THE ECONOMICS OF STRIPPER WELL OIL PRODUCTION IN OKLAHOMA

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STILLWATER, OKLAHOMA

1963

Submitted to the Faculty of the Graduate School of the
Oklahoma State University in partial fulfillment
of the requirements for the degree of
MASTER OF SCIENCE
August, 1963

THE ECONOMICS OF STRIPPER WELL

OIL PRODUCTION IN OKLAHOMA

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ACKNOWLEDGEMENTS

The author is indebted to Dr. Larkin Warner, Assistant Professor of Economics, Oklahoma State University, for his valuable assistance and guidance throughout the course of preparing this thesis. Appreciation is expressed to Ferril H. Rogers, Oklahoma Corporation Commission, Kenneth H. Johnston, U. S. Bureau of Mines, and W. C. Milan, Producers Pipe and Supply Company, who aided greatly in the collection of needed information. Grateful acknowledgement is made to J. R. Lindley, U. S. Bureau of Mines who drew the diagrams found in the thesis.

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CHAPTER I

INTRODUCTION

The oil producing industry in Oklahoma is faced with a tremendous problem resulting from water pollution caused by the stripper or marginal well. The Oklahoma Corporation Commission is charged with the responsibility of regulating oil production and must by law take steps necessary to stop water pollution. In most cases this would require stripper well operators to install salt water disposal systems. This would probably add so much to the cost of operating the wells that a large percentage of them would shut down. The effect of shutting down stripper wells could be to reduce the oil production in Oklahoma by 60 percent unless the decline in production from the stripper wells were offset by an increase in production from non-marginal wells.[1] The purpose of this thesis is to test the economic feasibility of one proposed solution: that the state use tax revenue coming directly from stripper well production to finance the installation of the needed disposal systems.[2]

In almost any type of industry there are considerations other than those that occur within the individual firm. These considerations

[1] National Stripper Well Survey, Interstate Oil Compact Commission and National Stripper Well Association, (Oct. 1962), p. 6. The possibility that the non-marginal well might offset the decline in production is examined in Chapter IV.

[2] This solution came out of a conversation between the author and Ferril H. Rogers, Oklahoma Corporation Commission, (Oklahoma City, Oklahoma, October 21, 1962).

are sometimes referred to as "external economies" or "external benefits." These are benefits which accrue to society as a whole from the continued operation of the industry. The external benefits of most concern in this thesis are the taxes paid by stripper well operators to the state. This thesis will be concerned only with the three most obvious taxes: (1) Gross production tax, (2) Excise tax, (3) Income tax on oil royalties. If the stripper wells shut down, the state would lose this revenue and would have to either raise taxes or reduce services provided to the public.

At the same time there are certain costs to society as a whole from the continued operation of these oil producing companies. These costs are referred to as "external costs" or "external diseconomies". The cost of most concern here is water pollution. While the damage caused by water pollution cannot be measured, the cost of alleviating the problem by constructing disposal systems can be estimated.[3]

The problem then becomes whether the state should shut down the stripper wells and lose the associated tax revenues, or whether the state should incur the cost of installing the necessary disposal systems. If the associated tax revenues are greater than the cost of installing the disposal systems, state action might be feasible. If, on the other hand, the cost of constructing the disposal systems is greater than the tax revenue that could be expected from the continued operation of the stripper wells, a strong case exists against such state action and the stripper wells should be shut down.

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[3]For a thorough discussion of external economies and diseconomies see William J. Baumal, Economic Theory and Operations Analysis, Prentice-Hall, Inc. Englewood Cliffs, New Jersey, (1961), pp. 258-262.

Importance of Oil Production in Oklahoma

The problem is made especially acute in Oklahoma by the vast importance of the oil producing industry to the state's economy. For example, in 1957, 22,414 persons were employed in crude oil production, and were paid a total of over $123 million dollars.[4] Petroleum production accounts for 93 percent of the value of all minerals produced in the state.[5] Moreover, in the fiscal year 1961-1962, the gross production tax and petroleum excise tax accounted for almost 34 1/2 million dollars or 11.68 percent of all taxes paid to the state of Oklahoma.[6] If the indirect taxes generated by oil production, such as sales and income tax, were added to this figure, it would be much higher. From this it can be seen that this problem is not one faced by the oil industry alone, but one which affects the entire state.

Definitions

In the statement of the problem the term "stripper well" was used. Because this term is so basic to this thesis, it is necessary to define a stripper well before we proceed any further with the analysis. In an extractive industry based on a wasting resource, the extractive units will always vary considerably in their productivity. In oil production there are good wells, average wells, and there are some wells that are on the margin. These marginal wells are just

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[4] Census of Mineral Industries, Vol. II Area Statistics, U. S. Department of Commerce, (1958), p. 33-35.

[5] The Oil Producing Industry in Your State, Independent Petroleum Association of America, Vol. 32, (1961), p. 62.

[6] Fifteenth Biennial Report of the Oklahoma Tax Commission, (July 1, 1960 - June 30, 1962), p. 23.

barely able to produce enough oil to make it profitable for the owners to continue producing. These are the stripper wells. The profitibility of a well depends on (1) the cost of its operation, and (2) the price of crude oil. Thus the margin cannot be determined exactly. However, the limitations of available data require the use of an arbitrary definition. Thus, for the purposes of this thesis, the maximum amount of oil a well can produce and still be classified as a stripper well will be set at ten barrels per day.[7] This definition has the merit of common industry usage and fits in with reported statistics.

Outline of the Thesis

Chapter II will deal with the historical tendencies in oil production. An attempt will be made to explain why the rate of output of a well declines to the point where it enters the stripper phase and why water pollution becomes a problem. Chapter III will examine what is currently being done to solve the problem. Chapter IV will look into the feasibility of the proposed solution of government action in drilling the necessary disposal wells. The final chapter will contain conclusions and recommendations which can be drawn from the analysis.

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[7]*National Stripper Well Survey*, *op. cit.*, p. 6.

CHAPTER II

DEVELOPMENT OF THE PROBLEM

One purpose of this chapter is to explain the principles of oil production and show how the problem of water pollution develops as the output of a well declines to the point where it can be classified as a stripper well. In addition, the harmful effects of merely putting the oil polluted water into the streams and rivers will be examined. After this has been done it will be possible to look at the importance of stripper well production in Oklahoma. This will give some indication of the seriousness of the problem of water pollution.

Principles of Oil Production

The production of crude oil is based on two simple physical principles: (1) fluids and gases tend to move toward the point of lowest pressure, and (2) crude oil by itself exerts no pressure. For a well to produce, the pressure necessary to move the oil must come from some other source. The method of classification used here is by the type of pressure exerted on the oil (this will be either _water_ or _gas drive_) and by the extent of pressure exerted on the oil. If the pressure is sufficient to move the oil out of the reservoir and up the well, the well is known as a _flowing well_. If the pressure exerted on the oil is not great enough to move the oil all the way to the surface and some additional pressure must be applied, the operation is known as _primary recovery with artificial lift_.

Finally, if the existing pressure is not sufficient to move the oil out of the reservoir to the well, and additional means (waterflood and gas injection) of moving the oil are applied, the process is known as secondary recovery. Thus a four-fold classification of wells includes: (1) Flowing Well - Water Drive, (2) Flowing Well - Gas Drive, (3) Primary Production with Artificial Lift, and (4) Secondary Recovery.

Flowing Well - Water Drive

In a water drive well, the pressure to move the oil comes from the existing water that is found with the oil. The pressure exerted by the water is known as hydrostatic pressure.[8] Water has a tendency, under all circumstances, to rise to the height of its source. This is the principle used to move many city water supplies. If the city's reservoir or water tower is higher than any of the buildings in the city, the hydrostatic pressure of the water will be sufficient to raise the water to any necessary level.

A water drive well is depicted in Diagram 2.1. In the diagram the

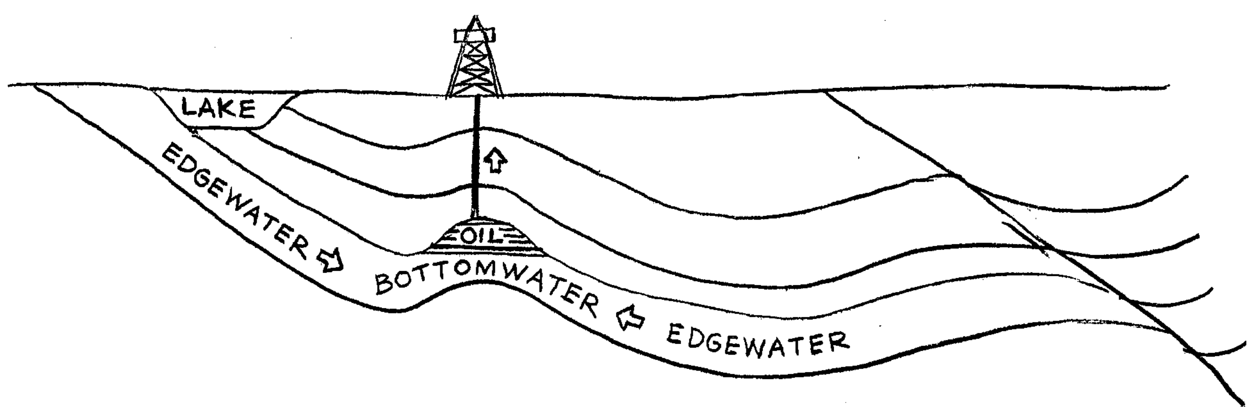

Diagram 2.1. A Hypothetical Water Drive Well.[9]

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[8] W. Fred Heister, Petroleum Production Practices, College Book Store Oklahoma A. and M. College, (Stillwater, Oklahoma, 1959, pp. 15-16.

[9] Ibid., p. 15.

source of the water is the lake at the left. The water below the oil, known as bottom water, is under pressure to rise to the level of the lake. Before a well of this type is drilled, the movement is blocked by the rock strata that overlies the oil formation. When the well is completed, the pressure in the well is less than the hydrostatic pressure exerted on the oil. This disparity of pressure starts the oil moving toward the well, and if the disparity is great enough it will move the oil to the land surface and will be known as a flowing well. After the well starts producing the pressure around the well will be less than the pressure in the reservoir. As long as the difference in pressure is great enough, oil will flow from the reservoir to the well.

This type of drive is the most efficient type of oil drive because the pressure exerted on the oil in the reservoir remains fairly stable over much of the economic life of the well.[10] Eventually, however, the rate of production for such a well as depicted in the diagram will start to decline. As more and more oil is extracted, the remaining oil becomes harder to move because of its tendency to cling to the strata in the reservoir. Another reason for decline is that the water may not move in fast enough to replace the oil removed. When this happens the pressure gradually falls off.[11] This results in more pressure being needed to move the oil and less pressure being available, thus causing production to decline.

The water produced with the oil comes from three sources. First there is some water already mixed with the oil. Everyone knows that under normal circumstances water and oil do not mix. Under pressure, however,

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[10]Frank J. Morgeson, A Petroleum Handbook, The Asiatic Petroleum Company Limited, (London, 1933), p. 55-56.

[11]Dorsey Hager, Fundamentals of the Petroleum Industry, McGraw-Hill Book Company, Inc. (New York, 1939), p. 246.

the two can be made to form an emulsion much like the emulsion of cream and milk in homogenized milk. Since this emulsion is extremely hard to break up, sometimes it is necessary to use electricity to separate the water from the oil.[12] This water is present even when the well is first brought in. After production has started, the oil that is produced is replaced with water which may come from either edgewater and bottomwater (see diagram 2.1).[13] As the additional water enters the reservoir it mixes with the oil and water solution already in existence to form an emulsion that is of a higher water content. The ratio of water to oil will increase steadily until the well is not economical to operate. In a few isolated cases, wells have continued up to the point where the ratio of water to oil is 95 to 5 or where 95 percent of the liquid produced is water.[14] Finally, the well will produce nothing but water and will be shut down. Long before this happens the problem of what to do with the water produced has become a significant problem. Because of the high salt and other solid material content, this water is classified as polluted. This means that some method other than dumping it in streams must be devised.

Flowing Well - Gas Drive

There are really two different types of gas drive. They are: (1) Gas cap drive, and (2) Gas in solution drive.

A gas cap is a collection of gas between the top of the oil and the rock strata. A gas cap drive well is depicted in Diagram 2.2 on the following page. In this type well the pressure for production comes from

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[12] Ibid., p. 67.

[13] Interview with Ernest C. Fitch and A. G. Comer, Assistant Professors of Mechanical Engineering, (Oklahoma State University, February 26, 1963).

[14] Interview with Kenneth H. Johnston, Petroleum Engineer, U. S. Bureau of Mines, (Bartlesville, Oklahoma, March 28, 1963).

the expansion of the gas in the gas cap. Before this type well is drilled the pressure from the gas found in the gas cap is contained. When the well is drilled, the pressure in the well is less than the pressure in the reservoir. This starts an expansion of the gas and a movement of the oil up the well.

The rate of production from a well of this type will start to drop off almost immediately. There are three reasons for this. (1) As the oil is produced some gas is produced along with it. This leaves less gas to exert pressure on the oil. (2) The area in which the gas is contained becomes larger as oil is produced. Because the pressure of gas is inversely related to the area it occupies this means that less pressure is exerted on the oil by the remaining gas. (3) As oil is

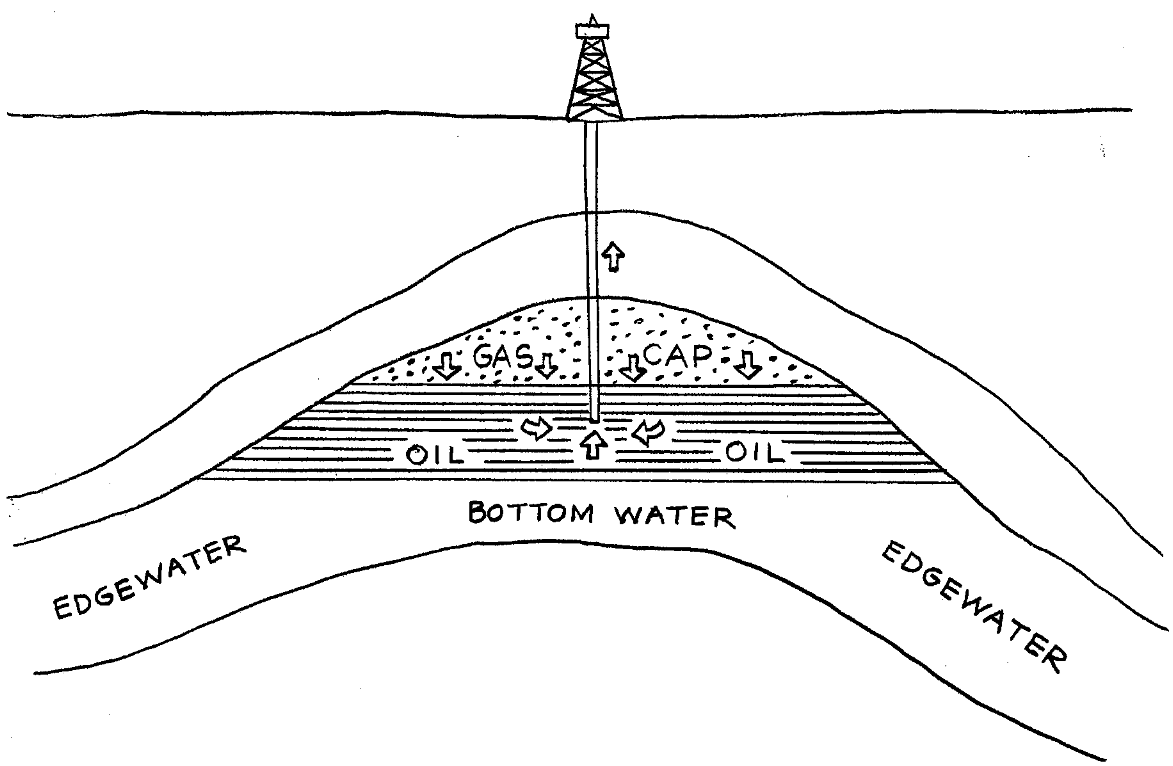

Diagram 2.2. Gas Cap Drive.[15]

[15]Frank J. Morgeson, op. cit., p. 54.

produced, the oil remaining in the reservoir becomes harder to move because of its tendency to cling to the strata in the reservoir. This means that more pressure must be exerted to move the same amount of oil.[16]

The water content of such a well will increase, as was the case with a water driven well, because of infringement from both edgewater and bottomwater. This is especially true if the initial production of the well is large. A sudden expansion of the gas cap will cause the water to move in more rapidly than usual and mix with the oil left in the reservoir to form an emulsion that is sometimes almost impossible to break up.[17] The early producing years in Oklahoma were characterized by producing as much oil as fast as possible. This might to some extent explain why some of the gas drive wells today produce such a large percentage of water.

In some wells there is no gas cap, but there are large quantities of gas mixed in the oil. The pressure for production for this type well comes from the expansion of gas that is mixed with the oil in solution. This operates on the same principle as a gas cap well. The oil moves toward the well because of the lower pressure contained in it.[18] From a technical point of view this is the least desirable type of production. The rate of production from this type well falls off sharply, and unless some other means of production is added, the greatest part of the oil will remain in the ground.[19] This sharp decline occurs mainly because

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[16]V. A. Kalichevsky, The Amazing Petroleum Industry, Reienhold Publishing Corporation, (New York, 1943), pp. 20-22.

[17]W. Fred Heister, op. cit. p. 37.

[18]Max W. Ball, The Fascinating Oil Business, Bobbs-Merril Company, (New York, 1939), pp. 139-142.

[19]Ibid.

much more of the propelling mechanism, the gas, is produced along with the oil than is the case with a gas cap well. As the gas is removed there remains less gas in the reservoir to exert pressure on the oil.[20]

The water in this case comes from the same sources as a gas cap well; that is, edgewater and bottomwater.

The point should be made at this time that many wells cannot be classified exclusively as gas drive wells or water drive wells. In many cases the pressure used in production comes from both sources. When this is the case, the well is classified by the type drive that is of dominant importance.

Acidizing and Fracturing

When a well is first brought in, it may or may not flow. If the pressure in the reservoir is not sufficient to move the oil to the surface, something must be done before production will start.

In some cases a process known as acidizing can be used to start the well flowing. The process consists of putting hydrocloric acid in the bottom of the well. This acid then eats holes in the rock strata in which the oil is found. This makes the strata more porous and thus less pressure is needed to move the oil from the reservoir to the well. This reserves more pressure for moving the oil to the surface. Acidizing is particularly effective in limestone formations.[21]

If the oil is found in a sandstone formation, rather than limestone, a process known as fracturing can be used to achieve the same results.

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[20] *Ibid.*, p. 142.

[21] Ibid., p. 121.

The process consists of lowering a high explosive, usually nitroglycerin, to the bottom of the well and igniting it. This explosion breaks up the rock strata and makes it easier for the oil to flow to the well. In addition, the gathering area for the oil is greatly enlarged.[22] This process conserves pressure that can be used to raise the oil to the surface.

These processes are not confined to use in new wells. In many cases they have been used in relatively old wells to increase their production.[23] This has led some writers to classify them as means of secondary recovery. This is not entirely correct. Even though they can be used to increase the production from old wells, they do it not by adding additional pressure, but rather by making the existing pressure perform more efficiently. Strictly speaking this is not secondary production. Secondary production involves the addition of some external source of pressure to move the oil from the reservoir to the well.

Primary Production - Artificial Lift

Regardless of the type of well, the pressure exerted by the propelling mechanism will eventually fall off to the point where it must have some artificial means of moving the oil to the surface. Such means are known as artificial lift.

The two most prevalent types of artificial lift are gas injection and mechanical pumping. While gas injection can be classified as a type of artificial lift, it is usually used as a means of secondary recovery. Because of this, a complete discussion of it will not be developed until the discussion of secondary recovery methods.

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[22] Ibid.

[23] C. H. Riggs, et. al., The Effect of Improved Oil Recovery Technology in Oklahoma, Petroleum Experiment Station, Bureau of Mines, (Bartlesville, Oklahoma, 1958), p. 44.

The most prevalent type of artificial lift, especially in Oklahoma, is the mechanical pump. The most popular type pump in Oklahoma is the rod-activated displacement pump.[24] This type pump is especially well suited for the shallow wells in Oklahoma, especially the old stripper wells.[25]

The principle behind this pump is the same as that of any ordinary suction pump. The pump is placed in the bottom of the well and is connected to the motor, usually electric of gasoline, by sucker rods. The pump piston is lowered to the bottom of the pump cylinder and then is pulled up rapidly by means of the sucker rods. This action creates a partial vacuum in the well, thus making the difference in the pressure in the well and the reservoir great enough to move the oil to the surface.[26]

A pump of this type is illustrated in Diagram 2.3.

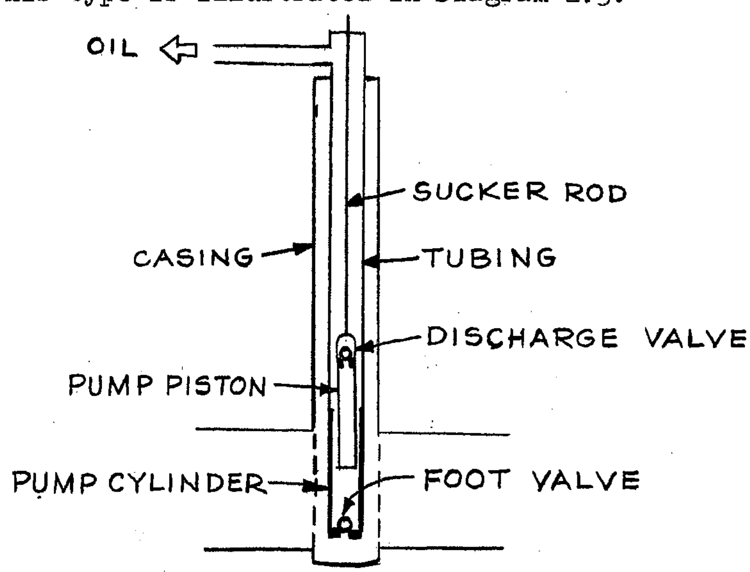

Diagram 2.3. Rod Activated Displacement Pump.[27]

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[24]Frank J. Morgeson, op. cit., p. 60.

[25]Interview with Ernest C. Fitch, op. cit.

[26]Frank J. Morgeson, op. cit. pp. 60-62.

[27]Ibid., p. 63.

Secondary Recovery

In all wells the time comes when they no longer have the pressure necessary to move the oil from the reservoir to the well. When this happens some artificial means must be devised to move the oil from the reservoir to the well. This is known as secondary recovery. In the United States this consists almost entirely of either gas injection or waterflood.

Gas Injection - In this method of secondary recovery natural gas, air, or some other gas is pumped back into the oil reservoir to propel the oil through the ground toward the well. To accomplish this an injection well is drilled, and gas is pumped through it back into the reservoir. When the gas enters the reservoir it starts to expand. This expansion of gas, as was the case with natural gas drive, is the propelling mechanism for moving the oil.[28] A gas injection system is depicted in Diagram 2.4 on the following page.[29]

The gas used in this method varies. The best is natural gas. When natural gas is used it not only forms the propelling mechanism for moving the oil, but it mixes with the oil in an emulsion and decreases the oil's viscosity, making it easier to move.[30] If any other gas is used it can only act to move the oil and cannot mix with the oil to decrease its viscosity. When natural gas is not cheaply available, air is usually the best substitute.

In many cases the quantity of gas produced along with the oil is so great that there is no market for it. Usually when this happens the gas

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[28] W. Fred Heister, op. cit., pp. 28-38.

[29] Ibid., p. 35.

[30] V. A. Kalichevsky, op. cit., p. 22.

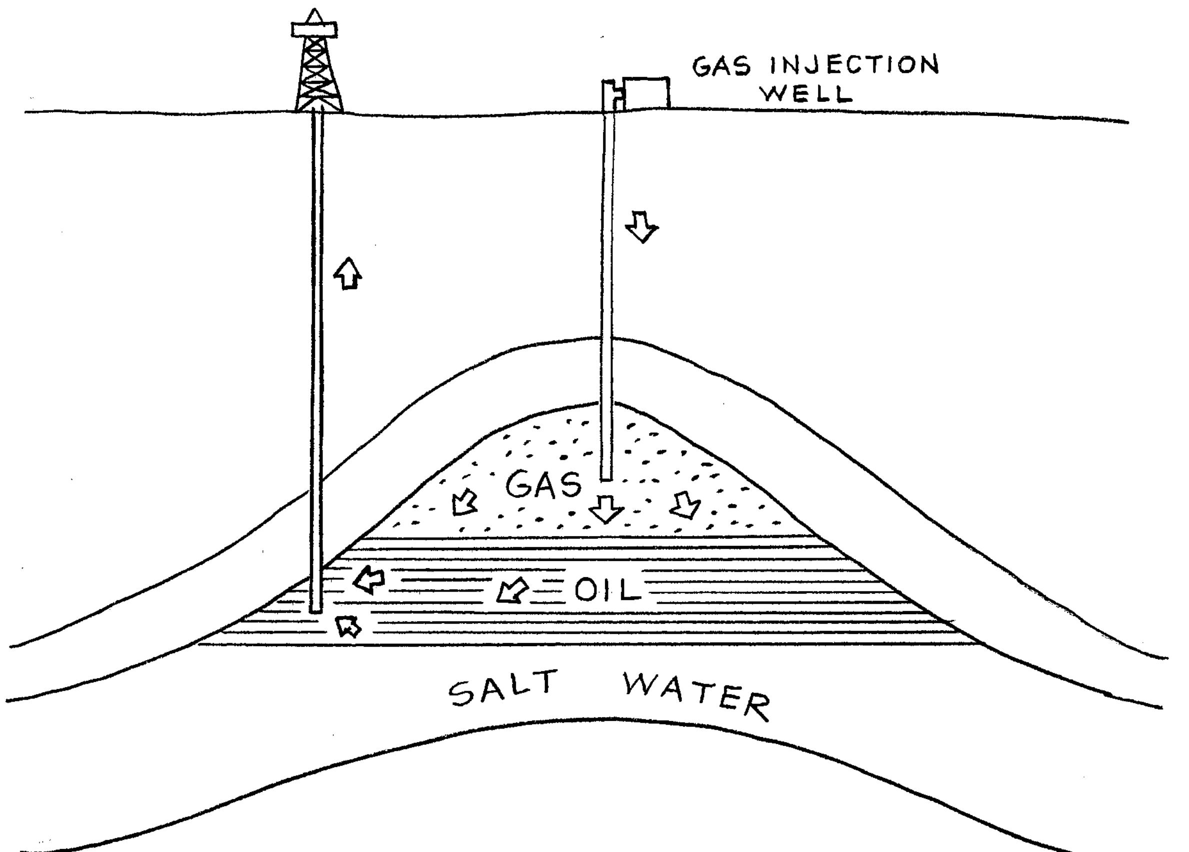

Diagram 2.4. Gas Injection System.

is returned to the reservoir.[31] This prolongs the life of the well and lengthens the time that the well can continue to produce without any noticeable decline in the rate of production. This also prolongs the time before a mechanical pump must be installed to raise the oil to the surface. In this case this could legitimately be classified as artificial lift. To be classified as secondary recovery the pressure of the well must have declined to the point where only small quantities are reaching the well.

One of the main problems with gas injection is that it is not applicable to low rates of production.[32] It takes a tremendous capital outlay to install a gas injection system. If the well is not capable of producing at high levels of production the cost per barrel of oil produced will be so great as to make it uneconomical to operate. This would exclude all the stripper wells that are now still on primary recovery. The system, to be profitable, must be installed early in the life of the well.

Another disadvantage of gas injection is that it increases the problem of water disposal. Not only is more water moved in the process of production, but water-oil emulsions are formed that are extremely hard to break.[33]

Waterflood - Waterflood is by far the most prevalent type of secondary recovery used in Oklahoma. It is used more than all other methods combined.[34] One reason for this is that it provides a means of controlling water

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[31]Robb Graham, "Repressuring with Gas and Water", Petroleum Monthly, Vol. 23, (May, 1959), pp. 30-32.

[32]Max W. Ball, op. cit., p. 161.

[33]W. Fred Heister, op. cit., pp. 37-38.

[34]Interview with Jerry Champlin, Petroleum Engineer, U. S. Bureau of Mines, (Bartlesville, Oklahoma, March 2, 1963).

pollution. In fact, that is how waterflooding was first developed. The first time it was used in this area was in east Texas. A field had a water pollution problem, and disposal wells were drilled and the water was pumped back into the reservoir. After this was done, an increase in oil was noticed.[35] Usually, however, disposal wells must be drilled below the oil formation in order to dispose of the salt water.

The propelling force in a waterflood is the same as that in natural water drive. The difference is that in water drive the pressure is hydrostatic pressure. In waterflood the pressure comes from water being forced into the reservoir through an injection well. This is depicted in Diagram 2.5. As the water enters through the injection well it puts pressure on the oil. The oil then starts moving toward the point of

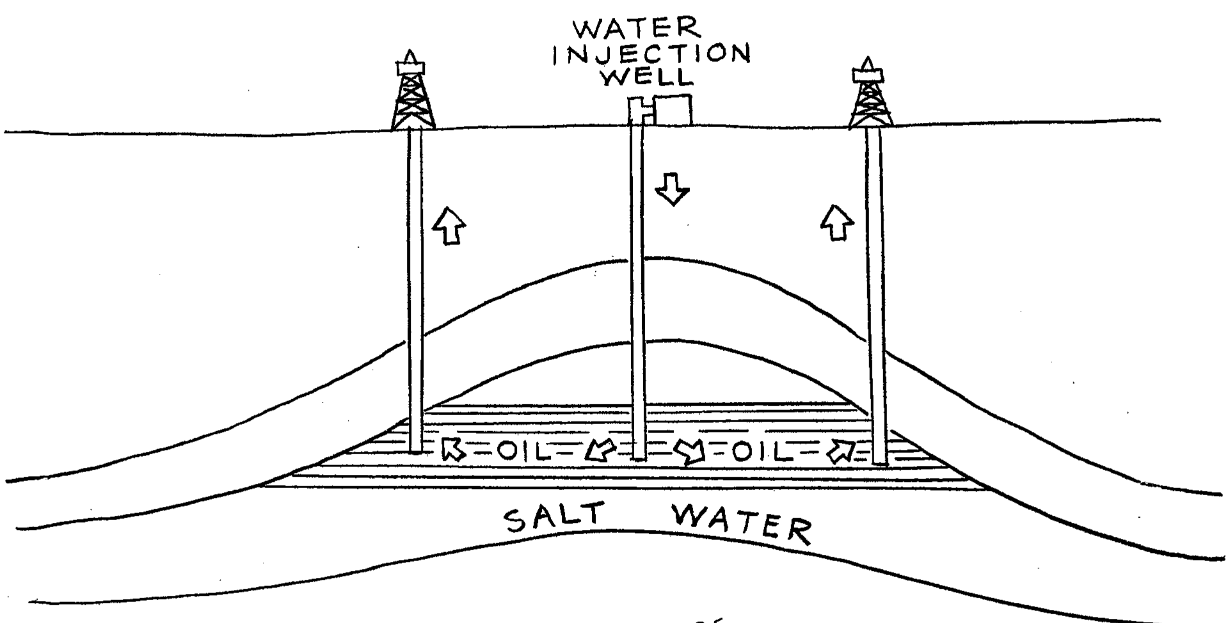

Diagram 2.5. A Water Injection System.[36]

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[35]Robb Graham, *op. cit.*, p. 35.

[36]*Ibid.*

lowest pressure which is the producing well. A major problem in waterflooding is the large initial cost of installing the system.[37] If it were not for this, waterflooding would be an ideal way to control the problem of water pollution from stripper wells. However, the production from these stripper wells is so low that the cost per barrel would make it unprofitable.[38]

Another trouble with waterflood, especially in the past, is that it might reduce the total amount of oil that can be produced from a well.[39] If the system is not installed properly, there is a danger of getting a layer of water above the oil reservoir. When this happens, the producing well will get nothing but water, and much oil is lost. This problem is not so pressing today because of progress in waterflooding technology.

Summary

It has been shown that regardless of the type of well, the rate of production will decline as the well ages. In some cases the decline is more rapid than others, but the output will decline for all wells. There are means of combating this decline, such as artificial lift or secondary recovery, but even with these a point will eventually be reached when the well becomes a stripper well.

At the same time that the output of the well declines the production of water increases. In some wells the production of water becomes critical at an early stage. When this is the case the problem of

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37Kenneth H. Johnston and Joe L. Castagno, Development in Waterflooding and Pressure Maintenance in Osage County, Oklahoma Outfield (1961), U.S. Department of Interior, Bureau of Mines Information Circular 8038, p. 19.

38Interview with Kenneth H. Johnston, op. cit.

39Interview with Jerry Champlin, op. cit.

salt water disposal can be overcome because the profit from a well of this type is great enough to warrant the expenses of an adequate disposal system.

If the well becomes part of a waterflood project, the problem of water pollution will also be solved. In this case the water produced with the oil, along with water from some other source, is returned to the reservoir to aid in moving the remaining oil to the well.

In many cases neither of these possibilities occurs. The problem of excess water does not become critical until late in the life of a well. When this happens, the profits do not exist from which to drill the necessary disposal wells, due to the limited production the well is capable of producing.

Effects of Water Pollution

When the problem of excess water develops, the question of what to do with the water becomes significant. In some states, for example Illinois, where the annual rainfall is fairly heavy it is possible to merely dump the salt water in the streams.[40] Because there is enough rainfall, the streams receive a continuous supply of fresh water and they never become so polluted as to make the water harmful. Dumping the polluted water in the streams in Oklahoma is not permissible because of the scarce rainfall.[41] This is especially true in the summer months. When

[40] Sam S. Taylor et. al., Study of Brine-Disposal Systems in Illinois Oil Fields, Report of Investigation 3534, Department of the Interior, Bureau of Mines, (1940), p. 3.

[41] Ludwig Schmidt and John M. Devine, The Disposal of Oil Field Brines, Report of Investigations, Department of Commerce, Bureau of Mines, 1929, p. 14. While much of the following analysis comes from this source the conclusions reached were verified by the author in a personal interview with Dr. William H. Irwin, Professor of Zoology, Oklahoma State University.

dumping has been used in the past, several undesirable effects have been noted.

Effect on Vegetation

Most plants cannot live in water where the salt content is above 1.5 percent or 15,000 ppm (parts per million).[42] From Table 2.1, it can be seen that the salt content of the produced water is considerably higher than this. If plants come in contact with this water most of them will be killed.

Effects on Soil

The effect of the polluted water on the soil in most cases is not permanent. In a number of places the abandoned oil leases are now under cultivation with no apparent detrimental effects to the portion of the property that was previously overflowed by salt water.[43] The polluted water will, however, for a short period of time make farming impossible in such an area, and this is an important short run problem. How long this problem will last cannot be determined exactly. It depends primarily on the amount of rainfall received.

Effects of Fish Life

No general statement can be made regarding the maximum concentration of salts in which fish can survive. Besides the species of fish, other important variables are the amount of hydrogen in concentration and the oxygen content of the water.[44]

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[42] Ibid., p. 3-4.

[43] Ibid., p. 4.

[44] Ibid., pp. 5-6.

Table 2.1. Analyses of Water Samples Obtained from Selected Representative Producing Areas in Oklahoma.[45]

Radical	Sample 1 ppm	Sample 2 ppm	Sample 3 ppm	Sample 4 ppm	Sample 5 ppm
Calcium	10,753	5,530	4,708	12,822	1,254
Magnesium	2,691	1,625	1,939	2,748	396
Sodium	76,915	36,914	34,058	75,400	12,229
Carbonate	--	--	--	--	--
Bicarbonate	31	177	--	92	119
Sulphate	348	2	44	184	8
Chloride	145,244	71,361	66,486	146,804	22,161
Total Solids	235,982	115,609	107,235	238,045	36,167
Specific Gravity at 60° F.	1.162	1.081	1.076	1.162	1.026

[45] *Ibid.*, p. 3.

One undesirable effect of salt water is that fish seem to migrate from slightly saline streams to fresh water. This would result in a scarcity of fish in the streams contaminated by oil produced water.[46]

Effects on Livestock

While horses have been found to live on water containing 7,860 ppm total solids, in some cases death has occurred where as little as 1,060 ppm total solids appeared in the water. In these cases the death was caused by a high content of sulphate (490 ppm) together with sodium and magnesium.[47]

The following excerpt from the late Senator Robert S. Kerr's book Land, Wood and Water, shows that polluted water from oil wells can have a detrimental effect on livestock.

> Others are being hurt and are joining the battle...farmers whose livestock have died from polluted water.
>
> One of the latter, his land spoiled and his cattle killed by brines pumped up from oil wells in Louisiana, told a Public Health Service hearing the tragic story of his ninety acres.
>
> "We used it mostly as a dairy farm," he said. "We had a lot of other land rented that we also used, and in 1952 pollution hit us. We felt it a little. In 1953, it almost got us, and in 1954 it completely got us."
>
> "What happened?" he was asked.
>
> The farmer replied glumly. "We quit."
>
> "How many head of cattle did you have?"
>
> "We had a hundred and thirty or forty head."
>
> "What did you do with them?"
>
> "We lost ninety-five of them; they died."[48]

Effects on Surface Water Supply

Diagram 2.6 shows the water resources in Oklahoma.[49] From the

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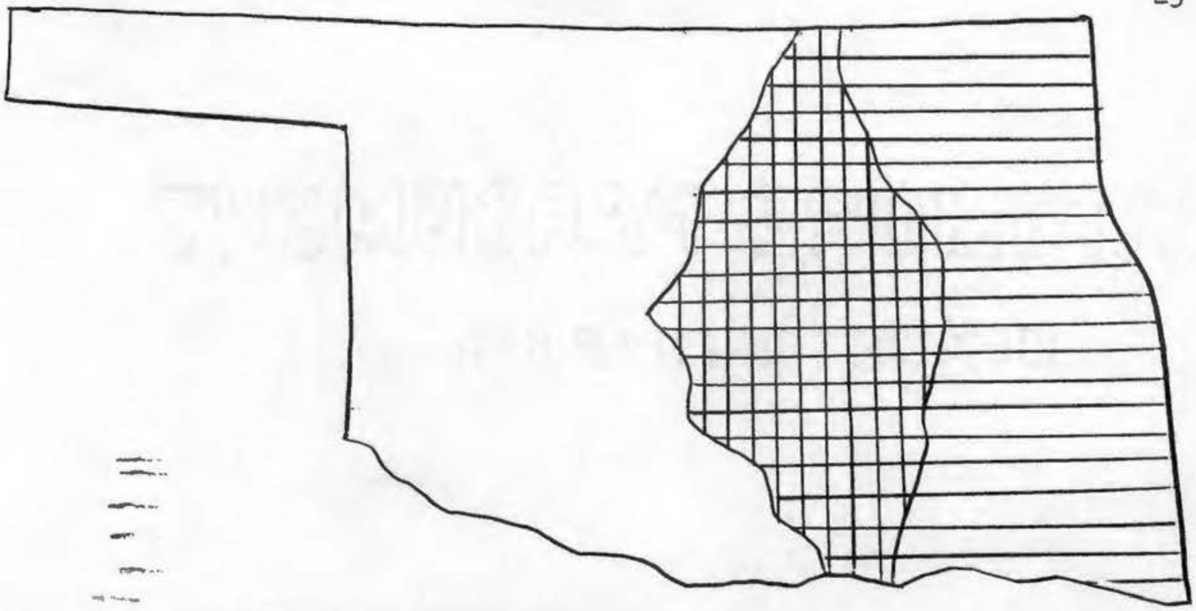
[46] Ibid.

[47] Ibid.

[48] Robert S. Kerr, Land, Wood and Water, MacFadden-Bartell Corporation, (New York, 1963), p. 143.

[49] Allen V. Kneese, Water Resources..Development and Use, Federal Reserve Bank of Kansas City, (1959), p. 3.



little or no water surplus in any season

summer deficiency and winter surplus

little or no water deficiency in any season

diagram it can be seen that in most of Oklahoma water is in short supply during the summer months and in many areas during the whole year. When a stream becomes polluted, the water it contains must be subtracted from the water available for use.[50] Since Oklahoma does not have a surplus of water by any means, it would seem desirable to preserve, as much as possible, the water resources that do exist.

Effects on Tourist Travel

While pollution coming from stripper wells may not in all cases cause contamination of the existing water resources to the extent that

[50]Interview with Dr. William H. Irwin, Professor of Zoology, Oklahoma State University, (May 13, 1963). (One possible source of information on the subject of water disposal is the 1957 Inventory Municipal and Industrial Waste Facilities published by the Department of Health, Education and Welfare. This was not appropriate for this thesis because it did not distinguish between disposal systems and waterflood projects.)

it becomes unfit for use, it does, in almost all cases, give the stream an unsightly appearance.[51] If the pollution continues it is only a matter of time until the lakes will become unsitely. If this occurs Oklahoma will have lost its major attraction to tourists. The effect of a decline in the number of tourists that visit Oklahoma lakes cannot be overlooked. In 1961 more people visited Lake Texoma (6.5 million) than any other government recreation area in the United States.[52] These 6.5 million people spent many millions of dollars in Oklahoma, that would surely be missed if it were to stop.

Effect on the Attraction of Industry

Though few people realize it, modern industry requires a tremendous amount of water. "For example, a five pound Sunday newspaper requires about 1,250 pounds of water in its manufacture and each pound of rayon fiber requires about 2,000 pounds of this resource."[53] From this it can be seen that water is a resource that must be possessed by a state if it is to be successful in attracting industry. Since Oklahoma is already short of water in many areas, this would seem to be another reason for trying to conserve the available water resources.

There is another way pollution might effect the attraction of new industry. Mention has already been made of the attraction for tourists the lakes in Oklahoma possess. It is possible that the lakes could be a factor considered by businesses that are considering locating in

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[51]Ibid.

[52]Robert S. Kerr, op. cit., p. 96. In 1957 it was estimated by the Department of Commerce and Industry that $66.5 million was spent on recreation in Oklahoma.

[53]Allen V. Kneese, op. cit., p. v.

Oklahoma. In fact, this was definitely the case when Goodyear decided to locate a new plant in Miami, Oklahoma.[54] Since the future development of Oklahoma is dependent upon the ability to attract new industry, this would seem to be another impelling reason to try to protect the water resources against pollution from stripper well oil production.

Importance of Stripper Well Production in Oklahoma

As was stated previously, 60 percent of the oil production in Oklahoma comes from stripper wells. This fact alone should indicate its importance in Oklahoma. To get a better idea of the role of the stripper well it will be necessary to look in more detail at the tendencies of oil production in Oklahoma. This will include, (1) The number of stripper wells, (2) Acreage involved in stripper well production, (3) Production from stripper wells, (4) Stripper well production as a percent of the state total.

Number of Stripper Wells

A stripper well is defined as one that produces a maximum of 10 barrels of oil per day. Diagram 2.6 shows the number of stripper wells for each year from 1950 to 1961, and the estimated number of wells to 1969. This shows that the number of stripper wells has been steadily increasing and by 1970 will probably number over 70,000. At first glance this finding would seem to be of major importance. In some regards this is true. This thesis is dealing with the problem of water pollution. If the number of stripper wells has been increasing, the number of wells causing water pollution has also increased. The major importance of

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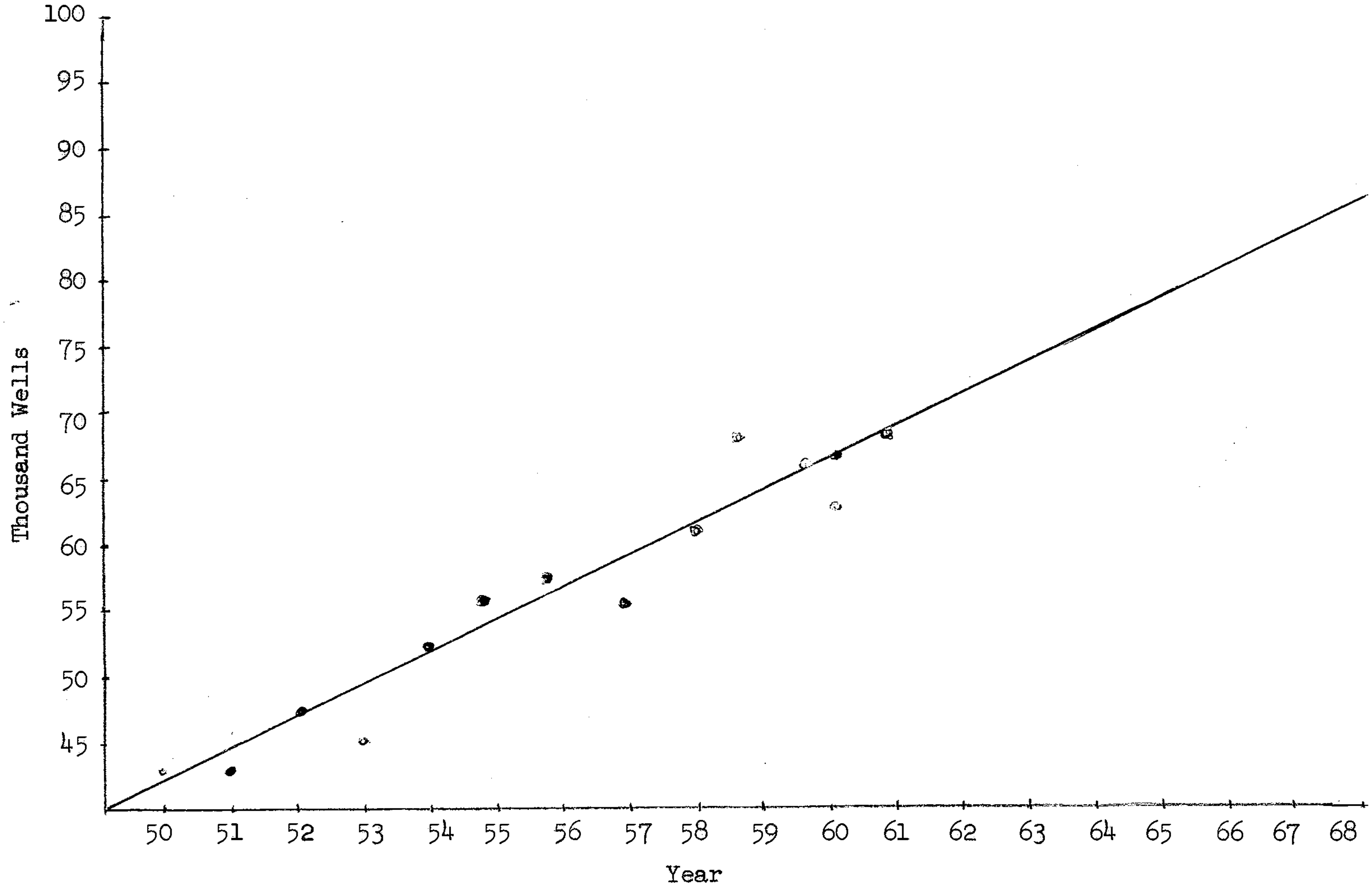
[54]Interview with Dr. William H. Irwin, *op. cit.*

Diagram 2.7. Number of Stripper Wells, 1950-1961.[55]



[55]National Stripper Well Survey, Interstate Oil Compact, (1949-1960). Note that almost all of the data comes from this source. Other sources such as Minerals Yearbook do not distinguish between oil production coming from stripper and nonstripper wells.

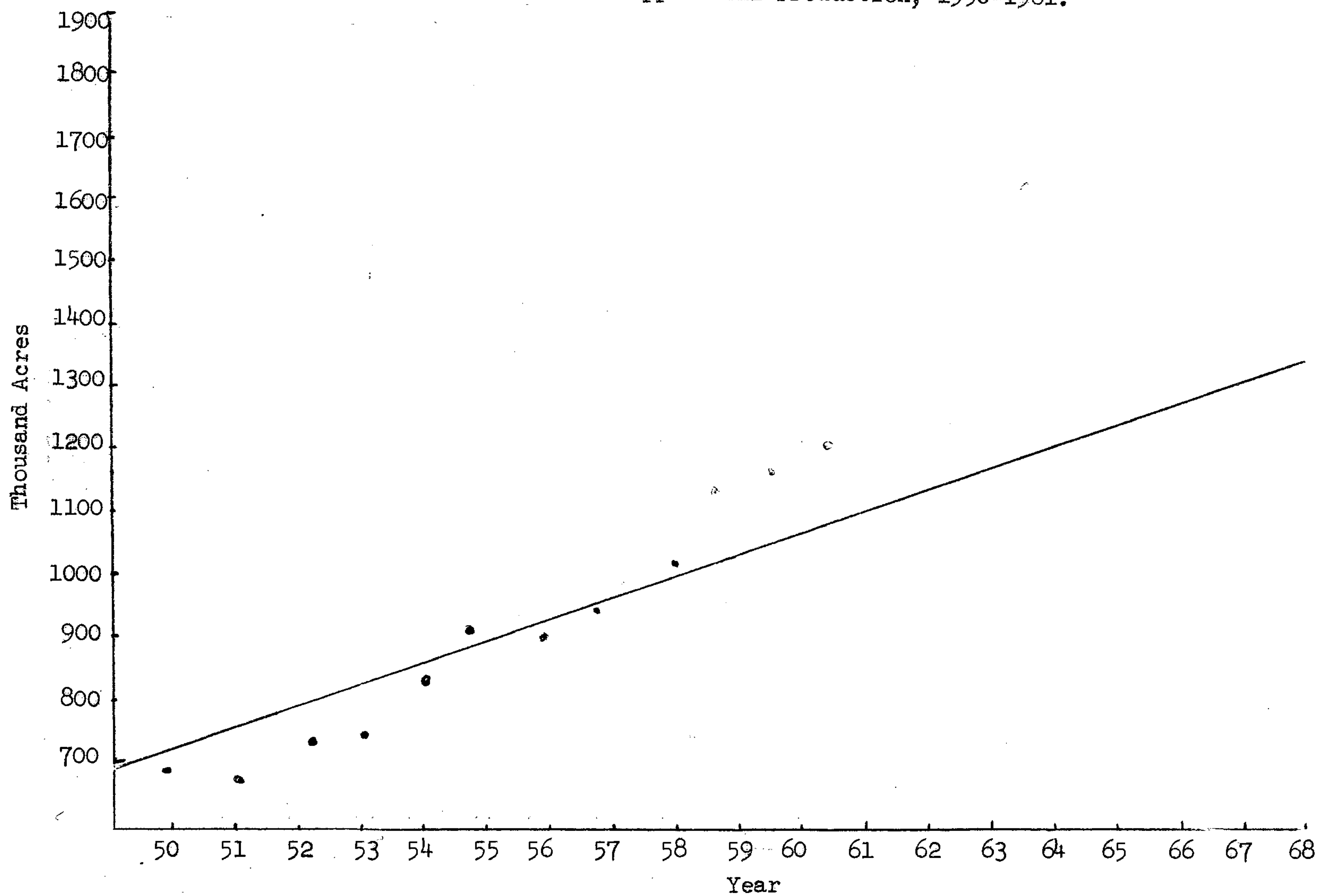
this fact would be to increase the cost of establishing a disposal system capable of handling the water produced. If the number of wells polluting water has increased, the number of needed disposal wells will have increased.

From another point of view, however, the fact that the number of stripper wells has been increasing is not by itself significant. For instance if the problem is to measure the economic significance of the stripper well, then the number of stripper wells is not very helpful. It might be possible that while the number of stripper wells has increased over the years the total production from these stripper wells has remained constant, or it might have even decreased. Because of this possibility it will be necessary to look at other indicators to see how the economic significance of stripper well production has changed through the years.

Number of Acres Involved in Stripper Well Production - As can be seen from Diagram 2.7, the number of acres involved in stripper well production has increased since 1949. As was the case with the number of stripper wells, a linear regression line has been fitted to the data. While this line does not fit the data as well as it did in the case of the number of wells, it would seem to be adequate for the purposes of this thesis. From looking at the graph it can be seen that the regression line underestimates the number of acres involved in the last few years in stripper well production. This is in keeping with the analysis in the rest of the thesis. Where it is impossible to get a completely accurate estimate, this thesis has taken the most conservative estimate available. By 1970 more than 14,000 acres will be involved in stripper well production.

What, then, is the importance of these figures? In dealing with water pollution, it is extremely difficult to get an overall single value

Diagram 2.8. Acres Involved in Stripper Well Production, 1950-1961.[56]



[56] *Ibid.*

estimate of either the extent or the importance of it. In working with this problem, the number of acres involved in stripper well production must be of some importance. If the stripper wells are a cause of water pollution, then as the number of acres involved in stripper well production increases, the number of streams and other water resources in danger of being polluted must increase.

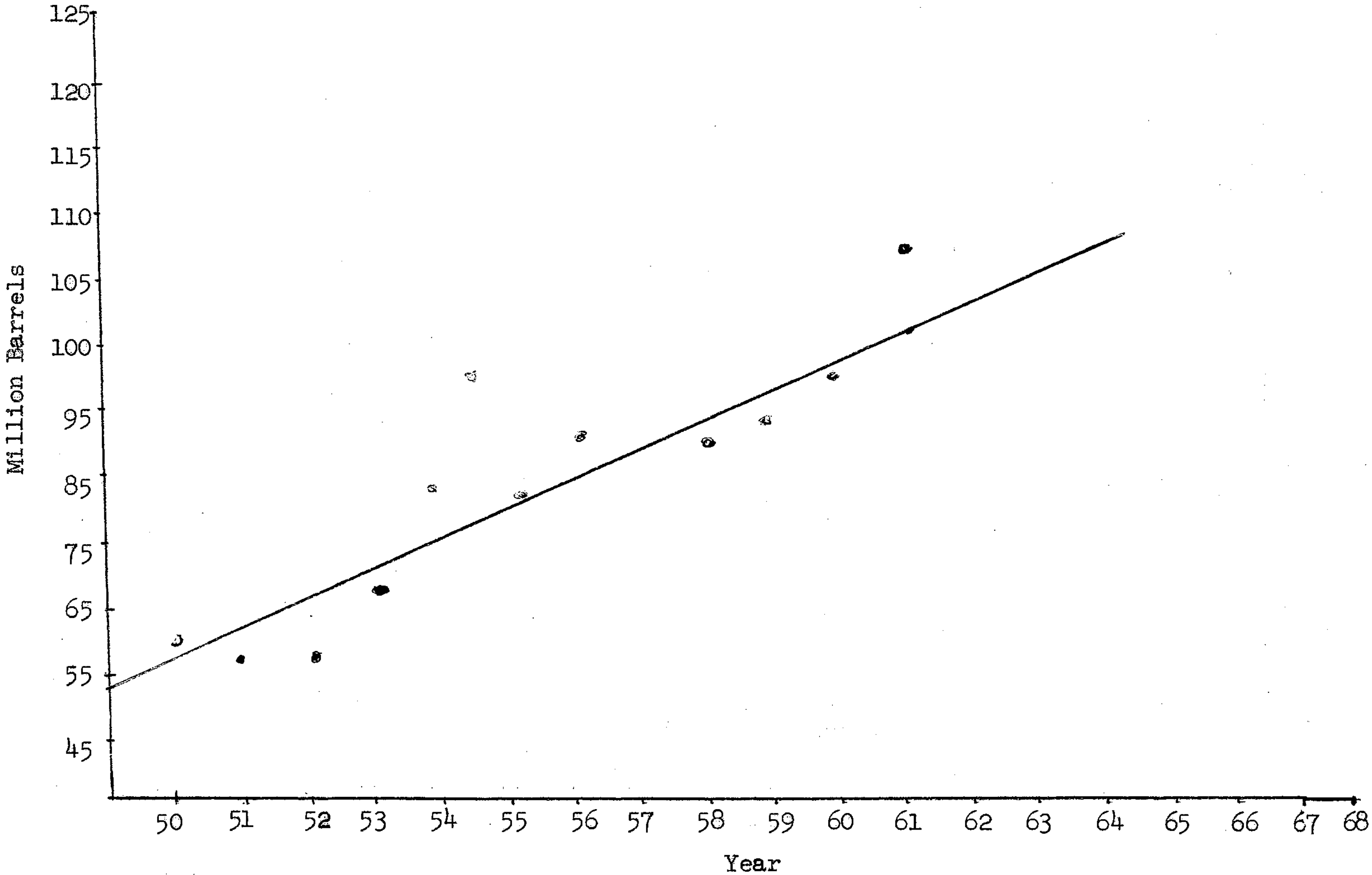
Production from Stripper Wells - A good indicator of the economic importance of stripper well production is the number of barrels of oil obtained from such wells. Diagram 2.8 shows stripper well production by years and a regression line has been fitted to the data. This graph shows that while production varies from year to year, the long run trend has been increasing. By 1970 stripper wells will probably produce over 130,000 barrels of oil.

When the value of crude oil is known for each year, it is fairly easy to change production data to value of crude oil produced. This has been done in Table 2.2. From the table it can be seen that the dollar value of the crude oil produced in Oklahoma has been increasing since 1948.

These figures are not sufficient as an indicator of the economic importance of the stripper well. It is possible that while the production from stripper wells has been increasing, the total state production has been increasing at a faster rate. This would mean that the relative importance of the stripper well has been decreasing.

Stripper Well Production as a Percent of State Total - Diagram 2.9 shows this figure for the last few years and a linear regression line has been fitted to the data. This graph shows that the percentage has

Diagram 2.9. Stripper Well Production, 1949-1962.[57]



[57]*Ibid.*

Table 2.2. Value Added By Stripper Well Production By Year.

Year	Production from Stripper Wells	Average Price of Crude Oil[58]	Value of Crude Oil Produced
1948	380,000	$2.58	110,580.00
1949	44,182,000	$2.56	128,569,620.00
1950	46,981,370	$2.57	136,715,786.70
1953	60,359,467	$2.70	175,646,048.97
1954	83,726,134	$2.79	243,643,049.94
1955	98,563,034	$2.78	286,818,428.94
1956	82,168,579	$2.78	239,110,564.89
1957	92,102,000	$3.03	268,016,820.00
1958	86,273,000	$2.96	251,054,430.00
1959	91,328,678	$2.92	265,766,452.98
1960	95,054,237	$2.92	276,607,829.67
1961	116,058,084	$2.91	337,729,024.44

[58]Minerals Yearbook, Vol. II Fuels, U. S. Department of Interior, Bureau of Mines, (1948-1961).

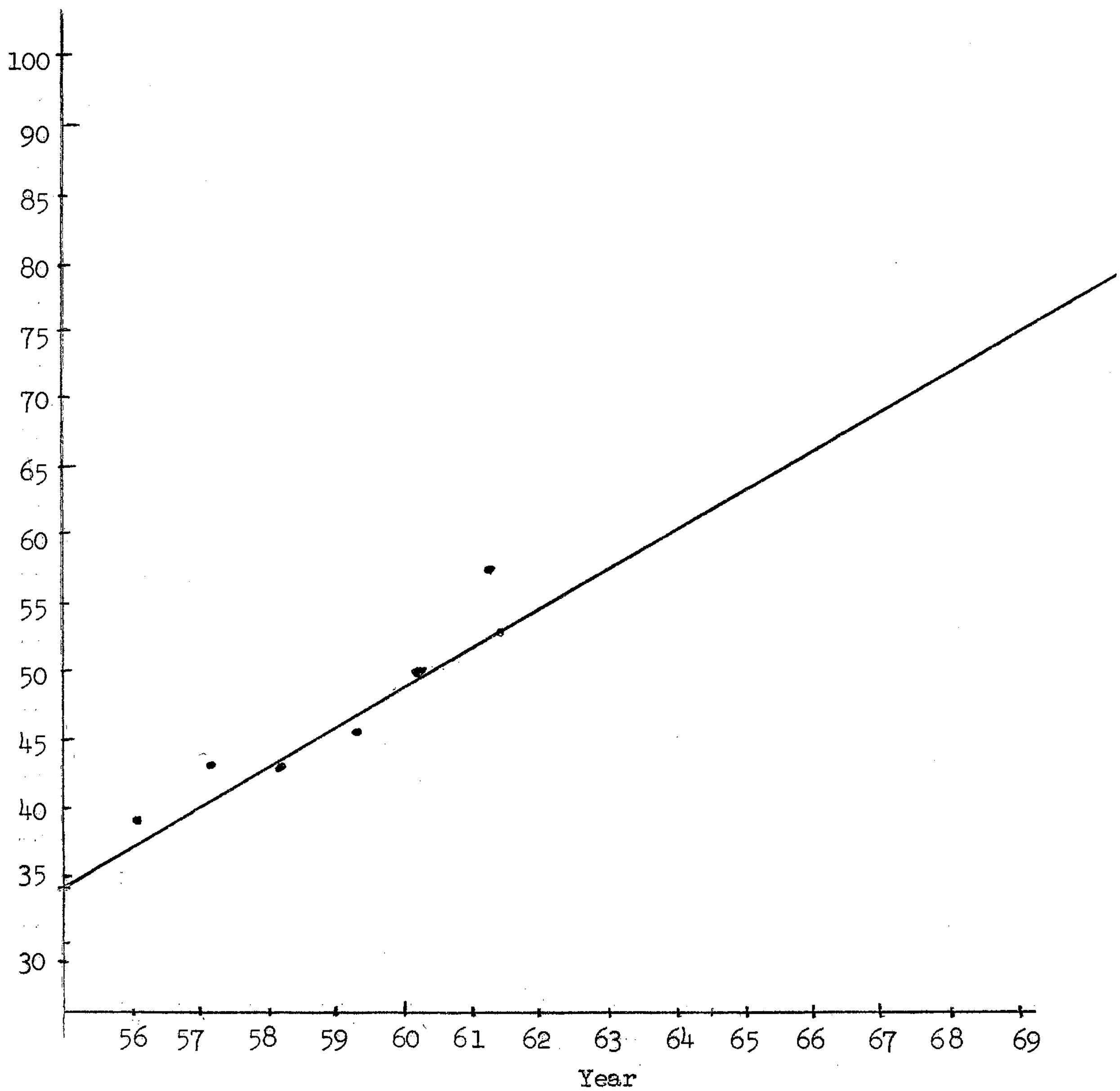
been increasing. By 1965, if the trend continues, stripper well production as a percentage of the state total will probably be over 70 percent.

Summary

A summary of the important statistics might be well at this point. By bringing them together it is possible to see the tremendous importance of stripper well production.

1. The number of stripper wells has been increasing. This means that the cost of drilling the necessary disposal wells has been increasing.

Diagram 2.10. Stripper Well Production as a Percentage of Total Production.[59]



[59] National Stripper Well Survey, op. cit.

2. The number of acres involved in stripper well production is increasing. This means that more and more water resources are in danger of being polluted, as water pollution covers a wider area.

3. The economic importance of stripper well output has been increasing both absolutely and relatively.

Table 2.3 bring these statistics together. It would seem that the problem of water pollution stemming from stripper well production has come to be a big problem.

Table 2.3. Importance of Stripper Well Production to Oklahoma.

Year[60]	Number of Stripper Wells	Production from Stripper Wells in Barrels	Total Production	Stripper Production Percent of Total	Acres in Stripper Wells	Abandonment (No. of Wells)
1961	68,740	116,058,085	191,851,000	60	1,212,700	2,546
1960	65,688	95,054,237	189,654,000	50	1,168,484	2,384
1959	68,836	91,328,678	196,480,000	46	1,142,194	1,331
1958	62,905	86,273,000	202,699,000	43	1,012,363	476
1957	50,093	92,102,000	213,685,000	43	950,300	831
1956	58,136	82,168,579	211,137,000	39	903,275	743
1955	56,797	98,563,034	201,739,000	49	909,480	1,050
1954	54,200	83,726,134	183,614,000	46	841,560	832
1953	47,724	60,359,467	Not Available	--	745,788	1,073
1950	42,810	46,981,370	Not Available	--	695,535	1,009
1949	43,602	44,182,000	Not Available	--	260,000	1,041
1948	43,425	380,000	Not Available	--	260,000	1,406

[60]See National Stripper Well Survey, Interstate Oil Compact Commission, Oklahoma City, for each year listed in the Table

CHAPTER III

WHAT IS CURRENTLY BEING DONE ABOUT THE PROBLEM

Chapter II showed how the problem of water pollution develops. The purpose of this chapter is to see what is currently being done to combat water pollution. The first line of defense against water pollution is the rules and regulations as set forth by the Corporation Commission. When these rules fail to prevent water pollution, the person damaged may sue for damages through private litigation.

Rules and Regulations by the Corporation Commission

The rules and regulations set forth by the Corporation Commission to combat water pollution are aimed at forcing the well operators to prevent their own water pollution. The rules are established by the Corporation Commission under the authority granted it by the state statutes.[61]

The Corporation Commission is given explicit authority to control pollution in Title 32.

> The Corporation Commission of Oklahoma....is hereby vested with jurisdiction power and authority and it shall be its duty to make and enforce such rules, regulations and orders governing and regulating the handling, storage, and disposition of salt water, mineral brines, waste oil, and other deleterious substances produced from or obtained or used in connection with the drilling, development, producing, refining and processing of oil and gas products

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[61] Oklahoma Statutes, Vol. 1, p. 1130, Sec. 52, (1961).

> within the State of Oklahoma or operation of oil or gas wells in this state as are reasonable and necessary for the purpose of preventing the pollution of surface and subsurface waters in the State, and to otherwise carry out the purpose of this act.[62]

The Corporation Commission has established a number of rules and regulations. These rules may be classified under six headings: (1) Administration, (2) Operation, (3) Underground disposal, (4) Inspection, (5) Protection of water supply, and (6) Prevention of water pollution.

Administration[63]

In Rule 802, pollution of fresh water is prohibited. The rule then goes on to state that the Corporation Commission is given the responsibility of preventing water pollution. Two other state agencies, the Planning and Resources Board and the State Game and Fish Department, assist the Commission by handling complaints and forwarding them to the Commission. Once the Corporation Commission receives a complaint, action must be taken within ten days. The Director of Water Pollution is the appointed head to coordinate all the Corporation Commission's activity on water pollution.

Operation[64]

All owners of producing wells are made responsible for constructing and maintaining their equipment so as to prevent water pollution. This

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[62]Oklahoma Statutes, Vol. 2, p. 378, Sec. 139, (1961).

[63]Fifty-fourth Annual Report of the Corporation Commission of the State of Oklahoma (1961), pp. 374-375, Rule 803 and 803.

[64]Ibid., pp. 375-376, Rule 804-813.

includes equipment such as storage tanks and pits, flow strings, waterflood equipment, disposal well equipment, etc. If the operator engages in any activity that might cause water pollution, such as acidizing or waterflooding, he must take special care to prevent water pollution.

Underground Disposal[65]

If the well operator wishes to dispose of salt water by the use of disposal wells he must first make application to the Corporation Commission. If the operator plans to use an old well for a disposal well he must first run a pressure test on the casing (the outer pipe in the well). If it proves defective he must replace it before he commences operation.

Inspection[66]

The Director of Conservation and the Director of the Pollution Control Division have the right to make an inspection of any disposal well and equipment used in oil production at any time. If it is found that the operator has not complied with the rules, or is the cause of water pollution, the wells will be shut down. The shutdown will last until all needed corrective action is taken.

Protection of Water Supply[67]

Any Oklahoma municipality has the right to file with the Commission an application to protect its fresh water supply. The Commission must take all steps necessary to protect the city's water supply.

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[65] *Ibid.*, p. 376, Rule 813 part B & C.

[66] *Ibid.*, p. 379, Rule 817.

[67] *Ibid.*, p. 378, Rule 816.

Prevention of Water Pollution

There are no laws to control water pollution before it occurs. If the small stripper well operator is capable of making a satisfactory profit with his limited production, then the owners of the better-than-marginal wells must be making some profit. Ideally, some of this profit should be used to drill salt water disposal wells, or to provide some other means of controlling water pollution, so that when such a well is faced with a water pollution problem it will have the means to combat it. If this action had been taken when the present-day wells were first brought in, the problem of water pollution would not have arisen.

We see that this is not what has happened. The rules do not exist to force an owner of a highly productive well to drill a disposal well that he will not use immediately. Consequently, in the past operators have disregarded water pollution until it became a problem. They did not drill disposal wells until they were needed. But when disposal wells were needed, the operator did not have the profit with which to drill them, because the well's output had declined to the point where it was a stripper well. The present-day producers show every sign of following the same pattern. Since there are no rules to prevent this from happening, and since stripper well production as a percentage of total production is increasing, the problem will become more acute in the future.

Private Litigation

One reason that private litigation must be resorted to is that there are no rules and regulations to control water pollution before it occurs. This, however, cannot be the complete answer. Though the action can be taken only *ex post*, it could conceivably be taken quickly enough to prevent pollution if there were thorough enforcement. Given the present limited staff and facilities of the Corporation Commission, enforcement of the rules is impossible. Instead of being able to make continuous inspection of each well, the Commission has just enough men to handle the complaints as they come in. Therefore, water pollution goes on unnoticed by the Corporation Commission unless a complaint is sent to it or a case goes to court.

A large number of cases that could be cited to show that private litigation has been used.[68] A typical example of such litigation is found in *Gulf Oil Corporation* v. *Hughes*.[69] In this case Hughes owned an improved tract of land valued at $18,950. Gulf Oil Corporation was involved in a waterflooding project adjacent to the land owned by Hughes. Subsequently, the water on Hughes' land became polluted, thus causing the value of the land to drop from the original value to $9,000 or by a total of $9,950. Hughes alleged that the waterflooding carried on by Gulf caused the pollution and sued Gulf for $9,950, the amount the value of the land decreased. In the lower court the judgement was in favor of Hughes, and the damage was set at $6,000.

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[68] *Cities Service Oil Company* v. *Merril*, 332 P_2d 677 (1959).
Darly Petroleum Corporation v. *Mason*, 176 Okla. 138, 54 P_2d 1046 (1936).
Harper-Turner Oil Company v. *Bridge*, 311 P_2d 947 (1957).
Pure Oil Co. v. *Chiselholm*, 181 Okla. 618, 75 P_2d 467 (1937).
British-American Oil Producing Co. v. *McClain*, 191 Okla. 40, 126 P_2d 530 (1942).
Humphrey Oil Corporation v. *Roy Lindsey*, 370 P_2d 296 (1961).
Rudco Oil and Gas Co. v. *Lafland*, 192 Okla. 256, 135 P_2d 494 (1943).
Sunray Mid-Continent Oil Co. v. *J. L. Tisdale*, 366 P_2d 614 (1961).
Commercial Drilling Co. v. Kennedy, 172 Okla. 475, 45 P_2d 614 (1961).

[69] *Gulf Oil Corporation* v. *Hughes*, 371 P_2d 81 (1962).

Gulf appealed the decision stating that (1) Hughes failed to show that Gulf had been negligent in its operation, and (2) the damage to Hughes' property was not permanent and that by drilling the water well 100 feet deeper, a fresh water strata could be found.

The State Supreme Court held that negligence did not have to be proved by Hughes. As for the second contention by Gulf that unpolluted water could be found 100 feet deeper than the present well, the Court held that this was a statement of probability and not of fact. The judgement for Hughes was affirmed.

Summary

This chapter has shown that there are three important defects in the present laws governing water pollution:

1. The law is remedial rather than preventative and thus has its primary impact after water pollution arises.

2. Given the present enforcement staff of the Corporation Commission, it is impossible to enforce the law.

3. Private litigation cannot do the job because damages must occur first and there is the chance that the damaged person will never bring the case to court because of the lack of legal fees or the chance of losing the case. In addition the damaged caused may be unreparable.

CHAPTER IV

A PROPOSED SOLUTION

This chapter will test the economic feasibility of the state government installing the needed disposal systems. To reach a tentative answer to this question it will be assumed that all stripper wells are guilty of water pollution and that all of these wells would shut down if forced to drill their own disposal systems. The question then boils down to a comparison of the tax revenue that could be expected from the stripper wells if they continued their operation with the cost of drilling disposal systems.

Before the economic consequences of shutting down the stripper wells can be estimated, the expected future production from the stripper wells in existence today must be estimated. After this has been done it will be possible to estimate state tax revenues lost because of shutting down the stripper wells. A comparison of these hypothetical tax revenue losses with the cost of the state providing necessary disposal systems will indicate possible feasibility of government action.

Estimated Rate of Decline in Production

This section will attempt to measure the total future production that can be expected from the stripper wells in existence today. Before this can be done, however, it is necessary to estimate the rate of decline that can be expected in the total production from these wells.

This may seem to conflict with Chapter two where it was shown that the production from stripper wells has been increasing. This increase, however, was due to an increase in the number of new stripper wells. The problem here is to estimate production for the following year from the stripper wells in existence in a given year, ignoring the production that comes from new stripper wells. Three initial assumptions will facilitate the analysis: (1) All abandonments that take place are stripper wells. (2) When a well first enters the stripper phase it is producing the maximum allowable by definition of ten barrels per day. (3) The rate of decline of production is constant over the life of the stripper wells. After the total production has been estimated, it will then be possible to go back and re-examine these assumptions to see if they are reasonable.

Under the assumption of a constant rate of decline in production, it is only necessary to estimate the decline in production during the first year. Once this decline is determined, the decline in all years is set. Table 4.1 shows the estimated rate of decline in production of the stripper wells in a given year during the next year of production. For example the decline in total production of the stripper well in existence in 1960 during 1961. The basic equation underlying this table is:

$$F_n = F_{n-1} - G_n + H_n \quad \text{where}$$

F_n = total number of stripper wells in the present year.

F_{n-1} = total number of stripper wells in existence in the preceding year.

G_n = number of abandonments in the present year

H_n = number of wells just entering the stripper phase in the present year.

Table 4.1. Estimated Rate of Decline for Given Stripper Wells During the Next Year, 1954-1961.[70]

Year (1)	Stripper Wells (2)	No. Wells Abandoned (3)	Production in Bar. (4)	Change in No. of Str. Wells (5)	New Str. Wells (Col. 3 + 5) (6)	Production from New Str. Wells (7)	Decline from Previous Yrs. (Col. 4 - 7) (8)	Amount of Decline in Bar. (Col. 4 - 8) (9)	Percent Decline (Col. 9 ÷ 4) (10)
1954	54,200	832	83,726,134						
1955	56,797	1,050	98,563,034	+2597	+3647	13,311,550	85,251,484	+ 1,525,350	+ 1.8
1956	58,136	743	82,168,379	+1339	+2082	7,599,300	74,369,279	-23,993,755	-24.3
1957	59,983	831	92,102,000	+1847	+2678	9,774,700	82,327,300	+ 158,721	+ .2
1958	62,905	476	86,273,000	+2922	+3398	12,402,700	73,870,300	-18,231,700	-19.8
1959	68,836	1,331	91,328,678	+5931	+7262	26,506,300	64,822,378	-21,450,622	-23.7
1960	65,688	2,384	95,054,237	-3148	- 764	278,096	95,332,333	+ 4,003,655	+ 4.4
1961	68,740	2,546	107,500,000	+3052	+5598	20,432,700	87,067,300	- 7,986,937	- 8.4

[70] National Stripper Well Survey, Interstate Oil Compact Commission, (Oklahoma City, Oklahoma, 1953-1961).

This equation can then be rearranged to give $H_n = F_n - F_{n-1} + G_n$. Since published statistics relative to the total number of stripper wells and abandonments are available for each year it is possible to calculate the number of new stripper wells (wells just entering the stripper phase) for each year. This is shown in column 6 of Table 4.1.

With the assumption that the new stripper wells produce the maximum allowable for a stripper well (10 barrels) the production from the new wells will be the number of new wells x 10 x 365 (number of days in a year). This is the maximum amount of oil the new stripper wells could produce. If the production from the new stripper wells is subtracted from the present year's total, the result is the production from last year's stripper wells. Take the decline in production of the 1960 stripper wells in 1961. The number of new stripper wells will be:

$$H_n = F_n - F_{n-1} + G_n$$
$$= 68{,}740 - 65{,}688 + 2{,}546$$
$$= 5{,}598$$

The production from these new wells = 5,598 x 365 x 10 or 20,432,700. Subtracting this from the 1961 state total of 107,500,000 leaves 87,067,300. This is the amount the 1960 stripper wells produce in 1961. Thus, there has been a decline of 7,986,937 barrels or about 8.4 percent. The rate of decline in the Table varies from +4.4 percent to -24.3 percent. Since the rate of production from a single oil well can always be expected to decline as it ages, it is logical that the total output from a large number of wells would decline. Table 4.1, however, shows three years in which the output from the stripper wells actually increased. In order for this to occur, the stripper well operators must have undertaken some type of improvement to raise the production from their wells, such as redrilling, acidizing, etc. It would also seem logical to assume that in the years where the decline was particularly sharp the well operators did not engage in external improvements on their wells.

If the assumption can be made that in the future improvements on stripper wells will vary somewhat as they have in the past, there would seem to be some justification for averaging these declines to get the rate of decline from the 1963 wells. The average rate of decline is 69.8 percent divided by 7 or 9.97 percent. For the purposes in the rest of the thesis, the annual rate of decline for the total existing stripper wells will be taken to be 10 percent per year.

Assumptions Re-examined

The decline of 10 percent per year would seem to be somewhat sharp. This would mean that all stripper wells in existence in a given year would be shut down in ten years. The data for 1961 indicates the conservative nature of this estimate. If the rate of decline is truly 10 percent, the stripper wells would produce only 591,250,000 barrels of oil. This is less than one-half the proved reserves that were in existence in stripper wells in that year.[71] Proved reserves are the total amount of oil that can be produced from the known resources under existing technology. This implies that over half of the oil reserves would be lost because they would be uneconomical to produce. Thus the 10 percent figure used in this study is probably a very conservative estimate of the productive capabilities of the stripper wells.

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[71] *National Stripper Well Survey*, *op. cit.*

One reason for this overestimate is that some abandonments come from non-stripper wells. Because of this, the number of new stripper wells is overestimated. When the production from this overestimate is subtracted from total stripper well production, it makes the decline sharper than it really is. Another reason for the sharp decline is the assumption that the rate of decline will be constant for each year. In reality the rate of decline probably decreases as the wells age. Even though it is fairly obvious that the 10 percent decline is too sharp, it will be used in the analysis in the next section. Since the decline in output of all existing stripper wells is impossible to forecast, a very conservative estimate will be used in its place. Given an initial production in 1963 of 116,500,000[72] and a rate of decline of 10 percent or 11,650,000 barrels per year, the production from 1963 stripper wells would decline at the rate indicated in Table 4.2.

Economic Significance of Shutting Down All Stripper Wells

If all the stripper wells were shut down, all the oil that they would have produced would be lost. In addition all the tax revenue that would have been collected on this oil would be lost, and some of the people working on the stripper wells would lose their jobs, at least in the short run. If this is true then the total effect of the shutting down of the stripper wells depends on the total amount of oil that they would have produced as estimated in Table 4.2

Given the estimated annual rate of decline, it is fairly easy to calculate the significance of shutting down stripper well production

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[72]This figure is taken from the regression equation developed in Chapter II for production from stripper wells.

Table 4.2. Expected Decline of the 1963 Stripper Wells.

Year	No. of Wells	Abandonments	Production (Barrels)
1963	73,000	7,300	116,500,000
1964	65,700	"	104,850,000
1965	58,400	"	93,200,000
1966	51,100	"	81,550,000
1967	43,800	"	69,990,000
1968	36,500	"	58,250,000
1969	29,200	"	46,660,000
1970	21,900	"	34,950,000
1971	14,600	"	23,300,000
1972	7,300	"	11,650,000
1973	0	"	0

by making the following assumptions. (1) The price of crude oil remains constant at $2.90 per barrel. (2) The state gross production tax, excise tax, and income tax remain at their present levels. (3) Non-stripper wells do not expand their production to offset the loss in output due to the decline in the number of stripper wells.

With these assumptions and the decline from the previous section, the significance of a shutdown in stripper well production would be as follows:

Loss of Gross Production Tax Revenue - The gross production tax in Oklahoma is 5 percent of the value of the crude oil at the well. Assuming a constant value of crude oil at the well of $2.90 per barrel, the loss in tax revenue through 1972 would be $92.9 million (Column 3, Table 4.3).

Table 4.3 Estimated Loss in Tax Revenue.

(1) Year	(2) Production	(3) Gross Production Tax (Column 2 x $2.90 x 5%)	(4) Excise Tax (Column 2 x 1/8 ¢)	(5) Income Tax for Royalty (Column 2 x 290/8 x 1%)
1963	116,500,000	$16,892,500	$145,625.00	$422,312.50
1964	104,850,000	15,203,250	131,062.50	380,081.25
1965	93,200,000	13,514,000	116,500.00	337,850.00
1966	81,550,000	11,824,750	101,937.50	295,618.75
1967	69,990,000	10,135,500	87,375.00	253,387.50
1968	58,250,000	8,446,250	72,812.50	211,156.25
1969	46,660,000	6,575,000	58,250.00	168,925.00
1970	34,950,000	5,067,750	43,687.50	126,693.75
1971	23,300,000	3,378,500	29,125.00	84,462.50
1972	16,650,000	1,689,250	14,562.50	44,231.25
1973	0	0	0	0
		$92,909,750	$800,037.50	$2,325,718.75

Loss in Excise Tax Revenue - The excise tax in Oklahoma is 1/8 ¢ barrel of oil. Thus the total loss in excise tax revenue is approximated at $800,000 (Table 4.3, Column 4).

Loss in Revenue from Income Tax on Royalties - The standard royalty contract calls for 1/8 of the gross income to go to the owner of the land. To estimate the income tax generated from royalties, the minimum income tax rate of 1 percent was used. If all owners of land on which stripper wells operate receive 1/8 of the gross income and if all pay 1 percent state income tax on this, the loss in income tax from royalties is shown in Column 6. This amounts to more than $2,375,000 for 1963 through 1972.

These are all the taxes that will be considered in this section. Others that might be included are income tax and sales tax generated indirectly by stripper well production. These were omitted because of the difficulty of computation. This omission will again give us an underestimate of the significance for state tax revenues of shutting down stripper well production. The total taxes paid by 1963 stripper wells during their economic life would be:

Gross Production Tax	$92,909,750.00	
Excise Tax	800,037.50	
Income Tax from Royalties	2,325,718.75	
Total	$96,036,406.25	or $96 million

This would be the equivalent of approximately $1300 per 1963 stripper well.

Cost of Disposal Well Systems

A study of disposal systems was made in 1942 covering three systems. Two of the systems were installed in the Fitts field in Washington County, and one was installed in the Moore field in Cleveland County.[73] The three systems serviced a total of approximately 1,000 wells and cost a total of $701,300. This is approximately $700 per producing well.[74]

Applicability of the Study Today

It was necessary to go back to the 1942 study in order to get comparable data. While there have been some recent reports on modern disposal systems, the systems were all based on 40 acre spacing (one producing well per forty acres).[75] Since all stripper wells are on ten acre spacing these studies were not suitable. If the forty acre spacing studies had been used, the cost of disposal systems would have been grossly overestimated because the producing wells are much further apart, thus necessitating more gathering lines. Several other considerations indicate that the study was made on a sample fairly representative of today's stripper wells. The depth of the disposal wells drilled in the 1942 study varied from 1,000 feet to 8,000 feet.[76] This would seem to be a fairly good cross-section of the needs of the proposed disposal wells. Furthermore the fact that the study involved a fairly large number of producing wells enlarges the chance that a representative sample was obtained.

A serious drawback in the applicability of the 1942 study stems from two decades of rising prices. Thus it is necessary to adjust the

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[73]Sam S. Taylor and E. O. Owens, Subsurface Disposal of Oil Field Brines in Oklahoma, U. S. Department of Interior, Bureau of Mines, Report of Investigations 3604, (January, 1942).

[74]Ibid., p. 32.

[75]Robb Graham, "Repressuring with Gas and Water", Producers Monthly, Vol. 23, May, 1959.

[76]Ibid.

1942 system cost to the level of current prices. Table 4.4 shows the 1942 prices and present prices of some of the material that goes into the construction of a disposal system. The increase in prices has varied from 12.8 percent to 67.8 percent. The average increase has been 33.9 percent. If this is taken as the increase in relative prices, it should provide an overestimate of the present-day price of a comparable disposal system. This is true since the prices of the more expensive and most frequently used items such as slush pumps and large steel pipe have not increased by this amount. Nevertheless initially an increase in prices of 34 percent will be used.

Table 4.4. Relative Prices of Material in Water Disposal Systems.[77]

Item	1942 Prices	1963 Prices	% Increase
Slush Pump	$9,500.00*	$12,000.00	26.3
Centrifugal Pump	2,995.00	4,200.00	40.2
Steel Pipe			
3 inch	80.00*	102.30	27.9
4 inch	110.00*	157.03	42.8
5 1/2 inch	135.00*	175.63	30.1
7 inch	200.00*	247.42	23.7
Cement Lined Pipe:			
3 inch	10.00*	16.78	67.8
4 inch	15.00*	22.77	51.8
5 inch	20.00*	27.23	36.1
6 inch	30.00*	34.10	13.7
7 inch	32.00*	36.08	12.8

*Approximate values

77Letter from W. C. Milan, Producers Pipe and Supply Company, (Hominy, Oklahoma, 1963).

A comparison of present roustabout wages and 1942 roustabout wages shows the following.[78]

	1942 Wages per Hour	1962 Wages per Hour	Percent Increase
Major Companies	$.87 - $1.00	$2.60 - $2.85	205.5
Small Companies	$.75 - $ .80	$1.50 - $1.75	200.0

If roustabout wages are representative of all wages paid, then the increase in wages has been about 200 percent. This, however, does not mean that the wage bill has increased by that amount. Since 1942 there has been tremendous advancements in technology in the oil industry. This would offset a substantial part of the increase in wages. To be on the safe side, however, the prices of the important materials in constructing a disposal system are set at 40 percent and not 34 percent of their 1942 level. This would make the cost of the systems $981,820.

One additional factor must be considered. In 1942 the systems serviced approximately 1,000 wells. Today there are only 817 wells in the same fields (441 in Fitts and 376 in Moore).[79] This means that if the same type systems were installed today on the same fields, the cost per well would be higher because there would be fewer wells to share the large fixed portion of the installation cost. Again, to be on the safe side the full cost of the systems established in 1942 was used, even though many of the gathering lines would not now have to be run because of the abandoned wells. This would make the present cost per well of the same system $981,820 divided by 817 wells or approximately $1,200

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[78] Ibid.

[79] "Bulk of Nations Reserves Stored in These Large Fields", Oil and Gas Journal, Vol. 6, No. 4, (January 28, 1956), p. 175.

per well. This would be an increase of about 70 percent over the 1942 cost of the same systems.

If these systems are truly representative of the state this $1200 can be taken as the average cost per producing well of installing the necessary disposal systems. When this cost of disposal systems per well ($1200) is compared with the tax revenue per well ($1300), it would seem that it is economically feasible for the state to construct the disposal systems rather than shut down the stripper wells.

Qualifications

The conclusion above would not hold true in all cases. Since the cost per well of installing a disposal system varies inversely with the number of wells in the field, there must exist some minimum number of wells a field must have, beyond which government action would not be feasible. This minimum number of wells cannot be determined exactly. Clearly for fields with more wells than the fields studied, the feasibility of government action is virtually assured. By the same token, operators with only two or three wells would have to be shut down if they were the cause of pollution. The problem of water pollution in this case would probably never arise, since it would be hard to produce enough water to do any harm.

For fields with a slightly smaller number of wells than the fields studied the feasibility of government action would have to be determined in each individual case by applying analysis similar to that developed in this thesis.

One final question must be asked; Once the disposal systems have been installed, could the stripper wells operate and still pay the cost of operating the disposal systems? The answer to this question is yes.

Since 1942 when the disposal systems were installed in the Moore and Fitts fields, both fields have declined to the point where they are stripper fields, and yet they are still operating and paying the cost of running their disposal systems. In fact the Fitts pool produces an average of less that six barrels per day and still pays for operating its disposal systems.[80]

Another reason for an affirmative answer to the question is that the cost of operating a disposal system and a waterflood project are roughly the same.[81] The northeast Oklahoma stripper area is almost entirely on waterflood and wells there average less than two barrels per day and still pay for operating the waterflood project. This is strong evidence that once the system is installed the stripper wells would continue to operate until they were completely exhausted.

Additional Considerations

The conclusion as to the feasibility of government action, given the preceding qualifications, would seem to be especially valid since there are other taxes that could have been considered such as income tax (other than income tax from royalties) and sales tax generated by stripper well production. In addition, the analysis could have included other factors besides tax revenue, such as employment created by stripper wells, the economic effects of stripper well production on the different towns, or the possibility that some stripper wells might produce some gas with the oil. This last possibility is not as important since very few stripper wells are capable of producing gas.[82]

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[80] Ibid.

[81] Interview with Kenneth H. Johnston, op. cit., (March 28, 1963).

[82] Interview with Kenneth H. Johnston, (May 11, 1963).

The Solution to the Problem Evaluated

Before the feasibility of the proposed plan can be established, it will be necessary to evaluate some of the basic assumptions that were made. One of the first assumptions made was that all stripper wells are the cause of water pollution. This assumption is obviously invalid since 44 percent of the stripper well production comes from secondary recovery.[83] In Oklahoma secondary recovery consists almost entirely of waterflooding. This means that in 44 percent of the cases the problem of water pollution does not exist since the salt water produced with the oil is returned to the reservoir. Since this is true, 44 percent of the stripper wells would not be affected by a crack-down on water pollution. This, however, does not invalidate the previous analysis. If 44 percent of the wells are not polluting the water, then the cost of building an adequate disposal system would be reduced by the same amount. This would merely reduce the scale of the problem, but would not affect the cost-revenue consideration, since both would be reduced by the same amount.

Another assumption was that all the stripper wells would shut down if they were forced to provide their own disposal systems. This assumption seems to be valid. It has been estimated by petroleum engineers that the cost of any capital expenditure on oil production cannot rise above one cent per barrel over the life of the well before it becomes uneconomical to undertake.[84] This is true no matter what type program is being considered.

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[83] National Stripper Well Survey, op. cit., (1962).

[84] Interview with Kenneth H. Johnston, op. cit., (March 28, 1963).

The per barrel cost of a disposal system would be almost six cents per barrel for a stripper well capable of producing 22,075 barrels of oil over its lifetime. Since this is the maximum a stripper well could produce, the per barrel cost of a disposal system could be no lower than this. Since this is six times the maximum set by petroleum engineers, there seems little doubt that the operator would find it uneconomical to continue operation.

Probably the most basic assumption made in this chapter is that the production from the non-stripper wells cannot increase to take up the slack created by the curtailment of production from the stripper wells. At first glance this assumption seems to be invalid. It has been estimated that the production from the relatively new wells could be increased by three or four times and still recover the maximum amount of oil in the field.[85] The rate of output from these new wells is set by the Corporation Commission as part of the nation's prorationing program. The main purpose of limiting the production from these wells is to limit supply so as to keep the price of crude oil up to its present level. The state is given a quota by the Interstate Oil Compact Commission. The stripper wells are not under prorationing so their total expected production is subtracted from the state quota.[86] The remainder of that production is then allocated to the wells that come under prorationing. If the production from stripper wells were eliminated these highly productive wells could increase production to

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[85] _Ibid._

[86] Stripper wells are not under prorationing since they must produce the maximum possible to make enough profit to justify their existence.

match the decline created by the abandonments of stripper wells, and the output of crude oil would remain unaffected. If this could be done it would be possible to produce the total state production without creating the social cost of water pollution. This would eliminate the problem of water pollution entirely.

This brings up the question: Could this be done without drastically reducing the oil reserves in Oklahoma? Once a stripper well is shut down, the oil that it could have produced is lost forever. Table 4.5 shows proved reserves in Oklahoma for 1953-1961, and proved reserves in stripper wells for the same period. While there might be some difference in the data since they come from different sources, no one can doubt that stripper wells account for a significant part of the

Table 4.5. Proved Reserves in Oklahoma, 1953-1961.

Year	Proved Reserves in Oklahoma[87]	Proved Reserves in Stripper Wells[88]	Stripper Well Reserves as a Percent of State Total
1953	1,752,000,000	1,588,303,000	90.66
1954	1,955,000,000	1,666,215,000	85.23
1955	2,000,000,000	1,590,865,000	79.54
1956	2,000,000,000	1,186,430,000	59.32
1957	1,941,521,000	1,317,380,000	76.85
1958	1,898,128,000	1,383,665,000	72.90
1959	1,864,759,000	1,242,244,000	66.61
1960	1,790,500,000	1,196,458,000	66.68
1961	1,787,429,000	1,295,940,000	72.50

[87] Minerals Yearbook 1953-1961, Area Statistics, op. cit.

[88] National Stripper Well Survey, op. cit.

state's total oil reserves. Assuming the data are correct, forcing the stripper wells causing water pollution to shut down would reduce the state's proved reserves by about 40 percent.[89] This would seem to indicate that shutting down the stripper wells and letting the other wells take up the slack is not the answer to the problem of water pollution. A reduction in proved reserves of 40 percent is probably too great a price to pay for eliminating water pollution.

Even though it might be possible to offset temporarily the reduction in proved reserves by increasing production from other wells, it would not be long before Oklahoma began to run out of oil. In the long run the shutdown of stripper wells would lose the state the revenue indicated even though the effect would not become immediately apparent.

A final question relates to the possibility that other energy sources might replace oil in the near future. If this occurred, then it would seem desirable to produce today's oil with the least total cost, i.e., shut down the stripper wells.

The major possibilities for an energy replacement for oil are (1) synthetic oil from other sources such as coal and shale and (2) atomic energy. These possibilities will be considered in turn.

It is possible to produce oil from coal and shale. However, unless the cost of oil from this source can be reduced, its possibility for replacing oil is not very high.[90]

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[89]This takes into account the fact that only 56 percent of the stripper wells would be shut down since 44 percent of the production comes from waterflood projects.

[90]R. M. Machal, "Are We Running Out of Oil", Popular Science, Vol. 170, (March, 1957), pp. 99-101.

Atomic energy presents tremendous possibilities for replacing oil. It would seem, however, that the time before atomic energy really promises to replace oil is so far in the future that it is not relevant to this thesis. Since gasoline is by far the major product from oil, atomic energy-powered cars would have to be in existence before a significant threat is made by atomic energy. This, indeed, is a far distant possibility.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

This thesis has shown that Oklahoma is definitely faced with the problem of water pollution caused by stripper wells. This problem has arisen because no provisions were made when the oil fields were high producers to control the eventual excess water that was sure to come. One recommendation is that the Oklahoma Corporation Commission establish rules forcing oil field owners to provide in advance for the prevention of water pollution. After salt water disposal systems, or some other means of preventing water pollution have been installed, all fields that produce water will be able to continue production until the field is completely depleted without creating the social cost of water pollution.

The current problem stems from the lack of advance provisions for water disposal. This study has indicated tentative feasibility of the provision by the state of the disposal systems necessary for the prevention of water pollution. This does not mean that this solution should be automatically adopted. There are several alternative solutions to the problem, one of which might be to shut down the stripper wells and let the non-marginal wells take up the slack in production caused by this action. Since this solution would cause Oklahoma to lose 40 percent of its reserves, it should be favored only if it becomes apparent that some other type of fuel might replace oil in the near future. Another solution might be to give the stripper well operator a tax credit for the construction of his own disposal systems.

The final recommendation of this study is that more research be made examining the feasibility of these and other possible solutions. Only after all possibilities have been viewed can the most economical solution to the problem be determined.

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A P P E N D I X

APPENDIX A

Computation of the Regression Equation for the Increase in Stripper Wells, 1950-1961

x = years   y = No. of wells

First code the years 1950 = 1, 1951 = 2, etc.

Divide Y's by 1,000. This reduces your numbers to workable figures.

Then

$$\bar{Y} = \frac{\Sigma Y_i}{h} \qquad \bar{X} = \frac{\Sigma X_i}{h}$$

$$\bar{Y} = \frac{675,837}{12} \qquad \bar{X} = \frac{78}{12}$$

$$\bar{Y} = 56,319.75 \qquad \bar{X} = 6.5$$

x $X_i - \bar{X}$	y $Y_i - \bar{Y}$	x^2	y^2	xy
-5.5	-13.5	30.25	182.25	74.25
-4.5	-14.3	20.25	204.49	64.35
-3.5	- 8.6	12.25	73.96	30.10
-2.5	- 8.3	6.25	68.89	20.75
-1.5	- 2.1	2.25	4.41	3.15
- .5	.5	.25	.25	- .25
.5	1.8	.25	3.24	.90
1.5	3.7	2.25	13.67	5.55
2.5	6.6	6.25	43.56	16.50
3.5	12.5	12.25	156.25	43.75
4.5	9.4	20.25	88.36	42.70
5.5	12.4	30.25	153.76	68.20
0	≈ 0	143.00	993.09	369.95

$$b = \frac{\Sigma XY}{\Sigma X^2} \qquad a = \bar{Y} - b\bar{X}$$

$$b = \frac{369.95}{143} \qquad a = 56.3 - 16.83$$

$$b = 2.59 \qquad a = 39.47$$

APPENDIX B

Computation of the Regression Equation for the Increase of Acres Involved in Stripper Well Production, 1950-1961

x = years   y = No. of wells

First code the years base 1950

Divide the Y's by 1,000 thus reducing the numbers

Then

$$\bar{X} = \frac{\Sigma X_i}{h} \qquad \bar{Y} = \frac{\Sigma Y_i}{h}$$

$$\bar{X} = \frac{78}{12} \qquad \bar{Y} = \frac{11,115,451}{12}$$

$$\bar{X} = 6.5 \qquad \bar{Y} = 926,287.6$$

x $X_i - \bar{X}$	y $Y_i - \bar{Y}$	x^2	y^2	xy
-5.5	-230.8	30.25	53,268.64	1,269.40
-4.5	-224.2	20.25	50,265.64	558.90
-3.5	-180.5	12.25	32,580.25	631.75
-2.5	- 94.6	6.25	8,949.16	236.50
-1.5	- 84.7	2.25	7,174.09	127.05
- .5	- 16.8	.25	282.24	8.40
.5	- 23.0	.25	529.00	- 11.50
1.5	24.0	2.25	576.00	36.00
2.5	86.1	6.25	7,413.21	215.25
3.5	215.9	12.25	46,612.81	405.65
4.5	242.2	20.25	58,660.84	1,089.90
5.5	286.4	30.25	82,024.96	1,575.20
0	0	143.00	348,336.84	4,999.50

$$b = \frac{\Sigma XY}{\Sigma X^2} \qquad a = \bar{Y} - b\bar{X}$$

$$b = \frac{4,999.50}{143.00} \qquad a = 926.3 - 227.24$$

$$b = 34.96 \qquad a = 699.06$$

APPENDIX C

Computation of the Regression Equation for the Increase in Stripper Well Production, 1953-1961

x = years y = production

Reduce years by subtracting 1952 from each year.

Then

$\bar{X} = \frac{\Sigma X_i}{n}$ $\bar{Y} = \frac{\Sigma Y_i}{n}$

$\bar{X} = \frac{45}{9}$ $\bar{Y} = \frac{805.8}{9}$

$\bar{X} = 5$ $\bar{Y} = 89.5$

x $X_i - \bar{X}$	y $Y_i - \bar{Y}$	x^2	y^2	xy
-4	-29.1	16		116.4
-3	- 6.2	9		18.6
-2	9.1	4		- 18.2
-1	- 7.3	1		7.3
0	2.6	0		0
1	- 3.2	1		- 3.2
2	1.8	4		3.6
3	5.6	9		16.8
4	32.2	16		128.8
0	0	60		270.1

$b = \frac{\Sigma XY}{\Sigma X^2}$ $a = 89.5 - (4.5 \times 5)$

$b = \frac{270.1}{60}$ $a = 89.5 - 22.5$

$b = 4.5$ $a = 67.0$

APPENDIX D

Computation of the Regression Equation for the Increase in Stripper Well Production as a Percent of Total State Production, 1956-1961

x = years   y = Percent of State Production

Reduce years by subtracting 1955 from each year

Then

$$\bar{X} = \frac{\Sigma X_i}{h} \qquad \bar{Y} = \frac{\Sigma Y_i}{h}$$

$$\bar{X} = \frac{21}{6} \qquad \bar{Y} = \frac{281}{6}$$

$$\bar{X} = 3.5 \qquad \bar{Y} = 46.8$$

x $X_i - \bar{X}$	y $Y_i - \bar{Y}$	x^2	y^2	xy
-2.5	-7.8	6.25	60.84	19.50
-1.5	-3.8	2.25	14.44	5.70
- .5	-3.8	.25	14.44	1.90
.5	- .8	.25	.64	- .40
1.5	3.2	2.25	10.24	4.80
2.5	13.2	6.25	174.24	33.00
0	0	17.50	274.84	64.50

$$b = \frac{\Sigma XY}{\Sigma X^2} \qquad a = \bar{Y} - b\bar{X}$$

$$b = \frac{64.50}{17.50} \qquad a = 46.8 - 3.69\ (3.5)$$

$$a = 46.8 - 12.915$$

$$b = 3.69 \qquad a = 33.805$$

VITA

Don William Looney

Candidate for the Degree of

Master of Science

Thesis: THE ECONOMICS OF STRIPPER WELL OIL PRODUCTION IN OKLAHOMA

Major Field: Economics

Biographical:

Personal data: Born in Fayetteville, Arkansas, July 8, 1940.

Education: Attended grade school in Fayetteville, Arkansas and Bartlesville, Oklahoma; graduated from College High School, Bartlesville, Oklahoma in 1958; received the Bachelor of Arts degree from Oklahoma State University, with a major in Economics, in May, 1962; completed requirements for the Master of Science degree in May, 1963.

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