MIOCENE GROUNDWATER OVERDRAFT IN SOUTHERN MISSISSIPPI

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INTRODUCTION

Miocene water level declines of approximately one foot or more per year have often been reported in the literature on Mississippi water resources. This paper will present data relative to water level declines in the Miocene in the area of Tatum Dome, 9 miles west of Purvis, Mississippi. The main thrust will be to present data from holes currently monitored on Tatum Dome by the Environmental Protection Agency (EPA). These data will be presented along with historical measurements in the same area to show the water level declines over a period of approximately 25 years. The original holes were drilled and completed in the Miocene in the Tatum Dome area in support of an AEC (now DOE) project. These holes have never been used to any extent for water production and the closest significant production from the Miocene is probably at Purvis, 9 miles to the east, also in Lamar County. The purpose of this paper is to provide some conclusions and discussions of the implications of the water level declines noted.

GEOLOGY AND HYDROGEOLOGY

Subsidence of the Mississippi embayment and Gulf Coast geosyncline has caused the accumulation of a thick wedge of Miocene sediments. Sedimentary processes were probably similar to those of today with the formation of bay, estuarine and deltaic deposits. As subsidence took place, the edge of the marine environment migrated south and southwest to its present position. Continental uplift also occurred so that the Miocene and older beds to the north and northeast were eroded and truncated. The derived sedimentary material was deposited in the marine environment of the ancient Gulf of Mexico. Towards the Gulf Coast the Miocene grades upward into the Pliocene and its difficult to differentiate between the two. The surface deposit, the Citronelle, is irregular in thickness and covers the Miocene and Pliocene surface except where it has been eroded away and partially replaced by Pleistocene terrace deposits, recent alluvium and, along the Gulf Coast, by beach sands. The truncated edge of the Miocene and younger deposits is illustrated on the map (Figure 1). The outcrop extends west by northwest from the northern part of Hines County in the east to the northern part of Payne County on the west side of the state.

Beneath the Miocene are the Oligocene and Eocene and these formations constitute important aquifers in the northern part of the state. Their depositional history is similar to that of the Miocene. Although aquifers can be identified locally and have been identified in the Tatum Dome area, the sands and clays tend to be in lenses and are discontinuous laterally. The Miocene contains many of these lenses and the aggregate thickness may be as much as 50% of the Miocene section (Taylor, et al, 1968, p. 65). The freshwater is in sand lenses from the top of the Miocene to 1,300 feet below sea level in Lamar County (op cit, p. 58). Geohydrologically, the lensiness of the sands and clays in the Miocene prohibit identifying specific aquifers in a regional sense, although some of the zones containing more sand or zones containing less sand are possible to trace. In a regional sense, one must consider the Miocene section to be sufficiently interconnected to represent a block of anisotropic sediments which are more transmissive along bedding planes than they are normal to those bedding planes. It is probably erroneous to consider individual wells, except locally, to be producing from any specific aquifer in the Miocene section.

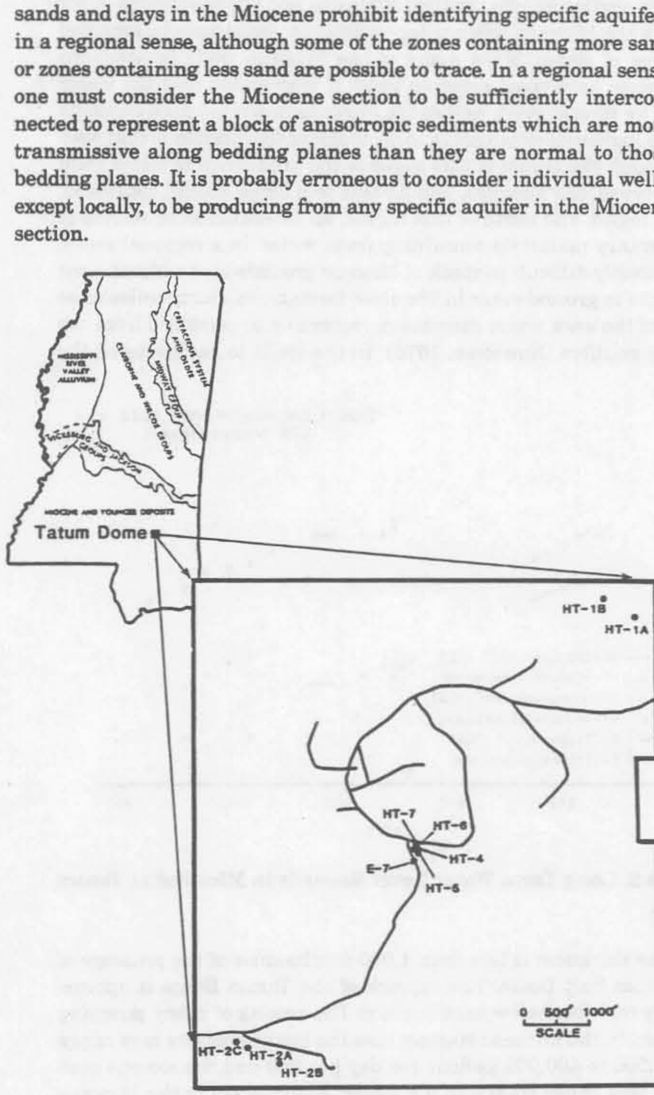

Figure 1. Location and Geologic Map (Modified from Arthur and Taylor, 1986.)

Prior to extensive development for water resources, the Miocene hydrologic system probably functioned as follows:

Most of the recharge to the Miocene aquifers is the result of precipitation in the area of outcrop of the aquifers. Some of the recharge water to the Miocene may also be underflow developed from the Eocene and Oligocene outcrops in northern Mississippi. Prior to development, water movement in the Miocene aquifers was from the recharge areas in the outcrops to the discharge areas along the Gulf Coast and along the Mississippi River as illustrated by Payne, 1968. Originally, moving ground water probably pushed back the fresh-water saltwater interface and flushed some of the saltwater out of the sand lenses. The discharge for this fresh water was along the Gulf Coast and may have also been out into the Gulf of Mexico as far as 12 miles. There are water wells on Ship Island that produce water of low chloride content and an electric log of an oil test on Horn island indicates that there may be fresh water bearing sands to a depth of 1,500 feet (Newcome, et al, 1968, p. 67). Municipal water supplies in the coastal communities such as Gulfport, Biloxi and Long Beach are close to 1,000 feet in depth. Many of them originally had artesian heads above land surface.

In brief, originally a large flow of groundwater was moving to the south by southwest into the Gulf of Mexico and the Mississippi River through the Miocene and earlier sediments. Wells have intercepted this flow of water. Since many of the Miocene wells in southern Mississippi have some artesian head, it is probable that the water supply for almost every well in the Miocene is derived from recharge at some higher elevation north to northeast of the location of that well.

Although the thrust of this paper is the production of water from the Miocene, the Miocene, and Eocene to a large extent, represent, in this region and north of this region, an interconnected section of sedimentary materials containing fresh water. In a regional sense, it is probably difficult to speak of Miocene groundwater without some reference to groundwater in the older formations. thirty miles or so north of the area under discussion, water is also produced from the Eocene aquifers (Newcome, 1975). In the wells to be discussed the

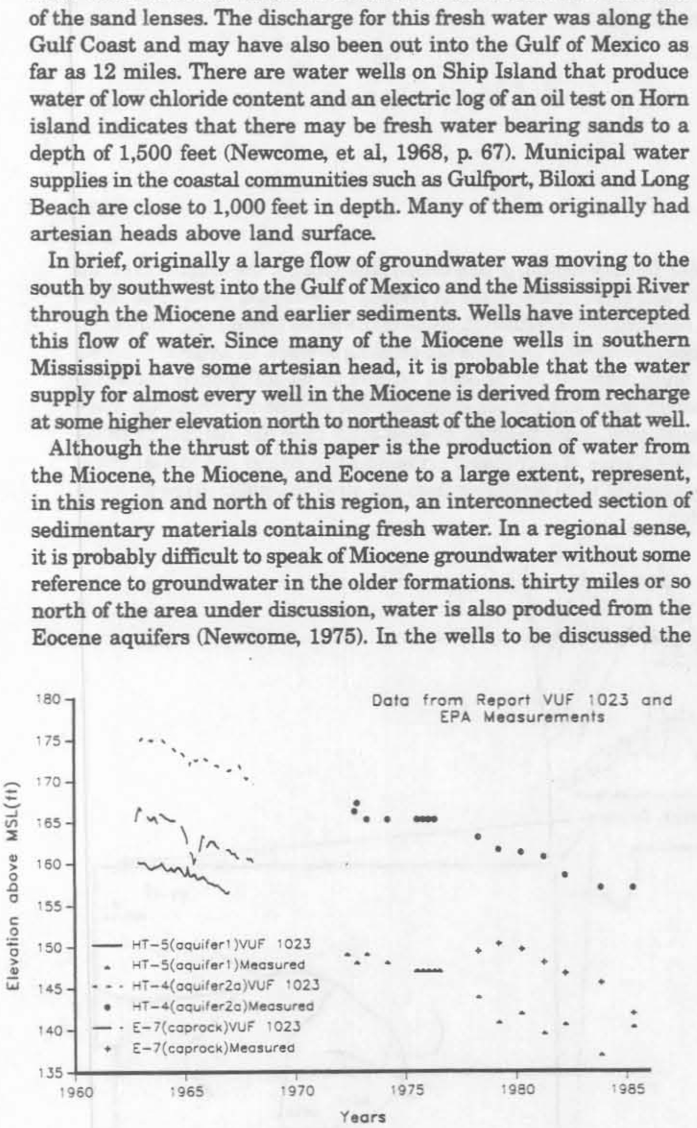

Figure 2. Long Term Water Level Records in Miocene at Tatum Dome.

Miocene thickness is less than 1,000 feet because of the presence of the Tatum Salt Dome. The caprock of the Tatum Dome is approximately 900 feet below land surface. The results of many pumping tests run in the Miocene suggest that the transmissivity may range from 1,500 to 400,000 gallons per day per foot and the storage coefficient may range from 3 to 6 x 10(-4). Water levels in the Miocene aquifers have been declining at about a foot per year since 1961 (Figure 2) and at lesser rate than that before 1961. This observation also applies to the flowing wells. The decline in water levels is particularly well illustrated by the Tatum Dome wells, since they are about nine miles from the closest significant extraction point, Purvis, and have not been significantly disturbed except for the collection of samples and measurement of water levels. The original hydrologic system has been modified by the substantial discharge points developed in that system to the extent that water now flows to the discharge points, rather than between recharge and discharge area. In the regional sense there is no indication that the clays between the sand layers act as confining beds. However, well tests in the Tatum Dome area did not indicate any significant leakage between aquifers. (Fenske and Humphrey, 1980). Based on Payne's (1968) work one would expect the hydraulic heads in the sandstones in the Tatum Dome area to be either constant or increasing with depth. Since this is not the case at Tatum Dome, a sand at 600 feet having the lowest head in the Miocene section above Tatum Dome (Fenske and Humphrey, 1980), the difference in heads is probably due to production of Miocene groundwater in this part of Mississippi.

WATER LEVEL RECORDS IN THE TATUM DOME AREA

A large number of holes were drilled into the Miocene in the Tatum Dome area for one purpose or the other. Many of these holes were converted from test walls to other purposes and ultimately plugged or abandoned. Presented here (Figures 2 and 3) are records from the early 1960's, '61 or '62, of the water levels on some of these wells in all the aquifers that have been identified over Tatum Dome. In general these wells were not used for producing water, but were used as water level and water quality monitoring wells. HT2C (Figure 3), however, was a well in the local aquifer, the top most aquifer that one finds in the Miocene, that was used as a water supply well for drilling purposes. Well HT2C was included to provide some water level data from the local aquifer. All but three of the wells were abandoned or converted to other purposes about 1967 when the Miracle Play program, a series of gas explosion experiments in the cavity created by the former nuclear detonations, took place at Tatum Dome. After the Miracle Play program in 1972, the site was decommissioned. At that time a hydrologic monitoring program was set up at Tatum Dome, and this program included the three wells, which exist today, that sample the aquifers in the Miocene above the salt dome. Subsequent to that time, 1979, a series of wells were drilled to each aquifer above Tatum Dome around the emplacement hole. However, water level

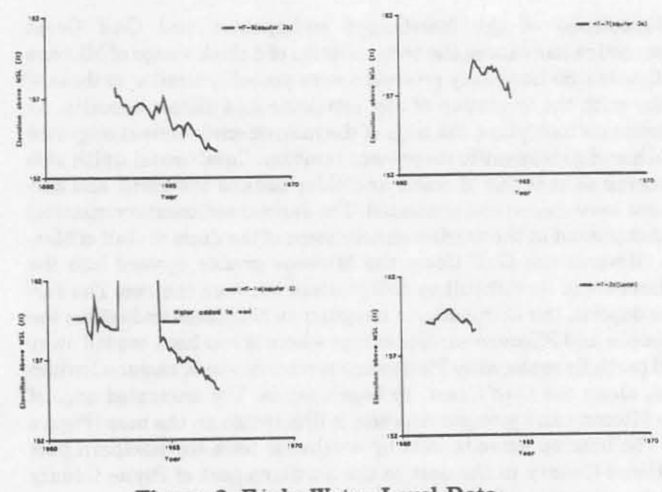

Figure 3. Early Water Level Data.

measurements cannot be obtained from these holes since they are pumped during the Environmental Protection Agency's sampling trips and there is not ready access to the well for water level measurement.

Three aquifers plus the local aquifer, the first Miocene sand encountered, have been identified in the Tatum dome area. Aquifer-2 and aquifer-3 have been divided into two parts so there is an aquifer-2A and 2B and 3A and 3B, all designations made on the basis of increasing depths. the most extensive water level records are in wellHT4, aquifer-1, well HT5, aquifer-2A and well E7, the caprock aquifer. All other water level records terminate in about 1967. Using the best straight line through these data to estimate the drawdown indicates that these aquifers are being drawn down between a foot to a foot and a half per year. Aquifer-1 drawdown may be slightly higher, and this is not unreasonable, since most wells are completed in the first zone that produces sufficient water, and there are more wells completed in the upper part of the Miocene than there are at greater depth in the Miocene. However, the fact that similar rates of drawdown are experienced by all aquifers illustrate the probable regional interconnection of the Miocene ground-water system.

DISCUSSION

Since the Miocene aquifer averages about 1,500 feet in thickness over southern Mississippi and, conservatively, probably only a fourth of that consists of Miocene sands (Taylor, et al, 1968), one can estimate the storage coefficient to be somewhere in the neighborhood of 3 x 10-4 to 6 x 10-4 comparable to the measured values. For the Miocene sands, this translates into an overdraft of 3 x 10-4 to 6 x 10-4 feet of water per year as compared to one foot of head loss per year. Since this loss in head is fairly universal, one can spread that amount of drawdown over the approximately 22,000 square miles of Miocene aquifer outcrop and estimates that the total amount of overdraft is about 4 to 7 million gallons per day.

In 1970 the total groundwater discharge for public supplies and industrial supplies from the Miocene aquifer was 195 million gallons per day (Callahan 1971). By 1974 this groundwater discharge from the Miocene aquifers had increased to 209 million gallons per day, an increase of 3.5 million gallons per day per year. On that basis, the current groundwater discharge from the Miocene aquifers is approximately 250 million gallons per day. Comparing the estimated overdraft to the total estimated discharge of 250 million gallons per day that are produced from Miocene wells in southern Mississippi, only 2 to 3 percent of the water appears to be produced from storage.

The Miocene sands are unconsolidated and separated from one another by lenses of water saturated Miocene clays, and it is possible that some of the additional water is derived from compaction of both the clays and the sands in the Miocene section as well as expansion of the cone of depression for each discharge center. Since surface subsidence does not appear to be a significant factor in Mississippi, the majority of the extra ground water must be derived through interception of recharge.

Three sources of water are envisioned for the current production of water from wells in the Miocene. One source is the production of water from storage, another source is the production of water as a result of consolidation of aquifers and aquitards and the third source is interception of recharge. That is, in the upgradient direction the asymmetrical cone of depression has already intercepted the recharge area for many of the sands that comprise the aquifers of the Miocene.

Most discharge from the Miocene is probably in a transient state. In an aquifer where substantial water is moving through the aquifer, the cone of depression of any well will continue to expand until the well intercepts a wide enough flow path in the aquifer to equal the discharge of the well. This phenomenon was investigated as early as 1899 by Slichter, and two of his illustrations are reproduced here (Figure 3). Figure 3a illustrates a single well in a flow field moving from left to right. Under equilibrium conditions the well intercepts exactly the width of the flow field required to equal the discharge of the well. The discharge of the well also equals the recharge to the aquifer. The cone of depression is stabilized and no decline in water levels occurs. Figure 3b illustrates a more complex and closer to reality situation involving interference between two extraction points. The width of the flow field of the second well is split into two parts. Nevertheless, the width intercepts the required flow to equal the discharge of the well. This last illustration is vaguely representative of the flow field construction based upon 1962 data (Table 1) in the Tatum Dome area (Figures 4a and 4b). These maps of the Tatum Dome area are not transient maps, they do not show the conditions in 1962 or in 1979 but show the conditions that would obtain, when steady state conditions are met in the distant future, if the discharge rates at the extraction points do not change significantly. One can see from these maps that the extraction of water from the Hattiesburg area, including Camp Shelby and several other locations, will overwhelm the effect of extraction from the Miocene by some of the smaller communities. The width of the flow field intercepted by this main extraction from the Miocene aquifers will be extensive, since the groundwater flow lines have barely started to curve up towards the north-northeast in the probable direction of regional flow. One can assume that this will be the case for all major extraction points from the Miocene in Mississippi. For the equilibrium situation to eventually occur and persist enough recharge is required to supply all the water discharged from the Miocene.

TABLE 1
Discharge Data for Groundwater Extraction Points in Vicinity of Tatum Dome (From Fenske and Humphrey 1980)

Map Identification	Name	Discharge (mgd) 1962[a]	1979[b]
1	Columbia	0.86	5.1
2	Lumberton	0.2	2.1
3	Purvis	0.16	1.7
4	Gulf Oil Company[c]	3.5	3.5
5	Sumrall	0.8	5.0[f]
6	Hattiesburg	6.5	16.7
7	Baxterville		.3
8	Southern Mississippi Electrical Power Association		11.5
9	Hercules Power Company[d]		3.6
10	Dixie Pine Products[d]		2.9
11	Camp Shelby, Bogalusa, Louisiana[e]	8.26	26.4

[a] Data from USGS report Dribble 34 Reference 4.
[b] Data supplied by Mississippi Geologic Survey except for Bogalusa Data, which is from Reference 11.
[c] This is apparently formerly Pontiac-Eastern Refining.
[d] These industries were apparently included in the Hattiesburg discharge in 1962.
[e] South of Figures 35 and 36, approximately 29 miles southwest of Lumberton.
[f] Sumrall is estimated.

A crude estimate can be made of the percentage of precipitation required to recharge the Miocene to equal the current discharge. However, to do this one must take into consideration the recharge into the older aquifers in northern Mississippi, since the groundwater in these aquifers also travels toward the Mississippi River and the Gulf of Mexico by underflow into and travel through the Miocene aquifers. All aquifers above the Midway of lower Pliocene age should probably be considered. The total outcrop area of these formations occupy approximately 84% of the state of Mississippi or 39,500 square miles (Arthur and Taylor, 1986).

On the average, Mississippi receives 55 inches of precipitation per year; more to the south where the precipitation is as high as 60 inches per year and less to the north where it decreases to 50 inches. This amount of precipitation represents an average of 2.6 million gallons per day on each square mile or 1 x 10^5 million gallons per day on the 39,500 square mile area of Citronelle, Pleistocene terrace deposits and outcrops of the Eocene through Miocene. Groundwater recharges the Citronelle, the terrace deposits and also the Miocene

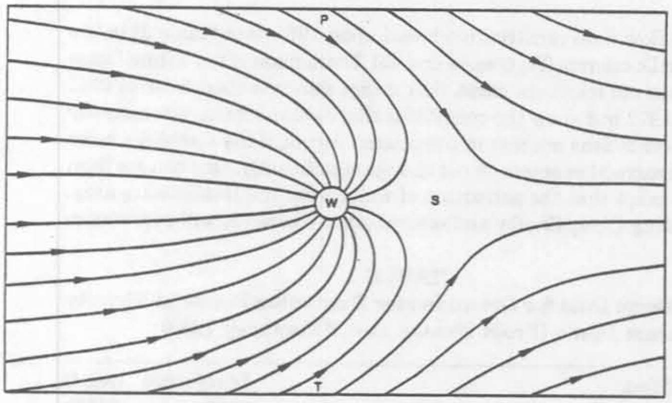

Figure 3a. Single Well in Steady Flow Field.

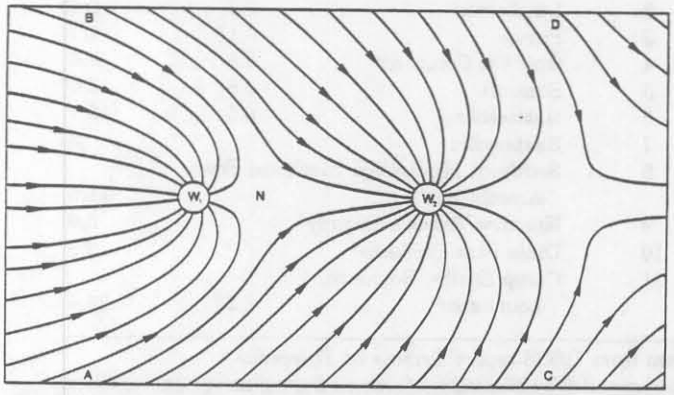

Figure 3b. Interference Between Two Wells in Steady Flow Field.

and older aquifers both directly through the outcrops and also through subcrops. Presumably water that recharges Citronelle will continue on downward into the Miocene and older aquifers if possible. If it cannot, if the Citronelle is in contact with a subcrop of clay in the Miocene or older rocks, it will move along this subcrop to recharge an aquifer or discharge as springs and seeps into the surface drainage system.

Not considering the Mississippi River, three major streams drain Mississippi, the Pearl River on the west and the Pascagoula River on the east which drain into the Gulf of Mexico, and the big Black in the north which drains into the Mississippi River. The low flow during drought periods of these rivers should represent the base flow and a crude estimate of natural groundwater discharge from the aquifer systems. While high flow in the rivers may recharge the groundwater system through outcrops intersected by the rivers and as bank storage. Conservatively estimated base flow of the three rivers is 2,300 million gallons per day. An estimate of the groundwater discharge from the Miocene and Eucene aquifers would be about 450 million gallons per day. Therefore, the total discharge of groundwater in Mississippi including low flow in the Pascagoula, Pearl, and Big Black Rivers is approximately 2,750 million gallons per day. Comparing this to the 1×10^5 million gallons per day of precipitation indicates that required recharge to the groundwater system to supply this discharge is not more than about 2.8% of precipitation. In view of the infiltration rates measured in the Tatum Dome area in 1979 of .5 to 1 inch per hour (Fordham and Fenske, 1987), this amount of recharge does not appear to be an excessive requirement. Indeed, several times this amount would probably be realizable.

Groundwater overdraft would certainly be of concern if the historic one foot per year of drawdown would continue into the distant future. A crude water budget presented here for the Miocene and older aquifers in Mississippi suggests that groundwater overdraft is not

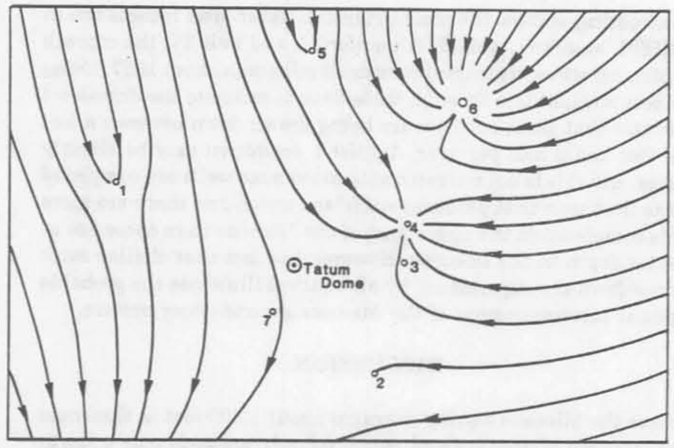

FIGURE 4a. Equilibrium Flow Field at Tatum Dome, 1962 Data.

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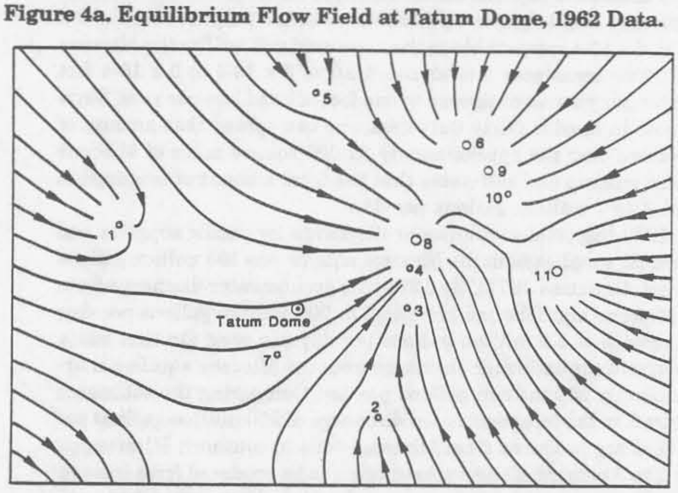

Figure 4b. Equilibrium Flow Field at Tatum Dome. 1979 Data.

taking place but that the cones of depression created by the withdrawal points are expanding to intercept the required amount of aquifer flow that is fed by recharge on the outcrops or subcrops of the Miocene.

The extraction in the Hattiesburg area will require water recharge at a different outcrop than the extraction from some area further south in Mississippi. For example, Newcome, et al (1968) feel that the 600 foot sands that supply wells at Keesler Air Force Base are probably replenished in an east-west band that crosses the south end of Stone County passing through the McHenry area. Also the recharge area for the sand that supplies the deep wells at Biloxi and Gulfport, Mississippi probably crosses Stone County in the Wiggins area. Therefore, since wells are almost always completed in the first sand that meets the water supply requirements, and the sands dip towards the Gulf with the outcrops truncated toward the north-northeast one would not expect serious well interference between main extraction points that are located in a north-south direction. There might be interference between major extraction points located in a generally east-west direction.

CONCLUSION

Although a constant rate of drawdown of approximately a foot per year in the Miocene aquifers strongly suggests that significant overdraft is taking place in the Miocene, consideration of the extensive outcrops and subcrops of Miocene along with the high precipitation rate, high infiltration potential and consequent high recharge potential indicate that the production of groundwater in Mississippi could be significantly higher than at present without causing an overdraft. The decrease in the water level in the aquifers is a transient situation which will persist until the cones of depression related to the extraction points are broad enough to capture a flow field equal to the extraction of groundwater in that area. When this happens the water levels will probably stabilize, although at a different time for different extraction points. Because of the nature of the hydrogeology of the Miocene, interference between major extraction points is not considered to be a significant future problem.

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