

**KANSAS GEOLOGICAL SURVEY
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**THE OGALLALA AQUIFER:
AN APPRAISAL OF POTENTIAL AND PROBLEMS**

by

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INTRODUCTION

The Ogallala Aquifer is one of the largest and most prolific aquifers in the United States. It is located in parts of Texas, New Mexico, Oklahoma, Kansas, Colorado, Nebraska, Wyoming and South Dakota. The region is basically high plains, with an altitude from 2,000 to 3,000 feet, sparse rainfall, and generally dry, hot summers. Figure 1 indicates the overall size and geographic location of the Ogallala Aquifer.

VOLUME, DEVELOPMENT AND PUMPING COSTS

Figure 2 is an overall generalized summary of areas, volumes, development costs and operational costs based upon a variety of assumptions. The first assumption under fluid volume is that the average thickness is some 80 feet over

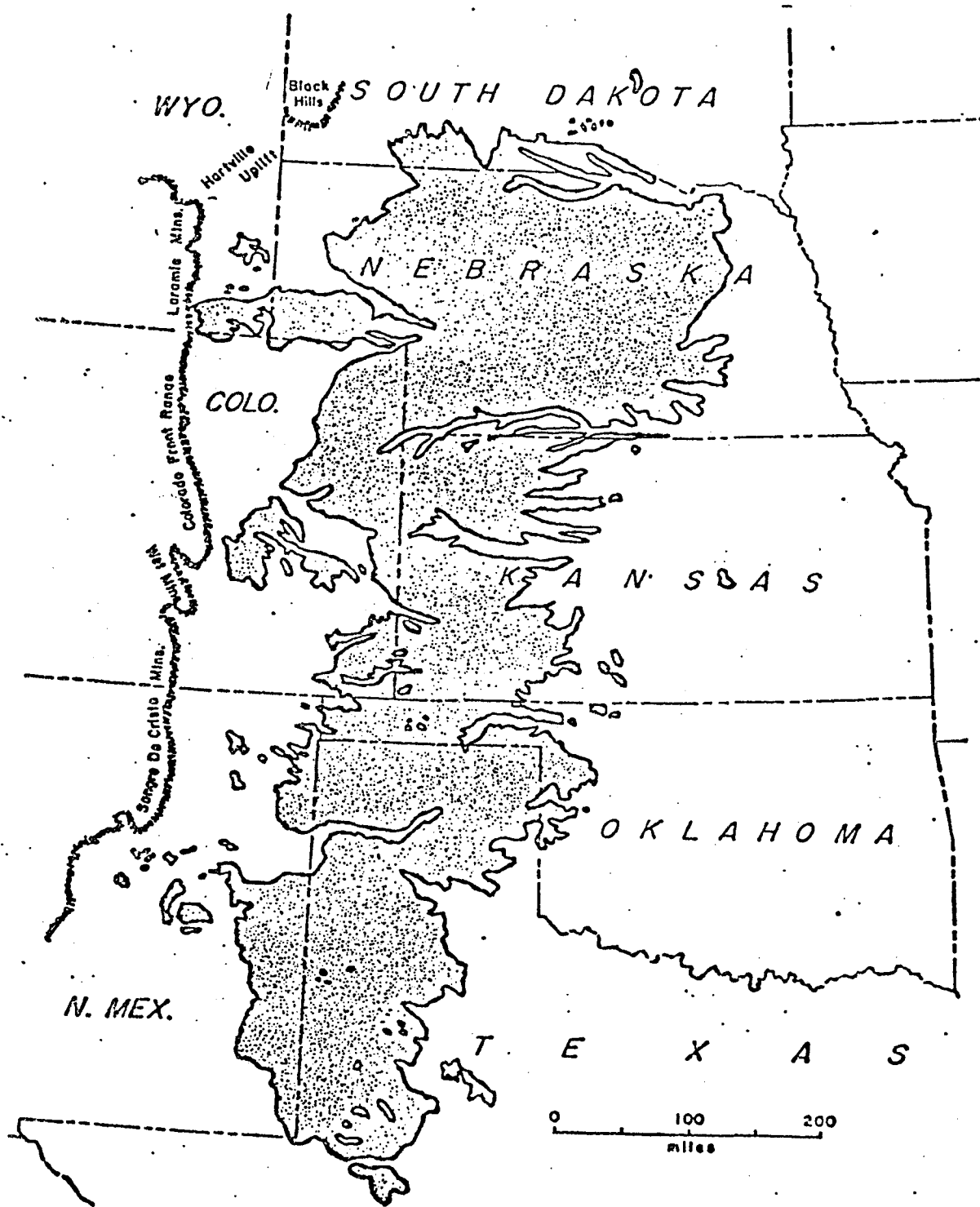


Figure 1. Distribution of Ogallala Formation in Great Plains (Merriam, 1963)

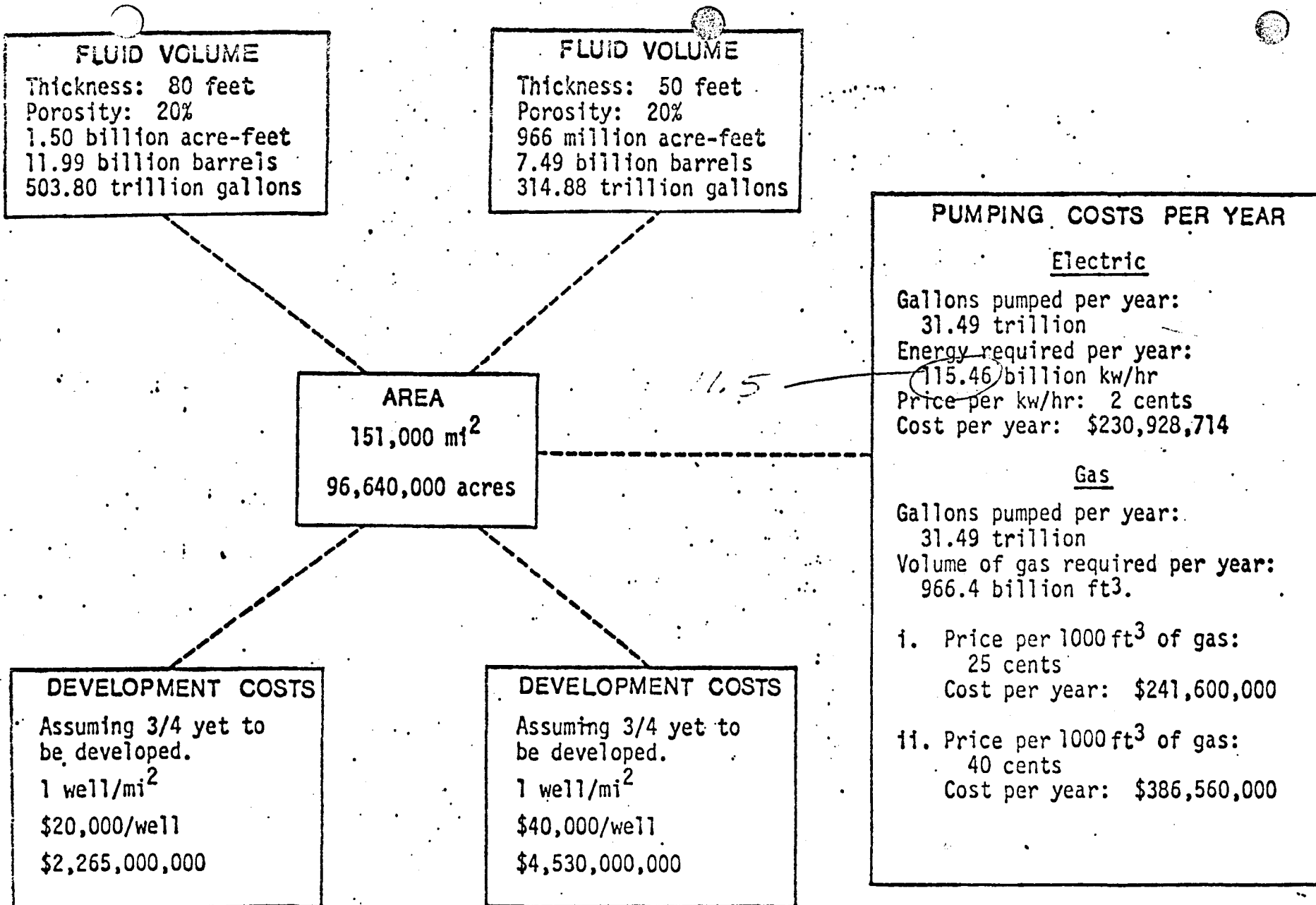


Figure 2. Basic Planning Numbers

the whole area of 151,000 square miles. It is also assumed that this area has a specific yield of approximately 20%. As you can see, based upon these assumptions, the quantity of fluid available in the overall Ogallala is approximately 1.5 billion acre feet. If we reduce the assumption concerning saturated thickness to 50 feet, we find that the overall water in storage is reduced to 966 million acre feet.

Development costs shown in Figure 2 are computed assuming that three-fourths of the system is yet to be developed and that the system ultimately will be completely developed. It further assumes that at the end of development, one well will be located on every square mile. Based upon the assumption that each well will cost some \$20,000 for installation, we see that the total capital expenditure for developing the whole area will be on the order of \$2 billion dollars. It is further seen that if the average well costs increase to some \$40,000 per well, the total capital expenditure will increase to some \$4.5 billion dollars.

The costs shown under pumping costs per year in Figure 2 are based on the assumption that the total system has been developed (151,000 wells) with one well per square mile and each well pumps 1 foot of water over a square mile. It is seen that a total of 31.5 trillion gallons of water will be pumped each year. It is further seen that the total energy required per year will be approximately 115 billion kilowatt hours. Based upon a hypothetical price of \$.02 per kilowatt hour, it is seen that the total operating costs

for this entire system to be operated electrically would be on the order of \$230 million dollars per year. If we take the same assumptions in terms of development and total pumpage per year but operate the system strictly with gas, we find that it would take some 966 billion cubic feet per year. Based upon a hypothetical price of \$.25 per thousand cubic feet, this figures to be approximately \$241 million dollars per year for gas. Based upon \$.40 per thousand cubic feet, this cost is shown to be \$386 million dollars per year. At 1,000 gallons per minute per well, one foot of water could be pumped over the entire area in 20 days.

Figure 2 is not intended to frighten or startle this audience; it is simply an overall basic summary of fluids in place, hypothetical development and operational costs of a system that is undergoing rapid development. It does in fact indicate that if the system is to be developed, a tremendous quantity of energy will have to come out of existing or future electrical systems or gas from gas systems or both. It also indicates the most urgent need for multi-state discussions regarding the orderly development of this system.

FREQUENT GEOLOGY AND HYDROLOGY PROBLEMS

Figure 3 is designed to illustrate equal volumes of fluid. The one acre foot of fluid represented at the surface in the figure is compared to the corresponding volume

of fluid if it were underground. The basic relationship here is one of approximately 5 to 1 which is, I might add, about as good as we can hope to expect.

Figure 4 illustrates three common hydrologic problems which I will explain. First of all, the well on the left, is shown to be "interfering" with the well on the right. This is a direct interference in that well 1 is reducing the level of the fluid in well 2. The two dashed lines at the top of the slide are meant to illustrate a different type of phenomenon. This phenomenon is long-term regional changes in the total water system. It is the latter change which ultimately make a system non-economical to pump. The curve shown in the well on the left is meant to illustrate "draw-down" and is a direct result of pumping fluid from the system over short periods of time. Obviously, long-term regional declines are not to be confused with the relatively short-term drawdown, or interference.

Figure 5 is designed to illustrate a common problem in attempting to find the best place to put a well. The well on the left has less saturated thickness because it missed the buried valley that the well on the right was sunk into. Obviously, the well on the right will have water long after the well on the left has been depleted. This raises an obvious sticky legal question if the well on the left has a senior water right. This simply serves to illustrate the difficulty of adjudicating or administering a system that was designed by nature.

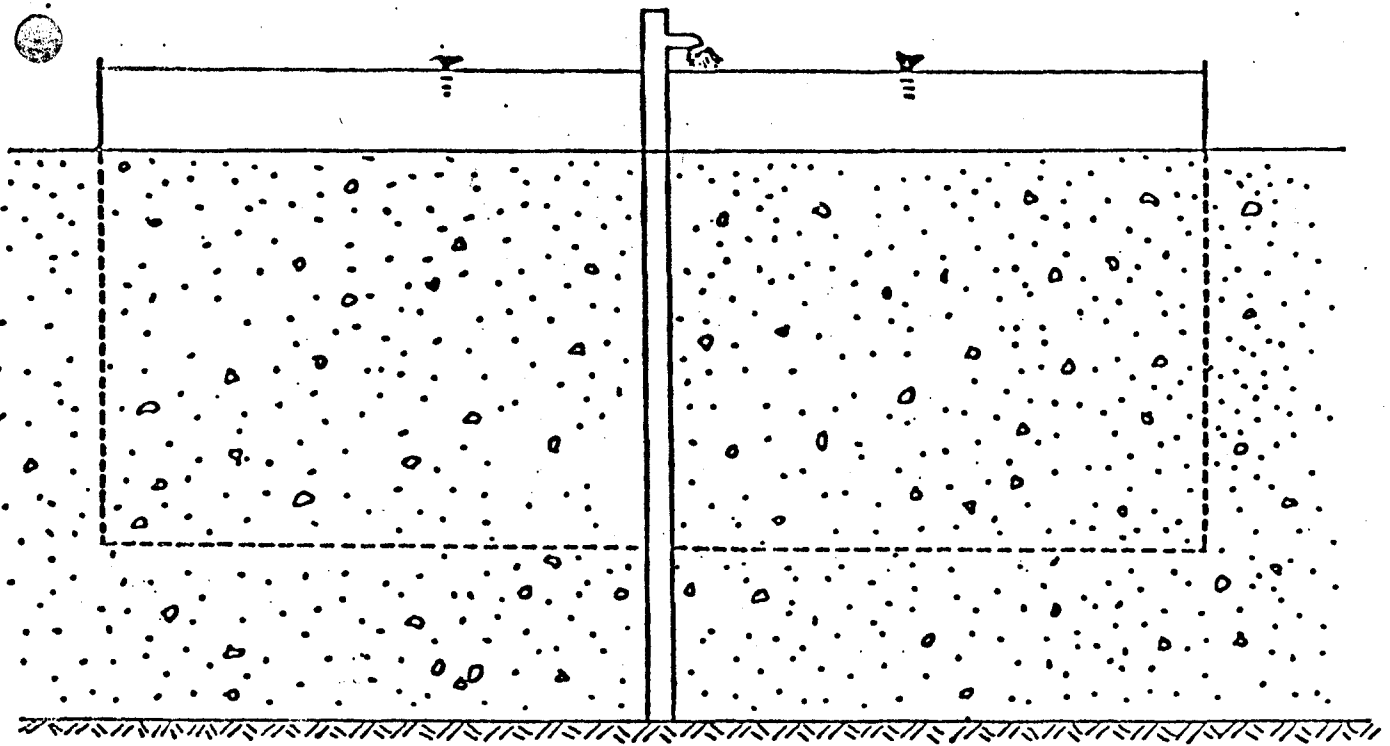


Figure 3. Graphic Representation of One Acre-Foot

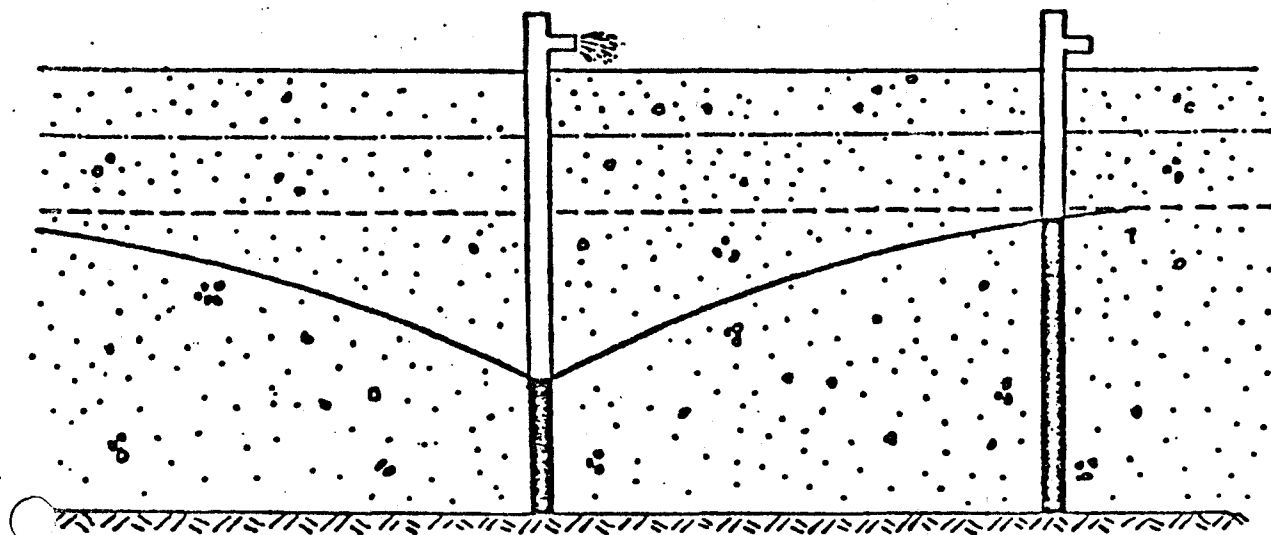


Figure 4. Graphic Representation of Drawdown, Interference and Regional Decline

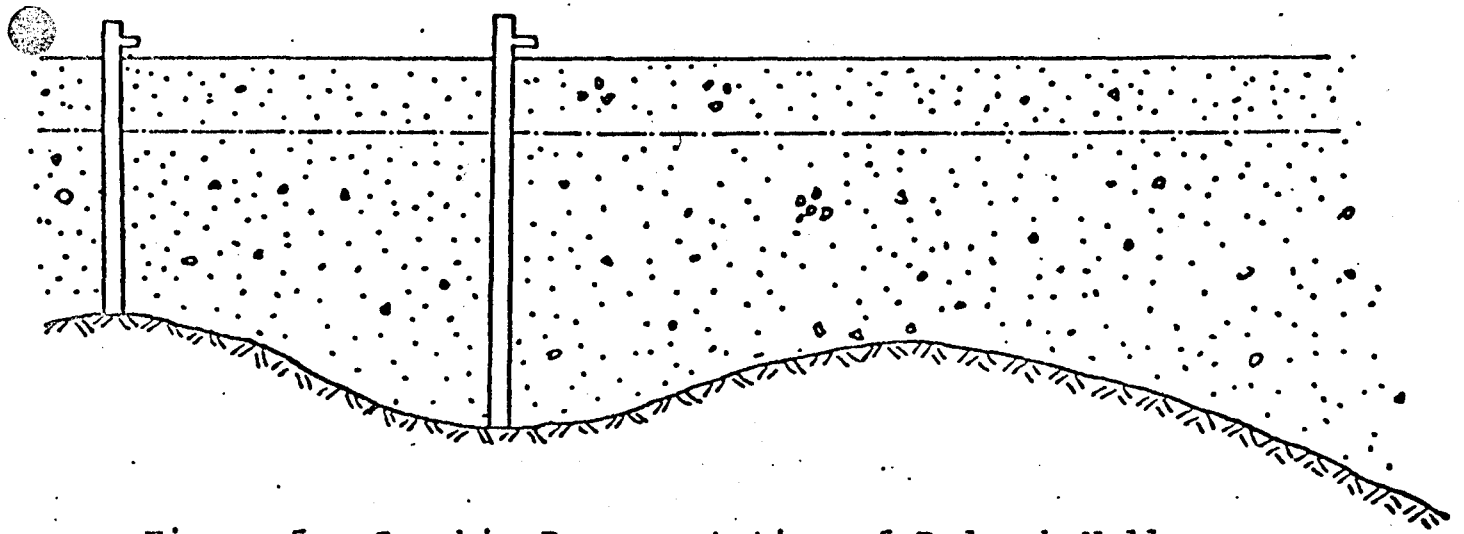


Figure 5. Graphic Representation of Bedrock Valleys or Channels

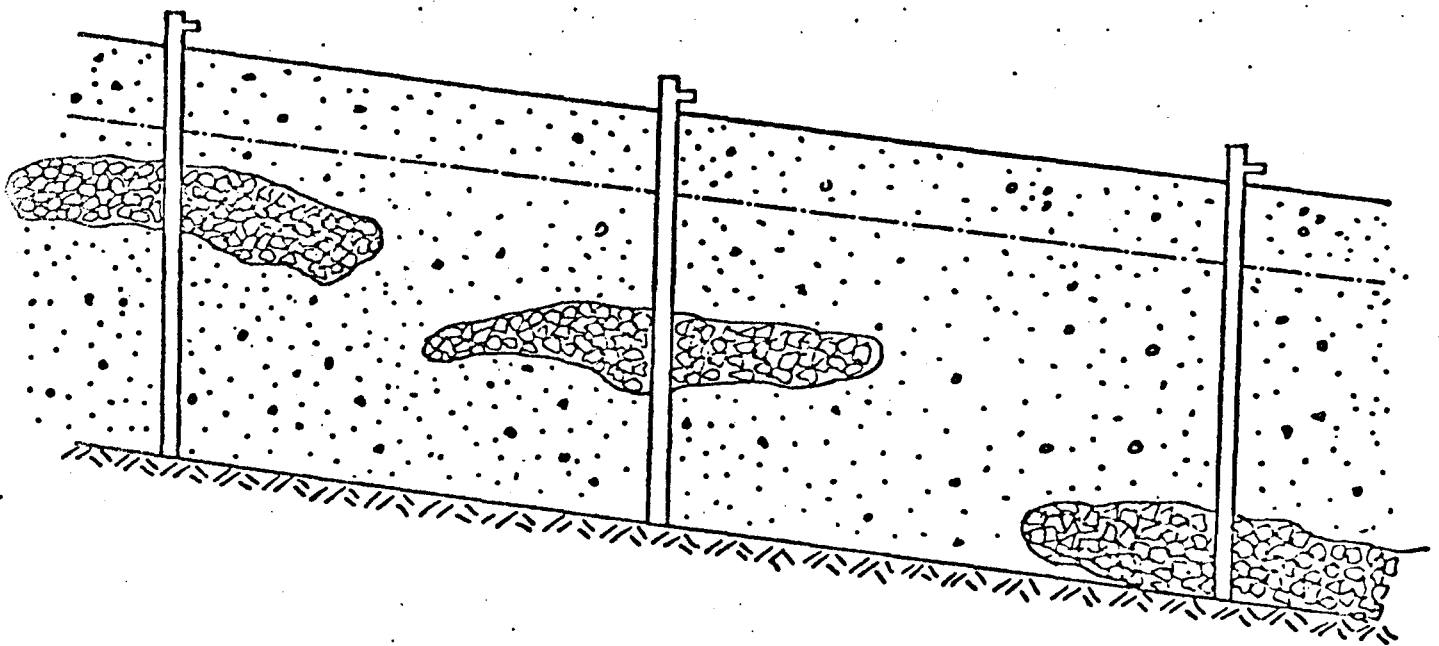


Figure 6. Graphic Representation of High Conductivity Intervals

Figure 6 illustrates another relatively common problem that one can experience in drilling a well. The well on the left is illustrated as having the highest conductivity interval near the top of the well, the one in the middle, near the middle, the one on the right near the bottom. Of these three wells, the one on the right will have the highest production rate over the longest period of time of all of the wells shown in Figure 6, assuming the high conductivity interval to be roughly the same for all three wells. Well 1 will fall off markedly in production once the water level has fallen below the main gravel member. The middle well will produce for a longer period of time, but it too will eventually dewater the gravel member. The well on the right will have high production yields and will ultimately wind up economically viable for the longest period of time.

Figure 7 is an idealized production vs. time plot for the three cases shown in the previous slide. Using slides 4, 5, 6 and 7, one could develop an endless string of examples to bedevil the various regulatory groups.

Figure 8 illustrates a problem that has to date received relatively minor attention in the high plains. This problem I might term as the long-term agro-environment and associated geochemical complications in an irrigation environment. It is illustrated here by a bucket of water being dumped upon the surface of the ground and leaching salts from the soil profile into the groundwater system. It can also be interpreted as importation of water not necessarily

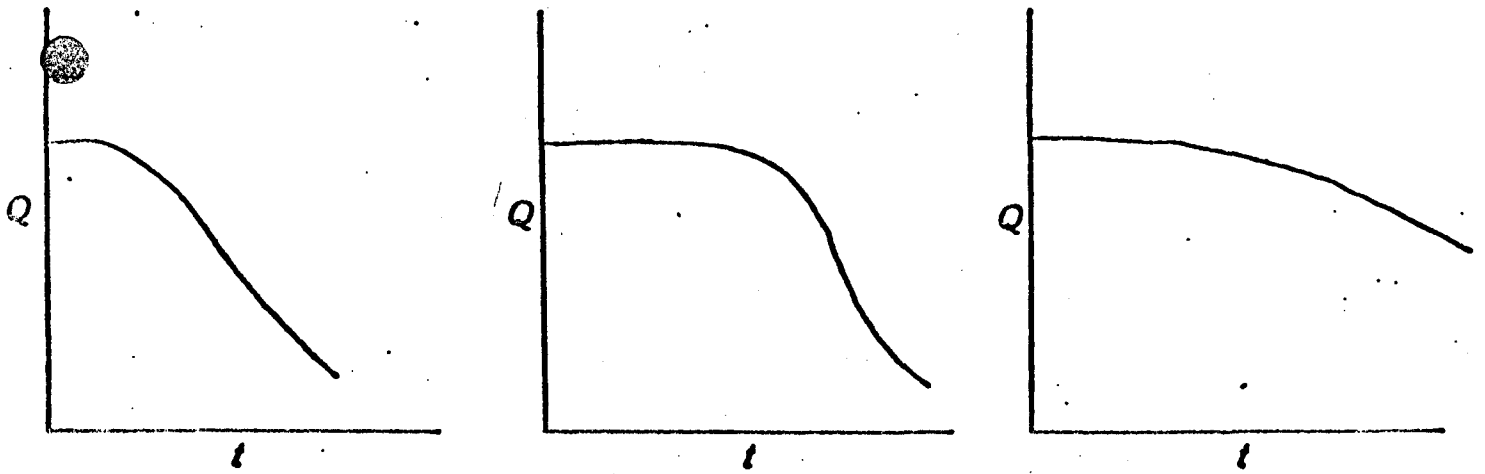


Figure 7. Idealized Production Versus Time Curves

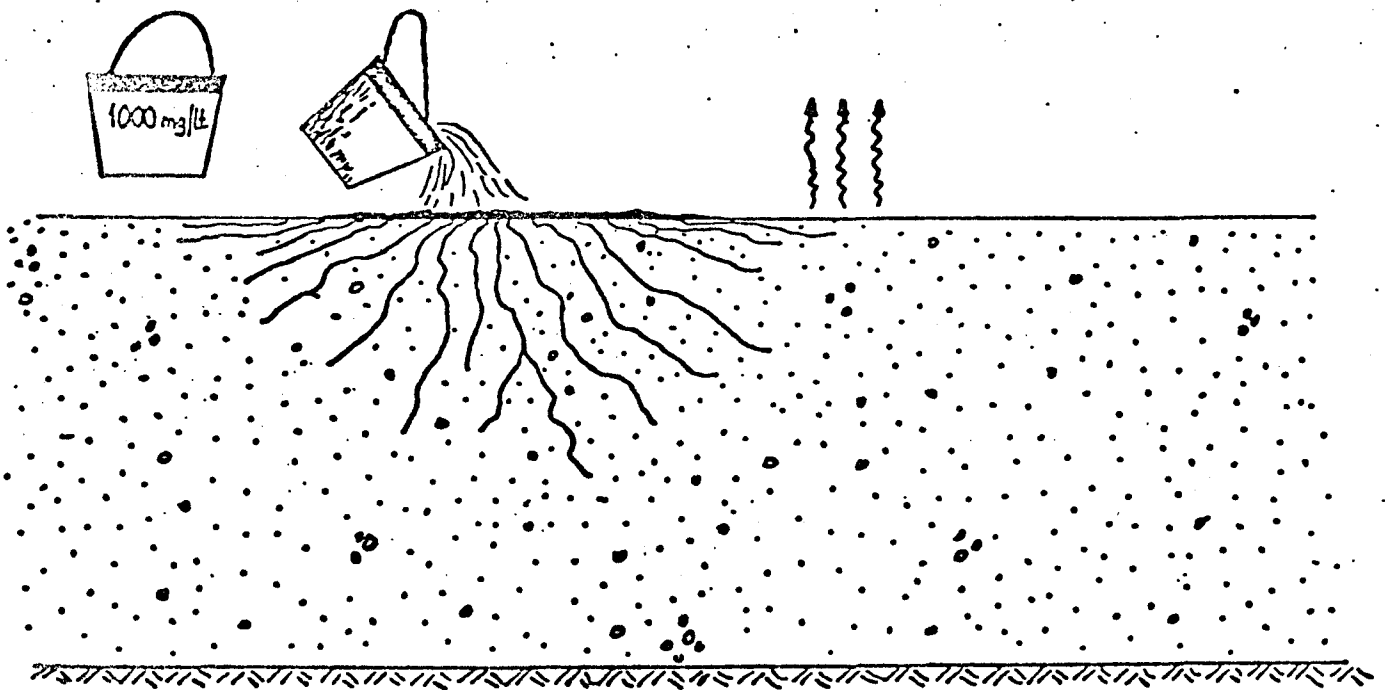


Figure 8. Geochemistry Problems

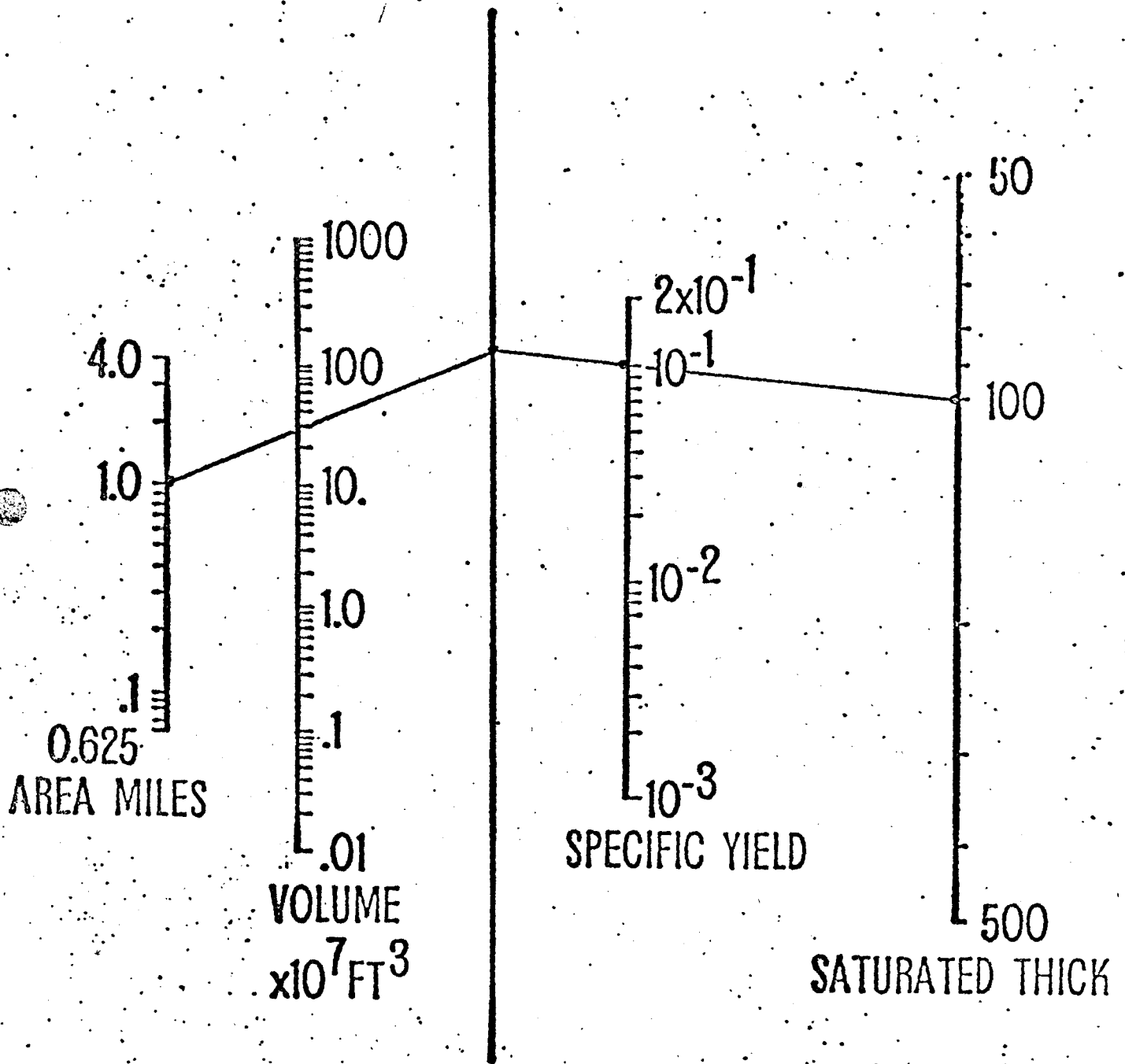


Figure 9. Groundwater Aquifer Nomogram

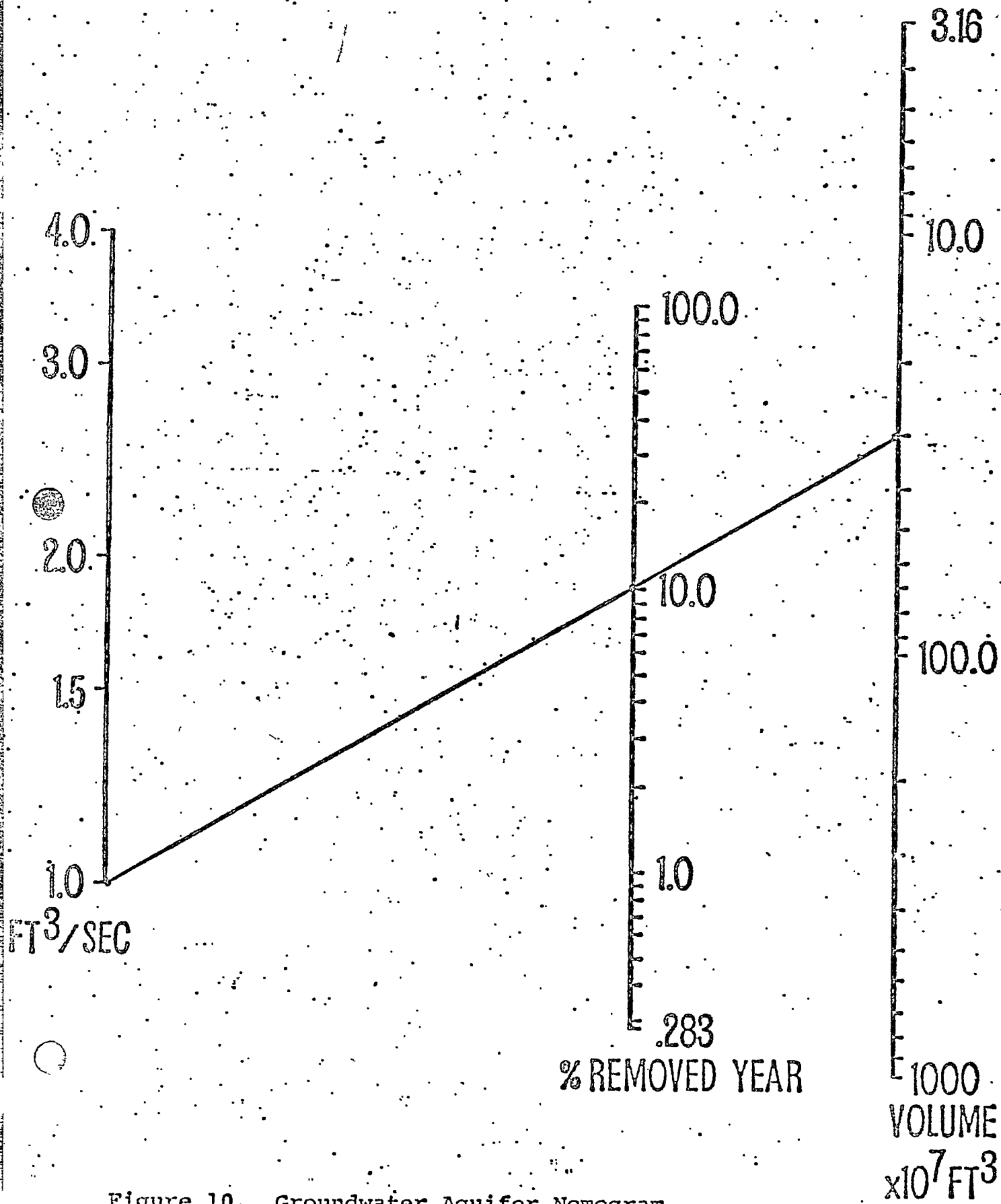


Figure 10. Groundwater Aquifer Nomogram

as rank as illustrated in the slide, but water other than high quality water. This is important because in the process of dumping the imported water on the ground, somewhere between probably 80 and 95 percent of this fluid will be lost leaving behind the salts that were contained in the water. These salts can either be carried on down into the groundwater system or, under certain conditions, can accumulate in the near surface soil profile. I will return to this topic a little later in the talk with slides showing the results of a study that was performed in western Kansas last summer.

Figures 9 and 10 are designed to in fact summarize some of the material shown in the previous slides. Looking at Figure 9, if one would choose the proper point on the saturated thickness line and join this to a point on the specific yield line, draw a straight line through these two points until it intersects the pivot line, from the pivot line, join this point to a point on the area line, it is seen that this will automatically compute a volume times 10^7 in cubic feet. Going on to Figure 10, it is found that if one takes the volume that was determined from the previous Figure and joins this point to the point shown in the column on the most left hand side, which is a rate column, this will intersect a column that will give an indication of the percent removed per year. While it is readily conceded that an illustration of this kind makes a whole host of assumptions, it should be pointed out that an illustration of this

type becomes more and more accurate as the density of the development becomes greater and greater. The problem worked in Figures 8 and 9 is an example problem only!

Specific Problems Relating But Not Restricted to Kansas
COMPACTS

It is apparent that problems exist in the whole basic subject of interstate compacts. For example, the Arkansas River Compact between Colorado and Kansas dated 1948 is reasonably specific concerning quantity of fluids entering the state and yet is silent on the whole subject of water quality. Yet in the Arkansas River Basin Compact, Kansas-Oklahoma, dated 1965, the Compact is loud and clear concerning both quality and quantity. It is difficult to understand how the state could be in a legal position with the state of Colorado to receive water independent of quality and yet be responsible to the state of Oklahoma for the same water in terms of both quality and quantity.

Similar comments could be made concerning the Republican River Compact of 1942 between the state of Colorado, Kansas and Nebraska. This compact is bound up in a variety of terms that are technically very very difficult to define much less understand. A typical example is the term virgin water supply which is defined to be the water supply within the Basin undepleted by man. It is apparent that the whole process of interstate compacts between the state of Kansas and its surrounding neighbors should be reviewed and updated.

WATER LAW

Another problem of a legal nature, and I will use Kansas statutes to illustrate this, is concerned with the basic property rights of an individual in the midst of irrigation development that chooses not to pump or develop irrigation. Basically, the law in Kansas says that one can acquire the right to pump fluids for beneficial use. This right to pump water in effect is promotional, primarily because there is no incentives under the current legal system to reduce pumpage or not to pump at all except from the standpoint of the basic pumping costs. Similar problems of a legal nature exist in other states and in fact are approached from a variety of legal remedies.

CONFLICT BETWEEN SURFACE AND GROUNDWATER.

Figure 11 is simply an illustration of the average rainfall over the area of interest. While one may argue that the basic squiggles shown in this illustration and perhaps even with the total amounts of rainfall, the major conclusion that western Kansas gets between 16 and 20 inches of rain per year is apparent. Figures 11 and 12 are used here to illustrate another problem that is present today and will certainly be more of a problem in the future. In the upper left hand corner of the slide one can see the beginning of a variety of streams and rivers that ultimately result in flow of one kind or another into surface storage. The development of groundwater in the area has over the last

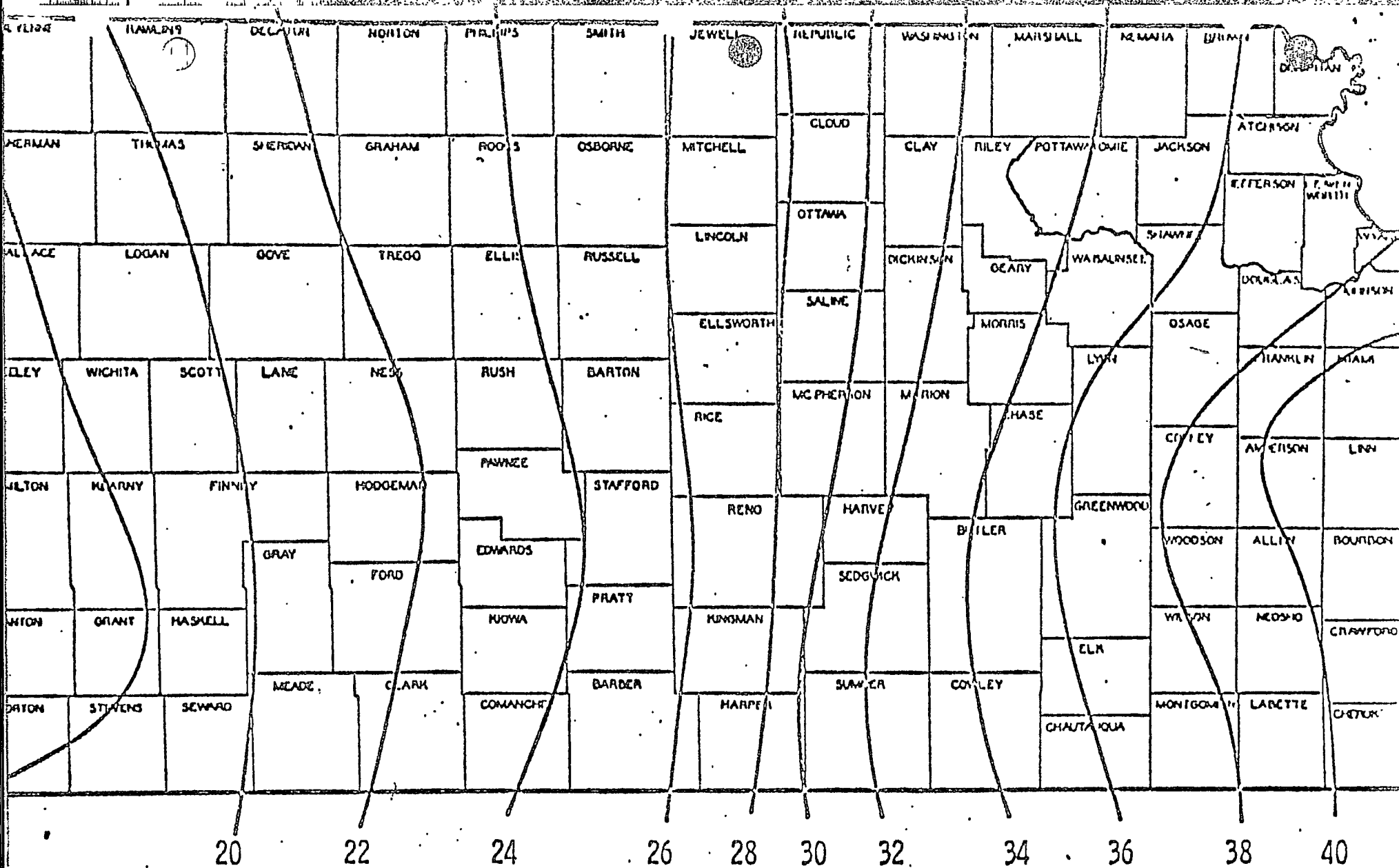


Figure 11

NORMAL ANNUAL PRECIPITATION - FOR KANSAS, 1941-1970

Prepared by the Kansas State Department of Geology

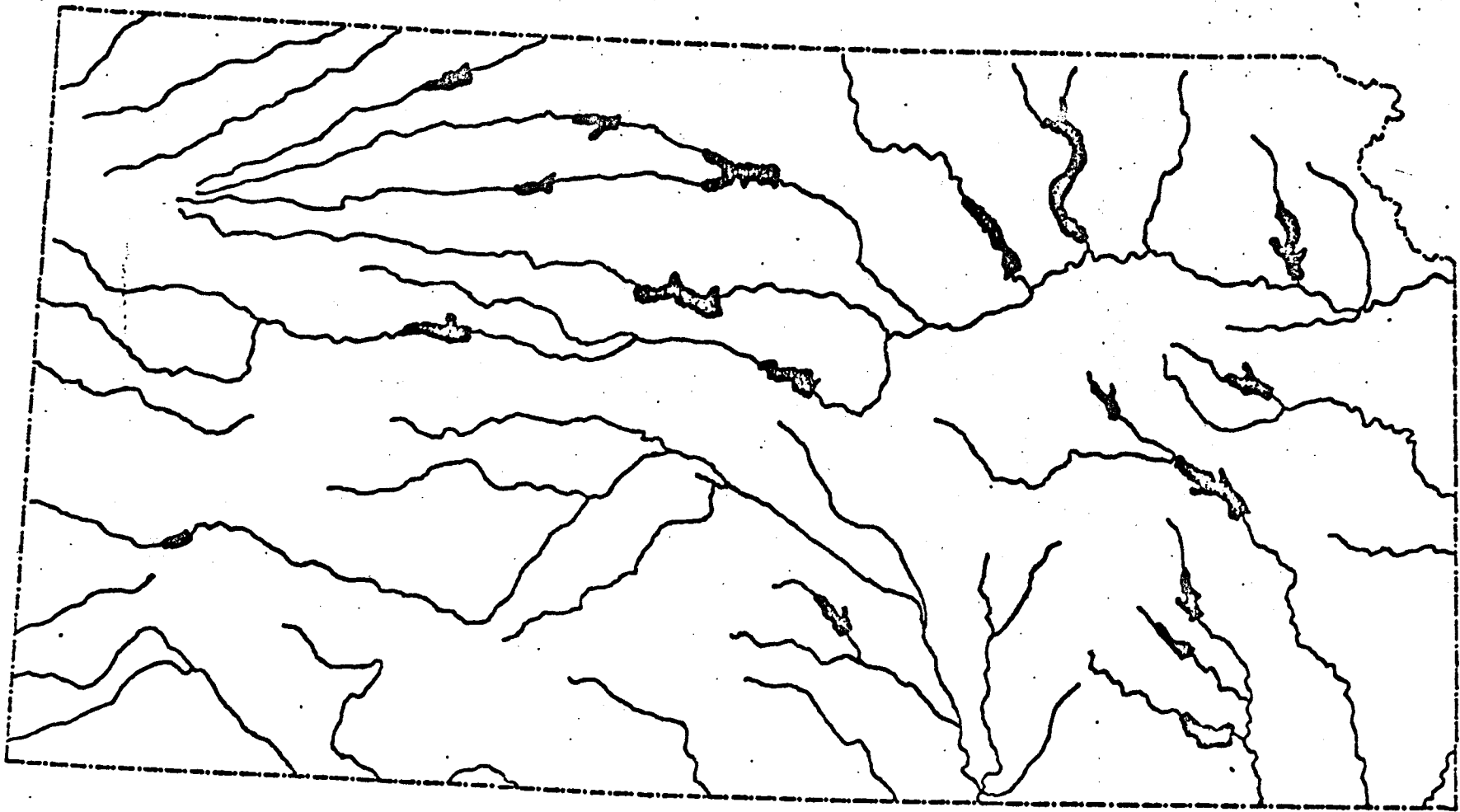


Figure 12. Streams and Rivers of Kansas

10 to 15 years resulted in reduced flows of water to surface water storage. It is also resulting in minor degradation of the surface water due to irrigation return flow and leached salts that ultimately wind up in the surface water reservoirs. It is clear that a collision between surface and groundwater rights in this area will take place.

GEOCHEMISTRY

Slide 13 is not included as a figure in this paper but simply is a brief summary of a study of a geochemical nature that was undertaken in the counties of Scott, Lane, Wichita, and Greeley this past summer. It consisted of geochemically sampling the irrigation waters in that area. Slide 12 shows the outline of the area of interest and the sampling points in the area. Slides 14, 15 and 16 are examples of the areal distribution of certain ions in this area. Slide 14 shows the chloride distribution in the area. Figure 15 shows the sulfate distribution in the area. Figure 16 shows the nitrate distribution in the area. This study, soon to be published, was performed under the direction of Dr. Larry Hathaway of the Kansas Geological Survey and was specifically designed to get high quality base line information of a regional nature. This study will continue and cover the entire western part of Kansas in the next five years.

Slide 17 is part of a recent study performed by the Space Technology Center of the University of Kansas for the Kansas Survey. In effect the Space Center was asked to

define where center pivots are presently located in southwestern Kansas and, based on soil type and availability of groundwater, what areas are likely to develop with center pivot irrigation. Currently, approximately 2,220 center pivots irrigate about 300,000 acres and represents about 12% of the land irrigated in the area. Based upon soil types and water availability, the area is approximately 20% developed. The figures and numbers discussed will be published soon by the Kansas Survey and the work was conducted by Don Williams and Jerry Coiner. Please note that with future development rates unknown, longevity of the groundwater is not assessed.

SUMMARY AND CONCLUSIONS

1. Tremendous potential for irrigation development exists in the high plains. Future development, depending upon rate, could strain the money and energy markets.
2. A multiplicity of geologic and hydrologic complications will always complicate legal and management efforts.
3. A continuous effort will be needed to resolve interstate and surface-groundwater legal questions.
4. An accelerated effort to define and resolve geochemical questions is necessary.
5. An interstate effort is overdue to monitor the entire system to better determine the present extent of development and to monitor future developments. Satellite imagery appears to offer the best solution.

6. Questions concerning longevity of the system will remain elusive under current legal and management practice, as compounded by a quasi stable economic present and future.