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HYDROGEOLOGIC ASSESSMENT
PROPOSED WATER AUGMENTATION MEASURES
ITEM NO 84--SEAWARD MIGRATION
OF GROUNDWATER
For
MONTECITO WATER DISTRICT

August 5, 1987

Our Job S8410-SWM



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FINDINGS

GENERAL STATEMENT

This report has been prepared to summarize the findings and conclusions of my hydrogeologic assessment of the feasibility of capturing groundwater that is moving southerly across Montecito Basin toward the ocean. Specifically, this assessment represents Item No. 84 - Seaward Migration of Groundwater, as part of the District's overall 15-item program of Proposed and Pending Water Augmentation Measures (letter to Board of Directors and Manager, MWD, dated Dec. 30, 1986, from Mr. H. J. Muller, Director).

The purpose of this assessment is to evaluate the feasibility of developing additional groundwater supplies for the District from possible wells to be installed along the southerly margin of Storage Unit No. 3 of Montecito Groundwater Basin. It is hoped by the District that such a wellfield would cut-off and intercept groundwater that would otherwise percolate southerly to the ocean and thus be lost permanently from the water system in the area. Figure 1 - Groundwater Storage Units Map - delineates Storage Unit No. 3 and illustrates the general directions of groundwater flow in the basin.

For this assessment, we have relied upon the following reports and data:

1. District water level monitoring and water quality data from MWD wells and private wells in the area.
2. Basin-wide hydrogeologic reports prepared by Geotechnical Consultants, Inc. and by Hoover & Associates.



3. Reports in my files and from District files on various private wells in the study area prepared by Geotechnical Consultants, Inc. and by Hoover & Associates.
4. Electric log data for nearby wells, as available from my files, those at the District, and those at the City of Santa Barbara.
5. Phase I, II, and III Groundwater Monitoring Reports for the Santa Barbara Groundwater Basin, which were prepared as Open-File Reports by the U. S. Geological Survey in 1979, 1984, and 1986, respectively.

HYDROGEOLOGIC CONDITIONS

Subsurface Correlations. Subsurface geologic conditions in the Montecito-Santa Barbara area were evaluated using numerous electric logs of water wells and test holes. The locations and names of these wells and/or test holes are shown on Plate 1 - Electric Log Data Points. As seen, there are 29 sites in Montecito Basin for which electric logs are available at this time. Included in this group are: 10 District wells and/or wells dedicated to the District; 6 test holes drilled for the District; and at least 13 privately-owned wells and/or wells owned by the City of Santa Barbara. As more wells are drilled, the data base for this map can be modified.

In addition to the above 29 wells with electric log data, it is estimated that an additional 50 wells have been historically drilled in Storage Unit No. 3 between the coastline and the Montecito fault; electric log data for this group of privately-owned wells are almost certainly non-existent. These additional wells, located within Storage Unit No. 3 only, are also plotted on Plate 1. The usage, viability and current status of the preponderance of these wells is not well documented at this time.

Using the electric logs and geologic logs of the various boreholes, we have picked the apparent base of fresh water

at each site, assuming the borehole was deep enough to encounter it. In addition, we attempted to correlate a specific electric log marker horizon from well to well.

Results of that work specifically for the base of fresh water in Storage Unit No. 3 are shown on Plate 2 - Map of the Base of Fresh Water - as contours of equal elevation on this particular horizon. Due to the nature of the bedrock underlying Montecito Basin, the base of fresh water has been selected on the basis of poor quality water and/or on nonwater-bearing shale-type bedrock, as defined by the electric log.

As noted on Plate 2, the base of fresh water deepens in a north to south direction across Storage Unit No. 3, from approximately an elevation of -400 ft below sea level on the north along the Arroyo Parida fault to roughly elevation -900 to -1000 ft along the Rincon Creek thrust fault just offshore. The contour pattern also reveals that sediments down to the base of fresh water have been folded, such that: an anticlinal or high structure occurs near the Bird Refuge/Santa Barbara Cemetery area; and a synclinal or low structure occurs immediately east of the anticline and also on the easterly side of Unit No. 3.

Depending on location, it appears that Unit No. 3 contains roughly 300 to 500 ft or more of Casitas Formation and/or younger sediments, which are in turn underlain by as much as 500 to possibly 600 ft of older Santa Barbara Formation sediments. These older strata, as evidenced by drilling and pumping in Santa Barbara Basin and the southern edge of Carpinteria Basin, are known to be fine-grained, gray-colored silty sands, containing groundwater with iron and/or manganese, and hydrogen sulfide. Well yields in these deeper strata, as noted from the groundwater basins to the east and west, can be as high as a few hundred gallons per minute.

The Rincon Creek thrust fault traverses east-west across the offshore area and forms the southern boundary of Storage Unit No. 3 (see also Figure 1). Because bedrock is thrust upward on the southern side of this fault, it may create at least a partial barrier to seawater intrusion at least in the deeper aquifers of this storage unit; the shallow aquifer zones do remain, however, open to potential invasion by seawater.

Water Level Data. To assess current groundwater levels in Montecito Basin, we prepared Plate 3 - Water Level Elevations, April 1986 - the data for which was obtained from District files; individual data points are annotated on this map. Notable on this plate are the following:

- a. The two east-west trending faults which cross Montecito Basin do create at least partial barriers to groundwater flow, as evidenced by the breaks in the contour elevations and shapes on opposite sides of these faults.
- b. Groundwater levels for April 1986 range from approximately +10 to +25 ft above sea level in Unit No. 3.
- c. Groundwater flows north to south across Unit No. 3 at a groundwater gradient of approximately 0.014 ft/ft, or about 75 ft/mi.
- d. A deep pumping trough, with water levels of -10 to -38 ft below sea level is seen in the eastern portion of the Santa Barbara Groundwater Basin.

Review of historical water level maps prepared previously by Geotechnical Consultants,, Inc. and Hoover & Associates, together with review of a May 1979 water level contour map prepared independently for this study (not presented herein) reveal the following:

- a. The two faults have historically been groundwater barriers in the Montecito Basin.

- b. Historic groundwater levels in the southwestern corner of Unit No. 3 have been: between sea level and about -30 ft below sea level in the period 1949-51; between sea level and about -20 ft below sea level in the period 1961-62; at roughly sea level in the period 1970-73; and above sea level in 1979.
- c. Our May 1979 contour map (not presented herein) shows water levels to range between about +32 to +4 ft above sea level from north to south, respectively, across Unit No. 3.
- d. All historic water level contour maps show that groundwater flows north to south across Unit No. 3. The groundwater gradient for May 1979 data was 0.008 ft/ft (44 ft/mi).
- e. There are, unfortunately, no data whatsoever on the effectiveness and/or integrity of the offshore Rincon Creek thrust fault as a continuous barrier to landward migration of seawater in the deeper, Santa Barbara Formation-type deposits.

Figures 2.1 and 2.2 - Hydrographs - were prepared to assess the long-term response of water levels to recharge and discharge from the basin. Hydrographs are presented thereon for MWD-Office Well and MWD-Neal Well (Figure 2.1) in Storage Unit Nos. 1 and 3, respectively; for the Cemetery Well near the coastline, between Montecito and Santa Barbara Basins; and for the City of Santa Barbara Yanonali Well in Santa Barbara Basin.

Notable on these figures is:

1. Seasonal and long-term water level highs and lows occur, but often to different degrees and in different years, depending on location of the well in the basin.
2. The rise in water levels in Unit No. 3 since the long-term drought years ended in the mid-1960's is evident from the Cemetery Well and Neal Well graphs.
3. Water levels in Unit No. 3 near the coast (Cemetery Well) were at or below sea level from the beginning of the data record until 1970. Since that time and up



until the present, water levels have been above sea level here but never higher than about +11 ft; for most of the period 1970-1986, water level elevations were generally at +5 to +8 ft. The total amount of water level fluctuation at this coastal well has been about 19 ft during the historical period of record.

4. The Yanonali Well clearly shows large-scale fluctuations that are caused by both seasonal and long-term pumpage from a proximal well field in the City of Santa Barbara. Maximum water level elevations in the period of record (1950-1986) were only about +5 ft, while minimum elevations were as much as 60 ft below sea level.
5. Since the recent highs of 1979-1983, water levels in Storage Unit No. 3 have been trending downward.

Water Quality Data. Most wells in Storage Unit No. 3 provide groundwater with acceptable inorganic quality to meet State standards for domestic usage, with the exception generally of iron and manganese. For the most part, total dissolved solids (TDS) for wells near the coast ranges between about 700 and 900 mg/l and the groundwater displays a calcium-bicarbonate-sulfate or calcium-bicarbonate character. Wells located near faults, and/or wells with very shallow perforations, and/or wells with improper sanitary seals tend to display higher TDS concentrations, and occasionally elevated nitrate (as NO_3) levels. Very deep wells encountering certain bedrock formations, and/or wells near the coastline often show elevated chloride levels.

To evaluate subsurface and water quality conditions near the coastline, we conducted a detailed review of electric logs of specific wells, namely the Montecito del Mar, Libbott, Biltmore, MWD-Neal and MWD-Las Entradas II wells (see locations on Plate 1. Based on our review of these electric logs, of reports and data prepared by other consultants for these

wells, and of the USGS reports for the Santa Barbara area, the following was determined:

1. Some wells very near the coast in Montecito have, upon occasion, yielded groundwater containing chloride concentrations as high as 1000 to 2000 mg/l. Chloride, alone, is not the sole indicator for potential intrusion. Increases in TDS, sodium, magnesium, sulfate, and in the ratio of chloride to bicarbonate are often used as indicators also. State limits for chloride in drinking water is 250 mg/l.
2. Other wells, such as 4N/27W-24D2, the Murphy Park well near Santa Barbara, show chloride concentrations increasing from about 80 mg/l in 1950 to about 500 mg/l in 1964, and to about 1100 mg/l in 1975. Because this time period was concurrent with a hydrologically dry cycle during which water levels were declining, it is possible the increasing chloride levels reflect some sort of intrusion. However, it is also possible that an inadequate cement seal in the well allows shallow brackish water into the casing. Wells in existence at that time near the Biltmore did not show a similar increasing chloride trend.
3. General water quality assessed from the electric logs suggests an overall decline in quality at irregular depths and locations along the coastline, mainly below about 120 to 150 ft in depth. Electric log analysis by others of the Biltmore well, drilled in the late-1970's approximately 850 ft from the coastline, revealed fresh water to maximum depths of 140 ft, followed by saline-type water between depths of 140 and 320 ft; below this depth to about 450 ft (total depth of hole) the water reportedly appeared fresher on the E-log. To minimize chloride production, the final well was perforated to only 120 ft and cement sealed below. A private well south of Highway 101 and east of Butterfly Lane was similarly sealed below about 120 ft in depth to minimize chloride levels.
4. The general depth zone of 150 to $\pm$ 300 feet on electric logs of wells near the coastline suggests brackish-type groundwater and fine-grained sediments. Previous investigators have suggested that these waters are brackish due to seawater intrusion. However, with the proximity of the offshore fault, intrusion may not

have occurred. Even if it had occurred previously, the intrusion would most likely have entered the coarser grained sediments, not the fine grained materials typically seen in this 150- to 300-foot depth range. As a result, we believe that these high chloride-poor quality waters in this depth zone occur as a result of the original (natural) deposition of these sediments in a shallow marine environment. In essence, these sediments have not been flushed of their original sodium-chloride connate waters.

5. Electric logs of some of the wells reveal that the Santa Barbara Formation may occur below depths of 300 to 350 ft very near the coast and that these sediments may have fresher water than that in the +150- to 300-foot depth range. No wells near the coastline currently produce from the Santa Barbara Formation in Storage Unit No. 3.
6. Select depth zone sampling by the City of Santa Barbara in the early-1970's in test holes drilled near City Hall and at Vera Cruz Park in Santa Barbara Basin revealed high levels of iron and manganese, and moderate TDS levels, in zones below 220 ft. Hydrogen sulfide odors were detected in zones below 650 ft. Several City wells and test holes in Santa Barbara produce from the Santa Barbara Formation. Heavy pumpage in the downtown area has created a deep and areally extensive pumping trough, wherein non-pumping water levels have been as much as 80 ft or so below sea level. This pumping trough may have helped create, together with pumpage from the Cemetery Well and others, the low water levels noted occasionally in the southwestern portion of Montecito Basin in the 1950's through the 1970's.

Aquifer Parameters. Review of limited aquifer test and production testing of wells in Storage Unit No. 3 and, in particular, along the coastline indicates the following:

1. Typical well yields southerly of the Highway 101 include: 60 gpm with a drawdown of 20 to 21 ft, with a specific capacity of less than 3 gpm per ft of drawdown, and a pumping level near elevation -10 ft below sea level (well is located east of Butterfly Lane); 150 to 200 gpm at the Cemetery Well during its early



years of use (1949), with pumping levels of 100 to 150 ft below sea level, and a resulting specific capacity of 1 to 2 gpm/ft of drawdown; 80 gpm wich a drawdown of about 20 ft, a specific capacity of 4 gpm/ft of drawdown, and a pumping level at sea level after 24 hours of pumping for a well located just west of Posilipo Lane; and about 45 gpm at a pumping level of 41 to 42 ft (pumping level elevation of about -1 or -2 ft below sea level), and a specific capacity of about 1 gpm/ft of drawdown for a well located south of Danielson Road.

2. Typical depths for these kinds of wells are on the order of 150 ft, with tops of perforations beginning near or even slightly above 50 ft, the minimum sanitary seal depth required by the State.
3. Typical transmissivity values determined by other consultants from these well are on the order of 1000 to roughly 7000 gallons per day per foot of aquifer (gpd/ft).

WELL LOCATIONS AND ESTIMATED BASIN UNDERFLOW

Not counting the 29 wells with electric log data, Plate 1 also reveals that at least 50 other privately-owned wells have been drilled in Storage Unit No. 3; the status, viability, and use of these wells is not known. Wells near the coast that are active or likely active would include such ownerships as Montecito del Mar, Libbott, Biltmore, MWD-Las Entradas II, Sykes Company, Miramar, Santa Barbara Cemetery, Quackenbush, the Hammond Estate, and DeGroodt.

An estimate of the magnitude of groundwater underflow southerly across Storage Unit No. 3 in the vicinity of Highway 101/Southern Pacific Railroad is as follows:

- a. An average groundwater gradient, I , of about 0.010 ft/ft;
- b. Cross sectional area, A , of saturated underflow occurs along: a basin width in this region of about 11,000 ft; and a saturated thickness of 6 ft, assuming that



non-pumping water levels are 11 ft above sea level and that new wells must not be allowed to drop below about elevation +5 ft (i.e., a positive seaward gradient for fresh water must be preserved).

- c. Permeability, P , of the shallow sediments is estimated to be on the order of 100 gallons per day per square foot (gpd/ft^2).
- d. Hence, the magnitude of shallow groundwater underflow near the coast is determined using the Darcy equation, and reveals a value of on the order of less than 100 gpm (140,000 gpd).

A major factor in the above assessment is the thickness of the saturated zone available for groundwater development by new wells. As stated in item "b" above, we used a six-foot thickness for the saturated zone as measured from the all-time high static water levels near the coast (about +11 ft) down to a minimal elevation of +5 ft above sea level. This latter elevation, if controlled, would still hopefully maintain a minimal seaward gradient of the water table. Such a condition is essential along this coastline to preclude a reversed gradient, in which case a well field could draw saline water into the shallow aquifers that are known to be in hydraulic continuity with the ocean.

It should be noted however, that the above discussion of the six-foot saturated flow thickness assumes:

1. Groundwater levels near the coast are always at their all-time high of +11 ft above sea level; obviously, water levels will not remain this high, and in fact data show historic fluctuations of at least 19 ft.
2. The estimated six-foot thick saturated zone that needs to be maintained requires that any future pumping should create no more than six feet of drawdown.
3. Given the known maximum specific capacities near the coast of only about 4 gpm per foot of drawdown (see Aquifer Parameters Section), a maximum single well yield of only 25 gpm would theoretically be possible

if drawdown is to be restricted to only six feet at the well. Even this calculation assumes that wells would be adequately spaced to preclude any mutual drawdown interference.

CONCLUSIONS

Based on the above information, it is our opinion that it is not hydrogeologically feasible for the District to construct a well field along the coastline in the southerly portion of Storage Unit No. 3 of the Montecito Groundwater Basin. Principal reasons for this conclusion include:

1. The shallow sediments are in hydraulic continuity with the ocean, because the proximal offshore fault likely only is effective as a barrier at depth.
2. The shallow sediments are known to be lenticular and interfingering.
3. As many as 60 to 70 wells have been drilled by the District and others in Unit No. 3. Although the current usage and activity of most of these wells is unknown, it is recognized that there are currently at least ten active wells located in Unit No. 3 roughly south of Highway 101. The potential drawdown impacts on nearby existing wells and the cumulative effects of existing wells and possible new ones in a MWD well field on all of Storage Unit No. 3 could be significant in the long term.
4. There exists an apparently irregular zone (both laterally and vertically along the coast) of poor quality water, such that wells very near the coast are typically restricted to depths of 120 to 150 ft or less.
5. Some older shallow wells and/or wells with very shallow perforations, in certain areas along the coast have historically but only locally displayed exceedingly high chloride levels and/or high TDS and nitrate levels.
6. Historically, water level elevations near the coast have never been higher than +11 ft above sea level,



and mainly have been in the range of only +5 to +8 ft above sea level. Groundwater flows from north to south across Storage Unit No. 3 at a gradient of about 0.010 ft/ft.

7. Other characteristics of existing coastal wells include: low specific capacities, on the order of 4 gpm/ft of perforations or lower; typical pumping levels are below sea level; and typical transmissivities of 1000 to 7000 gpd/ft.
8. Calculations of the magnitude of shallow groundwater underflow along the coast reveal a value of roughly 100 gpm (144,000 gpd) or less. This figure represents the magnitude of yield potentially available to a series of shallow wells spaced across the entire southern end of Unit No. 3, assuming: there was no mutual drawdown interference between proposed wells and the 10 or more already in existence; the pumping levels in the new wells always remained above elevation +6 ft above sea level. In essence, there is simply not sufficient drawdown room available along the coast between current/historic non-pumping levels and future pumping levels so that pumping levels can always remain above sea level.

There is and always will be a delicate balance between groundwater levels and sea water intrusion near this coast. It is recommended that a seaward groundwater gradient (from Unit No. 3 toward the ocean) always be maintained by proper management of the basin. Such a gradient, and maintaining groundwater levels always above sea level in the area, are necessary to maintain a buffer against intrusion in the shallow zones.

Finally, as an alternative to trying to develop groundwater from shallow aquifers near the coast, the District might consider the deeper strata. The Santa Barbara Formation likely occurs at depth below the Casitas Formation along the coast. From adjacent groundwater basins, it is known to produce a few hundred gallons per minute in wells, but often with



iron/manganese, and/or hydrogen sulfide. It is seen on electric log signatures below 300 ft or so near the coast, and is likely a few hundred feet thick. It may not be in direct hydraulic communication with the ocean due to the Rincon Creek fault. The effectiveness of this fault as a complete barrier is not known, along with quality, yield, or water levels in the Santa Barbara Formation. However, the District may wish to consider installing one or more test holes into this formation along the coast in the future. The impact of possible pumpage from deep wells into the Santa Barbara Formation near the coast on water levels/intrusion possibilities into the overlying aquifers should also be evaluated.

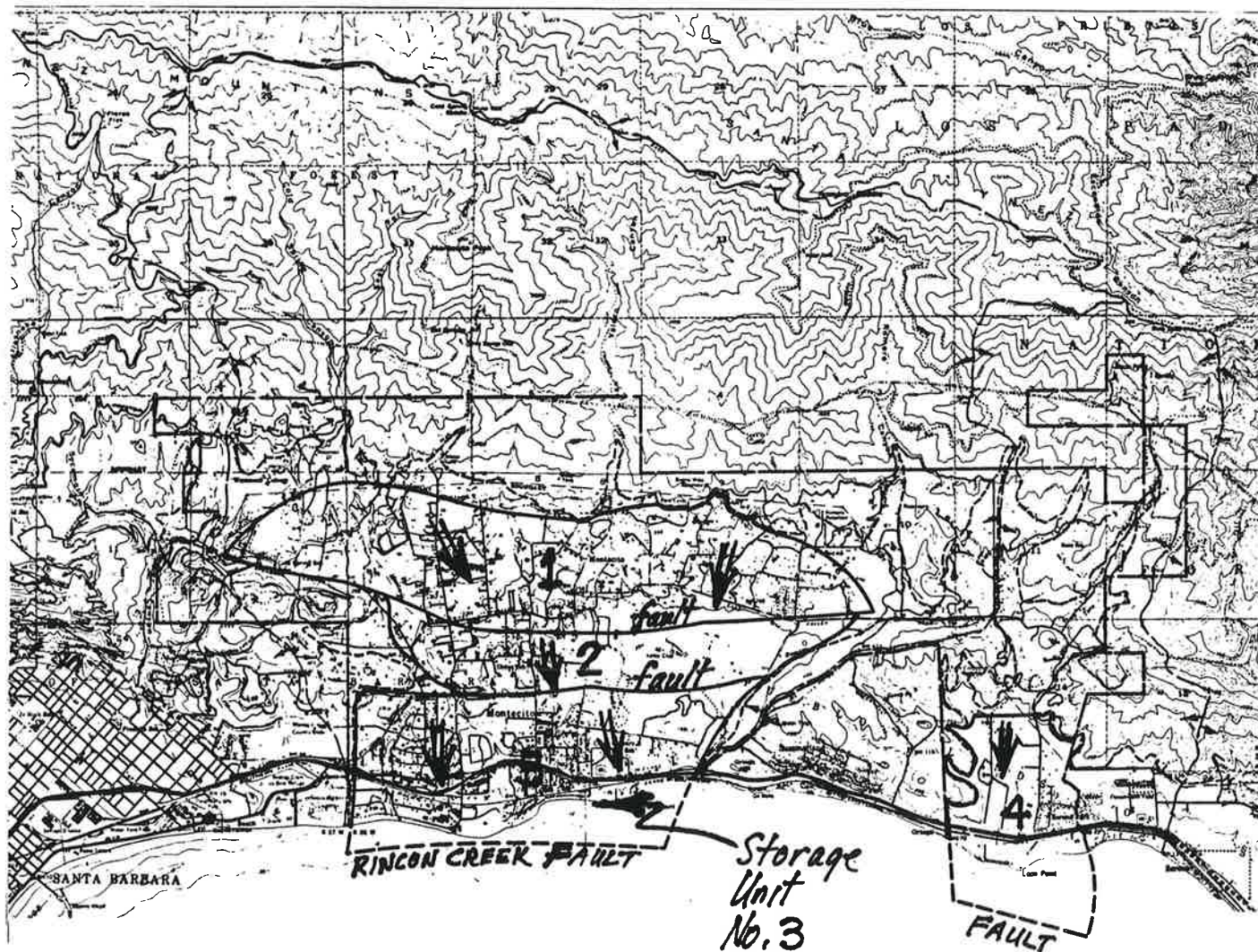
Respectfully submitted,

A handwritten signature in black ink, appearing to read "Richard C. Slade". The signature is fluid and cursive, with the first name "Richard" and last name "Slade" clearly distinguishable.

Richard C. Slade

Registered Professional Hydrogeologist

FIGURE 1
GROUND WATER STORAGE UNITS



LEGEND

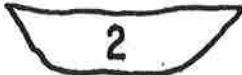
- GROUND WATER BASIN BOUNDARY
- MONTECITO COUNTY WATER DISTRICT BOUNDARY
- ↙ ————— WATERSHED DRAINAGE DIVIDE - ARROWS INDICATE DIRECTION OF SURFACE FLOW.
-  GROUND WATER STORAGE UNIT BOUNDARY



Figure adapted from GTC (1974)

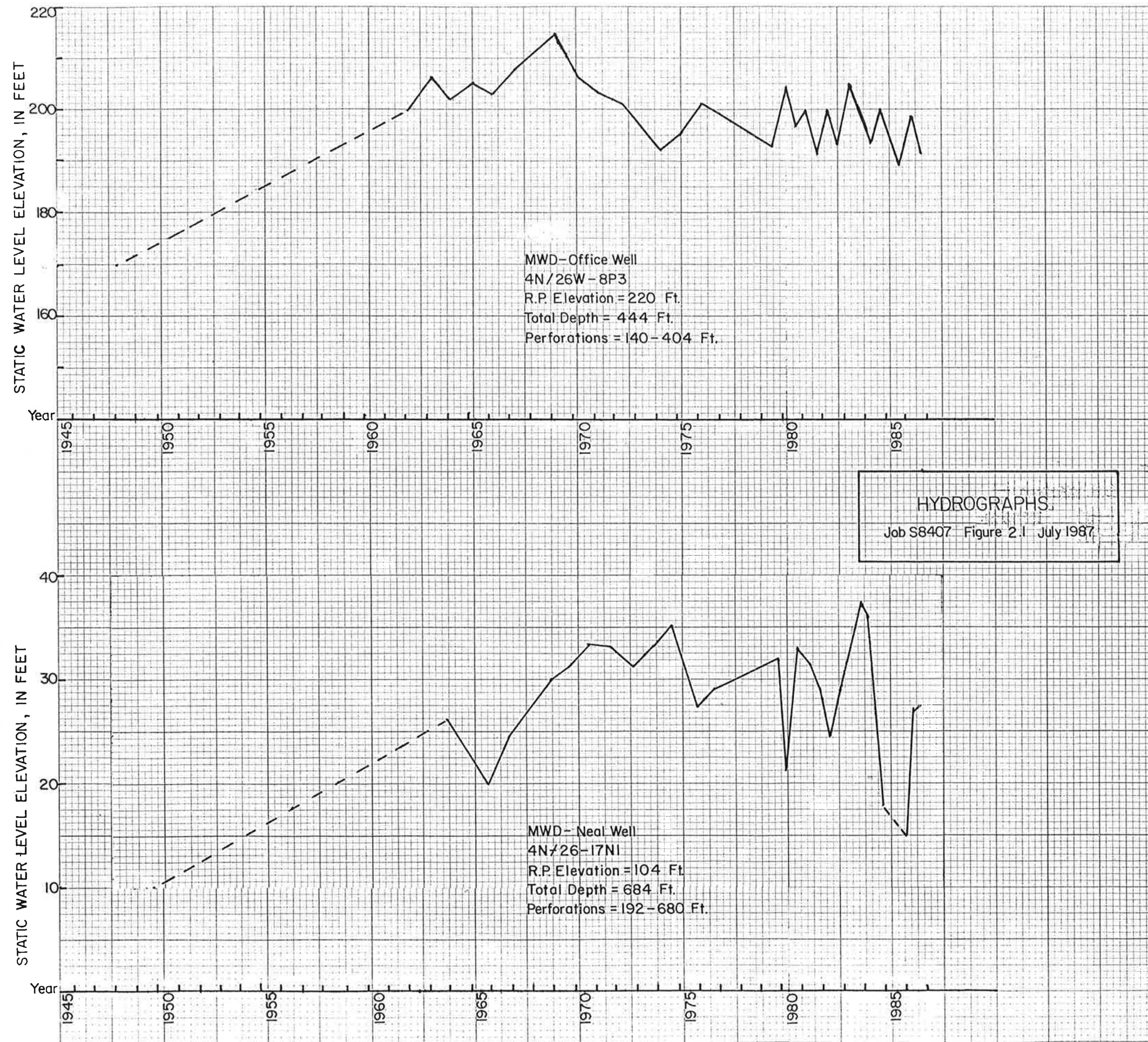
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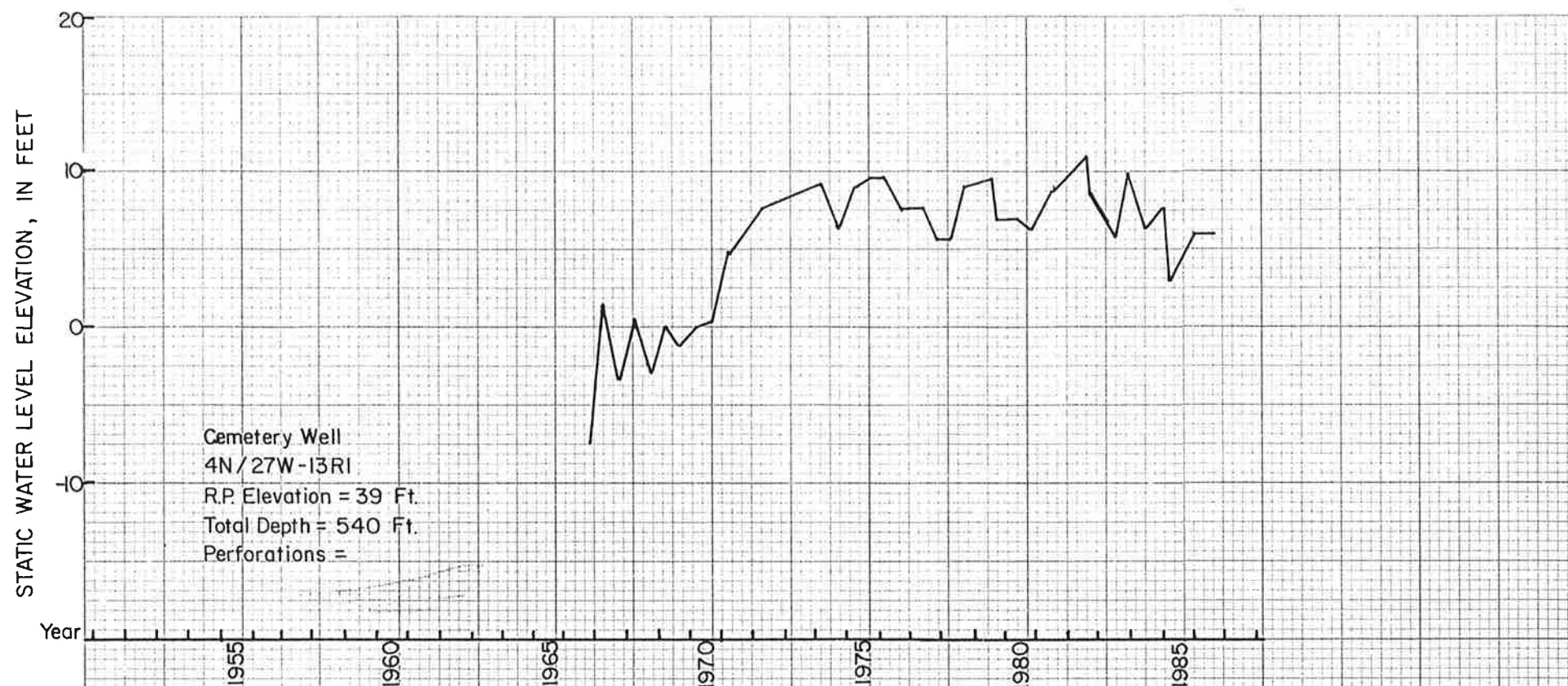
ARROW INDICATES GENERAL DIRECTION OF GROUNDWATER FLOW

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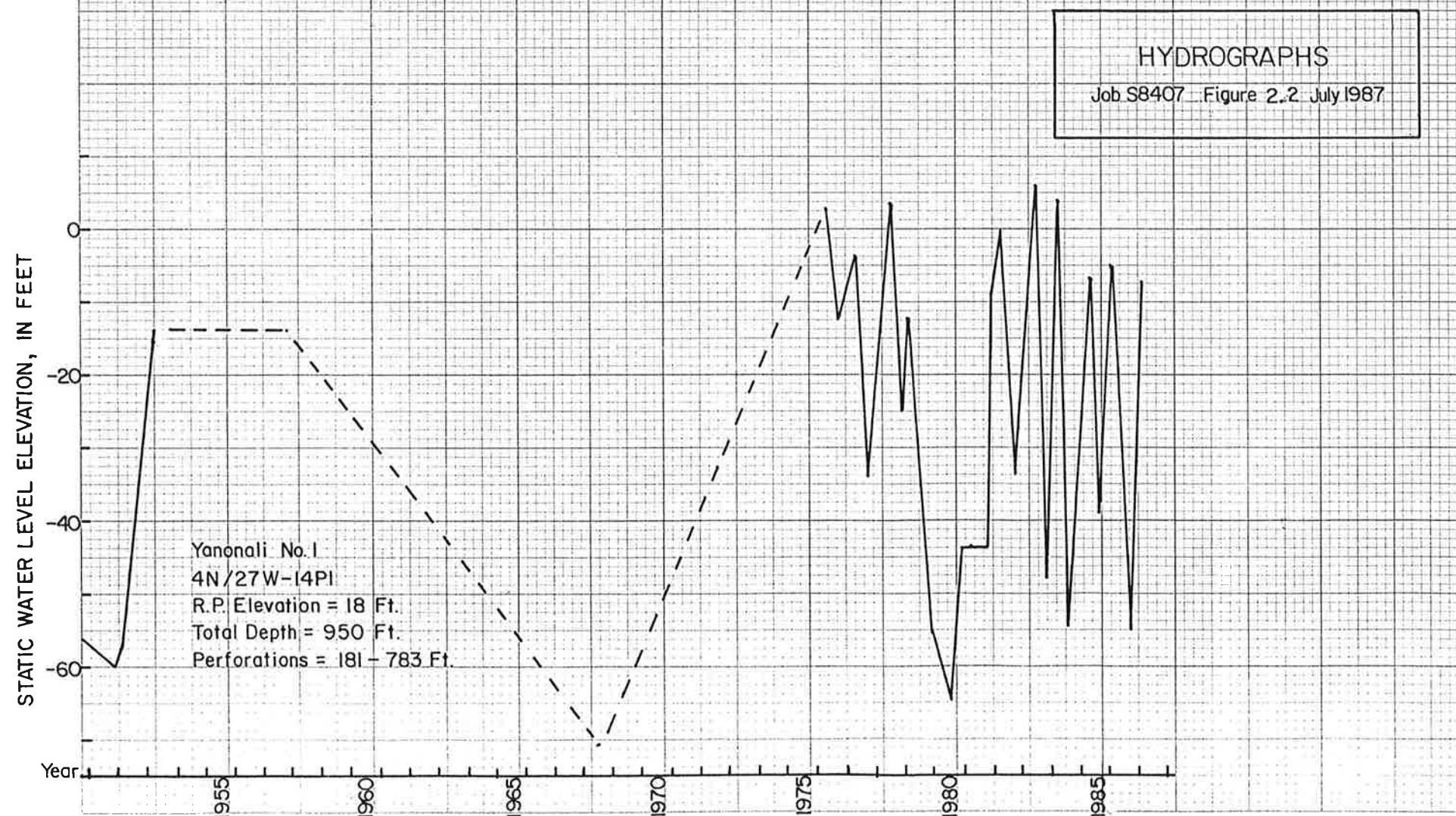


Plate 1 - Electrict Log Data Points - too big to scan

Plate 2 - Map of Base of Fresh Water - too big to scan

Plate 3 - Water Level Elevations April 1986 - too big to scan