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A SUBSURFACE INVESTIGATION WAS UNDERTOOK AROUND THE PERIMETER OF BASIN F. THE PURPOSE OF THE INVESTIGATION WAS TWO-FOLD: (1) TO DELINEATE THE GROUND WATER CONTAMINATION LEVELS AROUND THE RESERVOIR AND IDENTIFY POTENTIAL AREAS FOR LEAKAGE OUT OF THE BASIN, AND (2) TO DELINEATE THE SUBSURFACE CONDITIONS AROUND THE BASIN AS A FIRST STEP TO AID IN THE DESIGN FOR A FULL-DEPTH CONTAINMENT SYSTEM AROUND THE BASIN. CONCLUSION DRAWN IN THIS REPORT INCLUDE: 1) THE BEDROCK SURFACE UNDERNEATH THE BASIN IS AT MORE SHALLOW DEPTHS THAN PREVIOUSLY THOUGHT AND IN SOME PLACES HAS THE CAPABILITY TO TRANSMIT WATER. 2) GROUND WATER FLOWS UNDERNEATH BASIN F IN A GENERALLY NORTHWARD DIRECTION AND A GROUND WATER DIVIDE OCCURS ON THE NORTH SIDE OF THE RESERVOIR. 3) THERE IS A HYDRAULIC CONNECTION BETWEEN THE NEAR SURFACE AQUIFER AND A PERMEABLE BEDROCK SEDIMENT. 4) ON THE BASIS OF GROUND WATER GRADIENTS AND WATER QUALITY DETERMINATIONS, THERE ARE FOUR TO FIVE POTENTIAL LEAKAGE POINTS AROUND THE BASIN. 5) IT CAN'T BE DETERMINED IF THESE LEAKAGE POINTS OCCUR AT

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INTERIM REPORT ON BASIN F

An Analyses of the Subsurface Investigations
Conducted Around Basin F

March, 1978

Prepared by:

Geohydrology Division
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I. INTRODUCTION

A. General

The Geohydrology Division undertook a subsurface investigation around the perimeter of Basin F. This program was closely coordinated with Mr. Carl Loven, Chief, Process Development and Evaluation Division, and with Messrs. Britt Mitchell and Paul Miller of WES. The purpose of this investigation is twofold; (1) to delineate the groundwater contamination levels around the reservoir and identify potential areas for leakage out of the basin, and (2) to delineate the subsurface conditions around the basin as a first step to aid in the design for a full-depth containment system around the basin.

B. Methods of Study

The principal methods of investigation around Basin F consisted of auger drilling, collection of sediment samples, and installation of PVC well casing to collect water level and water quality information. Originally, potential drill sites were surveyed in on 100-foot centers around the reservoir outside the fence boundary. These sites were spaced as close as possible to the fenced perimeter and still allow sufficient room for safe operation of the drill rig. Along the southern perimeter of the reservoir the drill sites were located south of dike road within Basin C because of the lack of accessibility for the drill rig closer to the fence line. A total of 35 sites were drilled around the basin at 100, 200 and 400-foot centers (Figure 1). Drive samples were collected at about 5-foot intervals and at every lithology change. A field boring log was also prepared. The samples were brought into the Geophysical Analyses Lab for visual check against the field log, and samples from selected borings were subjected to laboratory analyses. The results of these analyses were submitted to Mr. Paul Miller of WES as part of the Basin F Containment Program.

To evaluate the groundwater conditions in the vicinity of Basin F, 27 of the 35 sites had monitoring wells installed in them (Figure 1). The monitoring wells consist of two-inch diameter PVC pipe with a four-foot length of slotted screen at the bottom. In some wells a length of solid plastic pipe extends below the screen to act as a sand trap. These wells are installed in such a manner so that the bottom of the screened interval coincides with the top of interpreted bedrock. The well installed in boring 458 is completed at a depth of 76 feet, which is about 40 feet below the top of the interpreted bedrock. The significance of this well is discussed in the section dealing with the hydrologic setting in the vicinity of Basin F.

Water samples collected from the monitoring wells were submitted to MALD for analyses. These samples were analyzed for chloride, fluoride, nitrate, pH, sulfate, hardness, sodium, DIMP, DCPD, sulfone, sulfoxide, oxathiane, dithiane, aldrin, dieldrin, endrin, isodrin, DDT, and DDE.

II. DISCUSSION

A. Physical Setting

The general subsurface conditions in the vicinity of Basin F consist of a surface fine to medium grained sand (SM) that varies in thickness from less than one foot to as much as fifteen feet. Underlying this surface layer is a clayey silt to clayey sandy silt to clayey sand (CL to SC) that may be as much as twenty feet thick. Underlying this sediment is coarse to very coarse sand (SP) that in some places is quite gravelly (SPGP). This is the unit that makes up much of the near-surface aquifer over the Arsenal and, in the vicinity of Basin F, it is saturated in the lower portions. The underlying bedrock is predominantly a mudstone of the Denver-Arapahoe formation that varies in depth from about thirty to sixty feet.

The bedrock surface, on the basis of the borings around the reservoir, appears to have little relief on it and the general slope on that surface is northward. The highest bedrock in the vicinity of Basin F occurs in the southeast corner where depth to bedrock is less than 40 feet. Initial borings at sites 456 and 460 indicated a depth to bedrock of about 32 feet and an overlying gravelly sand that is unsaturated. Because the bedrock encountered in these two borings was siltier than the mudstone normally found, it was determined to drill a deeper hole at site 458 to observe the character of the bedrock at a somewhat greater thickness than is normally drilled.

Bedrock was encountered at a depth of 33 feet in boring 458. The upper 10 feet of bedrock consists of a laminated clayey silt to sandy silt. Underlying this material is about 30 feet of fine to medium grained sand, completely saturated. Below the sand the typical mudstone that characterizes the Denver-Arapahoe formation in the vicinity of RMA is encountered. The occurrence of this lower saturated sand prompted a reexamination of some of the sands encountered in other borings around the perimeter of Basin F.

From this examination it appears that depth to bedrock is not as great as first interpreted in some places on the west and south side of the reservoir. In the vicinity of borings, 423 through 428 depth to bedrock is between about 1 foot and 12 feet shallower than previously interpreted. Along the south part of the basin, in the vicinity of borings 444 to 452, the bedrock is likely 11 to 33 feet shallower than previously thought. It also appears that along the east side of the basin the same thing occurs. The interpretations in these areas are a little more difficult because the near-surface aquifer material (SP and SPGP) lies directly over a fine to medium grained sand, and the intervening laminated clayey silt layer is absent.

The significance of these findings lie in the fact that some of the previously identified bedrock channels are not channels at all but simply areas where the bedrock consists of sand and silt rather than clay. This may or may not have profound effects on the interpretations dealing with contaminated groundwater flow at RMA. Specifically, in the vicinity of Basin F, the fact that bedrock materials are this variable affects the design and location of a full-depth containment system.

Figure 2 is a contour map showing the elevation of the mudstone (CH) layer that has traditionally been identified as bedrock. If full-depth containment of the basin is deemed necessary, this is the elevation to which a barrier would have to be completed to insure hydrologic integrity.

B. Hydrologic Setting

In order to understand what the groundwater conditions are in the vicinity of Basin F, 27 monitoring wells were installed around its perimeter (Figure 1). These wells are used for both water quality and water level determinations. The purpose of the water analyses was to determine the distribution of potential contaminants around the basin and possibly identify leakage points around it. Determining the groundwater potentials that exist around the basin is also necessary to relate the water chemistry to where it occurs in the flow system. For example, different contamination levels may indicate a downgradient diffusion from a single exit point or indicate several leakage points where the groundwater gradient and apparent diffusion gradient do not coincide.

The groundwater pattern in the vicinity of Basin F as shown in Figure 3 is interpreted only on the basis of the monitoring wells around the perimeter. Water-table data that might be collected utilizing additional points away from the basin could significantly alter the interpretation. For example, if groundwater mounding occurs as a result of the existence of Basin F, groundwater flow components would be outward from the reservoir in an essentially radial pattern. Isolated leakage points that might contribute significant quantities of fluid to the groundwater system over small areas can also affect the distribution of the hydraulic heads and their interpretation. The interpretation as shown in the illustration assumes that groundwater mounding has not occurred and the fluid contribution from Basin F, although maybe of significant chemical impact, has little overall impact on the distribution of the hydraulic heads.

The principal theory governing groundwater flow is that groundwater flows from a high potential to a lower potential. Without going into the mathematical proofs, groundwater potentials can be defined solely on the elevation of groundwater as measured in an observation well or piezometer. Contouring of these points, as in Figure 3, then shows the distribution of the hydraulic potential. Groundwater gradients are determined on the basis of potential drop across the distance of interest. Additionally, because the flow of groundwater is downgradient and that flowlines must cross the drops at right angles, the major and minor flow components can be evaluated.

The principal flow component underneath Basin F is in a northerly direction. Along the north side of the basin a groundwater divide occurs and results in two principal flow components, one in a northwesterly direction towards the northwest boundary, and the other in a northeast direction towards the north boundary. Along the east side in the vicinity of borings 468 to 474, a minor northeast flow component occurs. Minor west and northwest flow components occur along south and southwest of Basin F, respectively.

The gradients on the water table vary between a high of about 0.04 to less than 0.002. The average gradient is about 0.01. The steepest gradient occurs in the vicinity of the southeast corner of Basin F and may relate to the fact that this is the area in which the fine to medium grained bedrock sand occurs. As this material undoubtedly has a lower permeability than the surface aquifer gravelly sand, the gradient has to be steeper to account for the volume of water entering along the south and exiting along the north, plus whatever fluid volume is contributed by the basin itself. The area of steeper gradients may define the extent of the bedrock sand underneath Basin F, and where the gradients become shallow may define where the hydraulic connection between bedrock and near-surface aquifer materials occurs.

C. Water Quality

Water samples were collected from 25 of the 27 wells and were submitted to MALD for analyses. Table 1 shows the 19 parameters that were analyzed.

INORGANICS		ORGANICS		
Chloride	Sulfate	DIMP	Oxathiane	Endrin
Fluoride	Sodium	DCPD	Dithiane	Isodrin
pH	Harness	Sulfoxide	Aldrin	DDT
Nitrate		Sulfone	Dieldrin	DDE

Table 1. Parameters Evaluated in Water Samples from Wells Around Basin F.

Probably the two organic contaminants of greatest interest are DIMP and DCPD (Figure 4). DIMP was identified in nearly all the wells, but DCPD occurs only in the wells on the northeast corner in the vicinity of well 26-8 (#118). The low DIMP value at site 421 (74 ug/l) and the high DIMP value at site 422 (3520 ug/l) are not readily explainable. The same high-low relationship exists between sites 425 and 426. One explanation may be analyses error and water samples have been resubmitted. At the time of this writing the requested data has not been received. If, however, it turns out these original differences are, in fact, real, then a physical reason must exist. The only logical explanation may relate to the fact that the higher values occur in water moving through the bedrock sand. Although the saturated total thickness does not vary much, the well at site 421 which shows the lower DIMP value has a greater thickness of near-surface aquifer material than at site 422. This may indicate that the bedrock sand is transmitting contamination underneath Basin F from possibly the southeast part of the basin. The high-low relationship between sites 425 and 426 cannot be explained this way. These differences could be the result of a very narrow leak point out of Basin F or simply an analysis error. Further investigation is warranted. It is interesting to note that DCPD is only identified on the northeast side of Basin F.

Figure 5 shows the distribution of sulfoxide, oxathiane and dithiane around Basin F. No sulfone was detected in any of the wells. According to the data on analysis performed on Basin F fluids, no oxathiane was detected although dithiane was found in some places. The presence of these compounds in the wells around the basin are generally restricted to the east and northeast side. The fact that some sulfoxide and oxathiane is found on the west side but at concentrations just slightly above detectable may be due to analytical interferences rather than real occurrences.

The chlorinated hydrocarbons (aldrin, dieldrin, endrin, isodrin, and DDE) are detected in only a few wells (Figure 6) on the east and south side of Basin F. DDT was not found in any of the water samples. The study on Basin F fluid and sludge determined that there was no detectable DDT or DDE present. In most instances the levels of the chlorinated hydrocarbons are barely above detectable levels. Nor do these compounds appear in water near the vicinity of well 26-8 (#118). The presence of these compounds in the groundwater may be due to a source other than Basin F. It is known that the sanitary and contaminated sewer lines run along the east side of the basin and most the chlorinated hydrocarbons are found in the wells that parallel the sewer lines.

The inorganic compounds of most interest in the groundwater are chloride, sulfate and fluoride (Figure 7). In general the highest concentrations of these correlate with the high DIMP zones. However, the fluoride levels do not correlate as well with DIMP as do chloride and sulfate. Except for well 26-8 (#118) and the well at site 400, the highest fluorides occur where the DIMP is low (sites 418, 426, 436, 468). This indicates that fluoride in the groundwater is naturally high rather than being a contaminant as a result of Arsenal activity. As a matter of fact, higher fluoride contents are found in other parts of the Arsenal that are not at all close to known potential contamination sources.

III. CONCLUSIONS

The conclusions drawn in this report are the result only of the investigation around Basin F and additional work may alter some of these. Based on this data the following conclusions can be drawn:

a. The bedrock surface underneath the basin is at more shallow depths than previously thought. In some places bedrock is a clayey silt to sand that has the capability to transmit water.

b. Groundwater flows underneath Basin F in a generally northward direction and a groundwater divide occurs on the north side of the reservoir.

c. There is a hydraulic connection between the near surface aquifer and a permeable bedrock sediment.

d. On the basis of groundwater gradients and water quality determinations there are four potential leakage points around the basin. These are in the vicinity of sites 480-402, 478, 440 and 422-426. In addition, another site may potentially exist in the vicinity of site 414.

e. It cannot be determined if these leakage points occur at the edges of the basin. On the basis of the interpreted groundwater flow pattern contaminants can emanate anywhere underneath the basin and be detected at the edges.

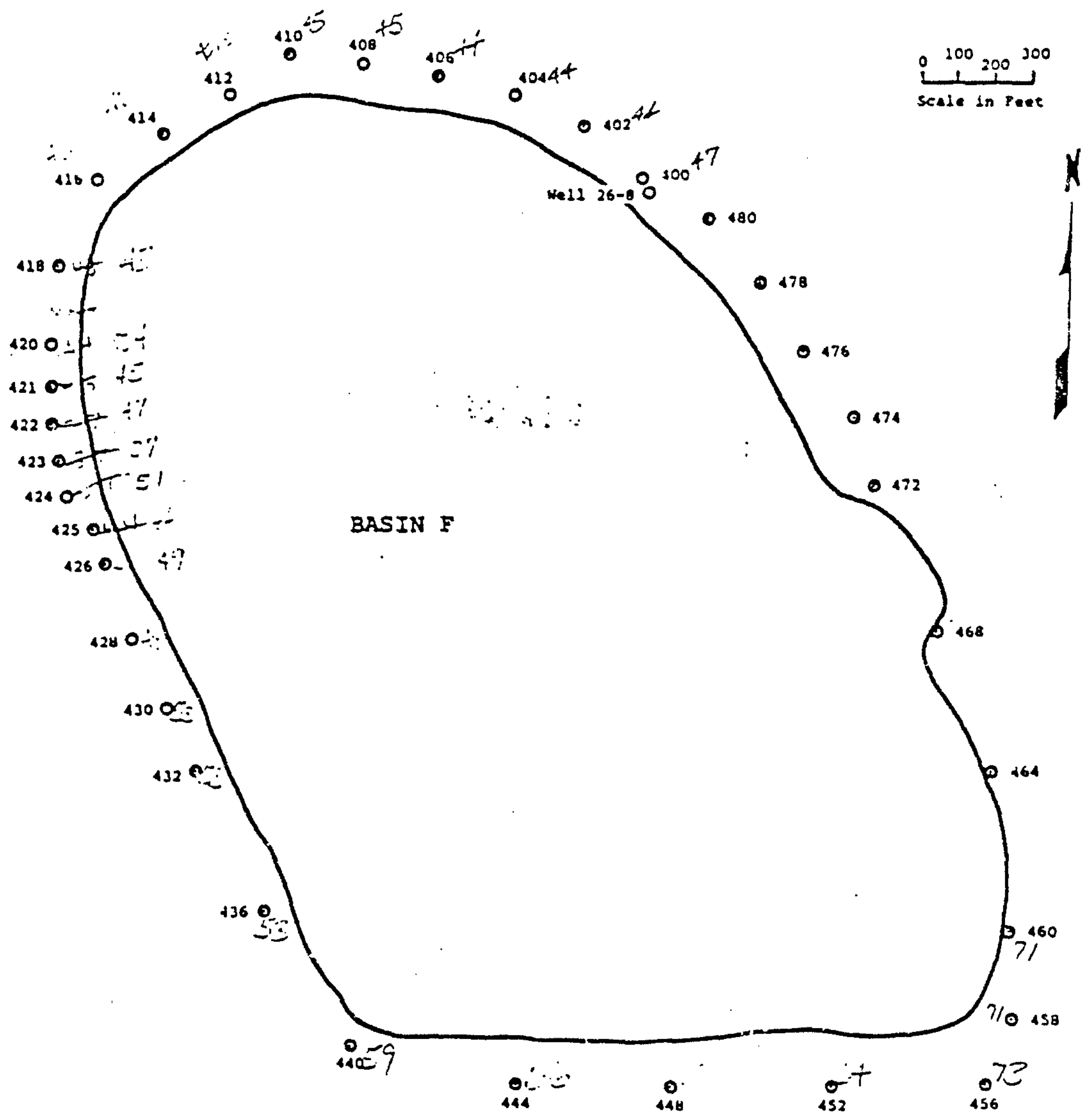
f. It seems likely that the sewer lines along the east side of the basi., particularly the sanitary sewer, contribute some contamination to the groundwater system. The sanitary sewer is probably the source for the chlorinated hydrocarbons.

IV. RECOMMENDATIONS

The results of this study indicate that further study is warranted in two major areas; (1) additional water-level monitoring some distance away from the reservoir, and (2) additional subsurface investigations to relate the hydrologic interactions between the near-surface aquifer and permeable bedrock zones.

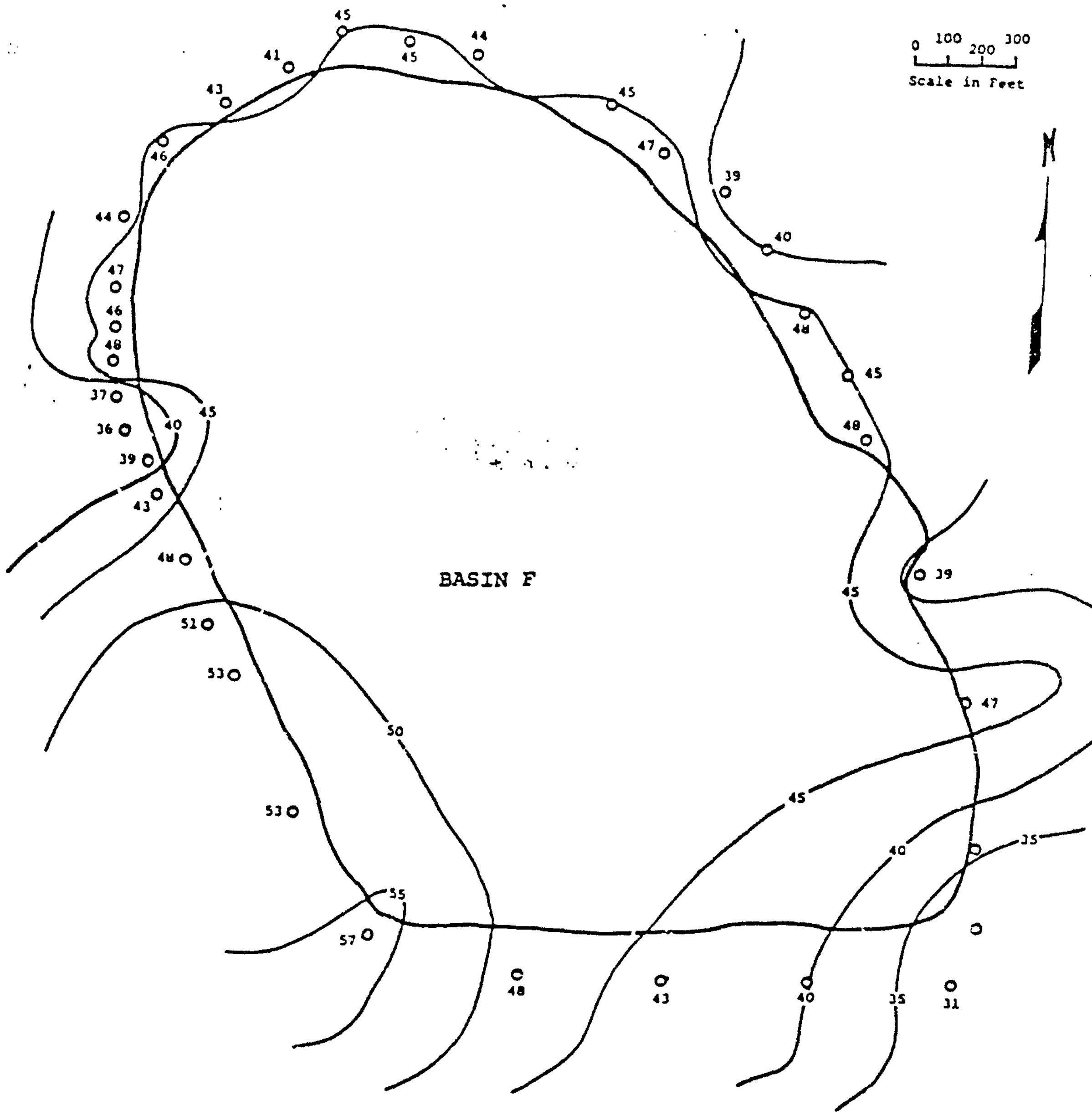
Additional well sites have already been located away from the basin where well casings will be installed. Water samples will also be taken from these sites for chemical analyses. The existing wells around Basin F will be resampled to check the accuracy of the analyses. This report will be updated as necessary and future findings warranted.

Deeper drilling into the bedrock formation needs to be done in order to understand how groundwater flows through the bedrock permeability zones. For example, if the groundwater potential is downward from the near-surface aquifer to a deeper horizon, contaminants may still be getting into the groundwater-flow system off Arsenal, and yet not be detected in the near surface aquifer.



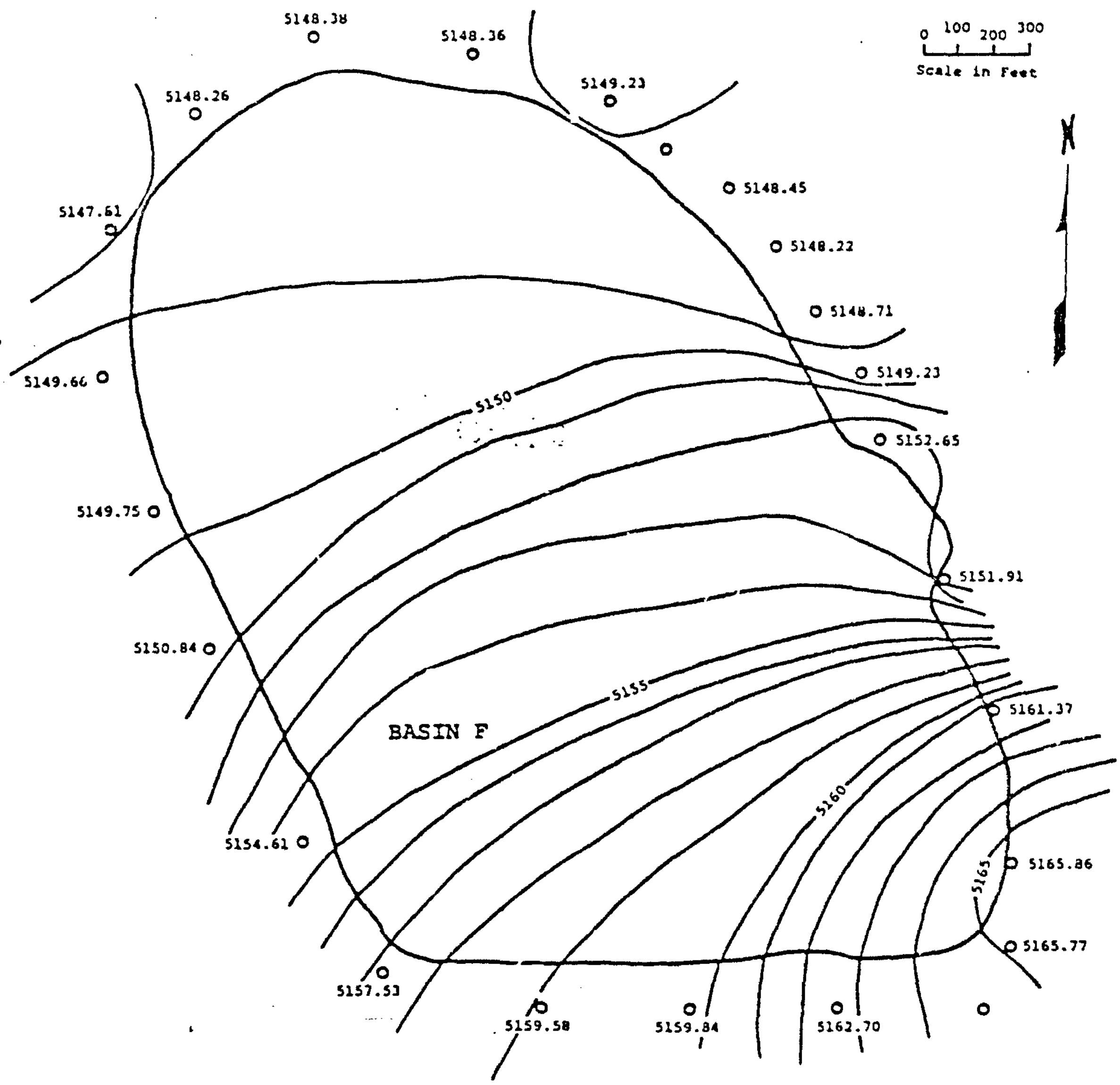
LEGEND
- Boring site only
- Cased bore

Figure No 1. Location of Boring Sites



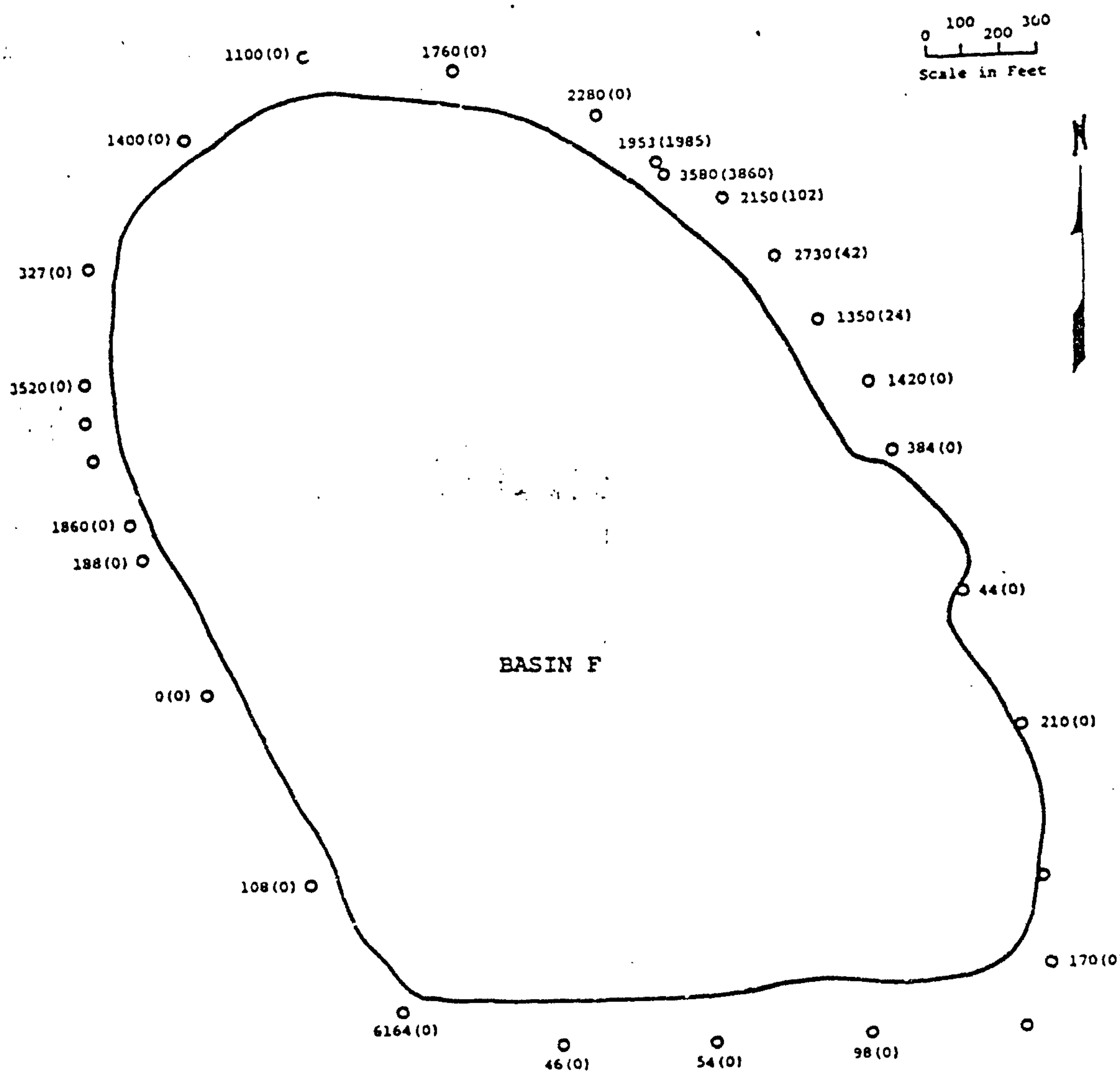
Notes
1. Contour interval of 5 feet
2. Elevations shown are based on a datum of 5100 MSL

Figure No 2. Elevation of Mudstone (CH) Layer



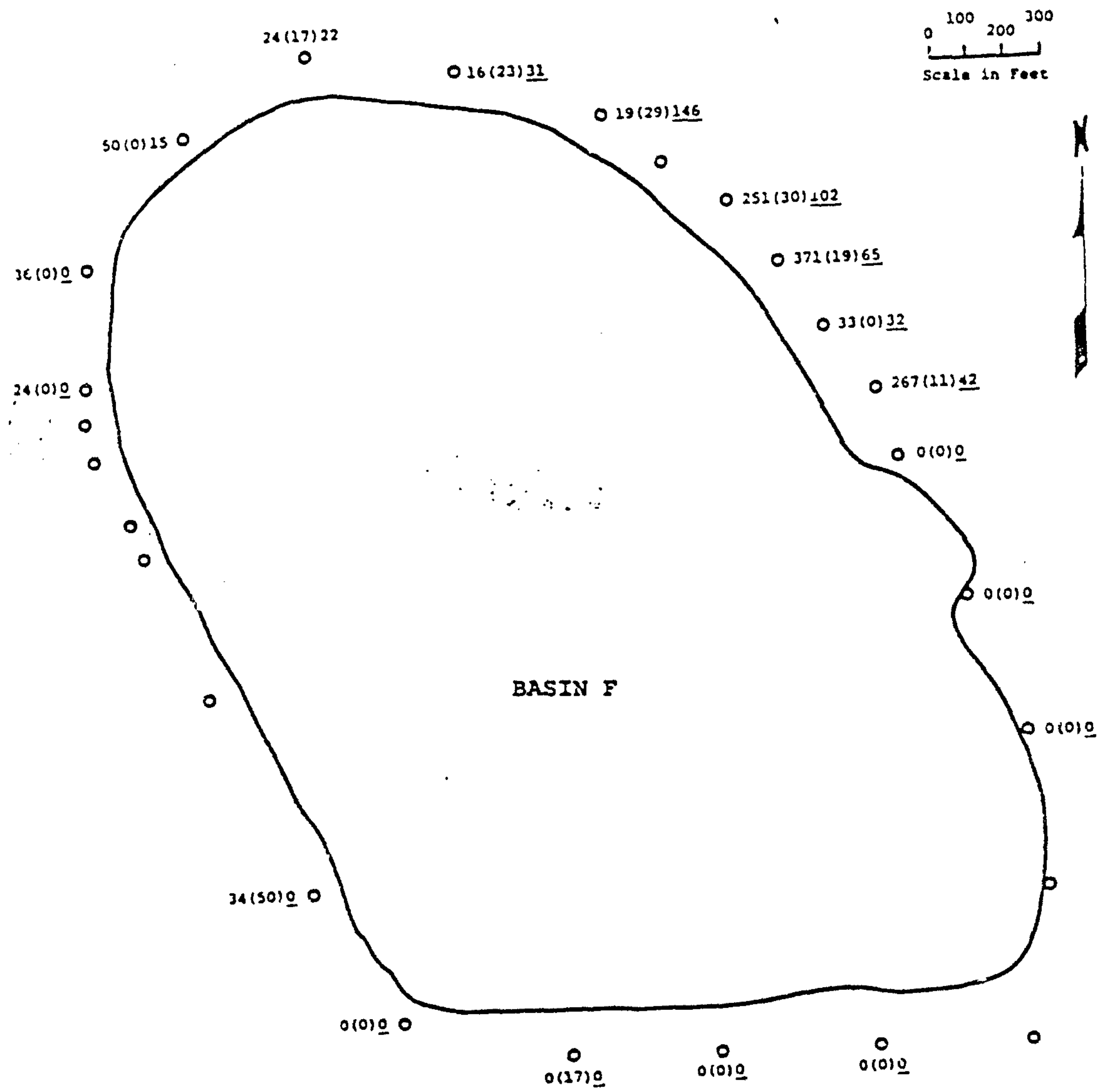
Note
Contour interval of 1 foot

Figure No 3. Water Table Elevations



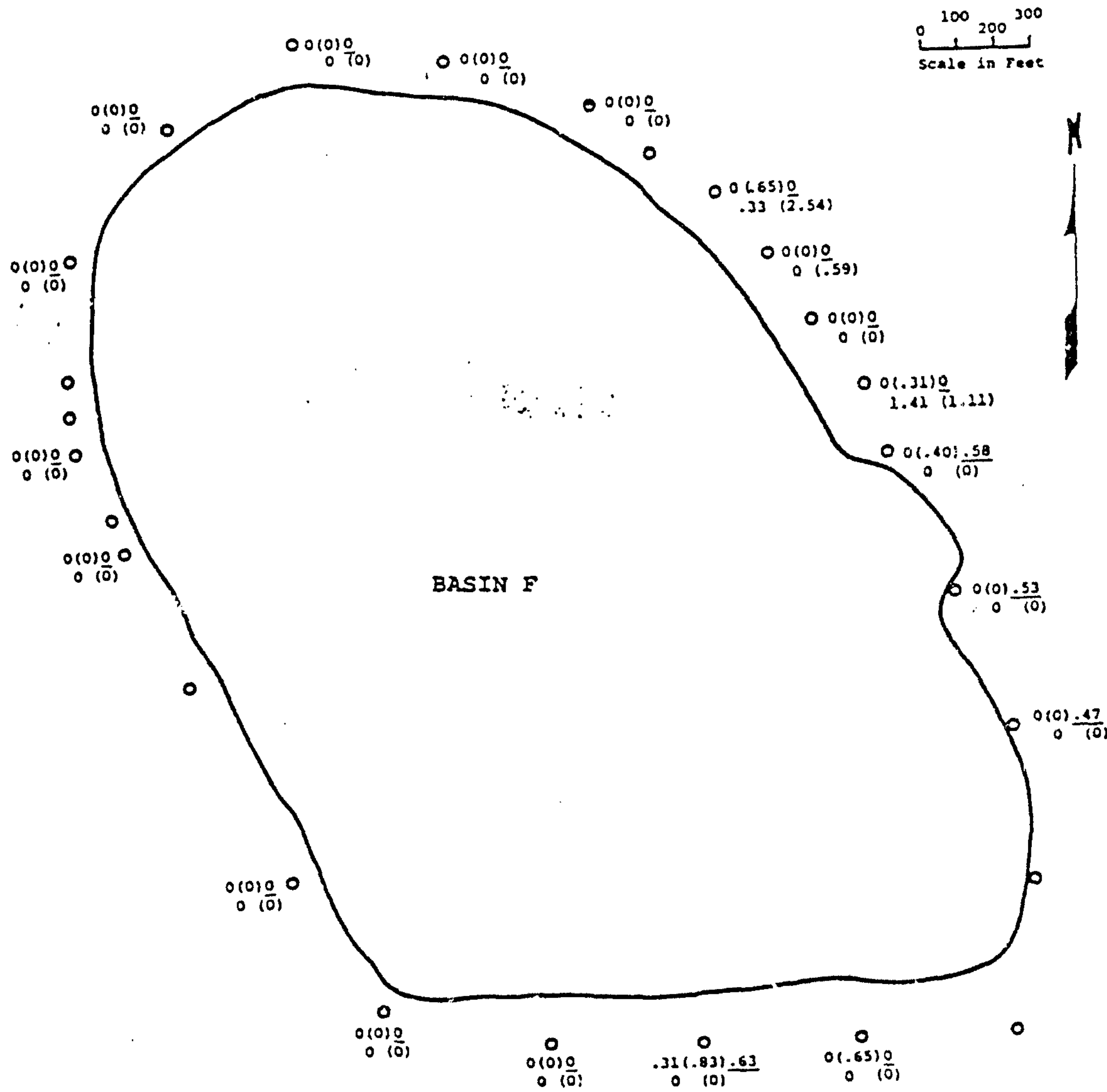
DIMP (DCPD)

Figure No 4. Distribution of DIMP and DCPD (PPB).



Sulfoxide (Oxathane) Dithiane

Figure No 5. Distribution of Organo-Sulfur Compounds (PPB)



Aldrin (Dieldrin) Isodrin
DDE (Endrin)

Figure No 6. Distribution of Chlorinated Hydrocarbons (PPB)