

**KANSAS GEOLOGICAL SURVEY
OPEN-FILE REPORT 97-82**

NATURAL MINERAL INTURSION IN KANSAS
Focus on Sources and Distribution of Chloride in Surface Waters

By

D. Whittemore

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NATURAL MINERAL INTRUSION IN KANSAS

Focus on Sources and Distribution of Chloride in Surface Waters

*Prepared for the
Surface Water Quality Commission*

by

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Kansas Geological Survey
Lawrence, Kansas*

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Kansas Surface Water Quality Commission Document Number 69**

TYPES OF SALTWATER SOURCES ADDING CHLORIDE TO STREAMS IN KANSAS

Natural saltwaters from dissolution of evaporite minerals, primarily rock salt

Salinization from evapotranspiration water loss and concentration of remaining salts

Formation brines associated with petroleum exploration and production

Salt mine wastes

Dissolution of deicing and water softener salt

Animal and human waste

Municipal and industrial waste and waste leachate

Spills and leaks of industrial chemicals such as hydrochloric acid

Fertilizers containing potassium chloride

SOURCES OF SURFACE WATER-QUALITY DATA

U.S. Geological Survey Stream Stations

Water-quality monitoring stations

Mainly from late 1950's to mid-1970's

Early analyses mainly by KDHE

Later analyses by USGS labs

1996 included only two stations in Kansas

Water-quality stations for specific studies of limited duration

Specific conductance determined during rating curve measurements at flow stations

Kansas Department of Health and Environment

Stream chemistry monitoring network

Some from late 1960; most from 1970's to present

Revisions in network according to data needs

Analyses by KDHE laboratories

Kansas Biological Survey

Surface-water chemistry determination in ecological or environmental studies

Analyses at KBS laboratories

Kansas Geological Survey

Surface-water chemistry determination in stream-aquifer studies

Analyses at KGS laboratories

Cooperative studies of other state agencies such as Kansas Water Office and Department of Agriculture with analyses by USGS, KDHE, KGS

Municipal and industrial water supply and stream monitoring

Miscellaneous college, university, and local agency studies

NATURAL SOURCES AND CONTROLS ON WATER SALINITY

Main source of dissolved salts is dissolution of soluble minerals, primarily the evaporite minerals halite (rock salt, sodium chloride) and gypsum and anhydrite (calcium sulfate)

Processes affecting salt concentration in water

Mixing of waters at surface and in subsurface

Dilution by rainwater and snowmelt (large variations due to weather and climatic changes)

Direct precipitation on surface waters

Overland flow and soil interflow

Infiltration to ground water

Intrusion of saltwater into fresher water

Mixing of ground waters

Stream-aquifer interactions

Ground-water intrusion to streams

Stream recharge to ground water

Concentration of salts by loss of water

Evaporation from surface or shallow subsurface

Transpiration of water from plants

MAIN AREAS OF INTRUSION OF SALINE GROUND WATERS TO SURFACE WATER

Intrusion of saltwater from Permian redbeds to overlying Dakota aquifer, then directly into streams or into alluvial aquifers which then discharge to streams in central and north-central Kansas where the Dakota aquifer outcrops or subcrops

Intrusion of saltwater from Permian redbeds into regional unconsolidated aquifers and alluvium followed by discharge into streams

Regional aquifers of south-central Kansas

Eastern Great Bend Prairie area aquifer

Western Equus Beds area aquifer

Alluvial aquifers

Cimarron River in southwestern Kansas

Arkansas River in south-central Kansas

Ninnescah River in south-central Kansas

Smaller streams in extreme south-central Kansas

Intrusion of saltwater from Permian rock containing salt beds (Wellington Formation) into alluvial aquifers followed by discharge into streams

Smoky Hill River valley in Saline and Dickinson Counties in central Kansas

Lower Arkansas and Ninnescah river valleys in south-central Kansas

ANTHROPOGENIC ACTIVITIES AFFECTING NATURAL CHLORIDE SOURCES

Change in flow characteristics of streams by reservoirs, ponds, and terracing thereby affecting stream mixing; a general result is reduction of natural salinity extremes

Decrease in fresh ground-water discharge to streams as a result of lower water tables, thereby decreasing freshwater for dilution of natural salinity

Increase in surface water area in reservoirs and ponds that can be affected by evaporation thereby increasing natural salinity

Increase in salinity of soil and shallow ground water through concentration of natural salts in irrigation waters by evapotranspiration thereby increasing salinity of runoff and shallow ground-water discharge

Induced movement of saline ground waters into discharging zones and recharge of saline stream waters into ground water due to aquifer pumping

Precipitation and evapotranspiration changes from climatic changes?

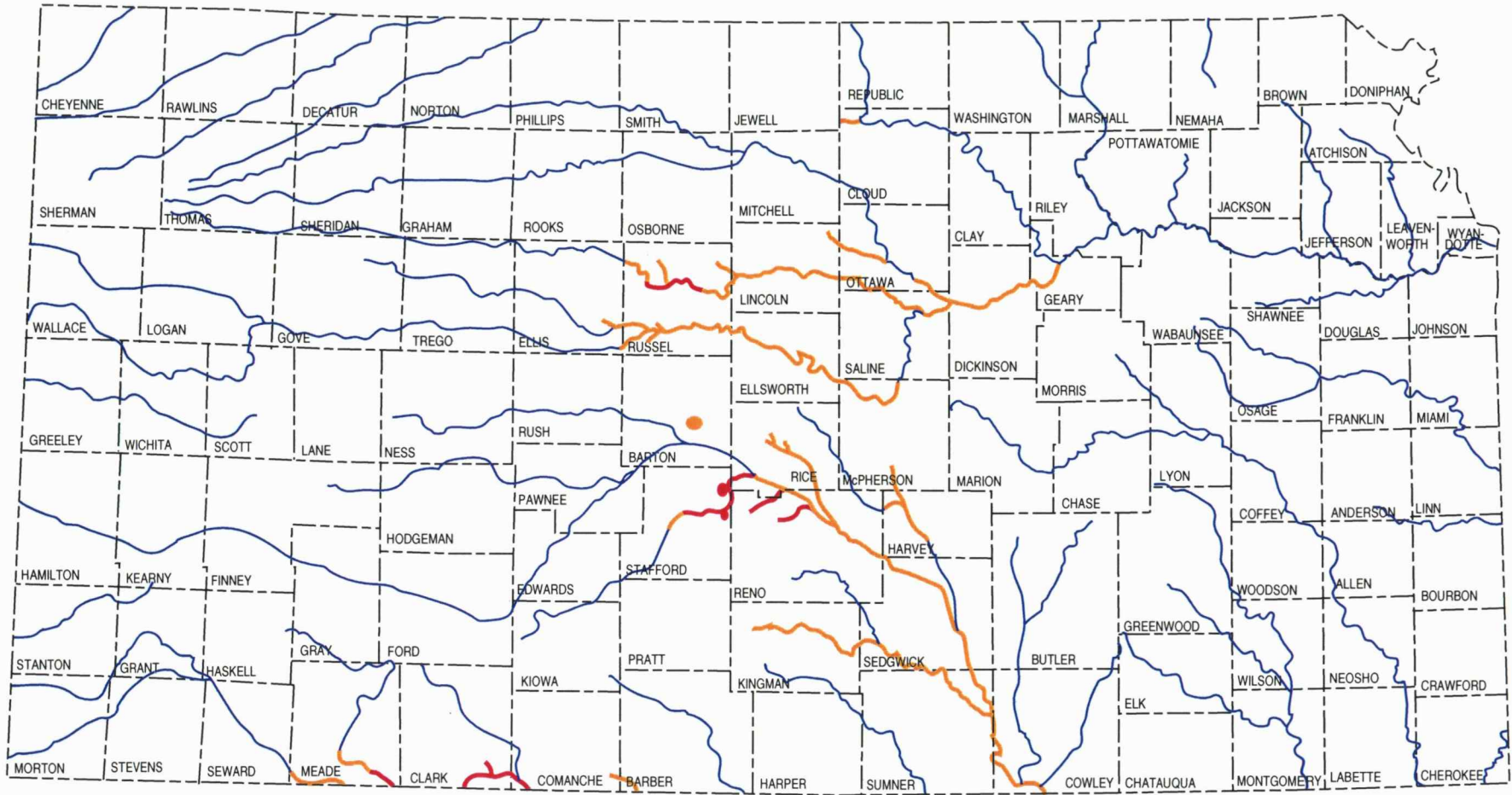
METHODS FOR IDENTIFICATION OF SOURCES OF SALTS IN WATER

Changes in bromide/chloride and sulfate/chloride ratios with change in chloride concentration relative to conservative mixing curves

Differentiation of sources and estimation of contributions from multiple sources in mixtures.

Deviations from conservative mixing on cation ratio versus chloride concentration graphs.

Cation ratios are affected by ion exchange but aid source differentiation and determination of relative age (geologic versus pollution) of saline water

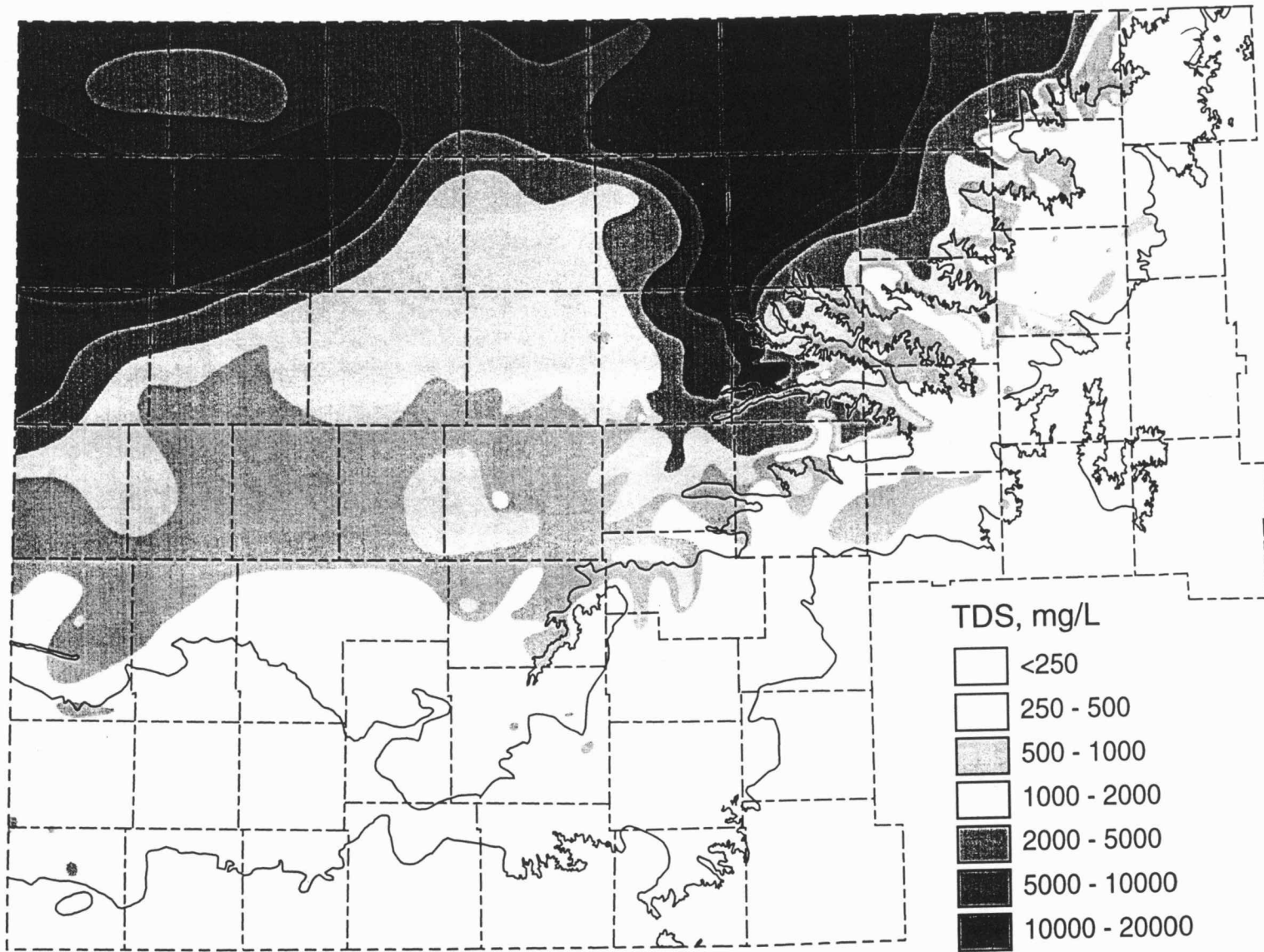


Saline Surface Waters in Kansas

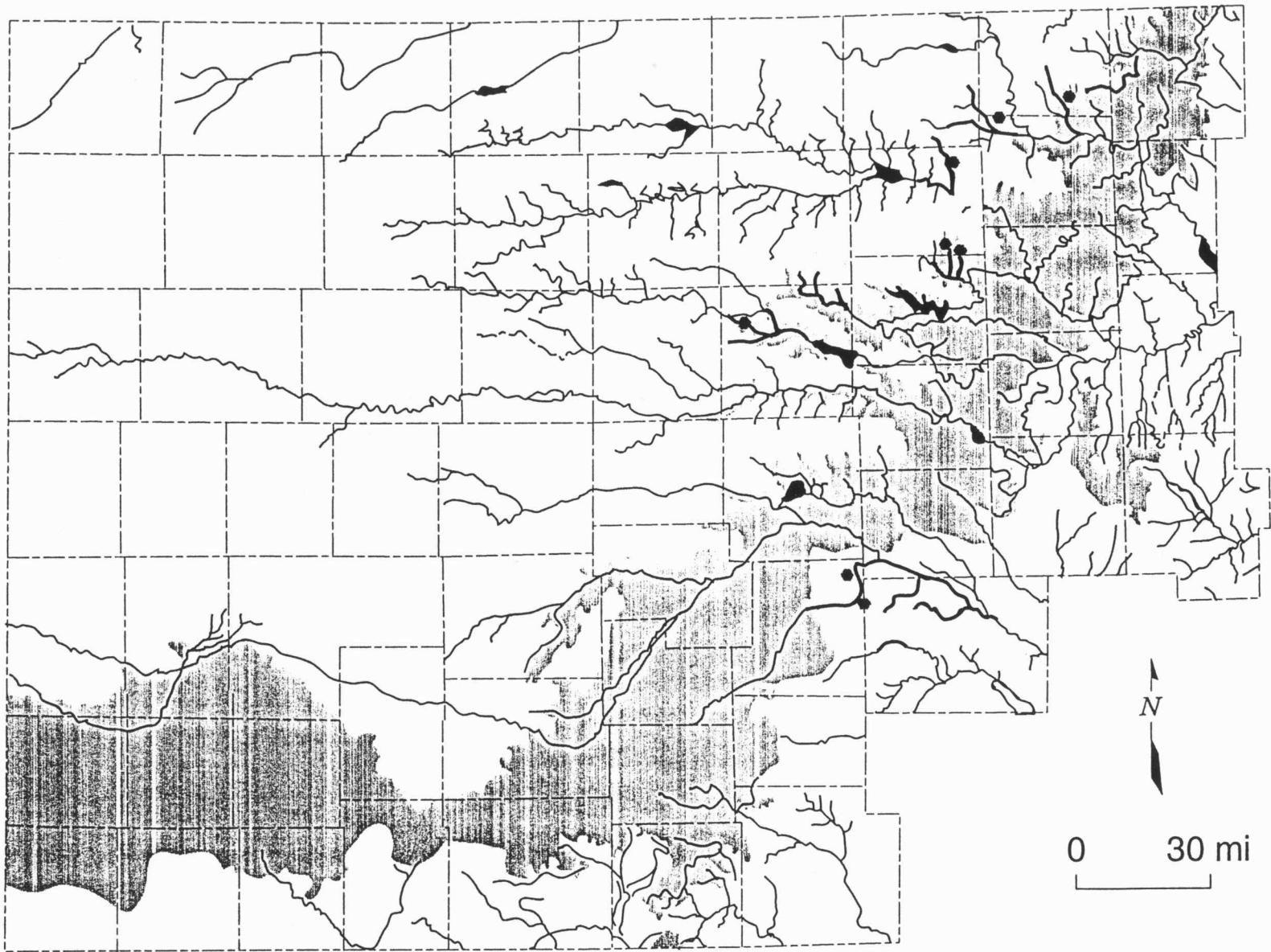
- Mean >230 mg/L Chloride
- Mean >860 mg/L Chloride

Based on data from Kansas Department of Health and Environment through 1996

Don Whittemore, Kansas Geological Survey, 9/1/97



Dakota Aquifer in Kansas



 Reservoirs

 Salt marsh

 Dakota aquifer outcrop

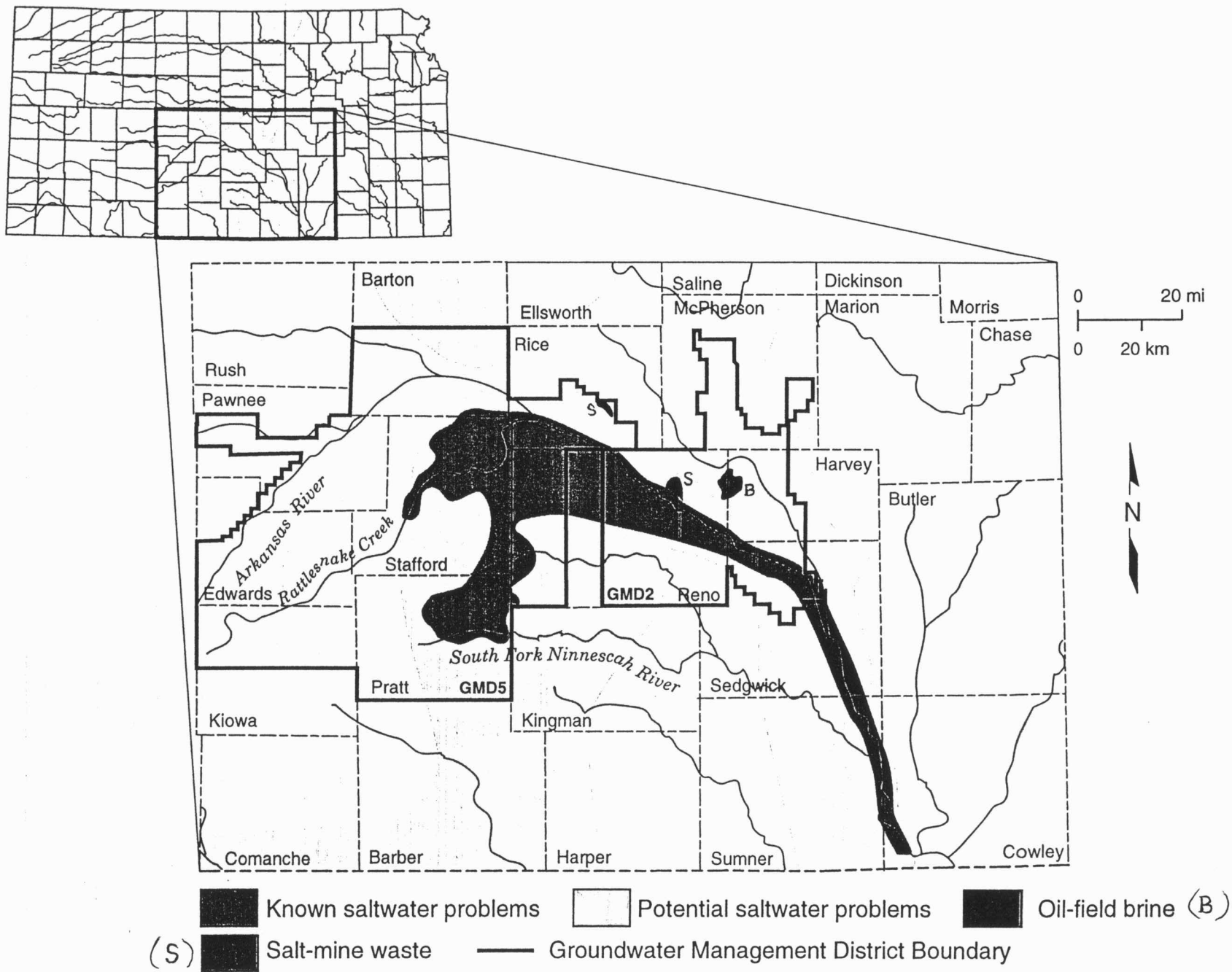
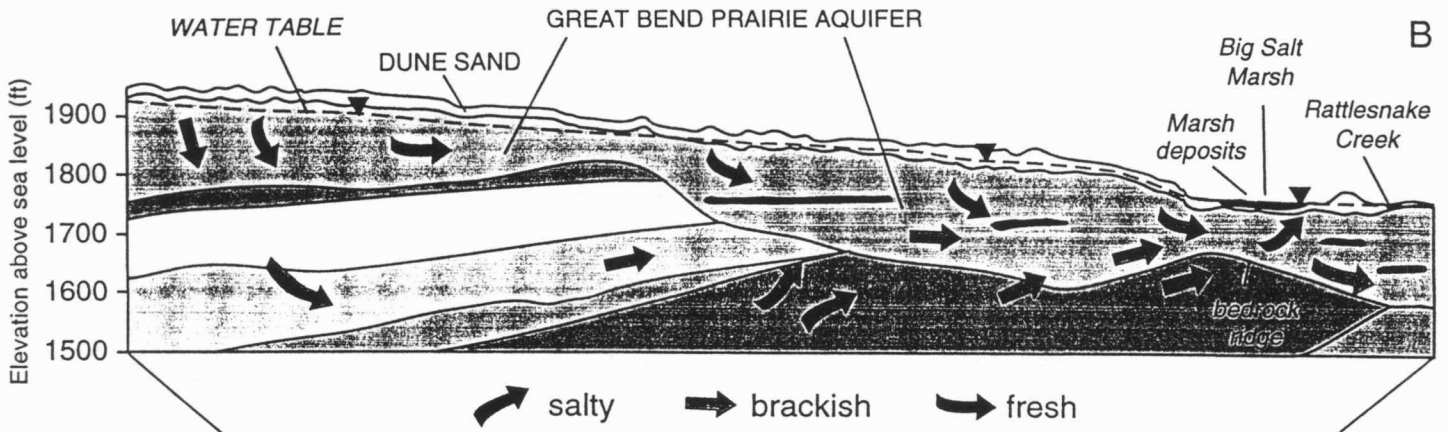


Figure 1. Areas with known or potential saltwater problems in south-central Kansas. The Great Bend Prairie aquifer lies within GMD5, and the Equus Beds aquifer within GMD2.

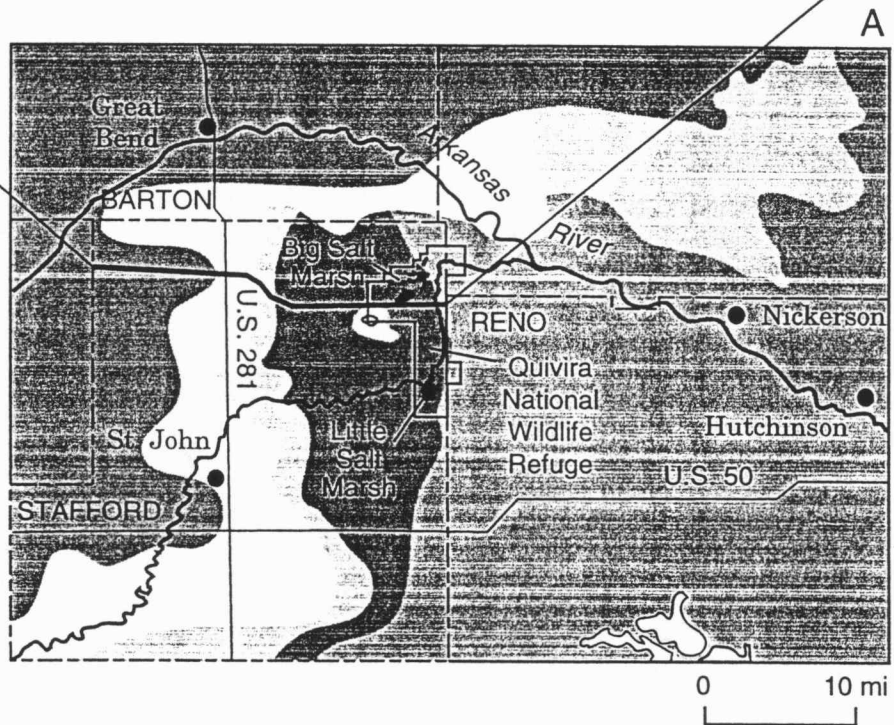


CRETACEOUS BEDROCK

- Upper Dakota aquifer
- Kiowa Shale aquitard
- Lower Dakota aquifer

PERMIAN BEDROCK

- Cedar Hills sandstone aquifer
- bedrock outcrop area
- Permian aquitard

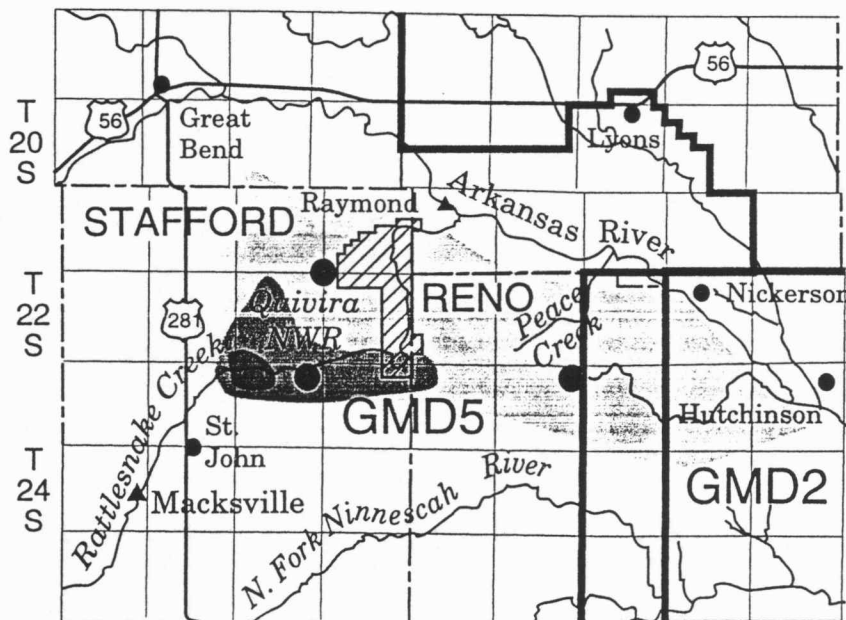


SALT LOAD IN AQUIFER

(EQUIV. FT OF 42 g/kg Cl BRINE)

- > 60'
- 60' > 30'
- 30' > 15'
- 15' > 5'

● ANOMALOUS LOW SALINITY BEDROCK HIGH



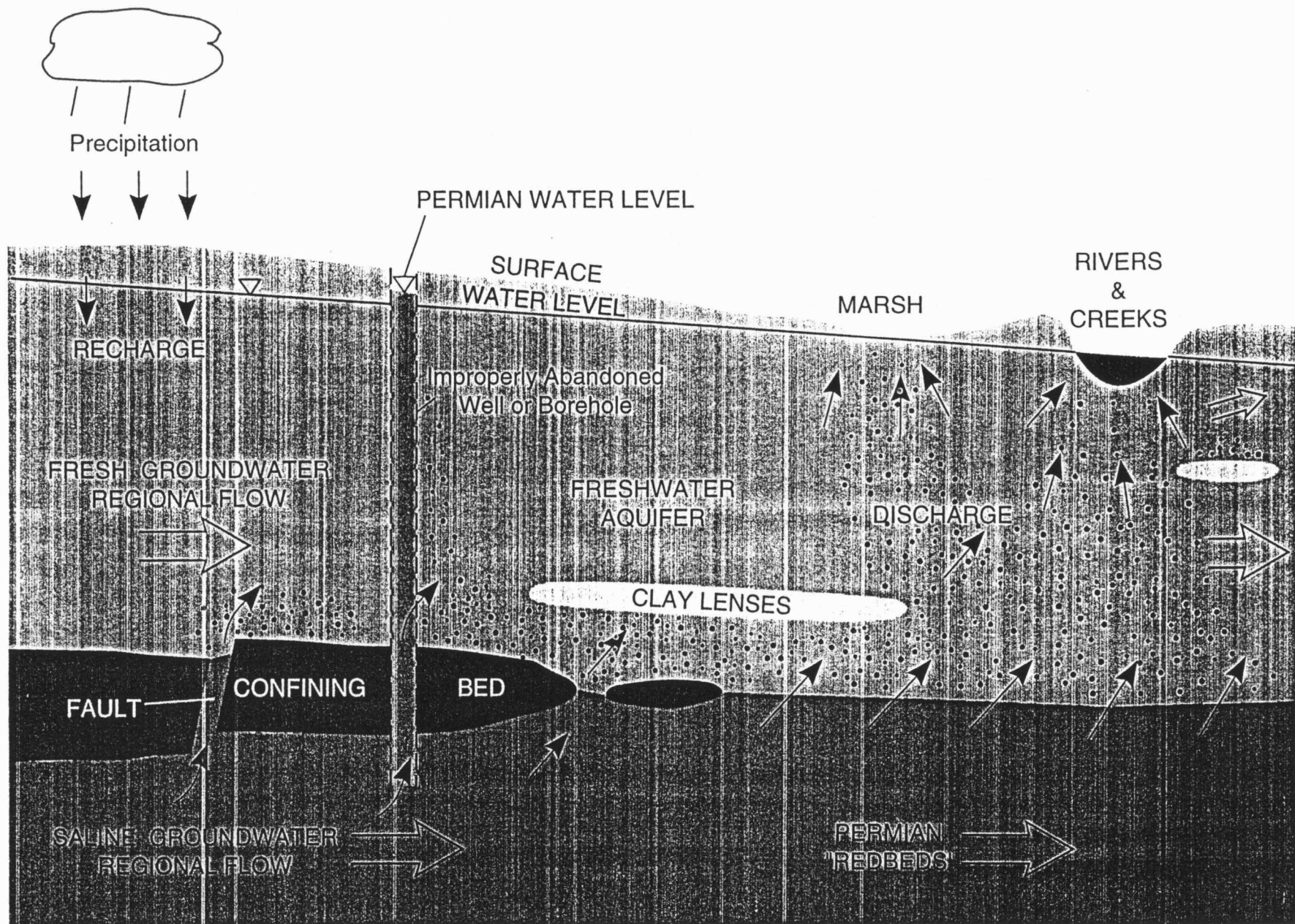
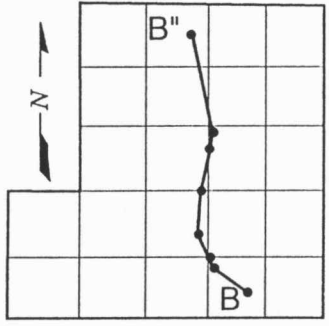
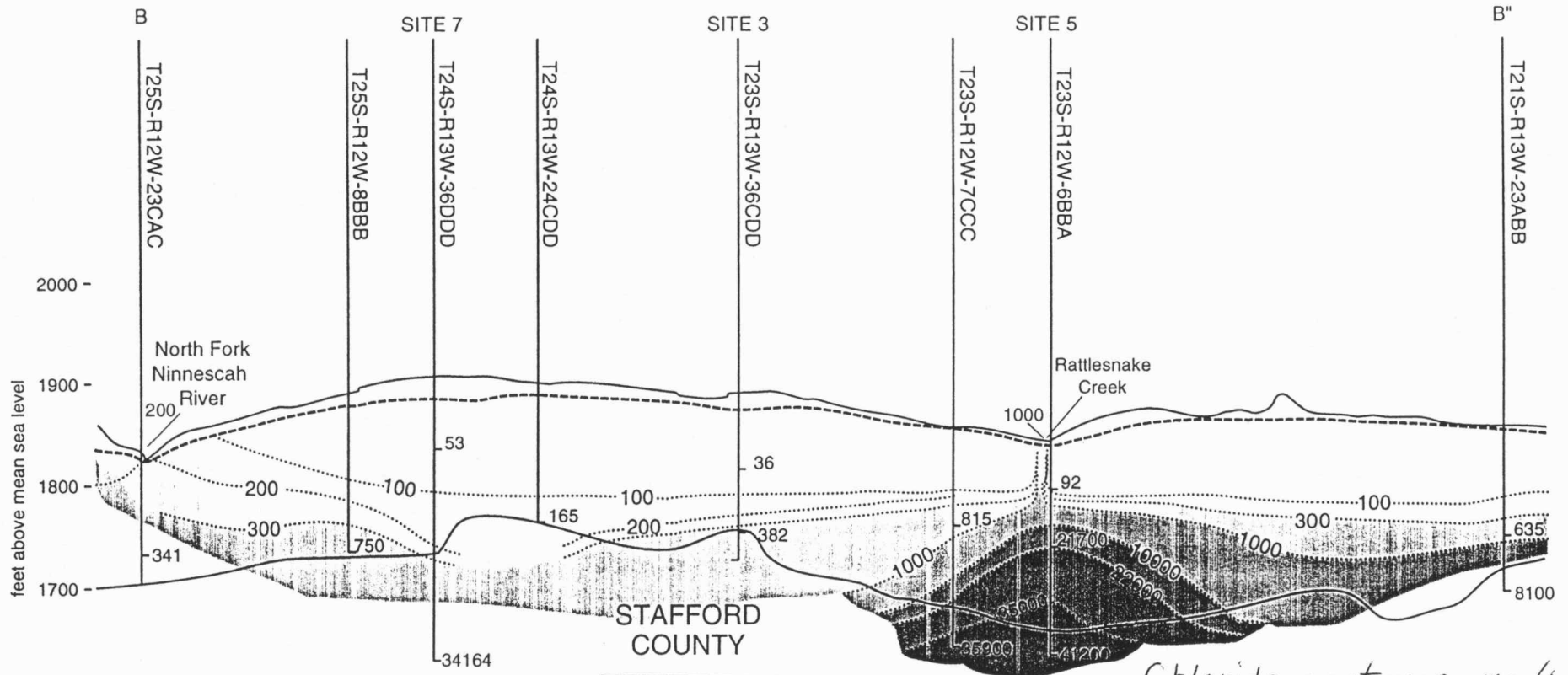
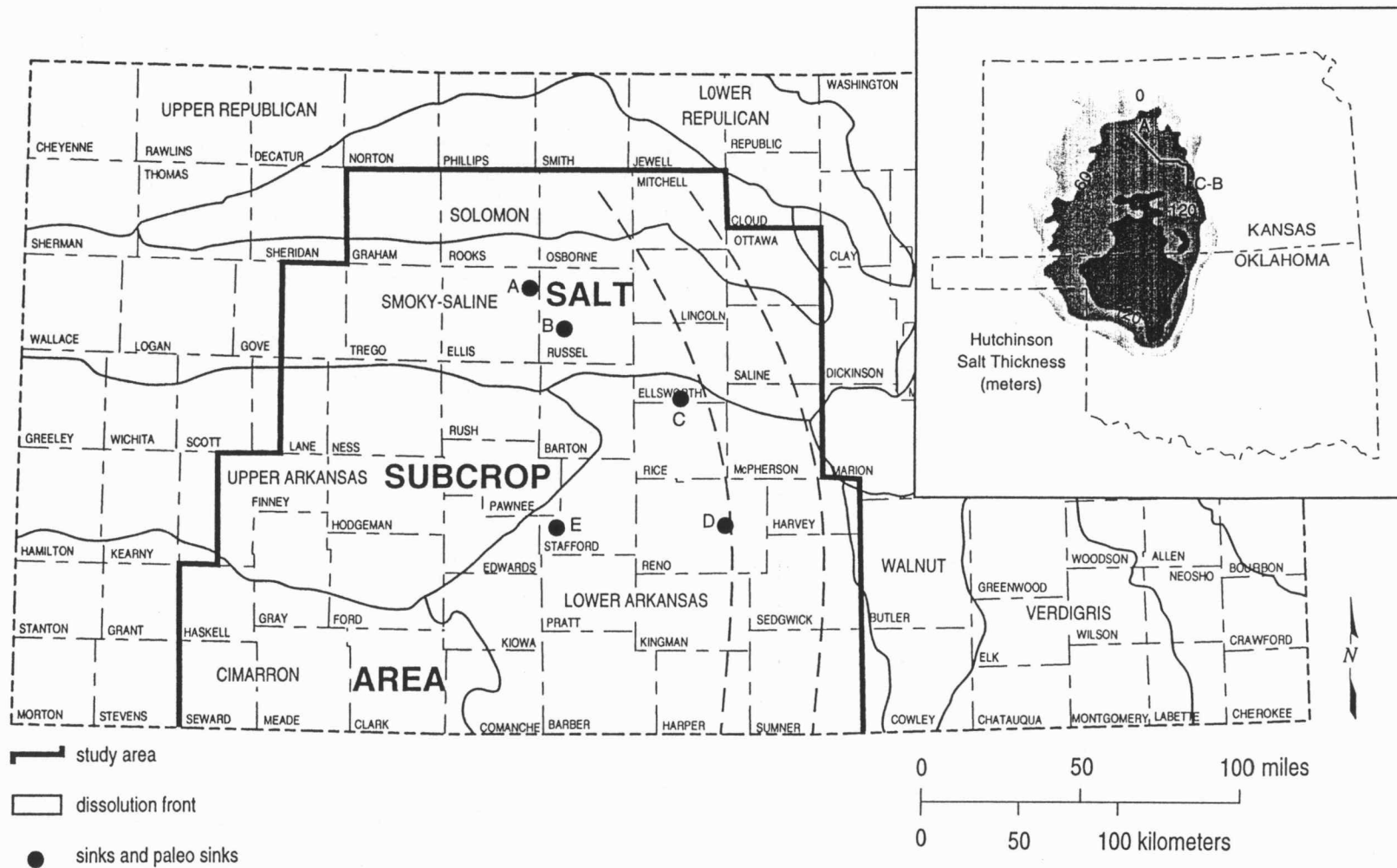
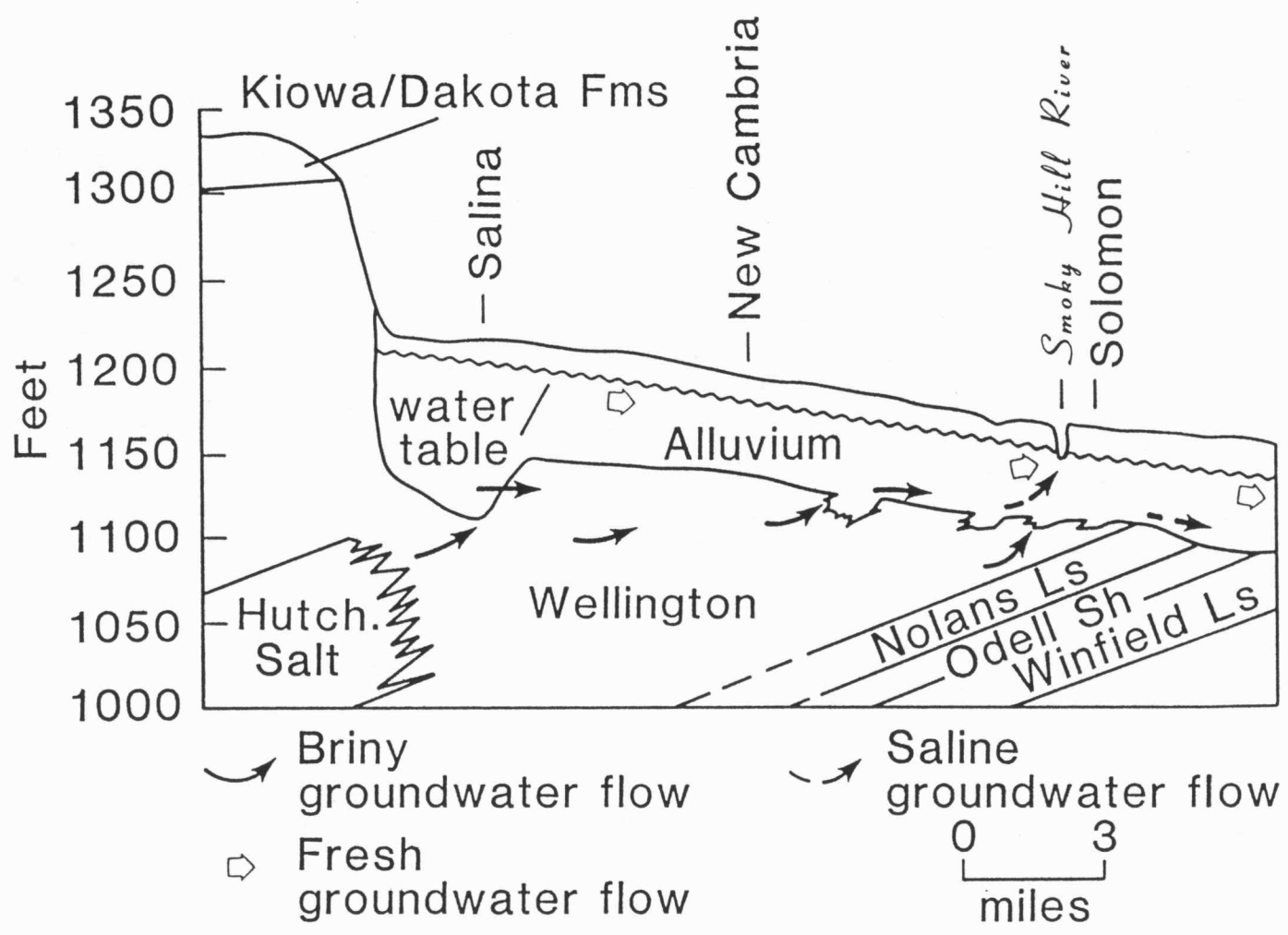


Figure 3. Schematic illustration of the factors influencing the movement of saltwater from a bedrock region of higher head into and within the overlying freshwater aquifer and surface water discharge areas.



Kansas Geological Survey Salt Dissolution Study 1989





PROJECT COMPLETION REPORT

FACTORS CONTROLLING VARIATIONS IN RIVER WATER
QUALITY IN KANSAS

by

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A Research Project Conducted

by

THE KANSAS WATER RESOURCES RESEARCH INSTITUTE

at

Kansas State University

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August 1978

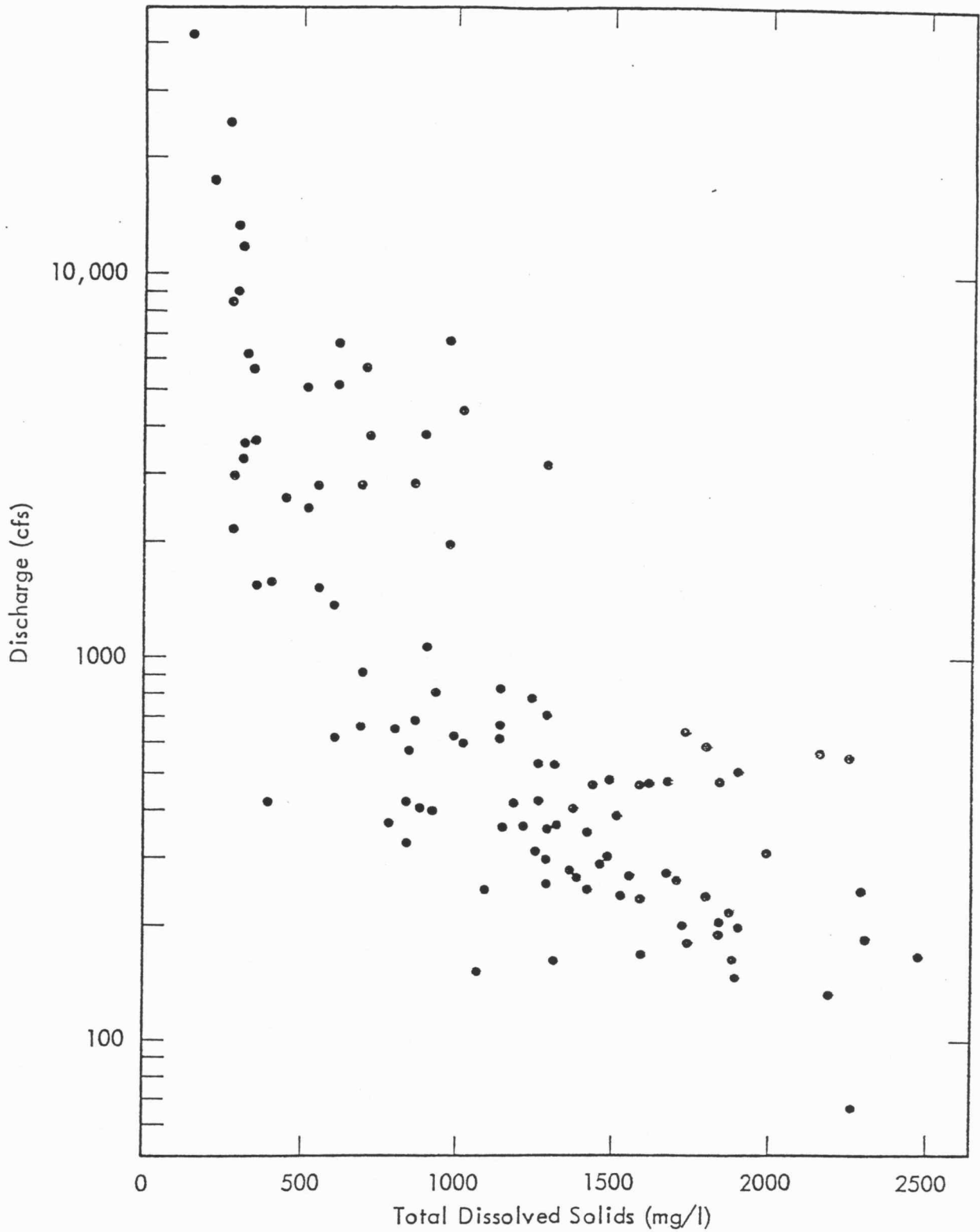


Figure 2. Discharge Versus Total Dissolved Solids for the Smoky Hill River at Enterprise, 1970-1977.

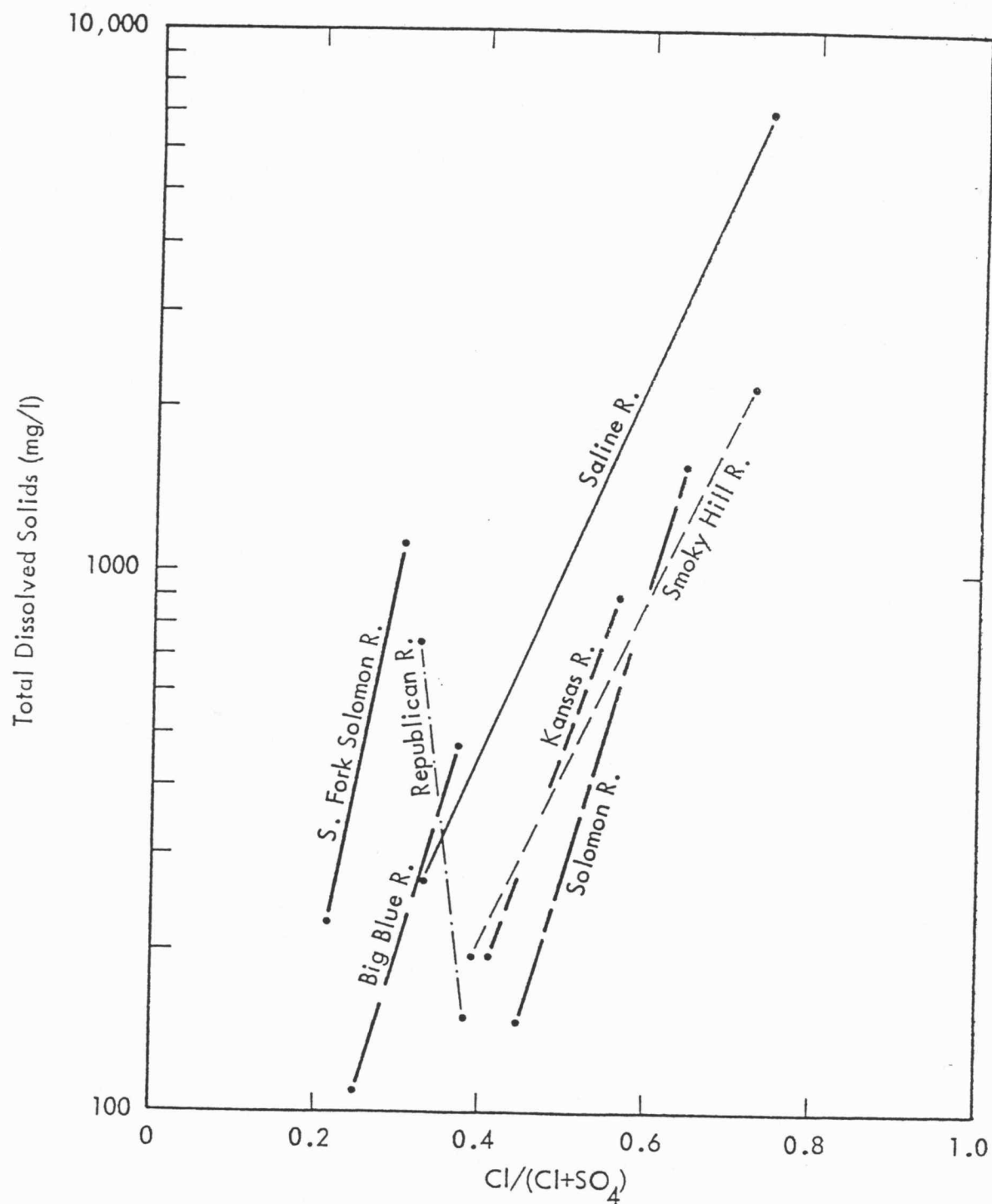


Figure 5. Comparison of $Cl/(Cl + SO_4)$ for the Highest and Lowest Total Dissolved Solids in Rivers of the Kansas River Basin. The points are the averages from Tables 2 and 4.

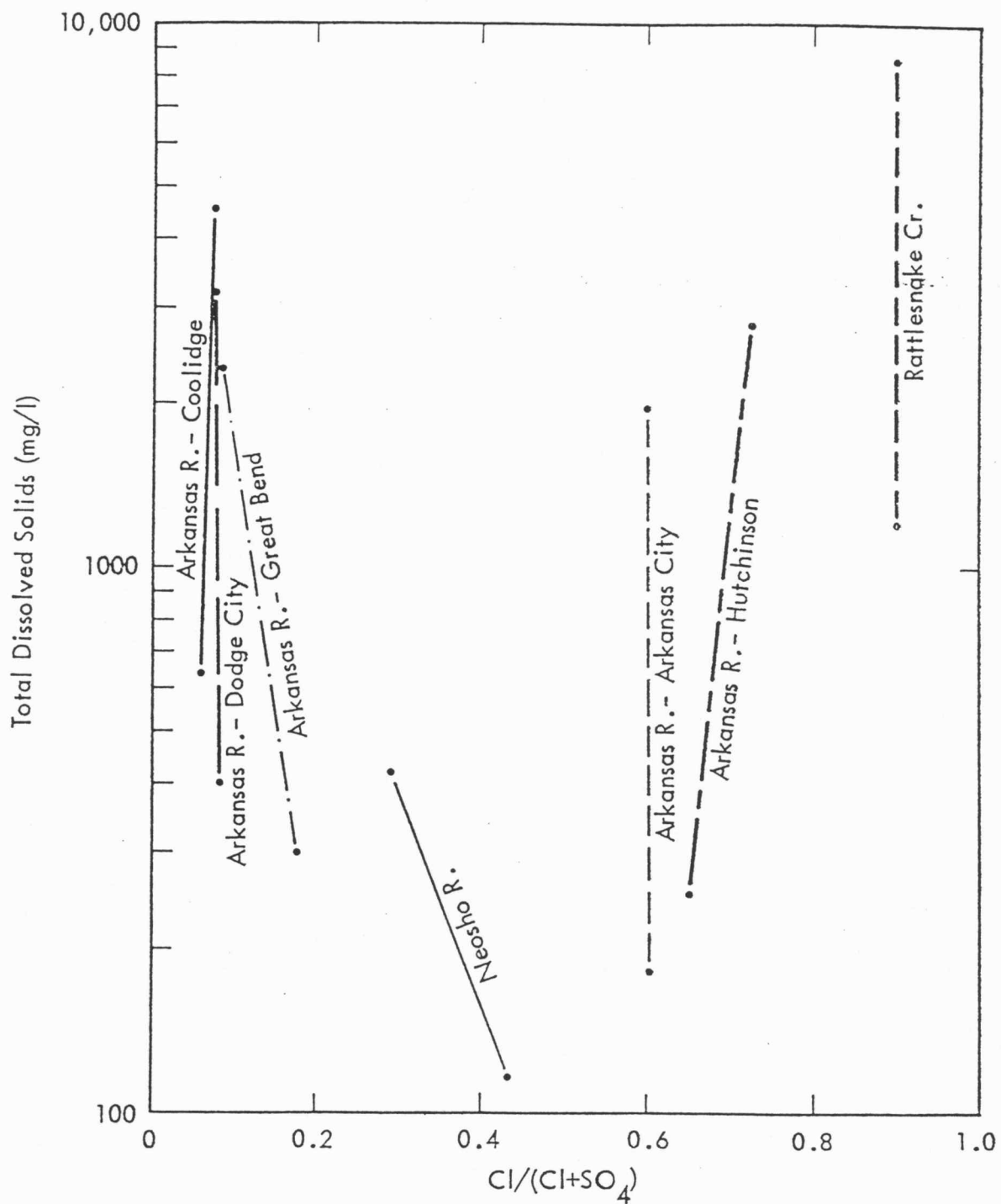


Figure 6. Comparison of Cl/(Cl + SO₄) for the Highest and Lowest Total Dissolved Solids in Rivers of the Arkansas River Basin. The points are the averages from Tables 3 and 5.

FLUSHING -
DILUTION
CYCLE

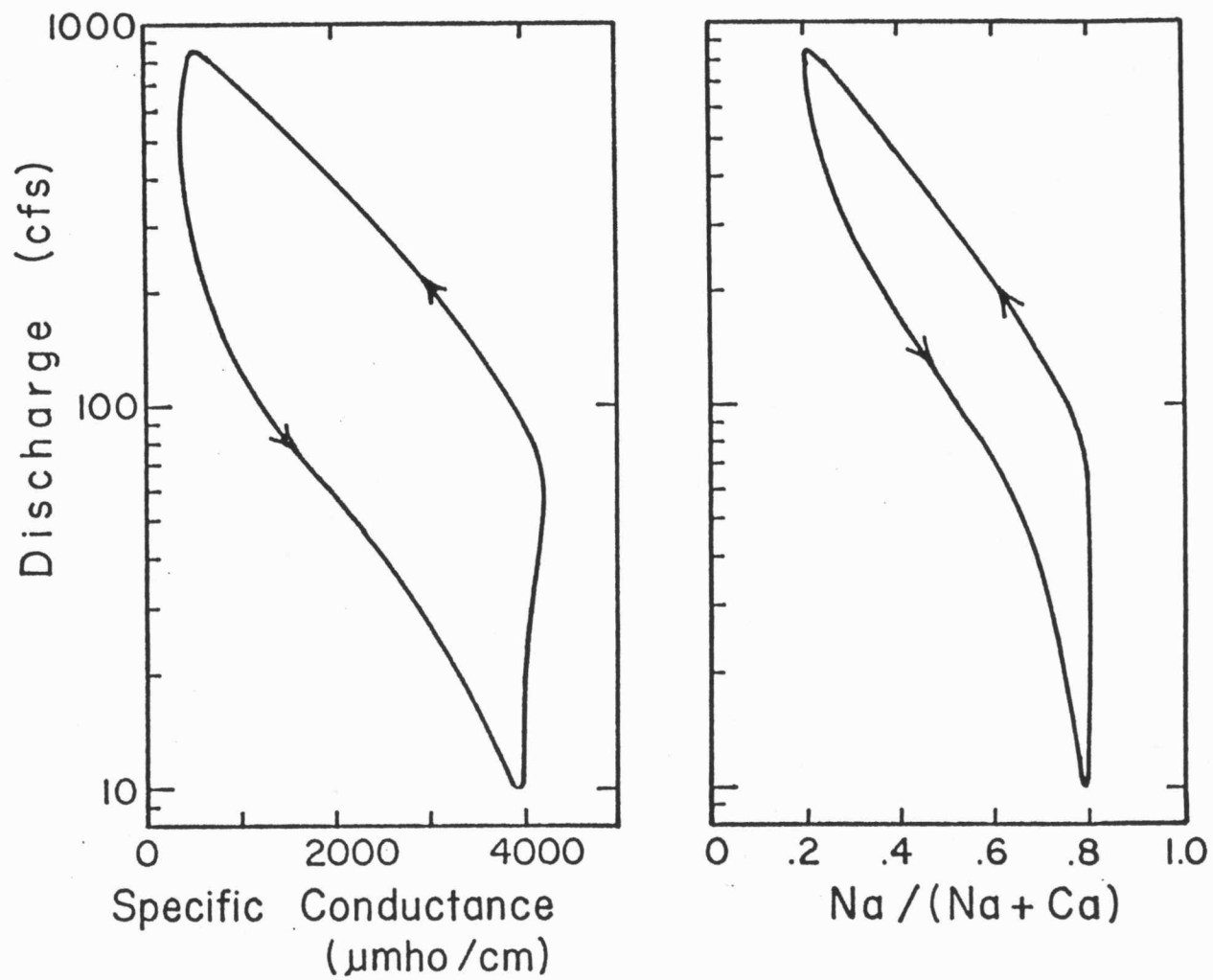


Figure 11. Generalized Cyclic Relationships of Discharge Versus Specific Conductance and $\text{Na}/(\text{Na} + \text{Ca})$ for the Saline River near Russell.

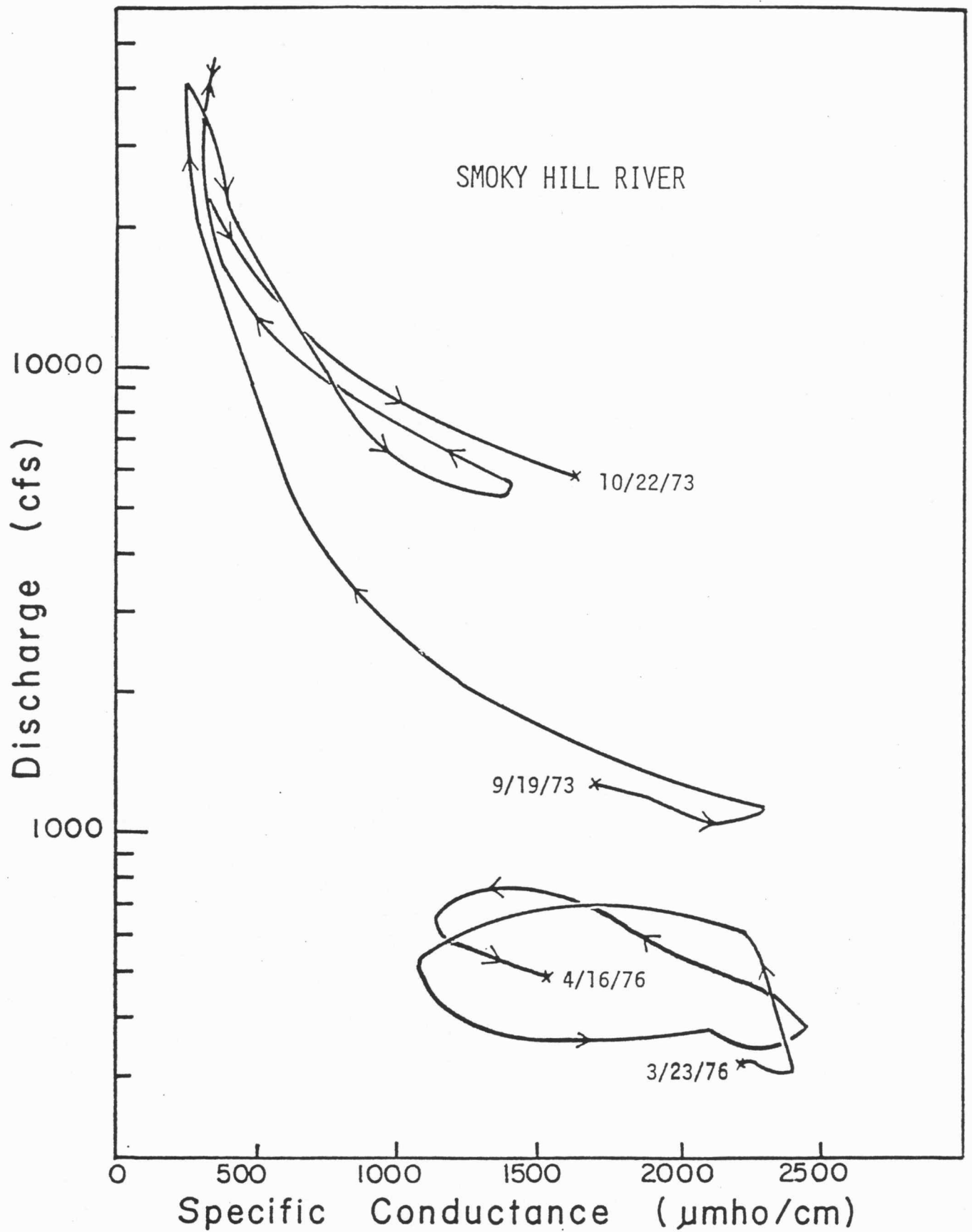


Figure 7. Discharge Versus Specific Conductance for Different Hydrologic Events of the Smoky Hill River at Enterprise.

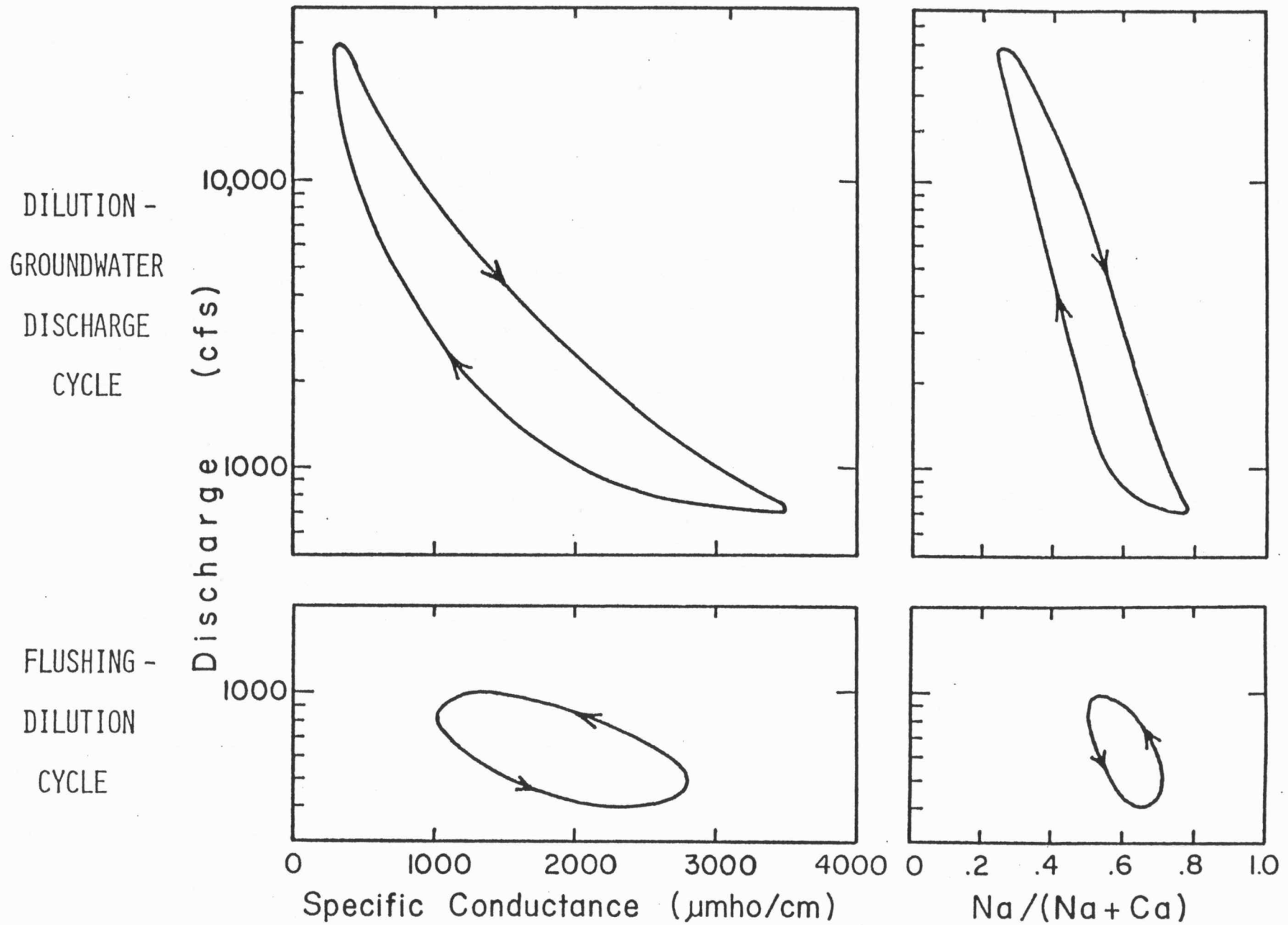


Figure 12. Generalized Cyclic Relationships of Discharge Versus Specific Conductance and $\text{Na}/(\text{Na} + \text{Ca})$ for the Smoky Hill River at Enterprise.

Stn. No.	Start year	End year	Station name	CO	Status	Obs. All	Mean All	S.D. All	Max. All	Min. All	Obs. 1990	Mean 1990	S.D. 1990	Max. 1990	Min. 1990	Obs. Pre.	Mean Pre.	S.D. Pre.	Max. Pre.	Min. Pre.
509	1990	1996	Buffalo Creek near Concordia	CD	F	38	420.3	252.8	939	26	38	420.3	252.8	939	26					
715	1995	1995	North Fork Big Creek near Walker	EL	R	5	273.2	17.7	298	252	5	273.2	17.7	298	252					
7	1975	1996	Smoky Hill River near Russell	RS	F	189	692.8	428.6	2213	10	38	659.1	478.9	1950	24	151	701.3	416.2	2213	10
714	1994	1994	Landon Creek near Russell	RS	R	3	290.3	52.6	351	258	3	290.3	52.6	351	258					
713	1994	1994	Fossil Creek near Russell	RS	R	3	510.3	23.8	526	483	3	510.3	23.8	526	483					
269	1973	1996	Smoky Hill R. at Ellsworth	EW	F	210	370.7	134.5	627	17	38	369.5	158.5	601	24	172	371.0	129.2	627	17
11	1975	1996	Saline River near Russell	RS	F	193	1277.0	910.9	4140	16	40	1000.8	948.6	3160	69	153	1349.2	889.9	4140	16
538	1990	1996	Paradise Creek near Waldo	RS	F	40	606.9	565.4	1750	27	40	606.9	565.4	1750	27					
82	1975	1994	Saline R. below Wilson Dam	LC	X	155	841.5	169.3	1149	30						153	844.4	164.4	1149	30
537	1990	1994	Wolf Creek near Sylvan Grove	LC	R	11	442.5	294.0	962	184	11	442.5	294.0	962	184					
513	1990	1996	Saline R. near Beverly	LC	F	39	442.0	219.6	898	55	39	442.0	219.6	898	55					
267	1973	1996	Saline R. near New Cambria	SA	F	212	349.6	172.6	991	22	39	352.8	169.8	741	53	173	348.9	173.7	991	22
512	1990	1996	Salt Creek near Minneapolis	OT	F	40	457.1	266.8	1330	31	40	457.1	266.8	1330	31					
266	1973	1996	Solomon R. at Niles	OT	F	216	233.2	118.6	490	16	39	215.9	124.8	443	25	177	237.0	117.3	490	16
265	1973	1996	Smoky Hill R. at Enterprise	DK	F	222	359.8	220.6	1264	25	43	385.4	266.1	1264	83	179	353.6	208.6	920	25
264	1973	1996	Smoky Hill R. at Junction City	GE	GWQI	120	268.0	148.3	710	29	26	227.7	118.5	471	31	94	279.1	154.2	710	29

Obs. = number of observations All = all data 1990 = data for 1990 through 1996 Pre. = data prior to 1990

Stn. No.	Start year	End year	Station name	CO	Status	Obs. All	Mean All	S.D. All	Max. All	Min. All	Obs. 1990	Mean 1990	S.D. 1990	Max. 1990	Min. 1990	Obs. Pre.	Mean Pre.	S.D. Pre.	Max. Pre.	Min. Pre.	
660	1992	1996	Rattlesnake Creek near Hudson	SF	R	11	1241.3	744.2	2546	85	11	1241.3	744.2	2546	85						
30	1975	1996	Rattlesnake Creek near Raymond	RC	F	200	2878.3	1207.0	5780	565	41	3303.2	1303.8	5780	565	159	2768.7	1160.0	5180	670	
658	1992	1996	Peace Creek near Sterling	RN	R	11	1796.7	492.8	2636	1260	11	1796.7	492.8	2636	1260						
659	1992	1996	Salt Creek near Hutchinson	RN	R	11	1366.9	129.1	1670	1220	11	1366.9	129.1	1670	1220						
523	1990	1996	Arkansas R. near Hutchinson	RN	F	40	512.1	178.9	848	64	40	512.1	178.9	848	64						
656	1992	1996	Little Cow Creek near Lyons	RC	R	30	274.1	123.6	460	8	30	274.1	123.6	460	8						
657	1992	1996	Cow Creek near Lyons	RC	R	29	378.7	148.2	609	16	29	378.7	148.2	609	16						
522	1990	1996	Cow Creek near Willowbrook	RN	F	42	254.0	94.2	442	22	42	254.0	94.2	442	22						
287	1974	1996	Cow Creek near Hutchinson	RN	F	222	612.6	425.2	4350	60	42	453.6	134.6	682	117	180	649.7	460.2	4350	60	
524	1990	1996	Arkansas R. near Yoder	RN	F	43	527.4	212.7	1190	88	43	527.4	212.7	1190	88						
283	1973	1989	Arkansas R. near Haven	RN	X	177	629.4	224.4	1190	23						177	629.4	224.4	1190	23	
536	1990	1996	Arkansas R. near Maize	SG	F	41	494.6	192.5	948	45	41	494.6	192.5	948	45						
533	1990	1996	Turkey Creek near Alta Mills	HV	R	11	351.8	191.3	668	45	11	351.8	191.3	668	45						
246	1975	1996	Little Arkansas R. at Alta Mills	HV	F	200	265.2	152.5	623	19	41	276.2	132.0	570	22	159	262.3	157.6	623	19	
281	1973	1996	Arkansas R. at Derby	SG	F	219	341.0	141.8	720	12	42	299.2	119.6	513	12	177	350.9	145.1	720	20	
36	1975	1996	South Fork Ninnescah R. near Murdock	KM	F	201	258.6	74.1	440	27	43	263.2	66.9	399	75	158	257.4	76.1	440	27	
280	1973	1996	Ninnescah R. near Belle Plaine	SU	F	217	215.4	96.2	500	17	41	231.7	89.0	485	24	176	211.6	97.7	500	17	
527	1990	1996	Arkansas R. at Oxford	SU	F	41	253.8	82.5	412	48	41	253.8	82.5	412	48						
218	1967	1996	Arkansas R. near Arkansas City	CL	F	250	323.8	139.9	720	22	41	308.9	112.6	488	39	209	326.7	144.7	720	22	
104	1981	1982	Arkansas R. near Newkirk, OK	KAY	X	11	264.5	139.3	444	58						11	264.5	139.3	444	58	
591	1990	1996	Salt Fork Arkansas R. near Hardtner	BA	F	34	255.3	119.5	536	37	34	255.3	119.5	536	37						
221	1967	1989	Salt Fork Ark. R. near Winchester, OK	Woods	X	91	285.5	137.9	730	16						91	285.5	137.9	730	16	
600	1990	1996	Crooked Creek near Englewood	ME	F	38	1122.7	212.5	1570	396	38	1122.7	212.5	1570	396						
701	1995	1995	Day Creek near Sitka	CA	R	6	1005.0	74.7	1097	879	6	1005.0	74.7	1097	879						
592	1990	1996	Cimarron R. near Protection	CM	F	33	924.3	282.1	1450	37	33	924.3	282.1	1450	37						
222	1967	1996	Cimarron R. near Forgan, OK	ME	F	132	753.3	208.2	1210	150	38	1005.2	82.5	1210	876	94	651.5	148.2	996	150	

Obs. = number of observations All = all data 1990 = data for 1990 through 1996 Pre. = data prior to 1990

Stn. No.	Start year	End year	Station name	CO	Status	Obs.	Mean	S.D.	Max.	Min.	M+SD	Obs.	Mean	S.D.	Max.	Min.	M+SD	Obs.	Mean	S.D.	Max.	Min.	M+SD	Comments	
			Kansas River basin																						
						All	All	All	All	All	All	1990	1990	1990	1990	1990	1990	Pre.	Pre.	Pre.	Pre.	Pre.	Pre.		
509	1990	1996	Buffalo Creek near Concordia	CD	F	38	420.3	252.8	939	26	673.1	38	420.3	252.8	939	26	673.1								
715	1995	1995	North Fork Big Creek near Walker	EL	R	5	273.2	17.7	298	252	290.9	5	273.2	17.7	298	252	290.9								
7	1975	1996	Smoky Hill River near Russell	RS	F	189	692.8	428.6	2213	10	1121.4	38	659.1	478.9	1950	24	1138.0	151	701.3	416.2	2213	10	1117.5		
714	1994	1994	Landon Creek near Russell	RS	R	3	290.3	52.6	351	258	342.9	3	290.3	52.6	351	258	342.9								
713	1994	1994	Fossil Creek near Russell	RS	R	3	510.3	23.8	526	483	534.1	3	510.3	23.8	526	483	534.1								
269	1973	1996	Smoky Hill R. at Ellsworth	EW	F	210	370.7	134.5	627	17	505.2	38	369.5	158.5	601	24	528.0	172	371.0	129.2	627	17	500.2		
9	1975	1994	Smoky Hill River below Kanopolis	EW	X	158	197.8	52.7	353	21	250.5							156	197.4	52.7	353	21	250.1		
548	1990	1996	Saline R. near Hays	EL	F	40	182.6	78.2	398	40	260.8	40	182.6	78.2	398	40	260.8								
11	1975	1996	Saline River near Russell	RS	F	193	1277.0	910.9	4140	16	2187.9	40	1000.8	948.6	3160	69	1949.4	153	1349.2	889.9	4140	16	2239.1		
538	1990	1996	Paradise Creek near Waldo	RS	F	40	606.9	565.4	1750	27	1172.3	40	606.9	565.4	1750	27	1172.3								
82	1975	1994	Saline R. below Wilson Dam	LC	X	155	841.5	169.3	1149	30	1010.8							153	844.4	164.4	1149	30	1008.8		
537	1990	1994	Wolf Creek near Sylvan Grove	LC	R	11	442.5	294.0	962	184	736.5	11	442.5	294.0	962	184	736.5								
513	1990	1996	Saline R. near Beverly	LC	F	39	442.0	219.6	898	55	661.6	39	442.0	219.6	898	55	661.6								
267	1973	1996	Saline R. near New Cambria	SA	F	212	349.6	172.6	991	22	522.2	39	352.8	169.8	741	53	522.6	173	348.9	173.7	991	22	522.6		
511	1990	1996	Solomon R. near Glasco	CD	F	39	219.7	153.4	740	46	373.1	39	219.7	153.4	740	46	373.1								
512	1990	1996	Salt Creek near Minneapolis	OT	F	40	457.1	266.8	1330	31	723.9	40	457.1	266.8	1330	31	723.9								
266	1973	1996	Solomon R. at Niles	OT	F	216	233.2	118.6	490	16	351.8	39	215.9	124.8	443	25	340.7	177	237.0	117.3	490	16	354.3		
265	1973	1996	Smoky Hill R. at Enterprise	DK	F	222	359.8	220.6	1264	25	580.4	43	385.4	266.1	1264	83	651.5	179	353.6	208.6	920	25	562.2		
264	1973	1996	Smoky Hill R. at Junction City	GE	GWQI	120	268.0	148.3	710	29	416.3	26	227.7	118.5	471	31	346.2	94	279.1	154.2	710	29	433.3		
518	1990	1996	Kansas R. near Ogden	RL	F	68	197.1	106.4	549	39	303.5	68	197.1	106.4	549	39	303.5								
262	1973	1996	Kansas R. at Manhattan	RL	GWQI	202	167.0	91.5	415	26	258.5	25	154.0	73.9	298	37	227.9	177	168.8	93.8	415	26	262.6		

Obs. = number of observations All = all data 1990 = data for 1990 through 1996 Pre. = data prior to 1990

Stn. No.	Start year	End year	Station name	CO	Status	Obs.	Mean	S.D.	Max.	Min.	M+SD	Obs.	Mean	S.D.	Max.	Min.	M+SD	Obs.	Mean	S.D.	Max.	Min.	M+SD	Comments	
Arkansas River basin																									
						All	All	All	All	All	All	1990	1990	1990	1990	1990	1990	Pre.	Pre.	Pre.	Pre.	Pre.	Pre.		
284	1973	1996	Arkansas R. near Great Bend	BT	F	214	128.3	62.1	565	4	190.4	38	139.0	96.1	565	11	235.1	176	126.0	52.1	275	4	178.1	Only two >230	
660	1992	1996	Rattlesnake Creek near Hudson	SF	R	11	1241.3	744.2	2546	85	1985.5	11	1241.3	744.2	2546	85	1985.5								
30	1975	1996	Rattlesnake Creek near Raymond	RC	F	200	2878.3	1207.0	5780	565	4085.3	41	3303.2	1303.8	5780	565	4607.0	159	2768.7	1160.0	5180	670	3928.7		
658	1992	1996	Peace Creek near Sterling	RN	R	11	1796.7	492.8	2636	1260	2289.5	11	1796.7	492.8	2636	1260	2289.5								
659	1992	1996	Salt Creek near Hutchinson	RN	R	11	1366.9	129.1	1670	1220	1496.0	11	1366.9	129.1	1670	1220	1496.0								
523	1990	1996	Arkansas R. near Hutchinson	RN	F	40	512.1	178.9	848	64	691.0	40	512.1	178.9	848	64	691.0								
656	1992	1996	Little Cow Creek near Lyons	RC	R	30	274.1	123.6	460	8	397.7	30	274.1	123.6	460	8	397.7								
657	1992	1996	Cow Creek near Lyons	RC	R	29	378.7	148.2	609	16	526.9	29	378.7	148.2	609	16	526.9								
522	1991	1996	Cow Creek near Willowbrook	RN	F	42	254.0	94.2	442	22	348.2	42	254.0	94.2	442	22	348.2								
287	1974	1996	Cow Creek near Hutchinson	RN	F	222	612.6	425.2	4350	60	1037.8	42	453.6	134.6	682	117	588.2	180	649.7	460.2	4350	60	1109.9		
524	1990	1996	Arkansas R. near Yoder	RN	F	43	527.4	212.7	1190	88	740.1	43	527.4	212.7	1190	88	740.1								
283	1973	1989	Arkansas R. near Haven	RN	X	177	629.4	224.4	1190	23	853.8							177	629.4	224.4	1190	23	853.8		
536	1990	1996	Arkansas R. near Maize	SG	F	41	494.6	192.5	948	45	687.1	41	494.6	192.5	948	45	687.1								
533	1990	1996	Turkey Creek near Alta Mills	HV	R	11	351.8	191.3	668	45	543.1	11	351.8	191.3	668	45	543.1								
246	1975	1996	Little Arkansas R. at Alta Mills	HV	F	200	265.2	152.5	623	19	417.7	41	276.2	132.0	570	22	408.2	159	262.3	157.6	623	19	419.9		
281	1973	1996	Arkansas R. at Derby	SG	F	219	341.0	141.8	720	12	482.8	42	299.2	119.6	513	12	418.8	177	350.9	145.1	720	20	496.0		
525	1990	1996	North Fork Ninescah R. near Castleton	RN	F	41	211.9	37.2	270	75	249.1	41	211.9	37.2	270	75	249.1								
36	1975	1996	South Fork Ninescah R. near Murdock	KM	F	201	258.6	74.1	440	27	332.7	43	263.2	66.9	399	75	330.1	158	257.4	76.1	440	27	333.5		
280	1973	1996	Ninescah R. near Belle Plaine	SU	F	217	215.4	96.2	500	17	311.6	41	231.7	89.0	485	24	320.7	176	211.6	97.7	500	17	309.3		
527	1990	1996	Arkansas R. at Oxford	SU	F	41	253.8	82.5	412	48	336.3	41	253.8	82.5	412	48	336.3								
218	1967	1996	Arkansas R. near Arkansas City	CL	F	250	323.8	139.9	720	22	463.7	41	308.9	112.6	488	39	421.5	209	326.7	144.7	720	22	471.4		
279	1973	1996	Walnut R. near El Dorado	BU	F	218	171.6	144.0	720	6	315.6	41	94.9	44.7	179	6	139.6	177	189.4	153.1	720	13	342.5		
38	1975	1996	Whitewater R. at Towanda	BU	F	199	188.1	141.0	946	5	329.1	42	116.9	44.8	197	5	161.7	157	207.2	151.6	946	7	358.8		
106	1981	1996	Walnut R. at Gordon	BU	F	135	132.4	80.6	450	6	213.0	41	101.0	46.0	170	6	147.0	94	146.1	88.5	450	16	234.6		
104	1981	1982	Arkansas R. near Newkirk, OK	KAY	X	11	264.5	139.3	444	58	403.8							11	264.5	139.3	444	58	403.8		
591	1990	1996	Salt Fork Arkansas R. near Hardtner	BA	F	34	255.3	119.5	536	37	374.8	34	255.3	119.5	536	37	374.8								
221	1967	1989	Salt Fork Ark. R. near Winchester, OK	Woods	X	91	285.5	137.9	730	16	423.4							91	285.5	137.9	730	16	423.4		
600	1990	1996	Crooked Creek near Englewood	ME	F	38	1122.7	212.5	1570	396	1335.2	38	1122.7	212.5	1570	396	1335.2								
701	1995	1995	Day Creek near Sitka	CA	R	6	1005.0	74.7	1097	879	1079.7	6	1005.0	74.7	1097	879	1079.7								
593	1990	1996	Bluff Creek near Protection	CM	R	40	156.7	218.7	960	19	375.4	40	156.7	218.7	960	19	375.4								
592	1990	1996	Cimarron R. near Protection	CM	F	33	924.3	282.1	1450	37	1206.4	33	924.3	282.1	1450	37	1206.4								
222	1967	1996	Cimarron R. near Forgan, OK	ME	F	132	753.3	208.2	1210	150	961.5	38	1005.2	82.5	1210	876	1087.7	94	651.5	148.2	996	150	799.7		

Obs. = number of observations All = all data 1990 = data for 1990 through 1996 Pre. = data prior to 1990

Stn. No.	Start year	End year	Station name	CO	Status	Obs. All	Mean All	S.D. All	Max. All	Min. All	M+SD90 All	Obs. 1990	Mean 1990	S.D. 1990	Max. 1990	Min. 1990	M+SD90 1990	Obs. Pre.	Mean Pre.	S.D. Pre.	Max. Pre.	Min. Pre.	M+SD90 Pre.	Comments
			Kansas River basin																					
509	1990	1996	Buffalo Creek near Concordia	CD	F	38	420.3	252.8	939	26	743.9	38	420.3	252.8	939	26	743.9							
715	1995	1995	North Fork Big Creek near Walker	EL	R	5	273.2	17.7	298	252	295.9	5	273.2	17.7	298	252	295.9							
7	1975	1996	Smoky Hill River near Russell	RS	F	189	692.8	428.6	2213	10	1241.4	38	659.1	478.9	1950	24	1272.1	151	701.3	416.2	2213	10	1234.0	
714	1994	1994	Landon Creek near Russell	RS	R	3	290.3	52.6	351	258	357.6	3	290.3	52.6	351	258	357.6							
713	1994	1994	Fossil Creek near Russell	RS	R	3	510.3	23.8	526	483	540.8	3	510.3	23.8	526	483	540.8							
269	1973	1996	Smoky Hill R. at Ellsworth	EW	F	210	370.7	134.5	627	17	542.9	38	369.5	158.5	601	24	572.4	172	371.0	129.2	627	17	536.4	
9	1975	1994	Smoky Hill River below Kanopolis	EW	X	158	197.8	52.7	353	21	265.3							156	197.4	52.7	353	21	264.9	
548	1990	1996	Saline R. near Hays	EL	F	40	182.6	78.2	398	40	282.7	40	182.6	78.2	398	40	282.7							
11	1975	1996	Saline River near Russell	RS	F	193	1277.0	910.9	4140	16	2443.0	40	1000.8	948.6	3160	69	2215.0	153	1349.2	889.9	4140	16	2488.3	
538	1990	1996	Paradise Creek near Waldo	RS	F	40	606.9	565.4	1750	27	1330.6	40	606.9	565.4	1750	27	1330.6							
82	1975	1994	Saline R. below Wilson Dam	LC	X	155	841.5	169.3	1149	30	1058.2							153	844.4	164.4	1149	30	1054.8	
537	1990	1994	Wolf Creek near Sylvan Grove	LC	R	11	442.5	294.0	962	184	818.8	11	442.5	294.0	962	184	818.8							
513	1990	1996	Saline R. near Beverly	LC	F	39	442.0	219.6	898	55	723.1	39	442.0	219.6	898	55	723.1							
267	1973	1996	Saline R. near New Cambria	SA	F	212	349.6	172.6	991	22	570.5	39	352.8	169.8	741	53	570.1	173	348.9	173.7	991	22	571.2	
511	1990	1996	Solomon R. near Glasco	CD	F	39	219.7	153.4	740	46	416.1	39	219.7	153.4	740	46	416.1							
512	1990	1996	Salt Creek near Minneapolis	OT	F	40	457.1	266.8	1330	31	798.6	40	457.1	266.8	1330	31	798.6							
266	1973	1996	Solomon R. at Niles	OT	F	216	233.2	118.6	490	16	385.0	39	215.9	124.8	443	25	375.6	177	237.0	117.3	490	16	387.1	
265	1973	1996	Smoky Hill R. at Enterprise	DK	F	222	359.8	220.6	1264	25	642.2	43	385.4	266.1	1264	83	726.0	179	353.6	208.6	920	25	620.6	
264	1973	1996	Smoky Hill R. at Junction City	GE	GWQI	120	268.0	148.3	710	29	457.8	26	227.7	118.5	471	31	379.4	94	279.1	154.2	710	29	476.5	
518	1990	1996	Kansas R. near Ogden	RL	F	68	197.1	106.4	549	39	333.3	68	197.1	106.4	549	39	333.3							
262	1973	1996	Kansas R. at Manhattan	RL	GWQI	202	167.0	91.5	415	26	284.1	25	154.0	73.9	298	37	248.6	177	168.8	93.8	415	26	288.9	
251	1972	1996	Mill Creek near Shawnee	JO	F	243	73.3	58.2	665	7	147.8	43	116.2	109.1	665	38	255.8							Winter highs, road salt?

M+SD90 = mean plus 1.280 times standard deviation (P=0.1)

All = all data 1990 = data from 1990 through 1996 Pre. = data prior to 1990

Stn. No.	Start year	End year	Station name	CO	Status	Obs.	Mean	S.D.	Max.	Min.	M+SD90	Obs.	Mean	S.D.	Max.	Min.	M+SD90	Obs.	Mean	S.D.	Max.	Min.	M+SD90	Comments	
			Arkansas River basin			All	All	All	All	All	All	1990	1990	1990	1990	1990	1990	1990	Pre.	Pre.	Pre.	Pre.	Pre.		
284	1973	1996	Arkansas R. near Great Bend	BT	F	214	128.3	62.1	565	4	207.8	38	139.0	96.1	565	11	262.0	176	126.0	52.1	275	4	192.7	Only two >230	
660	1992	1996	Rattlesnake Creek near Hudson	SF	R	11	1241.3	744.2	2546	85	2193.9	11	1241.3	744.2	2546	85	2193.9								
30	1975	1996	Rattlesnake Creek near Raymond	RC	F	200	2878.3	1207.0	5780	565	4423.3	41	3303.2	1303.8	5780	565	4972.1	159	2768.7	1160.0	5180	670	4253.5		
658	1992	1996	Peace Creek near Sterling	RN	R	11	1796.7	492.8	2636	1260	2427.5	11	1796.7	492.8	2636	1260	2427.5								
659	1992	1996	Salt Creek near Hutchinson	RN	R	11	1366.9	129.1	1670	1220	1532.1	11	1366.9	129.1	1670	1220	1532.1								
523	1990	1996	Arkansas R. near Hutchinson	RN	F	40	512.1	178.9	848	64	741.1	40	512.1	178.9	848	64	741.1								
656	1992	1996	Little Cow Creek near Lyons	RC	R	30	274.1	123.6	460	8	432.3	30	274.1	123.6	460	8	432.3								
657	1992	1996	Cow Creek near Lyons	RC	R	29	378.7	148.2	609	16	568.4	29	378.7	148.2	609	16	568.4								
522	1991	1996	Cow Creek near Willowbrook	RN	F	42	254.0	94.2	442	22	374.6	42	254.0	94.2	442	22	374.6								
287	1974	1996	Cow Creek near Hutchinson	RN	F	222	612.6	425.2	4350	60	1156.9	42	453.6	134.6	682	117	625.9	180	649.7	460.2	4350	60	1238.8		
524	1990	1996	Arkansas R. near Yoder	RN	F	43	527.4	212.7	1190	88	799.7	43	527.4	212.7	1190	88	799.7								
283	1973	1989	Arkansas R. near Haven	RN	X	177	629.4	224.4	1190	23	916.6							177	629.4	224.4	1190	23	916.6		
536	1990	1996	Arkansas R. near Maize	SG	F	41	494.6	192.5	948	45	741.0	41	494.6	192.5	948	45	741.0								
533	1990	1996	Turkey Creek near Alta Mills	HV	R	11	351.8	191.3	668	45	596.7	11	351.8	191.3	668	45	596.7								
246	1975	1996	Little Arkansas R. at Alta Mills	HV	F	200	265.2	152.5	623	19	460.4	41	276.2	132.0	570	22	445.2	159	262.3	157.6	623	19	464.0		
281	1973	1996	Arkansas R. at Derby	SG	F	219	341.0	141.8	720	12	522.5	42	299.2	119.6	513	12	452.3	177	350.9	145.1	720	20	536.6		
525	1990	1996	North Fork Ninescah R. near Castleton	RN	F	41	211.9	37.2	270	75	259.5	41	211.9	37.2	270	75	259.5								
36	1975	1996	South Fork Ninescah R. near Murdock	KM	F	201	258.6	74.1	440	27	353.4	43	263.2	66.9	399	75	348.8	158	257.4	76.1	440	27	354.8		
280	1973	1996	Ninescah R. near Belle Plaine	SU	F	217	215.4	96.2	500	17	338.5	41	231.7	89.0	485	24	345.6	176	211.6	97.7	500	17	336.7		
527	1990	1996	Arkansas R. at Oxford	SU	F	41	253.8	82.5	412	48	359.4	41	253.8	82.5	412	48	359.4								
218	1967	1996	Arkansas R. near Arkansas City	CL	F	250	323.8	139.9	720	22	502.9	41	308.9	112.6	488	39	453.0	209	326.7	144.7	720	22	511.9		
279	1973	1996	Walnut R. near El Dorado	BU	F	218	171.6	144.0	720	6	355.9	41	94.9	44.7	179	6	152.1	177	189.4	153.1	720	13	385.4		
38	1975	1996	Whitewater R. at Towanda	BU	F	199	188.1	141.0	946	5	368.6	42	116.9	44.8	197	5	174.2	157	207.2	151.6	946	7	401.2		
106	1981	1996	Walnut R. at Gordon	BU	F	135	132.4	80.6	450	6	235.6	41	101.0	46.0	170	6	159.9	94	146.1	88.5	450	16	259.4		
104	1981	1982	Arkansas R. near Newkirk, OK	KAY	X	11	264.5	139.3	444	58	442.8							11	264.5	139.3	444	58	442.8		
591	1990	1996	Salt Fork Arkansas R. near Hardtner	BA	F	34	255.3	119.5	536	37	408.3	34	255.3	119.5	536	37	408.3								
221	1967	1989	Salt Fork Ark. R. near Winchester, OK	Woods	X	91	285.5	137.9	730	16	462.0							91	285.5	137.9	730	16	462.0		
600	1990	1996	Crooked Creek near Englewood	ME	F	38	1122.7	212.5	1570	396	1394.7	38	1122.7	212.5	1570	396	1394.7								
701	1995	1995	Day Creek near Sitka	CA	R	6	1005.0	74.7	1097	879	1100.6	6	1005.0	74.7	1097	879	1100.6								
593	1990	1996	Bluff Creek near Protection	CM	R	40	156.7	218.7	960	19	436.6	40	156.7	218.7	960	19	436.6								
592	1990	1996	Cimarron R. near Protection	CM	F	33	924.3	282.1	1450	37	1285.4	33	924.3	282.1	1450	37	1285.4								
222	1967	1996	Cimarron R. near Forgan, OK	ME	F	132	753.3	208.2	1210	150	1019.8	38	1005.2	82.5	1210	876	1110.8	94	651.5	148.2	996	150	841.2		

M+SD90 = mean plus 1.280 times standard deviation (P=0.1)

All = all data 1990 = data from 1990 through 1996 Pre. = data prior to 1990

Str. No.	Start year	End year	Station name	CO	Status	Obs.	Mean	S.D.	Max.	Min.	M+SD90	M+SD95	M+SD98	Obs.	Mean	S.D.	Max.	Min.	M+SD90	M+SD95	M+SD98	Obs.	Mean	S.D.	Max.	Min.	M+SD90	M+SD95	M+SD98			
						All	All	All	All	All	All	All	All	1990	1990	1990	1990	1990	1990	1990	1990	1990	Pre.	Pre.	Pre.	Pre.	Pre.	Pre.	Pre.	Pre.		
Kansas River basin						All	All	All	All	All	All	All	All	1990	1990	1990	1990	1990	1990	1990	1990	1990	Pre.	Pre.	Pre.	Pre.	Pre.	Pre.	Pre.	Pre.		
509	1990	1996	Buffalo Creek near Concordia	CD	F	38	420.3	252.8	939	26	743.9	836.2	939.6	38	420.3	252.8	939	26	743.9	836.2	939.6											
715	1995	1995	North Fork Big Creek near Walker	EL	R	5	273.2	17.7	298	252	295.9	302.3	309.6	5	273.2	17.7	298	252	295.9	302.3	309.6											
7	1975	1996	Smoky Hill River near Russell	RS	F	189	692.8	428.6	2213	10	1241.4	1397.8	1573.1	38	659.1	478.9	1950	24	1272.1	1446.9	1642.8	151	701.3	416.2	2213	10	1234.0	1385.9	1556.2			
714	1994	1994	Landon Creek near Russell	RS	R	3	290.3	52.6	351	258	357.6	376.8	398.3	3	290.3	52.6	351	258	357.6	376.8	398.3											
713	1994	1994	Fossil Creek near Russell	RS	R	3	510.3	23.8	526	483	540.8	549.5	559.2	3	510.3	23.8	526	483	540.8	549.5	559.2											
269	1973	1996	Smoky Hill R. at Ellsworth	EW	F	210	370.7	134.5	627	17	542.9	592.0	647.0	38	369.5	158.5	601	24	572.4	630.2	695.1	172	371.0	129.2	627	17	536.4	583.5	636.4			
9	1975	1994	Smoky Hill River below Kanopolis	EW	X	158	197.8	52.7	353	21	265.3	284.5	306.0									156	197.4	52.7	353	21	264.9	284.1	305.6			
514	1990	1996	Smoky Hill R. near Mentor	SA	F	38	166.7	44.6	255	72	223.8	240.1	258.3	38	166.7	44.6	255	72	223.8	240.1	258.3											
548	1990	1996	Saline R. near Hays	EL	F	40	182.6	78.2	398	40	282.7	311.2	343.2	40	182.6	78.2	398	40	282.7	311.2	343.2											
11	1975	1996	Saline River near Russell	RS	F	193	1277.0	910.9	4140	16	2443.0	2775.4	3148.0	40	1000.8	948.6	3160	69	2215.0	2561.2	2949.2	153	1349.2	889.9	4140	16	2488.3	2813.1	3177.1			
538	1990	1996	Paradise Creek near Waldo	RS	F	40	606.9	565.4	1750	27	1330.6	1537.0	1768.2	40	606.9	565.4	1750	27	1330.6	1537.0	1768.2											
82	1975	1994	Saline R. below Wilson Dam	LC	X	155	841.5	169.3	1149	30	1058.2	1120.0	1189.2									153	844.4	164.4	1149	30	1054.8	1114.8	1182.1			
537	1990	1994	Wolf Creek near Sylvan Grove	LC	R	11	442.5	294.0	962	184	818.8	926.1	1046.4	11	442.5	294.0	962	184	818.8	926.1	1046.4											
513	1990	1996	Saline R. near Beverly	LC	F	39	442.0	219.6	898	55	723.1	803.2	893.1	39	442.0	219.6	898	55	723.1	803.2	893.1											
267	1973	1996	Saline R. near New Cambria	SA	F	212	349.6	172.6	991	22	570.5	633.5	704.1	39	352.8	169.8	741	53	570.1	632.1	701.6	173	348.9	173.7	991	22	571.2	634.6	705.7			
268	1973	1996	Smoky Hill R. near Salina	SA	F	218	143.7	42.1	262	13	197.6	213.0	230.2	39	162.3	41.9	250	71	215.9	231.2	248.4	179	139.7	41.2	262	13	192.4	207.5	224.3			
511	1990	1996	Solomon R. near Glasco	CD	F	39	219.7	153.4	740	46	416.1	472.0	534.8	39	219.7	153.4	740	46	416.1	472.0	534.8											
512	1990	1996	Salt Creek near Minneapolis	OT	F	40	457.1	266.8	1330	31	798.6	896.0	1005.1	40	457.1	266.8	1330	31	798.6	896.0	1005.1											
266	1973	1996	Solomon R. at Niles	OT	F	216	233.2	118.6	490	16	385.0	428.3	476.8	39	215.9	124.8	443	25	375.6	421.2	472.2	177	237.0	117.3	490	16	387.1	430.0	477.9			
265	1973	1996	Smoky Hill R. at Enterprise	DK	F	222	359.8	220.6	1264	25	642.2	722.7	812.9	43	385.4	266.1	1264	83	726.0	823.1	932.0	179	353.6	208.6	920	25	620.6	696.7	782.1			
264	1973	1996	Smoky Hill R. at Junction City	GE	GWQI	120	268.0	148.3	710	29	457.8	512.0	572.6	26	227.7	118.5	471	31	379.4	422.6	471.1	94	279.1	154.2	710	29	476.5	532.8	595.8			
518	1990	1996	Kansas R. near Ogden	RL	F	68	197.1	106.4	549	39	333.3	372.1	415.6	68	197.1	106.4	549	39	333.3	372.1	415.6											
262	1973	1996	Kansas R. at Manhattan	RL	GWQI	202	167.0	91.5	415	26	284.1	317.5	354.9	25	154.0	73.9	298	37	248.6	275.6	305.8	177	168.8	93.8	415	26	288.9	323.1	361.5			
251	1972	1996	Mill Creek near Shawnee	JO	F	243	73.3	58.2	665	7	147.8	169.0	192.8	43	116.2	109.1	665	38	255.8	295.7	340.3											

M+SD90 = mean + 1.280 x std. dev. (P=0.1) M+SD95 = mean + 1.645 x std. dev. (P=0.05) M+SD90 = mean + 2.054 x std. dev. (P=0.02)

All = all data 1990 = data from 1990 through 1996 Pre. = data prior to 1990

Stn. No.	Start year	End year	Station name	CO	Status	Obs.	Mean	S.D.	Max.	Min.	M+SD90	M+SD95	M+SD98	Obs.	Mean	S.D.	Max.	Min.	M+SD90	M+SD95	M+SD98	Obs.	Mean	S.D.	Max.	Min.	M+SD90	M+SD95	M+SD98				
Arkansas River basin						All	All	All	All	All	All	All	All	1990	1990	1990	1990	1990	1990	1990	1990	1990	Pre.	Pre.	Pre.	Pre.	Pre.	Pre.	Pre.	Pre.			
285	1973	1989	Arkansas R. near Dodge City	FO	X	84	137.8	69.1	463	58	226.2	251.5	279.7																				
284	1973	1996	Arkansas R. near Great Bend	BT	F	214	128.3	62.1	565	4	207.8	230.5	255.9	38	139.0	96.1	565	11	262.0	297.1	336.4	176	126.0	52.1	275	4	192.7	211.7	233.0				
660	1992	1996	Rattlesnake Creek near Hudson	SF	R	11	1241.3	744.2	2546	85	2193.9	2465.5	2769.9	11	1241.3	744.2	2546	85	2193.9	2465.5	2769.9												
30	1975	1996	Rattlesnake Creek near Raymond	RC	F	200	2878.3	1207.0	5780	565	4423.3	4863.8	5357.5	41	3303.2	1303.8	5780	565	4972.1	5448.0	5981.2	159	2768.7	1160.0	5180	670	4253.5	4676.9	5151.3				
658	1992	1996	Peace Creek near Sterling	RN	R	11	1796.7	492.8	2636	1260	2427.5	2607.4	2808.9	11	1796.7	492.8	2636	1260	2427.5	2607.4	2808.9												
659	1992	1996	Salt Creek near Hutchinson	RN	R	11	1366.9	129.1	1670	1220	1532.1	1579.3	1632.1	11	1366.9	129.1	1670	1220	1532.1	1579.3	1632.1												
523	1990	1996	Arkansas R. near Hutchinson	RN	F	40	512.1	178.9	848	64	741.1	806.4	879.6	40	512.1	178.9	848	64	741.1	806.4	879.6												
656	1992	1996	Little Cow Creek near Lyons	RC	R	30	274.1	123.6	460	8	432.3	477.4	528.0	30	274.1	123.6	460	8	432.3	477.4	528.0												
657	1992	1996	Cow Creek near Lyons	RC	R	29	378.7	148.2	609	16	568.4	622.5	683.1	29	378.7	148.2	609	16	568.4	622.5	683.1												
522	1991	1996	Cow Creek near Willowbrook	RN	F	42	254.0	94.2	442	22	374.6	409.0	447.5	42	254.0	94.2	442	22	374.6	409.0	447.5												
287	1974	1996	Cow Creek near Lyndon	RN	F	222	612.6	425.2	4350	60	1156.9	1312.1	1486.0	42	453.6	134.6	682	117	625.9	675.0	730.1	180	649.7	460.2	4350	60	1238.8	1406.7	1595.0				
524	1990	1996	Arkansas R. near Yoder	RN	F	43	527.4	212.7	1190	88	799.7	877.3	964.3	43	527.4	212.7	1190	88	799.7	877.3	964.3												
283	1973	1989	Arkansas R. near Haven	RN	X	177	629.4	224.4	1190	23	916.6	998.5	1090.3									177	629.4	224.4	1190	23	916.6	998.5	1090.3				
536	1990	1996	Arkansas R. near Maize	SG	F	41	494.6	192.5	948	45	741.0	811.3	890.0	41	494.6	192.5	948	45	741.0	811.3	890.0												
533	1990	1996	Turkey Creek near Alta Mills	HV	R	11	351.8	191.3	668	45	596.7	666.5	744.7	11	351.8	191.3	668	45	596.7	666.5	744.7												
246	1975	1996	Little Arkansas R. at Alta Mills	HV	F	200	265.2	152.5	623	19	460.4	516.1	578.4	41	276.2	132.0	570	22	445.2	493.3	547.3	159	262.3	157.6	623	19	464.0	521.6	586.0				
281	1973	1996	Arkansas R. at Derby	SG	F	219	341.0	141.8	720	12	522.5	574.3	632.3	42	299.2	119.6	513	12	452.3	495.9	544.9	177	350.9	145.1	720	20	536.6	589.6	648.9				
525	1990	1996	North Fork Ninescah R. near Castleton	RN	F	41	211.9	37.2	270	75	259.5	273.1	288.3	41	211.9	37.2	270	75	259.5	273.1	288.3												
36	1975	1996	South Fork Ninescah R. near Murdock	KM	F	201	258.6	74.1	440	27	353.4	380.5	410.8	43	263.2	66.9	399	75	348.8	373.3	400.6	158	257.4	76.1	440	27	354.8	382.6	413.7				
280	1973	1996	Ninescah R. near Belle Plaine	SU	F	217	215.4	96.2	500	17	338.5	373.6	413.0	41	231.7	89.0	485	24	345.6	378.1	414.5	176	211.6	97.7	500	17	336.7	372.3	412.3				
527	1990	1996	Arkansas R. at Oxford	SU	F	41	253.8	82.5	412	48	359.4	389.5	423.3	41	253.8	82.5	412	48	359.4	389.5	423.3												
218	1967	1996	Arkansas R. near Arkansas City	CL	F	250	323.8	139.9	720	22	502.9	553.9	611.2	41	308.9	112.6	488	39	453.0	494.1	540.2	209	326.7	144.7	720	22	511.9	564.7	623.9				
279	1973	1996	Walnut R. near El Dorado	BU	F	218	171.6	144.0	720	6	355.9	408.5	467.4	41	94.9	44.7	179	6	152.1	168.4	186.7	177	189.4	153.1	720	13	385.4	441.2	503.9				
38	1975	1996	Whitewater R. at Towanda	BU	F	199	188.1	141.0	946	5	368.6	420.0	477.7	42	116.9	44.8	197	5	174.2	190.6	208.9	157	207.2	151.6	946	7	401.2	456.6	518.6				
106	1981	1996	Walnut R. at Gordon	BU	F	135	132.4	80.6	450	6	235.6	265.0	298.0	41	101.0	46.0	170	6	159.9	176.7	195.5	94	146.1	88.5	450	16	259.4	291.7	327.9				
278	1973	1989	Walnut R. at Arkansas City	CL	X	174	115.0	76.3	390	9	212.7	240.5	271.7									174	115.0	76.3	390	9	212.7	240.5	271.7				
104	1981	1982	Arkansas R. near Newkirk, OK	KAY	X	11	264.5	139.3	444	58	442.8	493.6	550.6									11	264.5	139.3	444	58	442.8	493.6	550.6				
591	1990	1996	Salt Fork Arkansas R. near Hardtner	BA	F	34	255.3	119.5	536	37	408.3	451.9	500.8	34	255.3	119.5	536	37	408.3	451.9	500.8												
221	1967	1989	Salt Fork Ark. R. near Winchester, OK	Woods	X	91	285.5	137.9	730	16	462.0	512.3	568.7									91	285.5	137.9	730	16	462.0	512.3	568.7				
600	1990	1996	Crooked Creek near Englewood	ME	F	38	1122.7	212.5	1570	396	1394.7	1472.3	1559.2	38	1122.7	212.5	1570	396	1394.7	1472.3	1559.2												
701	1995	1995	Day Creek near Sitka	CA	R	6	1005.0	74.7	1097	879	1100.6	1127.9	1158.4	6	1005.0	74.7	1097	879	1100.6	1127.9	1158.4												
593	1990	1996	Bluff Creek near Protection	CM	R	40	156.7	218.7	960	19	436.6	516.5	605.9	40	156.7	218.7	960	19	436.6	516.5	605.9												
592	1990	1996	Cimarron R. near Protection	CM	F	33	924.3	282.1	1450	37	1285.4	1388.4	1503.7	33	924.3	282.1	1450	37	1285.4	1388.4	1503.7												
222	1967	1996	Cimarron R. near Forgan, OK	ME	F	132	753.3	208.2	1210	150	1019.8	1095.8	1180.9	38	1005.2	82.5	1210	876	1110.8	1140.9	1174.7	94	651.5	148.2	996	150	841.2	895.3	955.9				

M+SD90 = mean + 1.280 x std. dev. (P=0.1) M+SD95 = mean + 1.645 x std. dev. (P=0.05) M+SD98 = mean + 2.054 x std. dev. (P=0.02)

All = all data 1990 = data from 1990 through 1996 Pre. = data prior to 1990

Stn. No.	Start year	End year	Station name	CO	Status	Obs.	Mean	S.D.	Max.	Min.	M+SD	Obs.	Mean	S.D.	Max.	Min.	M+SD	Obs.	Mean	S.D.	Max.	Min.	M+SD	
Kansas River basin																								
7	1975	1996	Smoky Hill River near Russell	RS	F	189	692.8	428.6	2213	10	1121.4	38	659.1	478.9	1950	24	1138.0	151	701.3	416.2	2213	10	1117.5	
11	1975	1996	Saline River near Russell	RS	F	193	1277.0	910.9	4140	16	2187.9	40	1000.8	948.6	3160	69	1949.4	153	1349.2	889.9	4140	16	2239.1	
538	1990	1996	Paradise Creek near Waldo	RS	F	40	606.9	565.4	1750	27	1172.3	40	606.9	565.4	1750	27	1172.3							
82	1975	1994	Saline R. below Wilson Dam	LC	X	155	841.5	169.3	1149	30	1010.8							153	844.4	164.4	1149	30	1008.8	
Arkansas River basin																								
660	1992	1996	Rattlesnake Creek near Hudson	SF	R	11	1241.3	744.2	2546	85	1985.5	11	1241.3	744.2	2546	85	1985.5							
30	1975	1996	Rattlesnake Creek near Raymond	RC	F	200	2878.3	1207.0	5780	565	4085.3	41	3303.2	1303.8	5780	565	4607.0	159	2768.7	1160.0	5180	670	3928.7	
658	1992	1996	Peace Creek near Sterling	RN	R	11	1796.7	492.8	2636	1260	2289.5	11	1796.7	492.8	2636	1260	2289.5							
659	1992	1996	Salt Creek near Hutchinson	RN	R	11	1366.9	129.1	1670	1220	1496.0	11	1366.9	129.1	1670	1220	1496.0							
287	1974	1996	Cow Creek near Hutchinson	RN	F	222	612.6	425.2	4350	60	1037.8	42	453.6	134.6	682	117	588.2	180	649.7	460.2	4350	60	1109.9	
600	1990	1996	Crooked Creek near Englewood	ME	F	38	1122.7	212.5	1570	396	1335.2	38	1122.7	212.5	1570	396	1335.2							
701	1995	1995	Day Creek near Sitka	CA	R	6	1005.0	74.7	1097	879	1079.7	6	1005.0	74.7	1097	879	1079.7							
592	1990	1996	Cimarron R. near Protection	CM	F	33	924.3	282.1	1450	37	1206.4	33	924.3	282.1	1450	37	1206.4							
222	1967	1996	Cimarron R. near Forgan, OK	ME	F	132	753.3	208.2	1210	150	961.5	38	1005.2	82.5	1210	876	1087.7	94	651.5	148.2	996	150	799.7	

M+SD = mean plus standard deviation

Obs. = number of observations

All = all data

1990 = data from 1990 through 1996

Pre. = data prior to 1990

Stn. No.	Start year	End year	Station name	CO	Status	Obs.	Mean	S.D.	Max.	Min.	M+SD90	Obs.	Mean	S.D.	Max.	Min.	M+SD90	Obs.	Mean	S.D.	Max.	Min.	M+SD90
			Kansas River basin																				
			All	All	All	All	All	All	All	All	All	1990	1990	1990	1990	1990	1990	Pre.	Pre.	Pre.	Pre.	Pre.	Pre.
7	1975	1996	Smoky Hill River near Russell	RS	F	189	692.8	428.6	2213	10	1241.4	38	659.1	478.9	1950	24	1272.1	151	701.3	416.2	2213	10	1234.0
11	1975	1996	Saline River near Russell	RS	F	193	1277.0	910.9	4140	16	2443.0	40	1000.8	948.6	3160	69	2215.0	153	1349.2	889.9	4140	16	2488.3
538	1990	1996	Paradise Creek near Waldo	RS	F	40	606.9	565.4	1750	27	1330.6	40	606.9	565.4	1750	27	1330.6						
82	1975	1994	Saline R. below Wilson Dam	LC	X	155	841.5	169.3	1149	30	1058.2							153	844.4	164.4	1149	30	1054.8
Stn. No.	Start year	End year	Station name	CO	Status	Obs.	Mean	S.D.	Max.	Min.	M+SD90	Obs.	Mean	S.D.	Max.	Min.	M+SD90	Obs.	Mean	S.D.	Max.	Min.	M+SD90
			Arkansas River basin																				
			All	All	All	All	All	All	All	All	All	1990	1990	1990	1990	1990	1990	Pre.	Pre.	Pre.	Pre.	Pre.	Pre.
660	1992	1996	Rattlesnake Creek near Hudson	SF	R	11	1241.3	744.2	2546	85	2193.9	11	1241.3	744.2	2546	85	2193.9						
30	1975	1996	Rattlesnake Creek near Raymond	RC	F	200	2878.3	1207.0	5780	565	4423.3	41	3303.2	1303.8	5780	565	4972.1	159	2768.7	1160.0	5180	670	4253.5
658	1992	1996	Peace Creek near Sterling	RN	R	11	1796.7	492.8	2636	1260	2427.5	11	1796.7	492.8	2636	1260	2427.5						
659	1992	1996	Salt Creek near Hutchinson	RN	R	11	1366.9	129.1	1670	1220	1532.1	11	1366.9	129.1	1670	1220	1532.1						
287	1974	1996	Cow Creek near Hutchinson	RN	F	222	612.6	425.2	4350	60	1156.9	42	453.6	134.6	682	117	625.9	180	649.7	460.2	4350	60	1238.8
283	1973	1989	Arkansas R. near Haven	RN	X	177	629.4	224.4	1190	23	916.6							177	629.4	224.4	1190	23	916.6
600	1990	1996	Crooked Creek near Englewood	ME	F	38	1122.7	212.5	1570	396	1394.7	38	1122.7	212.5	1570	396	1394.7						
701	1995	1995	Day Creek near Sitka	CA	R	6	1005.0	74.7	1097	879	1100.6	6	1005.0	74.7	1097	879	1100.6						
592	1990	1996	Cimarron R. near Protection	CM	F	33	924.3	282.1	1450	37	1285.4	33	924.3	282.1	1450	37	1285.4						
222	1967	1996	Cimarron R. near Forgan, OK	ME	F	132	753.3	208.2	1210	150	1019.8	38	1005.2	82.5	1210	876	1110.8	94	651.5	148.2	996	150	841.2

M+SD90 = mean plus 1.280 times standard deviation (P=0.01)

Obs. = number of observations All = all data 1990 = data from 1990 through 1996 Pre. = data prior to 1990

Stn. No.	Start year	End year	Station name	CO	Status	Obs.	Mean	S.D.	Max.	Min.	M+SD90	M+SD95	Obs.	Mean	S.D.	Max.	Min.	M+SD90	M+SD95	Obs.	Mean	S.D.	Max.	Min.	M+SD90	M+SD95	
Kansas River basin																											
7	1975	1996	Smoky Hill River near Russell	RS	F	189	692.8	428.6	2213	10	1241.4	1397.8	38	659.1	478.9	1950	24	1272.1	1446.9	151	701.3	416.2	2213	10	1234.0	1385.9	
11	1975	1996	Saline River near Russell	RS	F	193	1277.0	910.9	4140	16	2443.0	2775.4	40	1000.8	948.6	3160	69	2215.0	2561.2	153	1349.2	889.9	4140	16	2488.3	2813.1	
538	1990	1996	Paradise Creek near Waldo	RS	F	40	606.9	565.4	1750	27	1330.6	1537.0	40	606.9	565.4	1750	27	1330.6	1537.0								
82	1975	1994	Saline R. below Wilson Dam	LC	X	155	841.5	169.3	1149	30	1058.2	1120.0								153	844.4	164.4	1149	30	1054.8	1114.8	
537	1990	1994	Wolf Creek near Sylvan Grove	LC	R	11	442.5	294.0	962	184	818.8	926.1	11	442.5	294.0	962	184	818.8	926.1								
512	1990	1996	Salt Creek near Minneapolis	OT	F	40	457.1	266.8	1330	31	798.6	896.0	40	457.1	266.8	1330	31	798.6	896.0								
Arkansas River basin																											
660	1992	1996	Rattlesnake Creek near Hudson	SF	R	11	1241.3	744.2	2546	85	2193.9	2465.5	11	1241.3	744.2	2546	85	2193.9	2465.5								
30	1975	1996	Rattlesnake Creek near Raymond	RC	F	200	2878.3	1207.0	5780	565	4423.3	4863.8	41	3303.2	1303.8	5780	565	4972.1	5448.0	159	2768.7	1160.0	5180	670	4253.5	4676.9	
658	1992	1996	Peace Creek near Sterling	RN	R	11	1796.7	492.8	2636	1260	2427.5	2607.4	11	1796.7	492.8	2636	1260	2427.5	2607.4								
659	1992	1996	Salt Creek near Hutchinson	RN	R	11	1366.9	129.1	1670	1220	1532.1	1579.3	11	1366.9	129.1	1670	1220	1532.1	1579.3								
287	1974	1996	Cow Creek near Hutchinson	RN	F	222	612.6	425.2	4350	60	1156.9	1312.1	42	453.6	134.6	682	117	625.9	675.0	180	649.7	460.2	4350	60	1238.8	1406.7	
524	1990	1996	Arkansas R. near Yoder	RN	F	43	527.4	212.7	1190	88	799.7	877.3	43	527.4	212.7	1190	88	799.7	877.3								
283	1973	1989	Arkansas R. near Haven	RN	X	177	629.4	224.4	1190	23	916.6	998.5								177	629.4	224.4	1190	23	916.6	998.5	
600	1990	1996	Crooked Creek near Englewood	ME	F	38	1122.7	212.5	1570	396	1394.7	1472.3	38	1122.7	212.5	1570	396	1394.7	1472.3								
701	1995	1995	Day Creek near Sitka	CA	R	6	1005.0	74.7	1097	879	1100.6	1127.9	6	1005.0	74.7	1097	879	1100.6	1127.9								
592	1990	1996	Cimarron R. near Protection	CM	F	33	924.3	282.1	1450	37	1285.4	1388.4	33	924.3	282.1	1450	37	1285.4	1388.4								
222	1967	1996	Cimarron R. near Forgan, OK	ME	F	132	753.3	208.2	1210	150	1019.8	1095.8	38	1005.2	82.5	1210	876	1110.8	1140.9	94	651.5	148.2	996	150	841.2	895.3	

M+SD90, M+SD95 = mean plus 1.280 (P=0.1), 1.645 (P=0.05) times standard deviation, respectively
 Obs. = number of observations All = all data 1990 = data from 1990 through 1996 Pre. = data prior to 1990

Stn. No.	Start year	End year	Station name	CO	Status	Obs.	Mean	S.D.	Max.	Min.	M+SD90	M+SD95	M+SD98	Obs.	Mean	S.D.	Max.	Min.	M+SD90	M+SD95	M+SD98	Obs.	Mean	S.D.	Max.	Min.	M+SD90	M+SD95	M+SD98	
Kansas River basin																														
509	1990	1996	Buffalo Creek near Concordia	CD	F	38	420.3	252.8	939	26	743.9	836.2	939.6	38	420.3	252.8	939	26	743.9	836.2	939.6									
7	1975	1996	Smoky Hill River near Russell	RS	F	189	692.8	428.6	2213	10	1241.4	1397.8	1573.1	38	659.1	478.9	1950	24	1272.1	1446.9	1642.8	151	701.3	416.2	2213	10	1234.0	1385.9	1556.2	
11	1975	1996	Saline River near Russell	RS	F	193	1277.0	910.9	4140	16	2443.0	2775.4	3148.0	40	1000.8	948.6	3160	69	2215.0	2561.2	2949.2	153	1349.2	889.9	4140	16	2488.3	2813.1	3177.1	
538	1990	1996	Paradise Creek near Waldo	RS	F	40	606.9	565.4	1750	27	1330.6	1537.0	1768.2	40	606.9	565.4	1750	27	1330.6	1537.0	1768.2									
82	1975	1994	Saline R. below Wilson Dam	LC	X	155	841.5	169.3	1149	30	1058.2	1120.0	1189.2									153	844.4	164.4	1149	30	1054.8	1114.8	1182.1	
537	1990	1994	Wolf Creek near Sylvan Grove	LC	R	11	442.5	294.0	962	184	818.8	926.1	1046.4	11	442.5	294.0	962	184	818.8	926.1	1046.4									
513	1990	1996	Saline R. near Beverly	LC	F	39	442.0	219.6	898	55	723.1	803.2	893.1	39	442.0	219.6	898	55	723.1	803.2	893.1									
267	1973	1996	Saline R. near New Cambria	SA	F	212	349.6	172.6	991	22	570.5	633.5	704.1	39	352.8	169.8	741	53	570.1	632.1	701.6	173	348.9	173.7	991	22	571.2	634.6	705.7	
512	1990	1996	Salt Creek near Minneapolis	OT	F	40	457.1	266.8	1330	31	798.6	896.0	1005.1	40	457.1	266.8	1330	31	798.6	896.0	1005.1									
265	1973	1996	Smoky Hill R. at Enterprise	DK	F	222	359.8	220.6	1264	25	642.2	722.7	812.9	43	385.4	266.1	1264	83	726.0	823.1	932.0	179	353.6	208.6	920	25	620.6	696.7	782.1	
Arkansas River basin																														
660	1992	1996	Rattlesnake Creek near Hudson	SF	R	11	1241.3	744.2	2546	85	2193.9	2465.5	2769.9	11	1241.3	744.2	2546	85	2193.9	2465.5	2769.9									
30	1975	1996	Rattlesnake Creek near Raymond	RC	F	200	2878.3	1207.0	5780	565	4423.3	4863.8	5357.5	41	3303.2	1303.8	5780	565	4972.1	5448.0	5981.2	159	2768.7	1160.0	5180	670	4253.5	4676.9	5151.3	
658	1992	1996	Peace Creek near Sterling	RN	R	11	1796.7	492.8	2636	1260	2427.5	2607.4	2808.9	11	1796.7	492.8	2636	1260	2427.5	2607.4	2808.9									
659	1992	1996	Salt Creek near Hutchinson	RN	R	11	1366.9	129.1	1670	1220	1532.1	1579.3	1632.1	11	1366.9	129.1	1670	1220	1532.1	1579.3	1632.1									
287	1974	1996	Cow Creek near Hutchinson	RN	F	222	612.6	425.2	4350	60	1156.9	1312.1	1486.0	42	453.6	134.6	682	117	625.9	675.0	730.1	180	649.7	460.2	4350	60	1238.8	1406.7	1595.0	
524	1990	1996	Arkansas R. near Yoder	RN	F	43	527.4	212.7	1190	88	799.7	877.3	964.3	43	527.4	212.7	1190	88	799.7	877.3	964.3									
283	1973	1989	Arkansas R. near Haven	RN	X	177	629.4	224.4	1190	23	916.6	998.5	1090.3									177	629.4	224.4	1190	23	916.6	998.5	1090.3	
536	1990	1996	Arkansas R. near Maize	SG	F	41	494.6	192.5	948	45	741.0	811.3	890.0	41	494.6	192.5	948	45	741.0	811.3	890.0									
600	1990	1996	Crooked Creek near Englewood	ME	F	38	1122.7	212.5	1570	396	1394.7	1472.3	1559.2	38	1122.7	212.5	1570	396	1394.7	1472.3	1559.2									
701	1995	1995	Day Creek near Sitka	CA	R	6	1005.0	74.7	1097	879	1100.6	1127.9	1158.4	6	1005.0	74.7	1097	879	1100.6	1127.9	1158.4									
592	1990	1996	Cimarron R. near Protection	CM	F	33	924.3	282.1	1450	37	1285.4	1388.4	1503.7	33	924.3	282.1	1450	37	1285.4	1388.4	1503.7									
222	1967	1996	Cimarron R. near Forgan, OK	ME	F	132	753.3	208.2	1210	150	1019.8	1095.8	1180.9	38	1005.2	82.5	1210	876	1110.8	1140.9	1174.7	94	651.5	148.2	996	150	841.2	895.3	955.9	

M+SD90, M+SD95, M+SD98 = mean plus 1.280, 1.645, 2.054 times standard deviation, respectively
 Obs. = Number of observations All = all data 1990 = data from 1990 through 1996 Pre. = data prior to 1990

Kansas Department of Health and Environment Data

Lakes with more than one sample >230 mg/L chloride

Donald Whittemore, Kansas Geological Survey 9/1/97

Station No.	Start year	End year	Station name	CO	No. obs.	Mean	S.D.	Max.	Min.
Kansas River basin									
52801	1989		Jamestown W.A. Station No. 1	CD					
11901	1980	1995	Rooks Co State Lake Sta 1	RO	8	244.1	156.1	457	37
14001	1976	1994	Wilson Reservoir Sta 1	RS	18	657.0	331.0	1005	28
14002	1976	1979	Wilson Reservoir Sta 2	RS	4	294.3	306.8	560	29
14003	1976	1979	Wilson Reservoir Sta 3	RS	4	294.4	306.8	560	29
14004	1976	1979	Wilson Reservoir Sta 4	RS	4	296.9	309.6	570	29
14005	1976	1979	Wilson Reservoir Sta 5	RS	4	297.0	309.4	570	29
14006	1976	1979	Wilson Reservoir Sta 6	RS	4	304.9	317.7	590	30
16001	1977	1994	Kanopolis Reservoir Sta 1	EW	19	230.2	87.5	359	82
47212	1990	1991	Herington Reservoir Inflow Sta 12	DK	12	313.7	119.3	518	81
47213	1990	1991	Herington Reservoir Inflow Sta 13	MN	13	466.7	82.5	592	305
Name									
Arkansas River basin									
50401	1988	1994	Cheyenne Bottoms Pool No. 1, Sta. 1	BT	6	626.7	42.3	664	567
50201	1988	1994	Quivira Little Salt Marsh Sta. No. 1	SF	6	1873.2	230.5	2200	1670
50601	1988	1994	Quivira Big Salt Marsh Sta. No. 1	SF	6	4380.0	1365.5	6150	3350