REPORT

RESULTS OF SEEPAGE TEST
ULTIMATE HEAT SINK RETENTION POND
CALLAWAY PLANT, UNITS 1 AND 2

FOR
UNION ELECTRIC COMPANY

Dames & Moore

D&M Job No. 07677-097-07
February 23, 1981

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February 25, 1981

Union Electric Company
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Attention: Mr. Donald W. Capone — DMUE-658
Manager - Nuclear Engineering

Gentlemen:

Re: Transmittal of Report
Results of Seepage Test
Ultimate Heat Sink Retention Pond
Callaway Plant, Units 1 and 2
For Union Electric Company

This letter transmits 25 copies of our report, "Results of Seepage Test, Ultimate Heat Sink Retention Pond, Callaway Plant, Units 1 and 2, for Union Electric Company." If you have any questions regarding this report, please feel free to call me.

Very truly yours,

DAMES & MOORE

Donald L. Ballmann

Donald L. Ballmann
Associate

DLB/EMF:lhk

25 copies submitted

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EXECUTIVE SUMMARY

During the period May 5 through September 26, 1980, a test was performed to determine the rate of seepage from the Ultimate Heat Sink Retention Pond at the Union Electric Company Callaway Nuclear Plant Site. The change in water level of the retention pond was recorded during the test, and a meteorology station was established adjacent to the pond to record precipitation and evaporation. These data were used in a water budget analysis to evaluate the rate of seepage from the retention pond. No water was pumped into or out of the pond during the test, and the site grading around the retention pond prevented surface water runoff into the pond.

The amount of seepage from the retention pond was evaluated by the following water budget:

Seepage = Net Volume Loss - Evaporation + Precipitation

Net volume loss and precipitation were determined by direct measurements. Retention pond evaporation could not be measured directly but was evaluated by applying a reduction coefficient to the evaporation measured by a U.S. Weather Bureau, Class A evaporation pan. There is no standard technique to select a specific value of pan coefficient for any site. Pan coefficients are site-specific and vary geographically, seasonally, and in response to short-term climatic conditions. The seepage test data were, therefore, analyzed using a range of pan coefficients considered appropriate for the Callaway site area during the test. A conservative pan coefficient was used for final interpretation of the results.

Another, independent estimate of the seepage rate was obtained by adjusting a seepage analysis performed by Bechtel Power Corporation, based on field permeability data obtained during this study. The field permeability tests indicated that the average coefficient of permeability for the soils was somewhat less than the value used by Bechtel.

The seepage rate from the UHS retention pond was found to be very small by both the water budget analysis and by adjusting Bechtel's seepage analysis. The average seepage rate was found to be less than 0.5 acre-foot for a 30-day period and probably on the order of 0.3 acre-foot. A seepage loss of 0.5 acre-foot would result in a 1.5-inch drop in the retention pond water surface at the normal operating level. The worst-case condition during the seepage test showed less than 1.0 acre-foot of seepage for 30 days. An allowance for 5 acre-feet of seepage was included in sizing the pond. The seepage loss determined during this study is much less than the design value.

The engineering behavior of the retention pond was also monitored during the period of the seepage test. Visual inspections did not reveal any areas of distress, and surveys of the movement monuments surrounding the pond indicated no excessive horizontal or vertical movements. The pond water was clear. The water levels in the observation wells surrounding the pond appeared to have reached equilibrium. All observations indicated that the retention pond is behaving normally.

1.0 INTRODUCTION

This report presents the results of the seepage test inspection program performed for the Ultimate Heat Sink (UHS) retention pond at the Callaway Plant site during the period May 5 through November 5, 1980. The inspection program consisted of a test to determine the amount of seepage out of the retention pond and engineering inspections of the pond. The seepage test consisted of a water budget analysis to estimate the amount of seepage from the pond based on measurements of precipitation, evaporation, and the pond water level. No make-up water was added to the retention pond and no water was removed from the pond during the test; therefore, the amount of seepage was equal to the amount of water lost from the pond after accounting for precipitation and evaporation. The seepage test was performed during the period May 5 through September 29, 1980.

During the period of the seepage test, engineering inspections were performed to monitor the behavior of the pond. One final inspection was performed on November 4, 1980.

The seepage test inspection program was the third phase of an overall retention pond inspection and testing program. The results of the first two phases, which consisted of a preservice inspection and an inspection during filling, were presented in two previous reports (Dames & Moore, 1980a; 1980b). Subsequent to the seepage test, periodic in-service inspections will be performed throughout the life of the UHS retention pond. The overall retention pond inspection program was designed to fulfill the commitments made by Union Electric Company (UEC) in Table 2.4-14 of the Final Safety Analysis Report, Callaway Plant Units 1 and 2, with respect to U.S. Nuclear Regulatory Commission (NRC) Regulatory Guide 1.127, "Inspection of Water-Control Structures Associated with Nuclear Power Plants."

2.0 SCOPE OF WORK

The scope of work for the seepage test inspection program was outlined in the UEC request for proposal in ULDM-328, dated August 30, 1979. A detailed description of the program and the procedures under which the work was performed are given in the Dames & Moore "Procedure for Seepage Test, Ultimate Heat Sink Retention Pond, Callaway Plant, Units 1 and 2, for Union Electric Company," Revisions 1, 2, and 3, dated May 2, June 20, and July 15, 1980, respectively. The work associated with the overall UHS retention pond inspection program was authorized on January 21, 1980 when the contract transmitted with DMUE-576, dated January 10, 1980, was approved by UEC.

Specifically, the Dames & Moore scope of work for the seepage test inspection program was as follows:

1. To prepare a procedure for the work;
2. To purchase, install, and maintain the meteorological equipment necessary for the seepage test [site preparation was performed by Daniel International Corporation (DIC)];
3. To instruct UEC and DIC site personnel in their monitoring and inspection responsibilities;
4. To evaluate the data obtained; and
5. To prepare a report presenting the results of the seepage test inspection program.

3.0 SEEPAGE TEST

3.1 GENERAL

A water budget analysis was performed to determine the amount of seepage from the UHS retention pond during the period May 5 through September 26, 1980. No water was pumped into or out of the pond during the period of the test; therefore, precipitation, seepage, and evaporation were the only additions to or losses from the system. The actual change in quantity of water in the pond was calculated based on direct measurements of the retention pond water level. Precipitation and evaporation were estimated from data obtained from a meteorological station established west of the northwest* corner of the pond as shown on Figure 1, UHS Area Plan.

The amount of water entering the pond as a result of precipitation was determined by assuming that uniform rainfall occurred over the entire UHS watershed. The volume of water entering the pond was therefore equal to a measured number of inches of rainfall times the plan area within the cut slopes of the pond. The ground surface surrounding the pond was graded to direct surface water runoff away from the pond. The plan area of the pond was calculated from survey data obtained during geologic mapping of the UHS retention pond (Dames & Moore, 1980c).

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*Directions presented in this report are given with respect to plant north of the plant coordinate system unless otherwise noted. The relationship between plant north and true north is shown on Figure 1.

The amount of water lost through evaporation was determined in the following manner. First, inches of evaporation measured by an evaporation pan were converted to inches of pond evaporation using a representative pan coefficient. Next, the inches of evaporation were converted to a change in volume by multiplying by the water surface area of the pond. The surface area was determined from data provided by DIC field engineers, who surveyed the edge of the pond water surface at regular intervals. To describe the pond's surface area as a function of pond elevation, a linear regression analysis was performed on the available data to develop a relationship between pond elevation and surface area.

The actual, net amount of water lost from or added to the retention pond over a period of time was calculated by multiplying the measured change in pond surface elevation by the water surface area using the relationship between pond elevation and surface area. Readings of pond surface elevation were obtained visually from a staff gauge installed in the Essential Service Water System (ESWS) pumphouse forebay.

The amount of seepage from the pond determined by the water budget was calculated by subtracting the volume of evaporation from the net volume loss and adding the volume of precipitation:

Seepage = Net Volume Loss - Evaporation + Precipitation

Another way to examine the data is to subtract the volume of precipitation from the volume of evaporation and then divide by the surface area of the pond. This yields an anticipated drop of pond water level that can be compared with the measured drop in water level. A measured drop greater than that anticipated would indicate seepage, whereas a measured drop less than anticipated would indicate apparent infiltration into the pond.

An estimate of the amount of seepage from the UHS retention pond independent of the water budget analysis was obtained by using the ground water flow net analyses performed by Bechtel Power Corporation (Bechtel, 1977). The seepage values obtained by Bechtel were adjusted by Dames & Moore based on field permeability tests performed in the five observation wells immediately adjacent to the pond (see Section 3.3.2).

3.2 SEEPAGE TEST DATA

3.2.1 Meteorological Data

3.2.1.1 General

A meteorological station established for measurement of evaporation and precipitation was located west of the northwest corner of the UHS retention pond as shown on Figure 1. The equipment site was surrounded by an 8-foot high chain link fence with a locked gate for security. A plan of the equipment layout is shown on Figure 2, Meteorological Station Plan.

The location of the equipment site was selected to best meet the following criteria:

1. Location in a prevailing upwind direction from the UHS retention pond;

2. Unrestricted air flow from all sides;

3. Location in an area where construction activities would not produce large amounts of fugitive dust emissions; and

4. Location in a secure area.

A relatively large clay soil storage pile approximately 20 to 25 feet high was located northwest of the equipment site in the prevailing upwind direction. The pile was more than 100 feet from the meteorology station and was, therefore, well beyond the 2-to-1 distance-to-height criterion recommended by the equipment supplier.

The meteorological equipment within the station was installed by Dames & Moore on April 10 and 11, 1980. Site preparation, equipment pallets, and fencing construction were performed under the direction of DIC. Regular Monday, Wednesday, and Friday readings and checks of the equipment by personnel of UEC Nuclear Operations were started on April 14, 1980, prior to starting the seepage test, to verify that the equipment was operating normally. The meteorological data were collected at this Monday, Wednesday, and Friday frequency throughout the seepage test.

During the course of the seepage test, as the initial data were received and analyzed, it appeared that water was infiltrating the pond rather than seeping out. This condition was not possible based on ground water level data, and it was suspected that the pan coefficient being used to convert pan evaporation to pond evaporation was too high. To determine if significantly more wind run was occurring over the pan than over the pond, which would increase pan evaporation compared to pond evaporation, two totalizing anemometers were used to measure wind run over the pond. The anemometers were installed near the water level on the slopes of the retention pond. To provide coverage over the entire retention pond, they were first located near the northwest and southeast corners of the pond, then later moved to the northeast and southwest corners. The anemometer locations are shown on Figure 1.

The meteorological data collected during the seepage test are presented in the following sections. The equipment used to record the meteorological data is listed in Table 1. Brief descriptions of the instruments are given in the following sections; a complete description of the equipment is presented in the Appendix to this report.

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3.2.1.2 Evaporation Data

A U.S. Weather Bureau Class A pan was used to monitor evaporation. The pan was 4 feet in diameter, 10 inches deep, and was constructed of stainless steel. The pan was mounted on a wood pallet with some separation between the planks. Water level in the pan was measured in a still well using a micrometer hook gauge; a maximum-minimum thermometer was used to measure the extremes of water temperature; and a totalizing, contact anemometer measured wind run over the pan. Containers of water were retained within the meteorology station to have water at air temperature for refilling the pan.

The wind run over the pan surface and the extremes of pan water temperature were used as qualitative checks of evaporation. For example, it is unlikely that high rates of evaporation would be associated with very low wind speeds and cool temperatures. The wind run over the pan was also compared to measurements of wind run at the edges of the retention pond.

A summary of weekly pan evaporation recorded is presented in Table 2. The total evaporation loss from the evaporation pan was 44.3 inches during the seepage test. Table 3 presents a comparison of the evaporation measured at the Callaway site with that measured during the same period by Class A pan stations at New Franklin near Boonville, Missouri (approximately 50 miles west-northwest of the Callaway site) and Lakeside (Bagnell Dam) near Lake Ozark, Missouri (approximately 60 miles southwest of the Callaway site). The Callaway site data compare well with the New Franklin data but are significantly higher than Lakeside.

The normal May through October Class A pan evaporation for the Columbia, Missouri area is approximately 38.5 inches with a standard deviation of about 5.7 inches (U.S. Weather Bureau, 1959). This means that about 68 percent of the time, the pan evaporation between May and October (184 days) should be between

33 and 44 inches. Evaporation measurements at the Callaway site indicate that the total pan evaporation was 45.3 inches for a 149-day period from May 1 through September 26, 1980.

To compare the measured evaporation at the Callaway site with that for Columbia, the data measured at the Callaway plant were extrapolated to 184 days to allow comparison over the same time period. The additional 35 days were assumed to have the same average daily precipitation rate as the period September 12 through 26 (0.23 inch/day). The resultant May through October evaporation was estimated to be approximately 53 inches. The difference between the pan evaporation at Columbia, Missouri, and at the Callaway site is 14.5 inches or 27 percent. The difference may have been less if the test had been continued because the projection for October based on September data may be slightly high.

To analyze why more than normal evaporation was measured during the seepage test, an examination of the meteorological parameters that affect evaporation was made for this time period. Table 4 presents the monthly averages for wind speed, temperature, and dew point temperature recorded in Columbia for both the current calendar year and the historical data record. Also presented in Table 4 is the deviation from the historical average. Examination of these data reveals that the measured wind speed and dew point temperatures did not depart from the norms. Analysis of the temperature data, however, indicates that during June, July, August, and September, average ambient temperatures were, respectively, 2.3°F, 9.7°F, 5.7°F, and 1.6°F higher than the expected norms. The variation of ambient temperature above the norm is further illustrated by examination of the number of days during which the maximum observed daily temperature was greater than or equal to 90°F. Table 5 presents the number of days during which the maximum temperature in Columbia was equal to or in excess of 90°F for the period of May through September of the current calendar year and for the historical data record. During this period in 1980, the maximum temperature was greater than or equal to 90°F 31 days more than during an average year.

The data presented above indicate that the seepage test was performed during a period with above average temperatures. Although no attempt was made to quantify the effect this would have on the recorded pan evaporation, it does indicate that above average evaporation would have occurred during the seepage test.

3.2.1.3 Precipitation Data

A tipping bucket rain gauge with a resolution to 0.01 inch was used to record precipitation on a continuous basis. A chart recorder for this gauge was housed in a small, weather-proof shelter mounted on the fence near the gauge. The chart paper was changed weekly by personnel of UEC Nuclear Operations. Precipitation was also measured by a nonrecording rain gauge mounted next to the continuously recording gauge. Precipitation readings for this gauge were taken with each meteorology station data check. Both rain gauges were located within a windshield, and the tops of the gauges were adjusted to the same level. The two gauges yielded nearly equal precipitation measurements.

A summary of the weekly precipitation measured at the meteorology station during the seepage test is presented in Table 2. A total of 13.9 inches was recorded.

Table 6 summarizes the precipitation data collected at both the Callaway site and at Columbia, Missouri for the period of May through September 1980 in addition to the historical data recorded for Columbia. These data indicate that a total of 13.9 inches of rain was measured at the retention pond, while during the same time period, Columbia, Missouri recorded 10.0 inches of precipitation. The historical data indicate that normal rainfall for Columbia during this time period is 20.7 inches. These data show that the seepage test was performed during a period of lower than average rainfall.

It was not possible to compare the precipitation measurements from the retention pond station with data from the Callaway Plant meteorological tower site precipitation gauge since the tower site gauge was out of order during much of this period.

3.2.1.4 Wind Run Data

Two totalizing anemometers identical to that used to measure wind run over the evaporation pan were used to measure wind run at the edge of the pond water surface after July 18,

1980. To provide coverage over the entire retention pond, the anemometers were located near the northwest and southeast corners of the pond until August 15, and then moved to the northeast and southwest corners of the pond. The cups of the anemometers were approximately 12 inches above the pond water surface.

The attempt to correlate wind passage over the evaporation pan and the UHS retention pond produced the following results:

1. Wind run measured at the northwest and southeast anemometer locations of the retention pond was greater than concurrent measurements taken at the evaporation pan.

2. Concurrent measurements made between the northeast and southwest anemometer locations of the pond were less than those measured at the evaporation pan.

Table 7 summarizes the wind run data collected.

As can be seen by these data, different flow fields exist between the evaporation pan and the retention pond. The anemometers showed more wind run at the northwest and southeast edges of the pond than the pan but showed less wind run at the northeast and southwest edges of the pond than at the pan. It appears that there may not have been a greater wind run over the pond than over the pan. However, insufficient data were obtained to fully characterize the differences. Therefore, this variable was eliminated from consideration in the selection of a representative pan coefficient used to convert pan evaporation to pond evaporation.

3.2.2 Retention Pond Water Level Data

The water level in the UHS retention pond was read from a staff gauge mounted in the ESWS pumphouse. Initially, water level readings were recorded to 0.1 foot and were taken twice a week in conjunction with engineering inspections of the pond. During the test, it was found that more precise readings were necessary to match the precision of the meteorological data. It was also decided to record the water level three times a week at the same time as the meteorology data. Therefore, beginning July 11, 1980, the water level in the pond was read to 0.01 foot. This could be performed with good reliability because the water was still within the pumphouse forebay. Beginning July 11, water level readings were performed by the engineering inspectors twice a week and also by the meteorology data recorder three times a week.

The weekly change of retention pond water level during the seepage test is given in Table 8. The water level changed from elevation 835.9 feet* to 834.85 feet for a drop of 12.6 inches during the 5-month period. The change in water level with time is shown to a relatively small scale on Figure 3, and to a larger scale on Figure 4.

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*All elevations presented in this report are based on mean sea level (MSL) datum unless otherwise noted. Elevation 840 feet MSL is equivalent to elevation 1999.5 feet SNUPPS plant datum.

3.2.3 Retention Pond Water Surface Area Data

The water surface area of the retention pond was calculated from survey data provided by DIC field engineers. The perimeter of the water surface was surveyed twice a week from May 5 through June 6, 1980; once a week from June 6 through July 14; and thereafter every 2 weeks until September 26. The water level in the pond was recorded at the time of each survey. To smooth the normal scatter in the data, a least square regression was performed to develop a relationship between pond surface area and water level. The relationship developed was the following:

Water Surface Area (ft^2) = [Water Level* (ft) x 4530] - 3,613,276

3.2.4 Field Permeability Test Data

Field permeability tests were performed in the five observation wells immediately adjacent to the retention pond prior to the Preservice Inspection of the pond to obtain a qualitative estimate of the response time of the observation wells and to obtain in-situ permeability values for the soils. The tests were performed on February 20 and 21, 1980. Falling head tests were performed by filling the observation wells to the top of the PVC pipe and then recording the drop in water level with time. The observation wells were filled with water for a

*Water level based on mean sea level datum (MSL).

period of time to allow some saturation of the surrounding soils before the tests were performed. It is doubtful that a long-term, steady-state condition was reached; however, the tests yielded consistent results when different time periods were analyzed for each observation well.

The results of the field permeability tests are presented in Table 9.

3.3 SEEPAGE TEST RESULTS AND DISCUSSION

3.3.1 <u>Water Budget Analysis</u>

3.3.1.1 General

The amount of seepage from the UHS retention pond was determined by subtracting the amount of evaporation and adding the amount of precipitation to the actual, measured change of water volume in the pond. The amount of precipitation and actual change in water volume could be determined by direct measurement. The amount of evaporation from the pan could not be used as a direct measurement of retention pond evaporation because pan evaporation is almost always more than lake evaporation. Direct use of pan evaporation data for pond evaporation would yield unconservative and, in the case of the seepage test, unrealistic values of seepage. A common practice is to multiply the measured pan evaporation by an appropriate pan coefficient to estimate the lake evaporation. No method exists that allows selection of one specific value of pan coefficient because the coefficient is site-specific and varies geographically, seasonally, and in response to short-term climatic conditions. Therefore, the seepage test data were analyzed using a range of pan coefficients.

Two time periods were analyzed during the seepage test. One period consisted of the entire test period from May 5 through September 26, 1980. The second period was July 11 through September 26, 1980, when more precise readings of the retention pond water level were taken. The greater precision of the later data reduced some of the scatter in the comparison of measured and calculated water loss from the retention pond.

3.3.1.2 Pan Coefficient

An average annual Class A pan coefficient of approximately 0.75 has been published as a representative value for the Callaway site area (U.S. Weather Bureau, 1959). The seepage test, however, was only conducted for 5 months, and 0.75 was found not to be representative over the entire test period. The pan coefficient is lower in the spring than in the fall. A value of 0.75 may be appropriate for the latter part of the seepage test, but not for the entire test period.

Due to seasonal variation of the pan coefficient, the seepage test data were evaluated for pan coefficients of 0.75, 0.70, 0.65, and 0.60. These values were anticipated to bracket the average pan coefficient over the period of the test. Coefficients derived and recommended by various investigators are presented in Professional Paper 229 by the U.S. Geological Survey (USGS, 1952). Although none of the studies presented were in the Missouri area, these data indicate that the coefficient is seldom below 0.60 during May through September. Pan coefficient data obtained from Union Electric Company for their Lakeside station (Bagnell Dam) near Lake Ozark, Missouri are presented in Table 10 (Miller, 1981). The Lakeside data also indicate that the average May through September pan coefficient would normally be greater than 0.60.

The amount of pond evaporation can be calculated from pan evaporation data using an approach that does not require a pan coefficient (Kohler and others, 1955). The method can also be used to calculate an equivalent pan coefficient with the same data. The method assumes that the Class A pan coefficient is 0.70 when air and water temperatures are equal and makes adjustments for advected energy when the temperatures are different. It also assumes that any energy advected into the lake is balanced by a change in energy storage. Pond evaporation can be calculated using the following equation:

$$E_l = 0.70\,[E_p + 0.00051\,P\,\alpha_p\,(0.37 + 0.0041\,\mu_p)(T_o - T_a)^{0.88}]$$

where: E_l = pond evaporation;

E_p = pan evaporation;

P = atmospheric pressure;

α_p = proportion of advected energy (Class A pan) used for evaporation;

μ_p = wind run at elevation of evaporation pan;

T_o = mean pan water surface temperature; and

T_a = mean air temperature.

An equivalent pan coefficient can be calculated by dividing the lake evaporation determined by this equation by the pan evaporation. We calculated equivalent pan coefficients for 3 periods when site data checks were performed approximately 24 hours apart. Air temperature data were obtained from the 10-meter level of the Callaway Plant meteorology tower, and the maximum/minimum thermometer was used to obtain mean pan water temperature. The coefficients obtained were 0.73 for May 27 to 28, 0.69 for August 19 to 20, and 0.72 for September 2 to 3. These data are limited but indicate a pan coefficient near 0.70. It should be repeated, however, that the Kohler method assumes that a pan coefficient of 0.70 is appropriate if air and pan water temperatures are equal.

The selection of a representative pan coefficient based on published data or the equation above may not be appropriate for the early part of the seepage test since the UHS retention pond was not an established lake. The pond was filled during the period March 7 to April 10, 1980 with well water at a temperature of approximately 62°F. We have not performed any heat flow analyses, but it is possible that the retention pond evaporation characteristics may have differed from those of an established lake during the early part of the seepage test.

The highest pan coefficient possible over a period of time can be calculated by assuming that there was zero seepage.

For this condition, the water budget would be as follows:

0 = Net Volume Loss + Precipitation - (Pan Coefficient x Pan Evaporation)

Any coefficient higher than that for zero seepage would indicate infiltration into the retention pond rather than seepage out of the retention pond. Infiltration, other than minor amounts after heavy precipitation, is unlikely based on the ground water levels recorded in the observation wells surrounding the retention pond. The maximum average pan coefficients possible for the period of the entire seepage test (May 5 through September 26, 1980) and for the period July 11 through September 26, 1980 were calculated to be 0.68 and 0.79, respectively.

Based on our review of the data presented in USGS Professional Paper 229 and the data from Lakeside (Bagnell Dam), and after review of the seepage calculations presented in the next section of this report, it is our opinion that the average pan coefficient would not be lower than 0.60 for the overall seepage test period and would not be lower than 0.65 for the period July 11 through September 26. Therefore, the range of pan coefficients used to reduce the data is considered sufficient.

3.3.1.3 Seepage Calculations

In order to determine the amount of seepage from the UHS retention pond, the volume of water that would have been lost from the pond assuming zero seepage was calculated from the precipitation and evaporation data using each of the four pan coefficients considered. The difference between the calculated change in volume and the actual measured change in volume yielded the amount of seepage. If the calculated volume change was greater than the measured change, apparent infiltration would result, indicating that the pan coefficient value used was too high. Table 11 presents the calculated and measured changes of water in the retention pond during the seepage test. Figure 5 presents these data in a cumulative graphical form. The data indicate that over the first part of the seepage test, the pan coefficient must have been less than 0.60. Over the entire test, pan coefficients of 0.60 and 0.65 yielded results showing seepage, whereas pan coefficients of 0.70 and 0.75 yielded apparent infiltration and were too high.

Another way to examine the data is to compare the actual measured drop in retention pond water level with the drop in water level calculated assuming zero seepage. These data are tabulated in Table 8 and are shown in a cumulative graphical form on Figure 4. This manner of presentation yields the same conclusions regarding the pan coefficients as indicated by comparing calculated vs. measured water volume change.

More precise readings of the water level in the pond were taken during the latter part of the seepage test to obtain measured values of water volume change closer to the precision of the precipitation and pan evaporation measurements. The pan coefficient should be larger during the latter part of the seepage test than during the early part of the test. Figure 6 presents a plot of the weekly measured change in water volume vs. the weekly calculated change for the period July 11 through September 26. Data are presented for pan coefficients of 0.60 and 0.75. Data for pan coefficients of 0.65 and 0.70 would fall between these limits. Linear regression analyses were performed to obtain best-fit representations of the data and to determine if there was any correlation between the calculated and measured volume change. The regression analyses indicate a good correlation, and the figure shows the best-fit lines for the data are nearly parallel to the zero seepage line. The shift to the right may be interpreted as the amount of weekly seepage.

Figure 7 presents average daily seepage and apparent infiltration values over the seepage test for the four pan coefficients considered. The data for May 5 through July 11 were combined because the retention pond water level readings were taken with less precision during this period. The apparent, sudden development of seepage on July 18 is due to averaging the data before July 11, which eliminated the high and low peaks. Figure 7 indicates that the pan coefficient must have been less than 0.60 during the first part of the seepage test and that all the pan coefficients yield positive seepage values during the latter part of the test. The seepage values for the periods August 15 to 22 and August 29 to September 5 are probably higher than shown because heavy precipitation during these periods probably caused splash-out from the pan that was recorded as evaporation.

The results of the seepage calculations and various methods of presentation show little seepage loss from the retention pond. Table 12 presents a summary of the seepage calculations for the four pan coefficients and the two time periods considered. The data were converted to the amounts of seepage for the 30-day design period that the UHS retention pond would have to supply water to the Essential Service Water System. It is our opinion that the coefficient may be as low as 0.60 for the overall seepage test period and may be as low as 0.65 for the period July 11 through September 26, 1980. This would indicate seepage to be on the order of 0.25 to 0.4 acre-foot in 30 days. If the pan coefficient were as low as 0.60 during the period July 11 through September 26, the worst case seepage, as shown on Figure 7, is approximately 0.03 acre-foot per day or 0.9 acre-foot for 30 days.

3.3.2 Flow Net Analyses

Bechtel Power Corporation performed flow net analyses during their soils engineering studies for the UHS retention pond (Bechtel, 1977). We did not perform additional flow net analyses for this investigation; however, the field permeability test data from this study provide additional data by which the analyses performed by Bechtel can be reevaluated. Based on the data available when Bechtel performed their analyses, a conservative value of 2×10^{-5} centimeters per second (cm/sec) was used for the coefficient of permeability of the soil surrounding the pond. Their flow net analyses yielded a total seepage loss of 0.8 to 1.3 acre-feet for 30 days. The seepage test was performed to determine the actual seepage from the retention pond and does not require the same conservativeness as the Bechtel design study. The field permeability test results from the five observation wells surrounding the pond are presented in Table 9. If it is assumed that a realistic average value for the coefficient of permeability of the soil surrounding the pond is $4x10^{-6}$ cm/sec, the seepage values determined by Bechtel can be adjusted by a linear proportion of $4x10^{-6}$ to $2x10^{-5}$, or 1/5. This results in total seepage values of 0.16 to 0.26 acre-foot for 30 days.

3.4 SEEPAGE TEST CONCLUSIONS

Both the water budget and flow net analyses indicate very little seepage from the UHS retention pond. Our evaluation of the data indicates that seepage during the test was less than 0.5 acre-foot for 30 days and probably on the order of 0.3 acre-foot for 30 days. A seepage loss of 0.5 acre-foot would result in a 1.5-inch drop in the retention pond water level from the normal pond operating level. The worst-case conditions yielded seepage less than 1 acre-foot for 30 days. The amount of seepage determined from the seepage test is much less than that allowed in sizing the pond. The "UHS Retention Pond, Soils Engineering Studies" report (Bechtel, 1977) states that the pond was sized for 5 acre-feet of seepage loss in 30 days.

4.0 ENGINEERING INSPECTIONS

4.1 GENERAL

The behavior of the UHS retention pond was monitored throughout the 5-month period of the seepage test, and one final inspection was performed on November 4, 1980. The behavior of the pond was monitored by visual observations, surveys of the movement monuments, and measurements of the ground water levels in the observation wells. Visual inspections of the pond were conducted tw'ce a week and ground water levels were recorded once a week during the seepage test by a Daniel International Corporation (DIC) civil engineer. Dames & Moore soils engineers visually inspected the pond every 2 weeks from May 5 through June 16, 1980 and then at monthly intervals until the end of the seepage test. One final inspection was performed on November 4, 1980. The movement monuments were surveyed by DIC field engineers at weekly intervals until July 14 and then every 2 weeks until the end of the seepage test.

The following sections of this report present the results of the engineering inspection of the pond.

4.2 RESULTS OF VISUAL INSPECTIONS

4.2.1 Riprap

No movement or erosion of the riprap was noted during the inspections. There was no evidence of filter bed exposure in any areas. There was no evidence of movement or slumping of the riprap that might indicate possible slope instability.

4.2.2 Ground Surface Surrounding Pond

The ground surface surrounding the retention pond was inspected to a distance of 80 feet from the pond, where possible, and no evidence of subsidence or cracking was noted that might indicate possible slope instability. There were no areas where any significant erosion had developed around the pond.

4.2.3 Seepage Under Outlet Structure

A small amount of apparent seepage was noted at the south end of the outlet structure. The outlet channel had not been excavated during the period of the seepage test, and a small pond of water always remained trapped in a small excavated area south of the outlet structure, even in periods of no precipitation. A Union Electric Company civil engineer performed a surveillance of this area for 2-1/2 weeks and determined that the quantity of seepage was less than 10 gallons per day. There could be no exact determination of whether the seepage water was from the retention pond or drainage from the soil between periods of precipitation. It was also not possible to determine whether the seepage was from the soil or from the coarse filter material under the outlet structure.

It is our opinion that the seepage may be from the retention pond but that it is not significant to the performance of the pond. The quantity of seepage is very small, less than 40 cubic feet in 30 days. The filter cloth and coarse filter material under the outlet structure will prevent the development of any piping. Union Electric Company and Dames & Moore will continue to monitor the seepage for any change in flow.

4.2.4 Outlet Channel

The outlet channel had not been excavated during the period of the seepage test, but rough excavation had been completed by November 4, 1980. The channel needed some final grading and needed to be lined with riprap. The riprap and filter material had not been placed on the south side of the outlet structure. It is our understanding that the work on the outlet channel was completed in January 1981.

4.2.5 Impounded Water

The water in the retention pond was clear throughout the period of the inspections.

4.3 RESULTS OF MOVEMENT MONUMENT SURVEYS

The results of the movement monument surveys are presented in Table 13. This table presents the results of all surveys performed to date, beginning with the Preservice Inspection. Some movements are indicated, but most of the movement is probably due to limitations in survey accuracy. The data do not indicate any significant horizontal or vertical movements.

4.4 RESULTS OF GROUND WATER LEVEL READINGS

The ground water levels measured in the five observation wells surrounding the pond are shown on Figure 3, plotted against the date of measurement. All data are presented from when measurements were started during the Preservice Inspection. Only OW5 had come to near equilibrium by the start of the seepage test. The other observation wells came to near equilibrium during July and August. As of November 4, 1980, the ground water level around the pond varied in the narrow range of elevations from 829 to 832 feet. The normal pond operating level is elevation 836 feet.

4.5 INSPECTION RECORDS

The original Dames & Moore inspection sheets are retained in our files. Photographs taken to document our visual observations are presently retained in our files and will be transmitted to Union Electric Company at a later date. Copies of inspection sheets prepared by Daniel International Corporation have been provided to us and will be retained in our files.

4.6 ENGINEERING INSPECTION CONCLUSIONS

No areas of distress were noted during visual inspection of the UHS retention pond, and no excessive movements were indicated by the movement monument survey data. The retention pond water was clear, and the water levels around the pond appear to have reached equilibrium. All observations indicate that the retention pond is behaving normally.

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5.0 REFERENCES CITED

Bechtel Power Corporation, 1977, Ultimate heat sink retention pond, soils engineering studies, Callaway Plant units 1 & 2, Missouri: Bechtel Power Corporation, Gaithersburg, Maryland (September).

Dames & Moore, 1980a, Results of preservice inspection, ultimate heat sink retention pond, Callaway Plant, units 1 and 2: Dames & Moore, Park Ridge, Illinois (June 20).

_____, 1980b, Results of inspection during filling, ultimate heat sink retention pond, Callaway Plant, units 1 and 2: Dames & Moore, Park Ridge, Illinois (August 19).

_____, 1980c, Results of detailed excavation mapping, ultimate heat sink area, essential service water system, and unit 1 power block subgrade, Callaway Plant, units 1 and 2: Dames & Moore, Park Ridge, Illinois (July 29).

_____, 1980d, Procedure for seepage test, ultimate heat sink retention pond, Callaway Plant, units 1 and 2; revision 3: Dames & Moore, Park Ridge, Illinois (July 16).

Kohler, M.A., Nordenson, T.J., and Fox, W.E., 1955, Evaporation from pans and lakes: U.S. Department of Commerce, Technical Paper No. 38, U.S. Government Printing Office, Washington, D.C. (May).

Miller, R., 1981, Superintendent of main terrace, Osage plant (Bagnell Dam), Union Electric Company: Personal communication (January 22).

National Oceanic and Atmospheric Administration, 1980, Climatological data: NOAA, Environmental Data and Information Service, National Climatic Center, Asheville, North Carolina, vol. 84, no. 5-9 (May-September).

U.S. Department of Commerce, 1968, Climatic atlas of the United States: U.S. Government Printing Office, Washington, D.C. (June).

U.S. Geological Survey, 1952, Water-loss investigations; volume 1 - Lake Hefner studies technical report; professional paper 229: U.S. Government Printing Office, Washington, D.C., 153 p.

U.S. Weather Bureau, 1959, Evaporation maps for the United States, technical paper no. 37: U.S. Government Printing Office, Washington, D.C., 13 p. with maps.

TABLE 1

METEOROLOGICAL EQUIPMENT

PARAMETER	INSTRUMENT	MANUFACTURER	MODEL	COMMENTS
Evaporation	Evaporation Pan	Weather Measure	E810	Equipped with: a) still well b) hook gauge c) max/min thermometer d) contact anemometer
Precipitation (continuous)	Tipping Bucket Rain Gauge	Weather Measure	501-I	Resolution 0.01"; mounted inside a wind screen
Precipitation (noncontinuous)	Rain Gauge	Weather Measure	P562	Resolution 0.01"; mounted inside a wind screen
Wind Run	Contact Anemometer	Weather Measure	W164B	

TABLE 2

SUMMARY OF WEEKLY PRECIPITATION AND EVAPORATION

DATA PERIOD	PRECIPITATION (inches)	PAN EVAPORATION (inches)
4/14 - 4/18[a]	0.29	0.49
4/18 - 4/25	0.00	2.11
4/25 - 4/30[b]	0.00	0.94
4/30 - 5/5[b]	0.00	1.05
-------------START OF SEEPAGE TEST------------		
5/5 - 5/9[a]	0.00	1.27
5/9 - 5/16	1.52	1.54
5/16 - 5/23	0.53	1.06
5/23 - 5/30	0.13	1.71
5/30 - 6/6	1.61	2.54
6/6 - 6/13	0.00	2.68
6/13 - 6/20	0.00	2.36
6/20 - 6/27	0.89	1.71
6/27 - 7/3[c]	1.66	2.48
7/3 - 7/11[d]	0.00	3.14
7/11 - 7/18	0.00	3.40
7/18 - 7/25	0.32	2.55
7/25 - 8/1	0.61	2.44
8/1 - 8/8	0.97	1.62
8/8 - 8/15	0.33	2.34
8/15 - 8/22	2.15	2.33
8/22 - 8/29	0.00	2.37
8/29 - 9/5	2.25	1.67
9/5 - 9/12	0.02	1.87
9/12 - 9/19	0.72	1.62
9/19 - 9/26	0.16	1.58
Total during Seepage Test	13.87	44.28

[a]4-day period.

[b]5-day period.

[c]6-day period.

[d]8-day period.

TABLE 3

EVAPORATION MEASUREMENTS

MONTH	PAN EVAPORATION (inches)		
	CALLAWAY SITE	NEW FRANKLIN NEAR BOONVILLE[a]	LAKESIDE (BAGNELL DAM) NEAR LAKE OZARK[a]
May[b]	5.58	5.08	4.30
June	10.70	9.22	6.34
July	11.68	13.20	9.64
August	9.58	9.60	7.11
September[c]	6.74	5.58	3.97
Total	44.28	42.68	31.36

[a]National Oceanic and Atmospheric Administration, 1980.

[b]Beginning May 5.

[c]Ending September 26.

TABLE 4

SUMMARY OF METEOROLOGICAL PARAMETERS FOR COLUMBIA, MISSOURI

	WIND SPEED			TEMPERATURE			DEW POINT TEMPERATURE		
	MONTHLY AVERAGE			MONTHLY AVERAGE			MONTHLY AVERAGE		
MONTH	1980 (mph)	HISTORICAL DATA RECORD[a] (mph)	DEVIATION FROM AVERAGE (mph)	1980[b] (°F)	HISTORICAL DATA RECORD (°F)	DEVIATION FROM AVERAGE[b] (°F)	1980 (°F)	HISTORICAL DATA RECORD[a] (°F)	DEVIATION FROM AVERAGE (oF)
May	7.6	10	-2.4	64.3	64.4	-0.1	51	52	-1
June	9.0	9	0.0	75.3	73.0	+2.3	68	62	+6
July	9.3	8	+1.3	87.0	77.3	+9.7	63	66	-3
August	8.8	8	+0.8	81.7	76.0	+5.7	63	64	-1
September	9.1	9	+0.1	69.9	68.3	+1.6	--[d]	55	--[d]

[a]U.S. Department of Commerce, 1968.

[b]National Oceanic and Atmospheric Administration, 1980. Data record from 1941 through 1970.

[c]U.S. Department of Commerce, 1968; 20-year data record.

[d]Data are not available.

TABLE 5

SUMMARY OF THE NUMBER OF DAYS DURING WHICH THE MAXIMUM TEMPERATURE AT COLUMBIA, MISSOURI EQUALED OR EXCEEDED 90°F

MONTH	NUMBER OF DAYS MAXIMUM TEMPERATURE EQUALED OR EXCEEDED 90°F: 1980	NUMBER OF DAYS MAXIMUM TEMPERATURE EQUALED OR EXCEEDED 90°F: HISTORICAL DATA*	DEPARTURE FROM NORM
May	0	1	- 1
June	11	8	+ 3
July	28	14	+14
August	27	14	+13
September	8	6	+ 2
Total	74	43	+31

*U.S. Department of Commerce, 1968; 27-year data record.

TABLE 6

PRECIPITATION MEASUREMENTS

MONTH	PRECIPITATION CALLAWAY 1980 (inches)	COLUMBIA 1980 (inches)	COLUMBIA HISTORICAL[a] (inches)
May	2.18	3.36	4.68
June	2.50	0.35	4.59
July	2.59	1.39	3.89
August	3.45	2.98	3.19
September	3.15[b]	1.93	4.39
Total	13.87	10.01	20.74

[a] Data recorded from 1941 through 1970 (National Oceanic and Atmospheric Administration, 1980).

[b] Measurements terminated on September 26, 1980.

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TABLE 7

SUMMARY OF WIND RUN DATA

DATA PERIOD	EVAPORATION PAN (miles)	WIND RUN SOUTHEAST ANEMOMETER (miles)	NORTHWEST ANEMOMETER (miles)	SOUTHWEST ANEMOMETER (miles)	NORTHEAST ANEMOMETER (miles)
7/18 - 7/25	23.4	51.4	49.6	-	-
7/25 - 8/1	23.8	42.4	51.4	-	-
8/1 - 8/8	30.7	62.9	58.0	-	-
8/8 - 8/15	30.0	47.0	54.3	-	-
8/15 - 8/22	36.4	-	-	28.7	10.9
8/22 - 8/29	41.5	-	-	19.0	19.5
8/29 - 9/5	48.0	-	-	28.6	26.3
9/5 - 9/12	43.5	-	-	14.7	31.4
9/12 - 9/19	52.1	-	-	28.9	34.1
9/19 - 9/26	61.9	-	-	30.4	33.2

TABLE 8

WEEKLY CHANGE IN UHS RETENTION POND WATER LEVEL

DATA PERIOD	MEASURED CHANGE IN WATER LEVEL[a] (inches)	CALCULATED CHANGE IN WATER LEVEL WITH ZERO SEEPAGE (inches) PAN COEFFICIENT = 0.75	PAN COEFFICIENT = 0.70	PAN COEFFICIENT = 0.65	PAN COEFFICIENT = 0.60
5/5 - 5/9[b]	- 1.20	- 0.96	- 0.89	- 0.82	- 0.76
5/9 - 5/16	+ 2.40 (5/9 - 5/23)	+ 0.75	+ 0.83	+ 0.90	+ 0.99
5/16 - 5/23		- 0.13	- 0.08	- 0.03	+ 0.02
5/23 - 5/30	- 1.20	- 1.12	- 1.04	- 0.95	- 0.86
5/30 - 6/6	+ 1.20	+ 0.12	+ 0.24	+ 0.36	+ 0.50
6/6 - 6/13		- 2.01	- 1.87	- 1.74	- 1.60
6/13 - 6/20		- 1.78	- 1.65	- 1.54	- 1.42
6/20 - 6/27	- 4.56 (6/6 - 7/11)	- 0.16	- 0.07	+ 0.01	+ 0.09
6/27 - 7/3[c]		+ 0.23	+ 0.35	+ 0.48	+ 0.60
7/3 - 7/11[d]		- 2.36	- 2.20	- 2.04	- 1.88
7/11 - 7/18	- 2.16	- 2.56	- 2.38	- 2.21	- 2.04
7/18 - 7/25	- 1.80	- 1.51	- 1.38	- 1.25	- 1.12
7/25 - 8/1	- 1.08	- 1.06	- 0.93	- 0.81	- 0.69
8/1 - 8/8	- 0.36	+ 0.02	+ 0.10	+ 0.19	+ 0.27
8/8 - 8/15	- 1.44	- 1.33	- 1.21	- 1.11	- 0.98
8/15 - 8/22	+ 1.32	+ 1.01	+ 1.11	+ 1.24	+ 1.35
8/22 - 8/29	- 1.80	- 1.78	- 1.66	- 1.54	- 1.42
8/29 - 9/5	+ 1.68	+ 1.62	+ 1.71	+ 1.79	+ 1.87
9/5 - 9/12	- 1.44	- 1.38	- 1.29	- 1.19	- 1.10
9/12 - 9/19	- 0.72	- 0.29	- 0.22	- 0.13	- 0.04
9/19 - 9/26	- 1.44	- 0.99	- 0.90	- 0.82	- 0.75
Total	-12.60	-15.67	-13.43	-11.21	- 8.97

[a]Measurements of water level were taken twice a week to a precision of 0.1 foot until July 11, 1980. Thereafter, readings were taken three times a week and to a precision of 0.01 foot. The water level was at elevation 835.9 feet (835'11") at the start of the seepage test.

[b]4-day period.

[c]6-day period.

[d]8-day period.

TABLE 9

FIELD PERMEABILITY TEST RESULTS

OBSERVATION WELL NUMBER	COEFFICIENT OF PERMEABILITY (centimeters/second)
OW1	4.0×10^{-6}
OW2	3.0×10^{-7}
OW3	2.9×10^{-6}
OW4	1.7×10^{-7}
OW5	9.6×10^{-6}
Numerical Average	3.4×10^{-6}

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TABLE 10

PAN COEFFICIENT DATA FOR LAKESIDE (BAGNELL DAM) NEAR LAKE OZARK, MISSOURI[a]

MONTH	PAN COEFFICIENT[b]
January	1.08
February	0.81
March	0.55
April	0.53
May	0.57
June	0.60
July	0.58
August	0.69
September	0.69
October	0.69
November	0.71
December	1.03
Yearly Average	0.71

[a]Miller, 1981.

[b]The pan is heated, if necessary, to prevent freezing during the period November through March. Therefore, the average yearly pan coefficient is not considered representative by the National Weather Bureau.

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TABLE 11

CHANGE IN UHS RETENTION POND WATER VOLUME

DATA PERIOD	MEASURED CHANGE IN WATER VOLUME (acre-feet)	CALCULATED CHANGE IN WATER VOLUME WITH ZERO SEEPAGE (acre-feet)			
		PAN COEFFICIENT = 0.75	PAN COEFFICIENT = 0.70	PAN COEFFICIENT = 0.65	PAN COEFFICIENT = 0.60
5/5 - 7/11	- 1.11	- 2.45	- 2.11	- 1.77	- 1.43
7/11 - 7/18	- 0.71	- 0.84	- 0.78	- 0.73	- 0.67
7/18 - 7/25	- 0.59	- 0.49	- 0.45	- 0.41	- 0.37
7/25 - 8/1	- 0.35	- 0.34	- 0.30	- 0.26	- 0.22
8/1 - 8/8	- 0.12	+ 0.01	+ 0.03	+ 0.06	+ 0.09
8/8 - 8/15	- 0.47	- 0.43	- 0.39	- 0.36	- 0.32
8/15 - 8/22	+ 0.43	+ 0.33	+ 0.36	+ 0.40	+ 0.44
8/22 - 8/29	- 0.58	- 0.58	- 0.54	- 0.50	- 0.46
8/29 - 9/5	+ 0.55	+ 0.53	+ 0.56	+ 0.58	+ 0.61
9/5 - 9/12	- 0.47	- 0.45	- 0.42	- 0.39	- 0.36
9/12 - 9/19	- 0.23	- 0.09	- 0.07	- 0.04	- 0.02
9/19 - 9/26	- 0.46	- 0.32	- 0.29	- 0.26	- 0.24
Total	- 4.11	- 5.12	- 4.40	- 3.68	- 2.95

NOTES:

1. The volume change from 5/5 to 7/11 was combined because measurements of water surface elevation were recorded to 0.1 foot during this period. Beginning 7/11, the readings were taken with more precision to 0.01 foot.
2. The difference between measured and calculated volume change would yield the seepage or apparent infiltration.

TABLE 12

SUMMARY OF SEEPAGE CALCULATIONS

PAN COEFFICIENT	30-DAY SEEPAGE (acre-foot) DATA PERIOD 5/5/80 TO 9/26/80	DATA PERIOD 7/11/80 TO 9/26/80
0.75	-0.21*	0.13
0.70	-0.06*	0.28
0.65	0.09	0.42
0.60	0.24	0.58

*Apparent infiltration.

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TABLE 13

MOVEMENT MONUMENT DATA

MONUMENT NUMBER	DATE OF SURVEY				
	2-19-80	2-26-80	3-10-80	3-14-80	3-18-80
BM1	N 100430.80 E 99446.22 El. 2001.309	N 100430.81 E 99446.23 El. 2001.315	N 100430.81 E 99446.20 El. 2001.317	N 100430.83 E 99446.20 El. 2001.328	N 100430.82 E 99446.21 El. 2001.314
BM2	N 100093.01 E 99445.88 El. 2000.575	N 100093.01 E 99445.88 El. 2000.572	N 100093.01 E 99445.88 El. 2000.577	N 100093.01 E 99445.88 El. 2000.578	N 100093.01 E 99445.88 El. 2000.576
BM3	N 99913.10 E 99220.88 El. 1999.981	N 99913.12 E 99220.86 El. 1999.987	N 99913.09 E 99220.87 El. 1999.987	N 99913.10 E 99220.89 El. 1999.987	N 99913.10 E 99220.89 El. 1999.987
BM4	N 100169.97 E 99090.96 El. 2001.744	N 100170.01 E 99090.97 El. 2001.751	N 100169.97 E 99090.96 El. 2001.752	N 100169.97 E 99090.95 El. 2001.758	N 100169.96 E 99090.94 El. 2001.751
BM5	N 100441.92 E 99091.16 El. 2003.284	N 100441.95 E 99091.17 El. 2003.293	N 100441.93 E 99091.20 El. 2003.293	N 100441.94 E 99091.19 El. 2003.301	N 100441.94 E 99091.19 El. 2003.292
BM6	N 100616.75 E 99271.24 El. 2002.854	N 100616.75 E 99271.24 El. 2002.859	N 100616.75 E 99271.24 El. 2002.861	N 100616.75 E 99271.24 El. 2002.872	N 100616.75 E 99271.24 El. 2002.861
BM7	N 100300.06 E 99471.81 El. 2001.978	N 100300.01 E 99471.72 El. 2001.985	N 100300.04 E 99471.74 El. 2001.986	N 100300.02 E 99471.74 El. 2001.996	N 100300.01 E 99471.74 El. 2001.982
BM8	N 100223.91 E 99417.76 El. 2001.988	N 100223.90 E 99417.72 El. 2001.999	N 100223.97 E 99417.76 El. 2002.000	N 100223.98 E 99417.77 El. 2002.010	N 100223.97 E 99417.75 El. 2001.993
BM9	N 99938.76 E 99271.22 El. 1995.980	N 99938.77 E 99271.21 El. 1995.987	N 99938.77 E 99271.23 El. 1995.985	N 99938.77 E 99271.23 El. 1995.986	N 99938.77 E 99271.23 El. 1995.986
BM10	N 100100.11 E 99121.75 El. 2001.532	N 100100.12 E 99121.71 El. 2001.538	N 100100.08 E 99121.79 El. 2001.539	Inaccessible (see Note 4)	N 100100.09 E 99121.78 El. 2001.538

Notes:

1. N indicates north coordinate; E indicates east coordinate; El. indicates elevation of movement monument.
2. Elevation given with respect to SNUPPS datum. Subtract 1159.5 from value given to obtain MSL equivalent.
3. See Figure 1 for locations of the movement monuments.
4. BM10 inaccessible on 3-14-80 due to construction activity.

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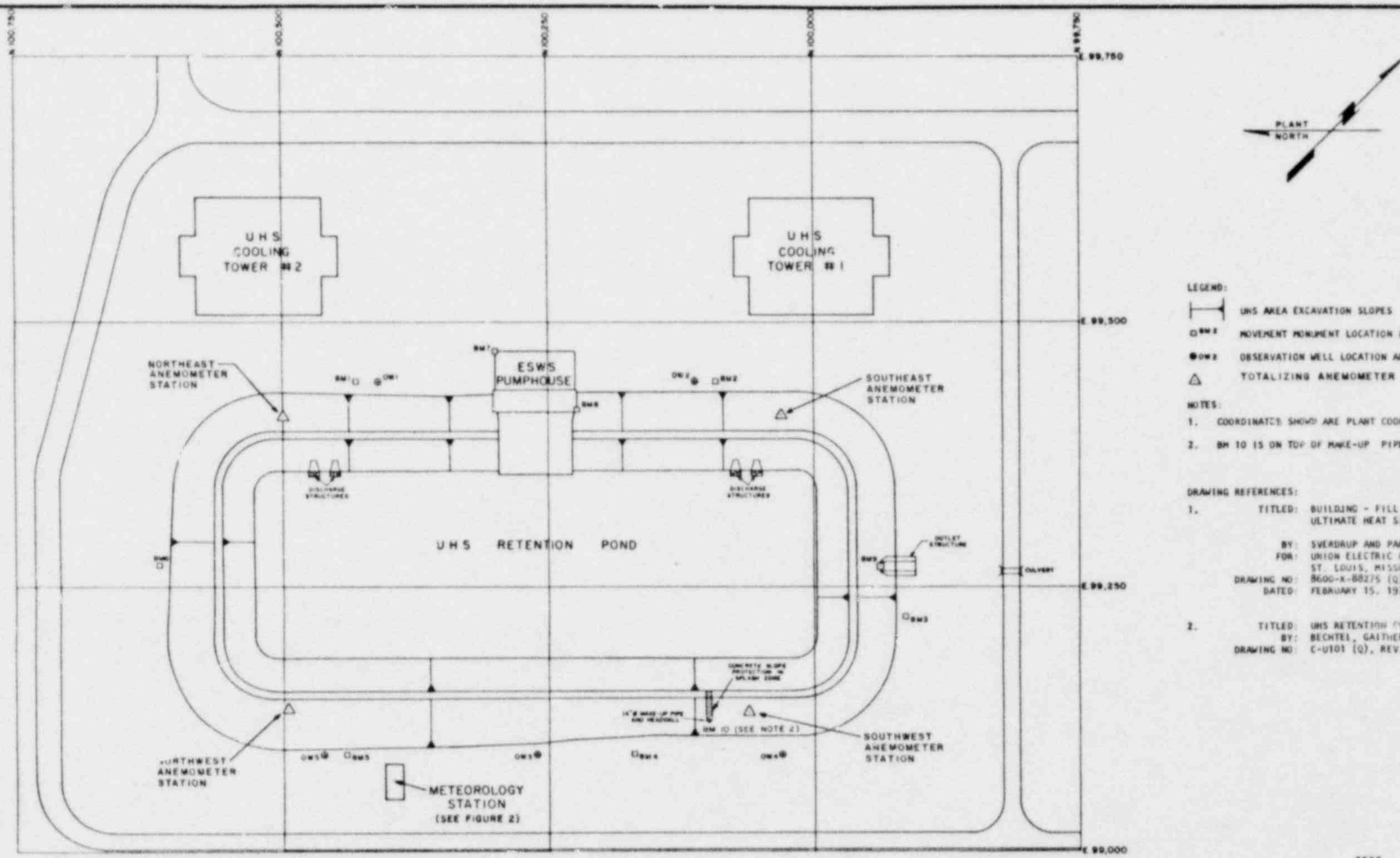
MONUMENT NUMBER	DATE OF SURVEY				
	3-26-80	3-31-80	4-7-80	4-10-80	5-5-80
BM1	N 100430.83 E 99446.20 El. 2001.313	N 100430.82 E 99446.21 El. 2001.318	N 100430.82 E 99446.19 El. 2001.318	N 100430.82 E 99446.21 El. 2001.313	N 100430.81 E 99446.20 El. 2001.322
BM2	N 100093.01 E 99445.88 El. 2000.57	N 100093.01 E 99445.89 El. 2000.569	N 100093.01 E 99445.88 El. 2000.571	N 100093.01 E 99445.88 El. 2000.573	N 100093.01 E 99445.89 El. 2000.577
BM3	N 99913.10 E 99220.89 El. 1999.980	N 99913.10 E 99220.89 El. 1999.985	N 99913.10 E 99220.89 El. 1999.983	N 99913.10 E 99220.88 El. 1999.983	N 99913.09 E 99220.88 El. 1999.992
BM4	N 100169.96 E 99090.95 El. 2001.748	N 100169.97 E 99090.95 El. 2001.748	N 100169.96 E 99090.95 El. 2001.752	N 100169.97 E 99090.95 El. 2001.749	N 100169.96 E 99090.96 El. 2001.754
BM5	N 100441.93 E 99091.19 El. 2003.290	N 100441.94 E 99091.20 El. 2003.292	N 100441.93 E 99091.20 El. 2003.295	N 100441.92 E 99091.14 El. 2003.295	N 100441.91 E 99091.18 El. 2003.305
BM6	N 100616.75 E 99271.24 El. 2001.859	N 100616.77 E 99271.26 El. 2001.861	N 100616.75 E 99271.24 El. 2002.860	N 100616.75 E 99271.24 El. 2002.863	N 100616.77 E 99271.28 El. 2002.869
BM7	N 100300.00 E 99471.74 El. 2001.977	N 100300.01 E 99471.75 El. 2001.980	N 100300.01 E 99471.74 El. 2001.978	N 100300.01 E 99471.74 El. 2001.973	N 100300.01 E 99471.74 El. 2001.976
BM8	N 100223.97 E 99417.74 El. 2001.987	N 100223.98 E 99417.74 El. 2001.996	N 100223.98 E 99417.73 El. 2001.986	N 100223.99 E 99417.72 El. 2001.980	N 100223.97 E 99417.74 El. 2001.987
BM9	N 99938.77 E 99271.23 El. 1995.980	N 99938.77 E 99271.23 El. 1995.984	N 99938.77 E 99271.23 El. 1995.981	N 99938.77 E 99271.23 El. 1995.983	N 99938.76 E 99271.24 El. 1995.996
BM10	N 100100.08 E 99121.77 El. 2001.533	N 100100.10 E 99121.77 El. 2001.537	N 100100.06 E 99121.77 El. 2001.538	N 100100.09 E 99121.77 El. 2001.536	N 100100.07 E 99121.78 El. 2001.544

MONUMENT NUMBER	DATE OF SURVEY				
	5-12-80	5-19-80	5-28-80	6-4-80	6-9-80
BM1	N 100430.79 E 99446.23 El. 2001.337	N 100430.80 E 99446.24 El. 2001.324	N 100430.80 E 99446.25 El. 2001.338	N 100430.82 E 99446.22 El. 2001.323	N 100430.80 E 99446.27 El. 2001.331
BM2	N 100092.98 E 99445.89 El. 2000.578	N 100092.99 E 99445.89 El. 2000.576	N 100093.01 E 99445.89 El. 2000.579	N 100093.01 E 99445.89 El. 2000.569	N 100092.99 E 99445.91 El. 2000.579
BM3	N 99913.09 E 99220.89 El. 1999.996	N 99913.10 E 99220.89 El. 1999.991	N 99913.11 E 99220.90 El. 2000.001	N 99913.10 E 99220.88 El. 1999.988	N 99913.09 E 99220.89 El. 1999.998
BM4	N 100169.97 E 99090.97 El. 2001.762	N 100169.99 E 99090.99 El. 2001.751	N 100169.98 E 99090.96 El. 2001.764	N 100169.99 E 99090.97 El. 2001.748	N 100169.97 E 99090.98 El. 2001.758
BM5	N 100441.90 E 99091.16 El. 2003.312	N 100441.93 E 99091.20 El. 2003.304	N 100441.92 E 99091.16 El. 2003.316	N 100441.93 E 99091.16 El. 2003.302	N 100441.93 E 99091.22 El. 2003.311
BM6	N 100616.77 E 99271.29 El. 2002.880	N 100616.81 E 99271.29 El. 2002.869	N 100616.81 E 99271.28 El. 2002.881	N 100616.81 E 99271.28 El. 2002.872	N 100616.81 E 99271.31 El. 2002.877
BM7	N 100300.00 E 99471.75 El. 2001.989	N 100300.00 E 99471.76 El. 2001.97[illegible]	N 100300.00 E 99471.75 El. 2001.987	N 100300.00 E 99471.76 El. 2001.974	N 100300.00 E 99471.77 El. 2001.981
BM8	N 100223.96 E 99417.74 El. 2001.994	N 100223.96 E 99417.75 El. 2001.987	N 100223.96 E 99417.74 El. 2001.996	N 100223.96 E 99417.75 El. 2001.987	N 100223.96 E 99417.75 El. 2001.990
BM9	N 99938.75 E 99271.23 El. 1995.997	N 99938.76 E 99271.23 El. 1995.994	N 99938.77 E 99271.23 El. 1996.004	N 99938.77 E 99271.23 El. 1995.992	N 99938.76 E 99271.24 El. 1996.000
BM10	N 100100.07 E 99121.77 El. 2001.551	N 100100.09 E 99121.78 El. 2001.541	N 100100.09 E 99121.77 El. 2001.555	N 100100.09 E 99121.78 El. 2001.541	N 100100.09 E 99121.78 El. 2001.551

MONUMENT NUMBER	DATE OF SURVEY 6-16-80	6-23-80	6-30-80	7-7-80	7-14-80
BM1	N 100430.81 E 99446.25 El. 2001.334	N 100430.79 E 99446.26 El. 2001.334	N 100430.79 E 99446.26 El. 2001.342	N 100430.78 E 99446.26 El. 2001.329	N 100430.78 E 99446.27 El. 2001.331
BM2	N 100093.02 E 99445.89 El. 2000.581	N 100093.00 E 99445.90 El. 2000.582	N 100093.00 E 99445.90 El. 2000.589	N 100092.99 E 99445.90 El. 2000.583	N 100092.97 E 99445.91 El. 2000.579
BM3	N 99913.10 E 99220.89 El. 1999.996	N 99913.09 E 99220.89 El. 1999.996	N 99913.09 E 99220.89 El. 2000.008	N 99913.10 E 99220.88 El. 1999.999	N 99913.10 E 99220.89 El. 1999.992
BM4	N 100169.98 E 99090.96 El. 2001.759	N 100169.98 E 99090.97 El. 2001.760	N 100169.98 E 99090.98 El. 2001.770	N 100169.998 E 99090.98 El. 2001.759	N 100169.98 E 99090.98 El. 2001.759
BM5	N 100441.93 E 99091.19 El. 2003.316	N 100441.93 E 99091.21 El. 2003.313	N 100441.93 E 99091.20 El. 2003.322	N 100441.92 E 99091.22 El. 2003.314	N 100441.92 E 99091.21 El. 2003.314
BM6	N 100616.82 E 99271.30 El. 2002.881	N 100616.82 E 99271.31 El. 2002.878	N 100616.80 E 99271.31 El. 2002.889	N 100616.80 E 99271.31 El. 2002.877	N 100616.80 E 99271.32 El. 2002.878
BM7	N 100300.01 E 99471.75 El. 2001.982	N 100300.00 E 99471.77 El. 2001.984	N 100300.01 E 99471.77 El. 2001.989	N 100300.01 E 99471.77 El. 2001.979	N 100300.01 E 99471.77 El. 2001.978
BM8	N 100223.97 E 99417.75 El. 2001.991	N 100223.96 E 99417.75 El. 2001.998	N 100223.96 E 99417.76 El. 2001.988	N 100223.96 E 99417.76 El. 2001.990	N 100223.96 E 99417.76 El. 2001.993
BM9	N 99938.77 E 99271.24 El. 1995.999	N 99938.76 E 99271.24 El. 1996.006	N 99938.76 E 99271.24 El. 1996.012	N 99938.76 E 99271.24 El. 1995.004	N 99938.76 E 99271.24 El. 1995.999
BM10	N 100100.10 E 99121.79 El. 2001.551	N 100100.10 E 99121.81 El. 2001.550	N 100100.09 E 99121.80 El. 2001.566	N 100100.10 E 99121.82 El. 2001.551	N 100100.09 E 99121.81 El. 2001.551

MONUMENT NUMBER	DATE OF SURVEY 7-28-80	8-11-80	8-25-80	9-8-80	9-22-80
BM1	N 100430.79 E 99446.27 El. 2001.336	N 100430.78 E 99446.27 El. 2001.346	N 100430.78 E 99446.28 El. 2001.324	N 100430.78 E 99446.28 El. 2001.329	N 100430.78 E 99446.28 El. 2001.329
BM2	N 100093.00 E 99445.89 El. 2000.584	N 100093.00 E 99445.88 El. 2000.583	N 100092.99 E 99445.89 El. 2000.583	N 100092.99 E 99445.90 El. 2000.585	N 100092.98 E 99445.90 El. 2000.585
BM3	N 99913.10 E 99220.88 El. 2000.000	N 99913.10 E 99220.89 El. 1999.998	N 99913.10 E 99220.89 El. 1999.994	N 99913.10 E 99220.89 El. 1999.997	N 99913.10 E 99220.89 El. 1999.997
BM4	N 100169.99 E 99090.98 El. 2001.760	N 100169.99 E 99090.99 El. 2001.772	N 100169.98 E 99090.99 El. 2001.760	N 100169.99 E 99091.00 El. 2001.758	N 100169.98 E 99091.01 El. 2001.758
BM5	N 100441.94 E 99091.22 El. 2003.319	N 100441.93 E 99091.21 El. 2003.330	N 100441.92 E 99091.22 El. 2003.318	N 100441.92 E 99091.22 El. 2003.316	N 100441.93 E 99091.22 El. 2003.316
BM6	N 100616.80 E 99271.32 El. 2002.882	N 100616.80 E 99271.32 El. 2002.896	N 100616.80 E 99271.32 El. 2002.879	N 100616.80 E 99271.32 El. 2002.880	N 100616.80 E 99271.32 El. 2002.880
BM7	N 100300.00 E 99471.78 El. 2001.986	N 100300.00 E 99471.78 El. 2001.994	N 100300.00 E 99471.78 El. 2001.972	N 100300.00 E 99471.78 El. 2001.978	N 100300.01 E 99471.78 El. 2001.978
BM8	N 100223.96 E 99417.76 El. 2002.006	N 100223.95 E 99417.75 El. 2002.005	N 100223.95 E 99417.75 El. 2001.984	N 100223.95 E 99417.75 El. 2001.978	N 100223.95 E 99417.75 El. 2001.989
BM9	N 99938.76 E 99271.24 El. 1996.006	N 99938.76 E 99271.24 El. 1996.005	N 99938.76 E 99271.24 El. 1996.002	N 99938.76 E 99271.24 El. 1006.006	N 99938.76 E 99271.24 El. 1996.006
BM10	N 100100.09 E 99121.81 El. 2001.554	N 100100.09 E 99121.81 El. 2001.565	N 100100.09 E 99121.81 El. 2001.552	N 100100.09 E 99121.81 El. 2001.553	N 100100.08 E 99121.81 El. 2001.553



LEGEND:

- UHS AREA EXCAVATION SLOPES
- MOVEMENT MONUMENT LOCATION AND NUMBER
- OBSERVATION WELL LOCATION AND NUMBER
- TOTALIZING ANEMOMETER STATION

NOTES:

1. COORDINATES SHOWN ARE PLANT COORDINATES.
2. BM 10 IS ON TOP OF MAKE-UP PIPE HEADWALL.

DRAWING REFERENCES:

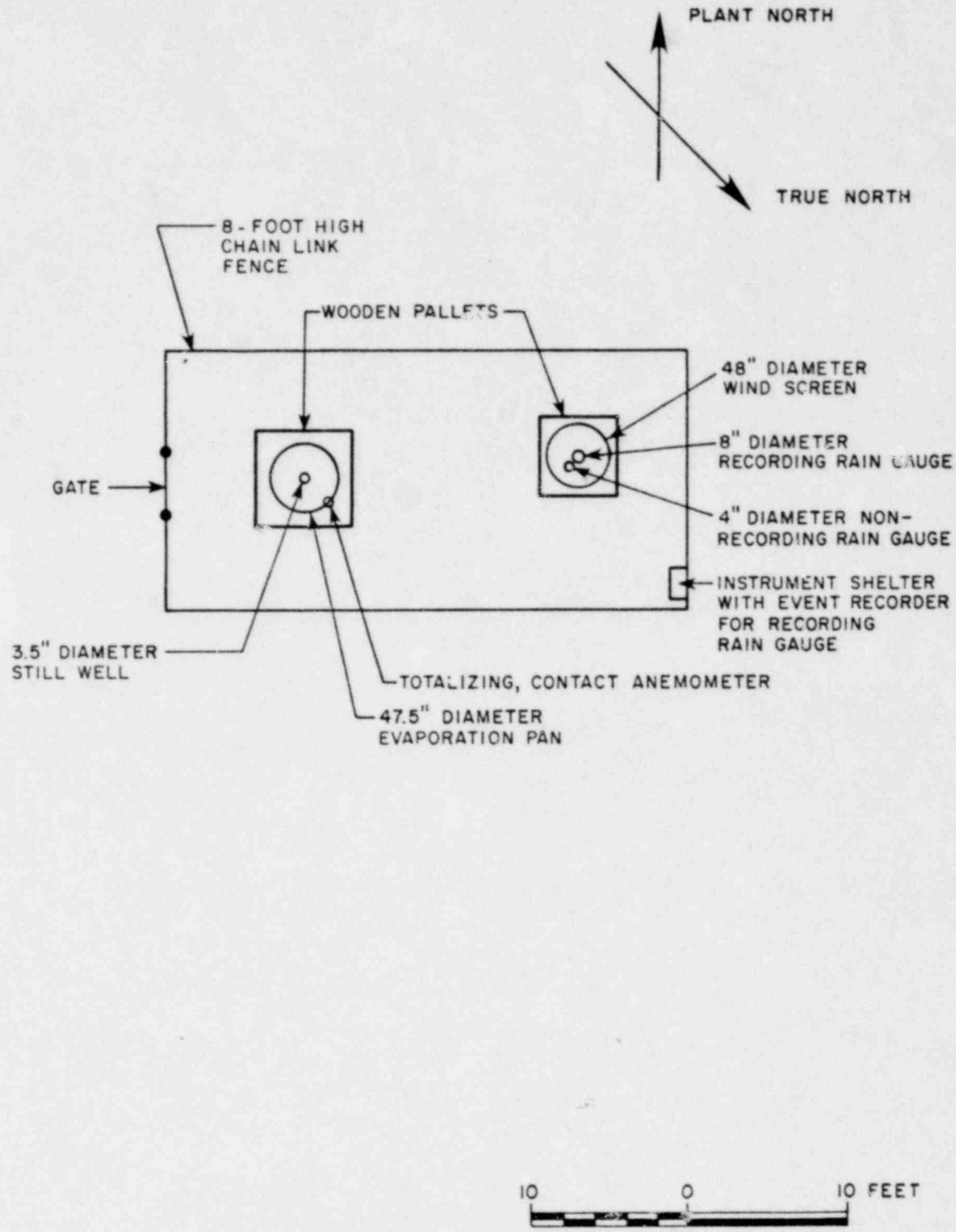
1. TITLED: BUILDING - FILL AND BACKFILL PLAN SHEET ULTIMATE HEAT SINK
   BY: SVERDRUP AND PARCEL AND ASSOCIATES, INC.
   FOR: UNION ELECTRIC COMPANY ST. LOUIS, MISSOURI
   DRAWING NO: 8600-X-88275 (Q), REV. 1
   DATED: FEBRUARY 15, 1977

2. TITLED: UHS RETENTION POND PLAN AND SECTIONS
   BY: BECHTEL, GAITHERSBURG MARYLAND
   DRAWING NO: C-U101 (Q), REV. 4 (UNO)

UNION ELECTRIC COMPANY
CALLAWAY PLANT UNITS 1 AND 2

FIGURE 1
UHS AREA PLAN

7677-097-07



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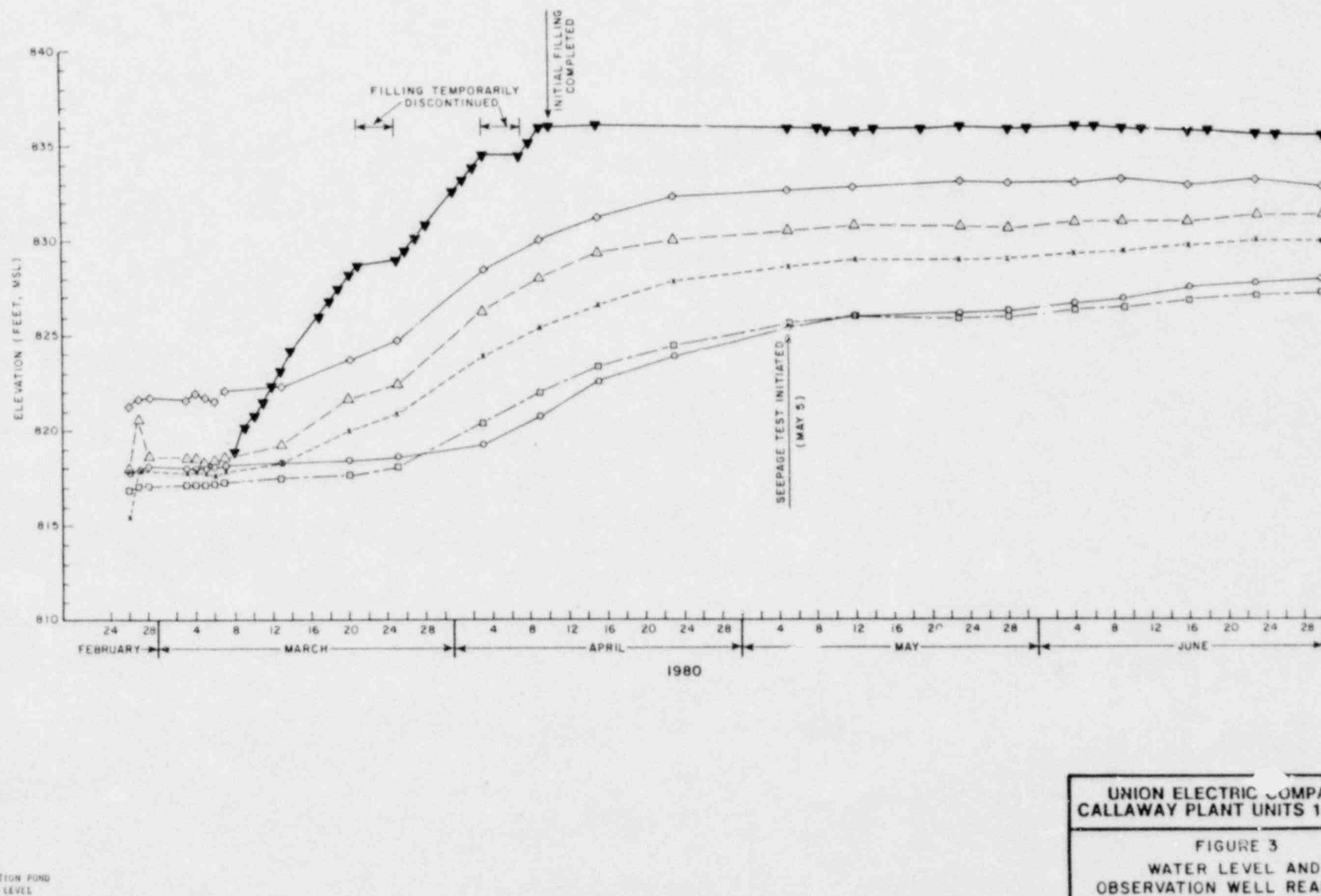
UNION ELECTRIC COMPANY
CALLAWAY PLANT UNITS 1 AND 2

FIGURE 2

METEOROLOGY STATION PLAN

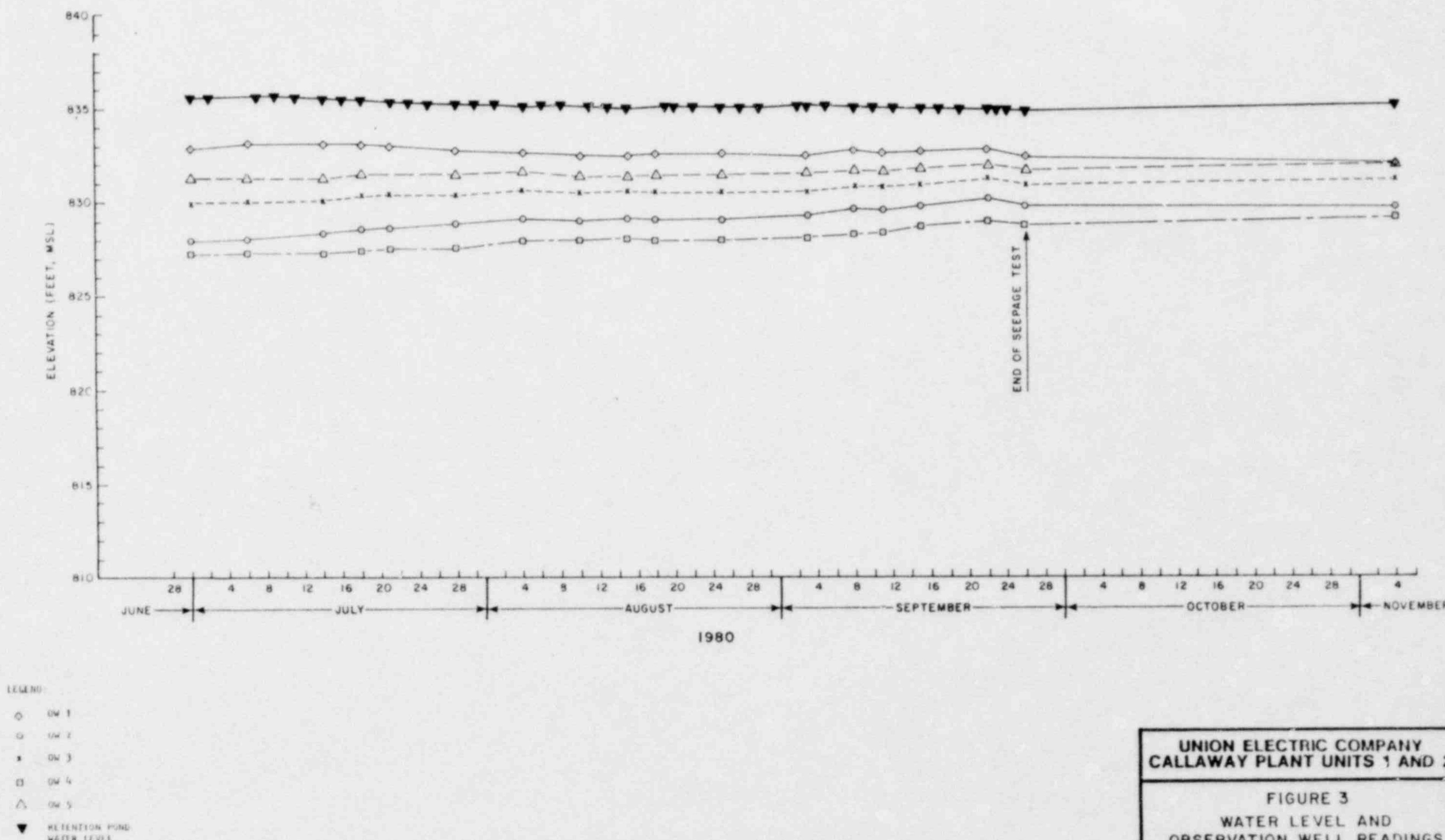
NOTE: SEE FIGURE 1 FOR LOCATION OF METEOROLOGY STATION.



UNION ELECTRIC COMPANY
CALLAWAY PLANT UNITS 1 AND 2

FIGURE 3
WATER LEVEL AND OBSERVATION WELL READINGS
(SHEET 1 OF 2)

7677.097-07



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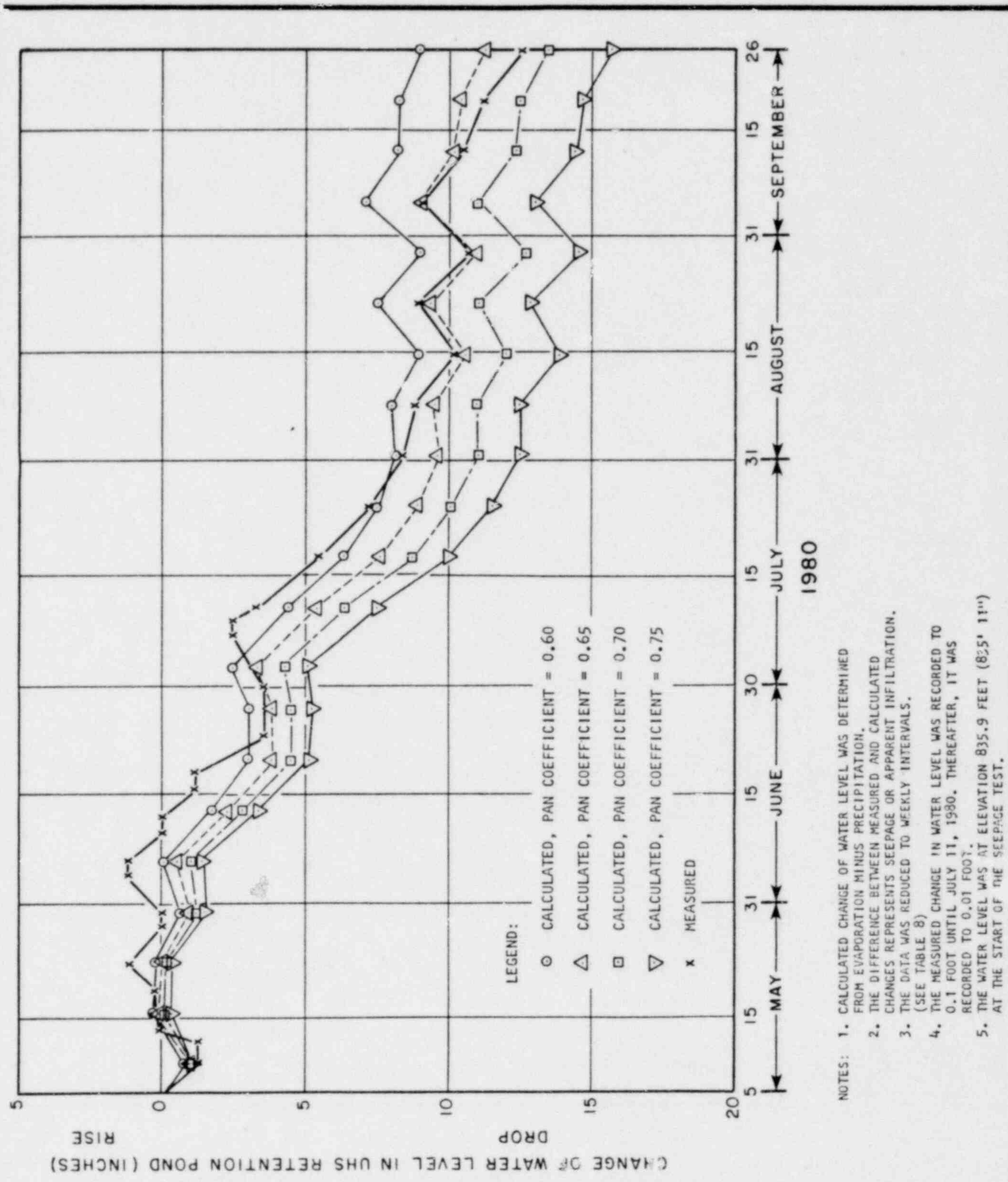
UNION ELECTRIC COMPANY
CALLAWAY PLANT UNITS 1 AND 2

FIGURE 3
WATER LEVEL AND
OBSERVATION WELL READINGS
(SHEET 2 OF 2)

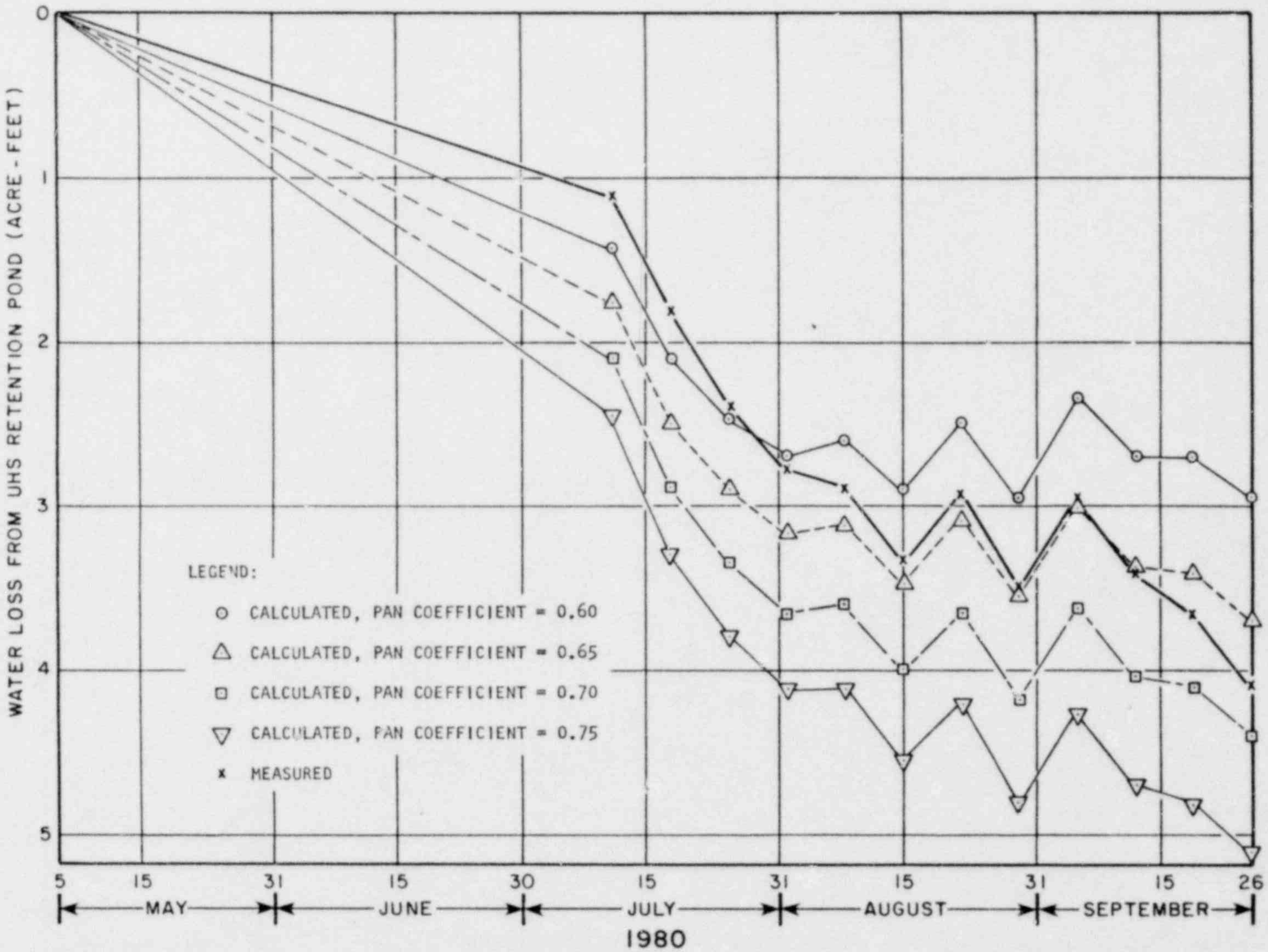
7677-097-07



UNION ELECTRIC COMPANY
CALLAWAY PLANT UNITS 1 AND 2

FIGURE 4
CALCULATED AND MEASURED
CHANGE OF WATER LEVEL

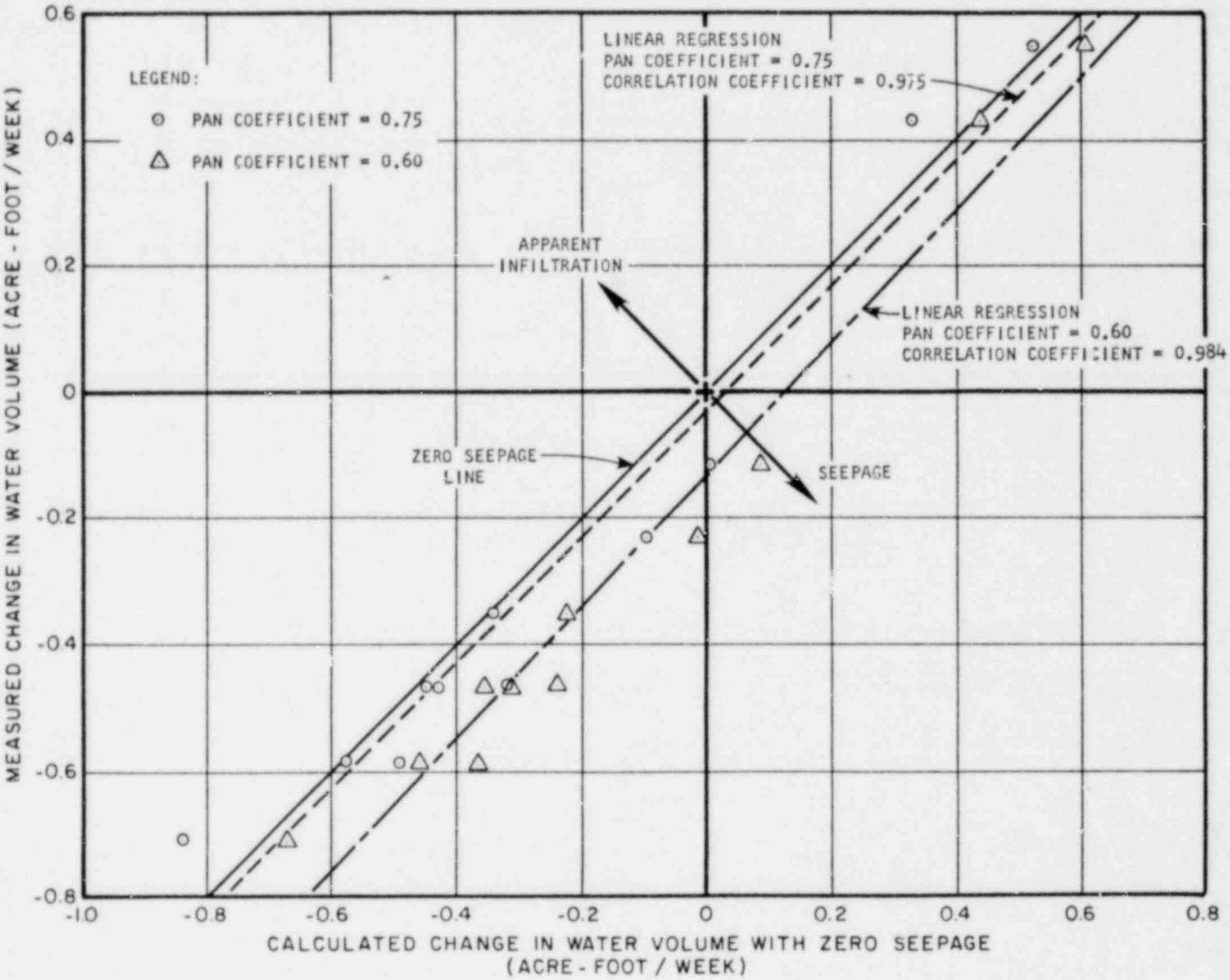
7677-097-07



NOTES:
1. CALCULATED LOSS OF WATER EQUALS EVAPORATION MINUS PRECIPITATION.
2. THE DIFFERENCE BETWEEN MEASURED AND CALCULATED WATER LOSS REPRESENTS SEEPAGE OR APPARENT INFILTRATION.
3. THE DATA WAS REDUCED TO WEEKLY INTERVALS (SEE TABLE 11).
4. WATER LOSS FROM MAY 5 TO JULY 11, 1981 WAS COMBINED BECAUSE RETENTION POND WATER LEVELS WERE RECORDED TO 0.1 FOOT. BEGINNING JULY 11, THE WATER LEVEL WAS READ WITH MORE PRECISION TO 0.01 FOOT.

UNION ELECTRIC COMPANY
CALLAWAY PLANT UNITS 1 AND 2

FIGURE 5
CALCULATED AND
MEASURED WATER LOSS



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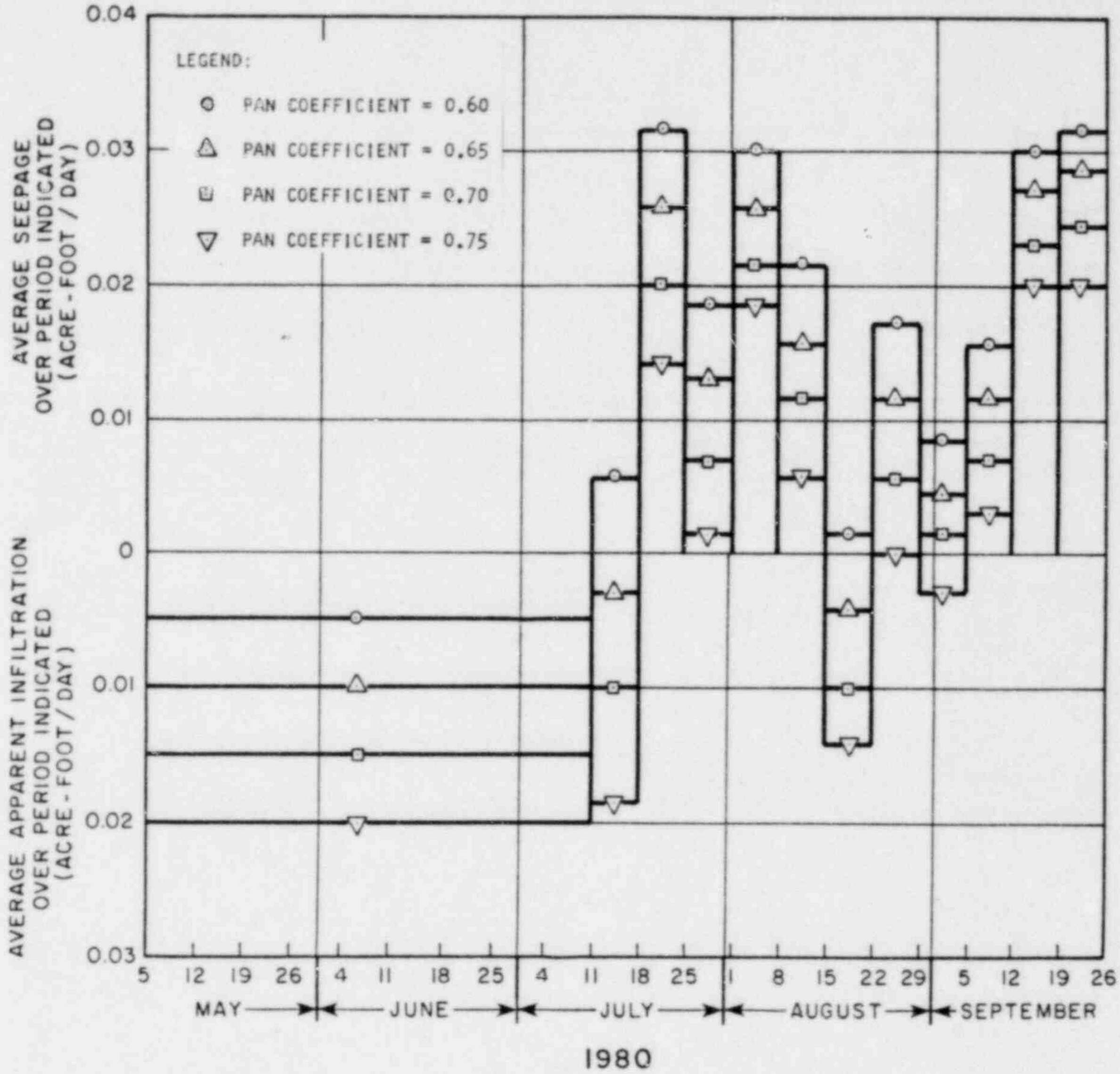
UNION ELECTRIC COMPANY
CALLAWAY PLANT UNITS 1 AND 2

FIGURE 6
MEASURED vs. CALCULATED
WATER VOLUME CHANGE
(JULY 11 THROUGH
SEPTEMBER 26, 1980)



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UNION ELECTRIC COMPANY
CALLAWAY PLANT UNITS 1 AND 2

FIGURE 7

AVERAGE SEEPAGE FOR RANGE OF PAN COEFFICIENTS

APPENDIX

METEOROLOGICAL METHODOLOGIES

METEOROLOGICAL INSTRUMENTATION

Precipitation Gauges

Two precipitation gauges were installed at the site to assure 100 percent data recovery. A Weather Measure Model 501-I tipping bucket rain gauge was used to record precipitation on a continuous basis. This instrument has two counterbalanced buckets; when a bucket fills with precipitation equivalent to the resolution of the instrument (0.01 inch), it falls and causes a mercury switch to close momentarily. The closure of the mercury switch and the corresponding amount of precipitation were recorded by an event recorder. The tipping bucket gauge required a 6-volt battery to operate the event recorder and two 1.5-volt batteries for the event recorder chart drive. The chart recorder and battery were protected in a weatherproof shelter adjacent to the gauge. The chart paper on the event recorder was changed weekly by Union Electric Company personnel.

The second precipitation gauge was a Weather Measure Model P562 nonrecording gauge. This gauge has a graduated cylinder marked in increments of 0.01 inch of rainfall to a maximum of 1.00 inch. If rainfall greater than 1.00 inch occurred during the period between site data checks, that water was collected in an overflow container.

Both precipitation sensors were located inside a windshield to prevent biasing the data by blowing precipitation.

Evaporation Station

A Weather Measure Model E810 evaporation station was used to measure evaporation at the site. This evaporation station is identical in design to those used by the National Weather Bureau. The evaporation station consisted of a stainless steel pan, 47.5 inches in diameter and 10 inches deep; a still well provided a point of measurement of the water level using a micrometer hook gauge; a maximum-minimum thermometer was used to measure the extremes of the water temperature; and a contact anemometer measured the air passage over the surface of the evaporation pan. The wind run across the pan surface and the extremes of the pan water temperature were used as qualitative checks for the measurement of evaporation.

Totalizing Anemometers

Two totalizing anemometers were used to investigate the air passage over the pond surface. These anemometers were identical to the one used to measure wind run across the evaporation pan. The anemometers were not installed before the seepage test with the other meteorological equipment but were added on July 18, 1980.

INSTRUMENT SITING

General

Figure 1 presents a plot plan indicating the locations of the meteorology station and the pond slope totalizing anemometer stations. Figure 2 gives a detailed plan of the meteorology station. All equipment was installed by Dames & Moore atmospheric services personnel. Site preparation, construction of the equipment pallets, and installation of the security fence were performed or supervised by Daniel International Corporation. The following subsections present a description of the siting of each instrument.

Nonrecording Rain Gauge

The nonrecording rain gauge was located inside the precipitation windshield and attached to a metal pi e mounted on a wood pallet. It was mounted so that its orifice was at the same elevation as the recording rain gauge. The gauge was adjusted so that its orifice was level by using a machinist's level in two different orientations.

Recording Rain Gauge

The recording rain gauge was also installed inside the windshield on the wood pallet. Extreme care was taken to ensure that the orifice of the gauge was level. A bubble level was affixed to the gauge as an indicator. The recorder and the battery used to power the recording gauge were contained in a wood shelter that was mounted on the security fence.

Evaporation Station

The evaporation station was installed on a wood pallet with some space allowed between the planks. The pallet was leveled before installing the evaporation pan. The totalizing anemometer was mounted on the true north side of the pan. It was mounted close enough to the pan that the anemometer cups would rotate over the surface of the water approximately 1 to 2 inches above the pan rim. The still well was located in the center of the evaporation pan and leveled using the leveling screws and a machinist's level. The pan was filled with water until the water level was approximately 2.5 inches below the pan rim, and several water level readings were taken with the hook gauge in different orientations to ensure that the still well was properly leveled. The maximum and minimum thermometer was placed in the bottom of the pan.

UHS Retention Pond Totalizing Anemometers

The totalizing anemometers were mounted on a pipe that was driven through the riprap at the edge of the water. A mounting fixture on top of the pipe was constructed so that the anemometer could be leveled after installation of the pipe. The anemometers were mounted with their cups approximately 12 inches above the water level of the pond. The two anemometers were located at the northwest and southeast stations shown on Figure 1 from July 18 to August 15, 1980, and then were moved to the northeast and southwest stations.

INSTRUMENTATION OPERATION AND MAINTENANCE

Routine Surveillance

Routine surveillance of the meteorological equipment was performed by personnel from UEC Nuclear Operations. These personnel were trained by qualified members of the Dames & Moore Atmospheric Services Group. In addition, the Procedure for Seepage Test (Dames & Moore, 1980d) prepared by Dames & Moore presented detailed descriptions of the procedures to be followed while conducting the instrument inspections.

Site checks were performed three times per week (Monday, Wednesday, and Friday). Data collected during the site checks were forwarded to Dames & Moore on a weekly basis. Telephone status reports were made at the end of each week.

Calibration and Maintenance

Monthly inspection trips were made by members of Dames & Moore's Atmospheric Services Group. During these inspection trips, the condition of each instrument was evaluated.

The evaporation pan, still well, and orifices of the precipitation gauges were checked to make sure they were level. The batteries for the event recorder were checked, and the precipitation gauges were calibrated. The exact procedures that were followed are presented in the Procedure for Seepage Test (Dames & Moore, 1980d).