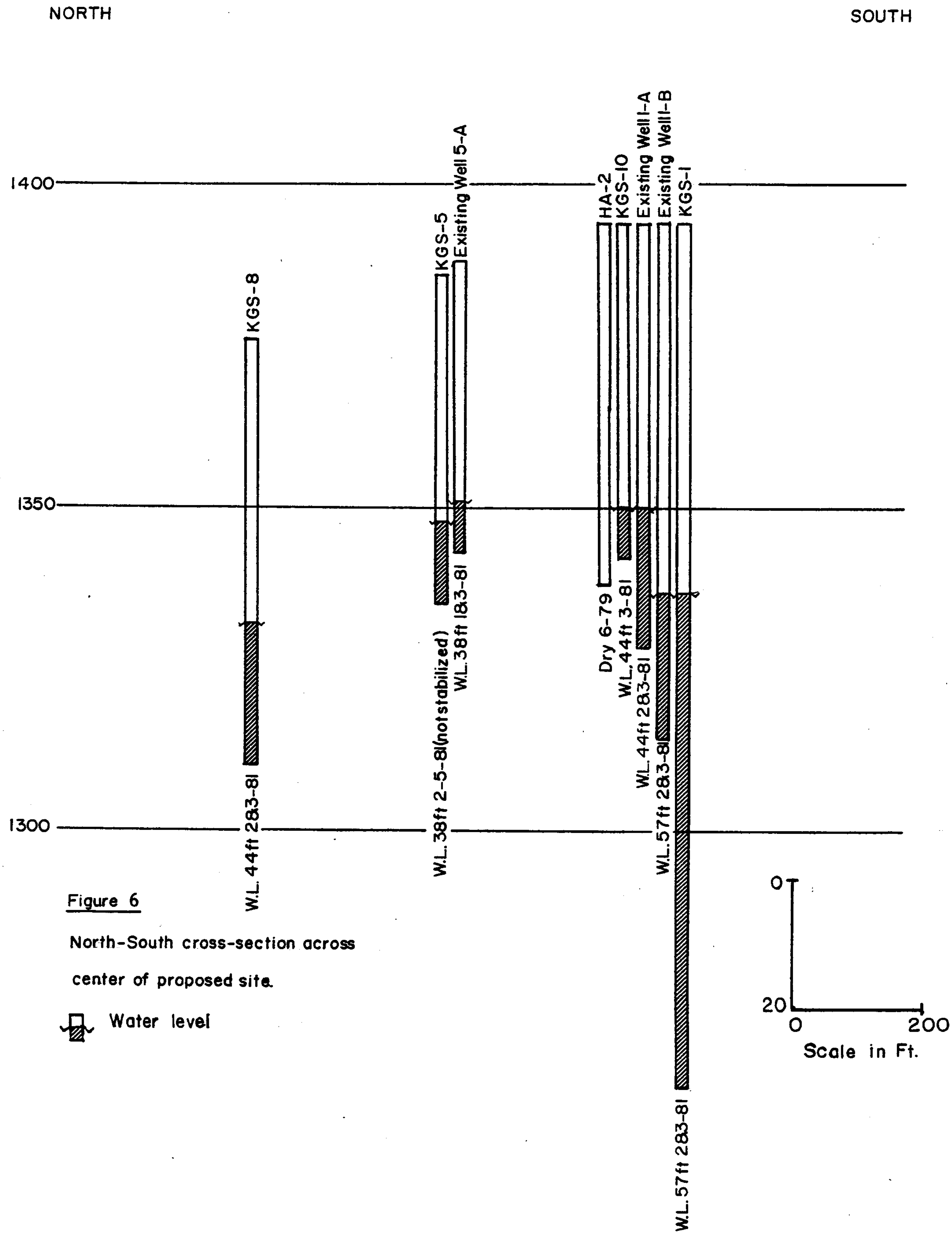


Figure 6

North-South cross-section across center of proposed site.

Water level

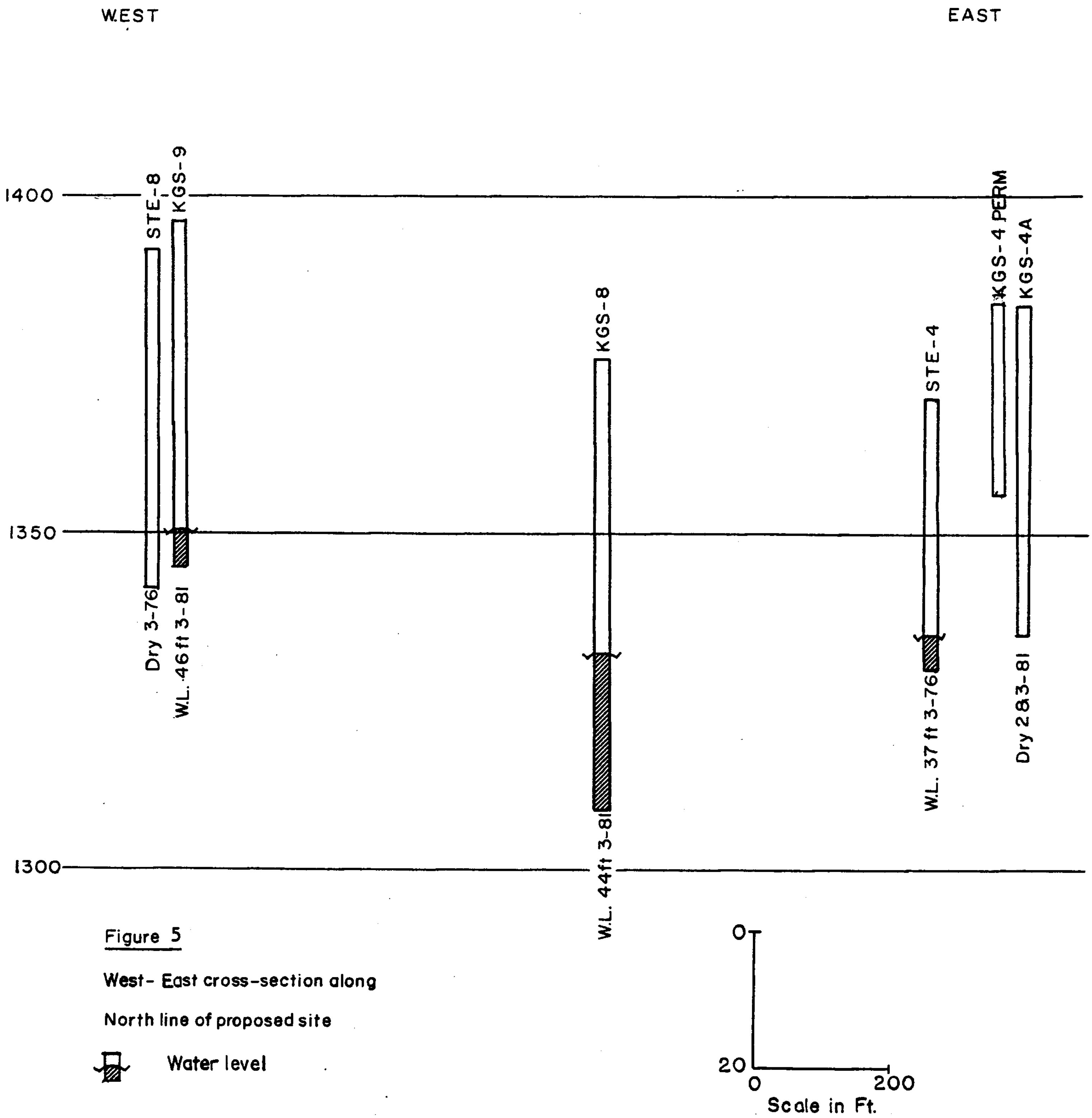


Figure 5

West- East cross-section along North line of proposed site

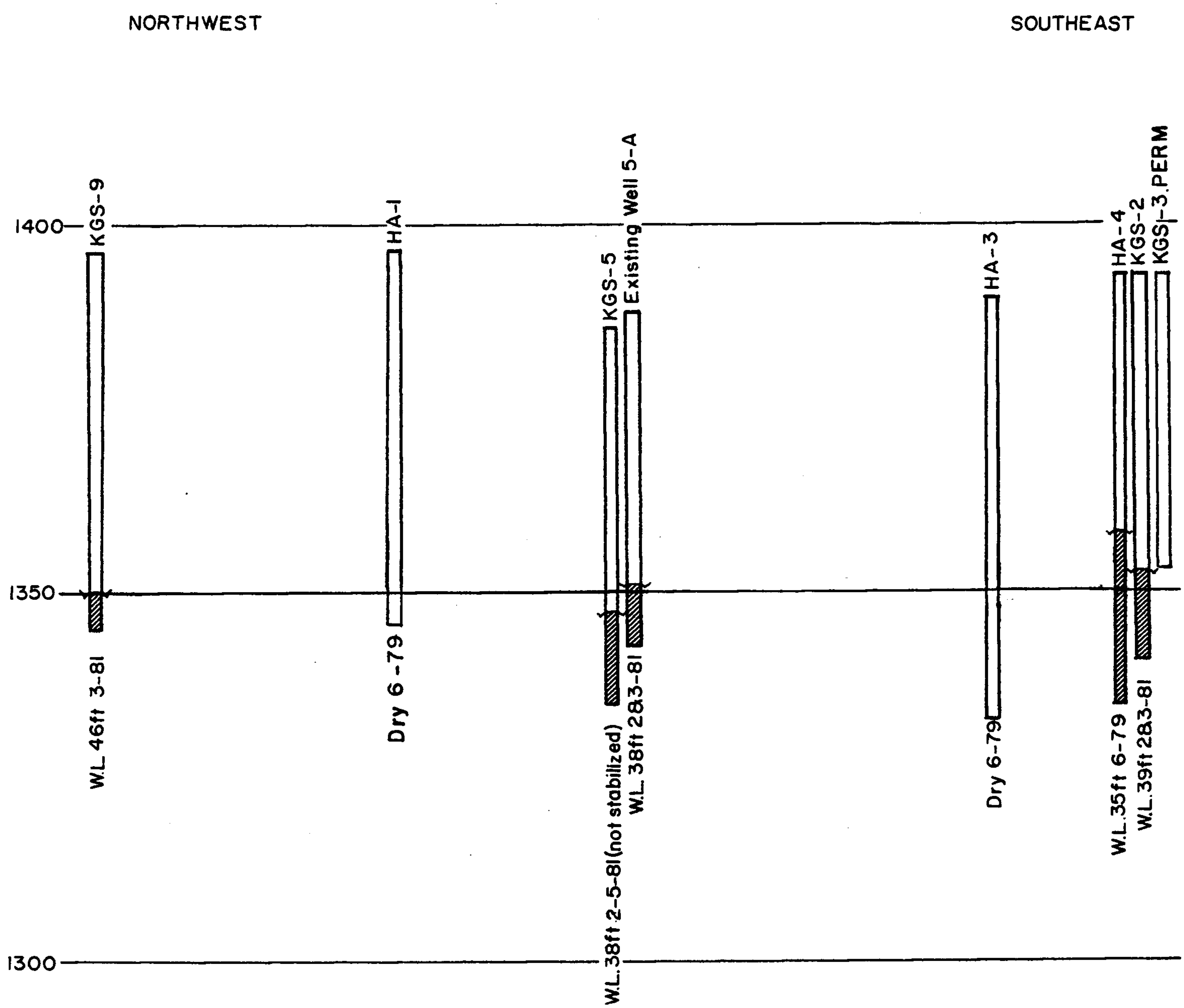
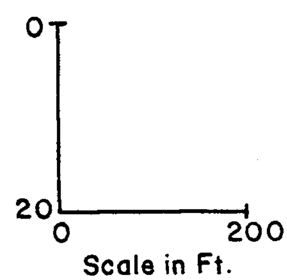


Figure 4

Cross-section from Northwest corner to Southeast corner of proposed site

Water level



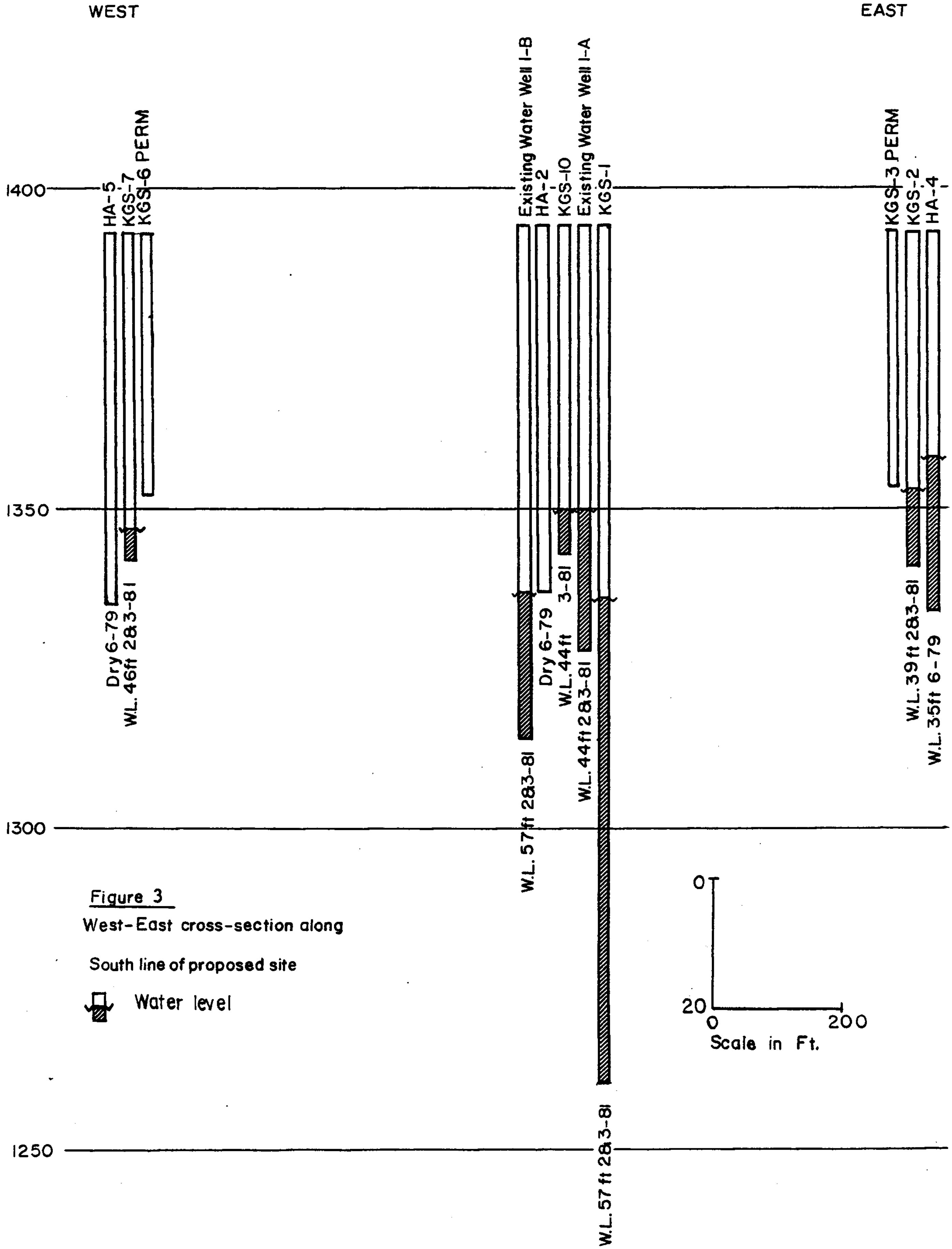
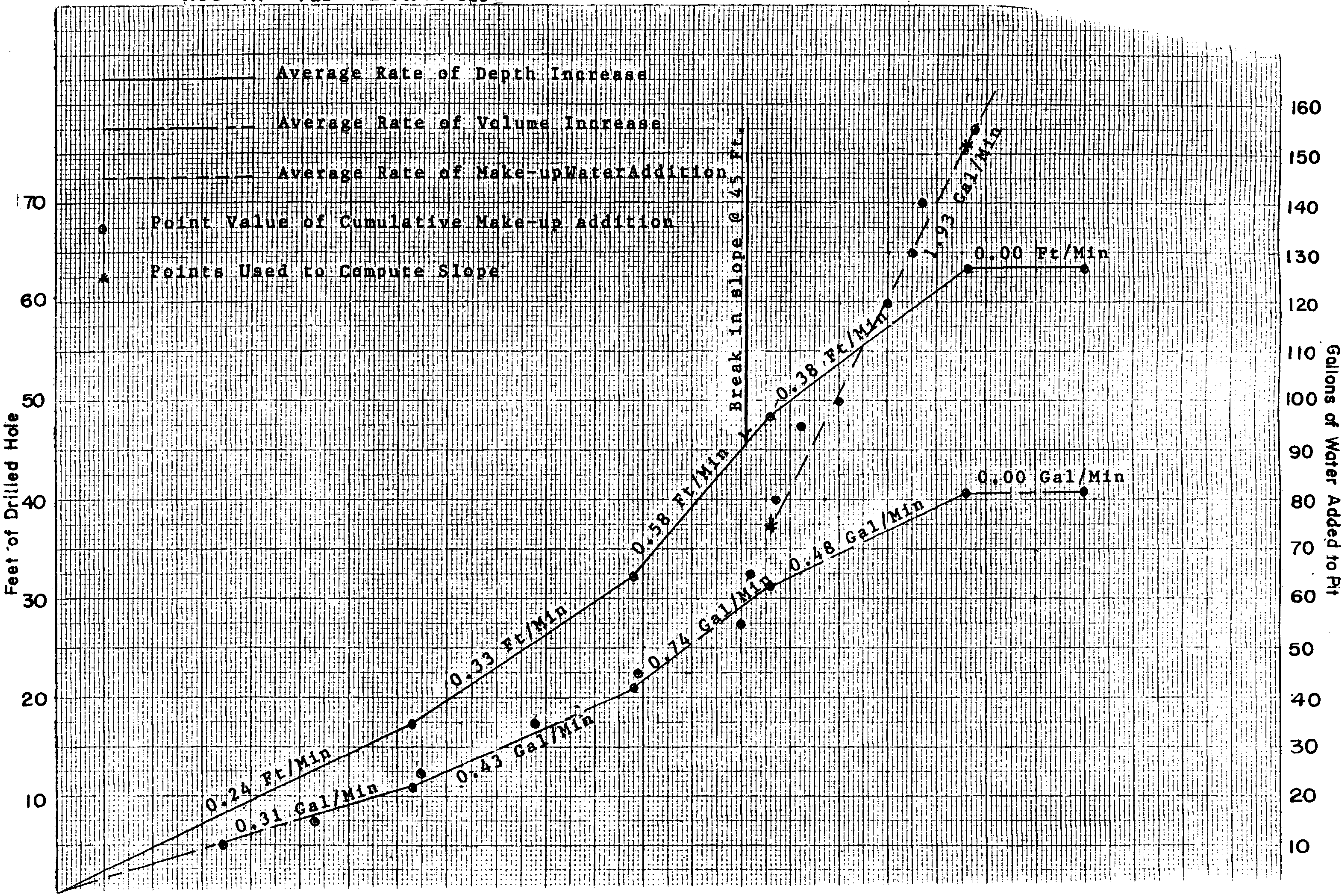


Figure 3

West-East cross-section along

South line of proposed site

Figure 9 Graph of Average Drilling Rate, Average Rate of Pit Make-up Vol...
KGS-R1 T25 R2E Sec 26 cdc1



meability soils. The permeability of shales is especially difficult to determine because special equipment is required to sample and test the material in relatively undisturbed condition. If the material is successfully sampled in the field and tested in the laboratory, there remains the question of actual field conditions, especially in the case of formations like the Wellington Shale where fracture permeability may be present. It was for this reason that field permeameters were used on this study. Although approximate, field permeabilities 2/ probably give a more accurate or reasonable estimate of the average range of hydraulic conductivity 3/ in the field than do laboratory tests of small specimens in the laboratory.

As in all such calculations, some broad assumptions were made:

(1) It was assumed that the open-hole segment of the permeameters extended from the elevation of the bottom of casing to the elevation of the drilled depth of the hole and that the hole was clean. Actually, some cuttings remained in the bottom of all wells and sloughing or swelling was observed during filling and saturation of the holes.

(2) It was assumed that the diameter of the open hole was equal to the nominal diameter of the auger bit. Actually, the diameter probably was less because of bit wear and swelling of the moderately expansive clays and shales.

(3) It was also assumed that casing was tightly sealed against the walls of the holes by swelling of the expansive clays and shales during saturation. This could not be confirmed, however, and it is possible that water might rise along the outside of the pipe to the first bell.

Descriptions of the permeameters and filling and measuring dates are included in Appendix C. Discussion of analysis data and calculations for each permeameter is in Appendix D.

Except for KGS-9, all permeameters were charged four times to assure saturation of the walls of the holes. If air bubbles or a rapid decline of water level were noted during charging, the wells were topped up until stable, before measurements were made.

KGS-3, near the southeast corner of the site, was designed to test the permeability of material above the aquifer at elevation 1353 ft. Its open-hole segment was between elevation 1357.4 and 1352.4 ft.

2/ Field Permeability -- The field coefficient of permeability of an aquifer has been defined as the rate of flow of water in gallons per day through a cross-sectional area of one square foot of the aquifer under a hydraulic gradient of one foot per foot at the prevailing temperature of the water.

3/ Hydraulic Conductivity -- Hydraulic conductivity is a measure of fluid flow velocity through a porous media (aquifer). It is the flow of water in gallons per day through a cross-sectional area of one square foot, under a hydraulic gradient of one foot at a temperature of 60°F.

Calculated permeabilities in cm/sec:

0-20 minutes	$K_h = 3.99 \times 10^{-5}$
4540-10080 minutes	$K_h = 1.12 \times 10^{-6}$
0-10080 minutes	$K_h = 1.65 \times 10^{-6}$

KGS-4, near the northeast corner of the site, was designed to test the more weathered material in the upper part of the site stratigraphic column. The open-hole segment extended from elevation 1366.7 to 1355.7 ft. Prior to the final charge, KGS-4 was dry at 20 ft.

0-310 minutes	$K_h = 1.47 \times 10^{-6}$ cm/sec
4380-9960 minutes	$K_h = 5.09 \times 10^{-7}$ cm/sec
0-9960	$K_h = 3.40 \times 10^{-7}$ cm/sec

KGS-5, near the center of the proposed site, was designed to test the permeability of the upper aquifer at elevation 1351 ft. The open-hole segment extended from 1370.9 to 1334.9 ft. However, four days after first filling, the hole was dry at 24.1 ft. Prior to final filling, it was dry at about 15.0 ft., or the bottom of the casing. Three days after final filling, the water level was 15.0 ft/ and one week after final filling, it was dry at 15.2 ft. Because of this, the calculated permeabilities are not considered valid.

0-185 minutes	$K_h = 2.38 \times 10^{-6}$ cm/sec
2225-4500 minutes	$K_h = 5.16 \times 10^{-8}$ cm/sec
0-4500 minutes	$K_h = 2.4 \times 10^{-7}$ cm/sec

KGS-6, near the southwest corner of the site, was designed to test material between the elevation of the bottom of the proposed disposal trenches and the top of the upper aquifer. The open hole segment of the well extended from elevation 1355.3 to 1352.3 ft. This hole was dry at 37.2 ft. prior to last filling and two days after last filling.

0-185 minutes	$K_h = 2.97 \times 10^{-5}$ cm/sec
1415-1685 minutes	$K_h = 1.66 \times 10^{-5}$ cm/sec
0-1685 minutes	$K_h = 1.79 \times 10^{-5}$ cm/sec

KGS-9, near the northwest corner of the site, was intended to test the permeability of the upper aquifer. It was not cased. Drilled depth was 51 ft.; natural standing water level was 45.1 ft. just prior to first filling. Two hours and 45 minutes after first filling the water level was 40 ft. and the hole was plugged at 45 ft. After second and final filling, the water level fell at an average rate of .85 ft. per minute. The water level 24 hours after final filling was 15.0 ft. The hole was dry at 15.0 ft, two days later. As with KGS-5, the assumed conditions for permeability calculations are extreme, but they are probably more valid than in the former case.

Assuming only the bottom three feet are permeable:

$$K_h = 1.21 \times 10^{-3} \text{ cm/sec}$$

Assuming the bottom 23 feet are permeable:

$$K_h = 7.29 \times 10^{-5} \text{ cm/sec}$$

Except for one value, all calculated permeabilities are greater than those obtained by Haliburton Associates on remolded or undisturbed shelbytube samples. It should be noted also that only one undisturbed sample was run by Haliburton on material which we consider to be weathered shale.

Well Sampling and Water Level Measurements

The well records for wells for which chemical analyses are available are given in Appendix E, Table E-1. The presence of three water-bearing zones is evident under the sections adjacent to the site. Their presence is also confirmed by the chemical analyses given in E-2. Figure E-1 shows the upper of the three water-bearing zones not to be present in sections to the north, northeast, east, and southeast of Section 26. Only two wells, 22ABB and 34DDC, are located in the upper aquifer. Ground elevations on the USGS 7.5 minute series topographic map of the area (Greenwich Quadrangle) were used in calculating water-level elevations. The water-level elevations in these two wells and KGS-1A (26CDC) show the upper aquifer to have a saturated thickness of about eight feet from elevation 1350 to 1342 ft. Twelve wells were found located in the middle aquifer and these show a saturated thickness of about eight feet from elevation 1338 to 1330 ft. Eight wells were found located in the lower aquifer at an elevation of about 1320 ft. This zone was not encountered by the Standard Testing and Engineering Company under the existing site or by us at the proposed site except in KGS-1 because the wells were not drilled deep enough to penetrate the lower aquifer.

DISCUSSION OF FIELD RESULTS

Two water-bearing zones are identified beneath the site at approximate evaluations of 1350 and 1337. This is 8 and 21 feet, respectively, below the bottom of the proposed disposal trenches. It should be noted, however, that the water level elevations were measured by KGS in February and March, 1981, during a period of abnormally low precipitation when the 365-day average was 10 inches below normal for the Wichita area. The water level elevation measured in early June, 1979, by Haliberton Associates in HA-4, near the southeast corner of the site, was five feet higher than that measured by us in adjacent KGS-2 in February and March, 1981.

Water-level conditions over the rest of the proposed site could not be compared because the geotechnical consultant did not report finding water in any other holes or wells. However, the water level elevation in the second aquifer in KGS-8 was also 3 to 5 ft. lower than those reported in holes 4, 6, and 7 on the existing site by Standard Testing and Engineering Company in 1976 (see Figure 2). It is thus possible that the water level or potentiometric head may be less than five feet below the bottoms of the proposed trenches during periods of normal precipitation.

The upper zone, which is of greatest importance to this study, was recognized under all of the proposed site except the extreme northeast corner where the limy zone apparently has been dissolved by weathering associated with a northward trending tributary of Prairie Creek.

It is also present in shallow dug wells on farmsteads adjacent to the site. Conversations with older residents in the area indicate that some of these wells went dry during the drought of the 1950's and some were deepened by drilling into the second or, in some instances, a third aquifer. These wells were often not cased through the upper aquifer and the water levels returned to the elevation of the upper aquifer when the drought ended. During times of normal precipitation the wells produce from all penetrated zones. Because of the mixing of waters in some wells, lower aquifers may be vulnerable to potential contamination if the material between them and the bottom of the proposed burial trenches are sufficiently permeable.

Although the yield is low and the chemical quality of the water in the upper zone is poor because of high sulfate levels, the water is being used for stock water and domestic water. The upper aquifer is considered to be a usable aquifer. A rural water line serves the area, but not all residences are using it and some users of the water line have become concerned because the supply comes from El Dorado, which is under water restriction because of present drought conditions. If the drought continues, local wells may continue to be used despite the poor chemical quality of the water.

Our studies suggest that the hydraulic conductivity of the soil, clay, and weathered shale above the aquifer is greater than indicated by the site geotechnical report. Although the conductivities calculated by us primarily reflect horizontal permeability, it can be inferred from the geologic processes that are known to have affected the area that vertical fracture permeability also may be present.

The upper water-bearing zone represents the level of a gypsum bed which has largely been dissolved. Gypsum is formed by the hydration of anhydrite; in this instance, bedded anhydrite. In the process, a one-third to two-thirds volume change or expansion occurs and the resulting pressure may fracture the overlying material. This phenomenon has commonly been observed and reported in other regions underlain by gypsum and anhydrite beds. If the gypsum subsequently is dissolved, renewed fracturing can be caused by settlement or collapse, depending upon the depth of the soluble horizon. These processes are responsible for disrupted bedding in thin limestone layers noted in the outcrop or shallow excavations into the Wellington Formation in this area (see Figure 10).

Vertical tensional joints tend to be more-or-less regularly spaced because of relief of stress in the material adjacent to the joint planes. Spacing is dependent to a certain extent on the tensional strength of the material and depth of burial at the time of stressing and fracturing. It is unlikely that many such fractures would be encountered by small-diameter, widely-spaced vertical drill holes.

Groundwater moving laterally downdip or downslope along the permeable zones associated with the fractured or partly dissolved anhydrite or gypsum beds can enter the vertical fractures and in turn cause hydration, swelling, fracturing, and dissolution of successively lower soluble horizons in bands parallel to the strike of their projected outcrop lines. The process can occur over short periods of geologic time and is accelerated by other causes such as water entering the beds through excavations, leaking wells, etc.

KGS staff members differ in their opinions as to the source of the water in the near-surface aquifers in the Wellington Formation. The chemical data suggest that an impermeable subsoil prevents any infiltration into lower beds and that the water must enter the porous zones themselves at their outcrops and then migrate laterally. Other staff members contend that, although the subsoil is tight, it is sufficiently permeable over large areas, especially where overburden is thin to provide vertical recharge of the aquifers.

In either instance the source of water is sufficiently large and long-lived that the springs in this and other streams in the area continue to flow strongly in periods of drought. The water, even in normal periods of precipitation, is high in sulfate, indicating that the gypsum and anhydrite layers are the conduits of lateral migration.

It seems probable from elevation relationships that the first and second aquifers contribute to the spring flow in Prairie Creek, but we did not attempt to directly confirm this by drilling. The upper aquifer is at a higher elevation than the stream directly north of the site, but where the limestone is dissolved in the highly weathered or oxidized zone near the surface, the water may migrate downslope along the weathered-unweathered interface and discharge as stream-bank or stream-bottom seepage. The second aquifer is at the level of Prairie Creek north of the site and may contribute directly as spring flow.

If there is a connection between the aquifers and the springs in Prairie Creek, there could be a possibility of contamination by any leachate escaping from the proposed burial trenches because the volume of water probably is not sufficient to dilute it.

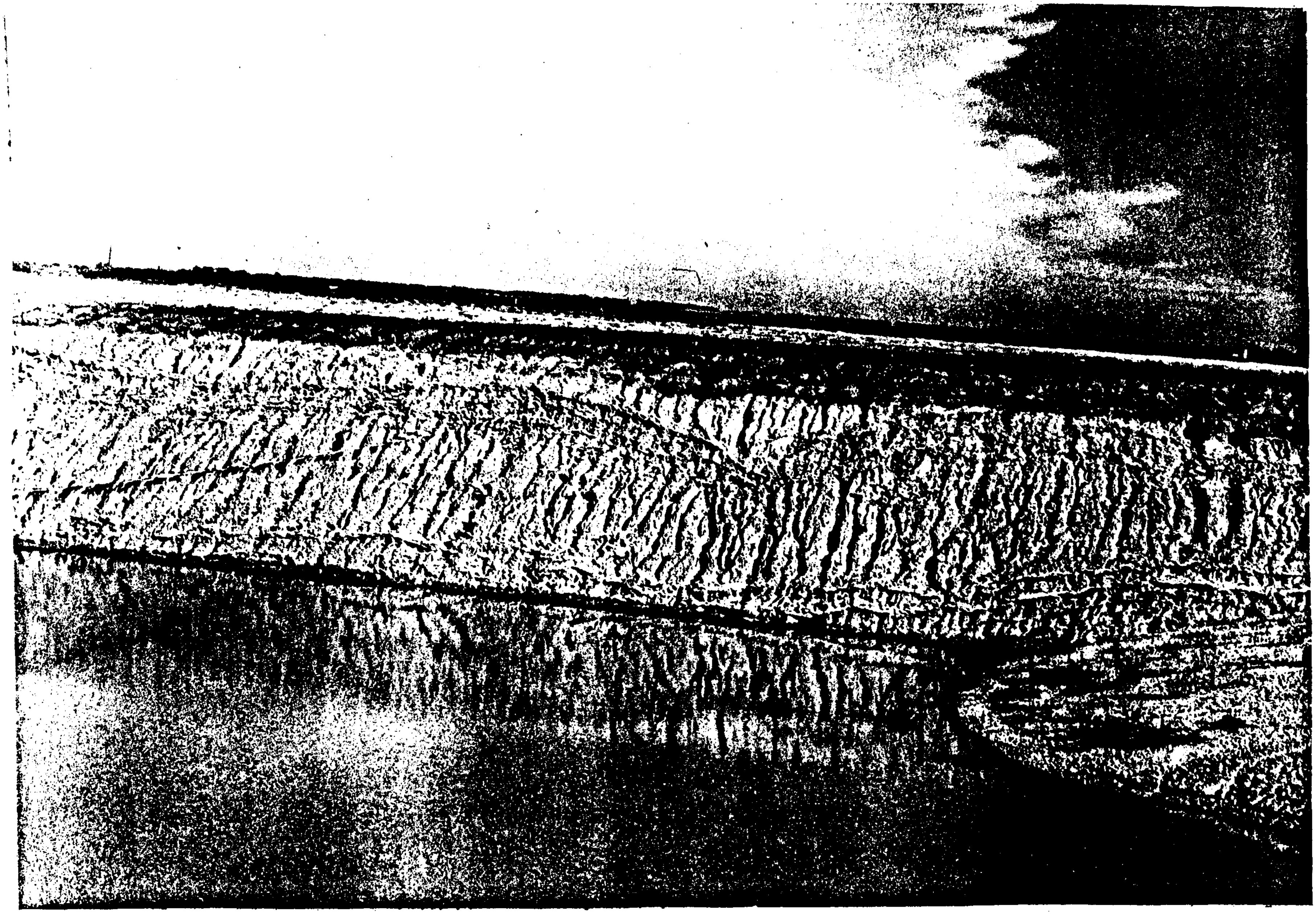


Figure 10
Disrupted bedding in thin limestone zones probably similar to the upper aquifer below the proposed site. Beds are exposed in the walls of an evaporating lagoon on the existing facility. Photo by Allen Macfarlane, formerly of EPA, now with KGS.

The site geotechnical report states that little potential for migration could exist because the hazardous material is relatively dry and layers of soil would be compacted between each layer. A thicker compacted layer would be mounded at the surface, therefore no water could get to the waste to provide a driving head.

In actual practice, however, although the separating layers may be initially compacted to specification, some unfilled spaces between drums and containers will likely remain no matter how carefully they are stacked or packed. Considering that three 10 ft. layers of waste are proposed, and the upper mounded layer is five feet thick, it seems likely that settlement into the open spaces and eventual deterioration of the drums may result in considerable differential settlement that could allow infiltration of water and development of a driving head.

It should be noted in connection with the design of the upper compacted layers as proposed in the engineering report and plans, that if the six inch lime-modified layer is used, it should be placed at a depth of 40 to 48 inches. Above this layer the soil should not be compacted to more than 90 pcf. Vegetation needs a 30 to 40 inch root zone to grow and survive under the climatic conditions of central Kansas.

CONCLUSIONS

1) At least two water-bearing zones exist beneath the site at approximate elevations 1350 and 1337 feet.

2) Both are usable aquifers. (Contains quantities of groundwater sufficient to provide domestic and stock water supplies in the local area.)

3) Comparison of the elevations of water levels measured by KGS in 1981 during a period of drought with those reported by site geotechnical consultants in 1976 and 1979 indicate that the water levels of the aquifers may be at least five feet higher, or at elevations 1355 and 1342 feet, during normal times.

4) The elevation of the bottoms of proposed disposal trenches is 1358-60 feet. The water levels in the upper aquifer will likely be less than five feet below the bottom of trenches in times of normal precipitation.

5) Tests suggest that material between the bottom of the proposed trenches and the top of the upper aquifer is more permeable than reported by the geotechnical consultant.

6) On the basis of the above, the site as it is proposed to be operated, does not meet the present criteria of USEPA or KDHE.

7) The site geotechnical consultant either did not find or did not report the presence of the upper aquifer except in HA-4 in the southeast corner of the proposed site. This was the only test hole at which the District Geologist of KDHE was present during the investigation and he observed saturated material being augered to the surface. All other holes, including existing water well 1-A were reported by the consultant to be dry. Test holes were drilled by KGS close to the locations of holes that were reported to have been dry by the geotechnical consultants for the existing site and the proposed site. Water was found immediately or within 24 hours at levels above the bottoms of the reportedly dry holes at the northwest corner, southwest corner, and in the center of the site. KGS investigators can think of no technical explanation for these apparent discrepencies.

RECOMMENDATIONS

1) Present criteria for site evaluation are inadequate. They pertain mainly to thickness guidelines and engineering properties of soils. They are not suitable for sites on which wastes are to be buried in shales containing beds of anhydrite and gypsum or other bedded geologic materials, especially if fracture or solution permeability is likely to be present.

Tests, standards, and guidelines should be developed for such materials. Field permeameter tests give some indication of in-place permeability and are probably a better measure of bulk hydraulic conductivity than laboratory tests run on small samples. It is our opinion now, however, that water pressure tests on segments of bore holes isolated by pneumatically or hydraulically inflated packers would be a better method. KGS does not have such equipment at present.

Where widely-spaced vertical fractures are suspected to be present, large-scale backhoe or bulldozer trenches should be excavated, carefully cleaned and mapped. At the same time, relatively undisturbed block samples can be taken for laboratory determination of vertical and horizontal permeability.

2) In the future a KDHE representative should be present at all times during the field investigation of a proposed site.

3) Site reports for a proposed facility should contain a detailed evaluation of regional and local geologic and hydrologic conditions. In addition to present conditions, any past geologic or geomorphic processes that might have adversely affected the site should be considered. This should include any relevant long-term hydrographs of wells to identify the normal range of water-level fluctuations to be expected. The geologic analysis part of the report should be prepared by a qualified geologist or geohydrologist.

ACKNOWLEDGEMENTS

Survey staff members who contributed to this investigation were: Patrick Cobb, hydrogeologist; Harold Dickey, soil scientist; Jerome Welch, soil geochemist; Gerard James, geochemist; Karmie Galle, chemist; Melvin Kleinschmit, driller; Ralph Biggs, assistant driller; John Vannicola and Ron Johnson, drillers' helpers. Esther Price and Julie Jaeger typed the manuscript. Laurie Scheer and Carolyn LaFrance drafted the figures. Howard O'Connor, senior geologist; Larry Hathaway and Donald Whittemore, geochemists, attended the early planning meetings and also provided technical advice during the study.

APPENDIX A

KGS-1, Near center, south line S 1/2, SW 1/4 Sec. 26, T.25S., R.2E. (See location map, Figure).

6.5 in. dia. strat. hole rotary drilled with tri-cone bit and fresh water. Completed 1-28-81. Hole cased with 6 in. dia. PVC to about 17 ft. below ground surface, spigot down. Sealed at surface with half bag of dry drilling mud and tamped cuttings. Cap glued on with epoxy and 1 in. dia. hole drilled in side.

	Elev.	Depth/ft.	Description
T.H.	1393.5	0 to 7	Soil, dark gray clay.
	1386.5	7 to 14	Clay, olive (weathered clay shale). Violent reaction with HCL. Reddish brown particles at 13 ft.
	1379.5	14 to 18	Silty clay, olive (weathered silty shale). Violent reaction with HCL.
	1375.5	18 to 44	Clay, olive, (weathered clay shale). Weak reaction to HCL. Some layers have a violent reaction to HCL.
	1349.5	44 to 50	Silty clay, olive (weathered silty shale). Large amount of carbonate particles. Violent reaction with HCL.
	1343.5	50 to 55	Clay, olive (weathered clay shale).
	1338.5	55 to 70	Clay and silty shale, olive. Layer about 60 ft. has a violent reaction to HCL. Carbonate concretions at 64.5 ft. A few dolomite particles.
	1323.5	70 to 74.5	Clay shale, dark gray. Selenite, dolomite, and carbonate particles.
	1319.0	74.5 to 75.5	Dolomite and clay shale, olive and dark gray. Siltstone, selenite and anhydrite particles.
	1318.0	75.5 to 90	Clay shale, dark gray and olive, and anhydrite. Selenite, dolomite, siltstone, and calcite particles. Shale has weak reaction to HCL.
	1303.5	90 to 134	Anhydrite and clay shale, dark gray and olive. Dolomite, calcite, selenite, and siltstone particles. Shale has weak reaction with HCL. Core taken at 109 to 112 ft. Anhydrite (top 2 ft.). Dark gray shale with gypsum deposits both vertical and horizontal.
T.D.	1259.5	134	W.L. 57.1 ft., elev. 1336.4 (F.W. Wilson and R.E. O'Connor)

Table A-1--Mineralogy of Stratigraphic Hole (KGS-1)

Mineralogical determinations were done by x-ray diffraction analyses of "whole rock" samples; sample preparation consisted of hand grinding analytical splits of the well cuttings and pressing the rock powder into pellets for diffraction analysis.

Analytical Results

Sample Depth	Mineralogy
0-3½'	quartz, mixed-layer montmorillonite; minor feldspar
4'	as above
5-7'	as above, trace 7Å clay
7-11'	quartz, mixed-layer montmorillonite and illite; minor calcite and 7Å clay; trace feldspar
13-13½'	quartz, mixed-layer montmorillonite and illite, 7Å clay; trace feldspar
14½-17'	quartz, mixed-layer montmorillonite and illite-mica, 7Å clay, calcite
20'	quartz, mixed-layer montmorillonite and illite-mica, 7Å clay; trace feldspar
30'	quartz, dolomite, calcite, mixed-layer montmorillonite and illite-mica; minor 7Å clay
32½'	as above
35'	as above, except calcite greater than dolomite
40'	as above
41'	as above
45'	dolomite, calcite, quartz; minor clay assemblage as above

Sample Depth	Mineralogy
50'	quartz, calcite, clay assemblage as above; minor dolomite
55'	as above
60'	as above
64½'	as above, but more dolomite, and trace gypsum
66'	dolomite, calcite, quartz, clay assemblage as above, and minor gypsum
70-73'	dolomite, quartz, gypsum; minor clay as above; trace calcite and feldspar
74'	gypsum, quartz, clay as above; minor calcite and dolomite
74½-75'	gypsum, calcite, quartz; minor dolomite and clay
75½-79½'	gypsum, quartz, clay assemblage as above; minor calcite, dolomite, and feldspar; possible anhydrite
80-85'	gypsum, calcite, quartz; minor clay and dolomite, trace anhydrite
87'	as above
90-95'	as above, but more anhydrite
97-101'	anhydrite, gypsum; minor quartz, calcite, and dolomite; trace clay assemblage as above and feldspar
102-108'	as above
123-126'	as above
129-134'	as above

Existing Water Well 1-A

Located on the abandoned farmstead about 200 ft. north of KGS-1. Drilled well, cased with 6 in. dia. galvanized pipe. Total depth 66 ft.

T.H. elev. 1393.9 W.L. 44.0, elev. 1350, 2-3-81.
43.8 1350, 3-24-81 (F.W.Wilson & R.E. O'Connor)

Existing Water Well 1-B

Approx. 150 ft. NW KGS-1, 6 in. dia. casing in 6 x 6 ft. concrete, above-ground well box. Total depth 80 ft.

T.H. elev. 1394 (est.) W.L. 57.3, elev. 1337, 2-26-81
57.0 1337, 3-24-81 (F.W. Wilson & R.E. O'Connor)

KGS-2, Near SE cor. S 1/2, SW 1/4, Sec. 26, T.25S., R.2-e.

4 in. dia. continuous flight auger and 1 1/2 in. USDA push tube. T.D. 51.0. Completed 1-28-80. Continuous push cores taken to refusal at 31.0 ft. Representative auger-cuttings bag samples taken each 5 ft. 6 in.. PVC set to about 7 ft. below G.S. Glued cap vented and surface sealed with dry drilling mud.

Elev.	Push Core/ft.	Description
T.H. 1392.4	0 to 3	Dry hard, very dark grayish brown (10YR3/2) clay (soil). (CH)
1389.0	3 to 5.3	Moist, very stiff, very dark grayish brown (2.5Y3/2) clay. (Soil formed in clayey sediments.) (CH)
1387.1	5.3 to 7.5	Moist, very stiff, coarsely mottled olive gray (5Y5/2) and yellowish brown (10YR5/6) clay. Weak reaction with HCL, and less than 10% carbonate concretions. (Weathered clay shale with few visible thin laminae.) (CH)
1384.9	7.5 to 8	Moist, stiff, olive (5Y5/3) sandy clay. Violent reaction with HCL, most particles >.074 mm are carbonates. Layer has more voids than above or below layers. (Weathered shale.) (SC or CL)
1384.4	8 to 9.5	Moist, very stiff, olive (5Y5/3) silty clay. Yellowish brown (10YR5/6) mottles. Mass shows no reaction to HCL. Less than 2% concretions and soft films of carbonates. A few slickensides in lower part. (Weathered clay shale.) (CH or CL)
1382.9	9.5 to 13	Moist, very stiff, olive (5Y5/3) clay, yellow brown mottles (10YR5/6) and 10% reddish brown (2.5YR4/4) shale-like fragments and laminae. (These fragments are slightly higher in clay content than the mass.) Weak reaction with HCL. Less than 5% carbonate concretions. (Weathered clay shale with a few visible laminae and shale fragments.) (CH)
1378.4	13 to 15	Moist, very stiff, olive (5Y5/3) clay. Yellow brown 10YR5/6 mottles. Weak reaction with HCL. Less than 5% carbonate concretions. (Weathered clay shale with a few visible shale fragments.) (CH)

(continued on next page)

KGS-2 (continued)

	Elev.	Push Core/ft.	Description
T.H.	1377.4	15 to 16	Moist, very stiff, coarsely mottled olive (5Y5/3) and yellowish brown (10YR5/6) clay. Violent reaction with HCL. Less than 5% carbonate concretions. (Weathered clay shale with a few shale fragments and a thin siltstone layer [not hard].) (CH or CL)
	1376.4	16 to 20.6	Moist, very stiff, olive (5Y5/3) clay. Yellowish brown (10YR5/6) mottles. No reaction with HCL. Less than 2% carbonate concretions. A few soft deposits of carbonates. (Weathered clay shale with a few visible thin laminae and a few shale fragments. A few calcite crystals at 19.5 ft. Slickensides at about 20 ft.) (CH)
	1371.8	20.6 to 21	Moist, very stiff, yellowish brown (10YR5/6) clay. Olive (5Y5/3) mottles. No reaction with HCL. About 15% concretions and soft deposits of carbonates. (Weathered clay shale with a few shale fragments.) CH or CL)
	1371.4	21 to 27	Moist, very stiff, pale olive (5Y6/3) clay. Yellowish brown (10YR5/6) mottles. Weak to no reaction with HCL. Less than 2% soft deposits and concretions of carbonates. A few visible calcite crystals. (Weathered clay shale with a few thin laminae and shall fragments. Slickensides at 21.5 to 23 ft.) (CH)
	1365.4	27 to 28	Moist, very stiff, pale yellow (2.5Y7/4) clay. Yellowish brown (10YR5/6) mottles. Violent reaction with HCL. Less than 2% concretions. (Weathered clay shale with a few shale fragments.) (CH or CL)
	1364.4	28 to 31.5	Moist, very stiff, light olive gray (5Y6/2) clay. Yellowish brown (10YR5/6) mottles and laminae. Laminae and shale fragments more visible than above layers. Weak reaction with HCL. Less than 2% carbonate concretions. (Weathered clay shale. Dryer than other layers.) (CH)

(continued on next page)

KGS-2 (continued)

Elev.	Push Core/ft.	Description
	Auger	
T.H. 1360.9	31.5 to 43	Moist, very stiff pale olive (5Y6/3 silty clay. Yellowish brown (10Y5/6) mottles and laminae. Laminae and shale fragments highly visible. Weak to moderate reaction with HCL. About 5% carbonate concretions. A layer at 34-35 ft. contains a higher percentage of carbonate concretions. (Weathered clay shale.) (CH)
1349.4	43 to 48	Saturated, pale olive (5Y6/3) clayey sand or silty clay. Most particles larger than .074 mm are carbonate concretions and calcite crystals. Violent reaction with HCL. (Weathered shale)
1344.4	48 to 51	Moist, stiff, pale olive (5Y6/3) silty clay. Thin yellowish brown (10YR5/6) laminae. Weak to moderate reaction with HCL. A few siltstone fragments. Laminated. (Silty shale.) (CL or CH)
1341.4	51	T.D.

Described in accordance with ASTM-D-2488-69. A procedure to describe soils and soil-like materials.

Lloyd B. Underwood, Classification and Identification of Shales, 1966.

NOTE: Measured water levels in this hole may be in error because the hole was crooked near the bottom and the walls coated with mud. Last measurement is correct.

W.L.		
39.4,	elev. 1353,	2-3-81
33.4(?),	elev. 1359,	2-9-81
38.2,	elev. 1354,	2-19-81
36.7,	elev. 1356,	2-26-81
41.6(?),	elev. 1351,	3-5-81
39.1,	elev. 1353,	3-17-81
39.0,	elev. 1353,	3-20-81

Not measured by Wilson & O'Connor, 3-24-81.

KGS-2 (Summary Log)

Elev.	Depth/ft.	Description
T.H. 1392.4	0 to 5	Soil, dark gray brown.
1387	5 to 15	Weathered clay shale; Olive gray with yellow brown mottling.
1377	15 to 31	Same as above. Some laminations and shale fragments.
1361	31 to 43	Weathered clay shale. Firm, laminated limy fragments or concretions.
1349	43 to 48	Pale olive clayey sand or silty clay (weathered shale) with limy concretions or calcite crystals. Saturated.
1344	48 to 51	Same as above. Firm laminated, a few siltstone fragments. Moist.
1341	51	T.D.

Table A-2--Mineralogy of KGS-2

Mineralogical determinations were done by x-ray diffraction analyses of "whole rock" samples and "two micron" fractions of the samples.

Analytical Results

Sample Depth	Mineralogy
2'	quartz, feldspar, and poorly crystallized mixed-layer illite-montmorillonite
8'	quartz, calcite, mixed-layer montmorillonite
12'	quartz, mixed-layer montmorillonite and illite-mica, minor 7Å clay
19'	as above, but with calcite
25'	as above, but with calcite and dolomite
33'	dolomite, quartz, mixed-layer montmorillonite and illite-mica, minor 7Å clay
41'	quartz, dolomite, calcite, mixed-layer montmorillonite and illite-mica, 7Å clay
45'	as above
51'	as above

The clay mineral assemblages in these samples are very similar throughout, with the exception of the poorly crystallized 2' sample.

The mixed-layer montmorillonite expands from 14Å to 16Å with glycolation, and appears to be a regularly stratified mixture of 10 and 15Å lattices.

The bulk of the 7Å clay appears to be chlorite with possible kaolinite, based on the predominance of the 3.54Å peak versus the 3.58Å peak.

Table A-2 --Laboratory data for KGS-2

Depth (ft.)	Moisture Content (%)	Density Dry (pcf)	Grain Size Distribution % Sand	% Silt	% Clay
2.5	21.9	96.7	1	49	60
8	25.3		7	30	63
9	27.0	94.2			
12	29.8	94.2	2	18	80
19	26.0		9	32	59
22	26.2	99.8			
25	29.4		12	22	66
30	24.9	101.1			
33	25.2		12	30	58
41	25.9		8	34	58
51	35.9		2	52	46

METHODS:

Moisture content: Gravimetric Method - ASTM Designation; D 2216-71.

Grain Size Analysis: Hydrometer Method - ASTM Designation; D 422-63.

Density: Core or Drive-Cylinder Method - ASTM Designation; D 2937-71.

KGS-4A, 20 ft. S. KGS-4

4 in. dia. continuous flight auger to 51.0.
4 ft., 6 in. PVC set 1.0 below surface, capped and sealed.
Completed 2-26-81.

Elev.	Depth/ft.	Description
T.H. 1383.7	0 to 3	Red-brown topsoil.
1381	3 to 5	Yellow clay; limy nodules.
1379	5 to 10	Yellow-green clay.
1374	10 to 11	Same as above; several limy zones.
1373	11 to 18	Orange-tan clay limy nodules.
1366	18 to 18.5	Gypsum layers.
1365	18.5 to 20	Orange-tan clay.
1364	20 to 21	Gypsum layers.
1363	21 to 26	Tan-gray clay; limestone or gypsum nodules or layers.
1358	26 to 26.5	Gypsum layers.
1357.5	26.5 to 31	Tan-gray clay; many gypsum nodules, damp.
1353	31 to 51	No sample.
1333	51	T.D.

Dry at 49.0, elev. 1335, upon completion and all measurements thereafter.

KGS-5A Existing Well, 87 ft., SE of KGS-5

3 ft. dia. dug well lined with fieldstone.

T.H. elev. 1388.5, T.D. 455

W.L. 37.5, elev. 1351, 1-29-81
W.L. 37.7, elev. 1350.8, 3-24-81 (F.W. Wilson and R.E. O'Connor)

KGS-7, Located 6.5 ft. N. of KGS-6. Completed 2-5-81.

4 in. dia. CFA drilled to 51.5 ft., Limy zone 45 - 51.5. Pushed core to refusal at about 52.0 ft. 1 ft. PVC. Surface sealed as above; capped but not glued.

Elev.	Depth/ft.	Description
T.H. 1392.8	0 to 3	Soil.
1390	3 to 45	Yellow tan with red shale.
1348	45 to 51	Yellow tan shale with numerous thin limy or gypsum beds.
1342	51	T.D. Saturated.
1351.3	W.L. 41.5, elev. 1351.3 immediately upon comp. 43.0, elev. 1350, 2-9-81. 46.0, elev. 1347, 2-19-81. 48.3(?), elev. 1345, 2-26-81. 45.8, elev. 1347, 2-27-81. 44.7, elev. 1348, 3-18-81. 45.8, elev. 1347, 3-20-81. 46.1, elev. 1347, 3-24-81. (F.W. Wilson and R.E. O'Connor)	

NOTE: Apparent variations in water levels above or below elev. 1347 probably are measuring errors caused by mud on the electric tape. Last measurement is correct.

KGS-8, 4 in. dia. continuous flight auger to 66 ft., capped but not cased. Completed 2-27-81.

Elev.	Depth/ft.	Description
T.H. 1375.5	0 to 1	Soil, black "A" horizon.
1374	1 to 16	Clay, yellow-tan limy nodules.
1359	16 to 28	Soft yellow-gray clay; limy nodules.
1347	28 to 31	Firmer, several thin limestone or gypsum beds.
1344	31 to 44	Yellow-tan limy shale, damp, sand and gravel size gypsum or limy nodules.
1331	44 to 45	Fractured gypsum zone.
1330	45 to 49	Gray, non-calcite shale.
1326	49 to 49.5	Gypsum.
1325.5	49.5 to 57	Gray shale; selenite fragments.
1318	57 to 58	Soft gray shale.
1317	58 to 58.5	Gypsum.
1316.5	58.5 to 66	Very soft drilling gray gypsiferous shale.
1309	66	T.D.

W.L. 43.6, elev. 1332, 3-5-81.
43.9, elev. 1332, 3-18-81.
43.4, elev. 1332, 3-20-81.
43.6, elev. 1332, 3-24-81, (F.W. Wilson and R.E. O'Connor)

KGS-9, Near NW cor. SW 1/4, SW 1/4, Sec. 26, T.25, R.2E.

4 in. dia. continuous flight auger to 51 ft., capped but not cased. Completed 2-27-81.

Elev.	Depth/ft.	Description
T.H. 1396.3	0 to 1	Topsoil.
1395	1 to 7	Yellow weathered shale with limy nodules.
1389	7 to 11	Same as above; limy zones at 7 and 8 ft.
1385	11 to 21	Orange-yellow clay; limy nodules; limy zones at 17 and 19 ft.
1375	21 to 45	Yellow clay; limy thin limestone or gypsum at 29 ft.
1351	45 to 45.5	Gypsum or limestone zone.
1350.8	45.5 to 51	Yellow clay, saturated. Numerous gypsum or limestone zones.
1345	51	T.D.

Water in hole upon completion; not measured.

W.L. 45.0, elev. 1350, 3-5-81.
45.1, elev. 1351, 3-17-81.

KGS-10, 40 ft. west of existing well 1-A and 10 ft. east of HA-2.

4 in. continuous flight auger to 51 ft. capped, but not cased. Completed 3-5-81.

Elev.	Depth/ft.	Description
T.H. 1394	0 to 5	Soil, black (A horizon).
1389	5 to 15	Shale, yellow, thin limestone stringers.
1379	15 to 17	Reddish clay.
1377	17 to 34	Shale, tan, damp.
1360	34 to 46	Shale, yellow gray, with limestone stringers, moist.
1348	46 to 51	Shale, yellow gray, more numerous thin limestone or gypsum stringers, saturated.
1343	51	T.D. water in hole upon completion. W.L. 43.4, elev. 1350, 3-10-81 43.5, elev. 1352, 3-18-81 43.8, elev. 1350, 3-24-81 (F.W. Wilson and R. E. O'Connor)

APPENDIX B

KGS-3, (Permeameter) 6.5 in. continuous flight auger at 40.0 ft. T.D. Some cuttings at bottom.

T.H. elev. set 35 ft. of 6 in. PVC, spigot down.
1394 Completed 2-4-81, 3:00 p.m. Not logged. Damp at bottom.
Sealed, capped and vented with 1 inch charging and measuring hole 2.0 above ground.

Charged with Wichita municipal water at dates and times indicated below.

Measured with cloth tape or electric tape at dates and times as indicated. Water levels below ground surface.

Date	Time	W.L. Depth/ft.	Elapsed time Hours/Minutes	Remarks
2-4-81	3 - 4 p.m.	1.0		Initial charge.
2-9-81	3 p.m.	19.4	96 hrs.	Measured with cloth tape, in snowstorm.
2-18-81	4 p.m.	1.0		Second charge.
2-19-81	6 p.m.	18.8	26 hrs.	Measured with electric tape.
2-26-81	2 p.m.	30.0	166 hrs.	Measured with electric tape.
2-26-81	3 p.m.	0.0		3rd charge.
2-26-81	6:15 p.m.	4.2	3.25	Electric tape.
2-27-81	7:45 a.m.	12.1	16.75	Electric tape.
2-27-81	1:15 p.m.	14.0	22.25	Electric tape.
3-5-81	5:43 p.m.	20.7		Electric tape.
3-17-81	11:00 a.m.	31.0		Cloth tape & weight.
3-17-81	11:00 a.m.	0.0		Final charge.
3-17-81	11:20 a.m.	1.8		Cloth tape & weight.
3-17-81	2:30 p.m.	5.0	3:30	Cloth tape & weight.

(continued on next page)

KGS-3 (Permeameter) (continued)

Date	Time	W.L. Depth/ft.	Elapsed time Hours/Minutes	Remarks
Not measured at 5:00 p.m. because of tornado in immediate vicinity and severe lightning.				
3-18-81	7:25 a.m.	13.0		Cloth tape & weight.
3-18-81	11:30 a.m.	15.0		Cloth tape & weight.
3-18-81	3:50 p.m.	16.0		Cloth tape & weight.
3-20-81	2:40 p.m.	22.0		
3-24-81	11:00 a.m.	28.7		

KGS-4 Permeameter, Near NE cor. SE 1/2, SW 1/4, Sec. 26, T.25S., R.2E.

6.5 in. continuous flight auger to 28 ft.
Not logged. Set 20 ft., 6 in. PCV to 17 ft., spigot down, sealed at surface with dry drilling mud. Capped. Completed 2-4-81. No water after 24 hours.

T.H. 1383.7

Date	Time	W.L. Depth/ft.	Elapsed time Hours/Minutes	Remarks
2-5-81	3 - 4 p.m.	1.0		Initial charge.
2-9-81	5 p.m.	15.4	98 hrs.	Cloth tape; snowstorm.
2-18-81	4:15 p.m.	1.0		2nd charge.
2-19-81	6 p.m.	13.0	1.75	Electric tape.
2-26-81	2:15 p.m.	17.5	1.66	Electric tape.
2-26-81	4:15 p.m.	0.0		3rd charge.
2-26-81	5:15 p.m.	5.3	3.0	Electric tape.
2-27-81	8 a.m.	8.2	15.75	Electric tape.
2-27-81	1:30 p.m.	8.5	22.75	Electric tape.
3-5-81	6 p.m.	14.1 T.D. 20.0		Cloth tape & weight.
3-17-81	11:20 a.m.	20.0 dry		
3-17-81	11:20 a.m.	0.0		Final charge.
3-17-81	2:50 p.m.	3.2	3.30	Cloth tape & weight.
3-17-81	5 p.m.	Not remeasured because of lightning and reported tornado sighting on ground.		
3-18-81	7:30 a.m.	7.0		3 mi. SW.
3-18-81	11:35 a.m.	0.0		Cloth tape.
3-18-81	4 p.m.	9.0		Cloth tape.
3-20-81	2:50 p.m.	12.4		
3-24-81	10:50 a.m.	14.5		

KGS-5, Permeameter, Near NW cor. SW 1/4, SE 1/4, SW 1/4 Sec. 26, T.25S., R.2E.

4 in. dia. CFA to 48 ft. Reamed to 6 1/2 in. to 15 ft. Drilled out cavings at 15 ft. Set 6 in. PVC bell down to 15 ft., sealed around bottom bell with 1/2 bag dry drilling mud. Surface sealed as above. Not capped. Cuttings logged. Completed 2-4-81.

Elev.	Depth/ft.	Description
T.H. 1385.9	0 to 3	Topsoil.
1383	3 to 20	Yellow-tan clay shale. Few thin limstone stringers.
1366	20 to 30	Tan gray shale. Limestone stringers.
1356	30 to 37	Same as above; slightly more firm; laminated.
1349	37 to 38	Pushed core to refusal. Tan gray laminated shale.
1348	38 to 48	Same as above; thin limestone stringers.
1338	48 to 51	Firm, rattle, more numerous limestone or gypsum beds.
1335	51	T.D.
		W.L. Feb. 5, 1981, 38.0, 1347.9 (may not have stabilized).
		Converted to permeameter by reaming hole to 6.5 in. dia. to 15 ft. Set 20 ft., 6 in. dia. PVC with bell down. Poured dry drilling mud around outside of pipe, top and bottom. Charged to ground line with clear water 2-4-81, 3 p.m.

KGS-5, Permeameter, (continued)

T.H. 1385.9

Date	Time	W.L. Depth/ft.	Elapsed time Hours/Minutes	Remarks
2-5-81	3 - 4 p.m.	1.0		First charge.
2-9-81	3 p.m.	24.1 (dry)		Cloth tape; blizzard.
2-18-81	4:30 p.m.	1.0		2nd charge.
2-19-81	5:15 p.m.	19.4		Electric tape.
2-26-81	3 p.m.	0.0		3rd charge.
2-26-81	6:20 p.m.	4.2		Electric tape.
2-27-81	7:50 a.m.	12.1		Electric tape.
2-27-81	1:15 p.m.	14.0		Electric tape.
3-5-81	5 p.m.	Dry--didn't measure.		Mirror.
3-17-81	12 noon	15.1 [dry] (bottom of casing)		
3-17-81	12 noon	0.0		Final charge.
3-17-81	3:05 p.m.	6.7	3:05	
3-18-81	7:45 p.m.	12.1		
3-18-81	11:50 a.m.	13.0		
3-18-81	4:10 p.m.	13.5		
3-20-81	3 p.m.	15.0		
3-24-81	10:20 a.m.	15.2 [dry]		(F.W. Wilson and R.E. O'Connor)

KGS-6 Permeameter, Near SW cor. S 1/2 SW 1/4 Sec. 26, T.25S., R.2E.

6 1/2 in. dia. CFA to 40.5 ft. Set 37.5 ft. 6 in. PVC, spigot down. Sealed at surface; vented and cap glued as above. Completed 2-5-81.

Date	Time	W.L. Depth/ft.	Elapsed time Hours/Minutes	Remarks
T.H. 1392.8				
2-5-81	3 - 4 p.m.	1.0		First charge.
2-9-81	1 p.m.	26.5		Cloth tape; snowstorm.
2-18-81	4:45 p.m.	1.0		2nd charge.
2-19-81	4:45 p.m.	33.2		Electric tape.
2-26-81	3 p.m.	0.0		3rd charge.
2-26-81	5:50 p.m.	6.4		Cloth tape.
2-27-81	9 a.m.	24.5		Cloth tape.
2-27-81	2:15 p.m.	28.2		Cloth tape.
3-5-81	5:15 p.m.	37.2		Cloth tape.
3-18-81		37.2 [dry]		
3-18-81	12:25 p.m.	0.0		Final charge.
3-18-81	3:30 p.m.	9.6	3.05	
3-18-81	8 a.m.	27.0		
3-18-81	12 noon	29.0		
3-18-81	4:30 p.m.	31.3		
3-20-81		37.2 [dry]		
3-24-81		37.1 [dry]	(F.W. Wilson and R.E. O'Connor)	

KGS-9, Converted to permeameter 3-17-81.

T.H. 1396.3

Initial natural W.L. 46.0, elev. 1350.3, T.D. 49.0, 2-27-81.

Date	Time	W.L. Depth/ft.	Elapsed time Hours/Minutes	Remarks
3-17-81	8:45 a.m.	45.1		Natural W.L.
3-17-81	12:50 p.m.	1.0		First charge.
3-17-81	3:35 p.m.	40.0	2:45	T.D. 45.0
3-17-81	3:40 p.m.	0.5		2nd charge.
3-17-81	3:45 p.m.	1.5	0:05	
3-17-81	3:50 p.m.	2.0	0.10	
3-17-81	3:55 p.m.	2.5	0:15	
3-17-81	4 p.m.	3.0	0:20	
3-17-81	4:05 p.m.	3.5	0:25	
3-17-81	4:10 p.m.	3.8	0:30	
3-17-81	4:15 p.m.	4.0	0:35	
3-17-81	4:20 p.m.	4.3	0:40	
3-17-81	4:30 p.m.	4.9	0:50	
3-17-81	4:40 p.m.	5.6	0:60	Discontinued measuring; rain, lightning, and tornado reports on ground - 3 mi. SW.
3-18-81	8:05 a.m.	14.0	16:20	
3-18-81	12:05 p.m.	14.5	20:20	
3-18-81	4:25 p.m.	15.0	24:20	
3-20-81	3:30 p.m.	Caved and dry at 15°.		
3-24-81		Dry, not measured by F.W. Wilson and R.E. O'Connor.		

APPENDIX C

APPENDIX C

NOTES ON ANALYSIS OF FALLING HEAD PERMEAMETER DATA *

The analysis of the permeameter data collected during the course of this study was analyzed in accordance with a method proposed by Hvorslev (1951). This method (see Fig. 1a) assumes that the permeameter is completed above an impervious layer and that the open hole between the bottom of the tube and the impermeable layer is of length L. The medium is assumed to be homogeneous, but anisotropic above the impervious layer. The ratio between the horizontal permeability (k_h) and the vertical permeability (k_v) is defined as $m^2 = (k_h/k_v)$. The appropriate formula is:

1) $$k_h = a^2 \ln[mL/a_p + \{1 + (mL/a_p)^2\}^{1/2}] \cdot \ln(h_1/h_2)/2L(t_2-t_1)$$

The quantities h_1 and h_2 are the heads measured from the undisturbed water level elevation at times t_1 and t_2, respectively.

Numerical experiments conducted on equation 1 for m^2 = 100 and 1,000 for L = 5 feet and a_p = .27 feet indicate a small sensitivity for the value of k_h. The quantity defined as

2) $$\alpha = \ln[mL/a_p + \{1 + (mL/a_p)^2\}^{1/2}]$$

was evaluated for m^2 = 100 and m^2 = 1,000, giving values of α of 5.91 and 7.08, respectively. Thus, an order of magnitude difference in m^2 produces only a 20% difference in k_h. Because of this, all calculations were carried out assuming m^2 = 100. As Δm^2 becomes larger $\Delta\alpha$ increases.

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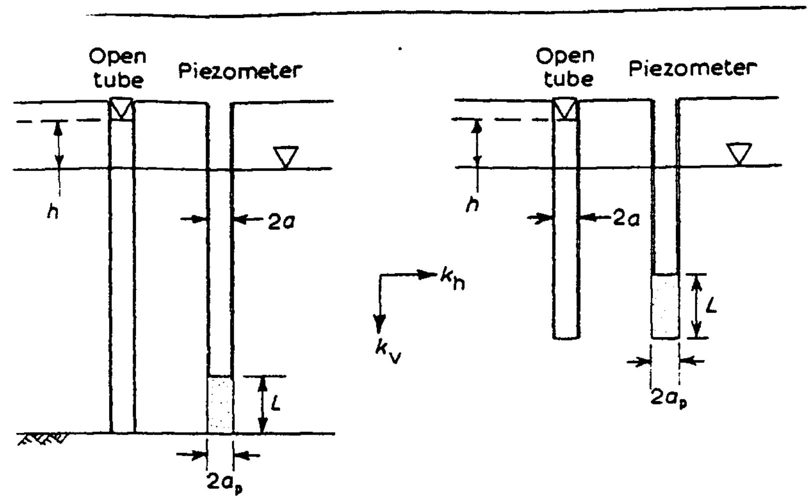
* By Patrick Cobb, hydrogeologist, Kansas Geological Survey

A second set of assumptions (see Fig. 1b) is also possible. This configuration assumes no lower impermeable boundary. Therefore, the entire aquifer is totally homogeneous, but retains the anisotropic condition expressed by m^2 (for $m^2 = 1$, the system is also totally isotropic). Here, L represents the length of the open hole. All other quantities are the same. The equation for k_h is the same as for equation 1, except that the quantity α has been redefined as

$$3) \qquad \alpha' = \ln[mL/2a_p + \{1 + (mL/2a_p)^2\}^{1/2}]$$

Numerical experiments comparing α and α' for L = 5 feet, m = 10 and a_p = .27 feet indicate only minor differences in the evaluation of k_e. For the above numbers, α was 5.91 while α' was 5.22, for a difference of 12%. If the soil is isotropic (m=1), α' = 2.23, for a 62% difference from method 1. The quantity α decreases from method 1 through method 3.

In general, it was felt that the first method (equation 1) was most representative of the study area, although the second method might also apply. In no case should the assumption m=1 be considered valid. The greatest possibility for error is in the estimation of m^2. Calculations indicate that for values of m^2 ranging from 10^2 to 10^6, a maximum difference of 80% occurs in the value of k_h, much less than an order of magnitude.



(a) anisotropic soil bounded by impervious layer – inlet at boundary

(b) infinite isotropic soil

Figure 1. Analytical Assumptions for Permeameter Analysis

h = elevation above water table

L = length of open hole

a_p = radius of open hole

a = radius of permeameter tube

k_h = horizontal permeability

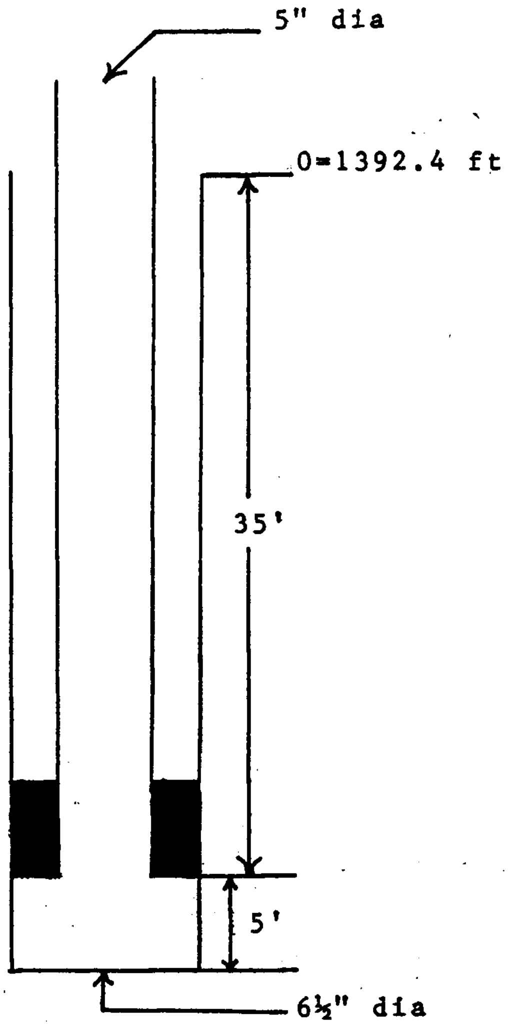
k_v = vertical permeability

APPENDIX D

Hydraulic Conductivity Calculations

by Patrick Cobb, Hydrogeologist

KGS-3 PERMEAMETER



a - .21
a_p = .27
m = 10
L = 5

α = 185.19
β = 185.19

$a^2 \cdot \ln(\alpha + \beta) = .26$

for early time

γ = .03
δ = .01

k_h = 3.99 x 10^{-5} cm/sec

for late time

γ = .47
δ = 1.8 x 10^{-5}

k_h = 1.12 x 10^{-6} cm/sec

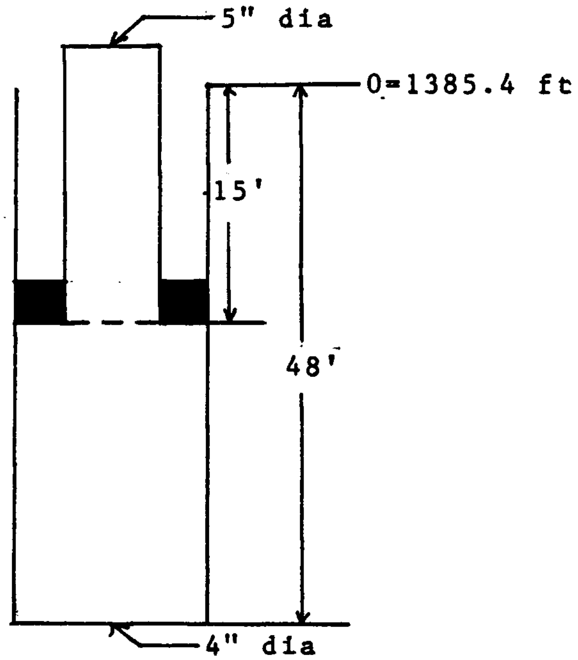
for long time

γ = 1.26
δ = 9.9 x 10^{-6}

k_h = 1.65 x 10^{-6} cm/sec

t(min)	H(ft)	h(ft)
0	0	40.0
20	1.8	38.2
190	5.0	
1225	13.0	
1470	15.0	
1730	16.0	
4540	22.0	18.0
10080	28.7	11.3

KGS-5 PERMEAMETER



$a = .21$
$a_p = .13$
$m = 10$
$L = 33$

$\alpha = 2538.46$
$\beta = 2539.46$
$a^2 \cdot \ln(\alpha + \beta) = .38$

for early time

$\gamma = .15$
$\delta = 8.19 \times 10^{-5}$

$k_h = \underline{2.38 \times 10^{-6}}$ cm/sec

for late time

$\gamma = .04$
$\delta = 6.66 \times 10^{-6}$

$k_h = \underline{5.16 \times 10^{-8}}$ cm/sec

for long time

$\gamma = .37$
$\delta = 3.36 \times 10^{-6}$

$k_h = \underline{2.4 \times 10^{-7}}$ cm/sec

t(min)	H(ft)	h(ft)
0	0	48
185	6.7	41.3
1720	12.1	
1965	13.0	
2225	13.5	34.5
4500	15.0	33.0
9960	dry	

$$k_e = \frac{\pi a}{5.5(t_2 - t_1)} \ln\frac{h_1}{h_2}$$

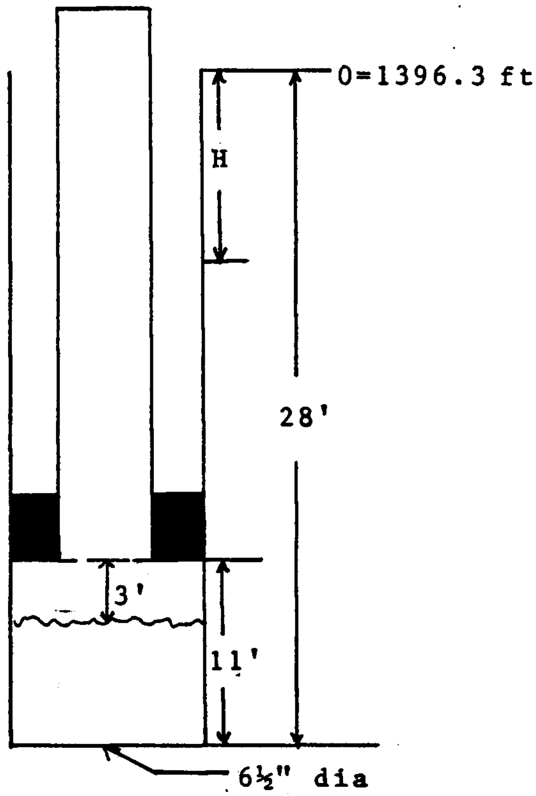
t(min)	h(ft)	
0	15.00	early
185	830	early
1720	2.90	
1965	2.00	late
2225	1.50	late
4500	0	
9960	0	

early time: $k_e = 1.95 \times 10^{-4}$ cm/sec

late time: $k_e = 3.12 \times 10^{-4}$ cm/sec

long time: $k_e = 6.3 \times 10^{-5}$ cm/sec

KGS-4, PERMEAMETER



$a = .21$
$a_p = .27$
$m = 10$
$L = 11$

$\alpha = 407.41$
$\beta = 407.41$
$a^2 \cdot \ln(\alpha + \beta) = 0.30$

for early time

$\gamma = 0.12$
$\delta = 1.47 \times 10^{-4}$

$k_h = \underline{2.67 \times 10^{-6}}$ cm/sec

for late time

$\gamma = 0.14$
$\delta = 8.1 \times 10^{-6}$

$k_h = \underline{3.40 \times 10^{-7}}$ cm/sec

for long time

$\gamma = .73$
$\delta = 4.56 \times 10^{-6}$

$k_h = \underline{5.09 \times 10^{-7}}$ cm/sec

t(min)	H(ft)	h(ft)
0	0	28
310	3.2	24.8
1000	7.0	
1245	8.0	
1570	9.0	
4380	12.4	15.6
9960	14.5	13.5

$L = 3$
$a = .21$
$a_p = .27$
$m - 10$

$\alpha = 142.86$
$\beta = 142.86$
$a^2 \cdot \ln(\alpha + \beta) = .25$

t(min)	h
0	20
310	16.8
1000	
1245	
1570	
4380	7.6
9960	5.5

for early time $k_h = \underline{1.16 \times 10^{-5}}$ cm/sec

$\gamma = .17$
$\delta = 5.38 \times 10^{-4}$

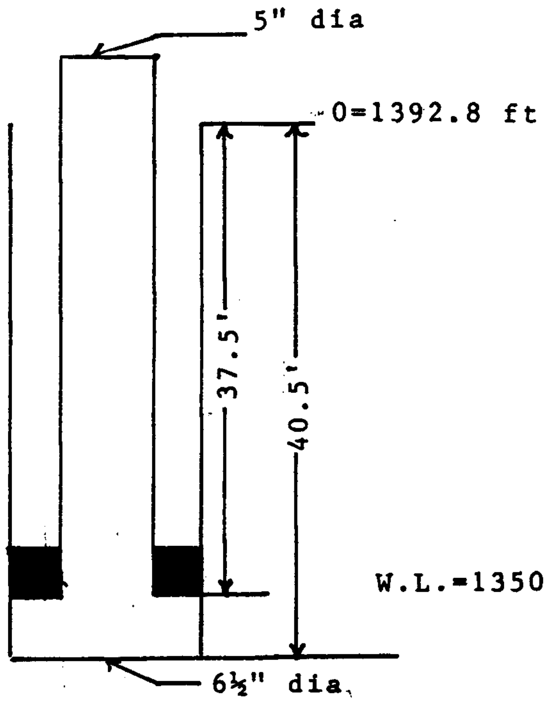
for late time $k_h = \underline{1.12 \times 10^{-6}}$ cm/sec

$\gamma = .32$
$\delta = 2.99 \times 10^{-5}$

for long time $k_h = \underline{2.74 \times 10^{-6}}$ cm/sec

$\gamma = 1.29$
$\delta = 1.67 \times 10^{-5}$

PERMEAMETER KGS-6



t(min)	H (ft)	
0	0	$h_1 = 40.5$
185	9.6	$h_2 = 30.9$
1175	27.0	$h_3 = 13.5$
1415	29.0	$h_4 = 11.5$
1685	31.3	$h_5 = 9.2$

a = .21 ft.

$\alpha = 111.11$, $\beta = 111.11$ } $a^2 \cdot \ln(\alpha + \beta) = .24$

$\gamma = .27$

$\delta = 9 \times 10^{-4}$

for early time

$k_h = \underline{2.97 \times 10^{-5}}$ cm/sec

for late time

$\gamma = .22$

$\delta = 6.17 \times 10^{-4}$

$k_h = \underline{1.66 \times 10^{-5}}$ cm/sec

for long time

$\gamma = 1.48$

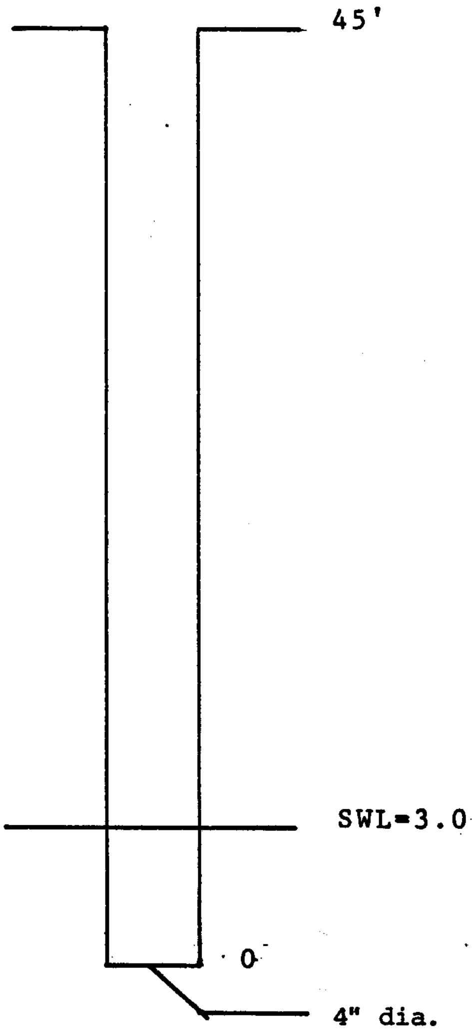
$\delta = 9.89 \times 10^{-5}$

$k_h = \underline{1.79 \times 10^{-5}}$ cm/sec

KGS-9 - Open Bore Hole

T.D. = 49.0

Initial Water Level @ 45



$a = .27$ $\alpha = 111.11$
$a_p = .27$ $\beta = 111.11$
$L_p = 3'$ $a^2 \cdot \ln(\alpha + \beta) = .39$
$m = 10$ $\gamma = 2.01$
$\delta = 3.03 \times 10^{-3}$

t(min)	H (ft)	h(ft)
0	1	45
165	40	6

$k_h = \underline{1.21 \times 10^{-3}}$ cm/sec

$a = .27$ $\alpha = 851.85$
$a_p = .27$ $\beta = 851.85$
$L_p = 23$ $a^2 \cdot \ln(\alpha + \beta) = .54$
$m = 10$ $\gamma = 2.01$
$\delta = 1.317 \times 10^{-4}$

$k_h = \underline{7.29 \times 10^{-5}}$ cm/sec

APPENDIX E

APPENDIX E

WATER CHEMISTRY *

The water table elevations in a ten square mile area surrounding the disposal site suggest that there are three separate aquifers. Elevations were recorded for domestic, stock, and abandoned wells (Tables E-1 and E-3) and springs, and are plotted in Figure E-1. Figure E-2 explains the well numbering system. Wells in Table E-1 are grouped according to elevations representing the three water-bearing zones. The group of wells below the dashed line could not be grouped according to water-level elevation with as much certainty as those above the line in Table E-1. The number of these zones encountered by wells increases going from east to west in Figure E-1 due to the increasing ground elevation and gentle regional dip of the strata to the west (Appendix F).

The chemistry of the waters in each of the three aquifers varies widely (Table E-2), depending on the areal location of the sampling point, the depth to the aquifer below the land surface, and the presence of local animal waste or septic effluent. Wells in Table E-2 are grouped according to water-bearing zones as in Table E-1. The fact that each aquifer contains high sulfate concentrations in certain areas indicates that gypsum is or was present in all three aquifers.

Wells are present in the upper water-bearing zone in the western half of Figure E-1. Waters from these wells are generally high in sulfate concentration. Strata of this zone probably contain thicker gypsum beds than the other two zones. A spring in the southwestern part of Section 22 has a very high sulfate content (1870 ppm) that is close to saturation with respect to gypsum. The spring probably issues from the bottom of the upper aquifer.

Well waters in the middle water-bearing zone range from low to very high sulfate levels. Sulfate concentrations are lower where the aquifer is nearer the surface, as in the southern part of Section 25 and the northern portion of Section 36, and higher where the aquifer is deeper, as in the southeastern corner of Section 35, west-central part of Section 25, and northern portion of Section 23. Thus, groundwater infiltration and subsequent dissolution and removal of gypsum from the aquifer appears to have been greater where the overburden is thinner. The water level elevation and chemistry of stratigraphic hole KGS-1 may primarily represent the influence of the middle aquifer in a location of greater depth than to the east. Springs near the border of Sections 22 and 23, and in the northwestern corner of Section 25 contain high sulfate concentrations (1510-1660 ppm), and probably issue from the base of the middle aquifer.

Similar large sulfate ranges occur in well waters in the lower aquifer. Depths to water in the western half of Section 24 range from 16 to 25 feet. This overburden depth is probably thin enough that waters can infiltrate through fractures to recharge the aquifer. The

* Welch, Jerome E., Soil Geochemist and Donald O. Whittemore, Water Geochemist.

possibly greater permeability of this location than where the overlying strata is thicker can explain why groundwater could have dissolved most of the gypsum in the immediate area, resulting in low sulfate concentrations. High sulfate in well waters in the southern part of Section 25 and the northeastern portion of Section 26 suggest that the lower aquifer contains undissolved gypsum in other locations.

A Piper diagram (Figure E-3), on which selected wells and Prairie Creek samples are plotted, shows graphically the general types of water chemistry present. The letters on the diagram represent the first letter of the last name of the well owner or tenant in Table E-1. Most of the waters on the diagram would be classified as $Ca\text{-}SO_4$ type representing the predominant effect of gypsum solution on the chemistry. In addition, however, these waters contain appreciable amounts of magnesium and bicarbonate reflecting the solution of limestone and dolomite. Based on studies of similar Permian strata in Pottawatomie County, the waters are probably saturated with respect to calcite and may be close to saturation with respect to dolomite. As the amount of gypsum left to be dissolved in a portion of a water-bearing zone decreases, the water type shifts from $Ca\text{-}SO_4$ to $Ca\text{-}SO_4\text{-}HCO_3$ to $Ca\text{-}HCO_3$. Well waters "D", "H", "U", and "C" on Figure E-3 show this trend. A few groundwaters contain nitrate and chloride pollution from animal waste and septic tank effluent which entered wells along the outside of the casings. For example, well "M" in the lower right triangle of the Piper diagram is displaced from the other waters due to a very high nitrate concentration.

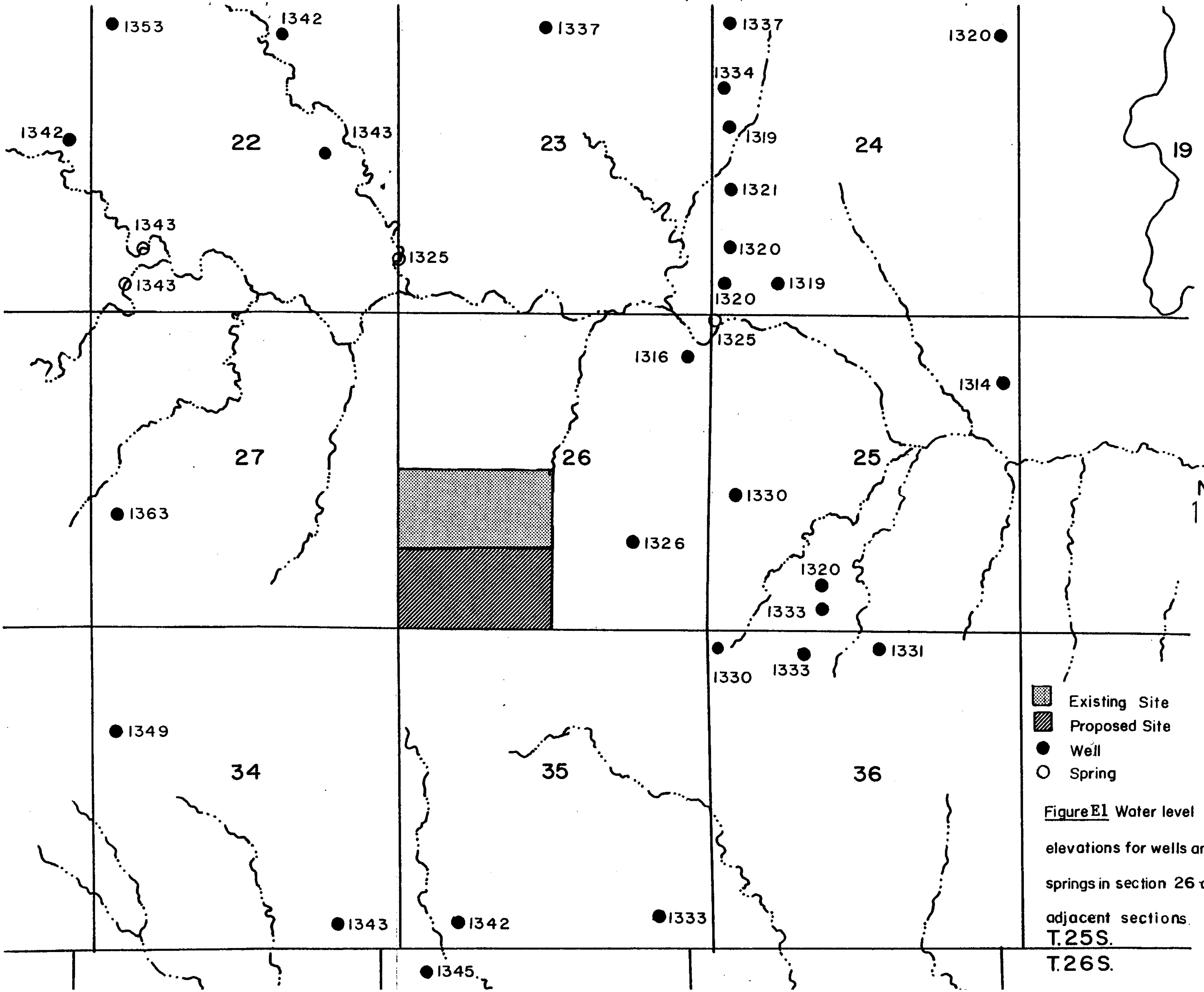


Figure E1 Water level elevations for wells and springs in section 26 and adjacent sections

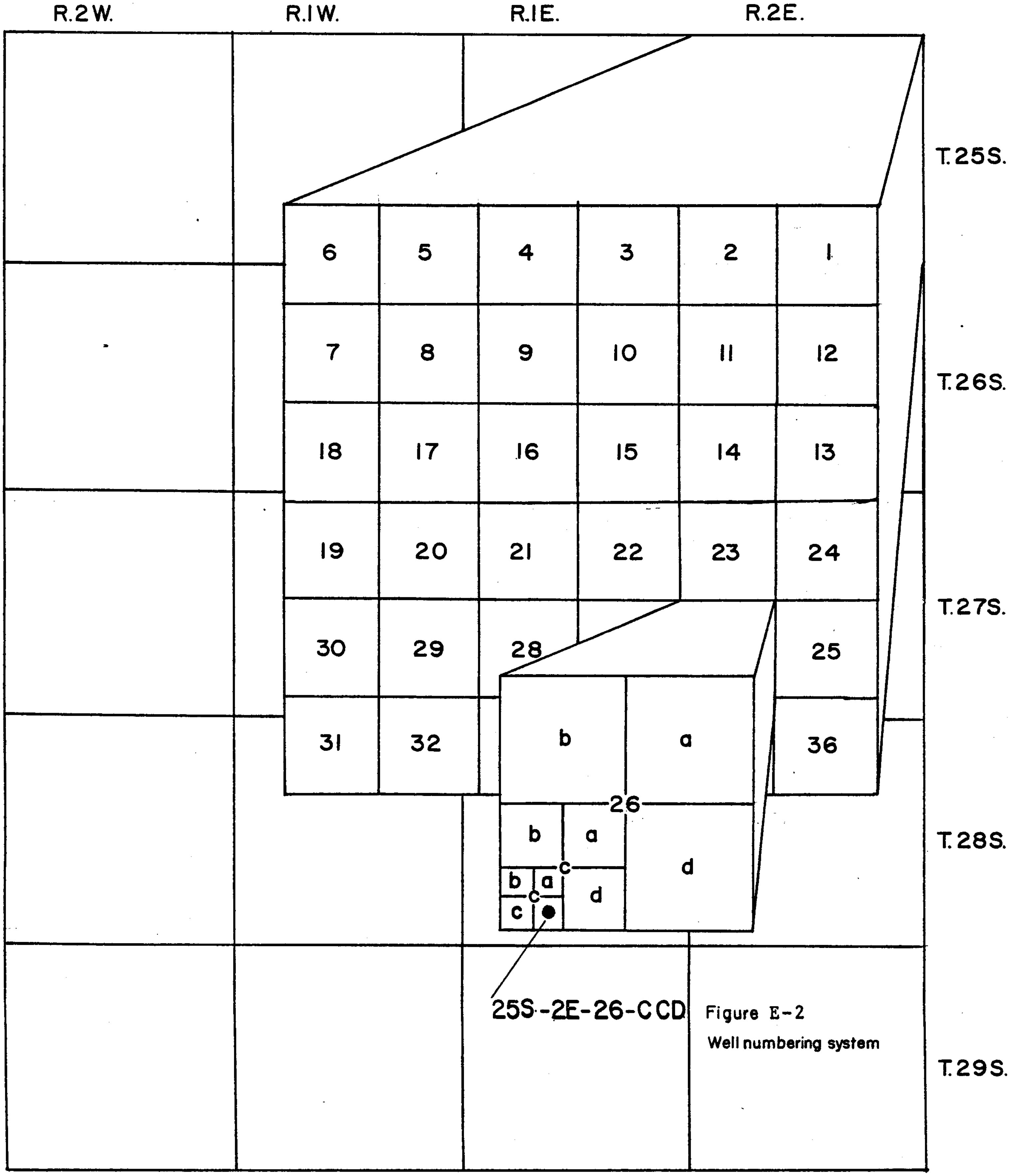


Figure E-2
Well numbering system

Figure E-3

Piper diagram for selected wells and Prairie Creek

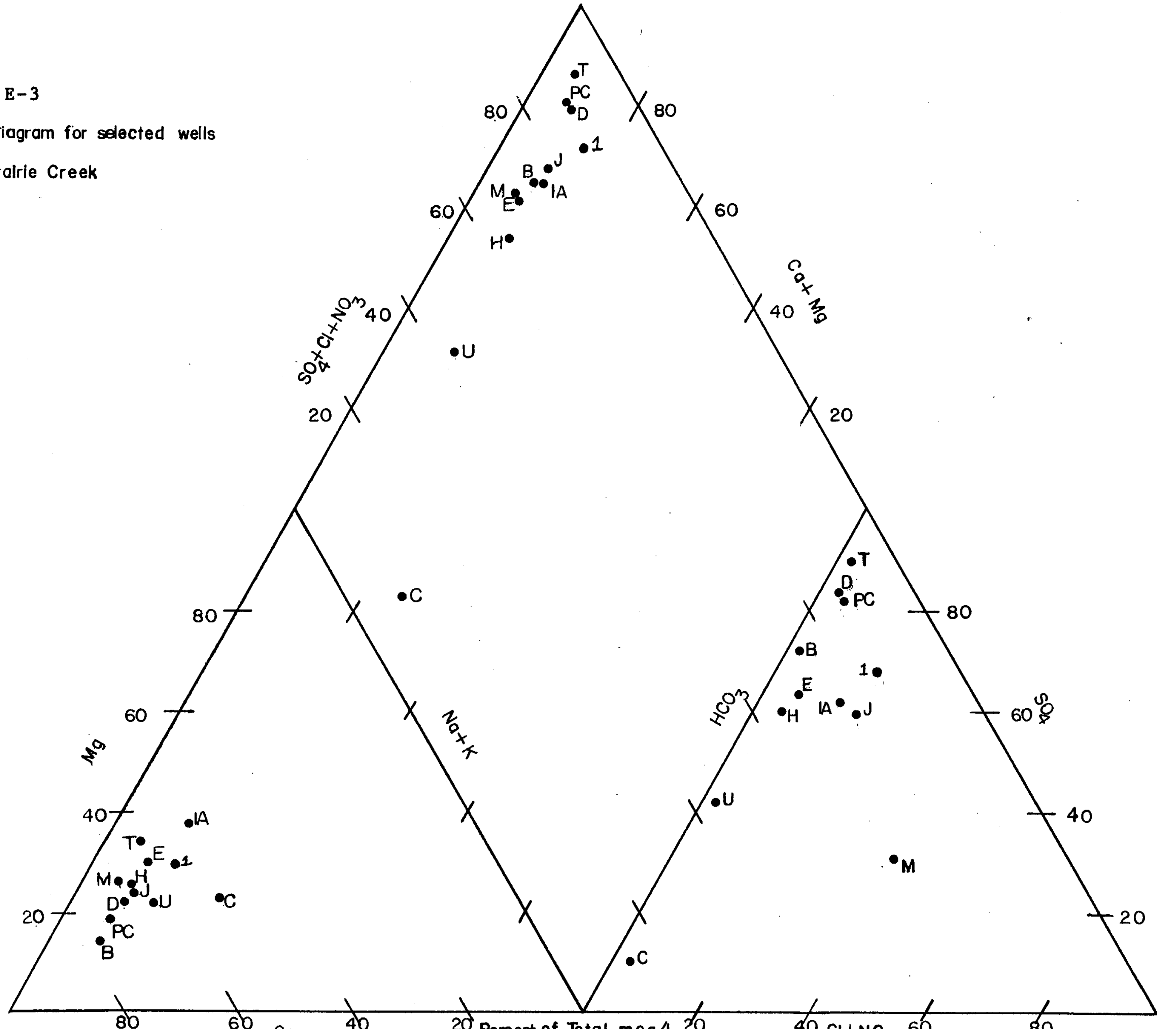


Table E-1 Records of wells in section 26 and adjacent sections that were measured for water level elevation and chemical quality

Water-bearing zone		Well Location	Owner or Tenant	Type of Well	Use of Water	Depth of Well, feet	Height of land surface above mean sea level, feet	Depth to water level below land surface, feet	Height of water level above mean sea level, feet	Date of water level measurement
Upper	b	25S-2E-22 ABB	Russ Jackson	Drilled	Stock	60	1380	38	1342	04-02-81
	b,c	26 CDC	KIES (KGS Well 1A)	Drilled	None	60	1393	43	1350	03-18-81
	b	34 DDC	Harry Erdwien	Dug	Domestic	35	1370	27	1343	04-02-81
Middle	b	25S-2E-23 BAA	Howard Ulmer	Drilled	Stock	—	1370	32 a	1338	04-02-81
		24 AAA	Richard Fritzler	Drilled	Domestic	65	1350	—	—	04-29-81
		24 BCB	Francis Joseph[1]	Drilled	Domestic	50	1355	24	1331	04-02-81
		24 BCB	Francis Joseph[2]	Dug and Drilled	Stock	60	1350	16	1334	04-02-81
		25 CDD	Blaine Bodecker	Drilled	Stock	44	1350	17	1333	03-18-81
		25 CBB	Don Potter	Drilled	Domestic	70	1360	30	1330	03-18-81
	b	35 DDC	Paul Duranleau	Drilled	Domestic	—	1370	37	1333	04-02-81
		35 CCD	W.D. Holcombe	Drilled	Domestic	—	1360	—	—	04-29-81
		36 ABB	Robert Merth	Dug and Drilled	Domestic	75	1355	24	1331	04-02-81
		36 BAB	John Meyersick	Dug and Drilled	Domestic	55	1365	32	1333	04-02-81
		36 DDC	Virgil Meyersick	Drilled	Stock	—	1355	—	—	04-02-81
		36 BBB	Lonnie Owens	Drilled	Domestic	32	1355	24	1331	04-02-81
Lower	b	25S-2E-24 CBB	Delbert Crowl	Drilled	Domestic	70	1345	24	1321	04-02-81
		24 CBC	C.W. Dixon	Drilled	Domestic	70	1345	25	1320	04-02-81
		24 CCC	Everett Kennedy	Drilled	Domestic	75	1340	20	1320	04-02-81
		24 BCC	Robert Teeter	Drilled	Domestic	—	1345	26	1319	04-02-81
		24 CCD	Dean Whitmore	Dug	Stock	75	1335	16	1319	04-02-81
	b	25 CDD	Blaine Bodecker	Drilled	Domestic	70	1345	25	1320	03-18-81
	b	26 AAD	Deane Hopkins[1]	Drilled	Domestic	—	1335	18	1317	04-29-81
		26 AAD	Deane Hopkins[2]	Drilled	Stock	34	1330	15	1315	03-18-81
	b	25S-2E-22 BBB	Eugene Thompson	Drilled	Domestic	90	1400	47	1353	04-02-81
	b	26 DAC	Mike Moreland	Drilled	Domestic	—	1360	—	—	05-04-81
	b,c	26 CDC	KGS-1	Drilled	None	134	1393	57	1336	02-03-81

a Information unattainable   b Wells represented on Piper diagram   c Samples collected and analyzed by KGS

Table E-2 Chemical quality data for wells in section 26 and adjacent sections [a]

Water-bearing zone	Well location	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Chloride (Cl)	Sulfate (SO_4)	Nitrate (NO_3)	Total dissolved solids (180°C)	pH	Specific conductance (µmhos at 25°C)	Total hardness (as $CaCO_3$)	Total alkalinity (as $CaCO_3$)
		ppm											ppm	
Upper b	25S-2E-22 ABB	344	76	63	2.3	356	98	757	102	1640	7.6	2090	1170	292
b,c	26 CDC	239	111	64	1.0	344	110	710	5.3	1430	7.8	1980	1052	282
b	34 DDC	232	69	30	2.2	351	38	584	15	1160	7.8	1560	862	288
Middle b	25S-2E-23 BAA	144	31	27	1.1	386	12	230	13	670	7.8	960	487	316
	24 AAA	136	35	63	0.9	442	53	43	164	730	7.6	1210	483	362
	24 BCB[1]	85	36	35	1.0	415	22	40	34	472	8.0	800	360	340
	24 BCB[2]	83	31	38	1.0	400	20	33	39	459	7.9	780	334	328
	25 CDD	106	47	28	1.2	417	58	33	75	571	8.0	1010	458	342
	25 CBB	154	40	41	1.3	344	16	250	75	765	7.8	1160	549	282
b	35 DDC	480	95	51	3.1	271	48	1400	16	2240	7.8	2490	1590	222
	35 CCD	126	40	34	1.1	415	61	111	28	623	7.7	1030	479	340
	36 ABB	115	45	18	1.1	393	42	52	84	566	7.9	980	472	322
	36 BAB	107	41	16	0.6	403	31	51	97	560	7.8	890	435	330
	36 DDC	131	40	25	1.3	376	19	206	5.7	634	8.0	980	491	308
	36 BBB	107	43	47	1.0	429	37	67	111	643	7.8	1040	444	352
Lower b	25S-2E-24 CBB	75	20	45	1.0	395	11	12	4.0	380	7.8	670	269	324
	24 CBC	78	21	35	0.7	385	10	36	12	400	7.8	650	281	314
	24 CCC	83	27	28	0.9	376	14	22	39	421	8.1	710	318	308
	24 BCC	78	23	29	0.7	383	11	24	14	384	8.0	640	289	314
	24 CCD	90	19	67	1.0	407	32	10	49	490	7.8	850	303	334
b	25 CDD	370	41	47	1.7	378	13	822	8.4	1510	7.6	1920	1090	310
b	26 AAD[1]	224	52	37	2.1	359	19	484	10.2	1020	7.8	1460	773	294
	26 AAD[2]	232	56	44	60	522	120	214	168	1170	7.8	1840	809	428
b	25S-2E-22 BBB	620	215	45	5.3	256	54	2220	8.0	3310	7.7	3400	2430	210
b	26 DAC	246	57	35	2.0	329	51	274	319	1160	7.8	1740	848	270
b,c	26 CDC	645	207	195	2.5	484	354	1908	6.6	3670	7.8	4100	2410	590

a Samples collected and analyzed by KDHE   b Wells represented on Piper diagram   c Samples collected and analyzed by KGS

Table E-3. Records of wells and springs in section 26 and adjacent sections measured only for water level elevation

Well Location	Owner or Tenant	Type of Well	Use of Water	Depth of Well, feet	Height of land surface above mean sea level, feet	Depth to water level below land surface, feet	Height of water level above mean sea level, feet	Date of water level measurement
25S-2E-21 ADD	Frank Hill	Drilled	Stock	------ [a]	1350	8	1342	04-02-81
22 ADC	Deserted	Dug	None	------	1350	7	1343	04-02-81
22 CCC	Deserted	Dug/Spring	None	------	1345	2	1343	04-02-81
22 CCA	———	Spring	Stock	———	1343	———	1343	04-02-81
23 CCB	———	Spring	Stock	———	1325	———	1325	01-27-81
23 BAA	Howard Ulmer	Drilled	None	------	1370	34	1336	04-02-81
24 BBB	Deserted	Drilled	None	------	1370	33	1337	04-02-81
24 AAA	Richard Fritzler	Dug	Garden	------	1345	25	1320	04-29-81
25 BBB	———	Spring	Stock	———	1325	———	1325	03-18-81
25 ADA	W.W. Whitson	Drilled	Domestic	60	1330	17	1313	04-29-81
25 ADA	W.W. Whitson	Drilled	Garden	40	1325	10	1315	04-29-81
26 DAC	Mike Moreland	Dug	None	------	1360	34	1326	04-02-81
27 CBC	Herbert Greenup	Drilled	None	------	1375	12	1363	04-29-81
34 BCB	Phyllis Gardner	Dug	None	------	1405	56	1349	04-29-81
35 CCD	Mrs. Elvern Hoch	Drilled	None	------	1360	18	1342	04-02-81
36 BBB	Lonnie Owens	Dug and Drilled	None	60	1355	26	1329	04-02-81
26S-2E-2 BBA	Deserted	Dug	None	------	1365	20	1345	04-29-81
2 BBA	Deserted	Drilled	None	------	1365	20	1345	04-29-81

a Information not available

APPENDIX F

APPENDIX F

SUBSURFACE GEOLOGY OF THE FURLEY WASTE DISPOSAL SITE *

Examination of subsurface oil-well electric logs in the vicinity of the Furley waste disposal site (SW/4 26-25S-2E, Sedgwick County) indicate:

1. From a disposal site elevation of 1395 ft., the Nolans Limestone (top of the Chase Group) should be encountered at a drilling depth of about 220 ft.

2. Several dense limestone-dolomite and or gypsum-anhydrite units should be encountered from near-surface (below extensively weathered horizons) down to the Nolans Limestone.

3. Regional subsurface structure maps contoured on the bases of Chase Group limestones indicate the Chase Group dips westward, fairly uniformly, at a gradient of 20 to 23 ft. per mile.

   Unless extensive evaporite dissolution has taken place, along with attendant slumping, one would assume the basal Wellington Formation would also dip westward at about 20 ft. per mile.

Attached are the following figures:

Figure F-1. Electric-log (SP-Resistivity) cross-section of the basal Wellington Formation, Chase Group, in the disposal site vicinity.

These logs are correlated to the Sedgwick County "Type-Log" of the Kansas Geological Society, which was drilled 16 miles west-southwest of the disposal site.

The Clark #1 well (SE-SE-NE 27-25S-2E) is located just diagonally across the road from the northwest corner of the existing site, at a ground level elevation of 1364 ft. The top of the Nolans Limestone lies at a log depth of 195 ft. The disposal site lies at a ground elevation of about 1395 ft.; hence, there should be about 220 ft. of basal Wellington above the Nolans in the site vicinity.

The lithology of the basal Wellington is difficult to interpret on the basis of SP-R log characteristics alone. Several highly resistant beds are indicated in the resistivity logs of wells lying a few miles west of the disposal site - these units could either be limestone-dolomite or anhydrite-gypsum beds.

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* James, Gerard, Geochemist.

Figure F-2. Expanded SP-Resistivity electric-log illustrating at least 12 highly-resistant units in the basal Wellington Formation. The subsurface cross-section (Figure F-1) indicates that many of these units may be continuous on a regional scale, and probably exist in the shallow surface in the site vicinity.

Figure F-3. Lithologic description of the basal Wellington as found in the Atomic Energy Commission Core Hole Number 1, located 65 miles northwest of the site. About 40 to 60 percent of the Wellington Formation below the salt zone is anhydrite; whether these beds carry southeastward to the disposal site is not known, but the resistant e-log characteristics indicate this is a possibility.

Figure F-4. Structure contour map of the base of the Chase Group-Winfield Limestone, indicating a regional westward dip at about 20 ft. per mile. Structure contour maps on the base of the Barneston and Wreford Limestones (not illustrated) are very similar to the Winfield.

CORRELATIONS

FIGURE F-1a.

USE

- ☆ Gas
- • Oil
- ✱ O&G
- ∀ Salt water disposal
- ⚲ Gas storage

SERIES	STAGE	GROUP	Formation	Member	USE
	CIMARRONIAN	Sumner	Wellington Fm.		∀
LOWER		Chase	Nolans Ls.	Herington Ls. Paddock Sh. Krider Ls.	
			Odell Sh.		
			Winfield Ls.		
			Doyle Sh.	Gage Sh. Towanda Ls. Holmesville Sh.	
			Barneston Ls.	Fort Riley Ls. Oketo Sh. Florence Ls.	
			Matfield Sh.	Blue Springs Sh. Wymore Sh.	
			Wreford Ls.		
	GEARYAN	Council Grove	Speiser Sh.		
			Funston Ls.		
			Blue Rapids Sh.		
			Crouse Ls.		
			Easly Creek Sh.		
			Bader Ls.		
			Stearns Sh.		
			Beattie Ls.	Cottonwood Ls.	
			Eskridge Sh.		
				Neva Ls.	

TYPE LOG

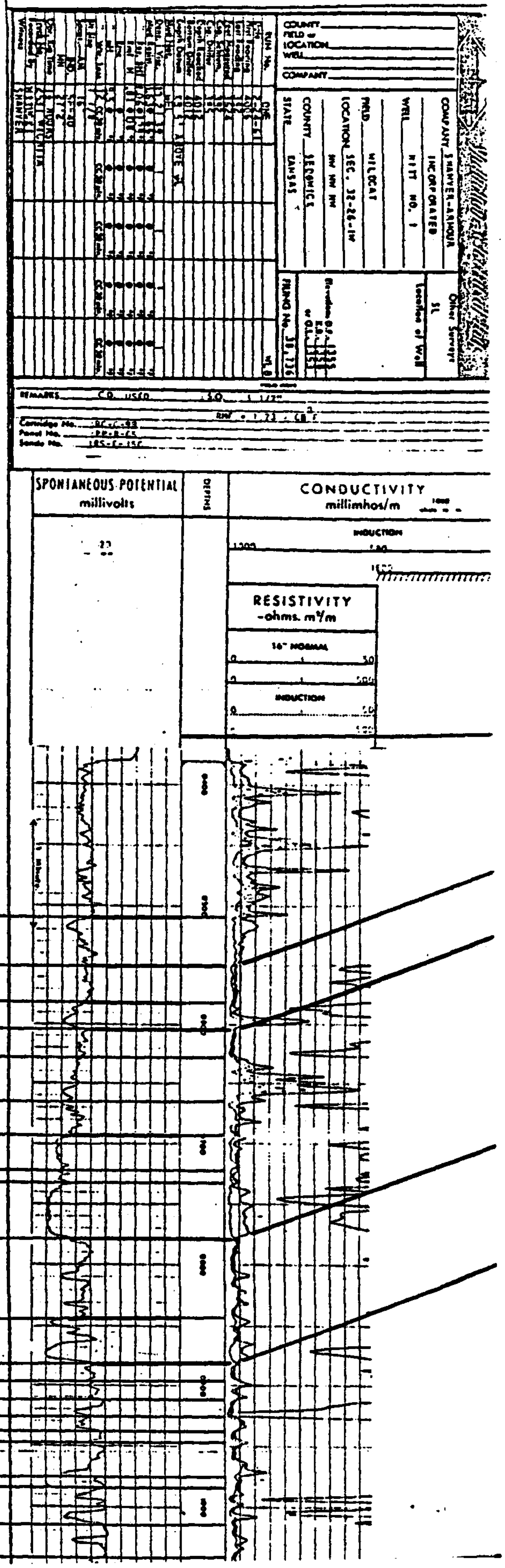
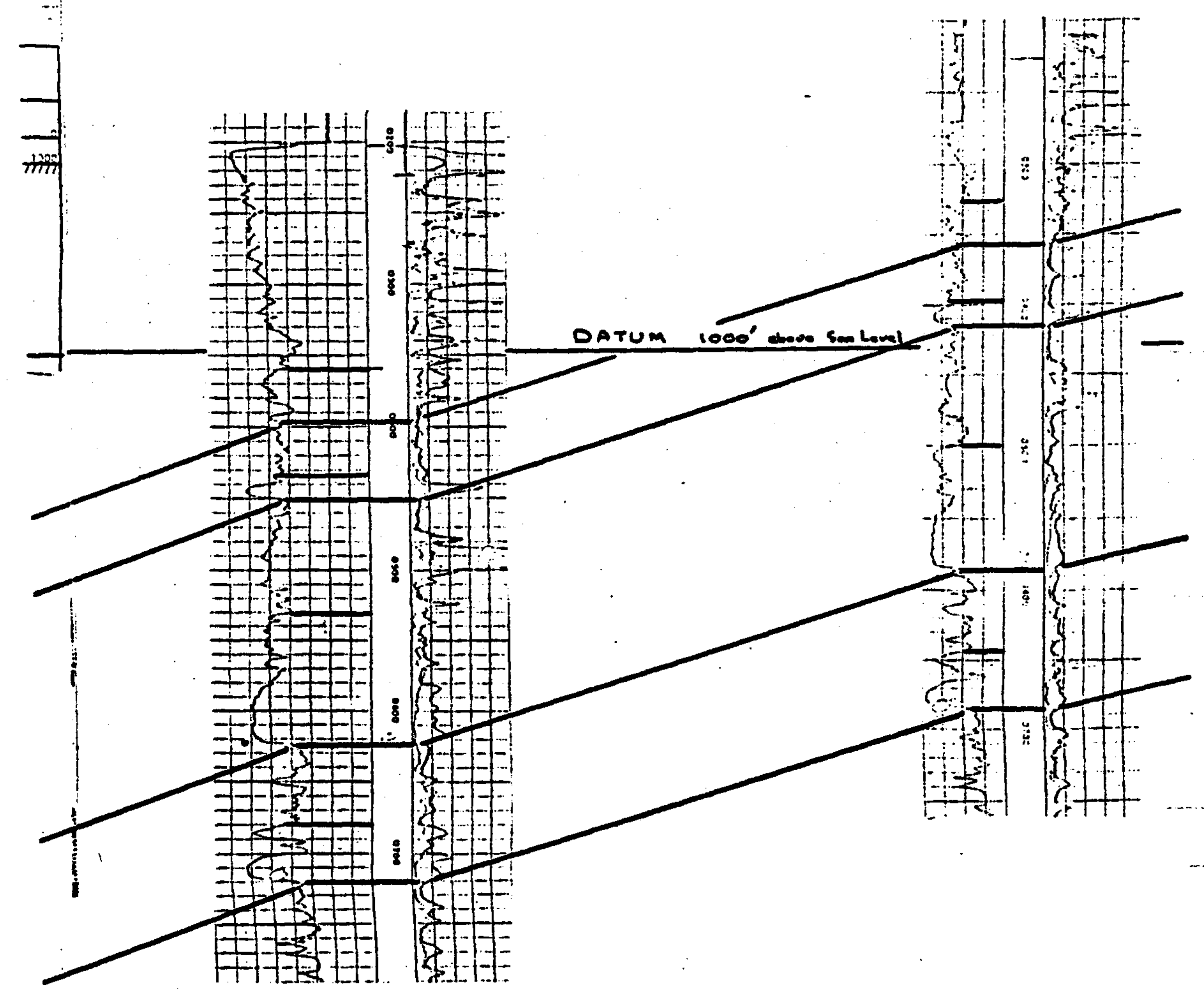
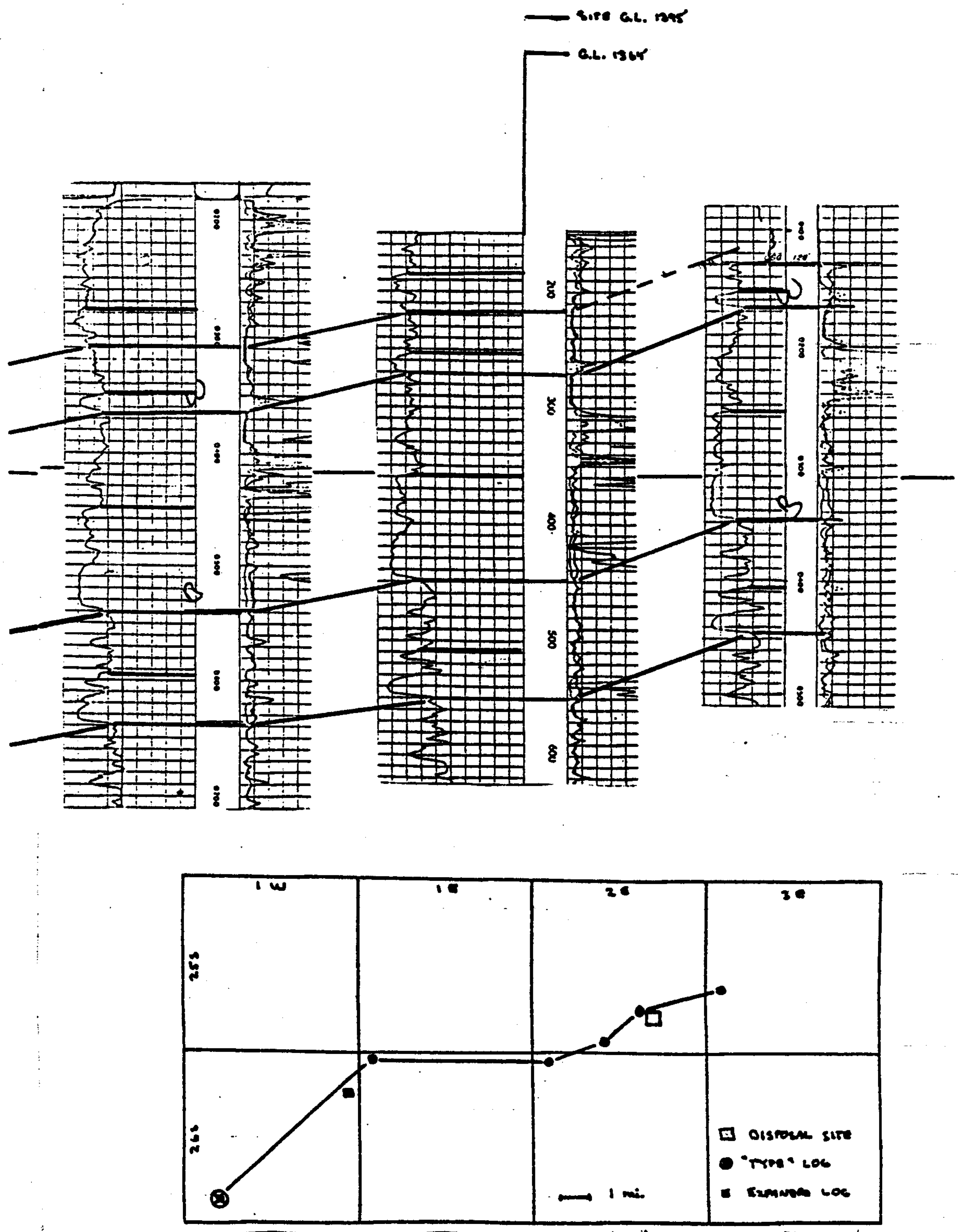


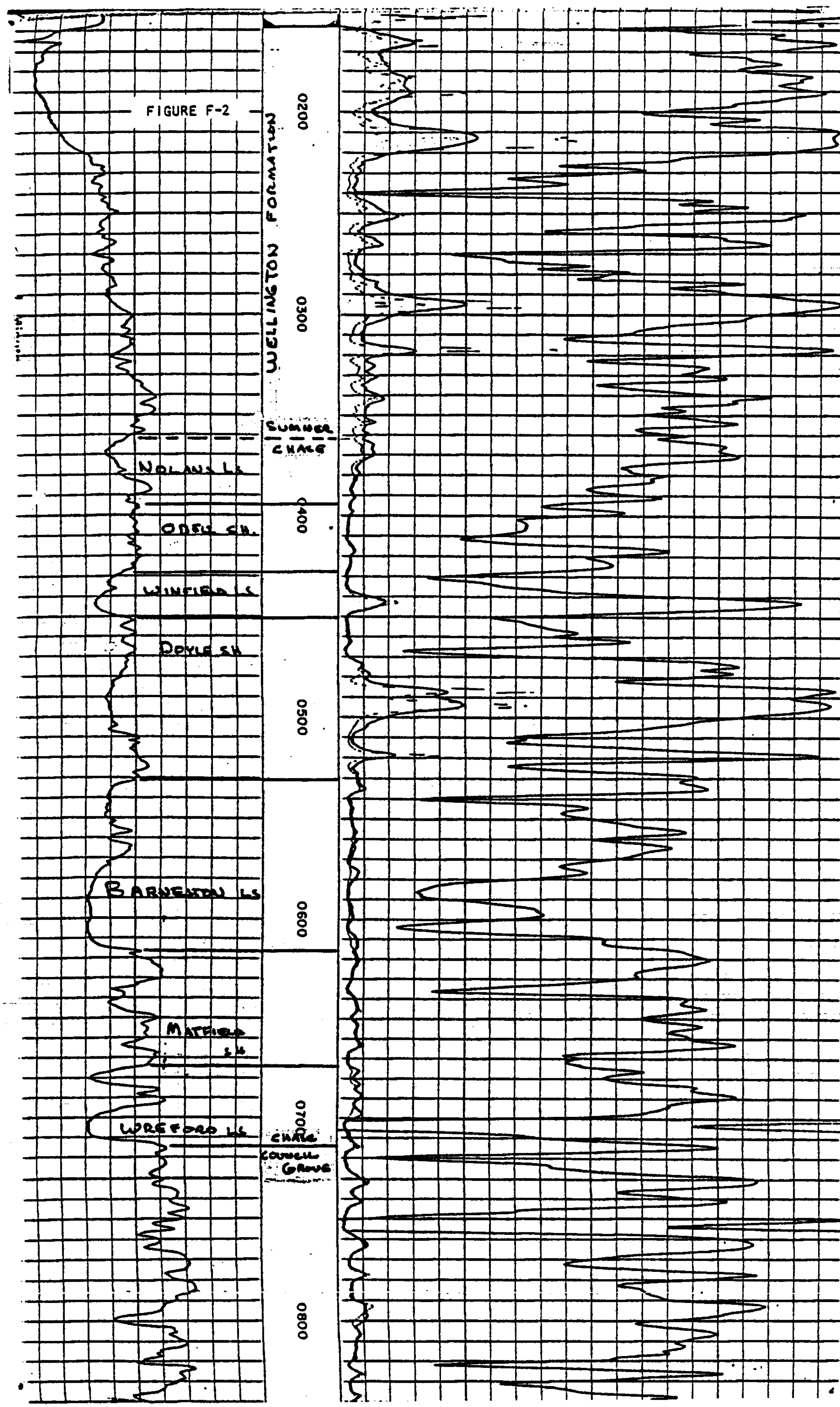
FIGURE F-1b.



G.W. James 1-81

FIGURE F-1c.





WELLINGTON FORMATION
0200
0300
SUMNER
CHASE
NOLANS LS
0400
ODELL SH.
WINFIELD LS
DOYLE SH
0500
BARNESTON LS
0600
MATFIELD SH
0700
WREFORD LS
CHASE
COUNCIL GROVE
0800

FIGURE F-2

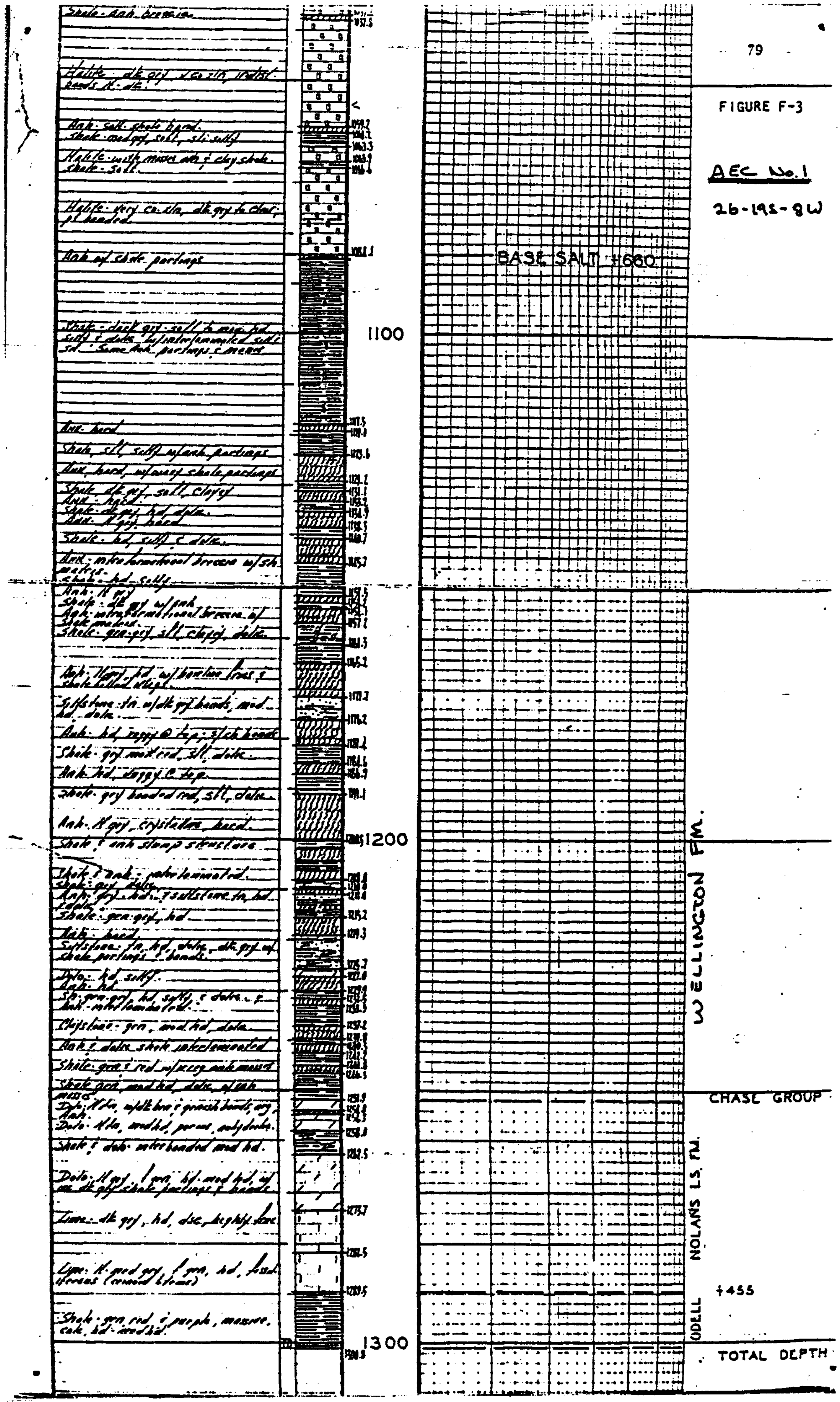


FIGURE F-3

AEC No.1

26-19S-8W

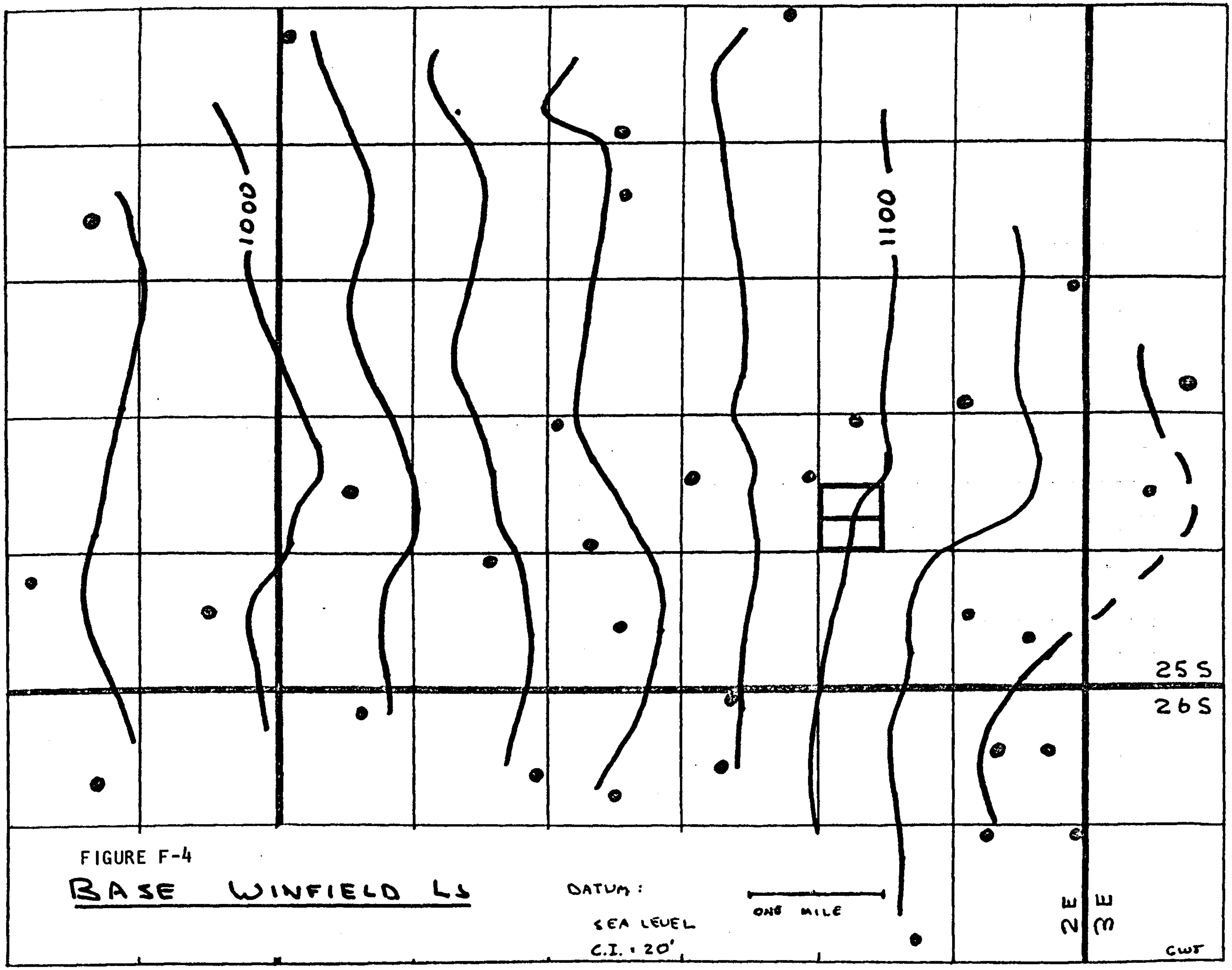


FIGURE F-4
BASE WINFIELD LS

FRANK W. WILSON

KANSAS GEOLOGICAL SURVEY

BEFORE THE SENATE COMMITTEE ON ENERGY AND NATURAL RESOURCES

This is an outline of the chronology and a description of significant events associated with the Kansas Geological Survey's investigation of the proposed expansion of the NIES industrial waste disposal site near Furley, Kansas, and subsequently.

In the late fall of 1980, KDHE was apparently on the verge of issuing a permit to NIES to expand its operations to an 80 acre site adjacent and south of its existing facility. This was based on a favorable review by KDHE staff of a geotechnical investigation and report done by Haliburton Associates of Stillwater, Oklahoma. The principal in that firm is T. Allen Haliburton, Ph.D., a professor of soils mechanics on the faculty of the Civil Engineering Department at Oklahoma State University.

Residents of the area objected to the Haliburton report because they felt it did not accurately reflect their knowledge of the conditions, especially of groundwater and geology on and near the site. They were supported in that contention by Dr. Robert Berg, a long-time professor of geology at Wichita State University. Dr. Berg appealed to Attorney General Stephan for an independent evaluation and suggested it be done by KGS. Attorney General Stephan then threatened to enjoin Secretary Harkens from issuing the permit unless this was done.

Secretary Harkins and several key members of his staff came to the KGS in late December, 1980, and met with Dr. William Hambleton and key members of our staff.

Secretary Harkins requested that we undertake field and laboratory investigations to verify the results of the Haliburton study.

KDHE stated that they did not have funding for this study and asked that we do it as a service to them. I objected because it would be necessary to take professional staff off on-going research and bring the drill crew in from the field where they were doing the annual state-wide water-level inventory. I've had considerable experience with trying to do studies involving core drilling and augering in the winter. Murphy's law and all its corollaries immediately go into effect. Further, I felt that KGS would be put in an untenable position between NIES-KDHE and the people.

Despite my objections, Dr. Hambleton agreed to do the study and put me in charge of lining up a team and putting together a program. Secretary Harkins requested that I prepare a work plan, with deadlines, as a part of a memorandum of agreement. He requested that, because this was a sensitive project, that all contact with the local people or media be referred to him. Again, I objected because we were undertaking the study with public funds. Dr. Hambleton agreed, however, with the stipulation that our data be released after one year from date of conclusion. Later, after studying the Haliburton report and attempting to write a memo of agreement, it became obvious to me that if we used the same field and soils laboratory procedures, we would likely duplicate and verify his results without addressing the objections of the people. Further, although we have standard soils laboratory testing equipment, we did not have the rather expensive equipment to test for permeabilities in the ranges reported by Haliburton.

Instead, I decided to do what we do best and put together a field laboratory and office study of the geology and hydrology of the site. The details of it are in the report which you have in your packet. Essentially, I decided to drill one deep core drill hole for site stratigraphy, auger a number of observation wells around the site, especially near the locations of Haliburton's holes, and to install near each observation well a field permeameter.

The field permeameters were similar to the observation wells, but instead of measuring static water levels, they would be filled with pure water. After initial saturation, the well would be refilled and the falling water levels measured against time.

I also outlined some standard soils sampling and tests and sampling for inorganic chemical analyses of water from site test holes, and offsite springs, and wells on surrounding farmsteads. The staff felt much more comfortable with this plan.

It was January 23, 1981, by the time the agreement was prepared and signed by both agencies, and men, equipment and supplies organized for the field work.

Upon arriving in the field, the core-drill crew and one of our geologist-hydrologists began drilling and carefully logging the strat hole. Our soils scientist and soils geochemist began auger sampling and logging of a hole in the SE corner of the site. I began taking water samples from the springs in creeks around the site and existing wells on the farmstead.

Haliburton had reported there was one well near the farmhouse, and that it was said by the farm occupant to be 55 feet deep and dry. He reportedly drilled a hole 40 feet west of the well to below the elevation of the bottom of the well and reportedly found no water. I measured that well as soon as we got organized, and found water at 42 feet. Another more modern well with a concrete block enclosure was plainly visible about a hundred feet west of the windmill well and it contained water at about 55 feet. I later found another abandoned well with a pump on it in a pasture north of the farmstead. It also contained water.

Springs in streams north and south of the site, especially Prairie Creek, were flowing strongly despite the fact that the area was in a period of drought, with precipitation 10 inches below normal.

As drilling on the strat hole progressed, the geologist logging the hole noted losses of water in the steel portable mud pit and began logging the quantities of make-up water that had to be added. It soon became apparent that the losses far exceeded the volume of the advancing hole and that zones of relatively high permeability were being encountered by the drill. Below the upper weathered clay shale zone the drill cuttings of the shale were brittle rather than plastic and showed stained laminations. Thin layers of soft limestone, gypsum, and anhydrite were frequently encountered and drilling fluid losses increased.

The soils scientists, working at the SE corner of the proposed site, augered up a creamy saturated mud and upon completion of the hole, a standing water level was measured about five feet below that reported by Haliburton in June, 1979. He had stated that water only was found in that hole and that it was an isolated discontinuous zone. I later learned that the District Geologist for KDHE was present for about 15 minutes when the water was found, but that he had not been present when the other holes were drilled.

We then drilled auger holes near most of Haliburton's test holes in the corners of the site and in the pasture in the middle of the site. Except for the northeast corner, we augered water to the surface immediately after encountering limy or gypsum zones either at a depth of about 40 or 60 feet. These were at elevations above the levels of the bottoms of Haliburton's reportedly dry holes.

The permeameters were installed, filled with Wichita city water (incidentally, the core hole was also drilled with city water and samples taken for analysis) then refilled several times before measurements were taken. All holes were cased with 4-inch PVC pipe sealed at ground level with tamped, dry bentonite drilling mud, vented, capped, and sealed to prevent tampering. I measured the drawdown of the permeameters and water levels in the observation wells in rotation every few hours for the first few days and every few days for a period of several weeks. All permeameters were recharged at least four times. Water samples for inorganic chemical analysis were taken from the observation wells several times. Ground-level elevations of all holes were surveyed in by me personally. The soils scientists and hydrologists sampled all of the known springs and measured and sampled all available farm wells within a several miles radius of the site.

Pumping tests were run at the request of KDHE on the core-drill hole and the windmill well. These were not successful because the capacity of the pump, intended for testing in unconfined alluvial aquifers, was too large to attain steady-state flow. However, while looking for a place to drill a drawdown observation well near the watermill well, we discovered Haliburton's hole and drilled about five feet from it. We augered water to the surface from 40 feet. The level coincided with the water level in the windmill well.

Field data collection was completed in early spring. Soils analyses, chemical water analyses, and permeability calculations were completed about a month later. I made final water-level measurements of the observation wells in early May, accompanied and witnessed by the district geologist, KDHE. Pipe was later retrieved from all holes (except CD-1 left for monitoring by KDHE) and they were plugged to the surface with dry drilling mud as approved by KDHE. Compilation of data, analysis and report writing required another month.

We delivered the report to KDHE on June 4, 1981, four days past the original deadline. Our conclusions and recommendations were as follows:

CONCLUSIONS

It seems probable from elevation relationships that the first and second aquifers contribute to the spring flow in Prairie Creek, but we did not attempt to directly confirm this by drilling. The upper aquifer is at a higher elevation than the stream directly north of the site, but where the limestone is dissolved in the highly weathered or oxidized zone near the surface, the water may migrate downslope along the weathered-unweathered interface and discharge as stream-bank or stream-bottom seepage. The second aquifer is at the level of Prairie Creek north of the site and may contribute directly as spring flow.

If there is a connection between the aquifers and the springs in Prairie Creek, there could be a possibility of contamination by any leachate escaping from the proposed burial trenches because the volume of water probably is not sufficient to dilute it.

1) At least two water-bearing zones exist beneath the site at approximate elevations 1350 and 1337 feet.

2) Both are usable aquifers. (Contains quantities of groundwater sufficient to provide domestic and stock water supplies in the local area.)

3) Comparison of the elevations of water levels measured by KGS in 1981 during a period of drought with those reported by site geo-technical consultants in 1976 and 1979 indicate that the water levels of the aquifers may be at least five feet higher, or at elevations 1355 and 1342 feet, during normal times.

4) The elevation of the bottoms of proposed disposal trenches is 1358-60 feet. The water levels in the upper aquifer will likely be less than five feet below the bottom of trenches in times of normal precipitation.

5) Tests suggest that material between the bottom of the proposed trenches and the top of the upper aquifer is more permeable than reported by the geotechnical consultant.

6) On the basis of the above, the site as it is proposed to be operated, does not meet the present criteria of USEPA or KDHE.

7) The site geotechnical consultant either did not find or did not report the presence of the upper aquifer except in HA-4 in the southeast corner of the proposed site. This was the only test hole at which the District Geologist of KDHE was present during the investigation and he observed saturated material being augered to the surface. All other holes, including existing water well 1-A were reported by the consultant to be dry. Test holes were drilled by KGS close to the locations of holes that were reported to have been dry by the geotechnical consultants for the existing site and the proposed site. Water was found immediately or within 24 hours at levels above the bottoms of the reportedly dry holes at the northwest corner, southwest corner, and in the center of the site. KGS investigators can think of no technical explanation for these apparent discrepancies.

The following day, Friday, June 5, I was contacted by KDHE and requested to visit them on Monday at 2 p.m. with some of my people to explain some of the technicalities.

On Monday at about 11 a.m. I was called by Randy Rathbun, a lawyer for the people around the site, inquiring about details of the report. I was amazed to learn from him that Secretary Harkins and Attorney General Stephan had flown to the Wichita airport and held a 10 a.m. news conference to read the executive summary of our report, answer questions, and to announce that the full report would be released within a week.

At 2 p.m., the geophydrologist who had worked with me at the site and I met with Bill Bryson, Mel Gray, Jim Aiken, Howard Duncan, and an EPA representative from Region seven who was an observer.

It was apparent from the start that they did not like our findings and Gray attempted to discredit our permeameter analysis. Pat Cobb did an excellent job of defending and explaining the certainties and uncertainties involved.

At 3 p.m. a hearing was held at the Shawnee County District Court on the suit by NIES, requiring KDHE to issue a permit to expand onto the proposed site. The judge took it under advisement. I learned later our report was not mentioned, although the reason stated by Harkins that KGS should not discuss it was because of the pending litigation.

On Tuesday, June 9, Gary Haden of the Wichita Eagle-Beacon called to tell me that he had learned that on the previous Friday, a day after they had received our report, KDHE had invited Haliburton, the NIES manager, and its lawyer to KDHE headquarters to review our report.

On Wednesday, June 10, Mel Gray called to ask for 20 additional copies of the report and to ask if I objected to their hiring an outside "independent" consultant to review Haliburton's and our report? I asked him where he was going to get the money since they did not have funds to support our study? He said, "from a non-funded account" or something to that effect. I then asked him why he hadn't informed me on Monday that NIES and Haliburton had been invited to review our report? He said he had not been "totally candid." I told him I did not object to their getting another consultant, but if I ever found out what they paid him, I was going to forward an invoice for that amount.

On Thursday, June 11, Hayden called to tell me that he had interviewed Haliburton by telephone about a hazardous waste study in Oklahoma which had been turned down by the Oklahoma Department of Environment because he had not reported the presence of shallow aquifers. Haliburton said, "My opinion was that it was not relevent; I was not paid to look for water, I was paid to look at the soil." I later informed Gray of this and he said a dirty word. Haden reported that Haliburton would be on vacation from June 14 to 29. Our full report would be released to the news media on Monday, June 15.

On Monday, June 15, a full week to the minute, the report was released simultaneously at 10 a.m. in Topeka and Wichita. Within an hour, I was besieged by media reporters asking about the report. I had to tell them that I couldn't talk about it and referred them to Secretary Harkins. Rex Buchanan, our director of information and education, called Haydn and asked if KDHE had issued a press release with the report. He said KDHE was engaging an independent consultant to review the KGS and Haliburton reports and that they would announce who by the end of June. NIES issued a press release shortly after saying it had engaged Woodward-Clyde Consultants of Chicago to do a complete study and evaluation of the proposed site.

Dr. Hambleton was on the east coast attending a meeting. After several attempts, I finally reached him and informed him of the situation, stating that I felt our agreement had been broken and asking for permission to talk with the media. At first he seemed to agree, but later called back to say he had talked to Secretary Harkins and that Harkins requested we not discuss it because of the pending litigation. I again objected quite strenuously.

Over the next week, Aiken, Goetz, and others from KDHE were quoted by the press.

About the middle of July, 1981, Dr. Hambleton and I were asked to meet with KDHE in Topeka to review the report by CH_2M-Hill, the consultant for KDHE.

The conclusions were as follows:

1. None of the work conducted by either Haliburton or KGS can be considered "state of the art" for investigative work for hazardous waste siting studies.

2. For the techniques utilized, permeability numbers determined in the laboratory by Haliburton and in the field by KGS are reasonable. The apparent discrepancy may be related to the fact that each study was measuring different materials. Also, sealing techniques for field measurements by KGS may have an impact on permeability computations.

3. The Haliburton report did not integrate hydrologic aspects. Similarly, the KGS report did not integrate geotechnical aspects. Thus, neither study is complete for siting evaluation.

4. Discrepancies in water-level readings between Haliburton and KGS work may be due to time differences between completion of drilling and recording water level, if any.

We were asked by KDHE whether we wanted to continue to be kept informed? I stated emphatically that as we had a considerable investment and considered our work to be a research project, and that we certainly did.

We heard nothing further until Friday, January 15, 1982, when Mel Gray called to inform me that he was sending a copy of the Woodward-Clyde report for my review. He also asked that Dr. Hambleton and I come to Topeka for a meeting on January 28. He did not say for what reason.

The Woodward-Clyde investigation of the proposed site was very similar to ours - using field permeameters and observation wells plus extensive laboratory tests and analyses. Their investigation took longer, was more extensive in that they did more core drilling, and undoubtedly was much more expensive. Their findings, however, were very similar to ours in that they came to the same conclusion as to the two water-bearing zones and that the field permeabilities were greater than the laboratory permeabilities. Their groundwater model was essentially the same as ours in that they concluded that local precipitation fed the water-bearing zones through vertical fractures and then moved laterally through broken zones or solution cavities associated with thin limestones and gypsum beds. Dr. Hambleton and I concluded that our investigation was state-of-the-art.

On Monday, January 18, a reporter from the Wichita Eagle-Beacon, called to tell me that Governor Carlin and Secretary Harkins had scheduled a 4 p.m. airport news conference. He speculated that something had been found at NIES and they were shutting it down. This was confirmed by the 6 p.m. television news.

Mel Gray called the next morning to tell me that KDHE geologists had drilled a line of auger holes along the north line of the existing site and late Thursday, January 14, and had discovered organics moving offsite near the evaporation ponds. The KDHE lab worked over the week-end analyzing the samples and confirming strong concentrations of organics. At 11 a.m., Monday, they contacted NIES and closed operation of the site.