Pollution Control for Oil Field Brines

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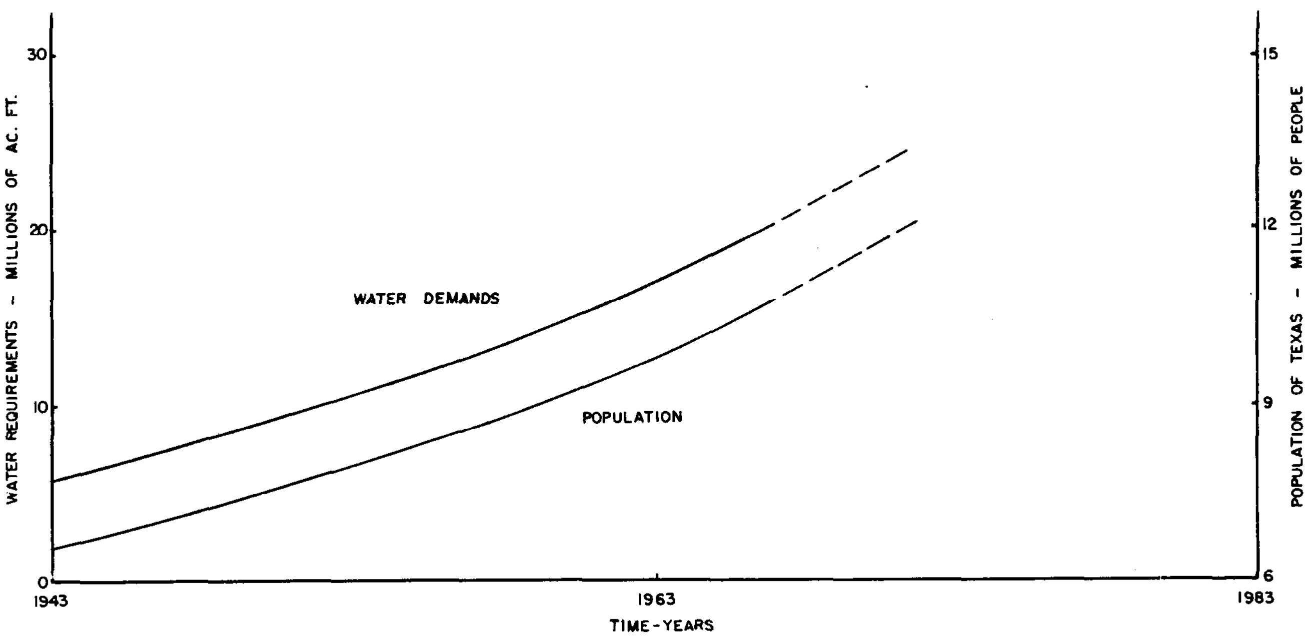
INTRODUCTION

Increased public attention resulting from publicity relating to oil field brine pollution would lead one to believe that this is a new problem. However, in reality, this concept is far from true. The problem of disposing of produced salt water has been with the oil and gas industry in Texas since the discovery of Spindletop in 1901.

With few exceptions, experience has shown that salt water will eventually be produced in conjunction with oil and/or gas. The percentage of salt water production varies considerably with individual oil wells, a reasonable average being 2½ to 3 bbl for every bbl of oil produced. Based on this ration, the total salt water production for the State now exceeds 7,500,000 BPD. The continued expansion of fresh water requirements for municipal and industrial use, projected into the future, as shown in Fig. 1[1], points toward the necessity that every possible effort be made to assure that the vital fresh water supply is not contaminated by oil field brine. Therefore, it is mandatory that industry devise safe and adequate means for the disposal of this ever increasing volume of salt water, which has been referred to as the unavoidable companion of oil and gas production.

The Railroad Commission, as the legally



FRESH WATER DEMANDS IN RELATION TO POPULATION INCREASE

FIG. 1

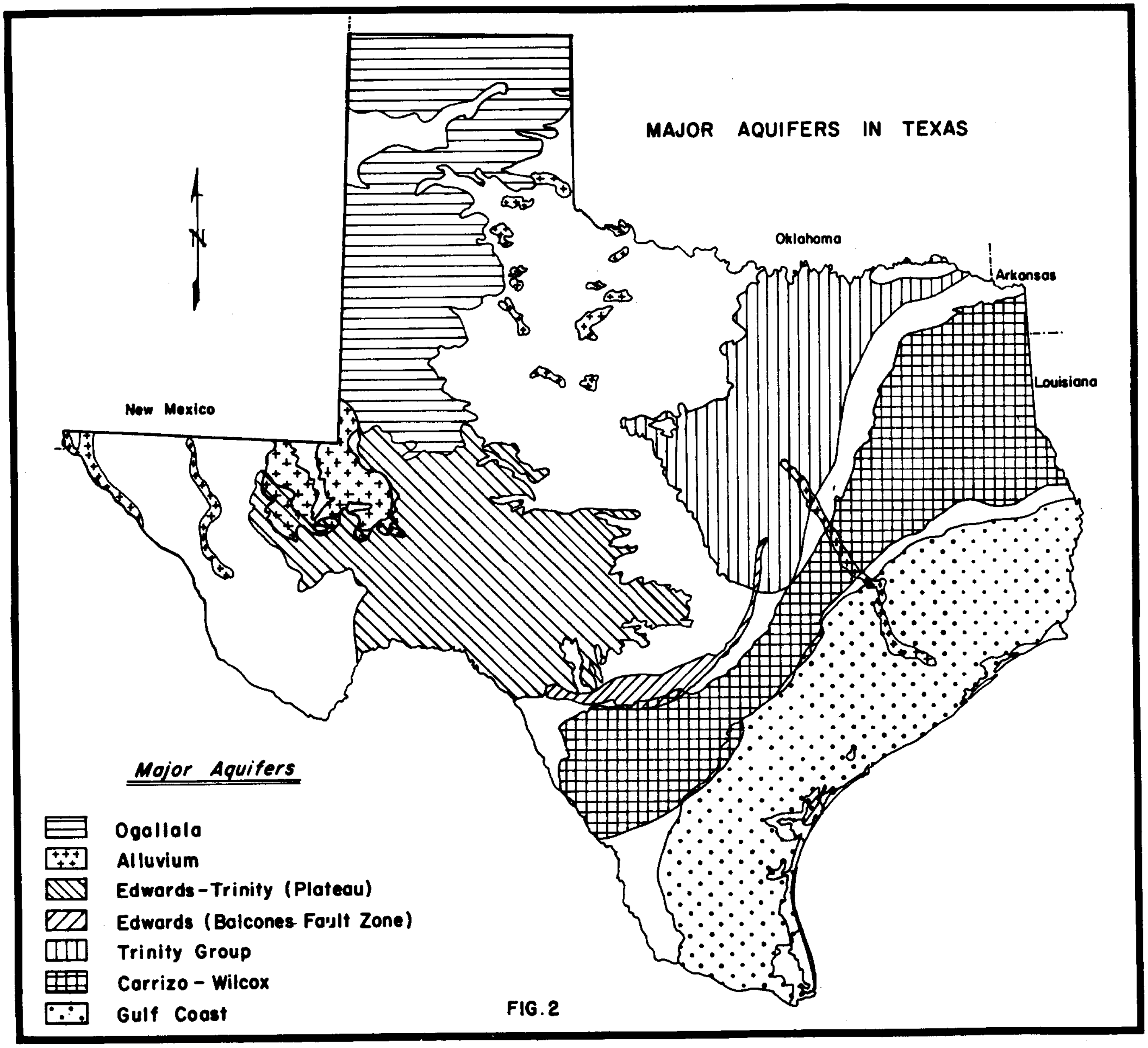


FIG. 2

designated regulatory body, has required operators in 44 counties to show cause why salt water pits should not be banned. As a result, pits have been or are being eliminated in all 44 counties. In addition to these counties, pits have been banned in more than 200 individual fields. Also, a statewide no-pit hearing was held by the Commission in Austin on December 6, 1966; Commission action is now pending.

All show-cause hearings pertaining to the elimination of salt water pits were for the express purpose of protecting fresh water supplies. Each hearing was preceded by a lease-by-lease inspection made by Commission personnel. These inspections revealed salt water pits to be one of the prime sources of pollution.

The major ground-water aquifers in Texas underlie about 65 per cent of the State and supply about 95 per cent of all ground water used in Texas. When combined with the ground water obtained from minor aquifers, the total accounts for approximately 70 per cent of all fresh water used.[2] In those areas where no other ground-water sources are available, the minor aquifer assumes critical local significance. Figure 2 depicts the major aquifers in Texas.

The majority of all oil and gas fields of this State co-exist in the limits of major aquifers and extensive development has also taken place in areas of limited water supplies. The tremendous volume of salt water being disposed of makes it apparent that a pollution problem does exist. The ground-water supply must be adequately protected. This protection can be assured by the oil and gas industry and the Commission working in close cooperation and approaching the problem objectively.

PAST AND PRESENT ACTIVITY

Following reorganization of the Commission in September 1963, the Commission District Offices were reorganized and converted from a records-keeping-field operational center to a strong field-operational and enforcement unit. Each District is managed by technical personnel under the direct supervision of the Field Operations Director. Under this plan, the field activity has been accelerated. The intensity of this acceleration is reflected by Table 1 showing a comparative review of field activity relative to pollution problems investigated by Commission personnel during the last 3 years. Figure 3 graphically illustrates this increased activity.

TABLE 1 — COMPARATIVE REVIEW OF TIME SPENT ON POLLUTION PROBLEMS BY RAILROAD COMMISSION PERSONNEL

1964 through 1966

	1964	1965	1966
Total Man Hours on Duty	107,531	139,610	165,684
Total Man Hours In Field	71,380	102,116	145,823
Per Cent of Time in Field	66.4	73.1	88.0
Man Hours on Pollution	47,529	58,809	99,004
No. Pollution Investigations	3,374	7,394	23,168
Per Cent of Time On Pollution	44.2	42.1	59.7
No. of Wells Plugged	8,740	8,842	8,733
No. of Pluggings Witnessed	1,752	4,342	6,778
Per Cent of Pluggings Witnessed	20.0	49.1	77.6

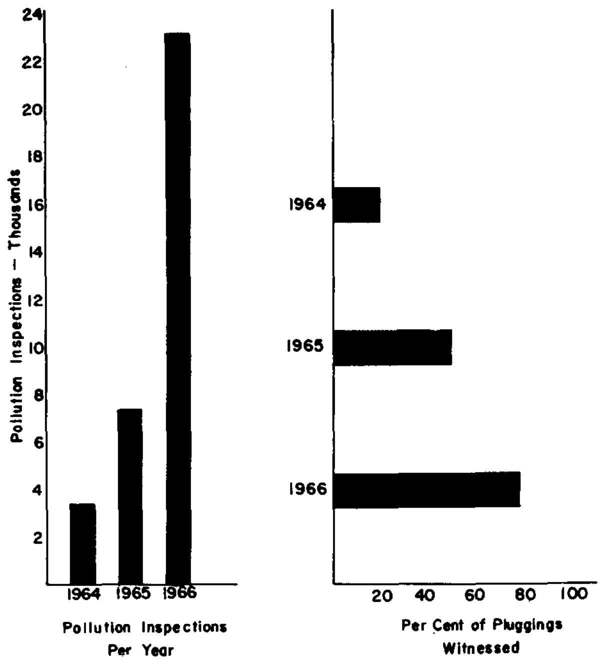


FIG. 3

EARTHEN PITS

The most common method of disposing of produced salt water in the past has been storage in unlined earthen pits. The theory behind the use of surface pits for the disposal of produced salt water, is that the water in pits will be evaporated. Unfortunately, this theory is not suported by the experience of the oil industry in pit use. There can be no question that salt water stored in unlined earthen pits has contributed to contamination of ground and surface water supplies. Studies by the Commission have shown that evaporation as the sole means for disposing of salt water is not an answer to the problem and, in fact, is of little practical value.

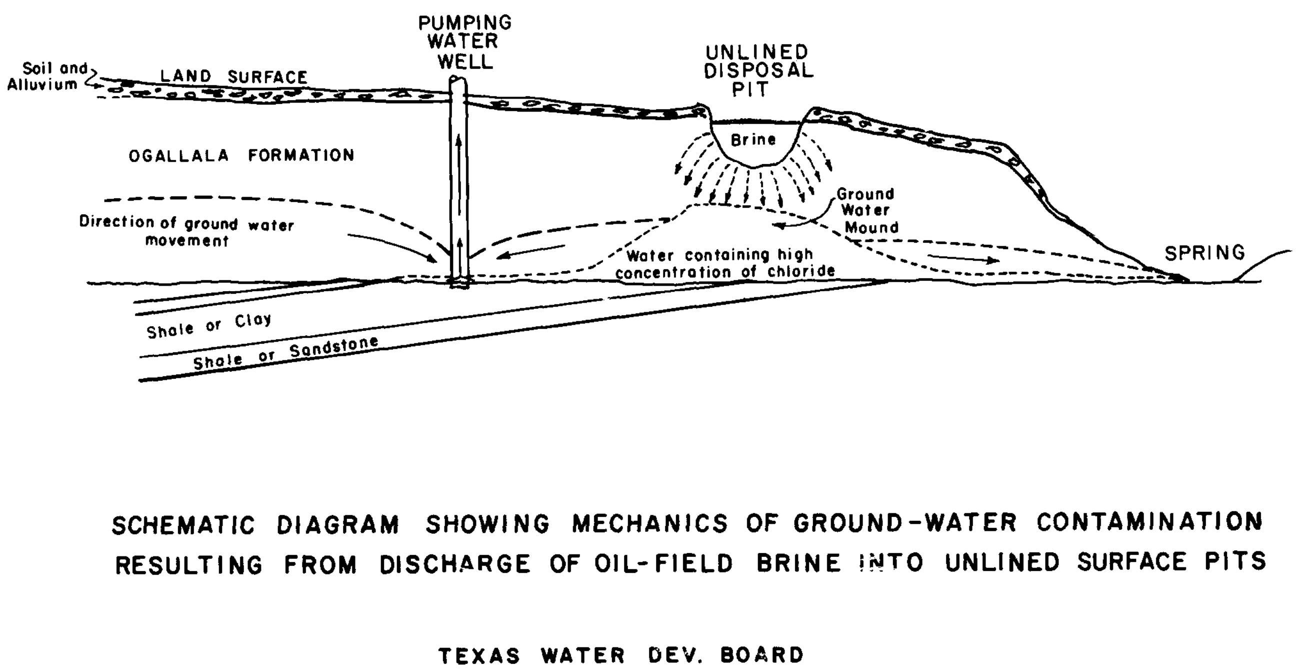
The use of earthen pits as a means for the disposal of salt water has repeatedly been found to be a source of pollution to fresh water supplies. Surface soil saturation and surface seepage will cause pollution by direct discharge into water courses and salt contamination of normal runoff. Pollution of fresh water has been observed as the result of the charging with salt water of shallow subsurface formations, such as gravel and caliche beds, in that salt water collected in these shallow formations will eventually discharge into water courses.

Pollution of subsurface fresh water sands has been observed as the result of vertical percolation of pitted water directly into fresh water aquifers. This is illustrated by Fig. 4[3]. The problem is compounded by the widespread salt concentration of oil field brines and the chloride potability limits that have been established for water usage. This chloride concentration spread has the effect of allowing only a small amount of concentrated oil field brine to contaminate a considerable volume of fresh water above the established chloride potability limits.

Because of the high degree of mineralization of most oil-field waters, extremely large volumes of ground water are required for dilution of even small amounts of brine. For example, approximately 400 bbl of chloride-free water are required to dilute one bbl of brine with a concentration of 100,000 ppm chloride to a level of 250 ppm chloride, the U. S. Public Health Service's recommended standard.

Salt contamination of water is, for all practical purposes, a permanent situation, with dilution the only rectifying remedy. The use of earthen pits for disposal of oil field brines has the effect of creating an irreversible salt-saturated environment in a rock system, which will be a source of pollution for an indefinite time period, approaching permanency. When a disposal system has repeatedly been observed to create an irreversible source of pollution to surface soils and fresh water supplies, then logic dictates that the system should be abandoned.

The Commission recognizes the existence of certain situations whereby exceptions to no-pit orders may be granted. In areas where it can be shown that there are no fresh water sands to be affected or that fresh water sands are overlain by brackish or salt water sands, or where the volumes of produced salt water are so small as to present no real danger of pollution, and in other instances where it can be shown that no contamination of the surface or fresh water sands is involved, then requests for exceptions will be considered. Emergency pits, collecting pits, and backwash pits used in connection with salt water injection systems may be considered. Many tidewater disposal systems also merit consideration for exceptions.



SCHEMATIC DIAGRAM SHOWING MECHANICS OF GROUND-WATER CONTAMINATION RESULTING FROM DISCHARGE OF OIL-FIELD BRINE INTO UNLINED SURFACE PITS

TEXAS WATER DEV. BOARD

FIG. 4

LINED PITS

Unfavorable climatic conditions, a properly constructed pit of adequate surface area and lined with an impervious material, may effectively evaporate the water content of a brine solution, assuming the brine surface is free of evaporation retardents, such as oil films, or stagnation, due to micro-organisms. However, the dissolved minerals in the brine cannot be evaporated and as the brine concentration increases, the evaporation rate decreases.

The relatively small surface area of most pits precludes the possibility of evaporation having any significant effect upon the dissipation of the water content of the brine, even under ideal conditions.

After extensive investigation of the various linings that will supposedly make an earthen pit "water tight", the following conclusions have been reached:

(1) The permanence of any lining is certainly questionable.
(2) Keeping a pit oil-free by burning is impossible.
(3) Leakage from these pits can occur and remain undetected.
(4) Maintenance costs would be prohibitive.

In the past many types of lining material have been used unsuccessfully. The ease with which some of the linings can be punctured, and the deterioration of others from the action of salt water, have compounded the problem of developing an adequate liner. Some liners that might prove to be adequate are too expensive for use by many operators.

LONG-RANGE PROGRAM

The Commission field staff is engaged in a long-range program to investigate all producing areas of Texas to determine where and how pollution is occurring or could occur from oil and gas operations.

A field force consisting of 31 engineers and/or geologists and 61 inspectors assigned to 10 District Offices (strategically located throughout the State) are subject to 24-hour call seven days a week. This year the Commission will endeavor to witness the plugging of all wells and also a high percentage of the setting and cementing of surface and production casing strings. Investigations will be made on all complaints on drilling and production practices and problems such as salt water production and alleged pollution.

The Commission program for controlling pollution has been established since the initial pollution control law in 1955. Under the civil statutes, the Railroad Commission of Texas regulates and policies the disposal of salt water from oil and gas waste. The Commission has the sole responsibility for the control and disposition of such waste and the abatement and prevention of water pollution resulting from activities associated with oil and gas operations.

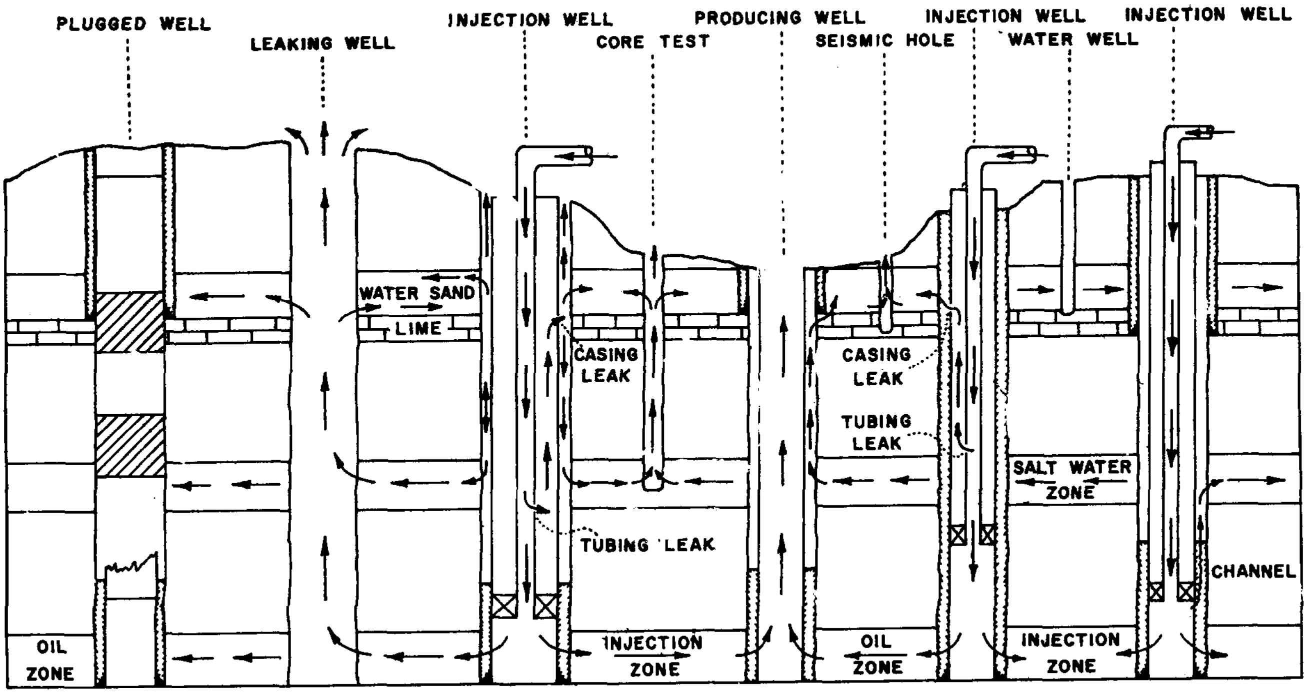
Acting on the authority of the statutes, the Commission has issued many rules, orders and memorandums designed to eliminate and prevent pollution. The Commission has had to move rapidly in order to fulfill its pollution control responsibilities. It is the intent of the Commission to continue to expand this program.

The aggressive efforts by the Railroad Commission have been more than matched by the petroleum industry. New salt water injection systems have been and are now being built; cooperative efforts among operators for field disposal systems have been greatly accelerated and millions of dollars are being budgeted annually by the industry for elimination of open pits and conversion to other acceptable disposal systems. The most desirable means of disposal is by controlled subsurface injection. Figure 5[3] depicts typical losses resulting from uncontrolled fluid injection.

The Commission in conjunction with the Texas Water Commission conducted a statewide survey in 1961 which indicated that 69 per cent of all produced water was injected through secondary recovery projects or disposal systems. This program has expanded with Commission approval of 3112 secondary recovery projects and the issuance of 4072 disposal well permits during the past five years. It is reasonable to assume that the percentage of injected salt water has increased substantially.

REVIEW OF FLUID INJECTION AND SALT WATER DISPOSAL SYSTEMS

The primary objective of oil operators in the past has been to dispose of produced salt water as quickly and as economically as possible. Historically, this has been done in such a way as to meet the minimum demands of the landowner, the public, or other persons directly affected by



MIGRATION OF SALT WATER FROM INJECTION WELLS

FIGURE 5

this disposal.

From the earliest days of oil and gas production, landowners have objected strenuously to the uncontrolled disposal of oil field brines on the surface of the ground; consequently, the construction of pits for storage and evaporation of brines was a simple and economic immediate solution to the problem. This solution continued until it became obvious that pits were contributing to contamination of ground and surface water supplies.

When pits were no longer allowed, the next obvious solution for disposal was by injection into the subsurface. One of the simplest and most economical methods used for injection of salt water underground was injection into the annulus between the producing string and the surface casing. In theory, this was a feasible solution because the surface casing was supposedly set at a sufficient depth to protect all fresh water sands and any disposal of salt water into the annulus would, therefore, be dispersed into a harmless area.

In practice, however, it soon became evident that the pressure required for injection into the annulus was so great as to either bypass the cement behind the surface casing or, in many instances, the surface casing was not run to a sufficient depth to protect fresh water sands. Again, in a distressingly large number of cases, the salt water migrated into fresh water supplies; consequently, effective objections to this type disposal were made both to the Railroad Commission and to the courts.

By a ruling of the courts it was found that an operator would be liable for damages resulting from this type injection. As a result the Commission changed its policy to that of granting annulus type disposal permits only in extraordinary cases, and upon a complete showing by the operator that the proposed injection would be harmless.

The next logical step in the procedure for disposal of salt water was injection into a porous formation nonproductive of oil or gas. In many cases this proved to be unsatisfactory since the formation selected would not actually take the water and under pressure there was migration back up the wellbore and outside the casing similar to an annulus injection well.

In many instances, the nonproductive formation used was productive of water which did not meet the U. S. Department of Health's standards of potability but was still sufficiently uncontaminated to be used for stock water or irrigation purposes.

In the opinion of the Railroad Commission's engineering department, the best place to dispose of produced brines and mineralized waters is in the formation from which it was produced. This has the double advantage of injection into a formation where there is no prospect of additional contamination of formation fluids and, at the same time, of contributing to some degree of reservoir voidage replacement, toward improving the recovery efficiency of the reservoir. The productive reservoir used may be either the reservoir from which the fluids were originally produced or some overlying or underlying reservoir which is also productive of oil and gas. These disposal systems are completely within the jurisdiction of the Railroad Commission and the Commission has taken affirmative steps to encourage their use. Such systems can generally be classified as pressure maintenance or secondary recovery operations of some type and the Commission customarily permits transfer of allowables and other proration advantage incentives in conjunction with their use.

A classic example of cooperative disposal of large quantities of produced salt water is in the East Texas Field where the world's largest salt water injection system is in operation. The Commission encouraged the organization and perfection of this disposal project to return salt water to the Woodbine sand reservoir by permitting the transfer of oil allowables on large water-producing wells and granting bonus allowables to the producer for water returned to the reservoir.

As of January 1, 1967, a cumulative total of 3,815,349,986 bbl of salt water had been returned by injection to the reservoir. Of this volume, 161,014,857 bbl were injected in 1966, representing 99.67 per cent of the year's total water production.

Pollution and contamination of fresh-water streams in the area of the East Texas oil field have been eliminated, and the bottomhole pressure in the reservoir has been maintained to a remarkable degree. It is estimated that as a direct result of the salt-water disposal program, more than 600 million bbl of additional oil will be recovered from the Field.

The possible production of brines and mineralized waters is the immediate concern of individual operators for every well drilled. With this in mind, each operator should consider the problem of salt water disposal as an integral part in the development and operating expense of the production of crude oil.

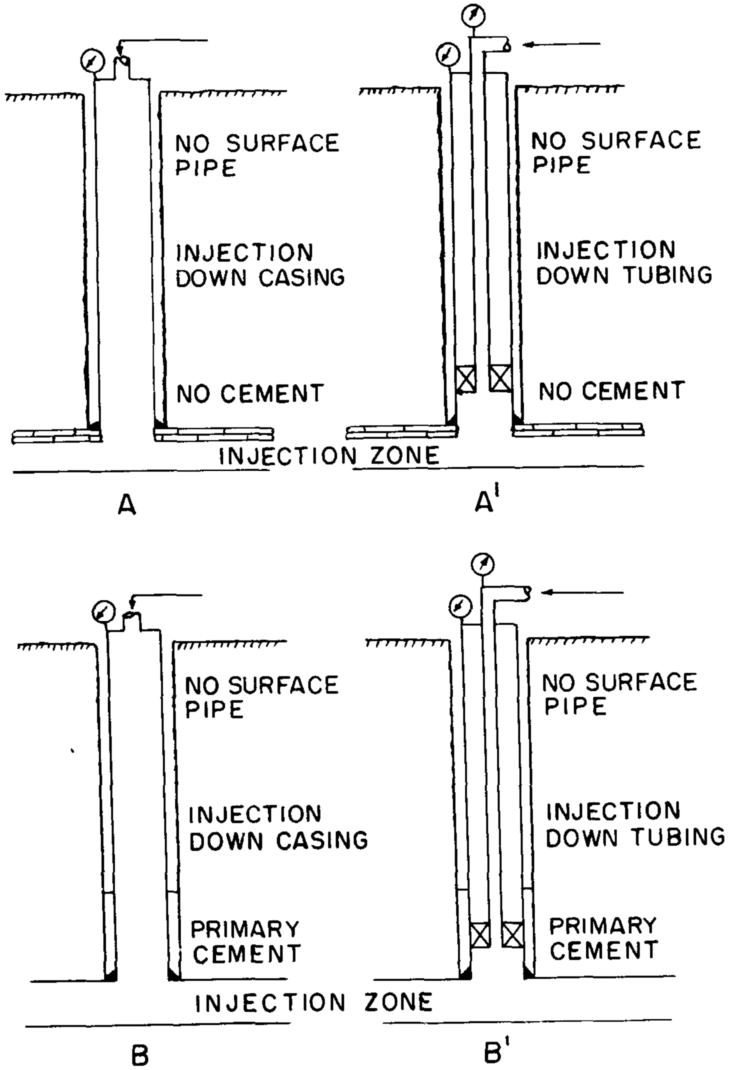
Produced brines and mineralized waters are here to stay and will stay as long as there is oil and gas production. It is sincerely hoped that the polution problem is not here to stay. Early recognition of the fact that every oil operator is expected and will be expected to make suitable disposition of produced brines and mineralized waters will expedite the solution and total elimination of this problem.

GUIDELINES FOR INJECTION AND SALT WATER DISPOSAL

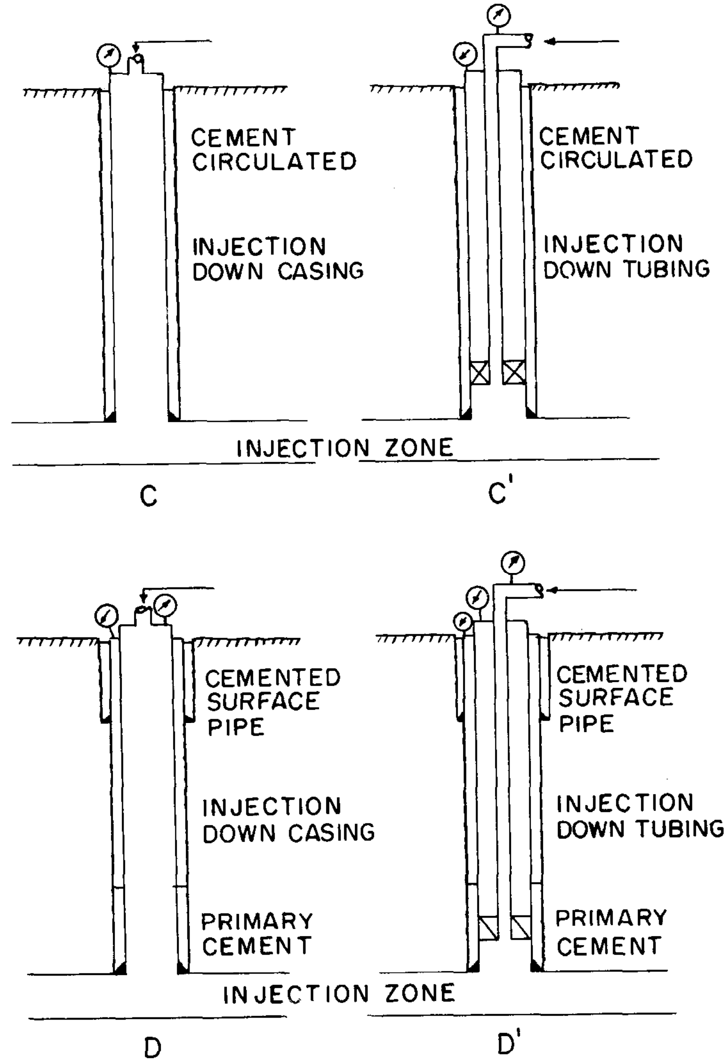
A major task facing the oil industry today, particularly its technical staff, is effective but economical subsurface fluid injection and disposal of produced salt water. The following recommendations are submitted toward the realization of this goal:

(1) Design well completions for fluid injection and salt water disposal service that may be effectively monitored and controlled by surface tests.
(2) Give due consideration to environmental conditions in area of project.
(3) In design of salt water disposal system, select zones that have sufficient reservoir volume to accept the present and and expected volume of produced water without developing overcharged conditions in the formation.
(4) Control operating conditions of injection systems to avoid mechanical failure.
(5) Encourage field personnel to be zealous in their checking of operating systems so that trouble may be detected at an early date.
(6) Attempt to design water treatment programs that will tend to control failures due to corrosion.
(7) Keep detailed records of injected volume and produced volume so that any loss of injected fluid might be detected at an early date.

These recommendations are submitted as



TYPICAL INJECTION WELL COMPLETIONS



TYPICAL INJECTION WELL COMPLETIONS

FIG. 6

guidelines and are not necessarily to be interpreted as Commission policy. On the other hand, the Commission does intend to encourage good engineering practices through its permitting procedures and its field investigative staff.

Insight into well system problems may be gained by reviewing the various types of completions presently being used for injection service. Figure 6 illustrates these various types of completions. On some of the illustrated completions, it is possible to monitor wells from the surface by means of casing and surface pipe observation valves. The type D' completion of Fig. 6 is submitted as one that may be effectively controlled and checked by surface test and is the type of completion that is encouraged for injection service.

CONCLUSION

While it is true that the present extent and seriousness of water pollution has probably been overemphasized in the wave of publicity and legislative activity in recent years, it remains one of the more serious and permanent problems faced by the oil and gas industry today. A good start toward a satisfactory solution to the problem has already been made; through the cooperative efforts of the Commission and industry the problem can not only be solved but solved in such a way as to benefit the producer, operators, the surface owner, and the general public.

Such a solution is not only possible but is expected of an industry which has long been a leader in the field of natural resource development and industrial achievement.

REFERENCES

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3. Payne, Roy D., Director of Field Operations, Railroad Commission of Texas, "Salt Water Pollution Problems in Texas", Journal of Petroleum Technology (September 1966) XVII, No. 9.