PART II

Area VIII Chloride Control Project

DESCRIPTION OF AREA VIII

Area VIII is located on the South Wichita River about 5 miles east of Guthrie, Texas, near the center of King County, Texas; and is about 4 miles north of the U.S. Highway 82. The terrain is typical for the area with steep valleys and rugged gypsum hills. Six separate springs in this area produce an average daily chloride load of 195 tons/day at approximately 2 cfs.

The selected plan for Area VIII calls for two low-flow collection dams on the South Wichita River. One dam (Bateman Dam), already completed at river mile 74.9, consists of a 5-foot high deflatable weir. The weir across the existing stream channel impounds a pool to facilitate pumping and deflates during periods of high flows. The brine is transported by the Bateman Pump Station via 23 miles of pipeline to Truscott Brine Lake for disposal. Truscott Brine Lake has an earthfill dam located at mile 3.6 on the Bluff Creek tributary to the North Wichita River. The lake has 116,200 acre-feet storage capacity. The second brine collection structure, if needed, would be located at river mile 61.5. According to design plans a pumphouse (Ross Pump Station) will be built to pump brine to Truscott Brine Lake, if warranted. The data used in the study by the panel was taken at three USGS gaging stations on the South Wichita River. One is located at Bateman immediately above the dam (Bateman Gage #07311782), one immediately downstream (Bateman Gage #0731183), and an additional gage 50.4 river miles downstream at the Highway 283 bridge (Benjamin Gage #07311800).

GEOHYDROLOGY

ORIGIN OF BRINES

During Permian time, the Texas Panhandle and western Oklahoma were in the central part of a broad shallow sea that covered much of the southwestern United States. Because of slow but continual sinking in the earth's crust beneath all parts of this inland sea, a thick sequence of red beds and evaporites (dolomite, gypsum, and salt) were deposited north of the major reefs and other carbonate deposits of West Texas.

Normal marine water entered basins in West Texas from the open ocean to the southwest, and after passing over the reefs it entered the shallow inland sea where evaporation of the water took place. Fresh water from land areas on the east and west mixed with the marine and saline waters; typically, sediments were deposited in the alluvial and near-shore environments, whereas the evaporites were deposited in the more central part of the inland sea, or the deeper part of the three major basins.

Permian shales, siltstones, and sandstones deposited in the region were derived by erosion of land areas on the east and west sides of the inland sea. Land areas on the east side of the sea included much of central and eastern Texas, eastern Oklahoma, and eastern Kansas; the principal source areas for sediments were probably the Texas and Oklahoma portions of the Ouachita Mountain chain and the northeastern Oklahoma and eastern Kansas portions of the broadly uplifted Ozark region.

Permian evaporites in the study region formed primarily as a result of evaporation of sea water. The concentration of dissolved solids in sea water was raised by evaporation until a series of "evaporite" rocks was precipitated on the sea floor. The typical cycle of evaporite precipitation from sea water begins with deposition of a carbonate (limestone or dolomite), followed by deposition of gypsum or anhydrite, and finally by deposition of salt (halite, NaCl).

GEOLOGY AND BRINE EMISSION ON THE SOUTH WICHITA RIVER

The South Wichita heads up in King County just west of Guthrie in the Whitehorse formation, then flows across a belt of Dog Creek shale to the source area where the river has cut through the Dog Creek shale exposing the Blaine formation at river level. Here the six major springs that contribute to the brine pollution are encountered, just upstream and downstream of the Bateman Ranch low-water crossing. These springs emit from the gypsums and dolomite of the Blaine formation. Several artesian aquifers, generally dolomites of the Blaine Elm Fork group, contribute to the poor quality ground water. The river flows through the steep valley and rugged gypsum hills of the Blaine and Flowerpot formations to a point just west of the Knox County line where the valley walls become less steep in a narrow belt of San Angelo sandstone. As the river begins its course across the Choza shale just west of Highway 283, the valleys widen and relief is less pronounced until its confluence with the North Fork in the eastern extremity of Knox County.

Ground water emitting to the surface by springs in the source areas is responsible for the natural brine pollution in the Wichita River system. The brine is primarily a sodium chloride type but does have a high sulfate concentration also. Tests on brines from the subsurface show a range from 5,000 to 30,000 Mg/L chlorides, and from 2,500 to 4,000 Mg/L sulfates. An exception to this was encountered in hole 4 on the South Wichita River which tested 169,000 Mg/L chlorides.

Stratigraphy, local structure, and topography control the occurrences of the salt springs. Several artesian aquifers, generally dolomites, transmit the water from a distant point of unknown origin to the points of emission, usually in the proximity of local structure and favorable topographic conditions. Brine emission from the springs accounts for the majority of the flows and chloride loads in the rivers. The deeply weathered rocks in the river courses provide the opportunity for some of the artesian aquifers to lose the formation water to the zone of weathering. This allows for dilution and recirculation of those waters with local ground water from the adjacent karst topography and surface waters.

The ground water in the flood plain alluvium is similar to those recirculated waters which migrate through the alluvium. Stratigraphy of the areas consists primarily of Permian shales and evaporites below the Whitehorse group and including the Dog Creek shale, the Blaine formation, the Flowerpot shale, the San Angelo sandstone, and the Choza formation. Total thickness of these formations is about 1,000 feet, with about 600 feet of the section represented by the Dog Creek shale, Blaine formation, and Flowerpot shale.

The principal artesian aquifers are found in the eight major dolomites of the Dog Creek shale and Blaine formation. These aquifers may be regional in extent since these beds occur over a great lateral extent and since preliminary studies in other areas in West Texas and Oklahoma indicate the same general phenomena along this belt. The origin of the brines is still problematical, but the pervious sandstones at the base of the Whitehorse group combined with sinks, dune sand, and alluvial pockets to the west of the Dog Creek-Blaine outcrop belt could serve as a topographically high catchment basin. The meteoric waters could then percolate downward through joints and fractures in the rock strata, eventually reaching a stratum or strata offering lateral transmissibility. Depending on the occurrence of halite, the water would take the salt into solution and due to the hydrostatic conditions the brine would then be forced laterally in the strata to its emergence in outcrop or to the deeply weathered subsurface zone. Since the investigations have been limited to the deeply weathered emission areas, no conclusive statements can be made as to the origin, other aquifer characteristics, or distinctions made between the aquifers in the deep subsurface.

In the source area, the principal springs emit from an interval below the Mangum dolomite in the upper Elm Fork group of the Blaine formation. Three principal aquifers are subsurface at this point, the Creta, Jester, and Gypsum Creek. Apparently most of these aquifers lose their flows to the weathered rock prior to outcropping farther downstream. No significant points of brine emission were noted downstream of the outcrop patterns of the dolomite, but alluvium sampling and the gage at Benjamin near Highway 263 shows some increase in total load, possibly from the Flowerpot-San Angelo belts.

In contrast to the ground water conditions in the Dog Creek-Blaine belt are the water table aquifers of the San Angelo and Choza formations. These formations are both relatively tight, and of the two, the Choza is the most impermeable. Therefore, where location and conditions allowed, this formation was exploited for pumping locations and reservoir siting. A few wells and wind mills in the area are developed in the San Angelo sandstone but are usually of low yield. Several seeps or low volume springs occur occasionally in the San Angelo. The quality varies from 100 to 3,000 Mg/L, but is generally considered of low quality even though isolated occurrences provide water for stock.

OPERATIONAL GUIDELINES FOR BATEMAN PUMP STATION

Truscott Brine Lake, Areas VIII and X, and the associated pipelines were designed for a fully automated operation. The three pumps at Bateman Pump Station of Area VIII were sized to pump an average of 5 cfs each for a total of 15 cfs needed to control the projected goal of removal of 85 percent of the chlorides. Switchgear has been installed which will automatically increase the pumping capacity from one pump to two and/or three pumps as the water level rises behind the inflatable weir in the river. When the water level rises to a height of 6 inches above the inflatable dam, the pump station will automatically shut down and the dam will deflate. Pumping is resumed after a visual inspection of the facilities has been conducted and the dam has been reinflated. A decreasing water level will cause a decreased pumping capacity in a reverse order. The pipeline and associated controls were designed to carry the collected brines from Area VIII (both Bateman and Ross Pump Stations) as well as Area X. During the start-up of the Bateman Pump Station it became apparent that the design of the flow control valves located at the outfall of the pipeline would not allow efficient, automatic operation of these facilities as initially designed. To achieve this automated operation, a new control valve configuration was designed and is scheduled to be installed by August 1988. During the redesign and installation, Bateman Pump Station and the outflow control valves were calibrated to run automatically in only a two-pump mode. It was also discovered during the start-up period that the combined efficiencies of the pumps and pipeline are such that a one-pump operation will produce an average flow of 7 cfs while a two-pump operation will produce an average flow of 14 cfs and three pumps an average of 18 cfs. It will be shown later in that data that the two-pump average of 14 cfs collected 86 percent of the chlorides during the first year of operation. Upon delivery and installation of the new flow control valves at the pipeline outfall, the pump station and associated pipeline controls will be recalibrated to allow for a fully automated, three-pump operation.

DATA COLLECTION PROGRAM

NETWORK

A network of continuous-record streamflow and water-quality stations on streams in the Red River basin has been operated for many years by the U.S. Geological Survey in cooperation with the U.S. Army Corps of Engineers and other Federal, State, and local agencies. Several of the stations are located in the drainage area of the South Wichita River (Area VIII of the Red River Chloride Control Project). Information on the location, drainage area, period of record, and types of instrumentation for stations applicable to this investigation are summarized in Table 4. Methods of data collection and computation of records by the Geological Survey are explained in a subsequent section. For an explanation of terms used in the following table and in the discussion of data collection and computation, the reader is referred to the section "Definition of Terms."

WATER-DISCHARGE RECORDS

Data obtained at a continuous-record streamflow station consist of a continuous record of water stage, individual measurements of water discharge throughout a range in stage, and notations regarding factors that may affect the relationship between stage and discharge. These data, supplemented by other information such as weather records, are used to compute daily discharge.

Continuous records of stage are obtained with analog or digital recorders. Instantaneous measurements of discharge are made with current meters by using methods adopted by the Geological Survey as a result of experience accumulated since 1880. In computing discharge records, stage-discharge relation curves are constructed by plotting results of individual discharge measurements against corresponding stages. These curves are then used to prepare rating tables that indicate the approximate discharge for any stage within the range of discharges measured. For extremes of discharge outside the range of current-meter measurements, the stage-discharge relation

TABLE 4

SUMMARY OF U.S. GEOLOGICAL SURVEY'S CONTINUOUS-RECORD STREAMFLOW AND WATER-QUALITY PROGRAMS FOR AREA VIII SOUTH WICHITA RIVER

U.S.G.S. Station and Number	Location	Drainage Area (sq. mi.)	Water-stage and water-quality instrumentation	Period of continuous water-discharge record	Period of daily or continuous water-quality record
South Wichita River near Guthrie, Texas (Bateman) #07311780 (discontinued)	Lat 33°27'29", long 100°13'04", King County, 60 ft upstream from ranch road, 3.9 mi upstream from Willow Creek, 6.1 mi east of Guthrie, and 92.5 mi upstream from mouth.	222	Water-stage recorder	1952-54, Oct 70 Sep 76 (discon)	--
			Specific conductance recorder		Aug 70-Sep 76 (discont.)
South Wichita River at low flow dam near Guthrie, Texas (Bateman) #07311782	Lat 33°37'19", long 100°12'31, King County, 1.0 mi downstream from ranch road crossing, 2.9 mi upstream from Willow Creek, 6.6 mi east of Guthrie and 91.5 mi upstream from mouth.	223	Water-stage recorder	Oct 84 - Sep 85 May 87-current[1]	
			Specific conductance and water temp. recorder	--	Oct 84-current
			Data Collection Platform (telemetry)	Mar 85-current	Mar 85-current
South Wichita River below low flow near Guthrie, Texas (Bateman) #07311783)	Lat 33°37'19", long 100°12'31, King County, 1.1 mi downstream from ranch road crossing, 2.8 mi upstream from Willow Creek, 6.6 mi east of Guthrie, and 91.4 mi upstream from mouth.	223	Water-stage recorder	Oct 85-current	
			Specific conductance and water temp. recorder	--	Oct 86-current year
			Data Collection Platform (telemetry)	Oct 85-current	Oct 86-current
South Wichita River near Benjamin, Texas (Bateman) #07311800	Lat 33°38'39", long 99°48'02", on state highway 6 bridge, 4 mi north of Benjamin, and 41 mi upstream from mouth.	584	Water-stage recorder	Dec 59-current	
			Specific conductance and water temp. recorder	--	Aug 68-current year (daily water-quality stat. Oct 67-Aug 68)
			Data Collection Platform (telemetry)	Mar 85-current	Mar 85-current

[1]Water discharge records for station 07311782 since May 1987 represents flow pumped from the South Wichita River at the low flow dam and diverted by pipeline to Truscott Brine Lake. Flows are determined by the Corps of Engineers (recording flowmeter in pipeline) and records are furnished to the Geological Survey.

curves are extended by using: (1) logarithmic plotting; (2) velocity-area studies; (3) results of indirect measurements of peak discharge, such as slope-area or contracted opening measurements, and computation of flow over dams and weirs; or (4) step-backwater techniques.

Daily mean discharges are computed by applying the daily mean stage (gage heights) to the stage-discharge curves or tables. If the stage-discharge relation is subject to change because of frequent or continual change in the physical features that form the control, the daily mean discharge is determined by applying shifts (correction factors) based on individual discharge measurements and notes made by personnel who made the discharge measurements.

For periods of missing or grossly inaccurate gage-height record, the daily discharges are estimated from the recorded range in stage, previous and subsequent gage-height records, discharge measurements, weather records, and comparison with other station records from the same or nearby basins.

WATER-QUALITY RECORDS

Data obtained at a continuous-record water-quality station depend on the purpose of the station, the type of instrumentation, and the number and types of measurements and analyses. A comprehensive discussion of the various types of continuous-record water-quality stations operated by the Geological Survey is beyond the scope of this report. The following discussion is applicable to those stations in Area VIII of the South Wichita River where specific conductance is measured on daily samples or is recorded continuously by a digital conductivity monitor.

At daily sampling stations, water samples usually are collected at about the same time each day. During periods of rapidly changing flow, samples may be collected more frequently to determine the changes in water quality. At each station equipped with a digital conductivity monitor, specific conductance of the water is measured at hourly intervals. At each of these stations, at least six samples per year representing the range in specific conductance are collected and analyzed for specific conductance and the major dissolved-inorganic constituents and related properties.

Specific conductance is a measure of the ability of a water to conduct an electrical current and thus is related to the types and concentrations of major ions in solution. Consequently, specific conductance values can be used for approximating the concentrations of dissolved solids and the major inorganic ions dissolved in water. For each of the daily or digital conductivity monitoring stations, mean daily, monthly, and annual discharge-weighted concentrations and loads for selected dissolved chemical constituents including dissolved solids, chloride, and sulfate are computed using the daily records of water discharges and specific conductance and regression relationships between specific conductance and each of the chemical constituents.

For periods of missing or grossly inaccurate specific conductance record, daily values are estimated from recorded range in values, previous and subsequent records, regression relationships between specific conductance and water discharge, and comparison with other nearby stations on the same stream.

SUMMARY OF FLOW AND WATER QUALITY RECORDS

The records on which this summary is based are for the period from May 1, 1987, through April 30, 1988. Locations of the Bateman Pump Station and the downstream gaging stations are shown on Figure 3. The complete daily records of the quantity and quality of the water diverted and the flow at stations downstream from the low-flow dam and near Benjamin are included in Appendix D and Appendix E. Monthly summaries are provided in Table 5, which includes the following:

(1) Monthly records of the quantities of flow and the concentrations and loads of chloride in flows diverted by pumpage,

(2) Monthly records of the quantities of flow and concentrations and loads of chloride in flow that passed downstream from the low-flow dam due to minor seepage under and around the dam, due to deflation of the dam when flows exceeded about 14 cfs and due to deflation of the dam during a 10-day period in January 1988 and a 7-day period in April 1988 when breaks were being repaired in the pipeline between the low-flow dam and Truscott Brine Lake. Hereafter, any or a combination of these flows that passed downstream is referred to as "spillage."

(3) Monthly records of the quantities of flow and concentrations and loads of chloride at the station near Benjamin.

Flow records show that monthly diversions ranged from 5.2 cfs in January 1988 to 11 cfs in June 1987 and averaged 7.2 cfs. The records show also that spillage at the station downstream from the low-flow dam ranged from less than 0.1 cfs during four months to 53 cfs during the extremely high-flow month of May 1987 and averaged 5.3 cfs. A comparison of these records shows that approximately 58 percent (7.2 of 12.5 cfs) of the total flow originating upstream from the Bateman Pump Station was diverted.

Water-quality records show that chloride concentrations in the monthly diversions ranged from 6,100 Mg/L during the relatively high flow month of June 1987 to 11,000 Mg/L during five months and averaged about 9,800 Mg/L. Conversely, chloride concentrations in spillage at the station downstream from the low-flow dam ranged from 1,100 Mg/L during the high-flow month of May to 11,000 Mg/L during February and April 1988. These data indicate that the diversion of the saline low flows resulted in an average reduction of 4,420 Mg/L of chloride in the spillage at the site downstream from the dam.

Water-quality records show that chloride loads in the monthly diversions ranged from 145 tons/day in January 1988 to 223 tons/day in March 1988 and averaged 192 tons/day. The records show also that chloride loads in spillage downstream from the low-flow dam ranged from less than 2 tons/day during four months to 158 tons/day during the high-flow month of May.

TABLE 5

WATER DISCHARGES AND CHLORIDE CONCENTRATIONS AND LOADS
FOR SELECTED SITES ON THE SOUTH WICHITA RIVER, TEXAS, MAY 1987 - APRIL 1988

	07311782 South Wichita River at Low Flow Dam at Bateman, Texas (Diversions)				07311783 South Wichita River below Low Flow Dam at Bateman Texas				07311800 South Wichita River near Benjamin, Texas			
	Water discharge	Dissolved chloride			Water discharge	Dissolved chloride			Water discharge	Dissolved chloride		
Period	(cfs)	(Mg/L)	(tons)	(tons/day)	(cfs)	(Mg/L)	(tons)	(tons/day)	(cfs)	(Mg/L)	(tons)	(tons/day)
May 1987	5.7	10,000	4,800	155	53	1,100	4,900	158	249	920	19,070	613
June	11	6,100	5,400	180	3.0	5,100	1,300	40	108	1,700	14,806	500
July	8.0	8,600	5,800	187	2.8	5,800	1,400	45	32	2,800	7,357	239
August	7.1	10,000	6,100	197	.76	10,000	640	21	21	2,400	4,317	142
September	7.8	10,000	6,500	217	.06	8,800	46	1.5	8.2	2,600	1,754	60
October	6.9	11,000	6,200	200	.06	9,000	42	1.4	1.3	5,200	585	19
November	7.3	11,000	6,400	213	.05	9,400	36	1.2	1.1	5,900	542	18
December	7.7	10,000	6,600	213	.26	9,600	210	6.8	3.6	5,400	1,594	52
Jan. 1988	5.2	10,000	4,500	145	2.1	9,500	1,700	55	5.6	4,700	2,188	71
February	7.3	11,000	6,200	214	.15	11,000	120	4.1	3.0	5,700	1,320	45
March	7.4	11,000	6,900	223	.05	10,000	39	1.3	3.9	4,100	1,321	42
April	5.4	11,000	4,900	163	.81	11,000	730	24	4.0	3,800	1,215	40
May 1987-Apr 1988	7.2	9,770	70,300	192	5.35	2,100	11,163	30	37	1,550	56,067	153

Records for the station near Benjamin show that monthly flows ranged from 1.1 cfs in November 1987 to 249 cfs in May 1987 and averaged 37 cfs. The chloride concentration in these flows ranged from 920 Mg/L in May 1987 to 5,900 Mg/L in November 1987 and averaged 1,550 Mg/L. The monthly chloride loads ranged from 18 tons/day during November 1987 to 613 tons/day in May 1987 and averaged 153 tons/day.