METHODS OF CHLORIDE ELIMINATION
IN THE RED RIVER BASIN

By

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IN THE RED RIVER BASIN

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TABLE OF CONTENTS

Chapter		Page
	Subsurface Cutoff Wall	25
	Low Flow Dams	25
	Well Points	26
	Shallow Wells	26
V.	DATA PRESENTATION OF RED RIVER BASIN RESULTS	27
	Area VI	27
	Area IX	32
	Area XIII-XIV	36
	Area XV	39
VI.	SUMMARY AND CONCLUSIONS	43
	Summary	43
	Conclusions	45
	Suggestions for Future Study	45
SELECTED BIBLIOGRAPHY		47

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

The Problem

The Arkansas-Red River Basin Chloride Control Project is a study of natural chloride pollution which degrades the Arkansas-Red Rivers and their tributaries. This study was to show the different methods or ideas of chloride elimination. This report will concentrate on the Red River portion of the Arkansas-Red River project, with a few suggestions for the Arkansas River portion. Figure 1 shows a map of the basin.

The Red River originates in New Mexico, crosses the high plains of Texas, and gathers flows from Oklahoma, Texas, and Arkansas and passes through Louisiana on its way to the Mississippi River. The portion of the Red River that concerns this study is located upstream of Lake Texoma. The natural chloride pollution occurs here in this area of the Red River Basin.

Ten salt source areas in the western portion of the Red River Basin (Figure 1) emit a major portion of the chlorides entering Lake Texoma. An average of 3,300 tons of chlorides per day enters Lake Texoma, of which about 450 tons originate in the Wichita River Basin, about 1750 tons originate in the remaining parts of the Red River Basin, and about 1,100 tons come from man-made (largely oil field

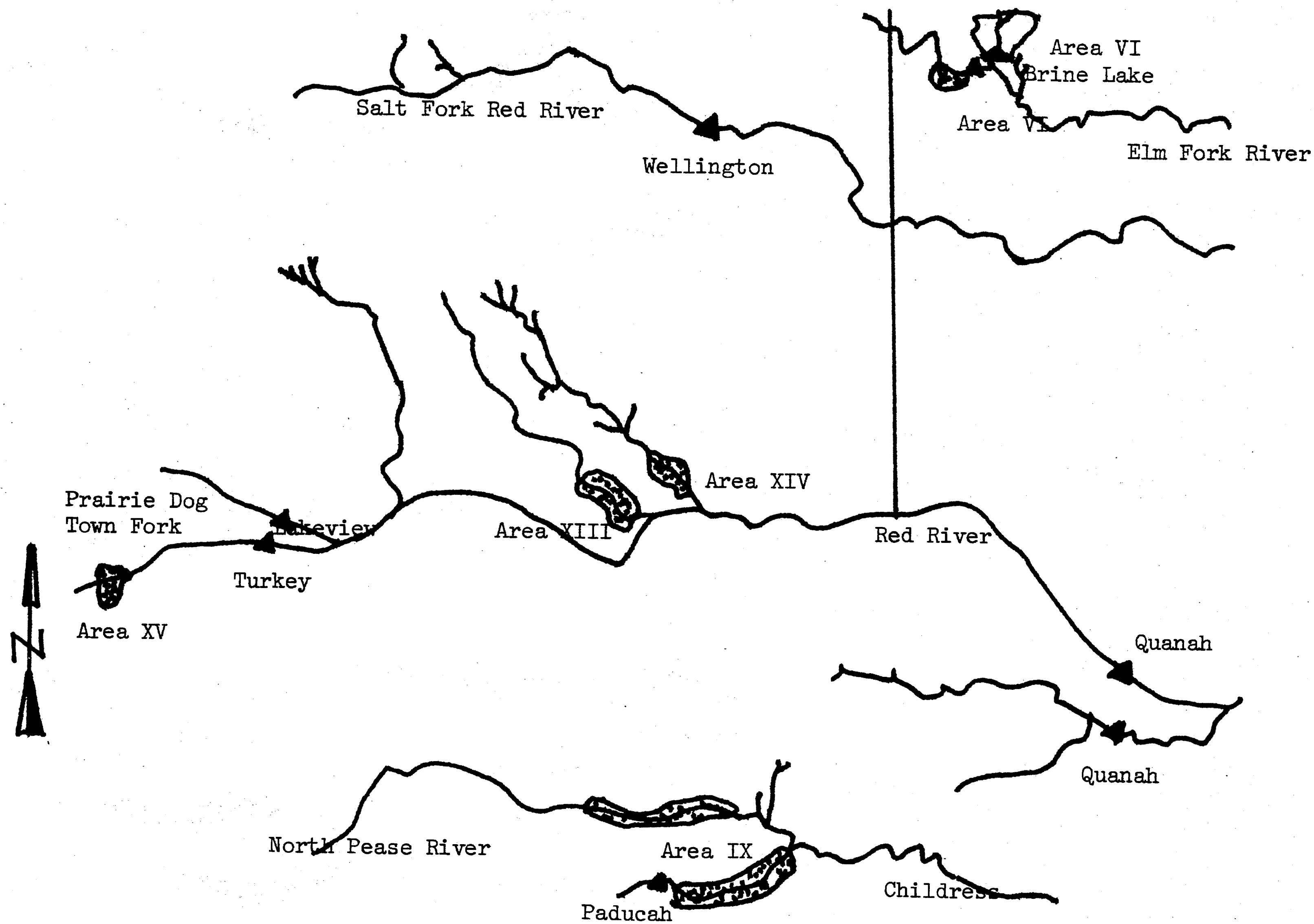


FIGURE 1. Source Areas.

activities) and minor natural sources of salt pollution.

Three of the ten salt source areas are located in the Wichita River Basin, which is the subject of a previous study. At another area, (Area V), the salt is being controlled by a circular dike constructed as an experimental project, and in still another area, (Area XI), control of the pollution was found not to be economically feasible (table 1).

Scope of Investigation

The study described in this thesis is to present the different methods or ideas of salt elimination that has risen. This study presents the thoughts of deep well injections as a method of salt elimination, brine reservoir, deportation, the use of plants, and ring dikes.

Desalination plants were considered, but were found to be practical only for small quantities of water. Importation of water from another basin for dilution of the brine was considered, but was found not to be economically feasible.

Study Objectives

The objectives of this study were:

1. To present the different methods of chloride elimination used to control stream pollution from natural sources to the degree that the concentration would not exceed an upper limit of 250 mg/l chlorides.
2. To control as much of the natural chloride pollutant as is practical near the source for the most efficient quality

improvement.

3. To prevent salt-water contamination of agricultural, industrial, and municipal water resources.
4. To improve the habitat for fish and wildlife conservation.

Table 1

Surface Water Criteria

Consistuents	Permissible Criteria	Desirable Criteria
Inorganic chemicals:	(mg/l)	(mg/l)
Ammonia	0.5	0
Arsenic	0.05	0
Chloride	250	less than 25
Iron	0.3	0
Lead	0.05	0
Manganese	0.05	0
Sulfate	250	less than 50
Total dissolved solids	500	less than 200
Organic chemicals:		
Cyanide	0.20	less than 0.04
Pesticides:		
Chlordane	0.003	0
DDT	0.042	0
Endrin	0.001	0
Heptachor	0.018	0
Herbicides:		
2,4-D plus 2,4,5-T, Plus 2,4,5-TP	0.01	0

TABLE 2

PROPOSED TEXAS STREAM WATER QUALITY STANDARDS FOR RED RIVER

	Stream Reach of Red River		Maximum Level of Constituent in mg/l		
	From	To	TDS	Chlorides	Sulfates
1.	Texas-Arkansas Border		1,100	375	250
2.	Texas-Arkansas Border	Lake Texoma	1,100	375	250
3.	Lake Texoma		1,500	600	300
4.	Head of Lake Texoma	Wichita River	6,000	2,000	1,200
5.	Wichita River	Pease River	10,000	5,000	2,000
6.	Pease River	Prairie Dog Town Fork	25,000	12,000	4,000
7.	Prairie Dog Town Fork		65,000	30,000	4,500

TABLE 3

ARKANSAS STREAM WATER QUALITY STANDARDS FOR RED RIVER

Stream	Constituent	Permissible Level - mg/l
Bayou Dorcheat	Chloride	250
Bayou Dorcheat	TDS	650
Crooked Creek	Chloride	350
Crooked Creek	TDS	650

TABLE 4
LOUISIANA STREAM WATER QUALITY STANDARDS FOR RED RIVER

Stream	Constituent	Permissible Level - mg/l
Red River - (Arkansas State Line to Three Rivers)	Chloride	250
	Sulfate	176
	TDS	780

CHAPTER II

ENVIRONMENT

Description of Basin

Physiography. The project areas (VI, IX, XIII, XIV, and XV) are located along the southwestern edge of the Osage Plains section of the Great Plains. The project areas are drained by various branches and tributaries of the Red River. These streams include the Elm Fork of the North Fork of the Red River (Area VI); the North and Middle Forks of the Pease River, a tributary of the Red River (IX); Jonah and Salt Creeks, tributaries of the Prairie Dog Town Fork of the Red River (Areas XIII and XIV); and the Little Red River, a tributary of the Prairie Dog Town Fork of the Red River (Area XV). The drainage of the project areas is to the southeast across a stretch of dissected rolling plains. Topographic relief ranges from low to moderate; some of the stream channels are as much as 100 to 300 feet below the level of the adjacent upland areas, but most are not so deeply incised. The region is in the late youthful stage of the geomorphic cycle. Downcutting by rivers prevails over valley widening in the smaller tributaries, where as valley widening is the dominant process along the major streams.

Geology. The rocks that outcrop in the project areas are predominantly marine sedimentary rocks of the Permian age. These rocks are mostly red to gray gypsiferous shale and mudstone with intercalated sandstone, dolemite, and gypsum beds. Where present, the resistant sandstone, dolemite, and gypsum beds forms mesas, buttes, and steep bluffs along valley walls. Remnants of Pleistocene terrace gravel of fluvial origin and lacustrine clay are found in several places, but are nowhere thick or extensive. Some recent alluvium is found as a thin veneer along valley floors. The Permian rocks belong to the Flowerpot, Blaine, and Dog Creek Formations of the Pease River Group and to the overlying Whitehorse Formation. The total exposed thickness of Permian rocks is estimated to be less than 300 feet. The Permian rocks are near-horizontal, with a slight westward dip. A few of the beds are somewhat contorted as a result of solution and collapse of evaporites. Local stratigraphy and topography control the occurrences of the salt seeps and springs. Salt is probably contained in several subsurface formations and solutioned out through groundwater movement.

Groundwater. Groundwater supplies in the area are usually brackish and contain varying concentrations of natural chlorides and sulfates. Some small quantities of fresh water are found in the recent alluvium in the stream valleys.

Climatology. The elevation of the projects areas ranges from 1,600 to 2,600 feet, with an average elevation of about 1,900 feet. The average annual precipitation is about 22 inches and most of this falls as rain during the months of May through October. The average annual snowfall is minor and does not materially contribute to the runoff. The temperature ranges from -13°F. to more than 119°F., with a mean annual temperature of about 63°F. The annual lake evaporation loss is around 60 inches.

Stream Characteristics. The drainage is in a southeasterly direction across an area of relatively low relief. The streams and tributaries are not deeply entrenched, except next to the High Plains escarpment to the west. In these areas, resistant dolemite and gypsum beds forms outliers, mesas, and prominent escarpments along the stream valley walls, which places the soluble gypsum and accompanying chlorides in direct contact with runoff waters. Rivers with sources in areas of steep slopes change from swiftly flowing to slow and sluggish streams as the slope flattens and the river meanders through wide alluvial valleys. During the extended droughts that are characteristics of this semiarid region, only major rivers maintain continuous flows. The Prairie Dog Town Fork of the Red River is frequently dry of surface flow in the western regions.

Flora

The vegetation associated with the Red River Basin can be separated into broad classifications, upland and bottom land. The project areas are located within the rolling plains biotic district where the major plant communities variously classified as either woodland, mixed shrub savannah, upland grassland and bottom land grass, juniper scrub, mesquite grassland savannah, mesquite thicket, and riparian vegetation types.

Woodland vegetation type. This vegetation type exists primarily on the escarpments bordering the level areas of the uplands and on steplike benches below steep ridges. It is underlain by soil classed in the badland type and in the cotton-vernon-acme complex. The vegetation is dominated by junipers. Commonly associated with the junipers are sumacs, mesquite, peabush, and condalia. The latter three shrubs are more common on the drier slopes. A relatively sparse ground cover of mixed grasses and forbs is interspersed among the woody species. Enclaves of locally abundant grasses are on some of the more nearly level benches. The common grass species are little bluestem, side-oats grama, hairy grama, and three-awn grasses. The areas occupied by this vegetation type have little agricultural value. The relatively small areas that support the locally abundant grasses provide some grazing value and provide a suitable habitat for wildlife.

Mixed shrub savannah vegetation type. This vegetation type occurs on gently sloping areas that are underlain by soils of the vernon-badland complex. These areas are usually adjacent to the steeper areas of the woodland vegetation type. Although these areas presently support a mixed shrub savannah, they seem to be suited to dominance by grasses under climax conditions. Disturbance by heavy grazing has apparently caused an increase in the number of shrubs, converting the climax grassland into a savannah disclimax. The shrub aspect includes junipers, mesquite, squaw bush sumac, condalia, and algerita. These shrubs are more widely spaced than those of the adjacent woodland vegetation type, and there is a greater proportion of the more xeric types such as mesquite and condalia. Also, those grasses, such as blue grama and side-oats grama, that decrease in cover with increased grazing pressure have been largely replaced by those grasses that increase under such conditions: Three-awns, tridens, tobosa, and buffalo grass. In addition, areas that have been severly overgrazed have been invaded by cacti, yucca, and various species of annual forbs.

Riparian vegetation type. This vegetation type occurs along the banks of the creeks that run through the area. It extends as a narrow band of vegetation parallel to the creek channels. Most of the trees and shrubs of the other vegetation types occur as components of the riparian community, but salt cedars seem to assume dominance here. Black willow, wolfberry, soapberry, hackberry, and mesquite complete the common woddy plant aspect. Cocklebur and ragweed are the most conspicous forbs.

Rare and endangered species. The Correll wild buckwheat, listed as "Scarce, endangered in Texas" by the University of Texas Rare Plant Study Center, is found in the area. This species is endemic to Texas and distributed in only a few counties throughout the area.

Fauna

Fishes. Streams throughout the area of influence are shallow low gradient watercourses with wide, flat sandy bottoms. The physical and chemical conditions of these streams do not favor the production of sport fishes. Channel catfish, white crappie, green sunfish, largemouth bass, and white bass furnish a limited seasonal sport fishing opportunity. Conditions are, however, favorable for the production of minnows. The abundance of several species of minnows is closely associated with different salinity conditions that occur. The Red River pupfish and plains killifish are most abundant in the shallow, highly saline streams. Areas of moderate salinity contain species such as the speckled chub, Red River Shiner, and emerald shiner. A substantial commercial bait fishery exists for minnows such as the Red River shiner, red shiner, and plains minnow. There are no endangered species of fish known to inhabit these streams, but the Red River pupfish is endemic to the western reaches of the Red and Brazos Rivers.

Birds. Bobwhite and blue quail, turkey, and dove are the most important game birds in the area. Despite the semiarid nature of this region, considerable numbers of waterfowl migrate through the general area. Ducks migrating through the area use farm ponds and stock tanks for resting and feeding areas. Sandhill cranes overwinter in the region and often use bottom lands along many of the streams. Many shore and wading birds are common. The southern bald eagle and American peregrine falcon are the only endangered wildlife species likely to occur as winter residents or migrants throughout the general area.

Mammals. Important game mammals in the area are the cottontail rabbit and the fox squirrel. Some whitetail deer also are found in the area. All of the mammals in the area are common species in the rolling plains area and there are no endangered species occuring in the project areas.

Amphibians. Amphibians species are not well adapted to the saline environment present in the area. Most of the species depend upon access to temporary waters, ponds, or lakes.

Reptiles. None of the reptiles occuring in the area are rare or endangered. Poisonous reptiles in the area include copperheads and various species of rattlesnakes. Rattlesnakes are especially common in the area.

Economic, Social, and Cultural Conditions

The study area consists of 10 counties - Cottle, Foard, King, Childress, Collingworth, and Hall counties in Texas, and Beckham, Greer, and Harmon counties in Oklahoma. These counties best represent the population, employment, and cultural trends adjacent to the study area and will be used as a basis for the social, economic, and cultural analyses. Between 1960 and 1970, the population of the study area decreased from 70,359 to 58,113, a loss of 17.4 percent. The 10-county study area population is projected to decrease until the year 2000 and to gradually increase past the turn of the century. The 10-county negative trend is caused by the decrease in employment attractions of the rural areas and is similar to projected rural trends in most of the United States. Agricultural production has been of significant economic importance in this area since settlement. All counties showed an increase in the number of farms between 1964 and 1969.

Land in farms and harvested cropland both increased slightly over the same period, while the market value of crops decreased 24.4 percent and the value of livestock and poultry increased by 138 percent. Major crops harvested in the study area in 1969 included cotton, wheat, sorghum, hay, and small grains. Projected trends for the study indicate, relative to state and national trends, that total personal income will increase at a slower rate. However, because of decreased birth rates, per capita income will increase at a faster rate.

The economic outlook for the 10-county area appears to be easy to discern. The economy is expected to grow at a slow rate, if at all. The economy is based upon agriculture. The economic benefits to be derived from agriculture will depend upon crop yield and the state of the national economy. There is little reason to expect a significant expansion in agricultural activity because much of the arable land is already in cultivation and the region has no abundant supplies of underground water which would permit additional lands to be placed under irrigation. The economy of the population centers in each county is nearly stagnant because there has been a continuous migration to urban areas outside the 10-county area for a period of about 40 years. This outward migration is largely due to the limited economic opportunity in the area. If this outward migration continues, retail sales and employment in each population center will be further adversely affected. There is no reason to expect any substantial growth in population in the area because there is no readily identifiable potential source of income to attract new residents or to persuade many of the young people to remain in the region. There is little likelihood that the region will attract industry, as it does not have the raw materials, labor force, market, or transportation facilities necessary. Tourism is not expected to increase substantially due to the geographic location and scenery of the 10-county area.

CHAPTER III

REVIEW OF LITERATURE

Several studies has been made on ways to eliminate salt from our water resources. The topics covered in this review are phreatophytes and spray systems - a method of increasing water evaporation.

Phreatophytes

Phreatophytes are plants that depends on the groundwater that lies within reach of their roots. Although not confined to the aris regions of the Western United States, their occurrence there is more common because of their effects on the water supply. Most phreatophytes have a low economic value, and consequently, the water they use and return to the atmosphere without any benefit to man is defined as consumptive waste.

Robinson (6) states that phreatophytes such as saltcedar, cottonwood, willow, and greasewood will consume several millions acre-feet of water annually. Because of their deep roots system and love for water, phreatophytes were used as a means of salt elimination.

Their is substantial evidence that phreatophytes utilize groundwater. Shallow wells has been setup to detect the fluctuation of the water level around these plants. The water level declines during the day when transpiration is greatest and rises during the night when transpiration is least.

Saltcedar and greasewood are examples of plants having a wide range of salt tolerance. These plants may be found associated with plants having a low salt tolerance but more frequently they occur where groundwater has a moderate to high salt content. Greasewood grows well in areas where the groundwater is high in sodium carbonate, which form black alkali. Saltcedar grows well where the groundwater is high in common salt (sodium chloride).

There are other phreatophytes that have a high salt tolerance, but the saltcedar grows in profusion in the Red River Basin.

Spray Systems

Brine ponds are designed mainly for the purpose of holding salt water for evaporation. The use of spray systems in brine ponds increases the water surface area with the air. Thus the evaporation rates are increased depending on the discharge through the spray nozzle.

Smoak (8) of the Water Conservation Branch designed a spray system using two lined ponds. Each pond was 100 feet square at the top and 5 feet deep with side slopes of 2:1; leaving an 80-foot square bottom. A continuous polyvinyl chloride liner was installed on the compacted and rolled pond subgrade and covered with 6 inches of backfill to reach the pond dimensions. The two ponds were made dimensionally equal.

A spray system was installed in the pond designated as the test pond. First, the system had six nozzles which produced a very fine mist that drifted away from the test pond. To reduce the formation of fine mist, the nozzles were replaced with a pipe tee such that two opposing nozzles was formed. From this arrangement the drifting mist problem was solved.

In Smoak's spray system, the evaporation rates increase ranged from 17.6 percent to 58.8 percent depending on the average spray discharge.

The problem Smoak had with the drifting mist is the reason this method is not planned for the Red River Basin. Drifting brine mist will only contaminate other water resources.

CHAPTER IV

METHODS OF ELIMINATION

In this chapter alternative methods of chloride elimination in the Red River Basin will be presented. The topics to follow will discuss the procedure of elimination, cost, benefits, and the effects upon the environment.

Deportation

General plans were made for a pipeline to the Gulf of Mexico which consisted of collection system at the salt areas and a disposal system which would transfer the collected brine to a main trunk pipeline that would have intermediate pumping stations to maintain pressure to the Gulf of Mexico. The length of the pipeline would be approximately 480 miles, with a total of 52 pumping stations. The energy required to pump the brine would be extremely high, since the pipeline will cross the State of Texas to the Gulf of Mexico, just south of Freeport, Texas.

This plan would utilize one or a combination of the following collecting systems depending on the source area: subsurface cutoff walls, wellpoints, low flow dams, or shallow wells. The brine carried by this pipeline would be collected from the following areas in the Red River Basin: Areas VI, VII, VIII, IX, X, XIII, XIV, and XV.

The pipeline would be reinforced concrete, lined with a protective coating that is inert to brine. The pipeline size would vary from 12 to 84 inches in diameter. This plan called for a total of 84.5 c.f.s. (42,250 g.p.m.) to be collected and transported through the pipeline to the Gulf.

The pumps at each station are designed to boast the pressure in the line when the velocity drops below 1.5 f.p.s. and are sized to pump the peak flow at that particular point in the pumping system. An additional pump of equal capacity is included in each station for standby use and use during peak flow conditions. The pumps include variable speed drives to adjust the pumping capacity to the amount of brine. The pump stations are 20 square feet buildings with reinforced concrete walls, electrically driven motors, and motor control panels.

In the route selected there would be 28 river crossings, 70 highway crossings, 21 railroad crossings, and 120 creek crossings. The highway crossings would be bored and would consist of a steel liner and transmission pipe.

The pipeline to the Gulf would have a first cost of one billion dollars and an annual cost of seventy-one million dollars. Disposal of brine in the Gulf would effect the marine communities located along the coast. This would cause a reduction in the yield of marine life, accompanied by diminution in recreational use of the Gulf.

Because of the excessive cost and potentially serious environmental impact, the pipeline to the Gulf of Mexico is not considered a feasible solution to the problem of chlorides in the Red River Basin.

Importation of Water for Dilution

A plan for importing water for dilution of the brine consist of a series of dams and canals in the river basins where water would be of high quality to justify its being pumped upstream to be used solely as mixing water.

One alternative of this plan would consist of importing water to Lake Texoma. Dams would be constructed downstream and pump stations and canals would be used to transfer the water to Lake Texoma for dilution. The greatest disadvantage about this plan is that the people downstream of high quality tributaries do not want to give up their water for dilution of brine in Lake Texoma for use elsewhere. If this plan was selected, certain political arguments would follow over whose water would be transported upstream, how it would be used, and who would pay for the transportation. There would be a problem of selecting an agency or political subdivision to set up the mechanism whereby water could be transported across basins for dilution purposes.

Another alternative would be to construct fresh water lakes upstream of Lake Texoma to store water that would be released to dilute the brine flows. Adequate damsites are difficult to locate because of foundation conditions. In addition, high evaporation rates would make it practically infeasible to build such a system of lakes. The major problem with this plan is the lack of a reliable water source for the lakes. The estimated annual water required to be imported for upstream fresh water lakes would be about 100 million acre feet a year. The cost would be in excess of one hundred dollars an acre feet. The annual cost would be approximately 22 million dollars. Importation of out-of-basin water would be highly controversive because of transbasin laws by the State of Oklahoma, Texas, Louisiana, and Arkansas. Since a Red River compact has yet to be consummated among the four states, importation of water from downstream fresh water sources would be an unrealistic answer to solving the problem of brine in the Red River waters originating in the upper basins. Importation of fresh water from the Mississippi River would be even more costly.

Since all estimated costs are excessive and political implications prohibitive, a plan of importation of water for dilution purposes is considered to be a nonviable plan.

Brine Impoundment

Brine impoundment consisted of a dam which is built to impound the brine water and to serve as an evaporation lake. The upstream side of the dam would be protected by a layer of soil cement and the dam would be made of imperious earthfill.

The brine water for impoundment would be pumped from a collection system. No other flow will be permitted to enter the reservoir except rainfall that falls on the damsite. The collection system would be a subsurface cutoff wall, low flow dams, wellpoints, or shallow wells. All pipes used would be either protected against corrosion or corrosion resistant. Each pumping station would have a backup pump.

The brine reservoir would be designed to maintain the maximum possible control of chlorides with a minimum loss of water and to impound a 100-year flood event after 100 years accumulation of brine and sediment.

Total Impoundment

The plan of total impoundment consists of a brine dam which would be located on the stream below the chloride source area and would completely impound all brine and fresh water flows above the dam site. The dam would be sized to retain an accumulation of 100 years of runoff and a 100-year flood. This plan is more economical for area XV, which is located several miles upstream from the other areas.

Deep Well Injection

Brine water would be pumped from a collection system to a station for preinjection treatment as required. Deep wells would be drilled into a geological formation in the area known to possess suitable porosity, permeability, and storage. The treated brine water would then be disposed of by pumping it down the well. Because of the geological formation in the Red River Basin this process is still one of the methods under study.

Desalination

Desalination is the chemical removal of salt from water to make the water useful for drinking and other purposes. It is accomplished by ion-exchange materials selected for the specific need. Salty water can be made as pure as distilled water; the process, however, is not economically competitive with destillation.

DESALINATION COSTS

5.0 MGD DESALTING PLANT

MAXIMUM ALLOWABLE TDS = 5000 mg/l

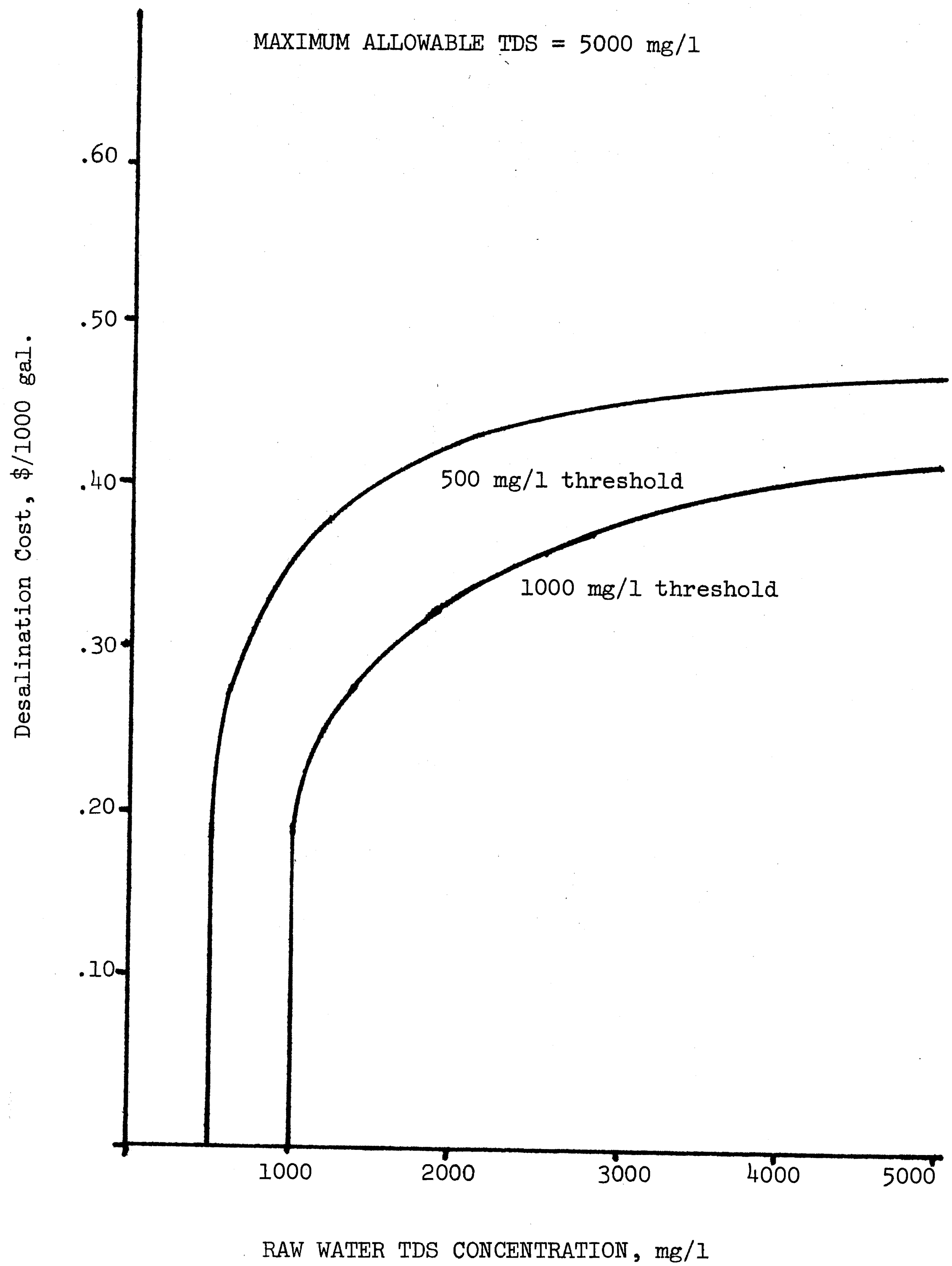


FIGURE 2

Several emergency desalting equipment has been developed by the United States armed forces to convert sea water into drinkable water for men who have been shipwrecked or forced down at sea. The equipment is provided in lifeboats, life rafts, and survival kits.

Ring Dike

A ring dike is generally for a site that is an individual brine spring. At source Area V this method was used. A circular earth dike with an impervious core down to film rock and containing a concrete outlet flume was constructed around the spring. Hydrostatic pressure was imposed on the spring by inserting stoplogs in the flume and 5 feet of backhead appears to have contained the brine flow.

Collection Systems

Subsurface cutoff wall. This system consists of a concrete cutoff wall down to bedrock, with a perforated collection pipe and lateral infiltration lines. The infiltration lines are set in a select filter bed which is located upstream and situated so that the drain pipe would flow by gravity to a sump. The brine would be pumped from the sump through a pipeline system to the disposal area.

Low flow dams. Low flow dams would channel the creek flow through a restricted area in the streambed. The brine would be impounded behind the low head dam and would be drained into a sump and pumped to a disposal system. The low flow dam would have a deflatable dam in the weir section which would allow floods to pass unimpeded.

Well points. Wellpoints consists of a system of well points designed to collect the subsurface brine from each collection point in the riverbed by suction and then pump the brine to a sump through a collection header pipe. Each wellpoint system consists of 215 wellpoints, and the number of wellpoint systems for a plan varies with the level of control desired. From the sump, the brine would be pumped to the main line going to the disposal facility.

Shallow wells. This system consists of drilling a specified number of wells. The location of the wells would be confined geographically to the salt emission areas and spaced about 250 feet apart, depending on the rock aquifer and alluvium characteristics. Each well would have a corrosion resistant well casing and submersible pump for collecting the brine flow in the top of the bedrock and remote motor controls on the surface. Each of the wells would be drilled so that the pump would be 5 to 10 feet into the bedrock. Brine from the wells would be transported to a sump and from there pumped through a pipeline to the disposal system. This system would capture the brine at each salt area before the brine water flows to the surface or enters the alluvium, thus preventing the formation of large salt deposits in the form of salt flats. Because the brine is collected at the emission source in a concentrated state prior to dilution by streamflows, pumping and storage requirements are reduced.

CHAPTER V

DATA PRESENTATION OF RED RIVER AREAS

BASIN RESULTS

Area VI

The three major chloride sources of Area VI are Salton, Robinson, and Kiser Canyons. They are narrow canyons with high brine concentrations and low average flows with the emission points confined to a small area. Those conditions are favorable for efficient collection of brine in a subsurface system. Therefore, subsurface collection in the three canyons, with a supplemental pickup system on the Elm Fork River to collect brine originating above the canyons and along the canyon walls of the Elm Fork, is the recommended collection system at Area VI.

The Fish Creek Brine Lake is the recommended disposal system at Area VI. Some questions exist regarding disposal of brine by deep well injection that have not been fully resolved. The well would have to be designed such that the brine effluent would be confined to the disposal horizon and fresh water supplies (usually near the surface) would not be jeopardized. There is some degree of uncertainty as to long-term projections regarding the storage capacity of the disposal zone. Computations are based on conditions

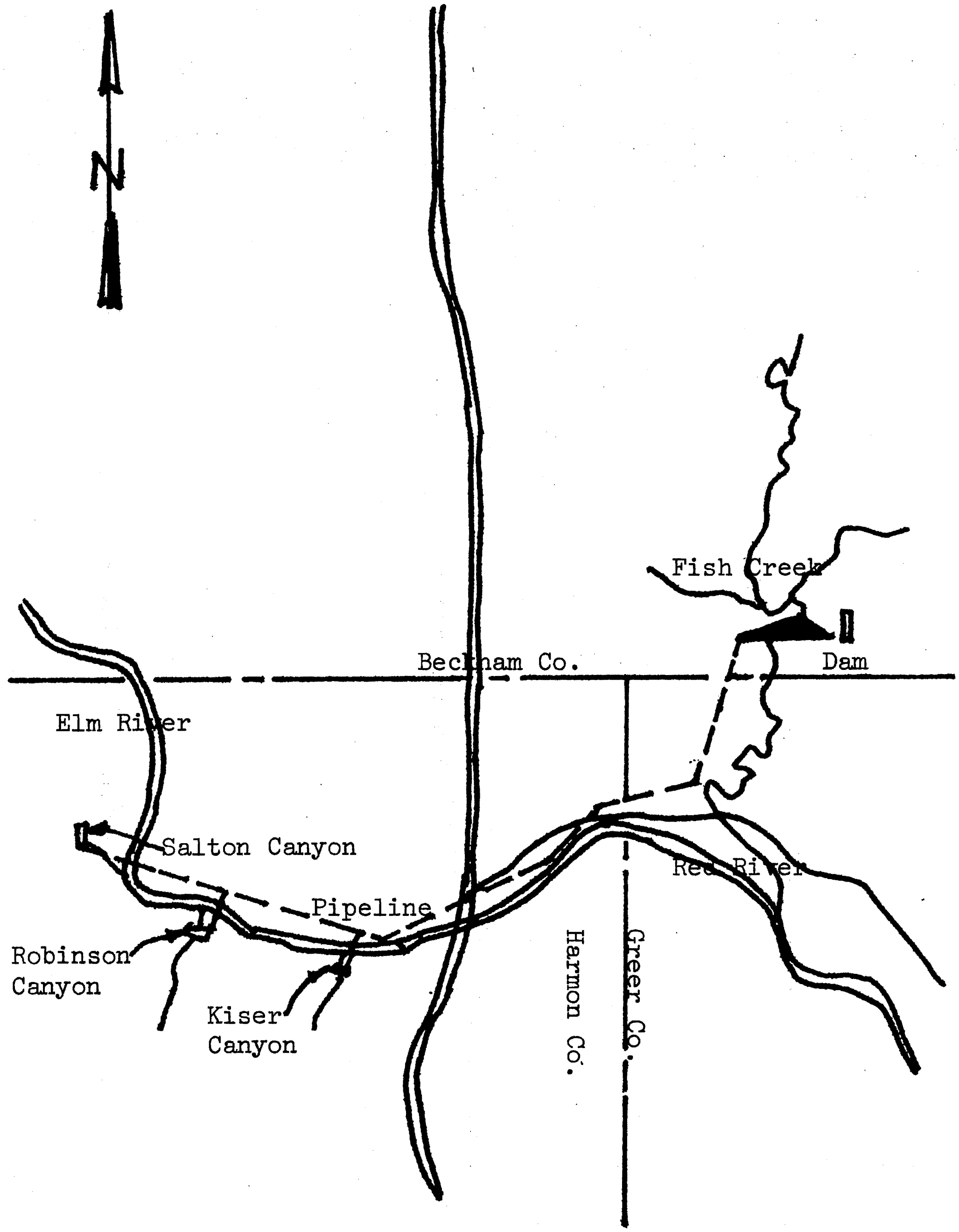


FIGURE 3. Area VI Plan

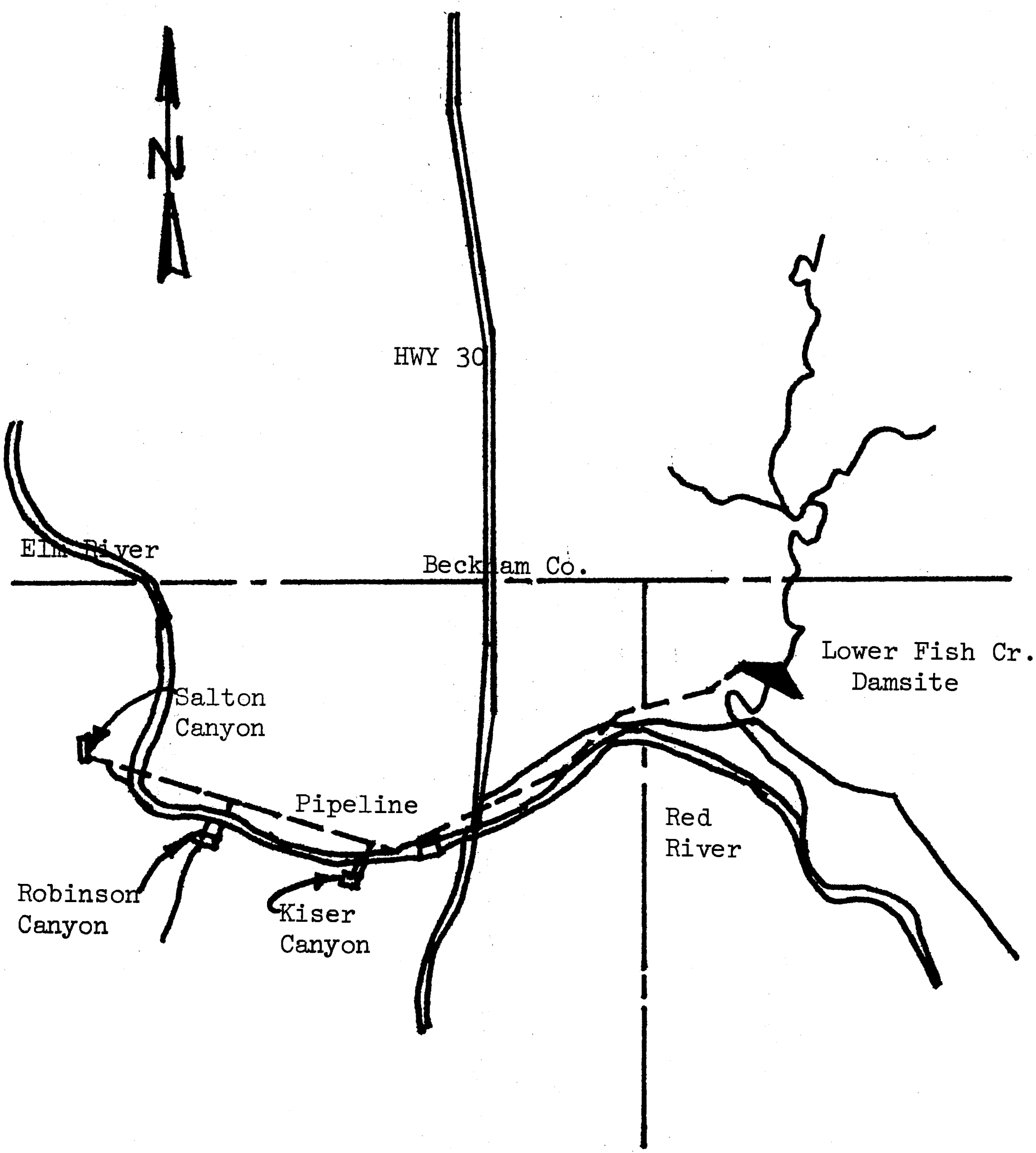


FIGURE 4. Area VI Plan B

Lower Fish Cr.

Damsite.

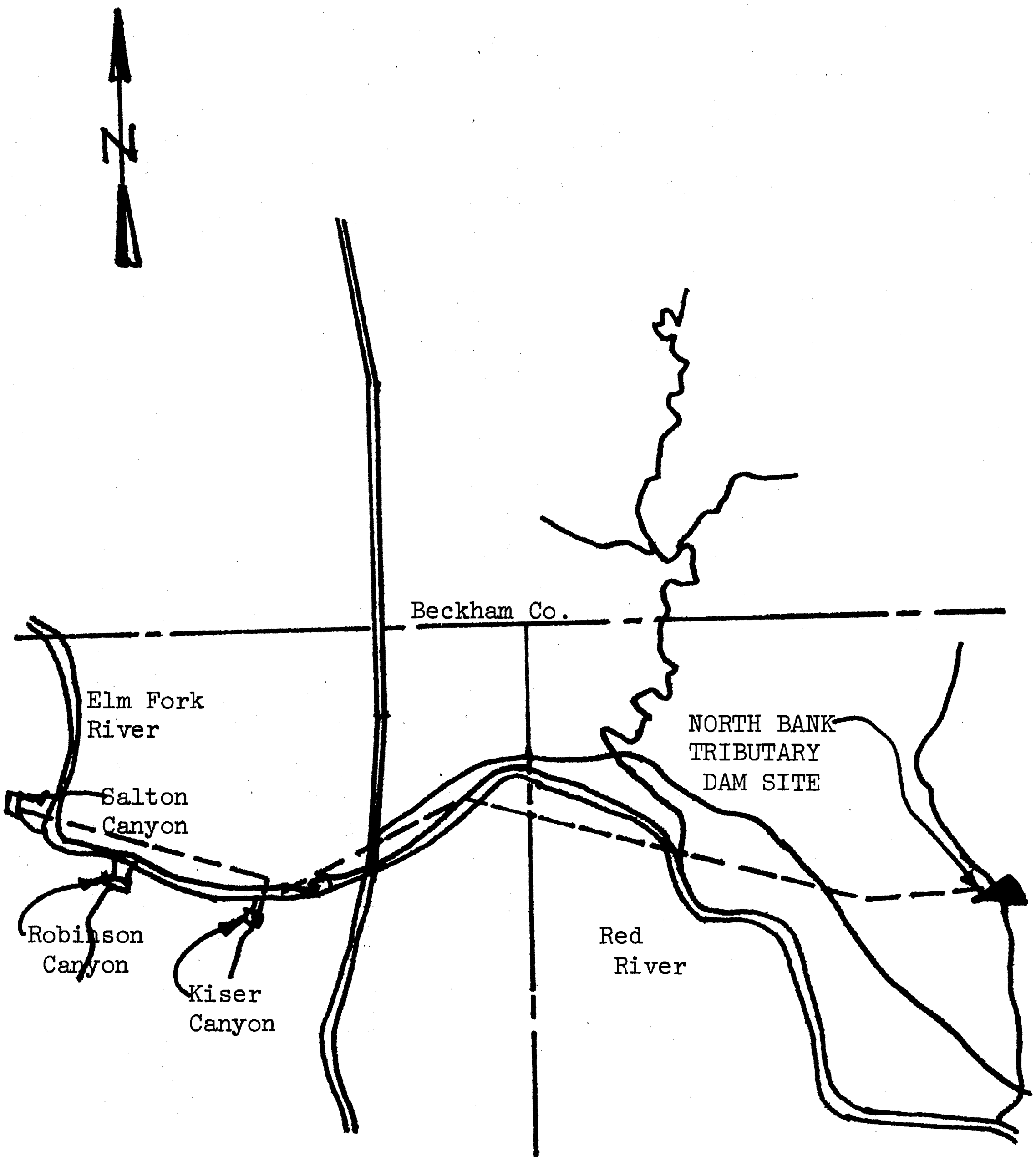


FIGURE 5. Area VI Plan C

North Bank Tributary Damsite

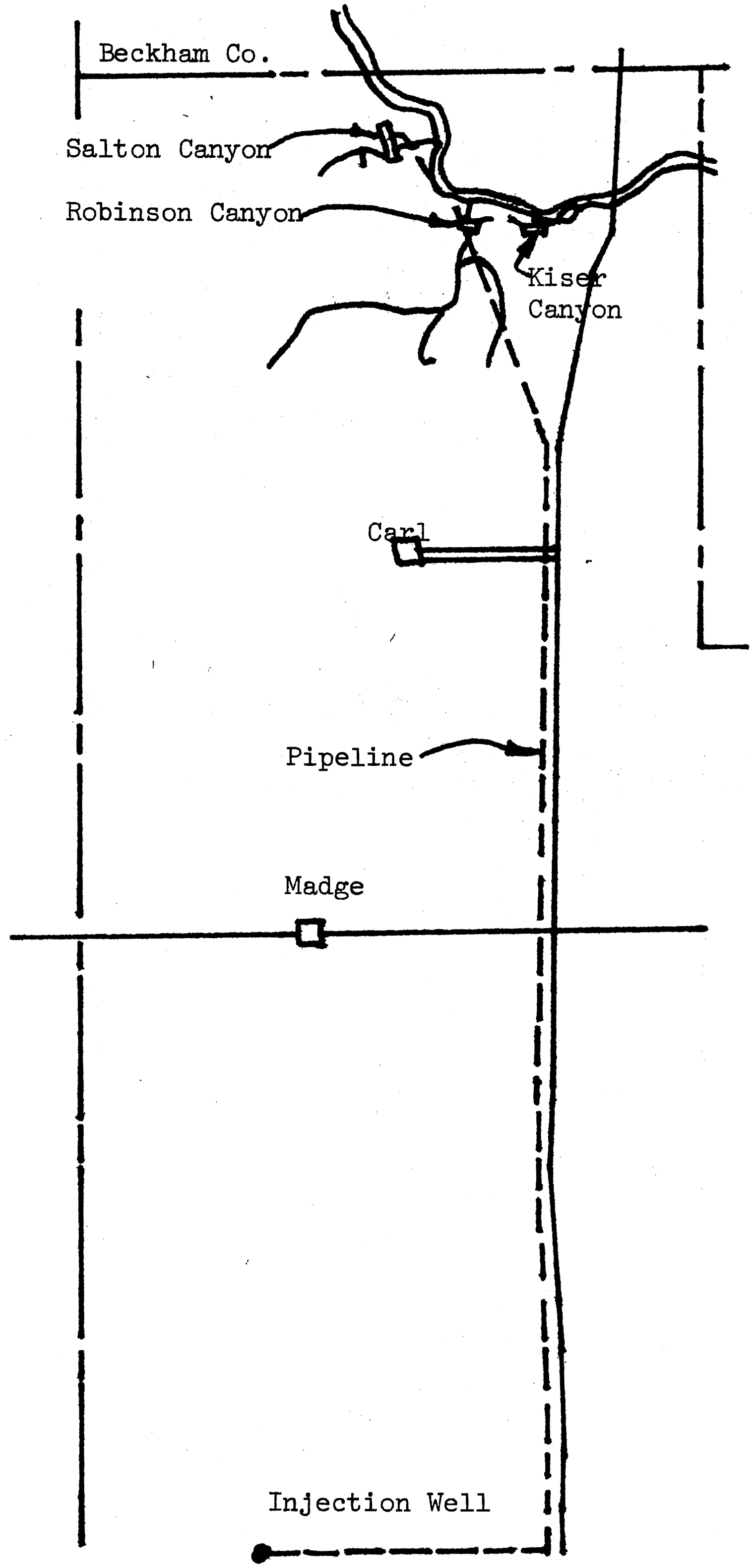


FIGURE 6. Area VI Plan D.
Deep Well Injection

found at the well bore and data from exploratory wells drilled in the project vicinity. However, the geologic formations evaluated as disposal zones may not be uniform over a wide areal extent. Such a change in uniformity would affect projections made for long-term reservoir storage. Experience in oil field practice shows that disposal wells occasionally require an increasing frequency of treatments (acidizing); sometimes to such an extent that drilling a new well is required. For these reasons, the Fish Creek Brine Lake is recommended for brine storage. The Fish Creek site should provide geologically competent foundation conditions relatively impervious to brine seepage.

Area IX

A shallow well collection system is the recommended plan for Area IX. The four collection systems considered were subsurface cutoff wall, wellpoints, a low flow dam, and shallow wells.

Subsurface cutoff wall is suitable where significant brine flows travel through the alluvium. However, alluvial ground water studies indicate that underflow in the alluvium at Area IX is not significant. For this reason, and because wide stream channels created high costs and construction problems, this collection method was not considered further.

The wellpoint system employs a screened piping network for collection of surface and subsurface flows. Supplemental studies conducted, using metal wellpoints which were installed by jetting, were frequently hampered by screen openings becoming clogged with fine particles and mineral deposits. This problem can be alleviated by changes in the design; however, the use of wellpoints as the major collection system was dropped from further consideration at Area IX because of the limitations of suction lift and the amount drawdown required to prevent formation of salt flats.

Low flow dams are best suited for streams with relatively narrow channels, 30- to 80-foot wide. The North and Middle Pease Rivers which have channel widths ranging to several thousand feet make this an unsuitable alternative. In addition, poor geological conditions at the site would create design and construction problems. For those reasons, low flow dams were eliminated from further study.

The shallow well system would not be affected by the problems mentioned above the the other collection systems. The shallow well system was selected as the collection system to be combined with the brine dam in Area IX for the following reasons:

1. Salt flats build up large quantities of salt that are later flushed downstream as a result of rainfall and runoff and can be eliminated by this collection method. The large salt flats occur at major emission points as a result of brine aquifers discharging salt water into the alluvium. The brine is drawn to the surface by capillary action where the water evaporates, leaving extensive salt crusts. Shallow well collection would capture the brine before it reaches the surface to evaporate or flow downstream, thus allowing relatively fresh water to flow over the area uncontaminated.

2. In addition, pumping rates would be reduced and made more uniform since only the concentrated brine from the emission sources would be collected and pumped.

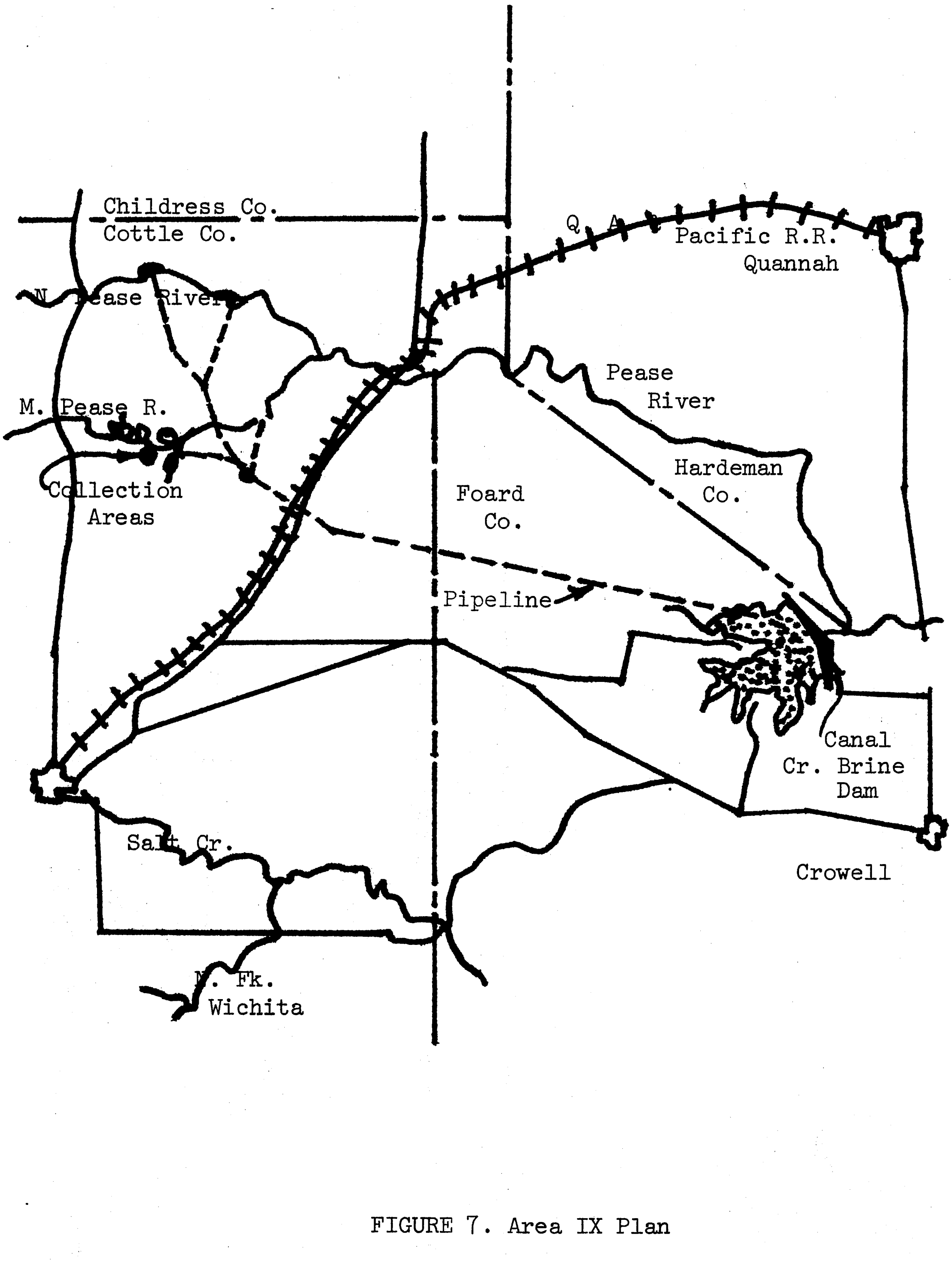


FIGURE 7. Area IX Plan

Plan A - Subsurface Collection with Brine Dam at Canal Creek

Plan C - Well Points with Brine Dam at Canal Creek

Plan D - Low Flow Dams with Brine Dam at Canal Creek

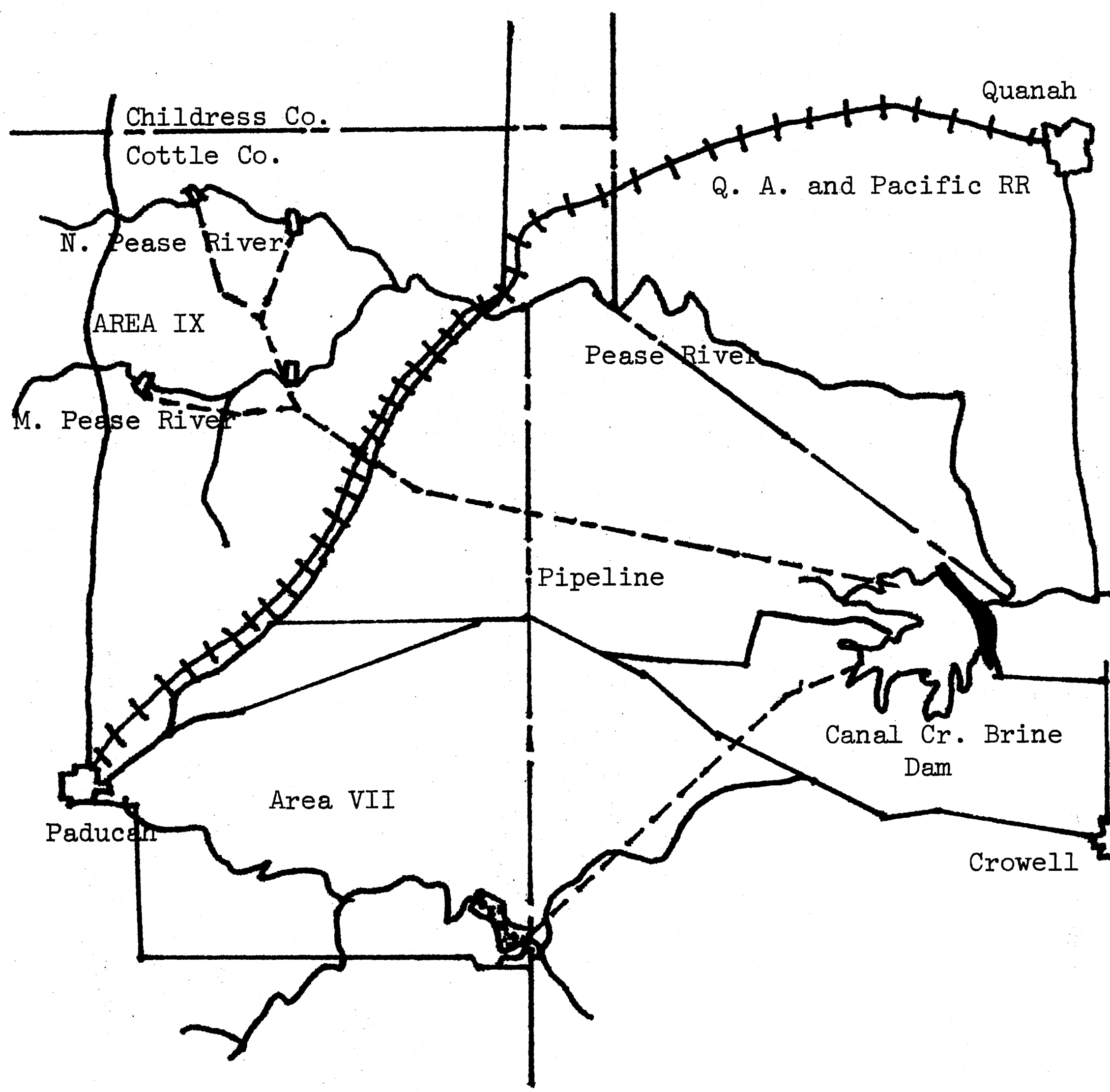


FIGURE 8. Area IX Plans A, C, & D

3. Finally, less storage space would be required in the brine lake because the brines collected would be more concentrated.

Construction of Crowell Brine Lake on Canal Creek for control of chlorides in the Pease River would be the most feasible disposal system for Area IX. Local interests have expressed support of the brine lake for its potential recreation and flood control.

Areas XIII-XIV

The collection alternatives for Areas XIII and XIV would be the same as those studied for Area IX, and for the same reasons the shallow well system is the most feasible.

Crowell Brine Lake is the recommended disposal system for Areas XIII-XIV. In selecting a disposal alternative, deep well injection was eliminated because of the high volume of flow and the relatively low concentration of brine; in addition, high volume flow rates could exceed the estimated storage capacity of the subsurface formation within the proposed project life. Construction of a brine dam is then the only remaining alternative disposal system. A brine dam located on Dry Salt Creek was eliminated because of uncertain foundation conditions. In addition, a minimum number of brine lakes is generally favored because of the adverse effects their construction has on the environment in loss of productive agricultural land, potential degradation of adjacent ground water supplies, loss or degradation of wildlife bahitat, and loss of vegetation. Although the Crowell Brine Dam on Canal Creek was originally designed to store for the brine from Areas XIII-XIV exists at this site. Therefore, brine disposal at Crowell Brine Lake for Areas XIII-XIV

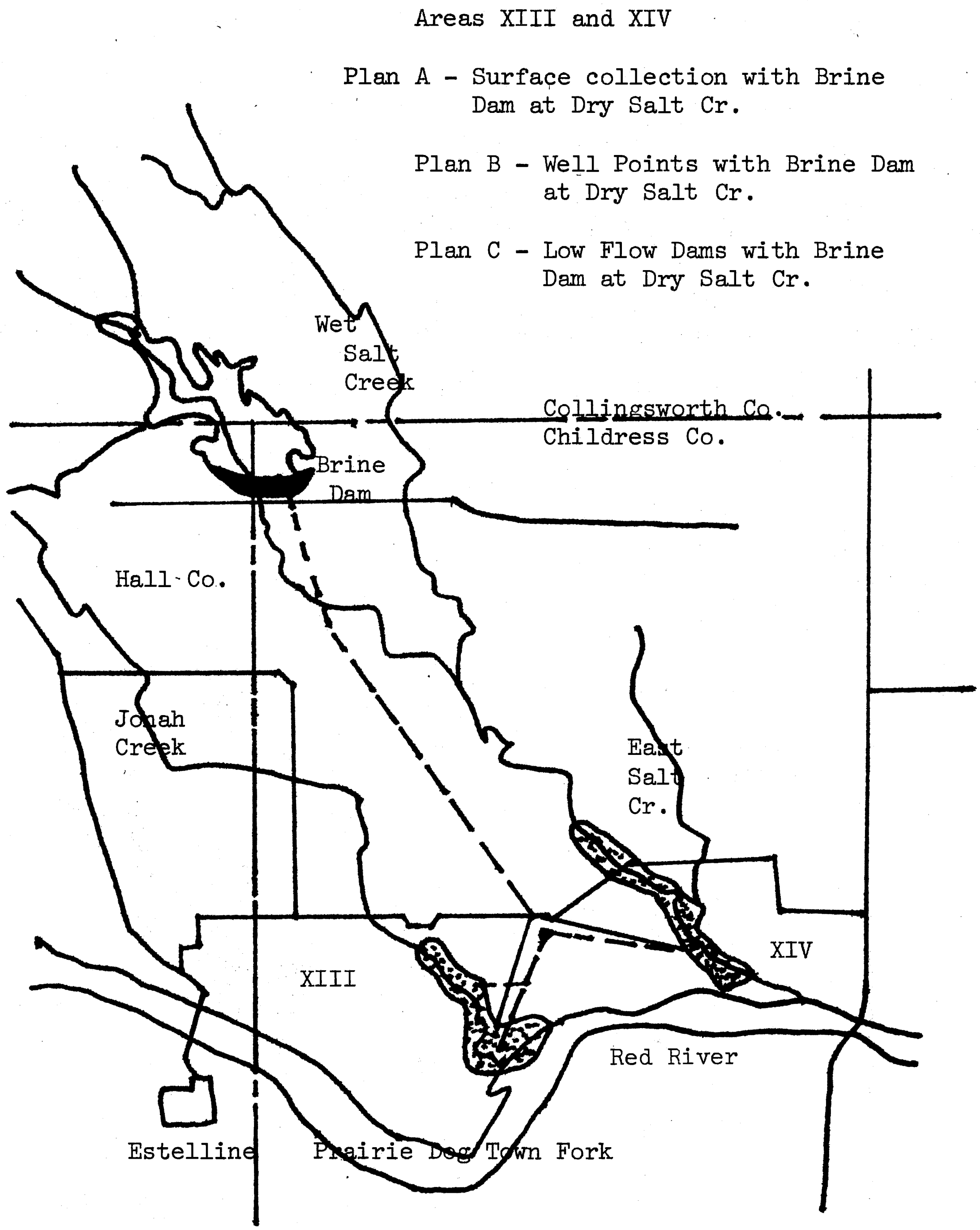


FIGURE 9. Areas XIII & XIV Plans A, B, & C.

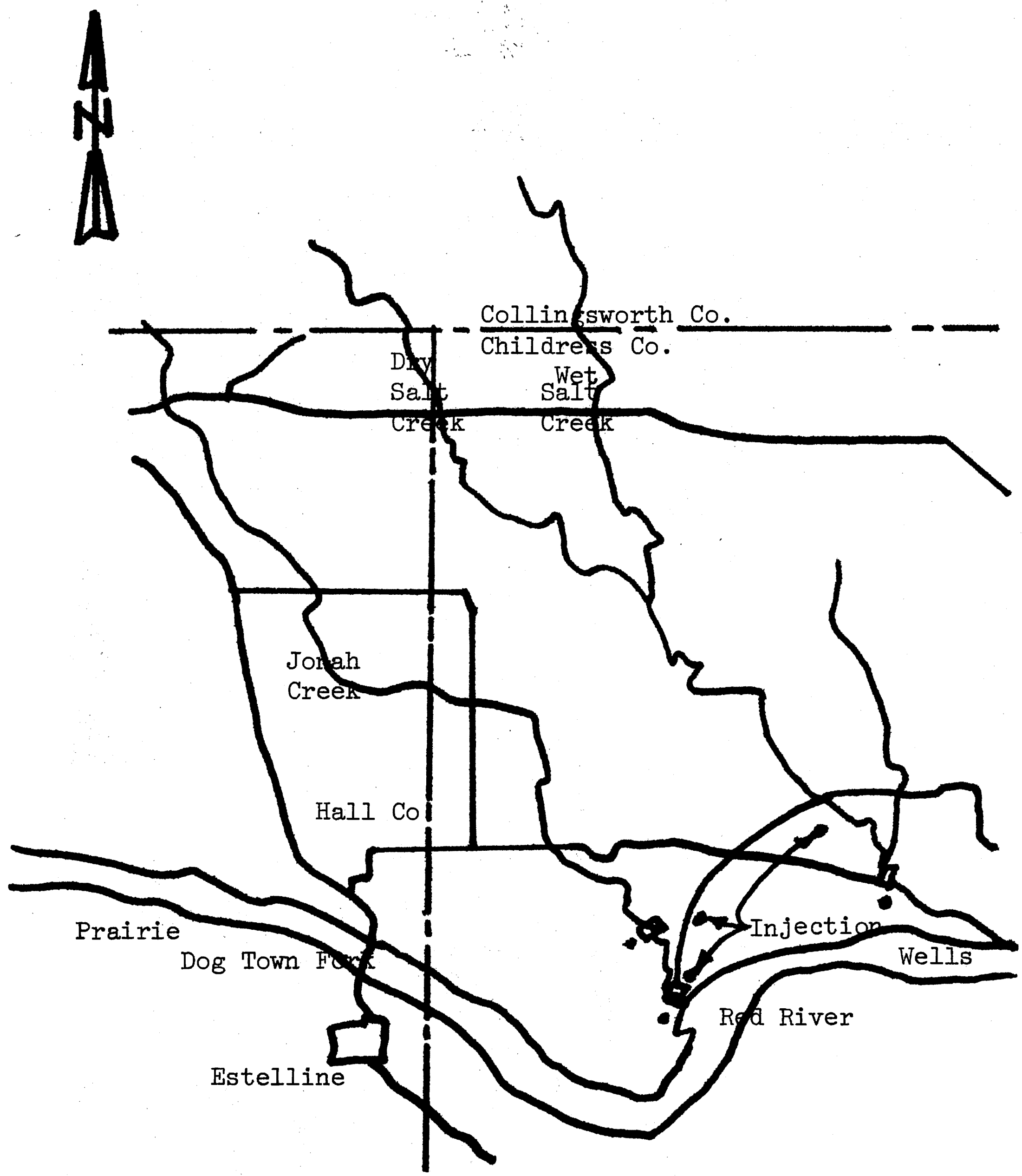


FIGURE 10. Areas XIII & XIV Plan D

Deep Well Injections

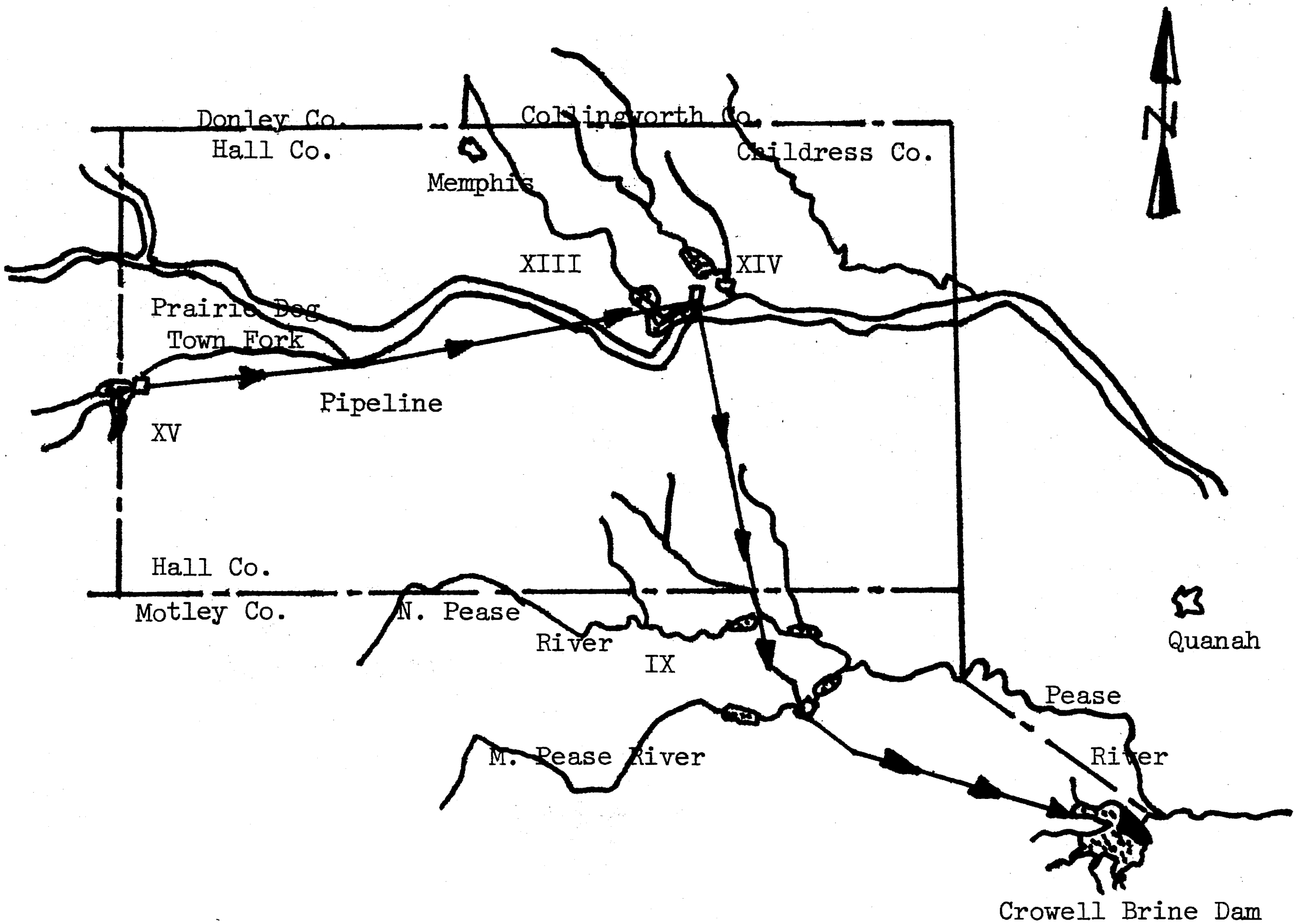
rather than the construction of another lake is preferable and is recommended for further study.

Area XV

For the same reasons as mentioned for Area IX, shallow wells were chosen for the collection system here. In addition, a subsurface cutoff wall was added downstream from each source area to collect any alluvial flow which might bypass the shallow.

Crowell Brine Lake is selected disposal plan for Area XV. Geological formations in the Little Red River area do not favor construction of a brine dam since bedded gypsum existing in the proposed brine storage area presents a leakage problem. Because relatively little is known about subsurface geological conditions in the area, deep well injection was eliminated. Brine storage in Crowell Brine Lake was studied for offsite brine disposal and proved to be the best disposal alternative for Area XV. Therefore, brine storage in Crowell Brine Lake and collection by shallow wells were selected to be considered in the optimization studies.

FIGURE 11. Areas XV Plan and
XIII - XIV Plan



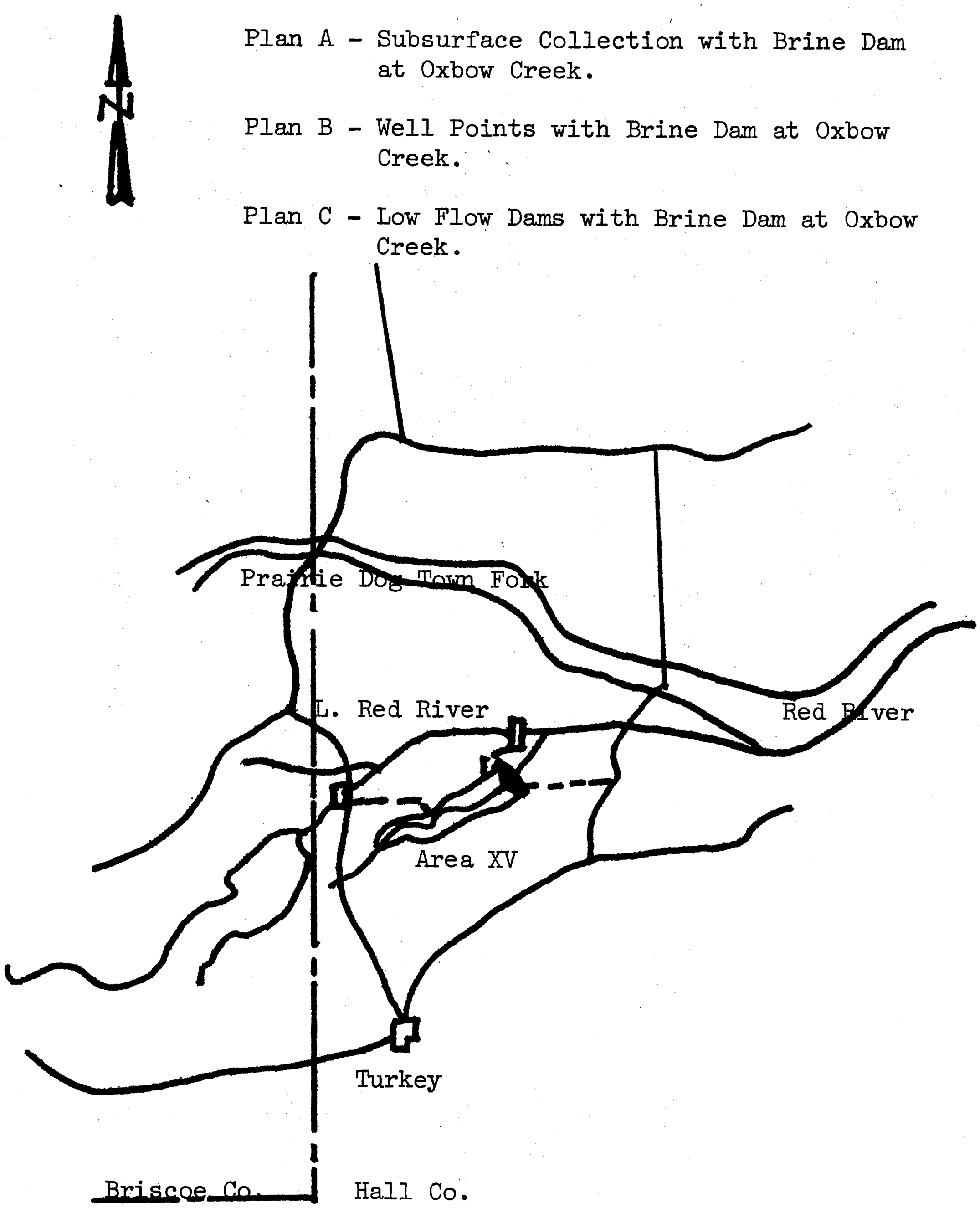


FIGURE 12. Area XV Plans A, B, & C.

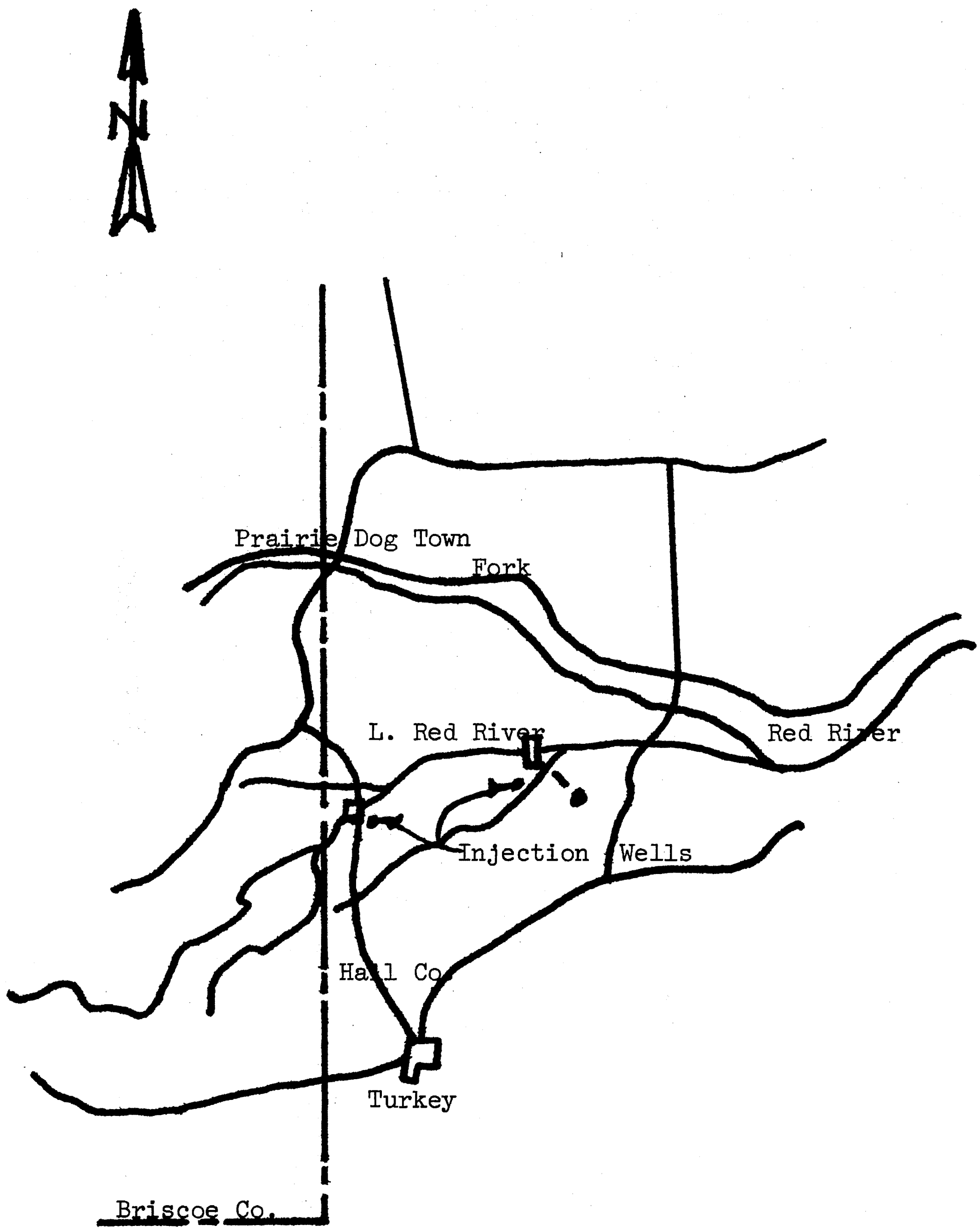


FIGURE 13. Area XV Plan D Deep Well Injection.

CHAPTER VI

SUMMARY AND CONCLUSIONS

Summary

A number of alternative plans were developed to control the salt pollution. These plans include a pipeline to the Gulf of Mexico, desalination, importation of water for dilution, and local collection and disposal systems. The plans are summarized in the following paragraphs.

A pipeline could be used to transport the collected salt from a collection point to the Gulf of Mexico. However, the plan would be too costly, have high energy requirements, and cause adverse environmental impacts along the route and to coastal marine life in the Gulf.

Desalination plants were considered, but were found to be practical only for small quantities of water. Because of the large volumes of water and high concentrations of chloride involved in this instance, desalination is not a competitive plan. Costs for desalination are high, ranging from 50 cents to one dollar per thousand gallons, excluding the cost of a collection and disposal system.

Importation of water from another basin for dilution of the brine was considered, but was not economically feasible. In addition, because of the number of political entities involved, interbasin transfers of water have many political and legal constraints related to water rights.

The most practical and economical methods of controlling the natural salt pollution is to capture and contain the brine as near the emission source as possible. The various collection and disposal systems are subsurface cutoff wall, which would capture brine flows migrating through the alluvium. Physical features would include a cutoff wall with a collection pipe and lateral collecting lines. The brine would be collected in a well and pumped to a disposal system.

Shallow wells, which could locate in the salt emission areas, would collect the brine flows in or near the bedrock and pumped through a pipe system to the disposal system.

Total impoundment would serve a dual function of collection and disposal. A dam capable of retaining all the salt-laden flows and other runoff expected to accumulate in the next 100 years would be constructed downstream of the emission areas. The brine disposal lake is similar to the total impoundment plan. However, the lake receives the brine from a separate collection source usually remote from the disposal site. The brine is pumped into the brine pool for disposal by evaporation.

Deep well injection could be used for disposal after treating and filtering the brine water. The deep wells would be drilled into a geological formation suitable for brine disposal. Use of this method of disposal would be dependent upon finding an adequate geological formation

Conclusions

Area VI. Because the three chloride sources are located in narrow canyons, a subsurface collection system was used with a supplemental pickup system on the Elm Fork River to collect brine originating above the canyons and along the canyons walls.

Area IX. Shallow well system was used here for the following reasons:

1. Salts flats build up large quantities of salt that are later flushed downstream as a result of rainfall and runoff and this can be eliminated by this method. The large salt flats occur at major emission points as a result of brine aquifers discharging salt water into the alluvium. The brine is drawn to the surface by capillary action where the water evaporates, leaving extensive salt crusts. Shallow well collection would capture the brine before it reaches the surface to evaporate or flow downstream, thus allowing relatively fresh water to flow over the area uncontaminated.
2. In addition, pumping rates would be reduced and made more uniform since only the concentrated brine from the emission sources would be collected and pumped.
3. Finally, less storage space would be required in the brine lake because the brines collected would be more concentrated.

Areas XIII-XIV. Shallow wells were also used for these two areas. The reasons for this are the same as those given for Area IX.

Suggestions for Future Study

1. Instead of a brine storage for 100 years, use a brine storage for 10 years with a regulated discharge valve. A pipeline connecting the brine pond with the river below Lake Texoma. During high flows discharge the brine into river at a regulated amount, but keep the chloride load in the range permissible.
2. A study using phreatophytes and brine ponds.

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