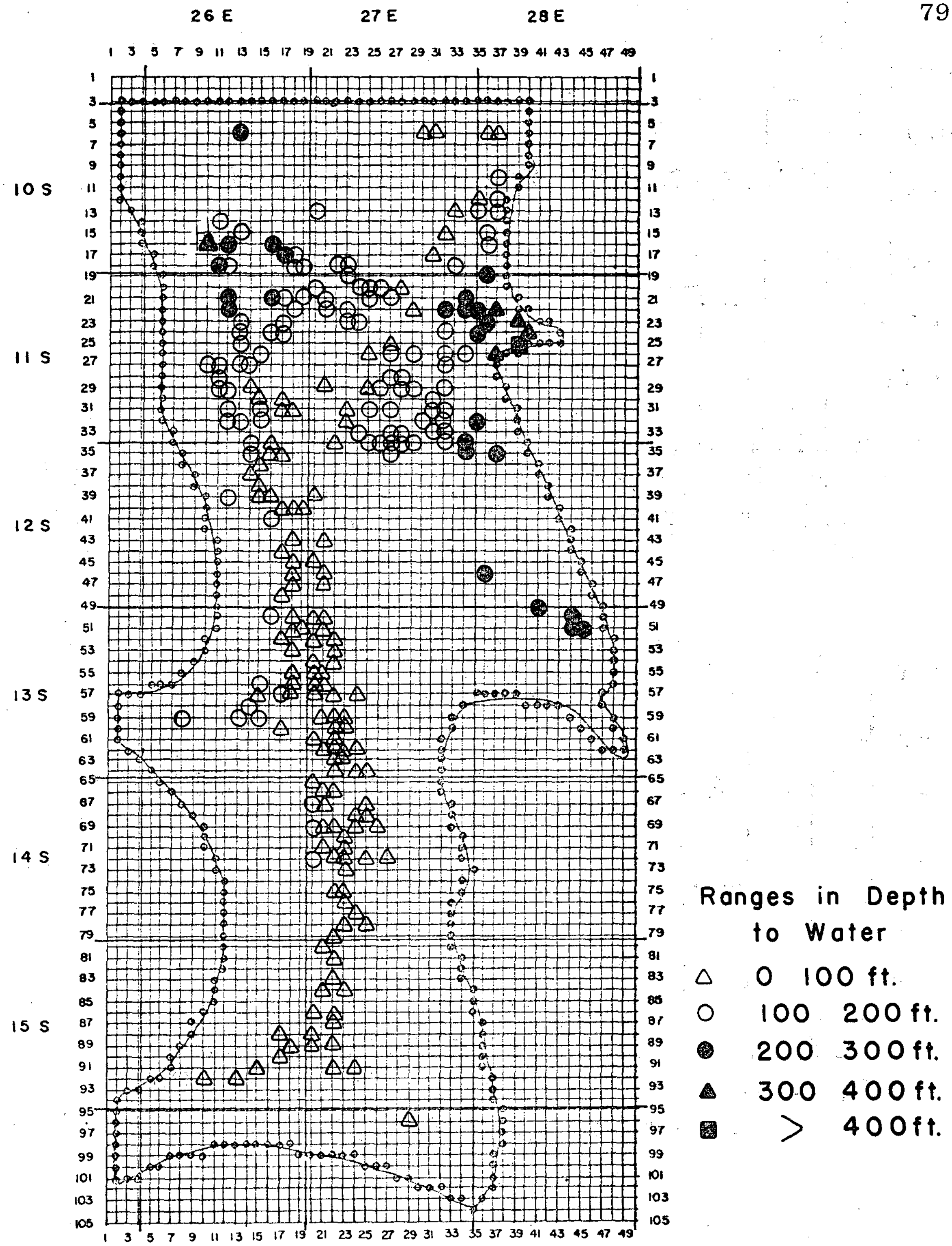


Figure 7

Depth to Pumping Water Level in Wells
at the End of the Pumping Season of 1975, Basis Run

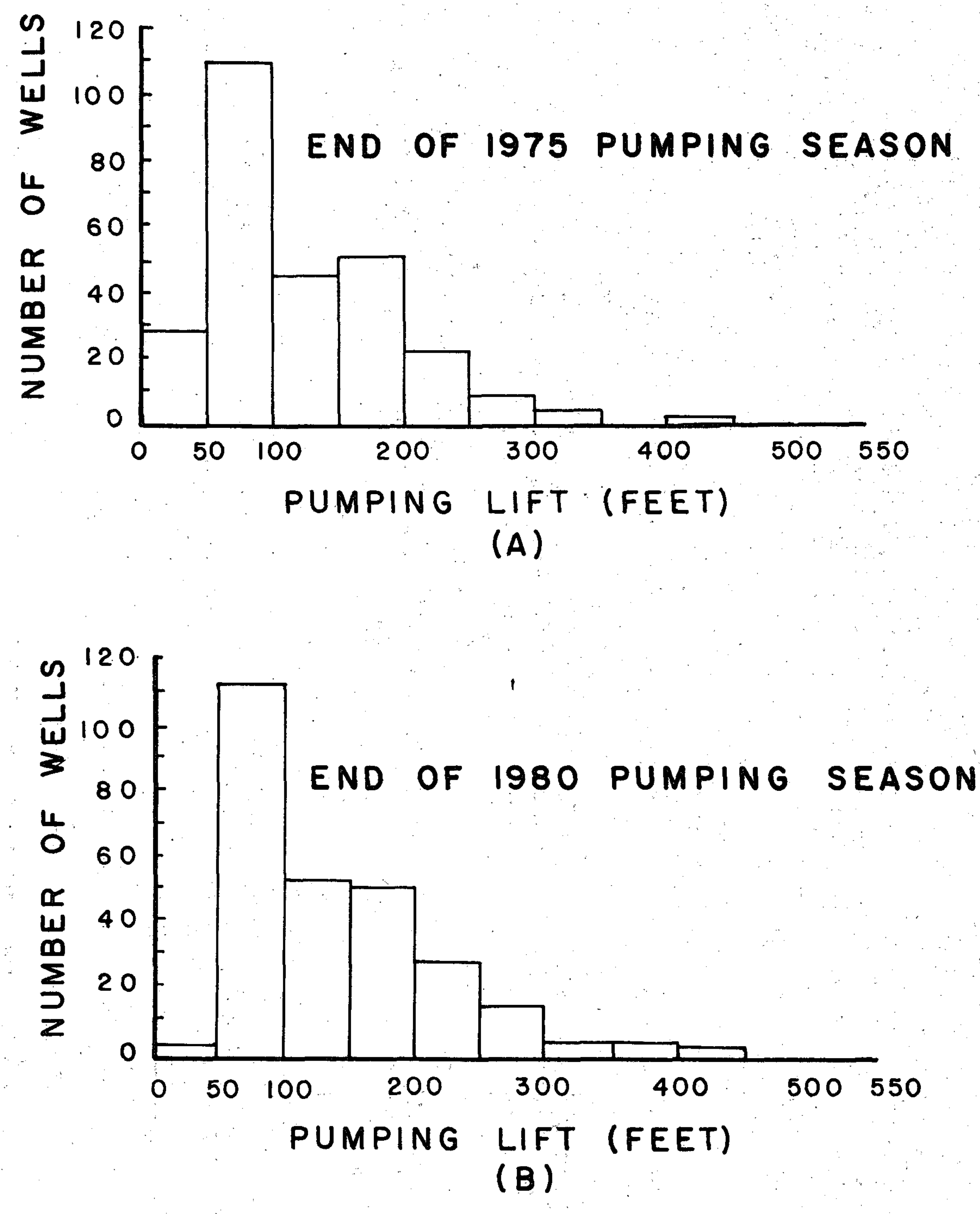
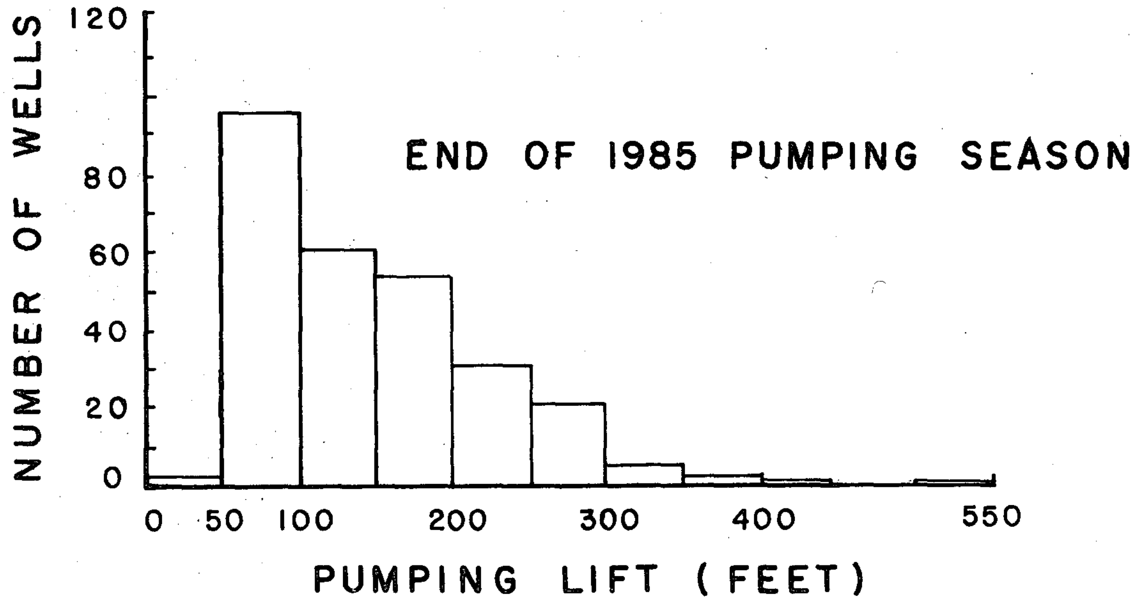
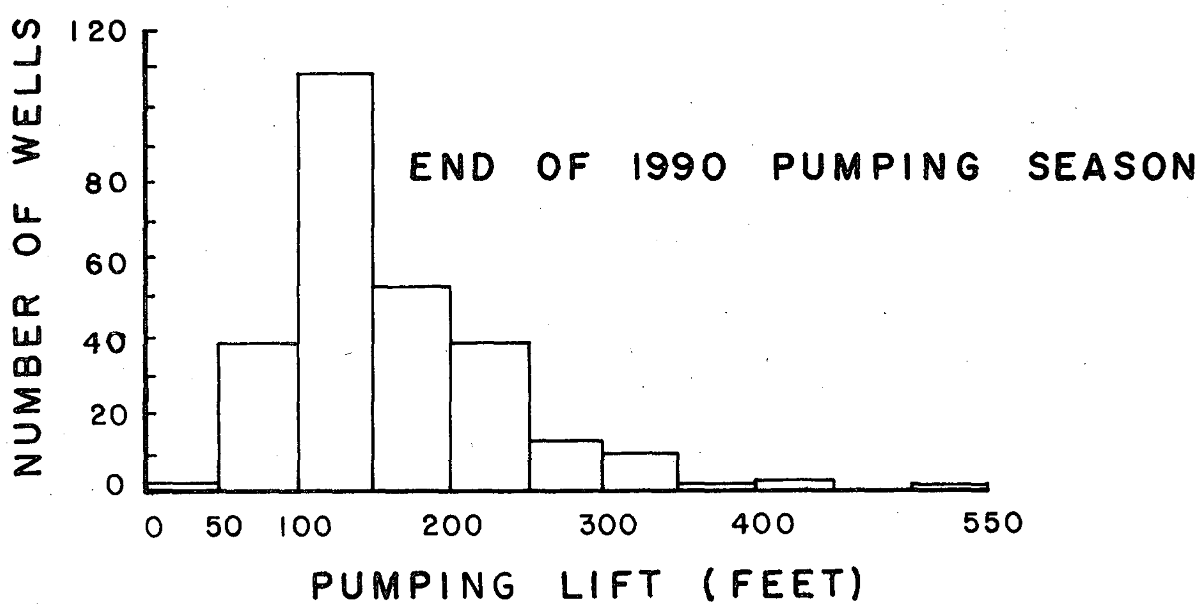


Figure 8

Distribution of Pumping Lift in the Study Basin
at End of Pumping Season of
(A) 1975, (B) 1980, (C) 1985 and (D) 1990



(C)



(D)

Figure 8 (continued)

published estimates of reasonable pumping levels for the study basin. They note a range of 450-550 feet as a reasonable lift in the northern portion of the basin, but suggest a lower but undefined lift for the southern portion of the area. The objective of this study is not the determination of a reasonable pumping lift value but rather the determination of the impact of administration under this guideline. The number of wells per year that have pumping lifts equal or exceeding selected reasonable pumping lift values are presented in Table 1. If the reasonable pumping level were selected as 300 feet, three wells would already exceed that level in 1971. However, if the level were selected at 450 feet, administration would not be initiated until 1981 when one well reaches that level. It is assumed in this study that administration is automatically initiated when the level is reached. In actual basin administration, management action would probably not occur until a senior pumper registered a complaint and asked for action.

The first operational run for analysis of impact from resource administration under the reasonable pumping lift concept was based on the following decisions (see Figure 3).

1. Reasonable pumping lift as the management tool.
2. Reasonable pumping lift defined as the maximum depth to pumping water level.
3. Entire basin selected as the administrative unit with administrative action continuing through 1990.
4. Reasonable pumping lift of 450 feet selected for administration.
5. Closure of junior users under plan A.

No administrative action would be required under this plan until 1981 when a single well reached the designated reasonable

Table 1: Number of Wells Per Year Equal or Exceeding Selected Reasonable Pumping Lift Values in Study Basin

	Pumping Lift Value				
Year	300 Feet	350 Feet	400 Feet	450 Feet	500 Feet
1971	3				
1972	3	1			
1973	4	1			
1974	4	1	1		
1975	5	1	1		
1976	5	1	1		
1977	5	1	1		
1978	5	3	1		
1979	5	3	1		
1980	5	3	1		
1981	5	3	1	1	
1982	8	3	1	1	
1983	8	3	1	1	
1984	8	3	1	1	1
1985	8	3	1	1	1
1986	10	4	3	1	1
1987	12	4	3	1	1
1988	13	4	3	1	1
1989	15	4	3	1	1
1990	17	4	3	1	1

pumping lift. Resource administration would then be based on the priority and location of the control user at the critical level. The critical depth of 450 feet was reached by a well at node 2539 with a priority of 272. Under plan A, all users junior to the user at node 2539 would discontinue pumpage for the remainder of the administrative period. In this case, sixty users were shut off with a combined discharge of 97.8 cubic feet per second. The location of these juniors is shown on Figure 9. The impact of this closure is shown on Figure 10 as water level changes from the Basis Run by 1990. Most of the water level change occurred

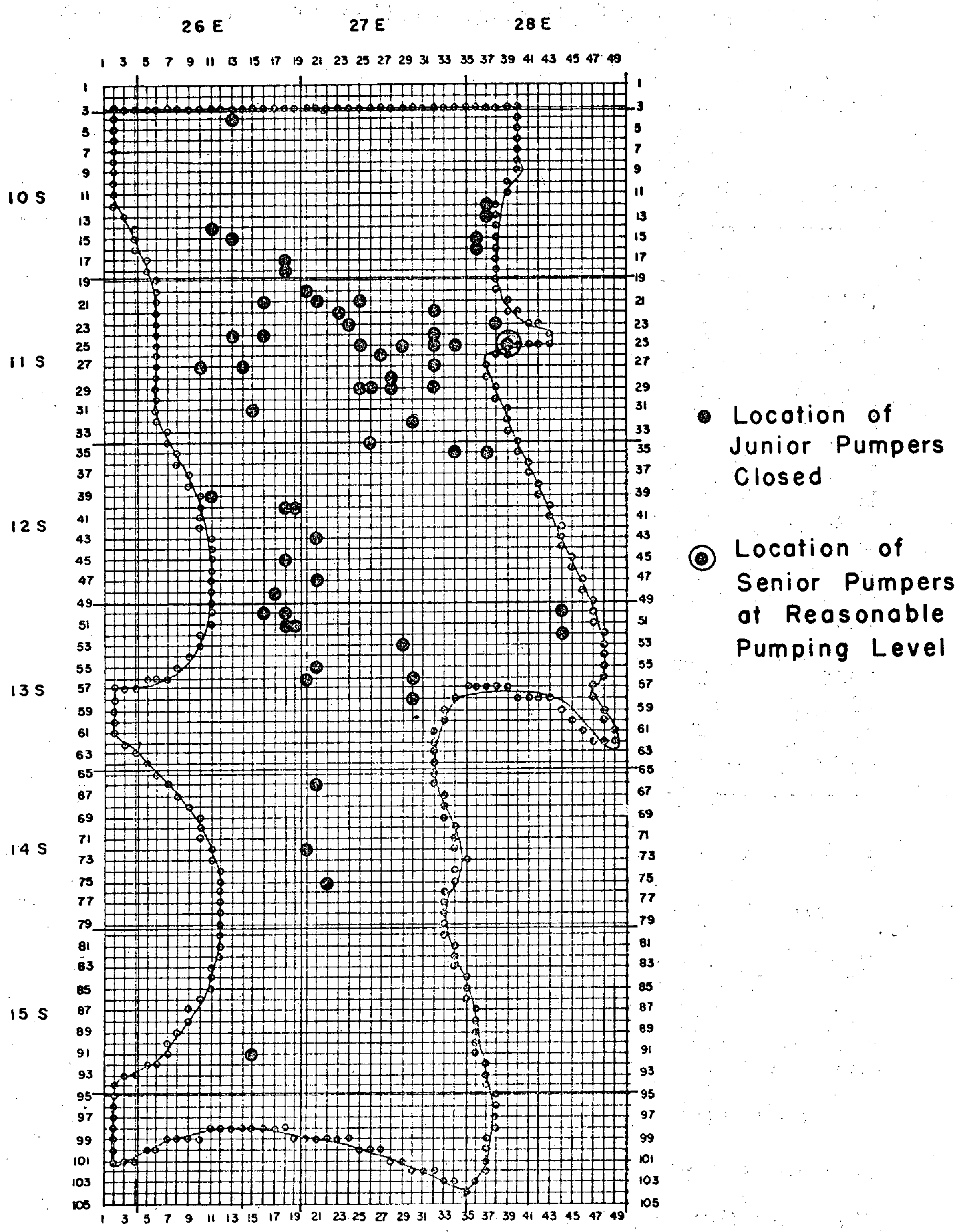


Figure 9

Location of Junior Pumpers Not Allowed to Operate
Under Plan A With Control Senior at Node 2439

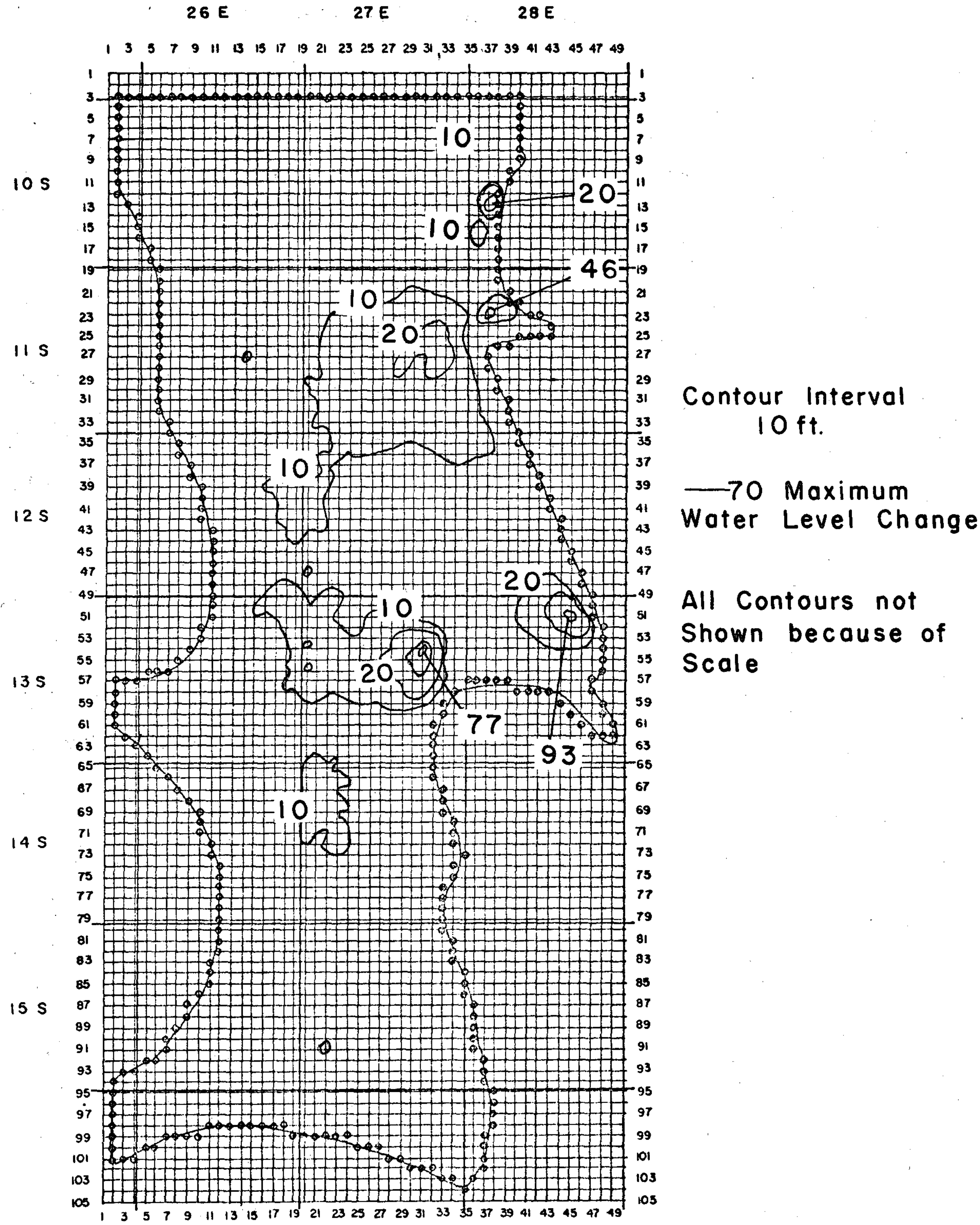


Figure 10

Water Level Rises by 1990 Because of Closure of Juniors
Under Plan A With the Control Well at Node 2539
as Compared to the Basis Run

in the center of the basin at some distance from the senior at the critical level. The senior received little benefit from this administrative action, even though twenty percent of the pumpage in the basin was discontinued. The lack of benefit to the senior was a result of the location of the senior with respect to the juniors and the hydrologic characteristics of the of the groundwater system.

The model was next operated with the first four decisions equivalent in order to determine the impact of the fifth decision (the pattern of closure of junior pumpers) on the water resource system. Administration of the resource was achieved with the closure of juniors under plan B (Figure 3). In this case, (n) percentage of the juniors were shut down each year for (1/n) years in reverse order of priority. A total of 12 users were shut down in each of five years to accomplish the closure. Changes in water levels between closure by plan A and plan B were minimal in the basin. Closure of juniors over a period of time lessens the impact of administration on the economic and social condition of the basin. More time is allowed for changes in land use and life style.

Plan C for the closure of junior pumpers was also evaluated. This plan involves the closure of (m) juniors per year starting with the junior nearest the control senior. Closure is dependent on location rather than relative priority among the juniors. This alternative was analyzed by closing five juniors per year for three consecutive years. Water level changes are more localized in the area of the senior pumper. However, the senior received little benefit from the closure. The economic and social impact of administration in the basin is more limited under plan C than plans A or B.

The impact of administration of the basin with different reasonable pumping lift values was also evaluated. A reasonable pumping lift of 350 feet was selected for examination. The 350 foot pumping level is first reached by the well at node 2539 in the pumping season of 1972 (see Table 1). Administrative action would be initiated by the closure of wells for the pumping season of 1973 under either plans A, B, or C. The only difference between this action and the one described earlier, is the length of the administrative period. Water level changes would be similar to those presented previously.

The well at node 2539 is not representative of the majority of the wells in the basin. It is located on the extreme eastern margin of the basin in a relatively thin section of the aquifer. The pumping lift is at least 50 feet greater than any other well in the study area. This well was temporarily removed from the analysis to determine the impact of administration based upon a different control senior.

The next wells to reach the designated reasonable pumping lift of 350 feet are located at nodes 2339 and 2440 in the pumping season of 1978. The priorities of the wells at nodes 2339 and 2440 are 270 and 271 respectively. They are located within one mile of the well at node 2539 with a priority of 272. The only difference between administration based on these wells and administration based on well 2539, is the closure of the well at node 2539. The water level changes resulting from administration based on the wells at nodes 2339 and 2440 would be very similar to that described previously. If these wells are also removed from the analysis, administration would be based on the well at node 2237. This well reaches the critical level in the pumping season of 1986. The location and priority (262) of this control senior would result in a similar physical impact from administration as that described above.

Administrative action based upon the following decisions provide a single general impact upon the basin.

Decisions:

1. Reasonable pumping lift as the management tool.
2. Reasonable pumping lift defined as the maximum depth to pumping water level.
3. Entire basin selected as the administrative unit with administration continuing from the time of administrative action through 1990.
4. Reasonable pumping lift selected as any value equal to or greater than 350 feet including or excluding the three users with the greatest lift.
5. Closure of juniors under plan A, B, or C.

Administration of groundwater is controlled by a group of wells along the eastern margin of the basin. These wells have consecutive priorities which may indicate ownership by a single individual. Users junior to these wells are located throughout the basin. Closure of the juniors results in general water level rise in the basin, but provides little improvement of the senior's pumping level. The depth to water in these wells is greater than other wells in the basin because of their location near the margin of the valley and the lower aquifer transmissibility. Given the decisions noted above, administration of the basin appears ineffective. Little protection is given to the senior user at the expense of closure of a large group of juniors.

The administrative action outlined above might benefit the senior user if the length of the administrative period is extended significantly. The analysis was limited to the period of 1970-1990 because of monetary limitations on the operation of the model. The length of the administrative period required to provide the senior with a measureable benefit could not be estimated from the available information.

The next series of operational runs was conducted with the following decisions:

Decisions:

1. Reasonable pumping lift as the management tool.
2. Reasonable pumping lift defined as the maximum depth to pumping water level.
3. Basin divided into two administrative units with the division line at node row I=37 with administration continuing from the time of administrative action through 1990.
4. Reasonable pumping lift of 450 feet selected for administration in the northern portion of the basin and a lift of 300 feet selected for administration in the southern portion of the basin.
5. Closure of junior users under plan A.

The division of the basin into two units has been suggested by Schatz (1974) on the basis of his analysis of economic return from irrigation by groundwater. He noted that the northern portion of the basin has the potential for row crop agriculture while the southern portion of the basin is limited to lower return grain and pasture operations. The division of the basin at node row 37 follows Schatz's economic division of the basin. Young and Ralston (1971) noted different reasonable pumping lift values for the northern and southern portions of the basin. Their division line is similar to that suggested by Schatz. A reasonable pumping lift of 300 feet was suggested by Schatz (personal communication 1974) for the southern portion of the basin on the basis of lower net returns from farm operation. The 450 foot reasonable pump lift value is that suggested by Young and Ralston (1971) as a minimum for the northern part of the basin.

The division of the basin into two administrative units limits closure of juniors to users within each unit. A senior user at the critical level in the northern portion of the basin may not force closure of a junior user in the southern portion of the basin.

Administrative action was initiated in the northern portion of the basin when the user at node 2539 reached the designated reasonable pumping lift of 450 feet in the pumping season of 1981. The first user to reach the designated level of 300 feet in the southern portion of the basin was at node 4941 in the pumping season of 1982. The water right for this well has a priority of 172. Under plan A, all users junior to priority 272 in the northern portion of the basin were closed in 1982, while all users junior to priority 172 in the southern portion of the basin were closed in 1983. Thirty-eight wells in the northern portion of the basin with a combined discharge of 58 cubic feet per second were not allowed to pump. An additional 61 wells totaling 103 cubic feet per second of discharge were not allowed to operate in the southern administrative unit. The location of the wells are shown on Figure 11. The results of the administrative action is presented in Figure 12 as water level change from the Basis Run by 1990. Extensive water level change may be

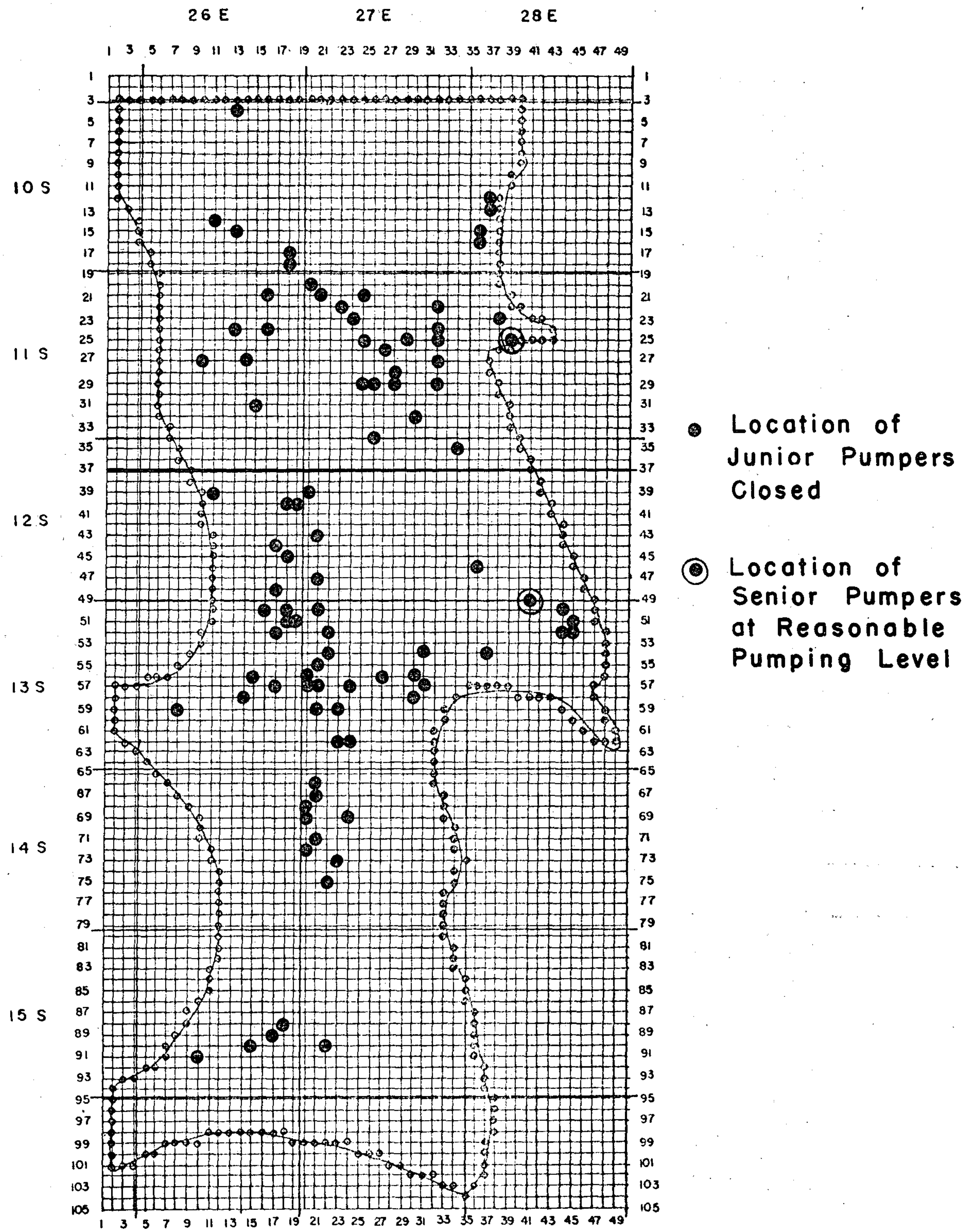


Figure 11

Locations of Junior Pumpers Not Allowed to Operate
Under Plan A with Basin Divided at I=37
and Control Seniors at Nodes 2539 and 4941

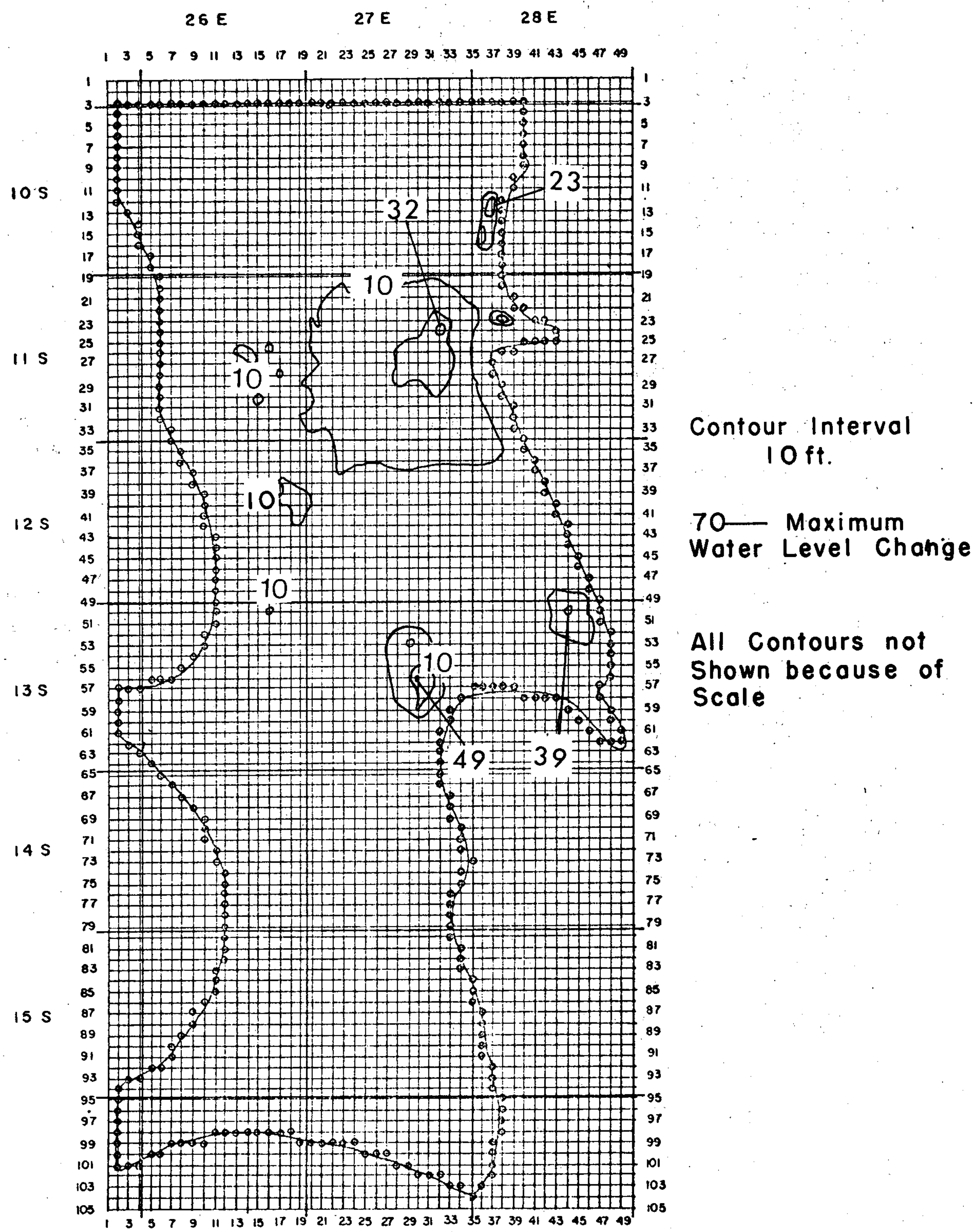


Figure 12

Water Level Rises by 1990 Because of Closure of Juniors
Under Plan A with Basin Divided at I=37
with Control Wells at Nodes 2539 and 4941
as Compared to the Basis Run

seen in the center of the basin. Little rise of water levels occurs near the northern control well. Some rise in water level is shown at node 4941, as a result of closure of wells to the southeast. The decreased rate of water level decline in well 4941 is shown in Figure 13.

Closure of juniors under plans B and C were evaluated in the next operational runs. Water level changes by 1990 from closure of juniors under plan B were very similar to those for plan A. The water level changes by 1990 from the Basis Run by closure of juniors under plan C is presented in Figure 14. The location of the wells is shown on Figure 15. Rises in water level are more localized to the areas of the control wells. The hydrographs from the well at node 4941 from the closure of juniors under plans B and C are similar to that for Plan A. The senior in the southern unit is provided with the same benefit within the administrative period by the closure of 12 wells closest to him as by the closure of all 61 users junior to him in the administrative unit.

The division of the basin into two administrative units does not increase the protection given to the senior at the cri-ical level but does increase the protection for the juniors from closure based on the water level conditions of a well in the other end of the basin. The division allows for administration of the water resource in the basin on more than one reasonable pumping lift. The degree of protection given the senior by administrative action is still more dependent on his location within the basin and with respect to other users than on the relative priority of his water right. Closure of 58 users in the northern

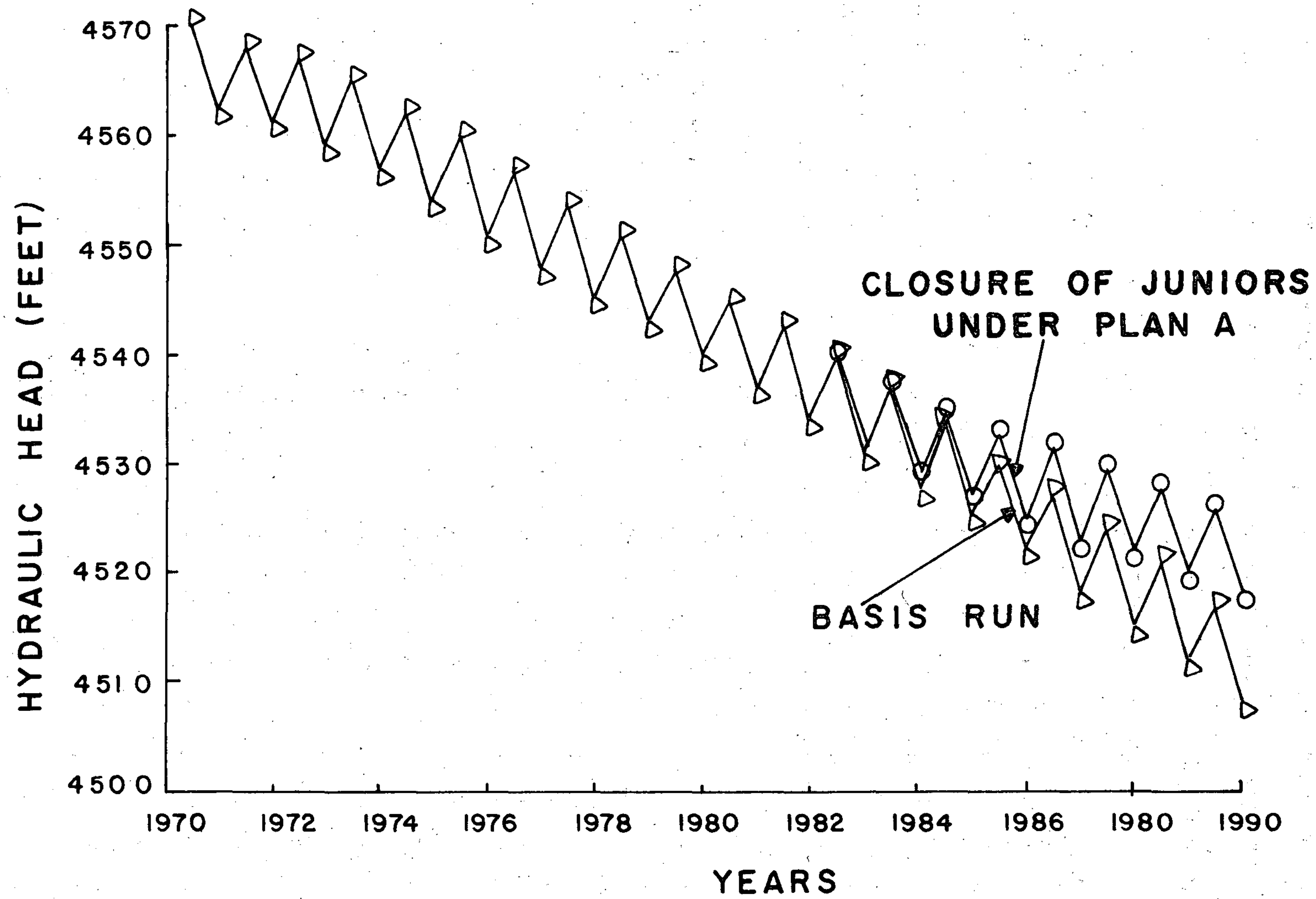


Figure 13

Hydrograph of Well at Node 4941 From Basis Run and From Operational Run with Closure of Juniors Under Plan A with Basin Divided at I=37

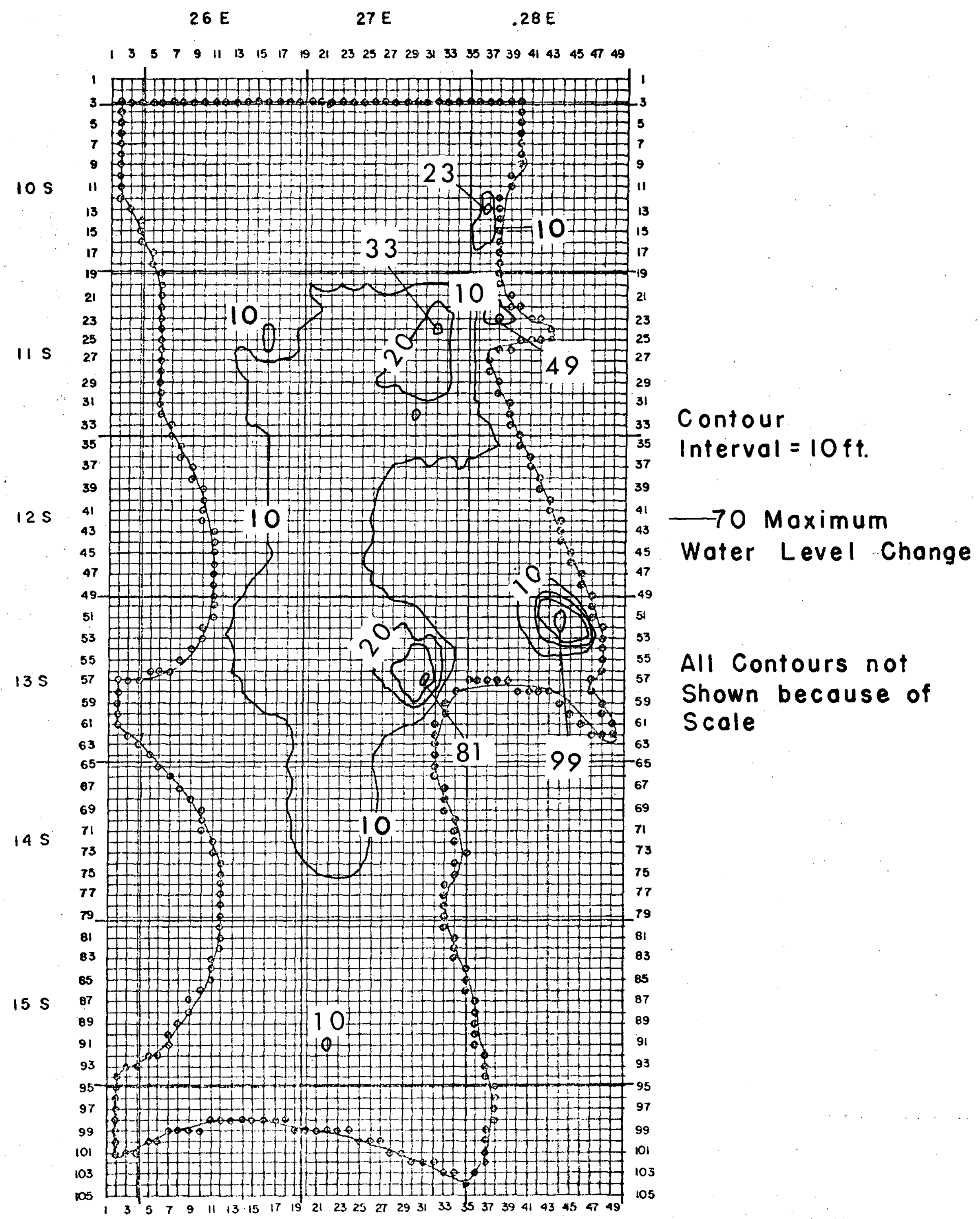


Figure 14

Water Level Rises by 1990 Because of Closure of Juniors Under Plan C with Basin Divided at I=37 with Control Wells at Nodes 2539 and 4941 as Compared to the Basis Run

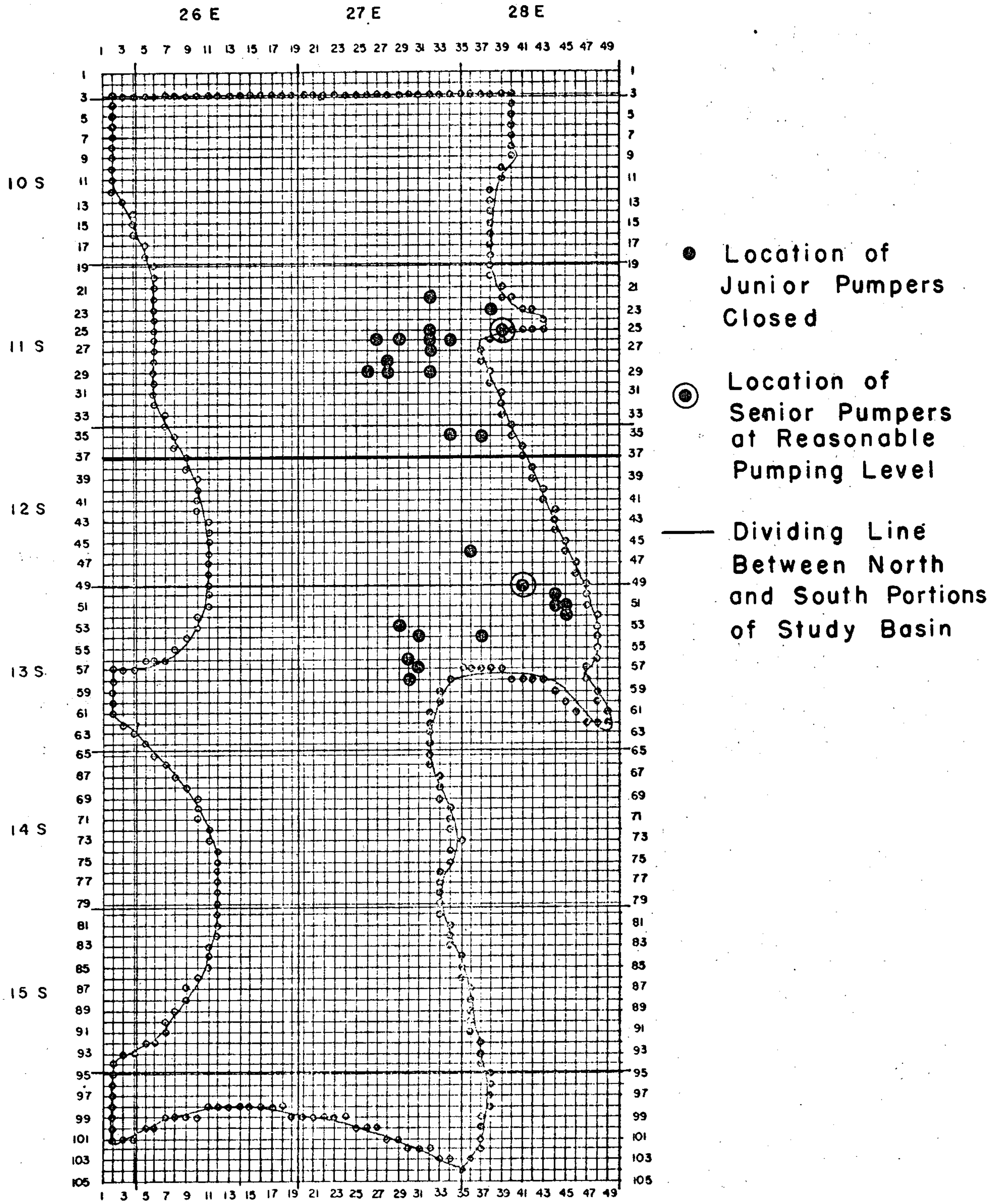


Figure 15

Locations of Junior Pumpers Not Allowed to Operate Under Plan C with Basin Divided at I=37 and Control Seniors at Nodes 2539 and 4941 portion of the basin did not benefit the senior because none of the juniors were located near him. However, closure of 12 juniors in the southern portion of the basin benefited the senior because they were located near him.

The reasonable pumping levels criteria was next evaluated as a limit on the rate of water level decline and the maximum depth of pumping water level. The annual water level change in each well in the basin was determined from the punched arrays of data generated from the Basis Run. The water level change in wells from 1982 to 1983 (measurements at the end of the pumping season) is presented in Figure 16 as an example of these annual changes. The distribution of these changes is presented in Figure 17. The mean annual change in water level shown on the figures is 2.8 feet. Only eight wells have a water level drop greater than five feet per year. Only one well has an annual decline greater than 10 feet.

Schatz (1974) evaluated the impact of various rates of water level decline on farm enterprises in the study basin. He studied annual decline rates of 1, 2, 3, 4, 5, and 10 feet and concluded that the lower rates have little economic significance on farm income in the area. Users have sufficient time to depreciate required changes in well depth and pumping equipment to minimize the impact. Schatz did note that a water level decline of ten feet per year or greater has a significant impact on the net return to the user. These rates of decline were found to be significant from an economic viewpoint as measured by the impact on farm income. Butcher and others (1972) concluded that a decline

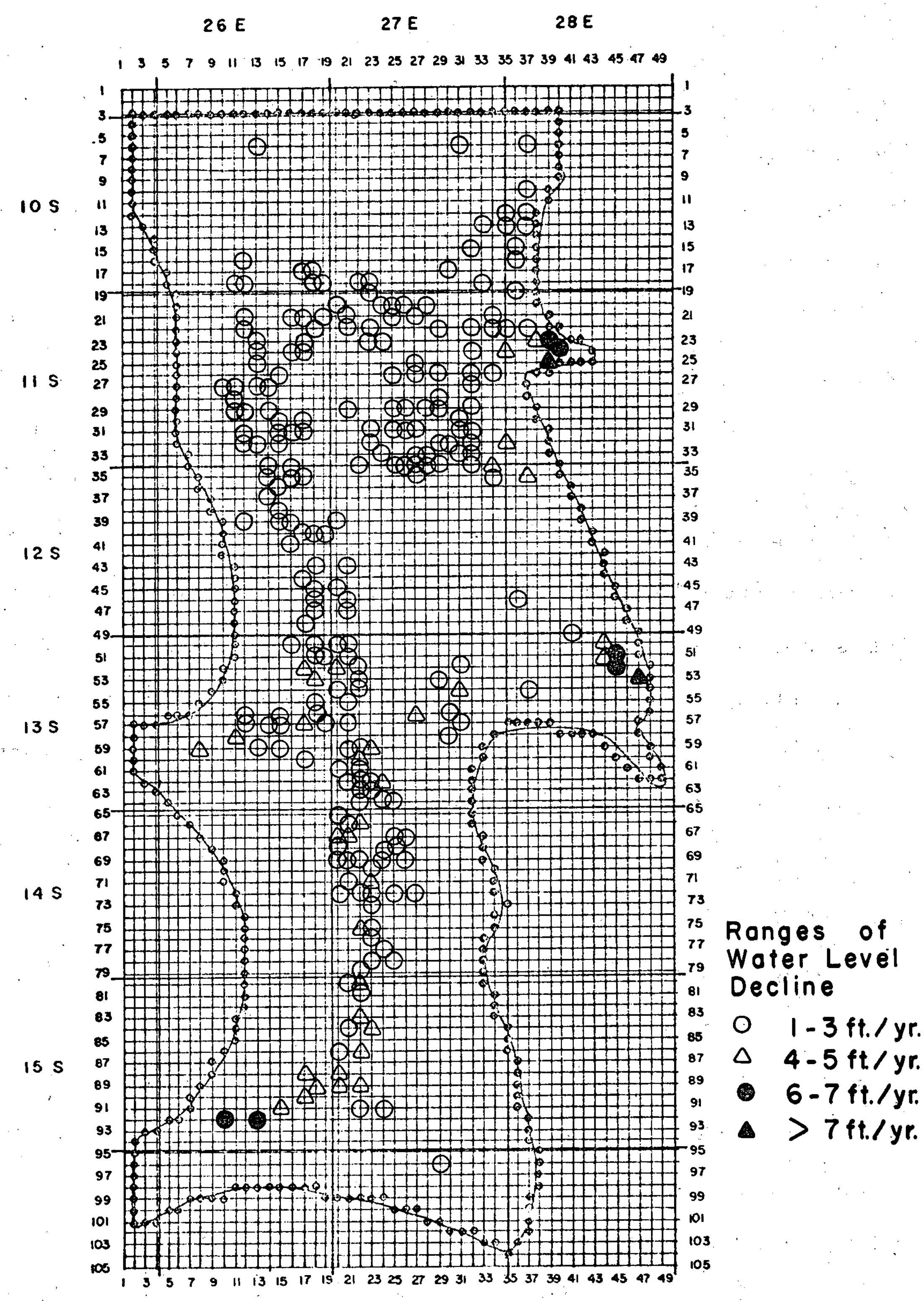


Figure 16

Water Level Decline in Wells for Period 1982-1983, Basis Run

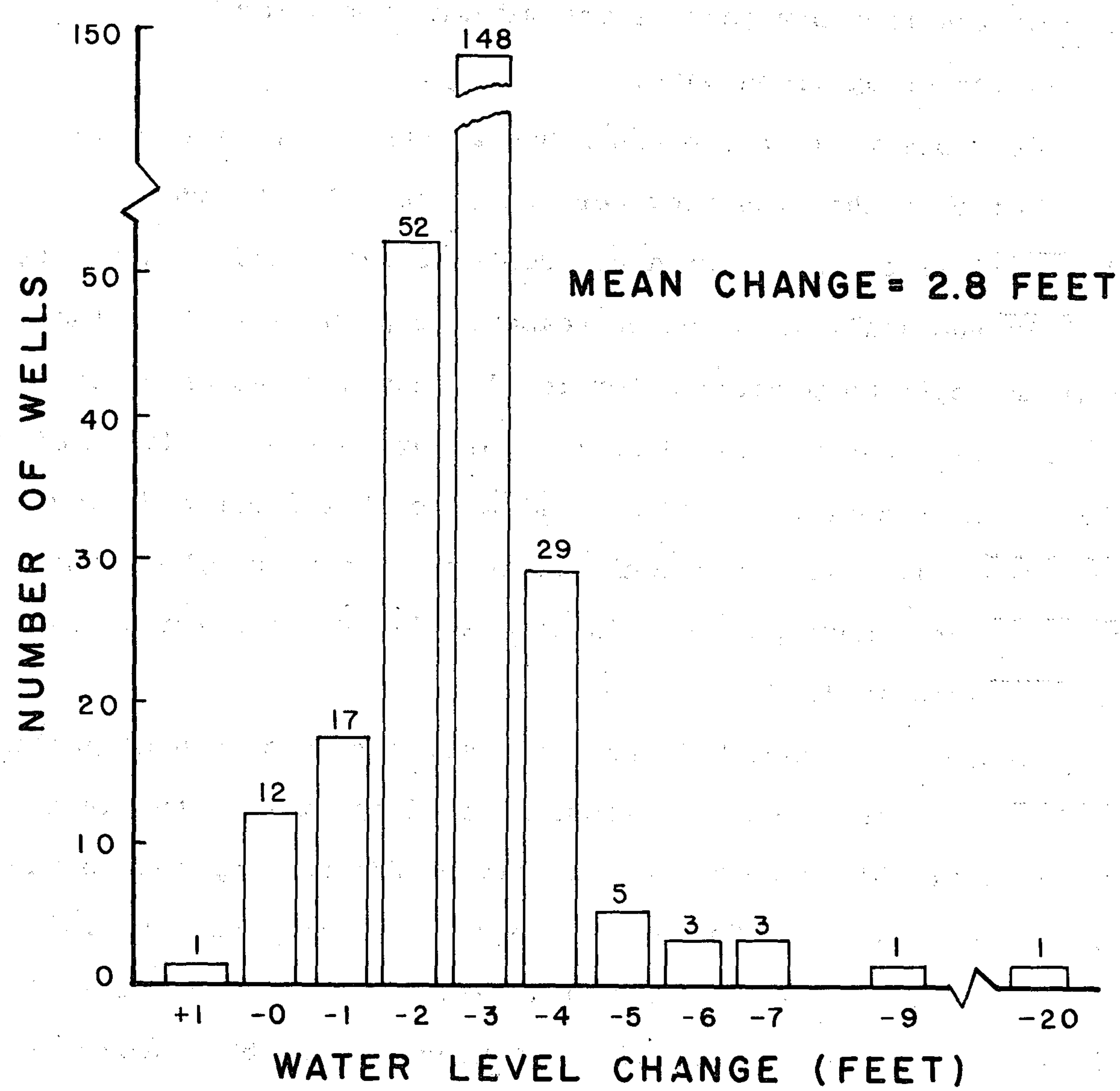


Figure 17

Histogram of Water Level Changes in Wells from 1982 to 1983, Basis Run rate of ten feet per year is the maximum limit for continued irrigation using groundwater.

Only one well in the basin has a consistent decline in water level of more than ten feet per year; the well at node 2539. This well also has the greatest depth to water and is controlling well in the analysis based on reasonable pumping lift as the maximum depth to pumping water level. Administration of the groundwater resource based on rate of water level decline using this well as control would be similar to that described previously. The only difference would be in the length of the administrative management period. In this analysis, administration would be initiated in 1972.

The well at node 5348 has an average rate of annual decline of 9.2 feet, the second greatest rate of decline in the area. The well at this node has a priority of 265 as compared to the priority of 272 for the well at node 2539. Basinwide administration under plans A and B would result in a similar water level change as shown on Figure 10. The user at node 5348 would have little relief under this administrative action. The water level decline in his well is primarily the result of his own withdrawal and his location near the edge of the aquifer system. Protection of a reasonable rate of water level decline is a function of the senior's location in the basin and the location and priority of nearby users as well as his own priority.

Analysis of the Recharge Limitation as a Tool for Resource Management

Administrative alternatives for management of groundwater under the guideline of limiting pumpage to the "reasonably anticipated average rate of future natural recharge" are presented in Figure 4. Five levels of decision are noted on that figure:

Decisions:

1. Selection of a management tool (recharge limit).

2. Definition of the recharge limit concept

   a. Recharge limitation defined as the total water available for man's use in the basin (water yield).

   b. Recharge limitation defined as the total recharge to the groundwater system.

   c. Recharge limitation defined as equal to the total recoverable discharge from the groundwater system.

   d. Recharge limit defined as time dependent as a function of the hydrologic, economic and well location conditions in the basin.

3. Selection of administrative management units and selection of the length of management periods.

4. Selection of recharge value or values.

5. Selection of method of application of the recharge restriction to junior users in the administrative units.

Administration of a groundwater resource under this criteria does not depend on a cause-effect type of resource response. Junior users are not shut down to provide immediate relief for seniors but rather to provide some long term certainty of water availability. The mathematical model of the water resource system in the study basin was not suited to long term analysis of impact from administration because of the limited period of calibration and the high cost of operation. The model was used to provide short term information on the impact from administration under the recharge limitation.

The major problem with administration of the resource under the recharge limitation is the definition of the concept and its quantification. The "water yield" of the study basin has been estimated in three separate studies. The yield estimates of the entire Raft River Basin, of which the modeled area is only a part, range from 140,000 acre-feet per year (Walker and others, 1970), to 320,000 acre-feet per year (Mundorff and Sisco, 1963). The third estimate was 183,000 acre-feet (Nace and others, 1960). Some difference occurs between the reports in the definition of the term water yield. If the highest estimate of water yield is adopted for administration, then no management action is warranted. Pumpage during the Basis Run was held at 203,000 acre-feet per year. Selection of the 140,000 acre-feet per year or the 183,000 acre-feet per year values would necessitate closure of a portion of the users in the basin. Ninety-seven users would be shut off with the former recharge value; thirty-four users would not be allowed to pump with the latter recharge estimate.

If the recharge limit is defined as the total recharge to the groundwater system, then a value less than the basin water yield would have to be used. Some water included in the water yield estimate is diverted and consumptively used for surface water irrigation. No estimates are available of the quantity of water annually recharged to the groundwater system. Direct recharge to the groundwater system was held at 74,000 acre-feet per year for the model operation. This figure is believed to be a conservative estimate of the recharge to the system. Pumpage would have to be reduced by about sixty-three percent if this value was selected as the basis for administration under the recharge limitation. Only the most senior 130 users would be allowed to pump in the basin.

The recharge limitation may be defined as equal to the total recoverable discharge from the groundwater system. It is often not possible to eliminate all natural discharge from the basin because of various physical, economic and social constraints. Well development must be limited to the portion of the discharge from the basin that is recoverable to have a long term equilibrium condition. Walker and others (1970) estimated that 29 percent of the natural discharge from the study basin was by consumptive use of riparian vegetation, 12 percent by surface water discharge and 59 percent by groundwater outflow. They noted that development by 1966 had resulted in a 50 percent reduction in the consumptive use of riparian vegetation, an 89 percent reduction in the surface water outflow and four percent reduction in the groundwater outflow. Walker further stated that a "reduction of the groundwater outflow by about half . . . would require lowering the water level several tens of feet in the area immediately north of the present areas of greatest water level decline. The time required to effect the reduction would be very great, and very large additional quantities of groundwater would be removed from storage". (Walker and others, 1970, p.91). If half of the groundwater outflow is considered recoverable, then the recharge value (based upon the 140,000 acre-feet per year water yield estimate) would be 100,000 acre-feet per year. If none of the groundwater outflow is considered recoverable, then the recharge value would be only 60,000 acre-feet per year.

A wide range of equilibrium conditions between recharge, natural discharge and artificial discharge can occur in the basin depending on the extent to which the water level is allowed to decline. The recharge value may be defined as a rate of pumpage which will allow equilibrium conditions to occur. A relatively shallow reasonable pumping lift would prevent major water level decline and limit the recovery of natural discharge. Pumpage would be limited severely under these conditions. The recharge limit under this definition has not been estimated.

The short term impacts of basinwide administration under three defined recharge levels are presented to illustrate the impact of management under this constraint. The water level change map presented in Figure 10 shows the impact of eight years of basin operation with a reduction of pumpage to 166,000 acre-feet per year. The impact of pumpage at a level of 143,000 acre-feet per year is shown on Figure 12 after seven years of administration. An additional run was made to show the impact of the extreme closure down to a pumpage level of 74,000 acre-feet per year after ten years of basin operation (Figure 18). Water level rises are seen from all three figures. Sufficient data are not available to interpret the long term impact from such administration.

The selection of administrative management units and the selection of the administrative management period would be based upon the definition of the recharge limitation. These administrative tools could be used to achieve the equilibrium condition with maximum basin pumpage.

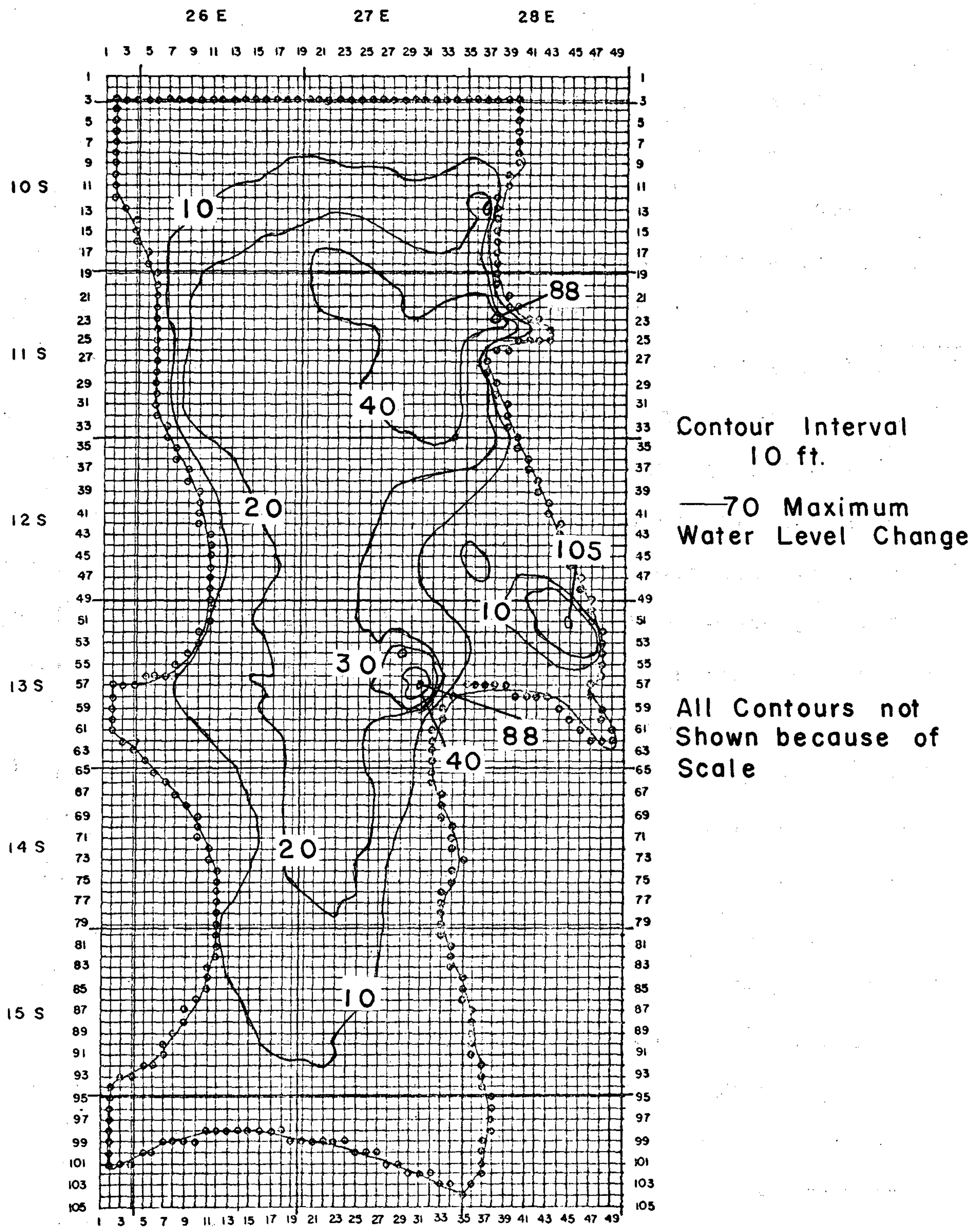


Figure 18

Water Level Changes by 1990 From Closure of Wells to Limit Pumpage to 74,000 Acre-Feet Per Year, as Compared to the Basis Run

Conclusions

1. Groundwater management in Idaho can be achieved by the administration of the resource under the state laws of water allocation.
2. The stock-flow characteristic of groundwater is an important factor affecting resource management under the appropriation doctrine.
3. Management of the groundwater resources in Idaho rests largely on the interpretation and application of two legislative phrases: 1) reasonably anticipated average rate of future natural recharge, and 2) reasonable groundwater pumping levels. These phrases must be considered in light of the stated legislative intent of full economic development of the underground water resources.
4. Five basic decisions may be outlined for administration of groundwater under the constraints set forth in the Idaho Code. 1) Selection of the management tool, 2) definition of the concept, 3) selection of the size of the administrative units and length of the administrative period, 4) selection of the reasonable pumping lift or recharge value or values for each administrative area, and 5) application of the selected value to junior users within the administrative area.
5. The reasonable pumping lift concept is based upon a cause-effect relationship. This relationship is dependent on a number of factors. The impact on a senior's well of closure of a junior appropriator's well may be very limited because of the stock characteristics of groundwater.

6. Operation of the mathematical model indicated that the senior users at the designated reasonable pumping levels received little benefit from closure of juniors under any of the management plans.
7. Alternative plans for the closure of junior appropriators under the reasonable pumping lift restriction had little impact on the groundwater levels in the vicinity of the senior user's well. The senior received equal or greater protection with lessened impact on the economy of the area by closure of juniors over extended periods or by closure of only those juniors nearest the senior.
8. Changes in the value of the pumping lift had little effect on the pattern of resource administration in the study plan.
9. Application of the constraint of reasonable groundwater pumping levels was based on senior appropriators who are located along the edge of the basin where the static depth to water is greater and the aquifer is thinner.
10. The division of the basin for resource administration had little impact on the protection given the control seniors.
11. The pattern of administration of the groundwater resource in the study basin was the same for either definition of the reasonable pumping lift constraint.
12. The degree of protection for a senior's means of diversion is only partially measured by his water right priority. It is also dependent on his location both in the basin and with respect to other users and the relative priority of the surrounding users. The user who is surrounded by users with

more senior rights receives little benefit from any plan of resource administration.

13. Administration of the groundwater resource under the recharge restriction is based upon long term impacts and is not dependent on any direct cause-effect relationship.

14. The most important decision in the administration under the recharge restriction is the definition of the concept.

15. Administration of the resource under the recharge restriction must include consideration of the time required for the establishment of hydrologic equilibrium conditions and the relationship between the level of equilibrium and the extent of groundwater mining.

16. Effective groundwater management may occur in Idaho by the development of adequate definitions and techniques of administration under the two major concepts of reasonable groundwater pumping levels and reasonably anticipated average rate of future natural recharge. Administrative plans must be designed for each basin within the general legal guidelines based on the specific hydrologic and geologic conditions and the pattern and extent of resource development. A sufficient range of alternatives is available in the concepts to allow efficient resource management of a wide range of situations.