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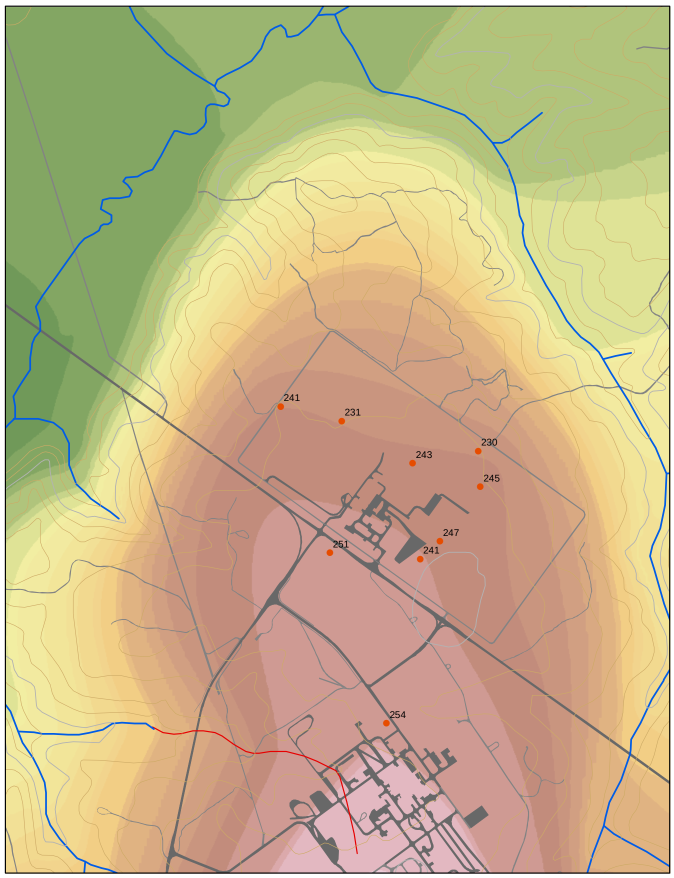
Rev. 0

Key Words:
Water table
Precipitation
Saltstone Disposal Facility

Retention:
Permanent

Saltstone Disposal Facility: Determination of the probable maximum water table elevation



Prepared by:
Robert A. Hiergesell

April, 2005

Westinghouse Savannah River Company LLC
Savannah River Site
Aiken, SC 29808

SRNL
SAVANNAH RIVER NATIONAL LABORATORY

Prepared for the U.S. Department of Energy under Contract No. DE-AC09-96SR1850

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LIST OF ACRONYMS and ABBREVIATIONS

ERDMS	Environmental Restoration Data Management System
Ft	feet
GIS	Geographic Information System
msl	mean sea level
PA	Performance Assessment
SDF	Saltstone Disposal Facility
UTM	Universal Transverse Mercator
WT	Water Table

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EXECUTIVE SUMMARY

A coverage depicting the configuration of the probable maximum water table elevation in the vicinity of the Saltstone Disposal Facility (SDF) was developed to support the Saltstone program. This coverage is needed to support the construction of saltstone vaults to assure that they remain above the maximum elevation of the water table during the Performance Assessment (PA) period of compliance.

A previous investigation to calculate the historical high water table beneath the SDF (Cook, 1983) was built upon to incorporate new data that has since become available to refine that estimate and develop a coverage that could be extended to the perennial streams adjacent to the SDF. This investigation incorporated the method used in the Cook, 1983 report to develop an estimate of the probable maximum water table for a group of wells that either existed at one time at or near the SDF or which currently exist. Estimates of the probable maximum water table at these wells were used to construct 2D contour lines depicting this surface beneath the SDF and extend them to the nearby hydrologic boundaries at the perennial streams adjacent to the SDF.

Although certain measures were implemented to assure that the contour lines depict a surface above which the water table will not rise, the exact elevation of this surface cannot be known with complete certainty. It is therefore recommended that the construction of saltstone vaults incorporate a vertical buffer of at least 5-feet between the base of the vaults and the depicted probable maximum water table elevation. This should provide assurance that the water table under the wet extreme climatic condition will never rise to intercept the base of a vault.

INTRODUCTION

The purpose of this investigation is to develop a coverage depicting the configuration of the probable maximum elevation of the water table in the vicinity of the Saltstone Disposal Facility (SDF). This coverage is based upon the available hydrologic data, including precipitation data, water level measurements from wells at or near the SDF and the integration of knowledge of hydrogeologic conditions in the vicinity of the SDF. The scope of the investigation includes evaluation of an earlier study (Cook, 1983) in which the estimated historical high water table elevation was calculated for the location of several wells at the SDF and updating that investigation with new data, obtained after 1983. This investigation employed the method formulated in Cook, 1983, incorporated additional hydrologic data accrued since 1983, and developed a map depicting the configuration of the probable high water table in the vicinity of the SDF. A map illustrating the location of the SDF is presented in Figure 1.

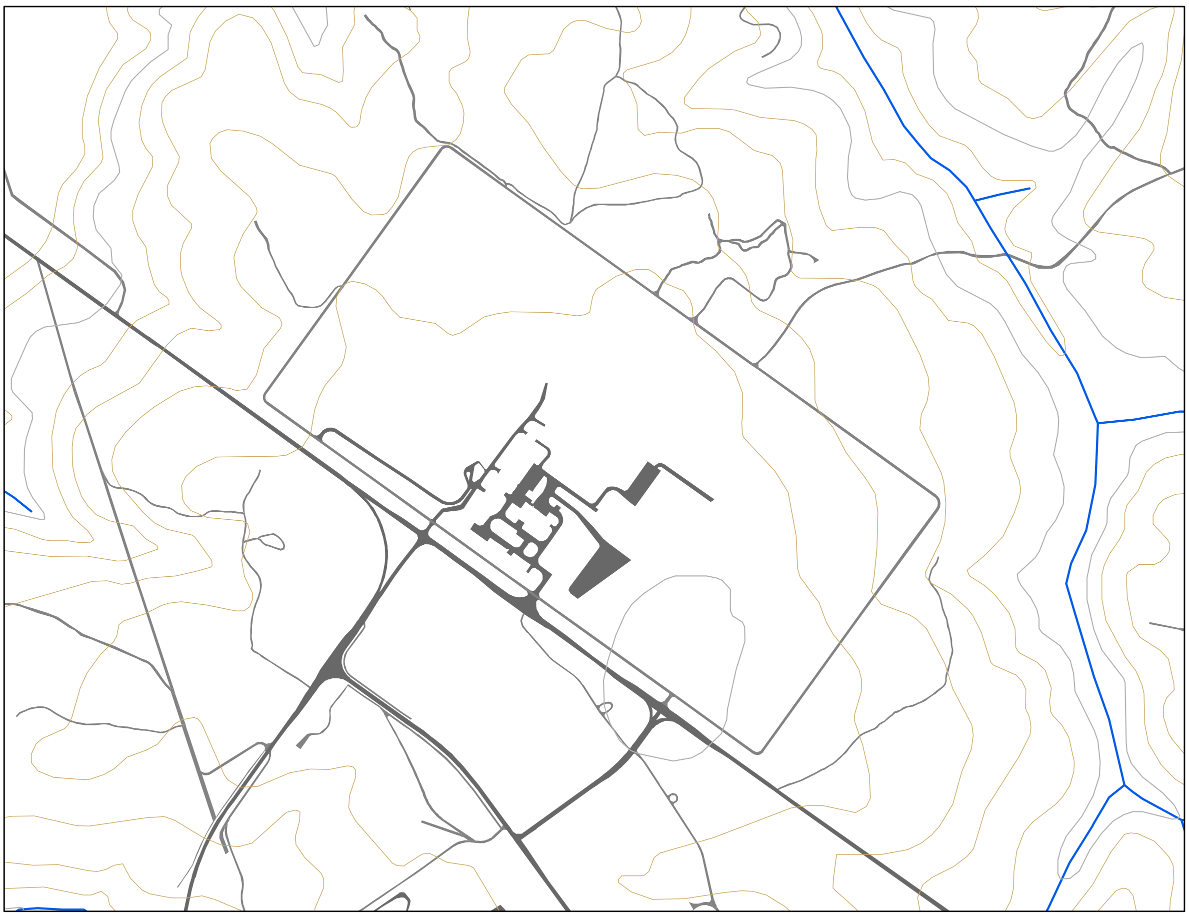

Figure 1. Location of the Saltstone Disposal Facility

It is expected that the probable maximum water table elevation will be used in establishing the locations for proposed saltstone vaults within the SDF. The bottom of vaults will be constructed so that they are a minimum of five (5) feet above the probable maximum water table.

Hydrology concepts

The water table is defined as the surface on which the fluid pressure in the pores of a porous medium is exactly atmospheric. The position of this surface is indicated by the level at which water stands in a shallow well, screened along its entire length, and penetrating the surficial deposits just deeply enough to encounter standing water in the bottom (Freeze and Cherry, 1979). There is also a zone immediately above this surface in which the pores are completely filled with water but where the pressure is slightly less than atmospheric. This zone is referred to as the capillary fringe and is estimated to extend approximately 1.5 feet above the water table in fine sand, a material similar to the subsurface sediments beneath the SDF (Lohman, 1979). There is also the potential for the existence of perched water to occur beneath the SDF. This condition can occur within the vadose (unsaturated) zone as infiltrating water builds up over a low-permeability material to form isolated lenses of saturated material (Hiergesell and Jones, 2003). This condition is discontinuous in space and time and is therefore not considered in this investigation.

The position of the water table fluctuates throughout the year in response to separate and distinct precipitation events. The extreme high and low water level elevations recorded in SRS wells occur in response to protracted wet or dry periods. In SRS wells monitored since the early 1980's the average range in the position of the water table is 12.5 feet (Hiergesell and Jones, 2003). This range is larger in wells situated in the upland areas away from flowing streams and smaller in wells situated in the vicinity of perennial streams.

The elevation of the probable maximum water table elevation in the vicinity of the SDF is related to the shallow hydrogeologic conditions. These conditions include the quantity and timing of precipitation events, the degree of incision of the valleys that flank the SDF facility, the proximity of the SDF to nearby groundwater discharge zones situated in those valleys and the porosity and permeability of the shallow hydrogeologic units through which the groundwater migrates.

The general configuration of the long-term average regional water table elevation in the vicinity of the SDF was established in a report titled *An Updated Regional Water Table of the Savannah River Site and Related Coverages*, Hiergesell and Jones, 2003. The general configuration of the probable maximum water table elevation near the SDF is likely very similar to this surface except at a slightly higher elevation and generally more pronounced in the upland areas between streams. Hence, the long-term average regional water table elevation surface near SDF was utilized to guide the development of contours that reflect the probable maximum water table elevation. The configuration of the long-term average regional water table elevation is shown in Figure 2.

To define the probable maximum water table elevation near the SDF the available, relevant, data was reviewed. This data includes long term precipitation records and water level measurements obtained from wells located near the SDF. Precipitation records utilized include the continuous record of total annual precipitation recorded at the Aiken weather station from 1854 to 1980, which was reported in Cook, 1983, and also from a SRS weather station from 1952 to 2002. This long-term record of precipitation in the Aiken-SRS region allowed the identification of the most likely time that the maximum water table elevation occurred beneath the SDF since 1854.

Also, water level measurements from wells were reviewed. Since 1952 there are a handful of wells that existed at one time near the SDF or which currently exist. These wells, along with their relevant construction information are listed below in Table 1 and their locations are shown in Figure 3.

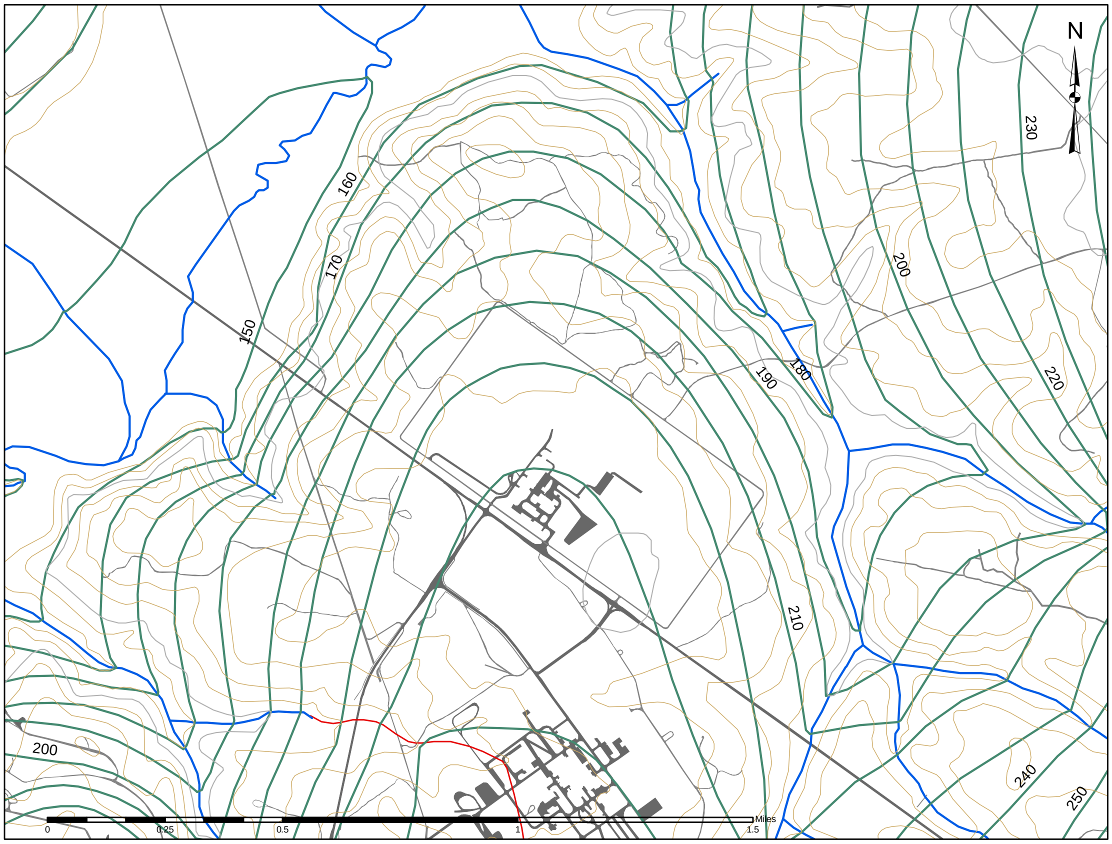

Figure 2 Configuration of the long-term average water table near the SDF

Table 1. Well construction information for previous or current wells located at the SDF

Well	UTM-N (meters)	UTM-E (meters)	Elev. Top Screen (ft-msl)	Elev. Bottom Screen (ft-msl)	Elev. of Land Surf. (ft-msl)	Reference Elev. (ft)	Installation Date
SBG 2	440353	3684166	235.9	205.9	287.9	290.1	2/23/85
SDS 1	440474	3684755	--	--	294.4	295.1	11/15/79
SDS 5	440545	3684820	238.2	218.2	288.2	289.8	4/24/81
SDS 6	440447	3685099	236.9	216.9	286.9	290.0	4/11/81
SDS 7D	440682	3685143	225.6	205.6	275.6	277.2	4/11/81
SDS 12C	440192	3685251	226.1	206.1	276.1	279.1	4/1/81
YSC 2D	439973	3685303	218.0	197.9	282.0	284.3	6/30/89
ZBG 1	440150	3684778	240.1	220.0	288.9	291.4	4/17/87
ZBG 2	440690	3685014	230.9	210.9	275.8	278.1	4/23/87
ZW 10	440217	3683556	252.2	242.2	297.6	300.4	1/25/52

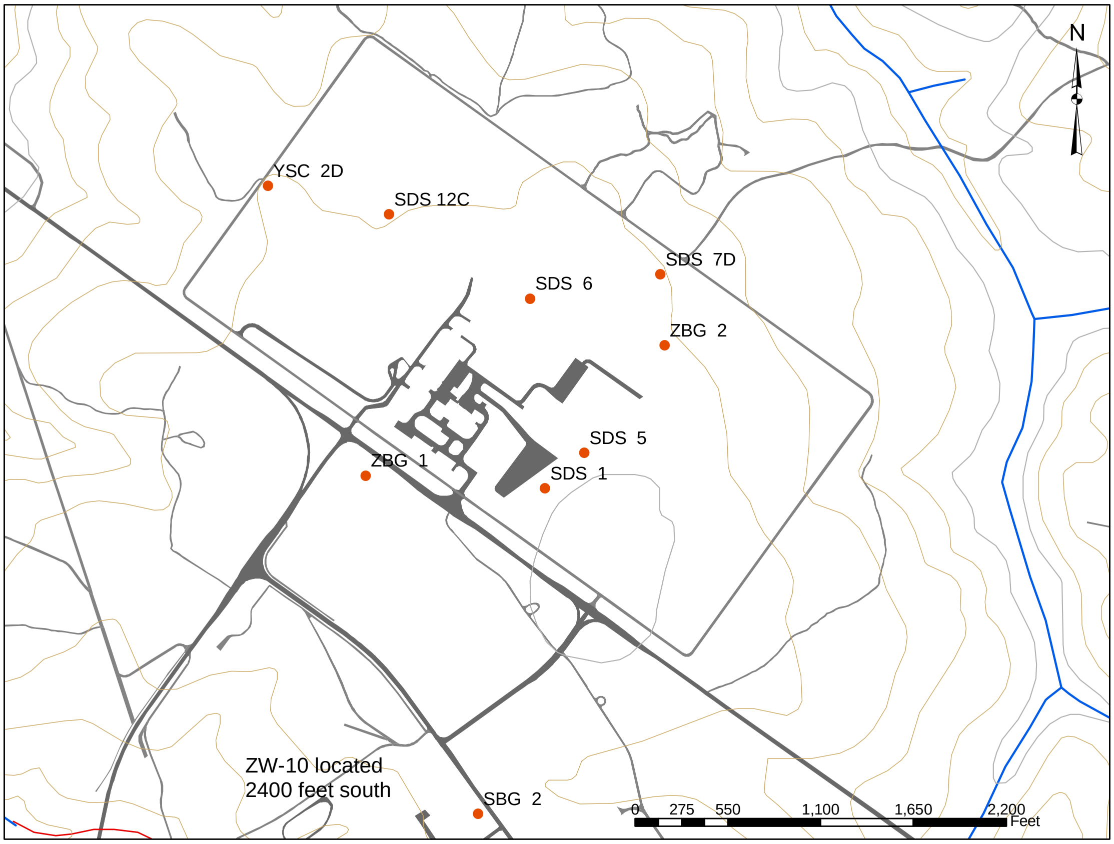

Figure 3. Location of wells used to project probable high water table elevations

Approach

The approach to determining the probable maximum water table elevation beneath the SDF was the same as that employed in the previous investigation that evaluated the probable high water table elevation for certain wells near the SDF (Cook, 1983). That approach involved an initial evaluation of the long-term precipitation records to determine at what point the highest elevation of the water table probably occurred. This is likely to have occurred at that point in time in which the highest amount of precipitation occurred. It is extremely fortuitous that the year in which the maximum recorded annual precipitation during the past 150 years, 1964, is within the period for which water level measurements were obtained from a particular well located near the SDF. Not surprisingly, the water measurements from this well, ZW-10, indicate that the highest elevation of the water table was measured in early 1965, a short time following the occurrence of the highest annual precipitation on record. ZW-10 still exists today and measurements obtained in this well are the key in formulating projections of the probable maximum water table elevation in other wells installed at later dates at or near the SDF.

The specific method used in Cook, 1983 utilized the difference between the highest recorded water level in ZW-10 (early 1965) and the mean water table elevation calculated from ZW-10 measurements in a later period when measurements from other wells were also available. Then, by comparing the ZW-10 water level variability and the variability of water levels in the other wells, an estimation of what the highest probable water level in the other wells was estimated. This comparison was performed by determining the difference between the highest water level measurement and the mean water level for each well during the period of overlapping records. The projection of what the high water table elevation in early 1965 was likely to have been for each of the new wells was determined by multiplying the factor, described above, by the difference in ZW-10 maximum water level elevation and the mean elevation calculated for the later period. The resulting number was added to the mean water level elevation of the new well to estimate the probable maximum water level for that well.

The key hydrologic concept in this approach is that all water table wells located in the vicinity of one another respond in a highly similarly fashion to precipitation events. Some wells may respond slightly sooner than other wells, depending on the thickness of the unsaturated zone at particular locations, and with a slightly different magnitude of response, but responses in different water table wells are basically in unison and of similar magnitude. This similarity is also true when considered over longer periods of time corresponding to particularly wet or dry climatic cycles.

The primary difference between this investigation and the earlier one documented in Cook, 1983 is that significant new data became available after 1983 in the form of water level measurements obtained in new wells at the SDF and additional records of annual rainfall. A summary of this data along with calculations of the probable high water table elevations at the locations of the newer wells are presented in the Analysis section. Another difference between this investigation and that of Cook, 1983 is that the probable high water table configuration is expressed for the entire SDF as contour lines that represent this surface. These contour lines are extended beyond the SDF facility to the nearby streams, where the water table elevation is the same as the elevation of the stream. The calculated maximum water table elevations for each well were used as a guide in development of the contour lines as were the general principles of groundwater hydrology.

ANALYSIS

The data available for projecting the configuration of the probable maximum water table elevation in the vicinity of the SDF include both measurements of precipitation and water level measurements in wells. These datasets are described below.

Precipitation data

Precipitation data has been acquired at two different stations, one in the city of Aiken, located approximately 18.4 mi. north of the SDF, and the other at the main weather station of the SRS, located in A-Area approximately 6.3 mi. northwest of the SDF. A chart showing the annual precipitation amounts at the Aiken weather station from 1854 to 1980 was reconstructed from the Cook, 1983 report and is shown in Figure 4. The data indicates that the highest annual precipitation amount was encountered in 1964, when 71.36 inches of precipitation was measured. Other years of elevated annual precipitation were 1888 (68 in.), 1929 (68 in.), 1948 (68.5 in,) and 1971 (70 in.). Precipitation amounts from the SRS weather station, from 1952 to 2002 are also shown in Figure 4.

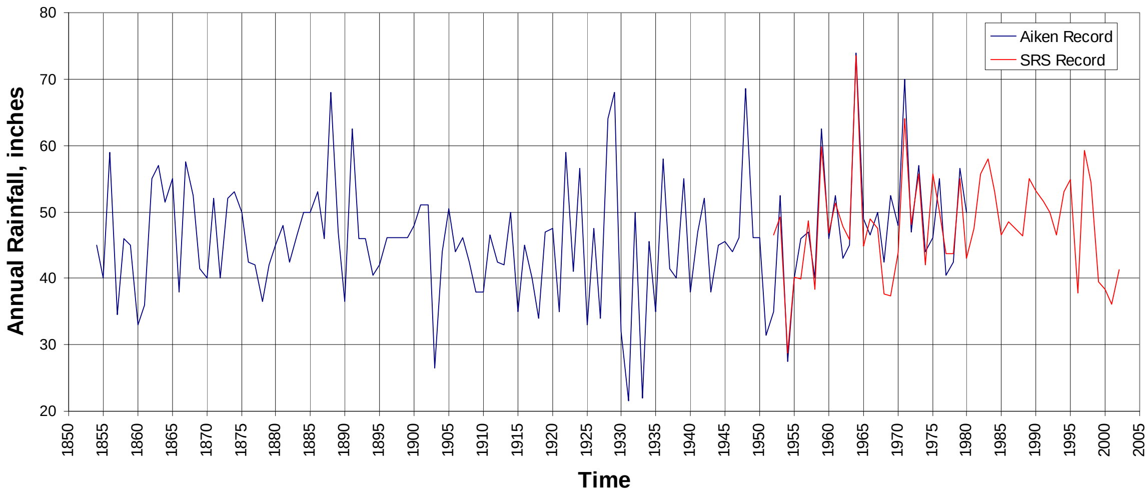

Figure 4 Annual precipitation amounts from Aiken and SRS, 1854-2002.

The precipitation record for the SRS weather station from 1952 to 1980 is illustrated in Figure 5 along with measurements obtained from the Aiken weather station over the same period. The correlation of these overlapping data sets is calculated to be 0.85, which confirms the striking similarity of the graphs. This high degree of correlation suggests that the Aiken precipitation data can be used to determine when the maximum water table elevation across the SDF most likely occurred.

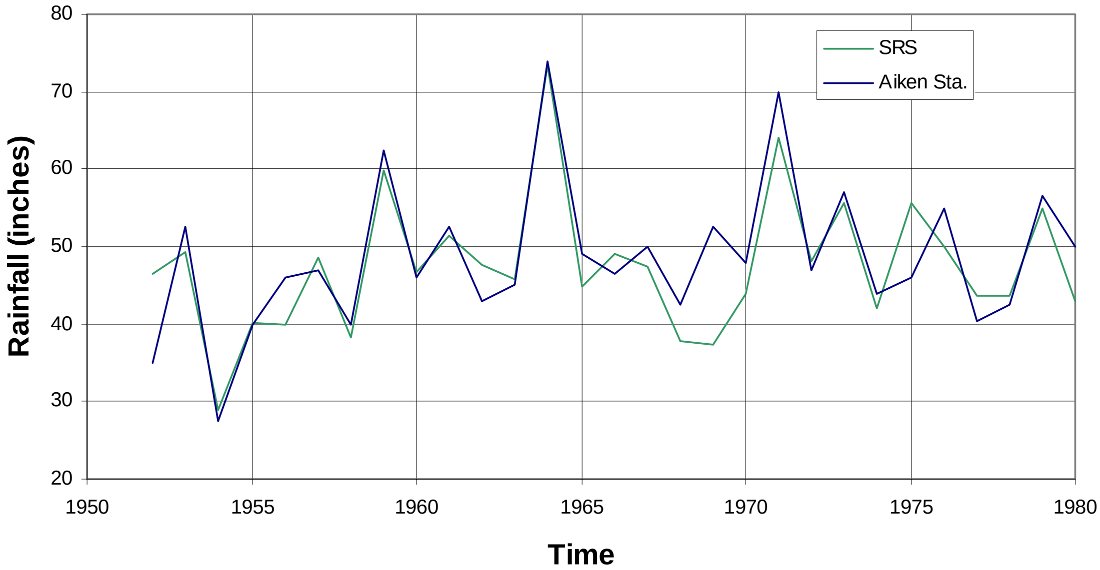

Figure 5 Annual precipitation amounts for the Aiken and SRS weather stations, 1952-1980.

Well measurement data

Water level measurement data at or near the SDF is available from the 10 wells listed in Table 1. These wells, however, were installed at different times and records of measurements from the wells are for different periods of time. Water level measurements for these wells obtained prior to 1983 are documented in Cook, 1983 while measurements after 1983 were obtained from the ERDMS database. The period of record for each of the 10 wells is listed in Table 2.

Table 2 Periods of available water level measurements for wells near the SDF

Well	From	To	Source
SBG 2	3/86	10/99	ERDMS
SDS 1	1/80	5/83	Cook, 1983
SDS 5	1/82	12/82	Cook, 1983
SDS 6	1/82	12/82	Cook, 1983
SDS 7D	1/82	12/82	Cook, 1983
SDS 12C	1/82	12/82	Cook, 1983
YSC 2D	6/90	10/99	ERDMS
ZBG 1	6/87	8/03	ERDMS
ZBG 2	6/87	8/03	ERDMS
ZW 10	1952	1982	Cook, 1983
ZW 10	6/86	3/95	ERDMS

The most important record of well water level measurements is from ZW-10, located approximately 0.93 mi. south of the center of the SDF. Water levels have been monitored relatively continuously in this well from 1952 through 1995. The hydrograph, illustrating ZW-10 water level elevations from 1952 through 1995, is shown in Figure 6 along with precipitation records for the same period. Note the general correspondence in rises and declines of water levels to higher and lower amounts of total annual precipitation.

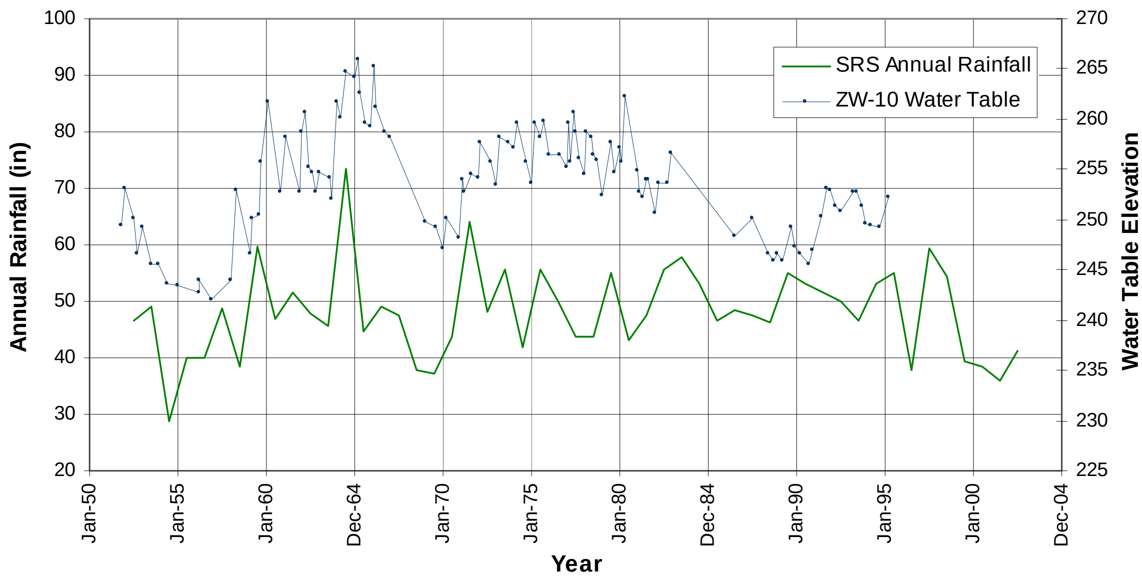

Figure 6 Correspondence of ZW-10 water levels and annual precipitation at SRS.

Hydrographs for the newer wells, SBG-2, YSC-2D, ZBG-1, ZBG-2 and ZW-10 are shown in Figure 7 for the time period from late 1990 to early 1995 when water level records for these wells overlapped. While the elevation of the water level within each of these wells is location dependent, it is noteworthy that all of the wells respond in unison to precipitation events, albeit with a slightly different magnitude of response.

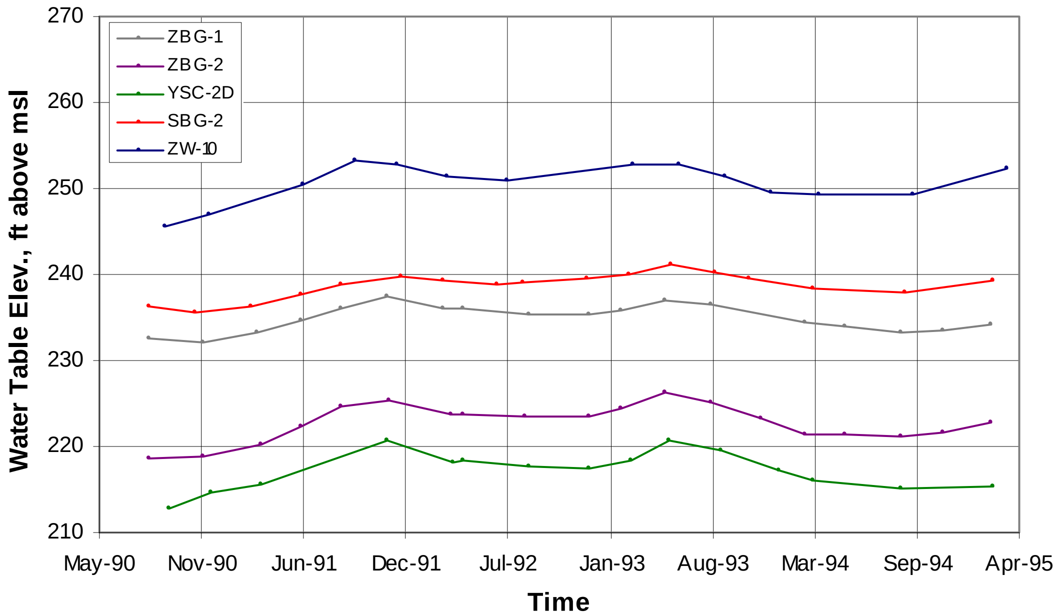

Figure 7 Hydrographs for SBG-2, YSC-2D, ZBG-1, ZBG-2 and ZW-10

To enable the analysis of the available measurements from wells located at or near the SDF the mean and maximum water table elevations were calculated for the periods of overlapping records between wells. These numbers were derived from calculations reported in Cook, 1983, except for the 1990-

1995 period of overlapping measurements for the newest wells near the SDF. These elevations are presented for the indicated time-periods in Table 3.

Table 3. Mean and maximum water table elevations for periods of overlapping records

	1952-1982		1980-1982		1982		1990-1995	
Well	Mean	Max	Mean	Max	Mean	Max	Mean	Max
SBG 2	--	--	--	--	--	--	238.7	241.1
SDS 1	--	--	231.7	236.9	228	229.1	--	--
SDS 5	--	--	--	--	236.1	237	--	--
SDS 6	--	--	--	--	230.5	231.5	--	--
SDS 7D	--	--	--	--	216.7	217.8	--	--
SDS 12C	--	--	--	--	221.8	222.5	--	--
YSC 2D	--	--	--	--	--	--	216.9	220.8
ZBG 1	--	--	--	--	--	--	234.9	237.4
ZBG 2	--	--	--	--	--	--	222.7	226.3
ZW 10	253.7	265.9	255.2	262	--	--	250.6	253.2

Method

The availability of long-term precipitation records that indicate the maximum recorded annual precipitation occurred in 1964. The maximum water table across the SDF is likely to have occurred in response to this period of elevated rainfall. While relatively high amounts (60+ inches) of precipitation also occurred in 1888, 1928, 1929, 1948, 1959 and 1971, the highest recorded annual precipitation was received in 1964. The availability of a relatively continuous record of water level measurements in a well located near the SDF, ZW-10, confirms that the highest recorded water levels occurred in early 1965, following this period of record rainfall. Based on these facts, the problem becomes one of estimating the water table across the SDF in early 1965.

The results documented in Cook, 1983 provided estimates of the historical maximum water table for the following wells, ZW-10, SDS-1, -5, -6, -7D, and -12C. The method described Cook, 1983 investigation utilized the mean and maximum water levels from measurements obtained in ZW-10 from 1952-1982 to compare with the mean and maximum water levels observed in ZW-10 during the period from 1980-1982. Water level measurements in another well located closer to the SDF, SDS-1, were also obtained over the 1980-1982 time period and the mean and maximum water levels were calculated such that comparisons could be made with ZW-10 measurements. This data was used to estimate what the maximum water table elevation in SDS-1 was likely to have been in early 1965.

This method was re-evaluated and the same method was applied to newer data from wells installed after 1983. The newer wells include SBG-2, YSC-2D, ZBG-1 and ZBG-2, all of which had water levels periodically obtained from 1990 through 1995. Water level measurements were also obtained from ZW-10 during this period and thus calculations could be made to estimate what the early 1965 water level in those wells might have been. Information required for the calculation is presented in Table 4.

The method developed in Cook, 1983 for estimating what the historical high water level in wells near the SDF requires that measurements be available from a reference well (e.g. ZW-10) during the period when the historical maximum water table elevation occurred (period from 1952-1982) and a well (e.g. Well A) installed at some later point in time. The logic of that method requires that a series of measurements from both wells be available over some later period of time (e.g. Period 1).

Table 4 Well water level information for high water table calculation

	90-95 Mean WL elev. (ft. above msl)	90-95 Peak WL elev. (ft. above msl)	90-95 Delta (peak-mean) (ft)	ZW-10 difference in means (52-82 minus 90-95) (ft)
ZW-10	250.6	253.2	2.6	3.1
SBG-2	238.7	241.1	2.4	--
YSC-2D	216.9	220.8	3.9	--
ZBG-1	234.9	237.4	2.5	--
ZBG-2	222.7	226.3	3.5	--

This logic is explicitly expressed in the following:

> Well A historic high water table elevation = Period 1 well A Average water table elevation + {[(1965 ZW-10 historic high water table elevation – 1952 to 1982 ZW-10 Average water table elevation) – (Period 1 ZW-10 Average water table elevation – 1952 to 1982 ZW-10 Average water table elevation)] × [(Period 1 well A peak water table elevation – Period 1 well A average water table elevation) / (Period 1 ZW-10 peak water table elevation – Period 1 ZW-10 average water table elevation)]}

This algorithm expressed above was used to evaluate data from the more recently installed wells, SBG-2, YSC-2D, ZBG-1 and ZBG-2. In these wells, located at or adjacent to the SDF, water level measurements were obtained over the period from 1990 to 1995, as were measurements from the reference well, ZW-10. The algorithm listed above, which expresses the Cook, 1983 method, was employed to calculate the probable maximum water table elevation in the more recently installed wells. The calculations for each of these wells is as described above with the addition of 1.5 ft to account for the thickness of the capillary fringe. It is important to account for the capillary fringe because pores within this zone are also completely filled with water although the pressure is less than atmospheric. The capillary fringe extends above the fluid level measured in water table wells. The following are the calculations for each well. The values used were taken from Tables 3 and 4.

SGB-2

(238.7) + [(265.9 – 253.7) – (250.6 – 253.7)] * [(2.4)/(2.6)] + (1.5) = 254.3 ft. above msl.

YSC-2D

(216.9) + [(265.9 – 253.7) – (250.6 – 253.7)] * [(3.9)/(2.6)] + (1.5) = 241.4 ft. above msl.

ZBG-1

(234.9) + [(265.9 – 253.7) – (250.6 – 253.7)] * [(2.5)/(2.6)] + (1.5) = 251.1 ft. above msl

ZBG-2

(222.7) + [(265.9 – 253.7) – (250.6 – 253.7)] * [(3.5)/(2.6)] + (1.5) = 244.8 ft. above msl

Using the values of the probable maximum water table elevation calculated for each of the 10 wells that exist or once existed near the SDF, lines of equal water table elevation, or contour lines, were constructed using the Geographic Information System (GIS) software program ArcMap. First the calculated values were posted at their geographic coordinates and contour lines were then developed using an interval of 2 feet. The contour lines were extended across the SDF and out to the adjacent flowing streams. Along the flowing, or perennial, streams the water table elevation is coincident with the land surface and the contours were therefore forced to honor the land surface elevations at those localities. Contour lines were constructed to honor the estimates of the probable maximum water table elevation at the locations of the most recently installed wells and at ZW-10, however conservative (higher) deviations were permitted near the location of SDS-1, SDS-7D and SDS-12C. These deviations are approximately 6 feet at SDS-1 and 10 feet near SDS-7D and SDS-12C. These deviations are justified considering the uncertainty introduced by the relatively few measurements available from these wells and the need to provide assurance that the maximum water table reported is not likely to be exceeded during the Performance Assessment (PA) compliance period. The slight deviation allowed the depiction of a “smoother” water table surface, as would be expected on a naturally occurring water table.

Once the probable maximum water table contour lines were configured, the ArcMap Spatial Analyst was utilized to interpolate the line features into a regular grid network, or raster format. Once in raster format, color shading was utilized to represent the surface for graphical display.

RESULTS

The results of this investigation include the reporting of calculations made in Cook, 1983 to determine the probable maximum water table elevations at wells ZW-10, SDS-1, -5, -6, -7D and 12C, along with the calculations made in this investigation for wells SBG-2, YSC-2D, ZBG-1 and ZBG-2. The probable maximum water table elevation calculated for each of these wells is reported in Table 5. These results were modified by increasing the elevation of the calculated water table by 1.5-ft to account for the likely presence of a capillary fringe immediately above the water table. This elevation is also reported in Table 5 for each of the wells.

Table 5 Projected probable maximum water table elevations for early 1965

Well	Probable maximum WT elevation, early 1965	Prob. Max. WT elev. + capillary fringe, early 1965
ZW-10	265.9[a]	267.4
SDS-1	239.9[a]	241.4
SDS-5	245.8[a]	247.3
SDS-6	241.3[a]	242.8
SDS-7D	228.6[a]	230.1
SDS-12C	229.4[a]	230.9
SBG-2	252.8	254.3
YSC-2D	239.9	241.4
ZBG-1	249.6	251.1
ZBG-2	243.3	244.8

Note: a – obtained from Cook, 1983

The contour lines of the surface of the probable maximum water table, including the overlying capillary fringe are depicted for the SDF in Figure 8. These contour lines were constructed using a 2-foot contour interval across the SDF such that detailed estimates of this surface might be interpolated at the corners of excavations of planned saltstone vaults. Also shown are the locations of wells where estimates of the probable maximum water table were available to guide contour configuration. The elevations of this surface range from 250 ft-msl to approximately 224 ft-msl at the eastern corner of the SDF. The surface generally decreases in elevation to the west, north and east, in the direction of perennial streams. The surface increases in elevation to the south, in the direction of the groundwater divide that separates Upper Three Runs Creek and Four Mile Branch. It should be pointed out that on this map, the contour interval is 2-ft between the elevations of 220 ft-msl and 250 ft-msl but is 10-ft outside of this range.

The contours of the probable maximum water table were extended to the nearest hydrologic boundaries at the perennial streams adjacent to the SDF. At these boundaries the water table elevation is always coincident with the land surface elevation and water table contours must coincide with land surface elevation contours. The extended coverage is illustrated in Figure 9. In this illustration color flooding of the elevation of this surface has been included along with the contour lines themselves. The outline of the SDF and the trace of perennial streams are also shown in Figure 9.

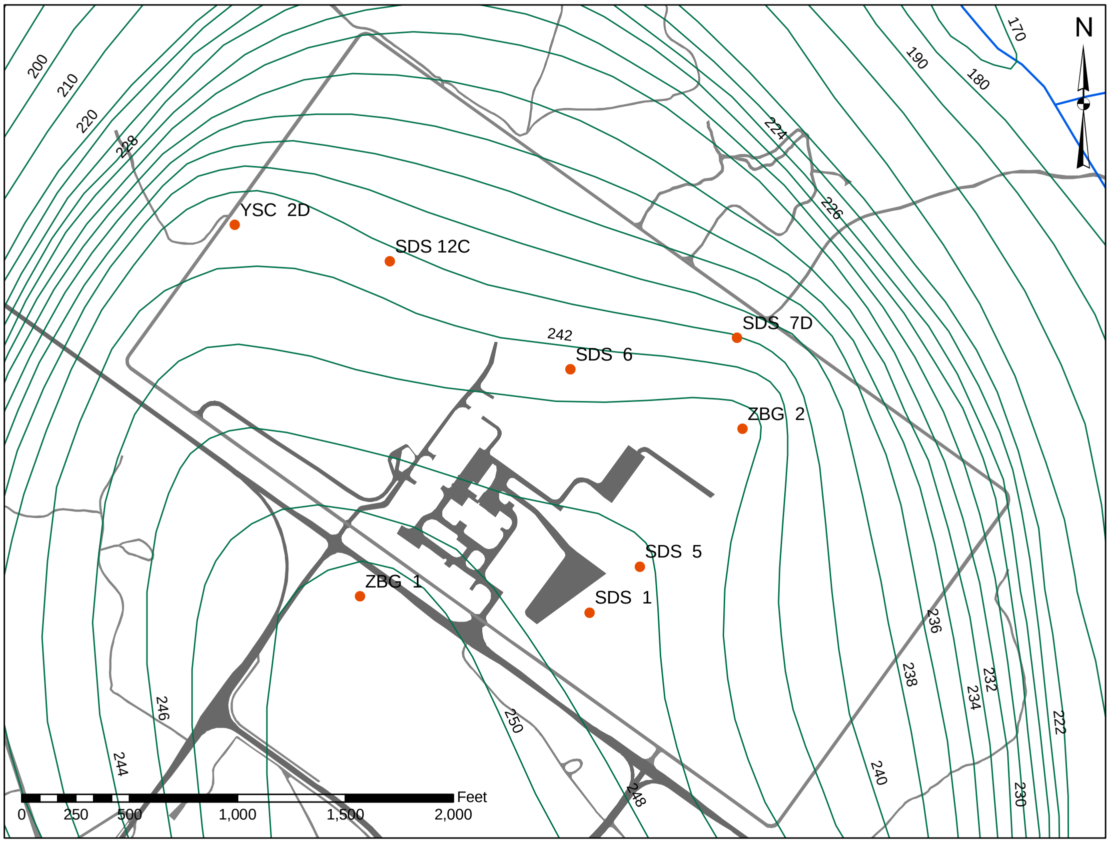

Figure 8 Probable maximum water table elevations across the SDF

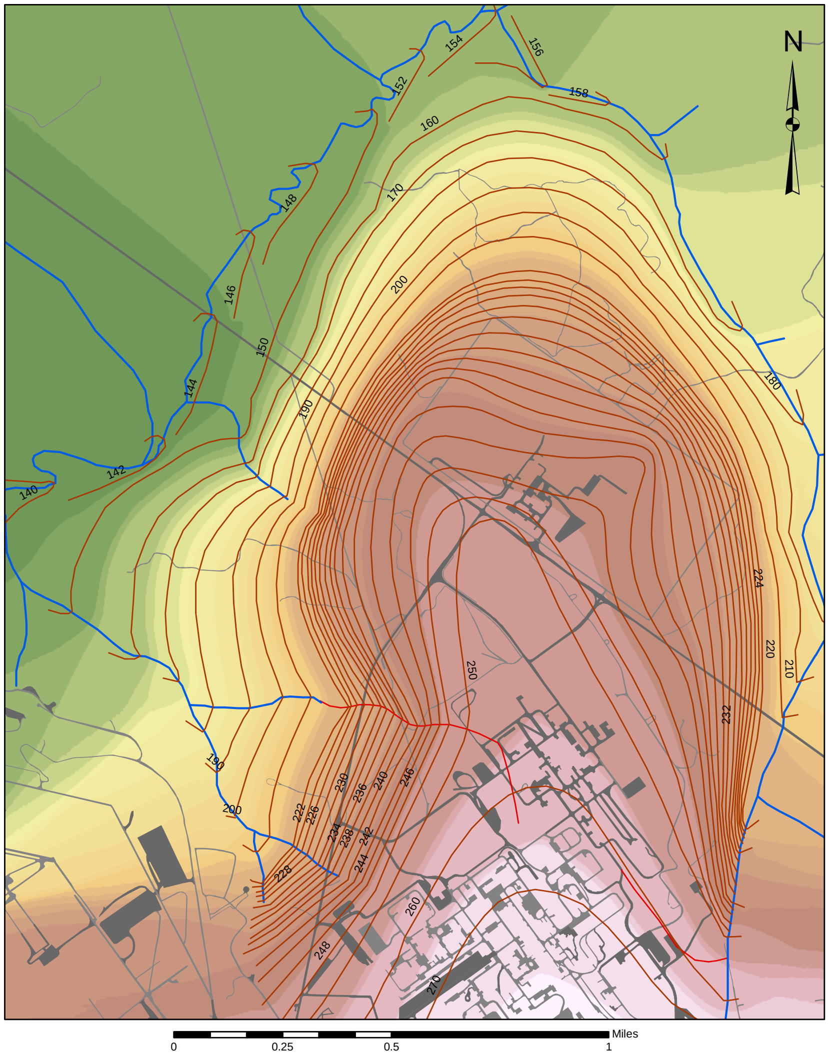

Figure 9 Probable maximum water table elevation extended to adjacent streams.

One immediate need of the Saltstone Vault 2 Design Team was for estimates of the probable maximum water table elevation near the planned location of that facility. The design team provided the coordinates of the excavation and estimates were obtained and are reported in Table 6.

Table 6 Probable maximum water table elevation at the corners of the Vault 2 excavation.

Vault 2 Corner	SRS East (ft)	SRS North (ft)	Prob. Max WT Elev. (feet above msl)
1	77511	66812	240.2
2	77585	67038	238.2
3	77205	67163	239.4
4	77131	66937	241.5

SUMMARY AND CONCLUSIONS

A coverage depicting the configuration of the probable maximum water table elevation in the vicinity of the Saltstone Disposal Facility was developed to support the Saltstone program. This coverage is needed to support the construction of saltstone vaults to assure that they remain above the maximum elevation of the water table during the Performance Assessment (PA) period of compliance.

A previous investigation to calculate the historical high water table beneath the SDF (Cook, 1983) was built upon to incorporate new data that has since become available to refine that estimate and develop a coverage that could be extended to the perennial streams adjacent to the SDF. This investigation incorporated the method used in the Cook, 1983 report to develop an estimate of the probable maximum water table for a group of wells that either existed at one time at or near the SDF or which currently exist. Estimates of the probable maximum water table at these wells were used to construct 2D contour lines depicting this surface beneath the SDF and extend them to the nearby hydrologic boundaries at the perennial streams adjacent to the SDF.

Fortunately, a record of annual precipitation in the region surrounding the SDF since 1854 is available to identify the year when the most precipitation in a single year occurred. This year was 1964. Water table fluctuations in a well located near the SDF are also available from 1952 to 1995 and clearly indicate that the highest water level occurred in early 1965 in response to the record high precipitation received in 1964.

The contour lines were constructed to depict the maximum elevation that the water table might conceivably rise to in response to precipitation events and this surface is shown in Figure 8. An accounting of the thickness of the capillary fringe was incorporated in the determination of the maximum elevation since it represents a significant thickness of saturated material above the water table. In addition, a measure of conservatism was introduced by allowing the contoured surface to exceed the well elevations by a few feet at three wells, SDS-1, SDS-7D and SDS-12C, such that a "smoother" surface, more consistent with the hydrogeologic conditions could be depicted.

From a hydrology standpoint the buildup of the water table beneath the SDF is limited by several factors. First, the degree of incision of the land surface exerts a primary influence on the basic configuration of the water table surface because such valleys form the discharge zones for the shallow groundwater. The SDF is flanked to the west, north and east with significant valleys that contain perennial streams, thus limiting the maximum elevation to which the water table can rise in response to precipitation amounts much greater than average amounts. Secondly, as the water table mounds upward in response to increased precipitation, the hydraulic gradient driving groundwater toward the adjacent streams (where the elevation remains constant) also increases, thus creating higher groundwater velocities to drain away the mounded water. One final consideration, over the 10,000-year Performance Assessment (PA) period of performance it is expected that the streams located adjacent to the SDF will gradually erode their valleys, thus resulting in a greater degree of incision and having the effect of further limiting the maximum elevation to which the water table beneath the SDF can rise. For these reasons, the probable maximum water table elevations presented in Figures 8 and 9 are thought to be the upper limit that the water table could rise to in response to precipitation.

Although certain measures were implemented to assure that the contour lines depict a surface above which the water table will not rise, the exact elevation of this surface cannot be known with complete certainty. It is therefore recommended that the construction of saltstone vaults incorporate a vertical buffer of at least 5-feet between the base of the vaults and the depicted probable maximum water table elevation. This should provide assurance that the water table under the wet extreme climatic condition will never rise to intercept the base of a vault.

REFERENCES

Cook, J.R., 1983. *Estimation of High Water Table Levels at the Saltstone Disposal Site (Z-Area)*, DPST-83-607, Technical Division, Savannah River Laboratory.

Freeze, R.A., and J.A. Cherry, 1979, Groundwater, Prentice-Hall, 604 p.

Hiergesell, R.A., and W. E. Jones, 2003. *An Updated Regional Water Table of the Savannah River Site and Related Coverages*, WSRC-TR-2003-00250, Rev. 0, Westinghouse Savannah River Company, Aiken, SC 29808.

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APPENDIX A

Design Check Instructions, Responses and Dispositions

Design Check Instructions for investigation of the probable maximum water table elevation near the Saltstone Disposal Facility (SDF).

Please refer to the two files attached to the email in which the Design Check instructions were transmitted to you. These are:

WSRC-TR-2005-00131 Rev 0.doc *and* **HighWT3.xls**

The design check responses are provided in red below the respective design check instruction.

1. In HighWT3.xls, tab labeled "Well WT Calculations" please check the calculations to insure that the logic of calculating the probable maximum water table elevations for wells SBG 2, YSC 2D, ZBG 1 and ZBG 2 is identical to the logic employed in the Cook, 1983 reference document for the other wells.

   The logic employed in HighWT3.xls, tab labeled "Well WT Calculations" to calculated the probable maximum water table elevations for wells SBG 2, YSC 2D, ZBG 1 and ZBG 2 is identical to the logic employed in the Cook, 1983.

   Response: Comment acknowledged.

2. Check that the summary statistical data from the "NewWells" tab has been transcribed correctly into these calculations.

   The summary statistical data from the "NewWells" tab has been transcribed correctly into the "Well WT Calculations" tab within HighWT3.xls.

   Response: Comment acknowledged

3. Verify that the appropriate elevations have been assigned to the calculations that originate in Cook, 1983 for wells ZW-10, SDS-1, -5, -6, -7D and -12C. Please note that 1.5-feet have been added to account for the presence of a capillary fringe immediately above the water table.

   Cook, 1983 provides reference elevations above mean sea level for wells ZW-10 and SDS-1. The appropriate reference elevations from Cook, 1983 have been assigned to these calculations. However Cook, 1983 does not specify reference elevations for wells SDS-5, -6, -7D and -12C. Therefore these calculations have taken the reference point for the depth measurements provided in Cook, 1983 as the top of casing rather than ground surface, since this produces more conservative results relative to calculations of the probable maximum water table elevations.

   Response: Comment acknowledged

4. Spot check Tables 1-4 in **WSRC-TR-2005-00131 Rev 0.doc** to assure that correct values have been transcribed from the calculation worksheet into the document.

   Table 1: HighWT3.xls does not provide information on the coordinates or installation dates for any of the wells therefore this could not be checked. HighWT3.xls also does not provide information on the screen elevations for SDS-1, -5, -6, -7D and -12C therefore this could not be checked. Within the "Well WT Calculations" tab the ground elevation of 294.4 is used as the reference elevation for the calculations which is consistent with Cook, 1983, rather than the listed reference of 295.1 in Table 1. Also within the "Well WT Calculations" tab the TOS for ZW-10 is shown as 297.6 rather than 300.4. Within the "New Wells" tab the screen elevations for ZW-10, SBG-2, YSC-2D, ZBG-1, and ZBG-2 appear to be incorrect relative to Table 1

(screen elevations should be based upon ground surface rather than TOC). None of these inconsistencies affects the calculations themselves.

Table 2: There is nothing to check versus HighWT3.xls.

Table 3: The 1990-1995 mean and max. values for well YSC 2D are not consistent between Table 3 and the "Well WT Calculations" tab. The Table 3 values should be changed to 216.9 and 220.8 for the mean and max. values, respectively.

Table 4: Table 4 and the "Well WT Calculations" tab are consistent.

Response: Comments acknowledge and the following changes were made to the calculation spreadsheet: In "Well WT Calculations" the TOS for well ZW-10 was changed to 300.4; in the "NewWells" tab, the elevations for the top and bottom of the screen zones were changed based on use of the land surface elevation and are now consistent with the values reported in Table 1; In addition to these changes, the following changes to the tables in WSRC-TR-2005-00131 were made: in Table 1 the screen elevations were reported to 1 decimal place; in Table 3 the 1990-1995 mean and max. values for well YSC-2D were changed to 216.9 and 220.8, respectively, to accurately reflect the calculated values. Also, the well coordinates and installation dates reported in Table 1 were double checked against values extracted from ERDMS and verified as accurate.

5. Check all values in Table 5 in **WSRC-TR-2005-00131 Rev 0.doc** to verify that the correct values have been transcribed into the report.

   Table 5 and the "Well WT Calculations" tab are consistent.

   Response: Comment acknowledged

6. Check the values in Table 6 in **WSRC-TR-2005-00131 Rev 0.doc** against the figure on page 2 of the Design Check instructions to insure that the elevations listed for the corners of the proposed Vault 2 location have been accurately interpolated.

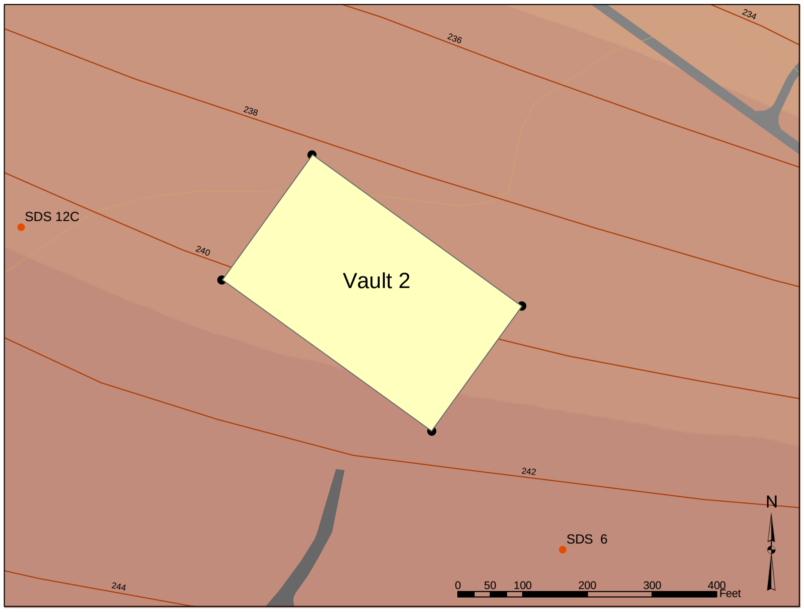
   An independent interpolation was perform versus the referenced figure and the same values as listed in Table 6 were obtained.

   Response: Comment acknowledged

7. Provide an overall technical/editorial review of **WSRC-TR-2005-00131 Rev 0.doc**

   WSRC-TR-2005-00131 is well written and provides a conservative estimate of the historic high water table elevation based upon the methodology of Cook, 1983. This document can be utilized for all future vault designs to ensure that the vaults are built above the high water table, as such it will be an invaluable tool. All previous comments and recommendations have been appropriately incorporated into the document. Only minor inconsistencies which do not affect the calculations were found during the design check.

   Response: Comment acknowledged


234
236
238
240
242
244
SDS 12C
Vault 2
SDS 6
N
0
50
100
200
300
400
Feet

APPENDIX B

Original report: Estimation of High Water Table Levels at the Saltstone Disposal Site (Z-Area)

DPST-83-607

TECHNICAL DIVISION
SAVANNAH RIVER LABORATORY

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SRL File (4)

MEMORANDUM

June 27, 1983

TO: E. L. Albenesius

FROM: James R. Cook JRC

ESTIMATION OF HIGH WATER TABLE LEVELS
AT THE SALTSTONE DISPOSAL SITE (Z-AREA)

INTRODUCTION AND SUMMARY

The design of the saltstone disposal site is such that the nitrate/nitrite will be slowly released over time, so that the concentration of nitrate/nitrite in the ground water leaving the disposal site boundary never exceeds the Environmental Protection Ageny drinking water standards for these compounds. The methods for attaining the low concentration levels include placing a low permeability cap over the monoliths to minimize water percolation to the monoliths, making the permeability of the monoliths very low to minimize flow through them, and placing the bottom of the monoliths three meters above the historic high water table.[1] This memorandum, done at the request of the DWPF Liason Group, addresses the last of these design objectives.

Based on rainfall data from 1854 to the present, the minimum depth to the water table should have occurred in 1965, and in that year the water table at wells within the saltstone disposal site should have ranged from 44 to 55 feet below ground surface.

DISCUSSION

Water table wells were installed in and around Z-Area to determine the depth to water at a number of locations in the vicinity of the area. The oldest of these, well SDS-1, has been measured regularly since December 1979. A search was made to find another water table well as close as possible to SDS-1 with a longer history of regular measurements. Well ZW-10, which has been measured since 1952 and is 0.91 miles from SDS-1, was selected. The locations of these wells are shown in Figure 1.

Variations from the mean water table measurements for wells SDS-1 and ZW-10 for the years 1980 through 1983 are shown in Figure 2. The means for wells ZW-10 and SDS-1 for this time period were 255.2 and 231.7 feet above mean sea level, or 45.2 and 62.7 feet below grade elevation, respectively. The correlation coefficient for the two sets of data is 0.76. The similarity in the two curves indicates that the processes governing fluctuations in the wells, i.e., precipitation, evapotranspiration, and ground water flow regime, are very similar. The response of well SDS-1 is somewhat slower than that of ZW-10, most likely because the soil in the vicinity of SDS-1 has a lower permeability.

The elevation of a water table surface balances the inflow and outflow of subsurface water in an area. As inflow increases, the water table rises, which increases the hydraulic head, which in turn increases the flow rate, and tends to return the water table to an equilibrium elevation. The primary driving force for water table fluctuations at SRP is precipitation. In a humid climate, with deeply weathered surficial material, the source of ground water is rainfall, and the ground water sink is flow to streams.

Figure 3 shows water level variations in well ZW-10 and total annual precipitation at SRP from 1952 to 1982. During this time period the mean elevation of the water table at ZW-10 was 253.7 feet above mean sea level. The 71.36 inches of precipitation in 1964 caused ZW-10 to peak 12.2 feet above its mean in April of 1965. Other years of high precipitation, for example 1959 and 1971, also produced elevated water table levels.

To extrapolate further back in time, precipitation data were needed for at least 100 years for a location close to SRP. A. J. Garrett of the SRL Meterology group provided precipitation data for Aiken, South Carolina, dating back to 1854. Figure 4 compares the SRP and Aiken precipitation data for the years 1952 to 1980, the years for which both sets of data exist. The correlation coefficient is 0.86. Therefore, one can estimate the SRP precipitation using Aiken data with some degree of confidence. Figure 5 shows the Aiken precipitation data from 1854 to 1980. It can be seen that in this time period the highest precipitation was that of 1964. Though 1964 had the highest precipitation on record, several other years had precipitation totaling over 60 inches. These were 1888, 1928, 1929, 1948, 1959, and 1971.

Based on the above, the problem becomes estimating the depth to the water table in Z-Area in 1964, given information on well ZW-10 from 1952 through 1982, and on wells ZW-10 and SDS-1 for 1980 through 1982. The known information is:

1) In the period 1952-1982 well ZW-10 peaked in 1964 at 12.2 feet above its mean for that time period.

2) In the period 1980 through 1982 well ZW-10 peaked at 6.8 feet above its mean for that time period.

3) For well ZW-10 the mean for 1980 through 1982 was 1.5 feet higher than the mean for 1952 through 1980.

4) In the period 1980 through 1982 well SDS-1 peaked at 5.2 feet above its mean for that time period.

To convert the 1964 peak at ZW-10 to an equivalent peak in terms of the 1980 through 1982 mean the difference in the means must be subtracted:

$$12.2 \text{ ft} - 1.5 \text{ ft} = 10.7 \text{ ft}$$

The 1964 peak at SDS-1 can then be estimated by multiplying 10.7 feet by the ratio of the SDS-1 peak to the ZW-10 peak for the period 1980 through 1982:

$$\text{SDS-1}_{peak} = 10.7 \text{ ft} * (5.2 \text{ ft} / 6.8 \text{ ft}) = 8.2 \text{ ft above mean}$$

Since the mean depth to the water table at SDS-1 was 62.7 feet, the depth to water in 1964 was:

$$\text{SDS-1}_{min} = 62.7 - 8.2 = 54.5 \text{ ft}$$

Nineteen other water table wells were installed in and around Z-Area, and have been measured since late 1981. Four of these, SDS-5, SDS-6, SDS-7D, and SDS-12C are within the area planned for saltstone disposal trenches. Figure 6 is a plot of water table variations of these four wells and SDS-1. The correlation coefficients for all of these wells with SDS-1 are greater than 0.90. Table 1 lists the minimum, maximum, and mean of the depth to water measurements for these five wells in 1982. Using the same methodology, but now using SDS-1 as the base well, and 1982 as the year with data for all wells, the minimum depth to the water table for these wells in 1964 can be estimated. The known information is:

1) In 1964 SDS-1 peaked at 8.2 feet bove its mean for 1980-1983.

2) In 1982 SDS-1 peaked at 1.1 feet above its 1982 mean.

3) For SDS-1 the 1982 mean was 3.7 feet lower than the mean for 1980-1982.

4) In 1982 wells SDS-5, SDS-6, SDS-7D, and SDS-12C peaked at 0.9, 1.0, 1.1, and 0.7 feet above their respective means.

To convert the 1964 peak at SDS-1, which was calculated on the 1980-1983 mean, the difference must be subtracted:

$$8.2 - (-3.7) = 11.9$$

The 1964 peak at any of the wells within Z-Area is then the 1982 average depth to water for that well minus 11.9 times the 1982 peak for the well in question divided by the 1982 peak for SDS-1. That is:

SDS-5

$$11.9 * (0.9/1.1) = 9.8$$

$$53.7 - 9.8 = \underline{43.9}$$

SDS-6

$$11.9 * (1.0/1.1) = 10.8$$

$$59.5 - 10.8 = \underline{48.7}$$

SDS-7D

$$11.9 * (1.1/1.1) = 11.9$$

$$60.5 - 11.9 = \underline{48.6}$$

SDS-12C

$$11.9 * (0.7/1.1) = 7.6$$

$$57.3 - 7.6 = \underline{49.7}$$

CONCLUSIONS

During the last 129 years the highest water table levels in the vicinity of Z-Area should have occurred in the period 1964-1965. Estimates for the depth to water in that year for wells within Z-Area range from 44 to 55 feet.

REFERENCE

1. R. L. Hooker and M. D. Dukes, Technical Data Summary, Decontaminated Salt Disposal as Saltcrete in a Landfill, Revision 1, Supplement 1,

Figure 1. Locations of Wells ZW-10 and SDS-1

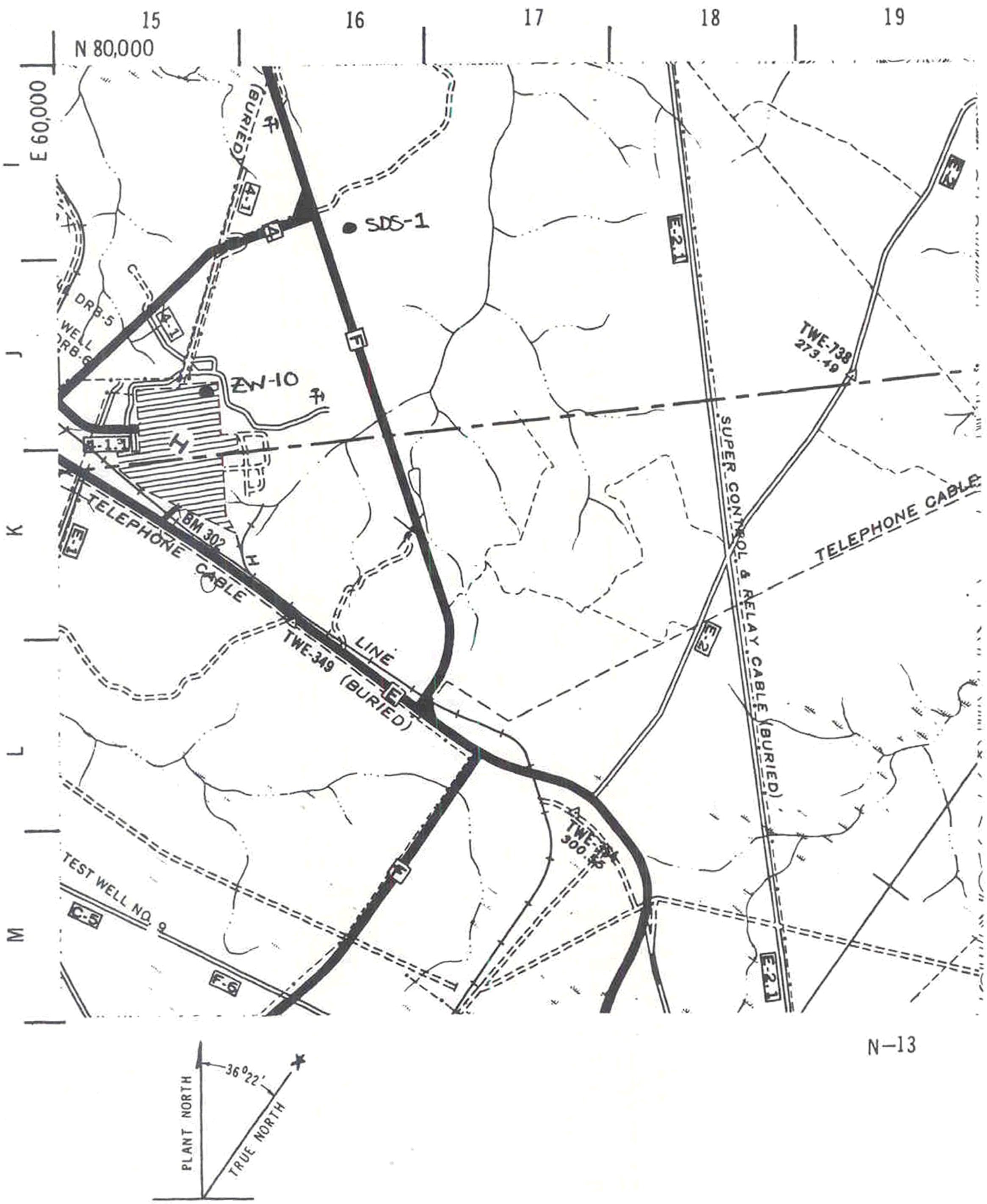


FIGURE 2. WATER TABLE VARIATIONS
SDS-1 AND ZW-10 1980-1983

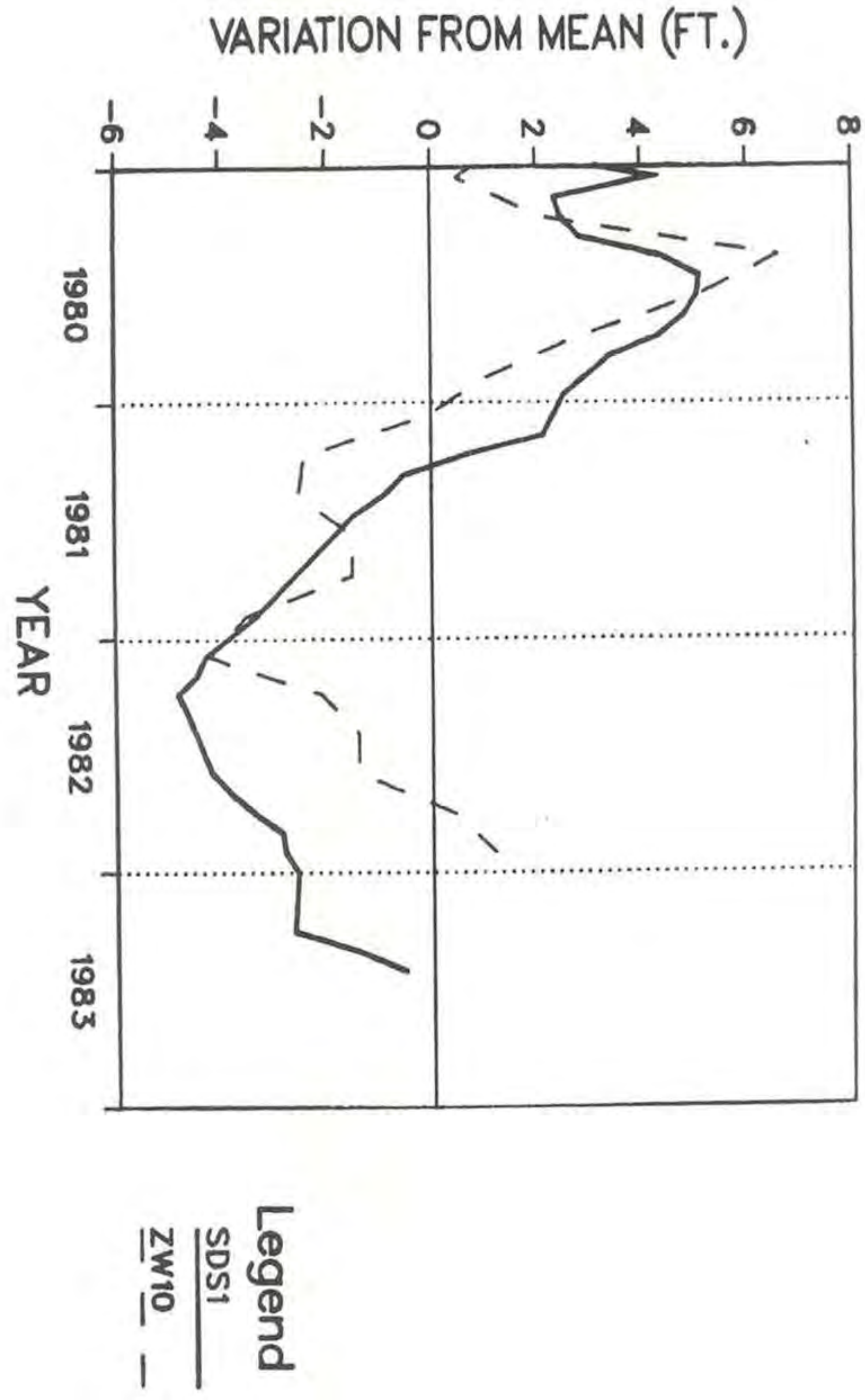


FIGURE 3. ANNUAL PRECIPITATION AND WELL ZW-10 VARIATIONS 1952-1982

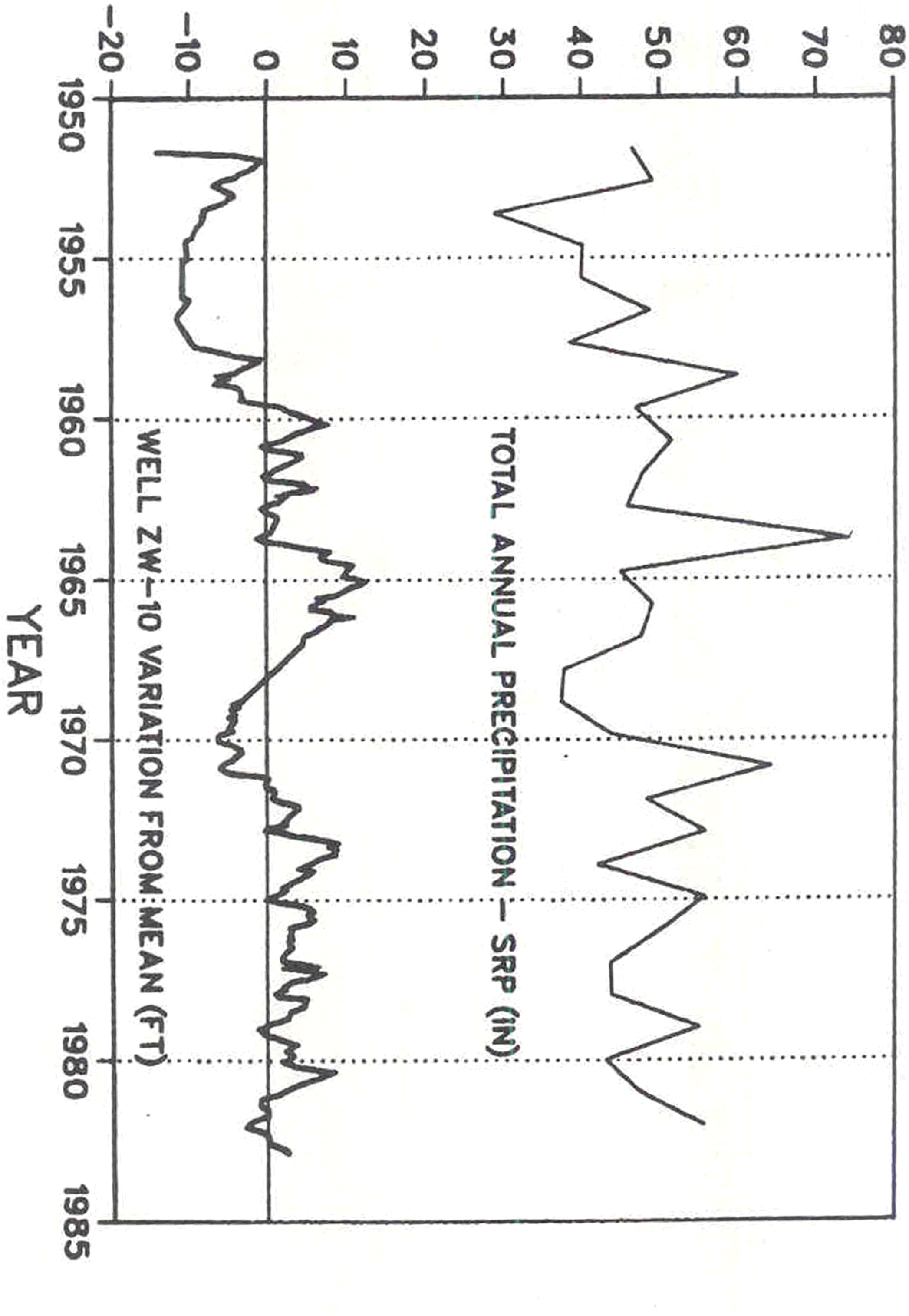
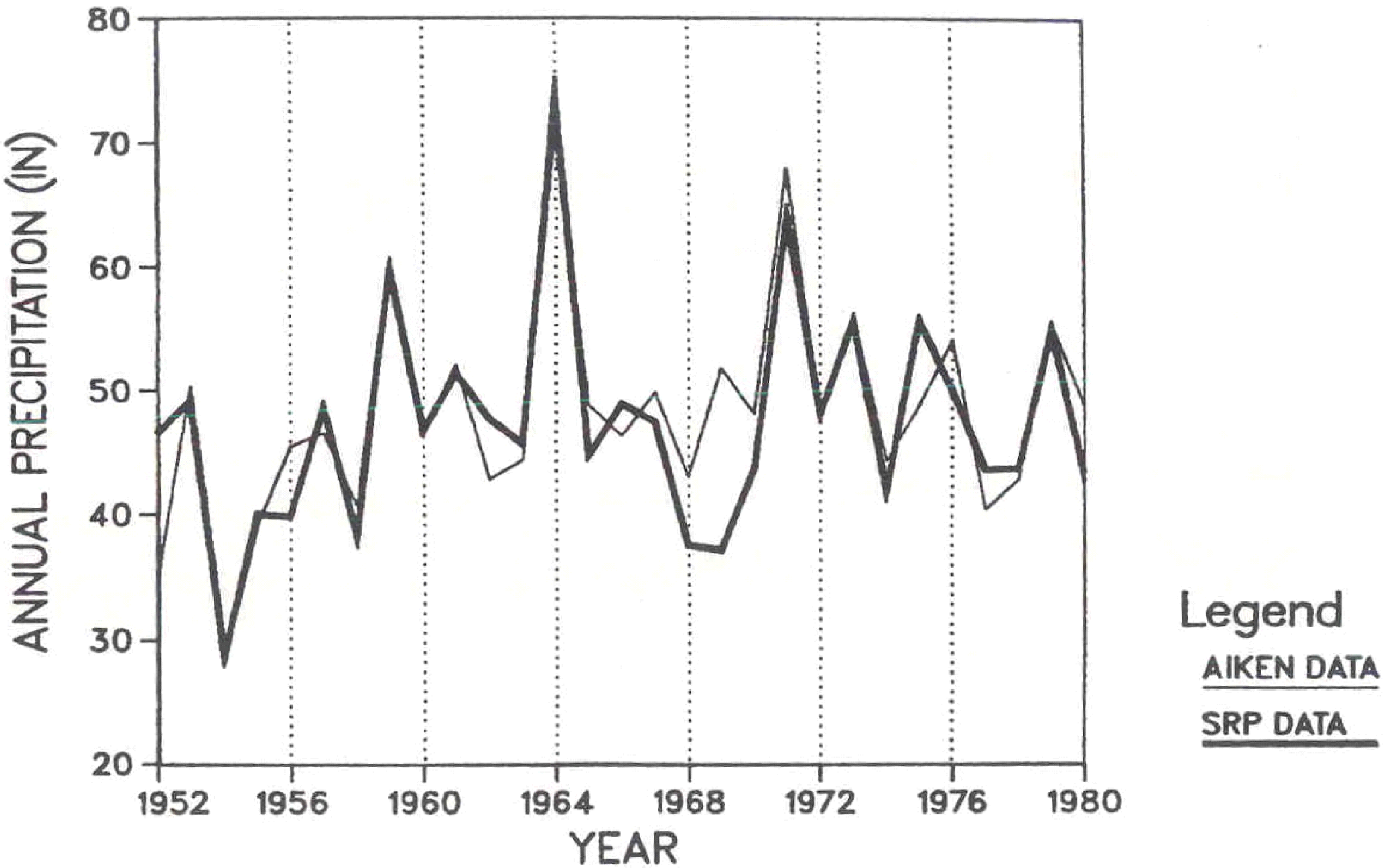


FIGURE 4. SRP AND AIKEN PRECIPITATION 1952-1980



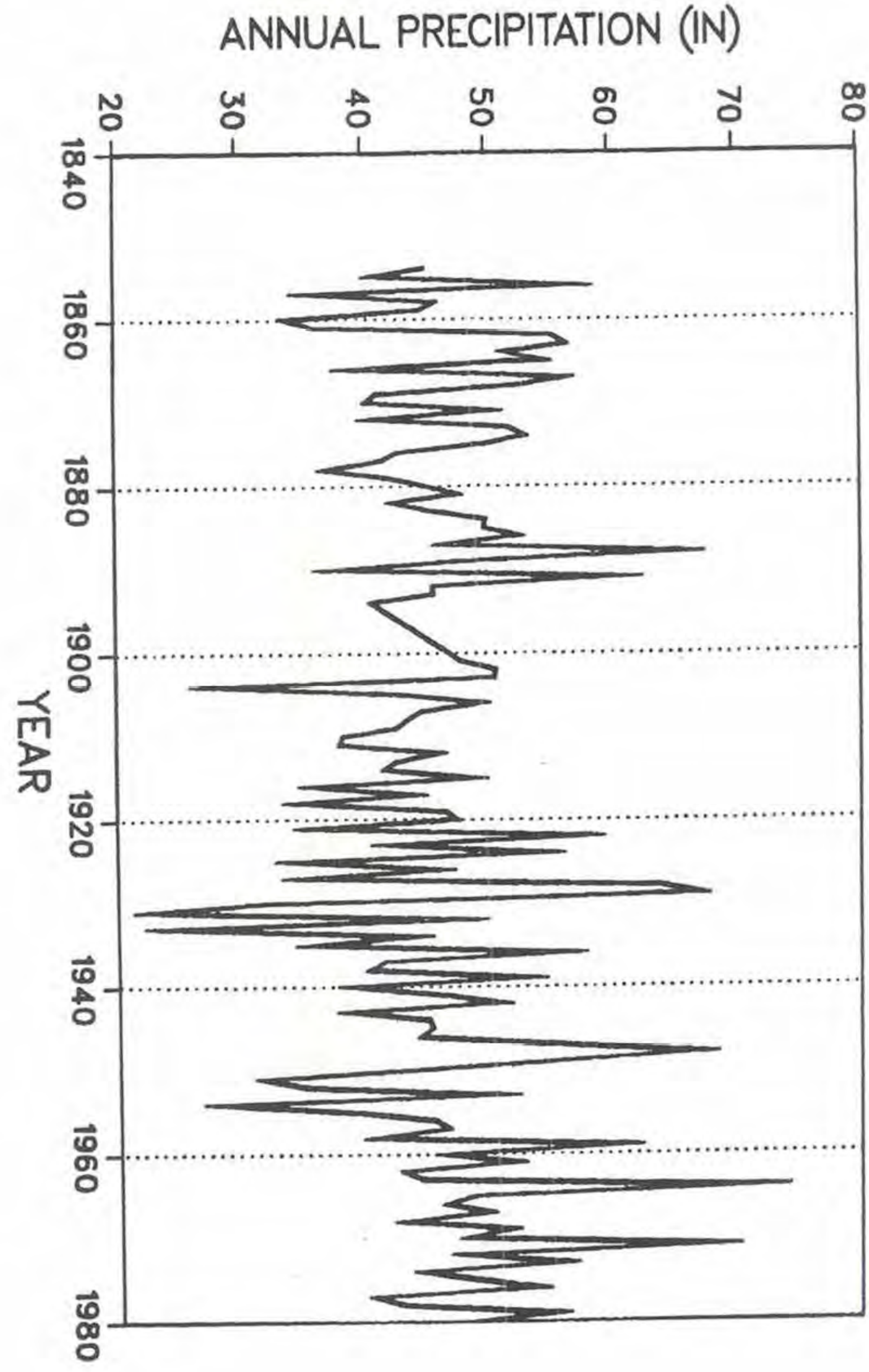


FIGURE 5. AIKEN PRECIPITATION 1854-1980

FIGURE 6. WATER TABLE VARIATIONS, Z-AREA WELLS 1982

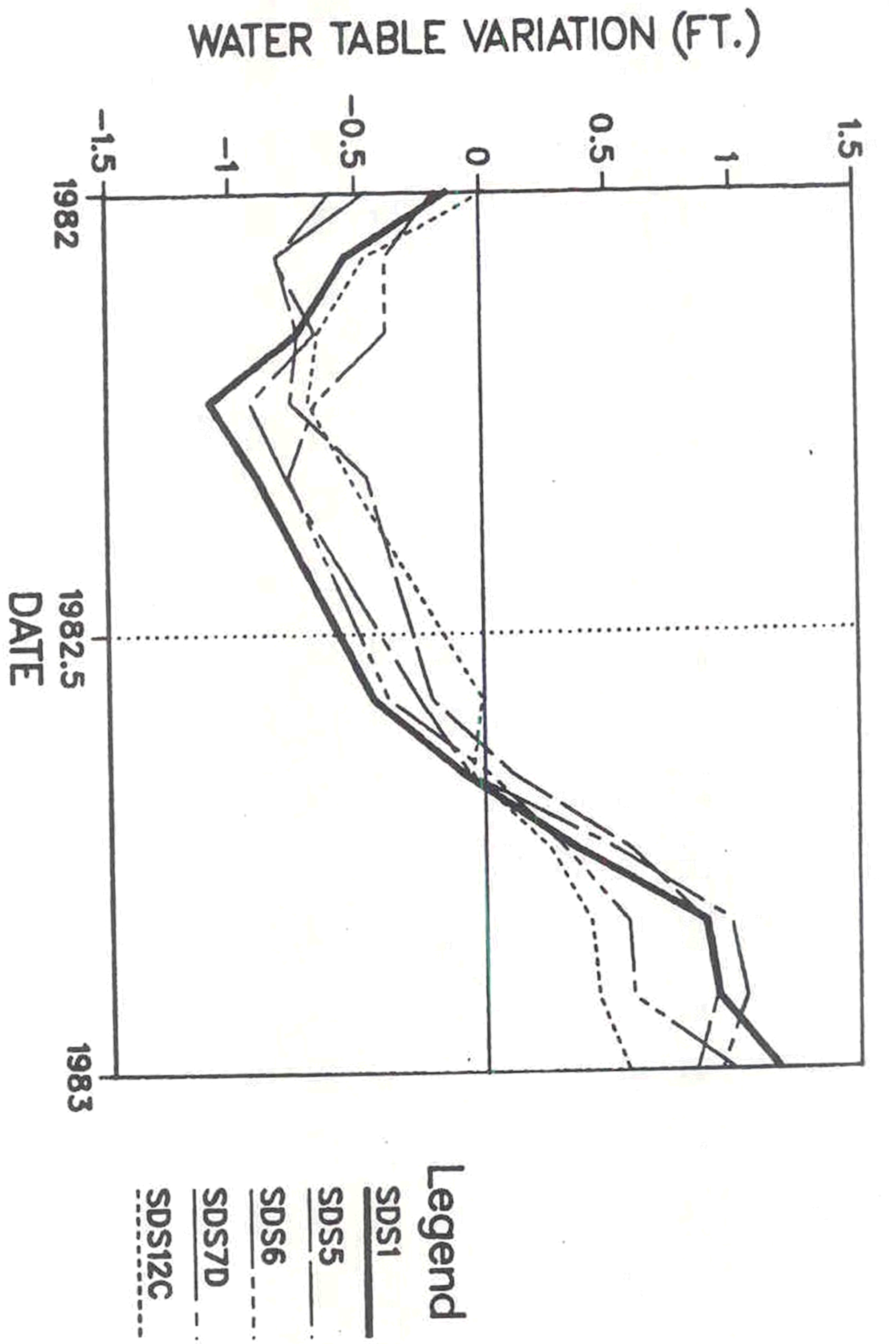


Table 1. Depth to Water Statistics for Z-Area Wells - 1982

Well	Minimum	Maximum	Mean
SDS-1	65.3	67.5	66.4
SDS-5	52.8	54.5	53.7
SDS-6	58.5	60.2	59.5
SDS-7D	59.4	61.4	60.5
SDS-12C	56.6	58.0	57.3

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