

**KANSAS GEOLOGICAL SURVEY
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A General Overview of the Use of Water
and the Longevity of Irrigation Systems
in Western Kansas

by

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INTRODUCTION

Irrigation in Western Kansas is perhaps one of the newest and most prolific industries in the state of Kansas. In this brief paper, an effort will be made to get a general overview of the entire system as it exists, not only in the state of Kansas, but in the neighboring states as well. This general overview will be included to indicate the type of demand that will be made upon fuel for irrigators in the entire system. And, in addition, an effort will be made to identify discreet parts of the system in Kansas, the total volume of fluid that exists in each system, the total number of wells that exist in each system, and, based upon a simplified model and a large number of assumptions, predictions concerning the longevity of each of the systems will be included.

KNOWN AND UNKNOWN FEATURES OF THE IRRIGATION SYSTEMS

Since very little is actually known about the systems in Western Kansas, I will begin by discussing the features that are known. Chief amongst the known features of the major systems, is the volume of water that is currently stored in the system. The next known feature is the number of wells that are contained within each region of the system.

Unknown features about the system include the following: the amount of fluid that is currently pumped from the wells, future development rate, future weather, recharge rates, and the possible impact of energy shortages in the future upon quantity of water pumped and the development rate.

With few things actually known, and a multiplicity of factors that are unknown, it is obviously quite precarious to make projections concerning future use of water and the longevity of the basic systems. However, since the consequences of not attempting to define these two major factors loom quite large, the icy plunge follows.

AN OVERVIEW

Figure 1 shows the distribution of the Ogallala Formation in the Great Plains area. From this figure one can see the overall extent of irrigation in surrounding states. One is immediately struck with the size and geographical immensity of the system. It is of interest to note that Kansas has some 17 percent of the area involved in the Ogallala Formation.

Figure 2 is a compilation of numbers, costs, volumes and expenses that will be involved in total development of the Ogallala system. First of all, the area involved is some 151,000 square miles and based upon assuming different saturated thicknesses for the system, there is between 150

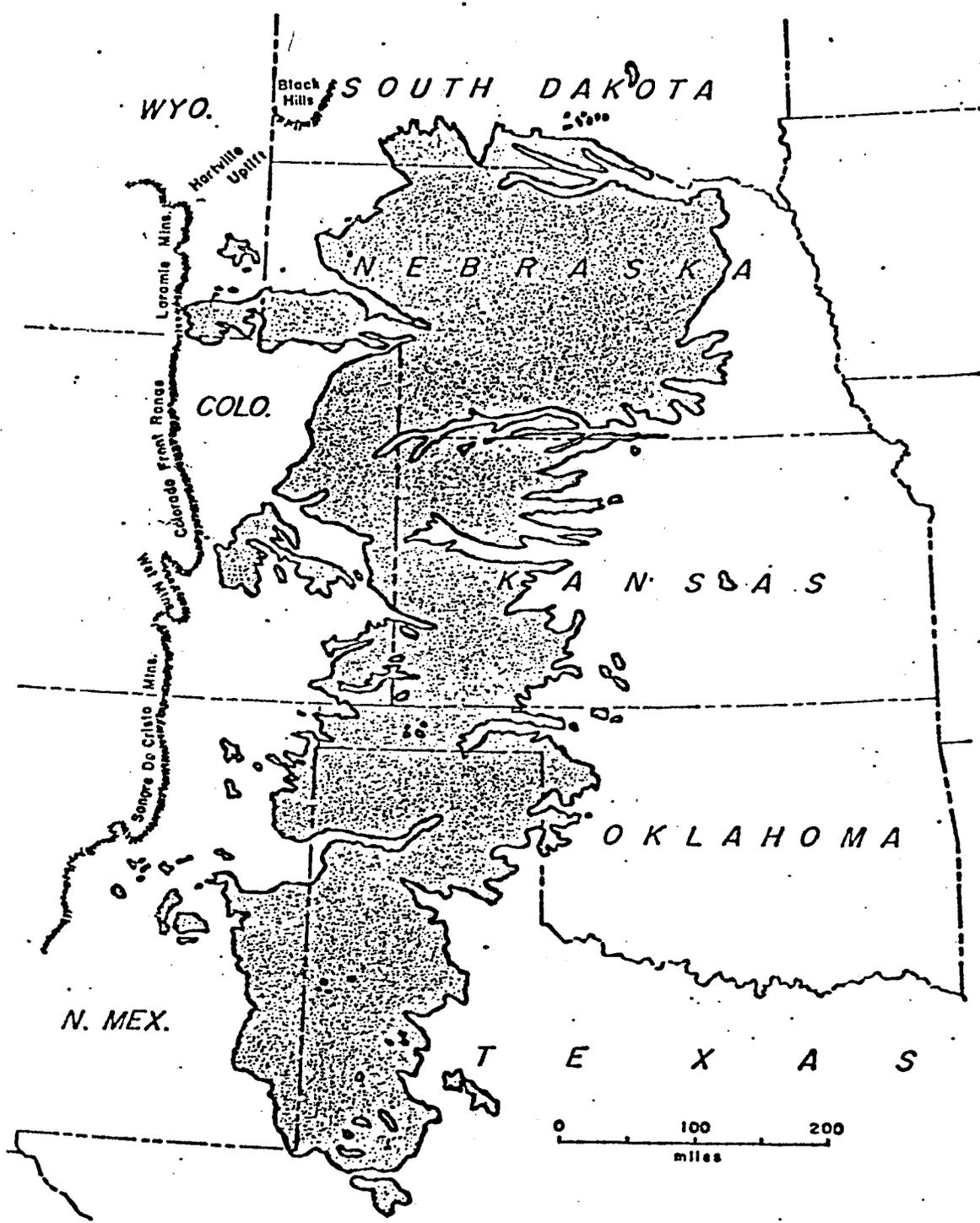


Figure 1. Distribution of Ogallala Formation in Great Plains (Merriam, 1963)

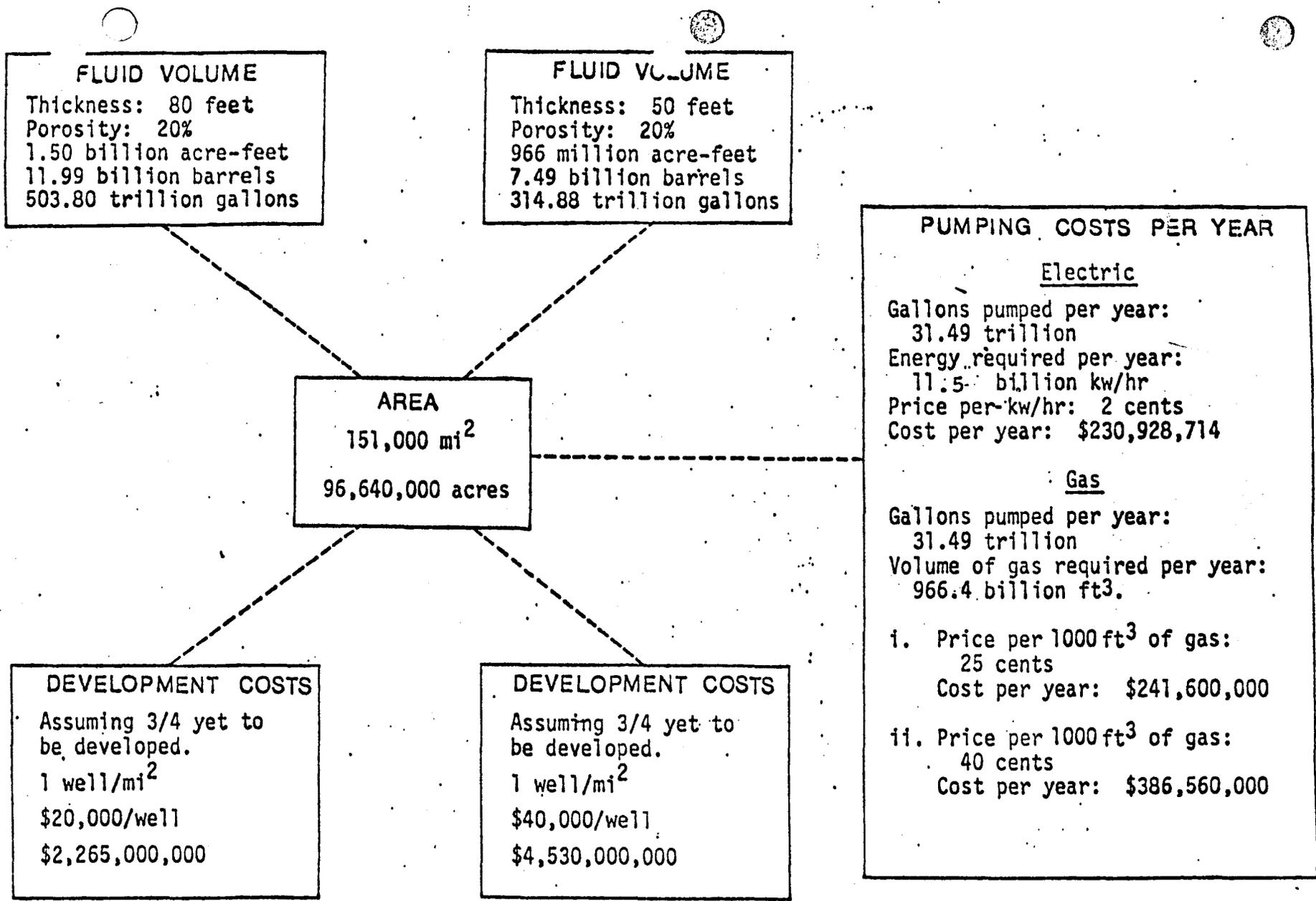


Figure 2. Basic Planning Numbers

billion acre feet and 966 million acre feet of water stored in the total system.

Based upon assuming that three-fourths of the system is yet to be developed, and that at total development one well will exist for each square mile, it is seen that development costs of the total system will range from 2-4½ billion dollars.

The cost of pumping fluids from this system with the whole system developed, are summarized in the right-hand box in Figure 2. It is seen that costs based upon the previous assumptions will range between 230 million and 380 million dollars per year. It is also of interest to note that if all wells pump, that one foot of water can be pumped over this entire surface (151,000 square miles) in as short a period of time as 20 days. This number is included to simply give an indication of the quantity of energy that conceivably be demanded in a relatively short period of time.

REGION I - GREAT BEND PRAIRIE

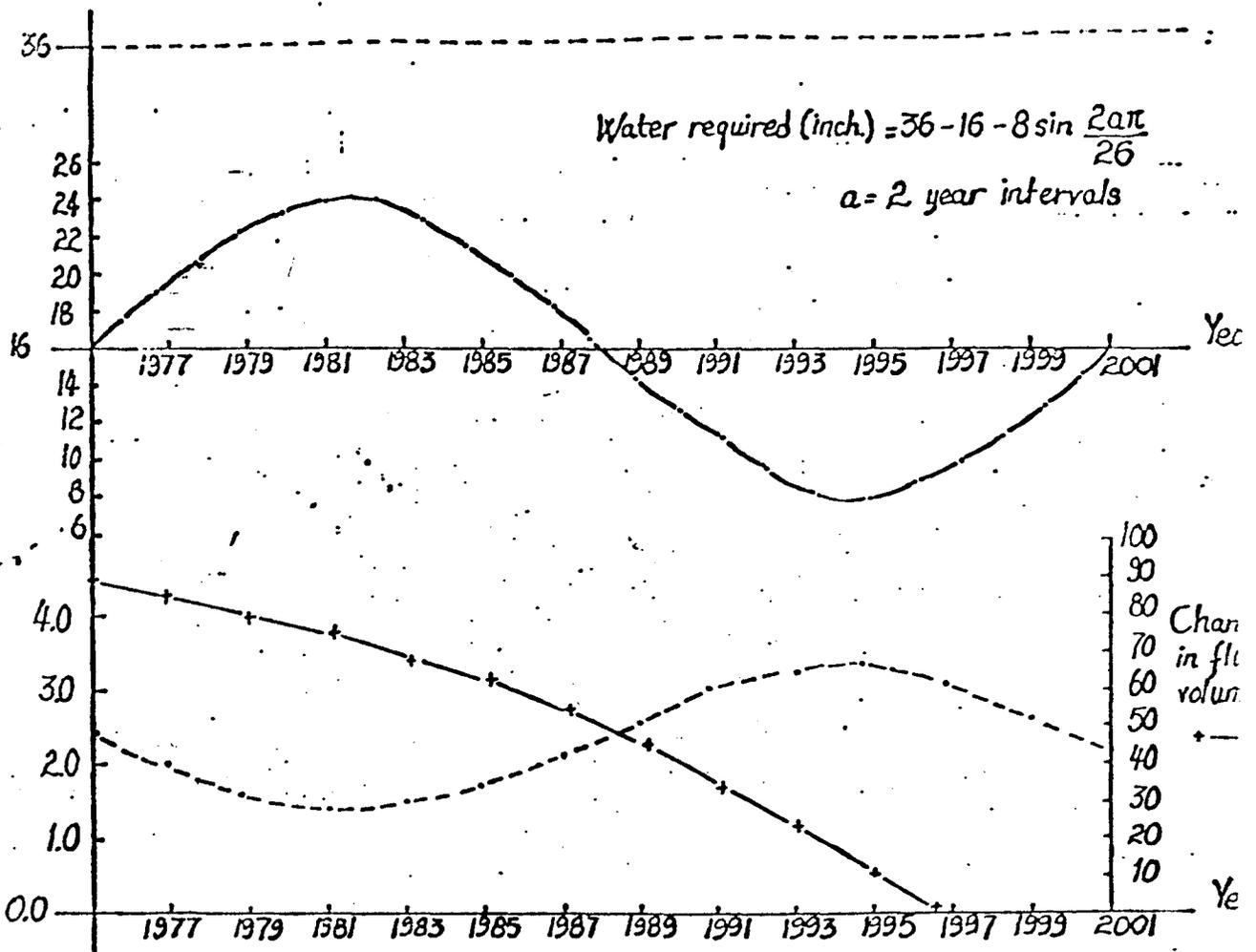
Figure 3 is a composite of graphs chosen to indicate a conceivable variation in weather, total demand of pumpage, a possible production decline curve, and energy costs, both electric and natural gas. At the top of Figure 3 is a basic graph indicating a conceivable relationship between the weather and pumping practices in the Great Bend area. This top graph indicates a total demand of 36 inches of water are necessary to satisfy the total demand for whatever farming practice is taking place. The sinusoidal function drawn on this graph is simply a representation of how much water natural rainfall may provide and what quantity of water will be necessary from irrigation wells to satisfy a total demand of 36 inches. The second graph on Figure 3 shows the amount of water necessarily pumped to satisfy the model outlined in Graph 1. Graph 2 also includes a decline curve for the volume of the entire system. Graphs 3 and 4 indicate energy requirements in both electrical energy or gas energy for the system as a whole. The above set of graphs are based upon the assumption that the area in Region I is totally developed and has a maximum of one well per square mile over 6,850 square miles. It is known that the area has only 1,200 wells, and is therefore only 18 percent developed. Since future development is unknown, it is reasonably assured that the longevity curve shown in Graph 2 of Figure 3 could be extended in time as much as five times, the extension in time will depend upon future development.

REGION II - SOUTHWEST KANSAS

Figure 4 uses the same sinusoidal weather model as used in the previous figure. Graph 2 on Figure 4 indicates the

Assumed rainfall variation (inch.)

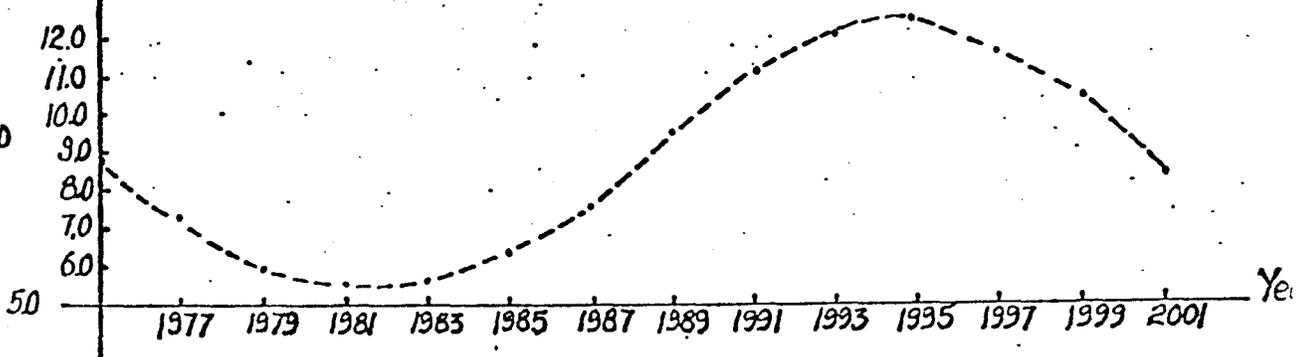
Water required (inch.) = $36 - 16 - 8 \sin \frac{2a\pi}{26}$
 $a = 2$ year intervals



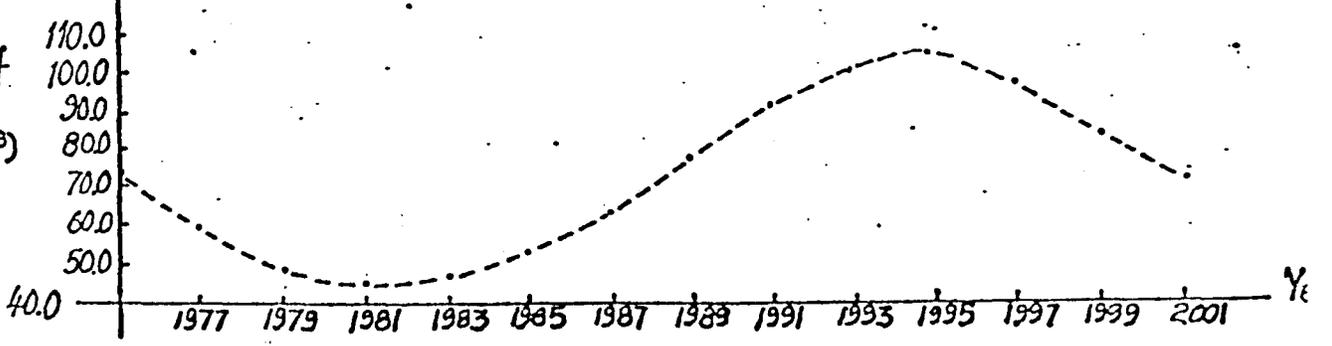
Amount to be pumped (trillion gallons)

Change in flow volume

Electric energy / 10.0 (billion kw/hr)



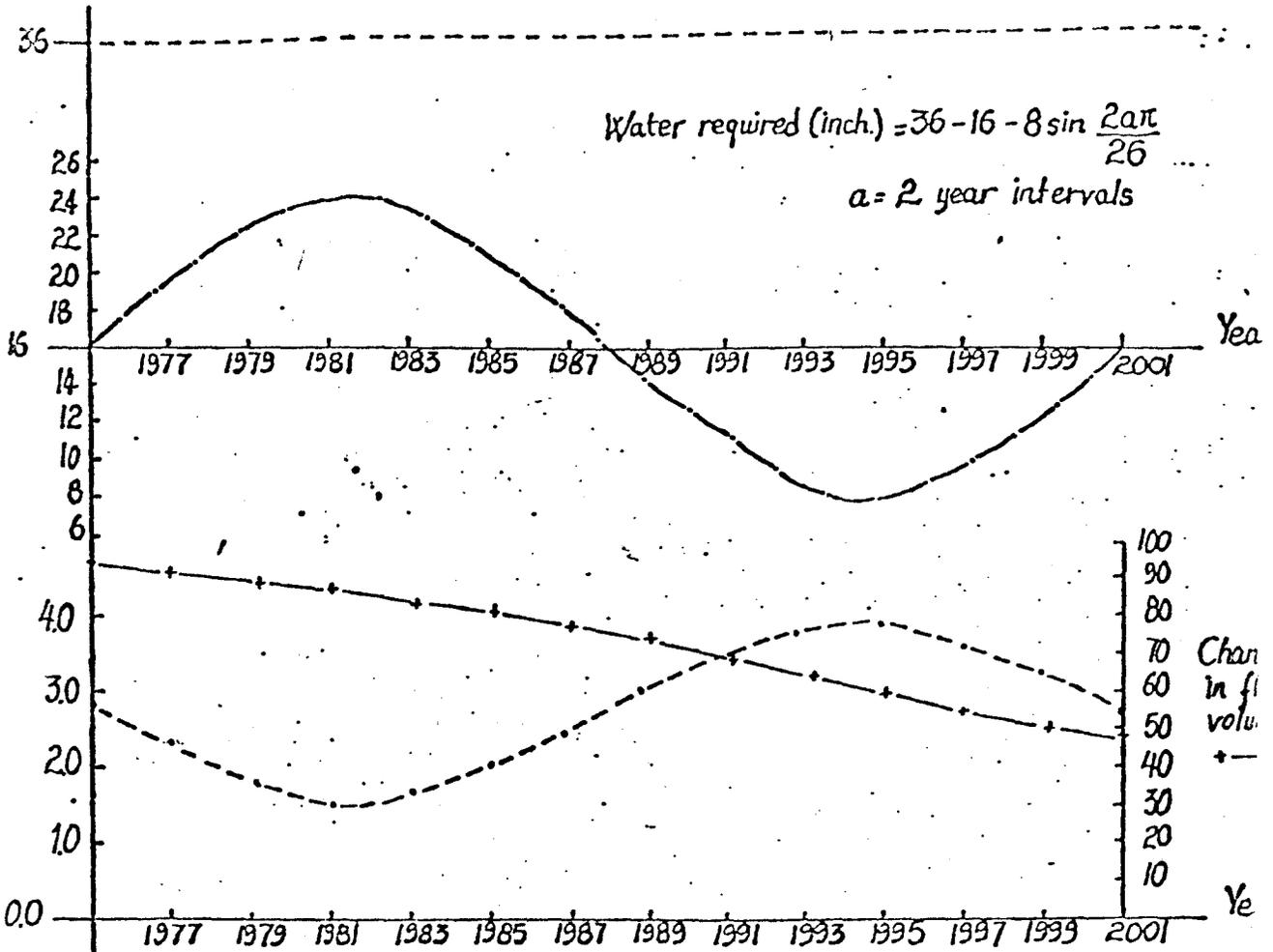
Volume of gas (billion ft³)



Assumed rainfall variation (inch.)

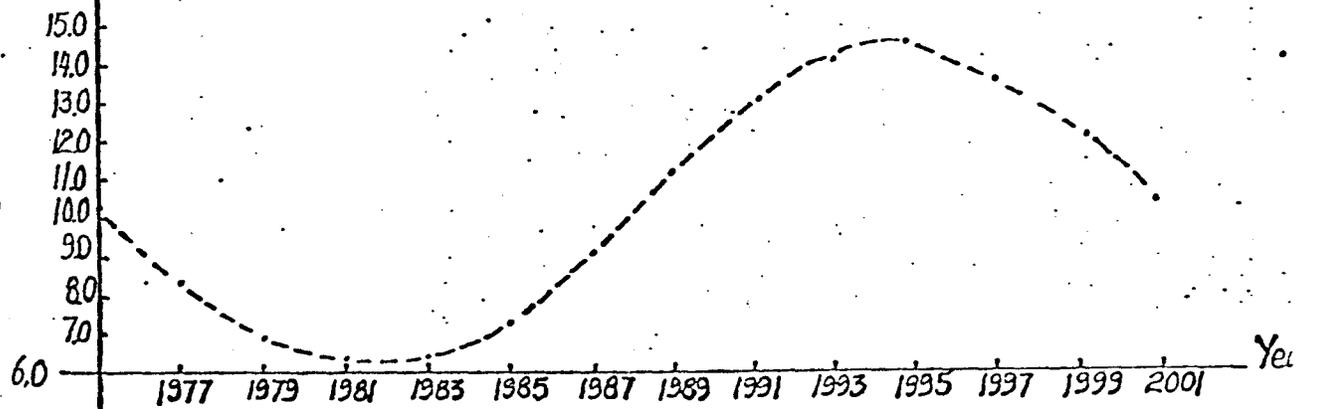
$$\text{Water required (inch.)} = 36 - 16 - 8 \sin \frac{2\pi t}{26}$$

$a = 2$ year intervals

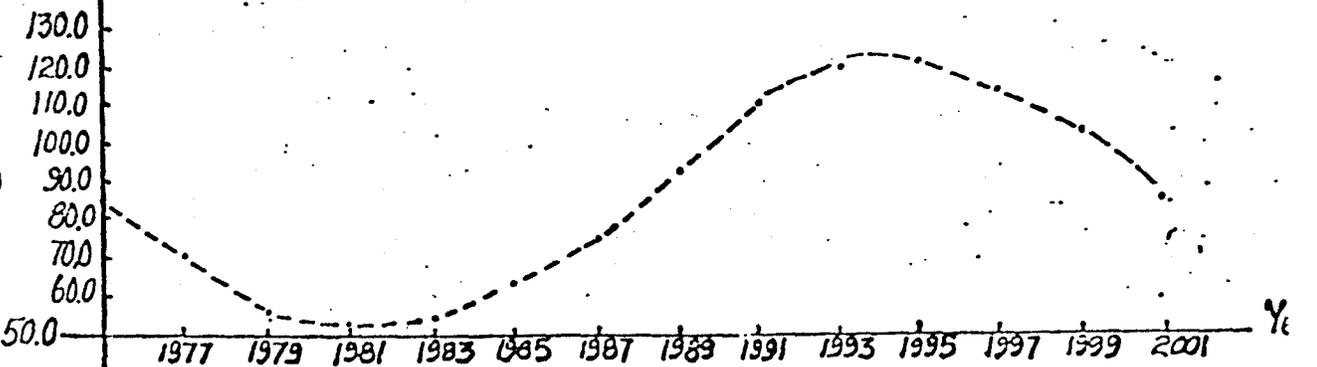


Amount to be pumped (trillion gallons)

Electric energy/10.0 (billion kw/hr)



Volume of gas (billion ft³)



amount to be pumped, and again includes a possible depletion curve for this system. Graph 3 and Graph 4, as in the previous figure, indicate the quantity of energy that may be required if one uses simply electrical energy or gas energy. This area contains approximately 8,170 square miles, and it contains 7,000 wells, and based upon a maximum density of one well per square mile, it is considered 86 percent developed. Clearly, if development of this system does not exceed one well per square mile, Region II will remain a viable economic community into the next century.

REGION III - WEST-CENTRAL KANSAS

Figure 5 contains the same general type of graphs as the previous figures. A sinusoidal weather function is again assumed and its effect upon total pumpage and depletion is shown.

Graph 2 indicates the amount of fluid to be pumped and a depletion curve. As in the previous graphs, Figures 3 and 4 indicate the energy required if one were to pump water using just electricity or just gas respectively. The area contained in Region III is about 2,490 square miles and presently contains about 2,500 wells. Based upon a total maximum density of one well per square mile, this system is 100 percent developed. Based upon the assumptions used, this region will clearly have problems meeting demand for irrigation within the next ten years.

REGION IV - NORTHWEST KANSAS

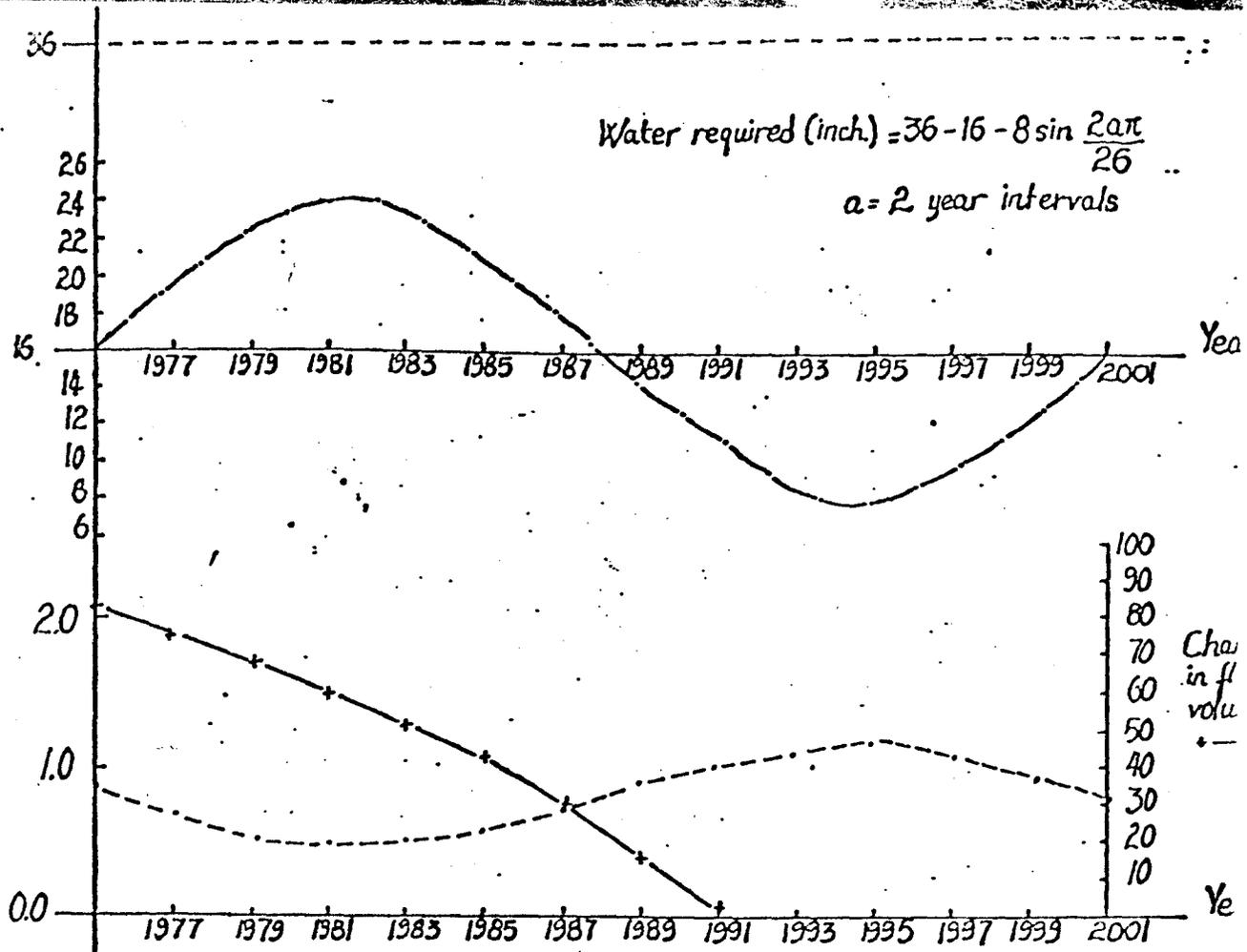
Figure 6, as the previous figures, has graphs indicating weather, amount to be pumped, depletion curves, and total energy requirements for the Northwestern Region. This area is 8,260 miles, and presently contains some 3,000 wells. It therefore follows that this area is approximately one-third developed, and it necessarily follows that the depletion curve shown in Graph 2 of Figure 6 could be extended by as much as three times. In the worst case, if development were to be completed very rapidly, the depletion curve shown would become more and more accurate. It appears clear that this area will probably have sufficient quantities of water into the next century.

SUMMARY & CONCLUSIONS

It is apparent from the foregoing, that a large number of sweeping grandiose conclusions could be reached. However, it is also apparent that for the most part the system as it

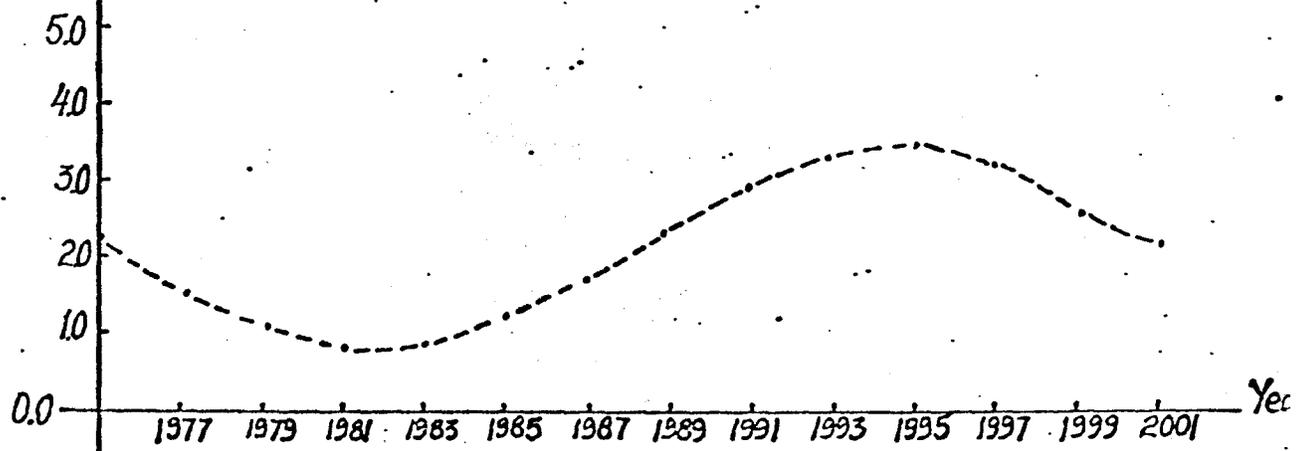
Assumed rainfall variation (inch.)

Water required (inch.) = $36 - 16 - 8 \sin \frac{2a\pi}{26}$
 $a = 2$ year intervals

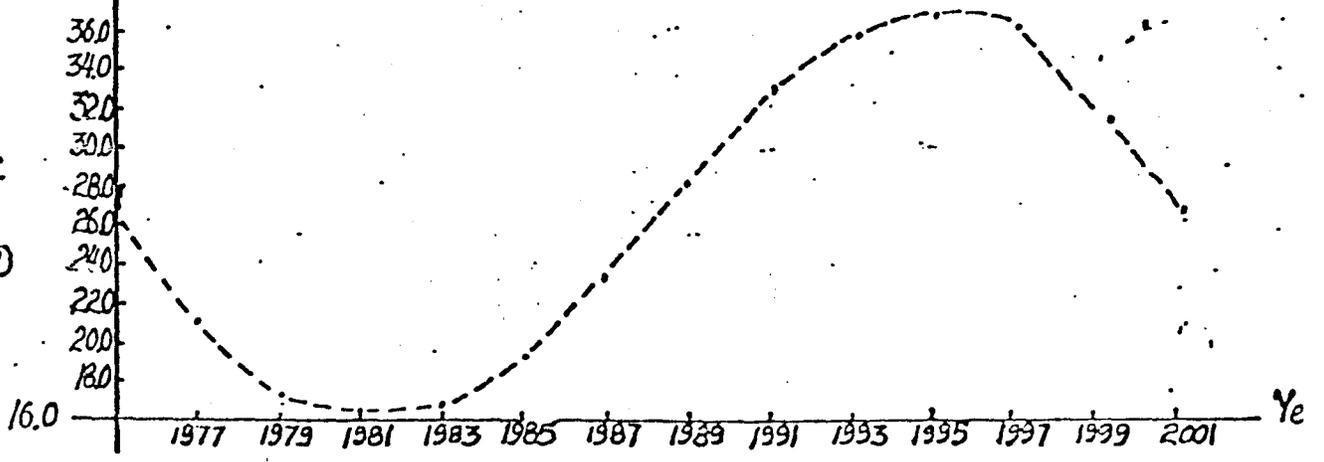


Amount to be pumped (trillion gallons)

Electric energy/10.0 (billion kw/hr)

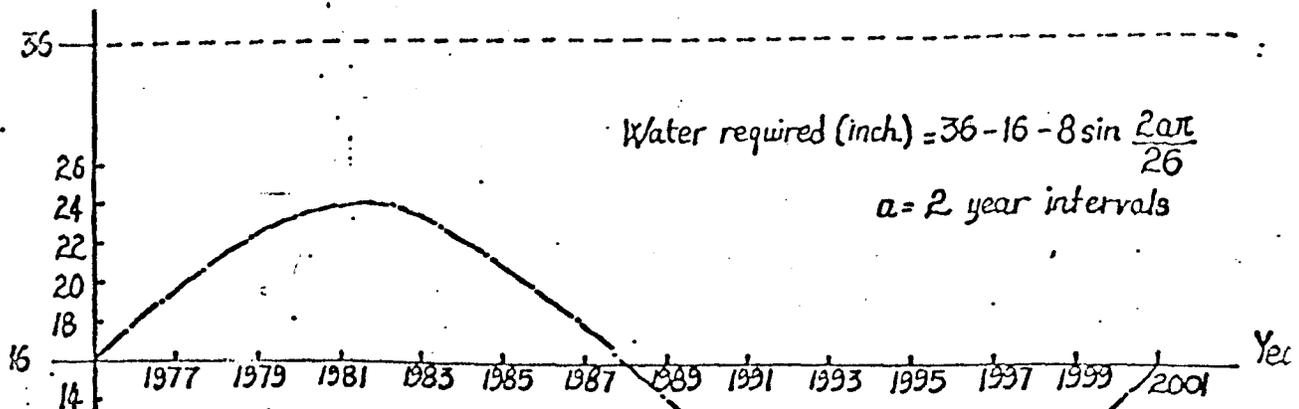


Volume of gas (million ft³)

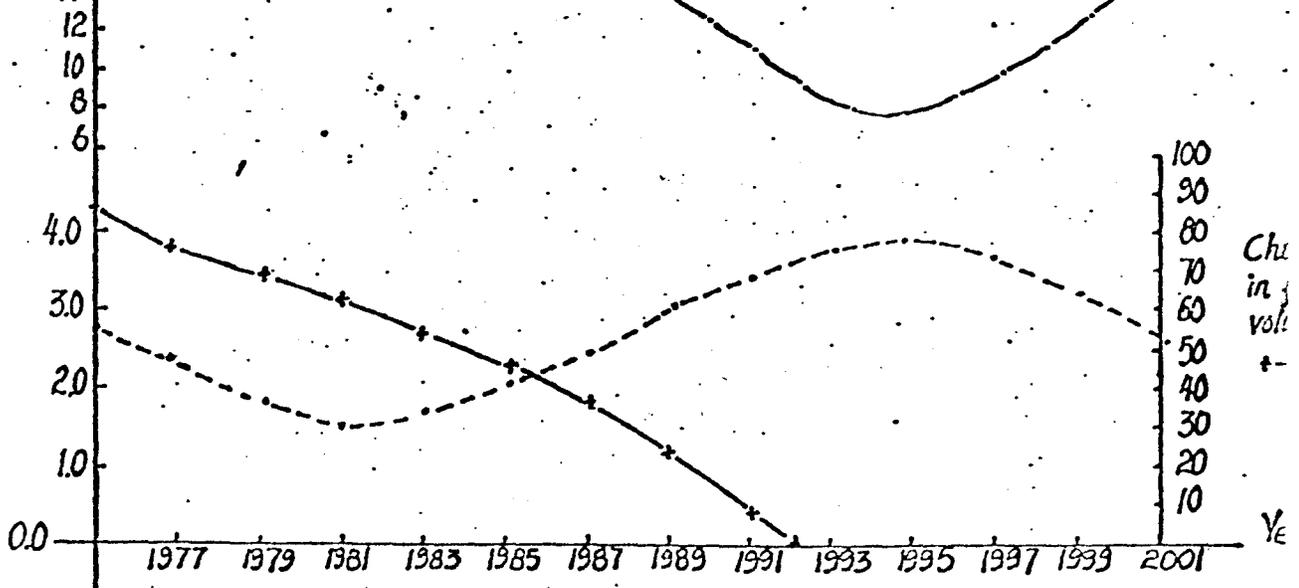


Assumed rainfall variation (inch.)

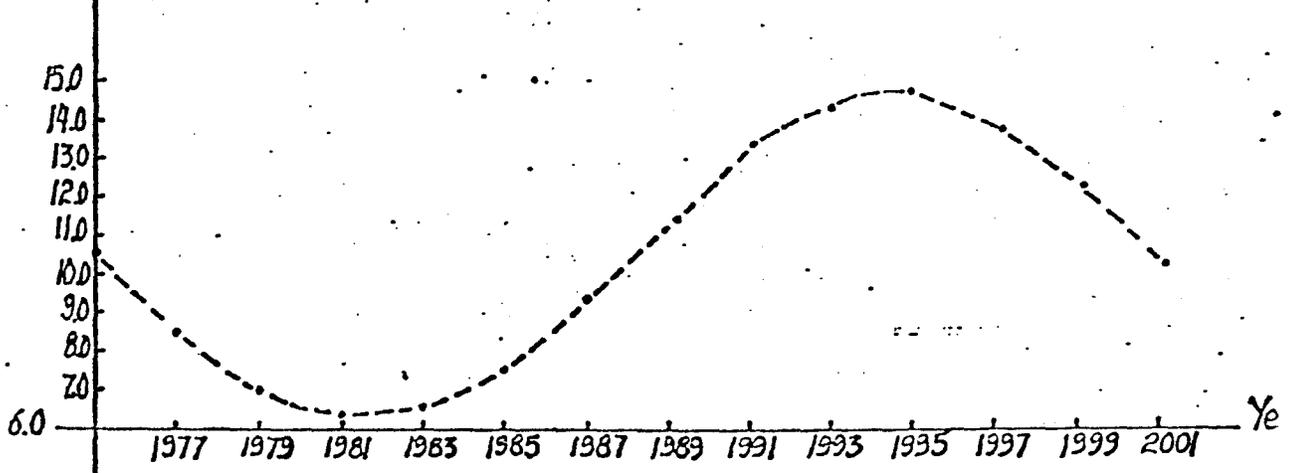
Water required (inch.) = $36 - 16 - 8 \sin \frac{2\pi t}{26}$
 $a = 2$ year intervals



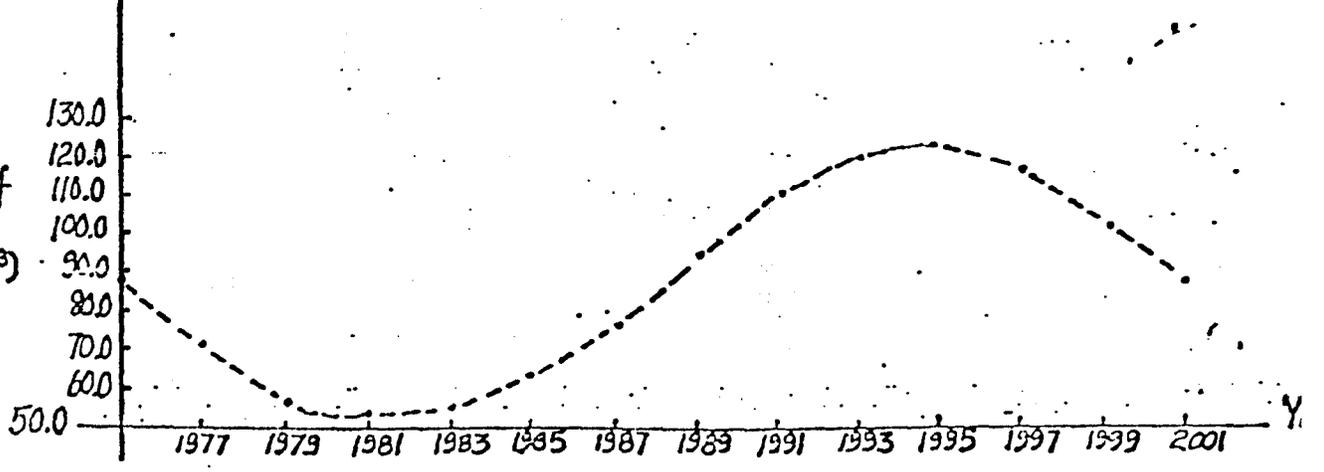
Amount to be pumped (trillion gallons)



Electric energy /10.0 (billion kw/hr).



Volume of gas (billion ft³)



currently exists and how it will be managed in the future, is, and will remain, the responsibility of the people of Kansas. It therefore behooves the legislature and the people involved to make every effort to understand the consequences of mining a depleting resource.

Chief amongst the considerations that should be made by the people directly involved in the irrigation community are the following:

1. Over what span of time do the people in the individual irrigation regions want the water to last?
2. Based upon the water in place and the period of time that the people want the water to last, definite ceilings should be placed upon the quantity of water to be produced each year.
3. How much water should be left in the system to strictly meet emergency needs for the municipal and irrigation purposes in the event of a drought?

Chief amongst the considerations that the legislature should make are at least the following:

1. Is the present law and the present regulatory system adequate to meet the challenge that obviously will come in the near future concerning depleting groundwater supplies in Western Kansas?
2. Should the system that is currently in place to regulate future development be markedly altered?
3. Should people that choose not to develop irrigation or not to pump be compensated for their efforts to conserve and to promote the overall longevity of the system?
4. What action should the legislature take to encourage income tax relief along the lines of a depletion allowance such as is currently accepted in the High Plains of Texas?

If the present institutions in place today are defective, these defects must be corrected prior to the onset of large scale problems. Solutions will become increasingly difficult and painful after the onset of large scale problems.

APPENDIX I

TABLES OF INFORMATION ON REGIONS I - IV

(Based on model and assumptions used in figures 3 through 6)

REGION: GREAT END PRAIRIE

AREA: 6,850 mi² 4,384,000 acres

WELLS: 1,200 area 18% developed

FLUID VOLUME

Thickness: 109 feet

Specific Yield: 0.18

86.0 million acre-feet

667.3 billion barrels

28.0 trillion gallons

Year	1975	1977	1979	1981	1983	1985	1987	1989	1991	1993	1995	1997	1999	2001
Fluid volume to be pumped (trillion gallons)	2.38	1.94	1.60	1.44	1.50	1.75	2.15	2.61	3.01	3.27	3.32	3.16	2.82	2.50
Fluid volume remaining (trillion gallons)	92	85	79	74	68	62	54	45	34	23	11	--	--	--
Electric energy required (trillion kw/hr)	0.87	0.71	0.59	0.53	0.55	0.64	0.79	0.96	1.10	1.20	1.22	1.16	1.03	0.90
Volume of gas required (billion ft ³)	73.04	59.60	49.07	44.13	45.88	53.77	66.04	80.07	92.34	100.23	101.89	97.01	86.48	73.04
Cost for electricity (2¢ per kw/hr) in billion dollars	17.46	14.26	11.74	10.56	10.98	12.86	15.80	19.16	22.08	23.98	24.40	23.20	20.68	17.46
Cost for gas (25¢/1,000 ft ³) in billion dollars	18.26	14.90	12.27	11.03	11.47	13.44	16.51	20.01	23.08	25.05	25.47	24.25	21.62	18.26

REGION: SW KANSAS

AREA: 8,170 mi² 5,228,800 acres

WELLS: 7,000 area 86% developed

FLUID VOLUME

Thickness: 250

Specific Yield: 0.18

235.0 million acre-ft

1.83 trillion barrels

76.70 trillion gallons

Year	1975	1977	1979	1981	1983	1985	1987	1989	1991	1993	1995	1997	1999	2001
Fluid volume to be pumped (trillion gallons)	2.84	2.32	1.91	1.72	1.78	2.09	2.57	3.11	3.59	3.90	3.96	3.77	3.36	2.84
Fluid volume remaining (trillion gallons)	96	93	91	89	86	84	80	76	71	66	61	56	52	48
Electric energy required (trillion kw/hr)	1.04	0.85	0.70	0.63	0.65	0.77	0.94	1.14	1.32	1.43	1.46	1.38	1.23	1.04
Volume of gas required (trillion ft ³)	87.13	71.11	58.56	52.63	54.72	64.14	78.78	95.51	110.15	119.57	121.66	115.73	103.18	87.13
Cost for electricity (2¢ per kw/hr) in million dollars	20.84	17.00	14.00	12.58	13.08	15.34	18.84	22.84	26.34	28.60	29.10	27.68	24.68	20.84
Cost for gas (25¢/1,000 ft ³) in million dollars	21.78	17.77	14.64	13.15	13.68	16.03	19.69	23.87	27.53	29.89	30.41	28.93	25.79	21.78

REGION: WC KANSAS

AREA: 2,490 1,593,600 acres

WELLS: 2,500 area app. 100% developed

FLUID VOLUME

Thickness: 72

Specific Yield: 0.18

20.6 million acre-ft

160.2 billion barrels

6.73 trillion gallons

Year	1975	1977	1979	1981	1983	1985	1987	1989	1991	1993	1995	1997	1999	2000
Fluid volume to be pumped (trillion gallons)	0.87	0.71	0.58	0.52	0.54	0.64	0.78	0.95	1.09	1.19	1.21	1.15	1.02	0.9
Fluid volume remaining (billion barrels)	87	77	68	60	52	43	31	17	1	--	--	--	--	--
Electric energy required (billion kw/hr)	0.32	0.26	0.21	0.19	0.20	0.23	0.29	0.35	0.40	0.44	0.44	0.42	0.38	0.3
Volume of gas required (billion ft ³)	26.55	21.67	17.83	16.02	16.66	19.55	24.00	29.09	33.54	36.43	37.07	35.26	31.43	26.5
Cost for electricity (2¢ per kw/hr) in million dollars	6.34	5.18	4.26	3.84	3.98	4.68	5.74	6.96	8.02	8.72	8.86	8.44	7.52	6.3
Cost for gas (25¢/1,000 ft ³) in million dollars	6.63	5.41	4.46	4.00	4.16	4.88	6.00	7.27	8.38	9.10	9.26	8.81	7.85	6.6

REGION: NW KANSAS

AREA: 8,260 mi² 5,286,400 acres

WELLS: 3,000 area 36% developed

FLUID VOLUME

Thickness: 80

Specific Yield: 0.18

76.12 million acre-ft

590.50 billion barrels

24.8 trillion gallons

Year	1975	1977	1979	1981	1983	1985	1987	1989	1991	1993	1995	1997	1999	2001
Fluid volume to be pumped (trillion gallons)	2.87	2.34	1.93	1.73	1.80	2.11	2.60	3.15	3.63	3.94	4.01	3.81	3.40	2.80
Fluid volume remaining (billion barrels)	88	79	71	64	57	48	38	25	10	--	--	--	--	--
Electric energy required (billion kw/hr)	1.05	0.86	0.71	0.64	0.66	0.78	0.95	1.16	1.33	1.45	1.47	1.40	1.25	1.10
Volume of gas required (billion ft ³)	88.11	74.88	59.20	53.22	55.33	64.85	79.64	96.55	111.34	120.86	123.01	116.99	104.32	88.00
Cost for electricity (2¢ per kw/hr) in billion dollars	21.08	17.20	14.16	12.72	13.24	15.50	19.04	23.10	26.62	28.90	29.42	27.98	24.94	21.60
Cost for gas (25¢/1,000 ft ³) in billion dollars	22.02	17.97	14.80	13.30	13.83	16.21	19.91	24.13	27.83	30.21	30.75	29.24	26.08	22.00