LAKE MEREDITH SALINITY CONTROL PROJECT

HYDROLOGY/HYDROGEOLOGY

APPENDIX

- - - -

CANADIAN RIVER - NEW MEXICO-TEXAS

DECEMBER 1984

Prepared by

SOUTHWEST REGION HYDROLOGY BRANCH
U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
AMARILLO, TEXAS

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CHAPTER I - INTRODUCTION

In fiscal year 1983, the U.S. Bureau of Reclamation (Reclamation) initiated the Lake Meredith Salinity Control Project to determine the magnitude and extent of saline water inflow to the Canadian River between Ute Reservoir near Logan, New Mexico, and Lake Meredith, Texas. The impact of this saline water on the long-term operation of Lake Meredith was also to be determined along with the selection and evaluation of methods to remove the brine inflow to the river.

During the study, considerable fieldwork was completed to evaluate the hydrologic and hydrogeologic environment of this reach of the Canadian River. The work included sampling surface and ground water to determine concentrations of chemical constituents, core drilling, alluvial piezometer installations, and seismic surveys. Reclamation was assisted in the fieldwork by the Canadian River Municipal Water Authority (CRMWA). Laboratory analyses of water samples were provided by CRMWA and the city of Amarillo.

A contract was also awarded to Hydro Geo Chem, Incorporated (HGC), of Tucson, Arizona, to complete certain phases of the work. Two reports were prepared by them and are commented on within this appendix.

Because of certain internal procedural conflicts and problems with operational feasibility, several items outlined within the Plan of Study were dropped and the project shortened by about 1 year. The most significant deletion was the abandonment of a long-term, brine aquifer pumping test with an associated river monitoring program.

CHAPTER II - PREVIOUS INVESTIGATIONS

In November 1960, the Lake Meredith Definite Plan Report for the Canadian River Project, Texas, was prepared (USBR 1960). Hydrologic information prepared for this report was summarized in appendix B. As reported, an evaluation of the existing quality of water data available at Amarillo gauge showed that during critical drawdown periods for the proposed Sanford Reservoir (Lake Meredith), chloride and sulfate concentrations would be in excess of the U.S. Department of Health and Human Services recommended limits.

In February 1970, the Texas Water Quality Board (TWQB) completed a reconnaissance survey of the Canadian River between Logan, New Mexico, and Tascosa, Texas (TWQB 1970). This survey was initiated because concentrations of chlorides, sulfates, and total dissolved solids (TDS) reported at two monitoring stations located upstream of Lake Meredith Reservoir exceeded maximum levels set by TWQB. During this limited investigation, four points along the Canadian River were sampled along with three tributary drainages above Lake Meredith. Sulfate, chloride, and TDS concentrations were found to increase substantially just below Ute Reservoir near Logan. The chloride and TDS concentrations were highest just below Ute Reservoir and decreased steadily downstream to Lake Meredith. Sulfate concentrations fluctuated downstream from the reservoir, but no significant overall increase was observed at Lake Meredith.

In April 1972, Mason-Johnston and Associates, a consulting engineering firm under contract with CRMWA, completed a report summarizing water quality data obtained for the Canadian River above Lake Meredith (Mason-Johnston and Associates, Incorporated, 1972). They looked primarily at chloride, sulfate, and TDS concentrations during base flow conditions. They concluded that the source of these chemical constituents to the base flow of the river was of natural origin; i.e., from the discharge of ground water containing these constituents and from the weathering and solutioning of soluable materials contained within the Permian to Pliocene rocks cropping out within the drainage. They recommended that a detailed hydrologic and geologic study be conducted within the Canadian River drainage upstream of Lake Meredith to Ute Reservoir to determine the source or sources of the natural contamination. They further recommended that particular attention be given to geologic exposures in the vicinity of Ute Dam and Revuelto Creek so that an evaluation of ground water conditions could be made.

In October 1979, Reclamation published an appraisal-level report summarizing work completed for the Lake Meredith Salinity Project (USBR 1979). The area of investigation included Lake Meredith and the Canadian River upstream to Ute Reservoir. The purpose of the investigation was to identify the source or sources of water discharging into the Canadian River containing high concentrations of chlorides and sulfates. The project was also to evaluate methods to control or contain this discharge. After sampling water from riverbed sands and exploratory drill holes, it was determined that a significant source of saline contamination to Lake Meredith originated near Logan, downstream of Ute Reservoir. A geologic unit containing water under pressure with a TDS concentration in excess of 30,000 milligrams per liter (mg/L) was identified and called the "Brine Artesian Aquifer." Using water quality analyses from the river, Lake Meredith, and the aquifer, it was postulated that the Brine Artesian Aquifer leaks approximately 0.6 cubic feet per second (ft^3/s) to the river and contributes 31, 44, and 20 percent of the sodium, chlorides, and sulfates, respectively, entering Lake Meredith.

A short-term aquifer test was performed on the Brine Artesian Aquifer. The test showed that large volumes of brine could be pumped from the aquifer and that the aquifer potentiometric surface was lowered substantially in the vicinity of the pumping well.

A plan to control the leakage of this brine was proposed. It was postulated that if the Brine Artesian Aquifer was pumped and if the potentometric surface could be lowered throughout the aquifer, then leakage to the river could be reduced or eliminated. The brine was to be transported by pipeline to a nearby playa for disposal by evaporation. The effects of removing the brine seepage from the river were also estimated. The total of the sodium, chloride, and sulfates discharging from the Brine Artsian Aquifer was calculated to be about 32 percent of the inflow of these chemicals to Lake Meredith. It was surmised that a 32-percent reduction of these constituents entering Lake Meredith would produce a long-term change in their average concentration from about 500 to about 350 mg/L under the present reservoir condition. This would result in an average TDS reduction from about 1,250 mg/L to 800 or 900 mg/L. It was recommended that further testing and studies be conducted to validate the long-term effects of removing the brine from the Canadian River-Lake Meredith system.

In September 1982, Espey, Huston and Associates, Incorporated (EHA), a consulting engineering firm, submitted a short preliminary report to the CRMWA summarizing a computer model analysis of the long-term chlorides accumulation in Lake Meredith (EHA 1982). They concluded that a more accurate estimate of the chloride load of the Canadian River was needed and that it was essential to establish a realistic estimate of the surface inflows for reservoir management; i.e., chloride concentration variations with surface inflows needed to be determined more accurately, model analysis needed to be done with and without the Brine Artesian Aquifer contribution, and the average flow used in the model analysis would depend on which period of record was used.

CHAPTER III - FIELD INVESTIGATIONS

Project fieldwork completed by Reclamation began in May 1983 and ended in September 1984. The purpose of the work was to collect hydrologic and hydrogeologic information along and near the Canadian River from Ute Dam to about 10 miles downstream. Numerous piezometers were placed in the river bottom sands and sampled periodically. The Canadian River and Revuelto Creek were also sampled periodically. Additional reconnaissance work along the river was completed downstream to Lake Meredith. A deep exploratory hole was drilled and cored, then completed as an observation well and the formation water sampled. Several existing water wells in the area were also sampled.

Surface Water and Alluvium

The Canadian River in New Mexico, where most of the detailed fieldwork was completed, meanders within a steep-walled canyon. This canyon bottom is filled to a depth of about 60 feet with silt, sand, and gravel. Leakage of brine up through the bedrock must first pass through this thick sequence of sediment where it mixes and is diluted with fresher water as it flows upward to the river channel. In order to determine the actual thickness of these sands and the spatial and temporal variations of saline water within the river alluvium, a drilling and sampling program was designed.

Seven sites located along the Canadian River and Revuelto Creek from Ute Dam to about 10 miles downstream of the dam were selected for water quality and flow monitoring. Piezometers were installed in the alluvium using a crawler tractor-mounted, mud rotary drill rig. Bore holes were drilled using a polymer-based, water-soluble mud to hold them open. When the drill hole was completed, flush-coupled schedule 80 PVC pipe (inside diameter 1.5 inches) with 4 feet of slotted (0.010 inch) screen attached to the bottom was installed. The PVC pipe was protected by installing about 5 to 15 feet of 2-inch inside-diameter galvanized steel pipe (with threaded caps) around it. The steel pipe was buried deep into the alluvium for stability. All piezometers were surveyed, and their exact locations and elevations determined.

Site 0 was located at the toe of Ute Dam at river mile (RM) 0 (plate No. 1, figures 1 and 2). No drilling was done at this site since a piezometer was already in place in the river sands for monitoring hydraulic head below the dam. After pumping the piezometer once, it was determined that it was clogged and of no use. Several water quality samples were collected from the toe drains at this site and one sample from the piezometer. Site 0 was not a regular sampling site, and no discharge data were collected there.

Site 1 was located 1.6 miles below Ute Dam and just upstream of the U.S. Geological Survey (USGS) Logan gauge (plate No. 1, figures 1 and 2). Two piezometers were installed at this site in sand and gravel. A staff gauge was also installed about 25 feet downstream of the piezometers.

Piezometer 1A was set at 22 feet total depth, and 1B was set at 16 feet total depth. The deeper piezometer was placed on what appeared to be bedrock; however, the depth of sand at this point on the river was expected to be about 50 to 60 feet. The canyon bottom was probably deepest several hundred feet to the south of this drill site. Since one of the purposes of the piezometer installations was to provide representative samples of water flowing at the

7-1654 (7-73)
Water and Power

COMPUTATION SHEET

BY C. Newcomb
DATE 7-13-83
PROJECT Lake Meredith Salinity
SHEET 1 OF 2
CHKD BY
DATE
FEATURE Figure 1 - Sampling Site Locations near Logan, NM
DETAILS Piezometer locations & Elevations

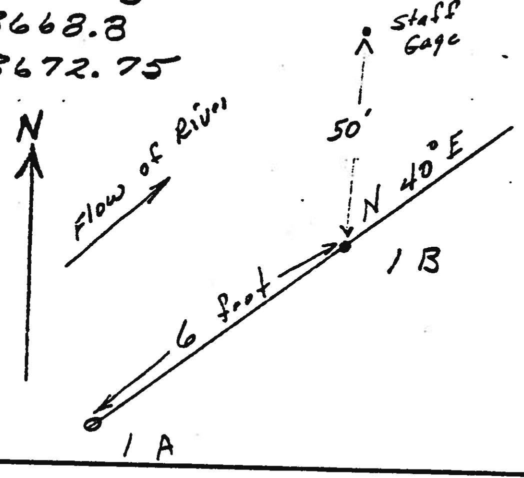
Piezometer # 0 site 103° 27' 36" — 35° 20' 40"

Location = 13 · 33 · 21 · 1224 @ Toe of UTE DAM
Elevation Ground = 3682.7
Elevation Top Pipe = 3685.48 w/cap off

Piezometer # 1 Site 103° 25' 17" — 35° 21' 12"

Location = 13 · 33 · 15 · 4112 A "0" on Staff Gage = 3665.62
Elevation Ground = 3668..9
Elevation Top PVC = 3672.59

Location = 13 · 33 · 15 · 4112 B
Elevation Ground = 3668.8
Elevation Top PVC = 3672.75

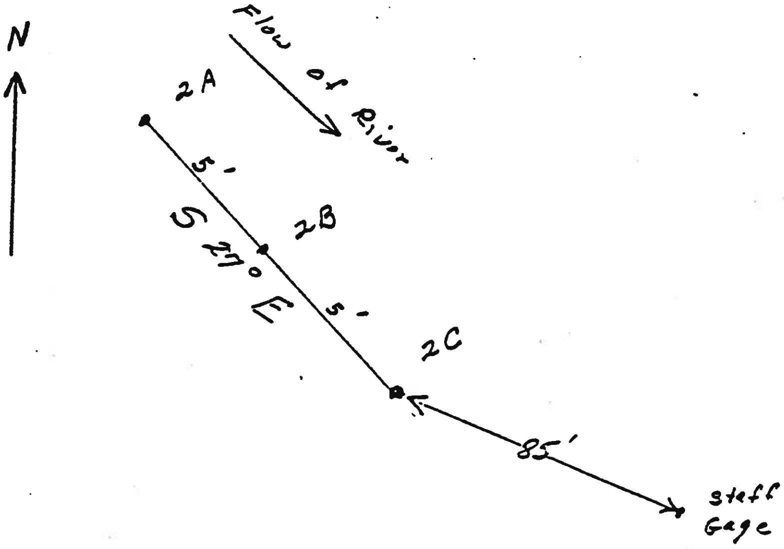


Piezometer # 2 site 103° 24' 52" - 35° 2" 14'

Location = 13 · 33 · 14 · 1332 A
Elev. Ground = 3668.7
Elev Top PVC = 3672.55

Location = 13 · 33 · 14 · 1332 B
Elev. Ground = 3668.7
Elev. Top PVC = 3670.41

Location = 13 · 33 · 14 · 1332 C
Elev. Ground = 3668.5
Elev Top PVC = 3672.73



"0" on Staff Gage = 3663.32

"0" on **USGS** Staff Gage = 3665.61

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Water and Power

COMPUTATION SHEET

BY	DATE	PROJECT	SHEET 2 OF 3
CHKD BY	DATE	FEATURE Figure 1 (continued)	
DETAILS			

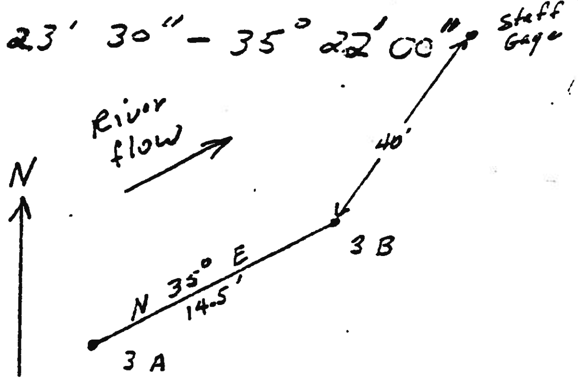
TW-1 103° 24' 50" – 35° 21' 12"

13-33-14-1333
Location = N 1585252.5 E 774291.3
Elev. on outer ring = 3674.01 white paint on west side

Piezomoter #3 Site 103° 23' 30" – 35° 22' 00"

Location = 13·33·12·3214 A
Elev. on Ground = 3655.1
Elev. Top PVC = 3658.38

Location = 13·33·12·3214 B
Elev. Ground = 3655.1
Elev. Top PVC = 3658.08

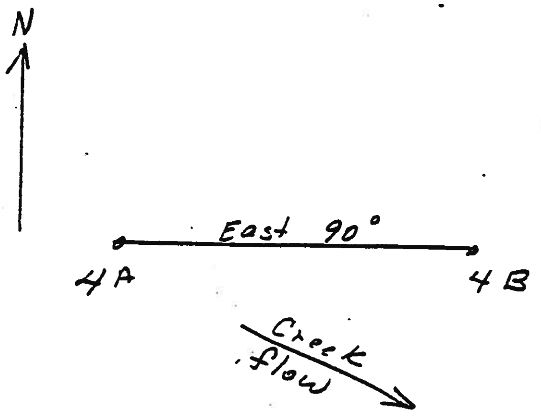


"0" on Staff Gage = 3651.86

Piezomoter #4 Site 103° 22' 58" – 35° 21' 48"

Location = 13·33·12·4412 A
Elev on Ground = 3653.7
Elev Top PVC = 3658.77

Location = 13·33-12-4412 B
Elev. Ground = 3653.7
Elev Top PVC = 3656.68



No Staff Gage

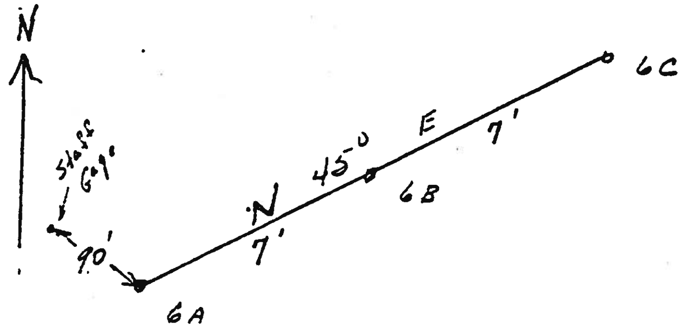
103° 20' 22" – 35° 23' 30"

Piezometer #6 Site "0" on Staff Gage = 3631.98

Location = 14·34·33·3324 A
Elev. Ground = 3638.0
Elev. Top PVC = 3640.99

Location = 14·34-33·3324 B
Elev. Ground = 3637.9
Elev. Top PVC = 3640.70

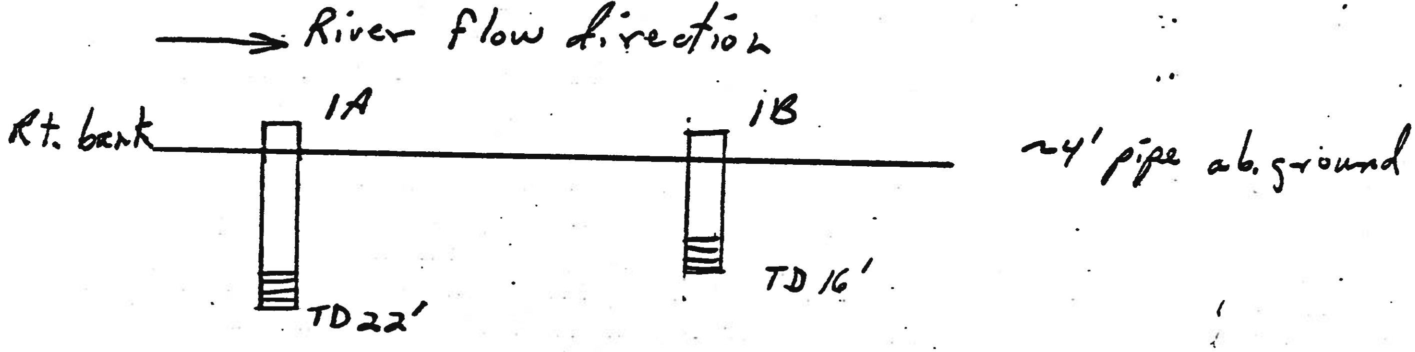
Location = 14·34·33·3324 C
Elev Ground = 3637.6
Elev Top PVC = 3640.74



7-1654 (7-73)
Water and Power

COMPUTATION SHEET

BY
DATE
PROJECT Lake Meridith Salinity
SHEET 1 OF 7
CHKD BY
DATE
FEATURE River Alluvial Holes RAH 1A, 1B
DETAILS Figure 2 ( ) –River Site 1–



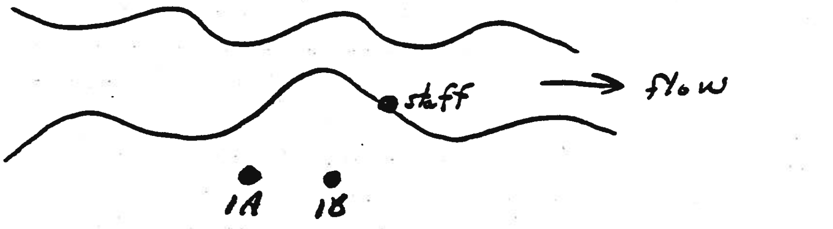
Screen 17.5 – 21.5'
22' at bedrock
drilled in sand w/ gravel interbeds
11' galv pipe below ground level to protect plastic pipe

11.5'–15.5'
6' galv pipe in top hole

Staff gage placed ~ 25' downstream on rt bank

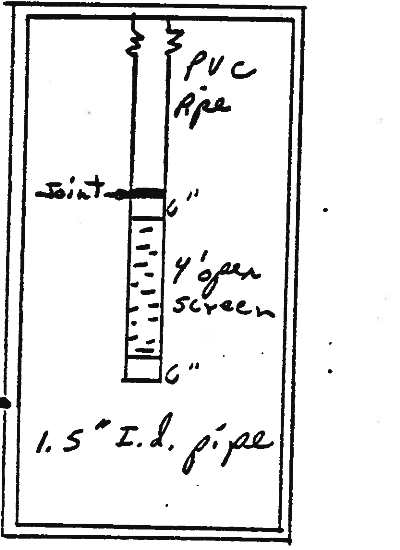
water level elevation 8/24/83
No density corrections

River 3666.03'
1A 3666.69'
1B 3663.40'
gradient up



River Mile – 1.6 mi below Ute Dam

Note: screen configuration



Note: piez. Prob Not in Deepest part of channel deepest is prob 100 yds south – May effect QW

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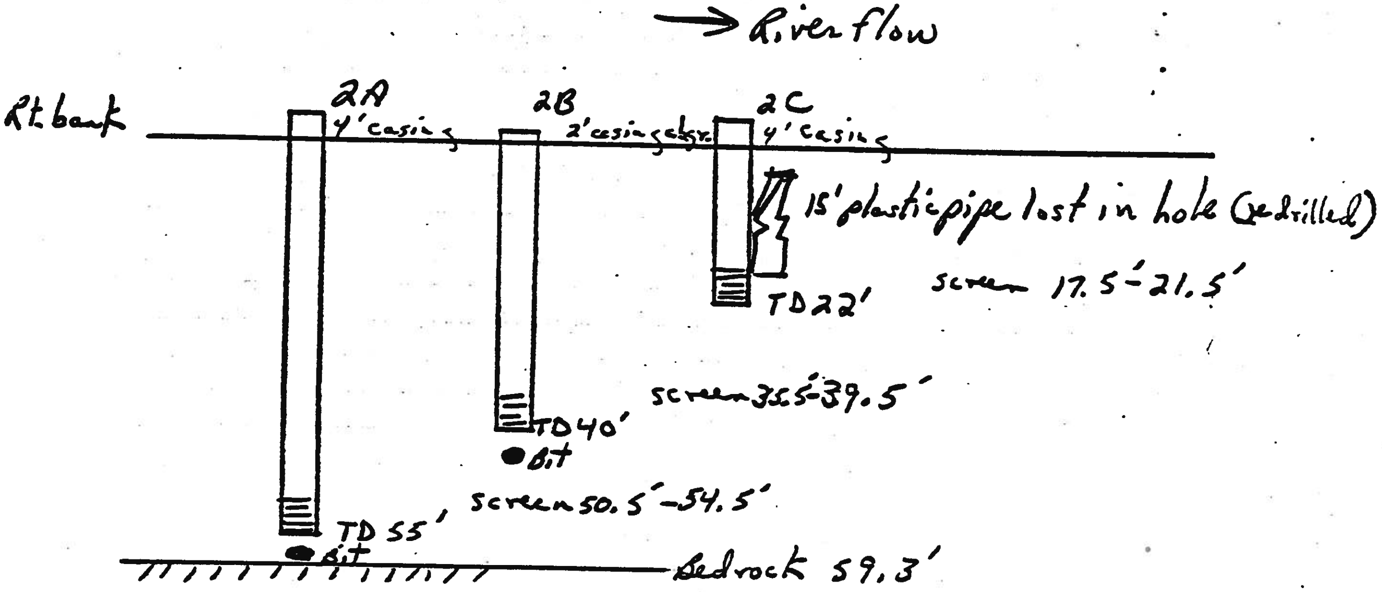
Water and Power

COMPUTATION SHEET

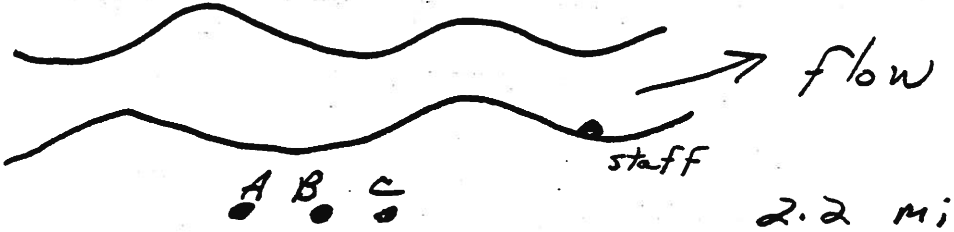
BY	DATE	PROJECT Lake Maridith Salinity	SHEET 2 OF 7
CHKD BY	DATE	FEATURE RAH 2A, B, C	
DETAILS Figure 2 (continued)		— River Site 2 —	



Steel bit was left in the bottom of holes A + B
11' galvanized casing was placed in top of hole
Drilling in Sand w/ pea size gravel lenses

Holes were drilled in Sand bar ~10' ab river surface on Rt. bank.

Staff gage ~40' downstream on Rt bank



2.2 mi below Ute Dam

water level elevations 8/24/83
No Density Corrections

River	3664.40'
2A	3664.85
2B	3664.70
2C	3664.73

gradient up

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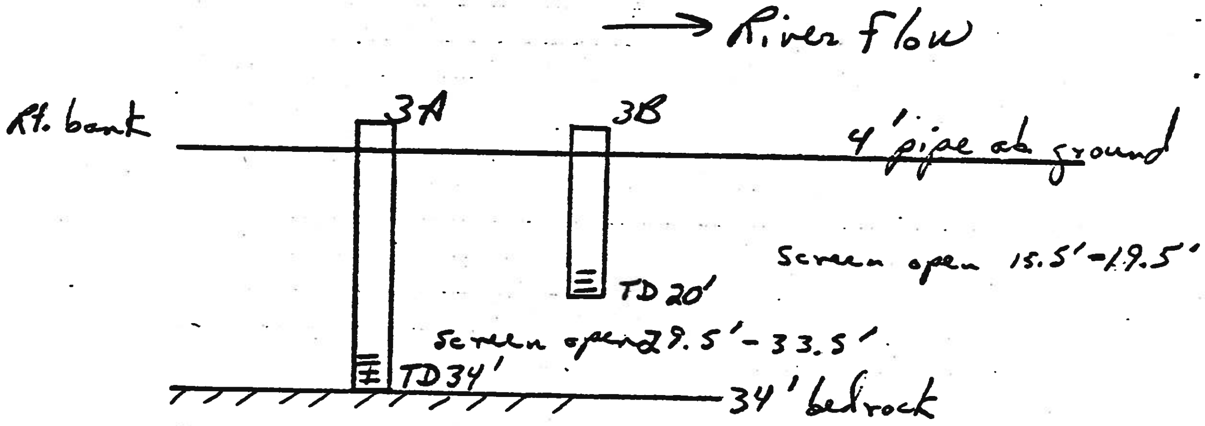
Water and Power

COMPUTATION SHEET

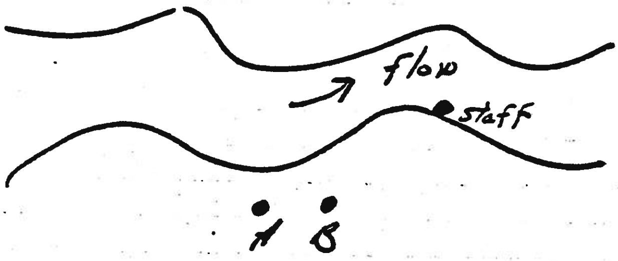
BY
DATE
PROJECT Lake Maridith Salinity
SHEET 3 OF 7
CHKD BY
DATE
FEATURE RAH 3 A, B
DETAILS Figure 2 (continued) -River Site 3-



11' galvanized pipe in top of holes

Drilled in ~~Sand~~ & clayey ~~Sand~~ w/some pea size gravel, red and lt. grey clay

staff gage ~ 10' downstream



5.4 mi below Ute Dam

water level elevations 8/24/83
no density corrections

River	3652.72'
3A	3652.48'
3B	3652.73'

gradient down?

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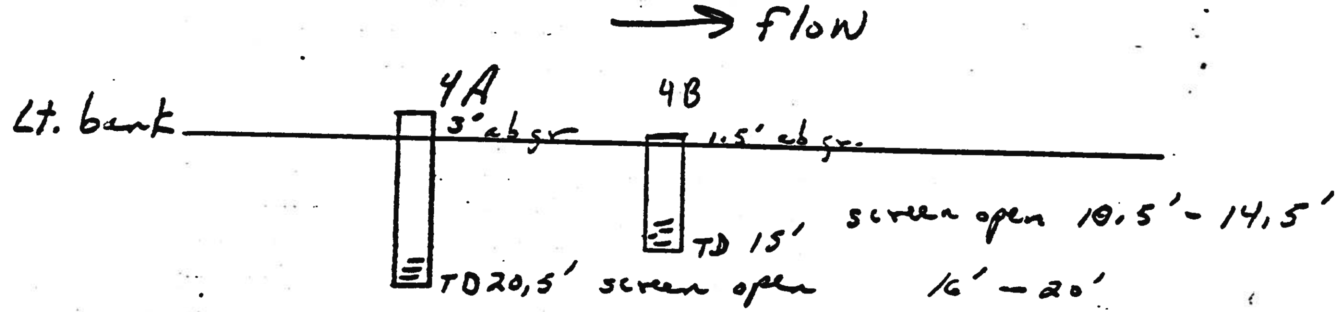
Water and Power

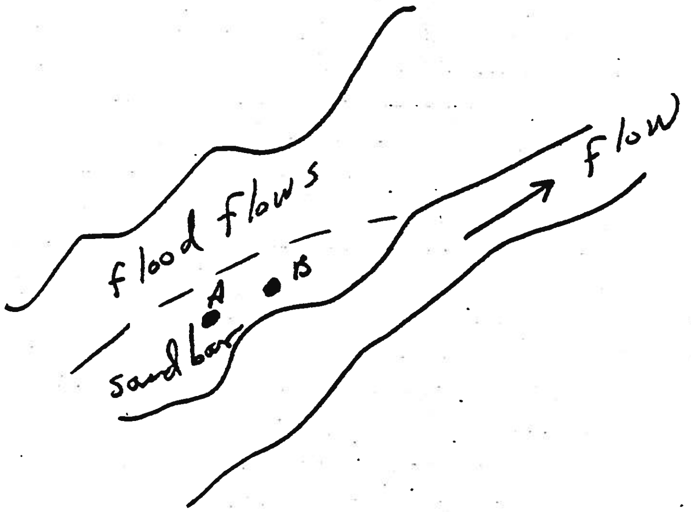
COMPUTATION SHEET

BY
DATE
PROJECT Lake Meridith Salinity
SHEET 4 OF 7
CHKD BY
DATE
FEATURE RAH 4, A, B -Revuelto Cr.
DETAILS Figure 2 (continued)
-River Site 4-



Bedrock ~18-20' very soft contact
drilled in Sand & pea size gravel
A-has 15.5' galvanized pipe in top of hole
B-has 8' galv pipe in top of hole
holes drilled in sand bar ~3' above Cr. Surface
hole "B" is ~9' directly downstream of A

No staff gage



0.2 mi ab. Mouth

Canadian R. Mi 6.3

Water Level elevations 8/24/83
No density Corrections

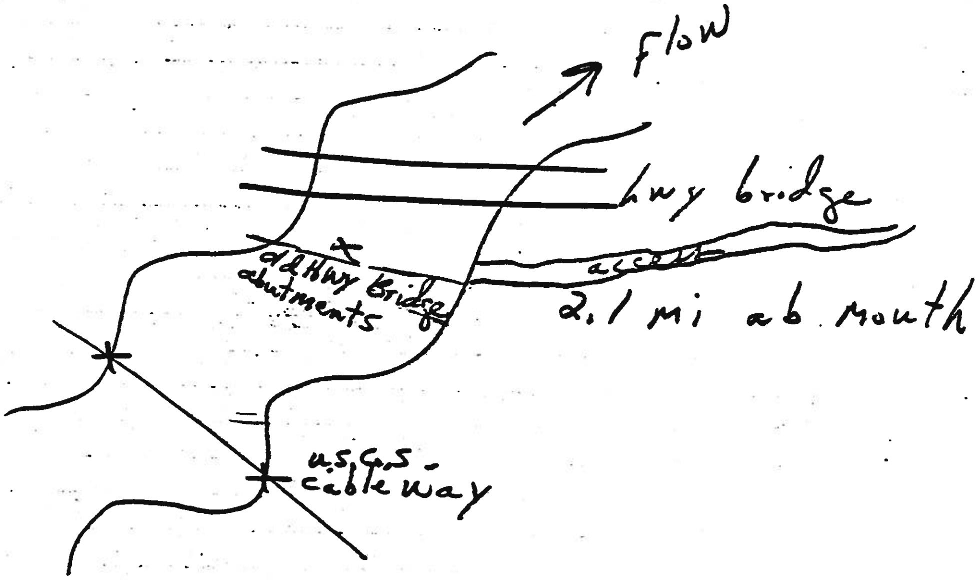
River —
4A 3653.27
4B 3653.18
gradient-up

7-1654 (7-73)
Water and Power

COMPUTATION SHEET

BY	DATE	PROJECT Lake Meridith Salinity	SHEET 5 OF 7
CHKD BY	DATE	FEATURE RAH 5A Revuelto Cr	
DETAILS Figure 2 (continued)		-River Site 5-	

Not completed as of 6/7/83



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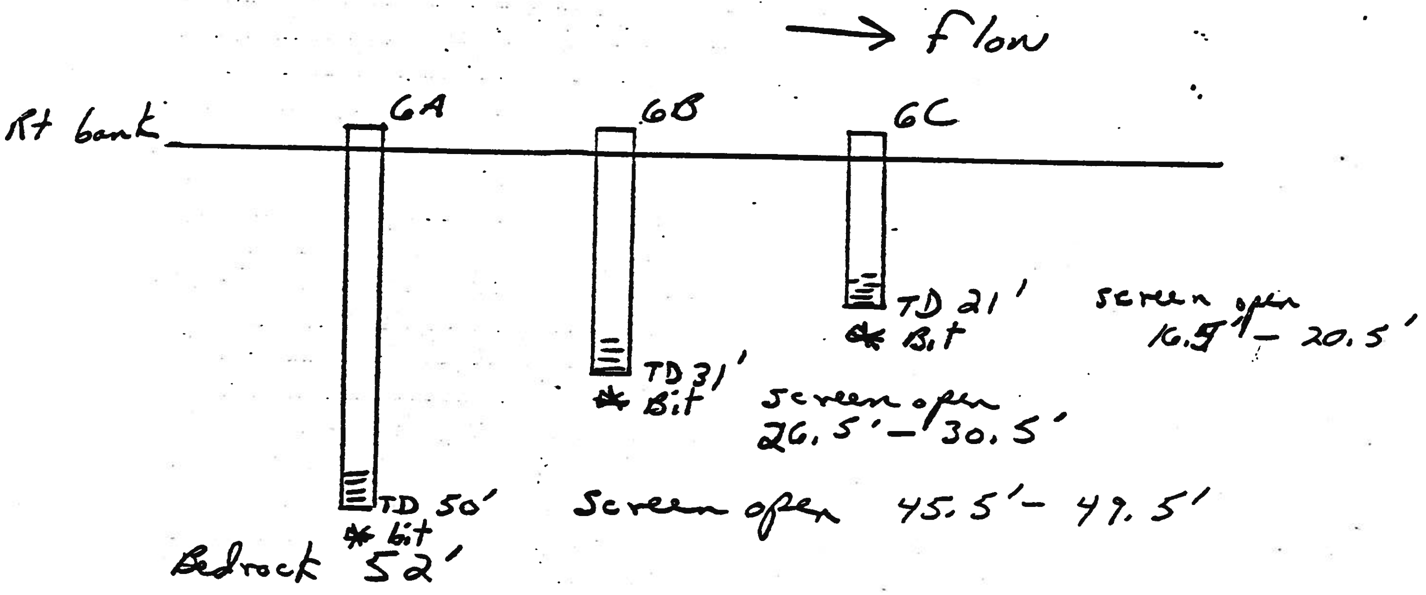
Water and Power

COMPUTATION SHEET

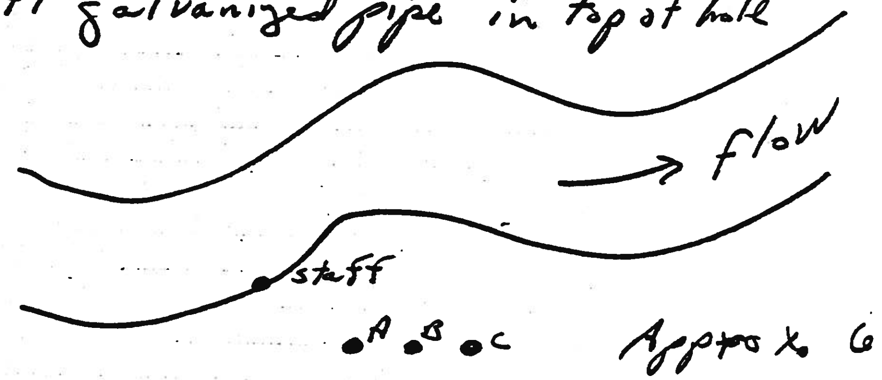
BY	DATE	PROJECT Lake Meridith Salinity	SHEET 6 OF 7
CHKD BY	DATE	FEATURE RAH 6 A, B, C	
DETAILS Figure 2 (continued)		-River Site 6-	



Bits in bottom of each hole

drilled in clayey sand at surface, gravel at 10',
Sand w/ clay lenses
gravel on top of bedrock

11 ft galvanized pipe in top of hole



Approx. 6' ab river surface

9.9 mi below ute dam

Water level elevations 8/24/83
No Density Corrections

River - 3632.19'
6A - 3631.99'
6B - 3632.20'
6C - 3632.24'
gradient?

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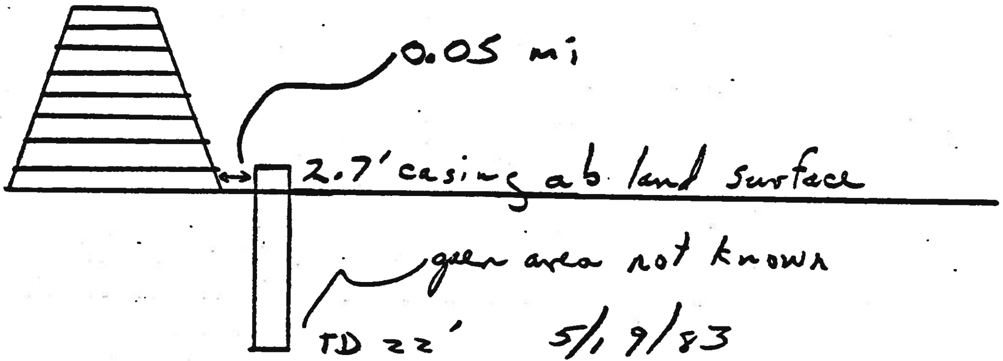
Water and Power

COMPUTATION SHEET

BY	DATE	PROJECT Lake Meridith Salinity	SHEET 7 OF 7
CHKD BY	DATE	FEATURE Piezometer below Ute Dam	
DETAILS Figure 2 - Sampling Site Descriptions Near Logan, NM			

Site 0 River mi 0 (River Site 0)



5/19/83

OD pipe 1 13/16"

reasonably good road to w/in 50' of piez.

deepest point of the alluvium, correlation of this deep piezometer with downstream deep piezometers may not be proper.

Site 2 was located 2.2 miles below Ute Dam (plate No. 1, figures 1 and 2). Three piezometers were installed at this site in sand containing lenses of pea-sized gravel. The total depth of piezometers 2A, 2B, and 2C were 55, 40, and 22 feet, respectively. A staff gauge was installed about 40 feet downstream of the piezometers. Steel drill bits were left in holes 2A and 2B but should not have affected water quality samples. Bedrock was encountered at 59.3 feet. This depth was probably at or near the deepest point in the canyon bedrock bottom.

Site 3 was located 5.4 miles below Ute Dam on the south side of the river (plate No. 1, figures 1 and 2). Two piezometers were installed at this site in sand containing lenses of clay and gravel. The total depth of piezometer 3A was 34 feet and piezometer 3B was 20 feet. Bedrock was encountered at 34 feet-this may not have been the deepest point of the channel. A staff gauge was installed about 10 feet downstream of the piezometers.

Site 4 was located in the middle of Revuelto Creek about 0.2 mile above the confluence with the Canadian River at RM 6.3 below Ute Dam (plate No. 1, figures 1 and 2). Two piezometers were installed in sand containing lenses of pea-sized gravel. Piezometer 4A was set at 20.5 feet total depth, and piezometer 4B was set at 15 feet total depth. Bedrock was encountered at about 18 to 20 feet. Soft sandstone, which forms the canyon bottom, made determination of the bedrock top very difficult. However, this depth was probably near the lowest point of the bedrock channel. No staff gauge was installed at this site.

Site 5 was planned for Revuelto Creek about 2.1 miles above the Canadian River confluence, just downstream of the USGS Revuelto Creek gauge (plate No. 1). It was not possible to physically enter the creek with the drill rig at this point because of steep streambanks, so the piezometer installations were not completed. Flow and water quality data were obtained from USGS.

Site 6 was located 9.9 miles below Ute Dam on the south side of the river. Three piezometers were completed in sand containing clay and gravel lenses (plate No. 1, figures 1 and 2). Piezometer 6A was completed to 50 feet total depth, piezometer 6B was completed to 31 feet total depth, and piezometer 6C was completed to 21 feet total depth. Drill bits were left in all three holes, but their presence should not have affected the water quality samples. Bedrock was encountered at 52 feet. This depth should have been close to the maximum depth of the bedrock channel. A staff gauge was placed just upstream of the site.

Water quality samples were collected on a regular schedule from all the piezometers of sites 1 through 4 and 6. Samples were obtained by injecting air at the bottom of the piezometer via a small-diameter tube to lift the water to the surface where it could be collected. Piezometers were pumped in order from the shallowest to the deepest. Water was discharged away from the site.

Samples were collected from the stream at the same time and a discharge measurement made. Additionally, supplemental data were acquired by HGC, under contract for this project, and from the USGS.

Several samples were collected from the surface and the outlet works of Ute Reservoir, and several stream water quality surveys were completed to determine the changes in quality of the surface waters at different places.

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Water and Power

COMPUTATION SHEET

BY	DATE	PROJECT Lake Meredith Salinity Control	SHEET ___ OF ___
CHKD BY	DATE	FEATURE Observation Well Locations	

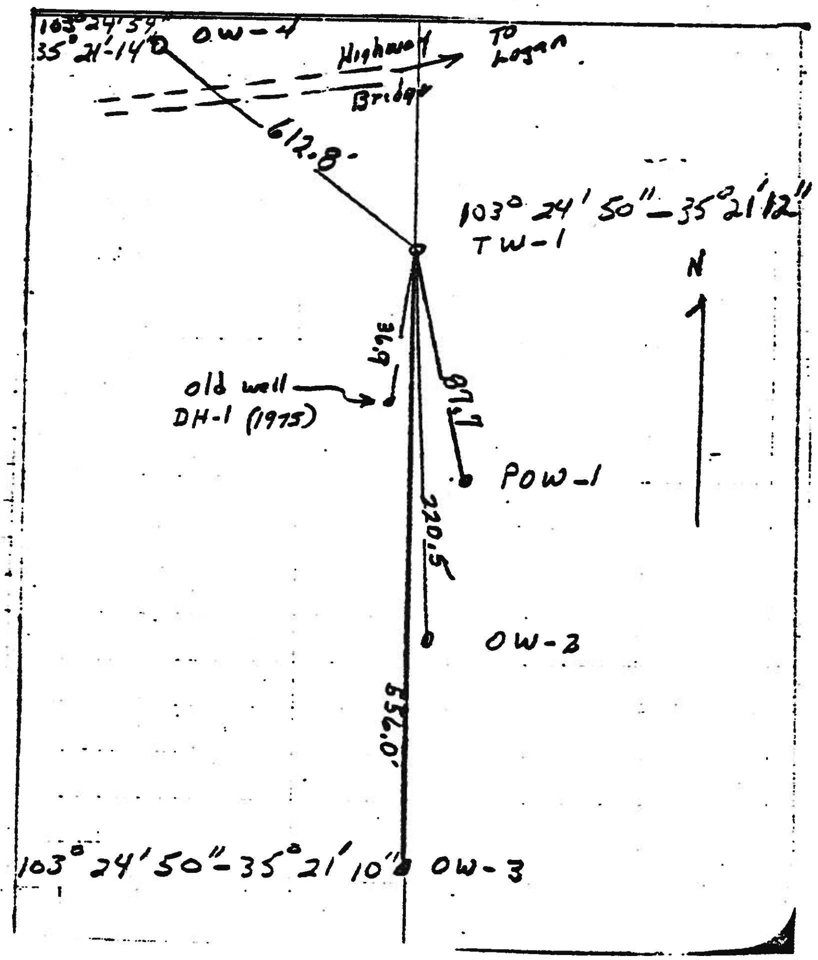
DETAILS
Figure 3 – Observation Well Locations Near Logan, NM

Well No.	State Plane Coordinates North	East	Elevation
DH-1	1585226.9	774266.3	3674.5 (bolt)
DH-2			3655.72 (Top spigot - Land Surface)
DH-3	1585902	770028	3781.0 (Land Surface)
TW-1	1585252.5	774291.3	3674.01 (Top outer ring - Land Surface)
POW-1	1585178.6	774245.7	3675.9 (pipe)
OW-2	1585081.1	774153.6	3682.8 (pipe)*
OW-3	1584830.4	773931.6	3673.0 (Land Surface)
OW-4			3676.5 (Land Surface)

*~1 foot of pipe has been cut off since elevation was determined

DH-2 Location – 13-34-17-1342 or 103°22'32", 35°22'10"

DH-3 Location – 13-33-15-3124 or 103°25'40", 35°21'05"



Ground Water

Water level recorders were installed on two wells (completed in the Triassic/ Brine Artesian Aquifers) which were drilled during the previous Reclamation investigation (plate No. 1, figure 3). A recorder installed on the DH-2 hole was in operation for 2 months before it was discontinued because water levels were responding to fluctuations in the riverflow (table 1). A second recorder was installed on well TW-1 near the State Highway 54 bridge (table 1). The recorder was in operation from May 1983 until August 1984. The major fluctuations in water levels observed were small and reflected atmospheric pressure changes and earth tides. Limited water level data were also collected from observation wells OW-4, OW-3, and DH-3 (table 1).

Water surface elevation data for Ute Reservoir were acquired from USGS for the period August 1982 through September 1984 (figure 4). These data were used to determine the relationship, if any, of the lake surface elevation and the water levels in the Brine Artesian Aquifer as depicted by observation wells TW-1, OW-3, OW-4, and DH-3 (plate No. 1, figure 3, and table 1).

Eleven relatively consistent water level observations were recorded for DH-3 between September 1983 and July 1984, at which time the well was pumped and sampled (table 1). After pumping the water level recovered to a point about 5 feet lower than previously recorded. The change in water levels may have been due to improper development and cleaning of the well just after completion in September 1983. The pumping may have cleared any drilling mud and/or foreign materials from the well, allowing a true water level to be reached.

7-1654 (7-73)
Water and Power

COMPUTATION SHEET

BY	DATE	PROJECT	SHEET ____ OF ____
	8/20/84	Lake Meredith Salinity	
CHKD BY	DATE	FEATURE	
		DH-2, OW-4	

DETAILS
Table 1 – Water Level Elevations for observation wells...

	Date	elevation	
OW-4	7/19/84	3677.52	surface elevation - 3676.50ft
DH-2	7/6/83- 9/13/83	3658.12 Min 3659.07 Max	Surface elevation 3655.72ft

recorder removed 9/13/83 - Well is not cased below bedrock and is closed at ~ 160 feet.
Hydrograph appears to be a reflection of stream flows.

7-1654 (7-73)
Water and Power

COMPUTATION SHEET

BY	DATE 8/20/84	PROJECT Lake Meredith Salinity	SHEET ___ OF ___
CHKD BY	DATE	FEATURE TW-1 water level elevations	
DETAILS Table 1 (continued) 3674.01 surface elevation			

Date	**elevation**		
5/25/83 –			
→ 8/17/84	0.66 ft	Maximum	3674.67' elev.
	0.05 ft	Minimum	3674.06' elev.

all fluctuations appear to be Earth tides and Barometric, – Barometric data from Tucumcari Airport

w.L. elev. Measured in stand pipe by Jim Rogers 1982

Aug 3, 1982	~ 23.90 inches ab LSD	3676.0' elev ab NGVD
Aug 10, 1982	~ 22.25 inches ab LSD	3675.9' elev
Aug 17, 1982	~ 16.25 inches ab LSD	3675.4' elev
Aug 28, 1982	~ 16.25 inches ab LSD	3675.4' elev

flow ~ 23 gpm from stand pipe – barometric P ~ same as 1983/84

~20 ft higher lake elev. if measured accurately

~ 2.0 ft higher w.L. elev. from min

barometric & earth tide fluctuations with constant lake elevation of ~ 3740' were as great as 0.60 ft

need at least ~6 ft of Lake rise to possibly see affects 0.1 ftwl/ft lake .60/.1 = ~6 ft

+4 ft change at Sep 6, 1984 w/ no noticible change

7-1654 (7-73)
Water and Power

COMPUTATION SHEET

BY	DATE 8/20/84	PROJECT Lake Meredith Salinity	SHEET ____ OF ____
CHKD BY	DATE	FEATURE OW-3 - water level elevations	
DETAILS Table 1 (continued)		Surface elevation = 3678.3'	

Date	elevation
11/17/83	3680.91
12/13/83	3680.98
1/12/84	3680.95
2/15/84	3681.10
3/16/84	3681.01
4/13/84	3681.03
5/10/84	3681.26
6/8/84	3680.69
7/10/84	3680.88
8/17/84	3681.04
9/6/84	3681.03

7-1654 (7-73)
Water and Power

COMPUTATION SHEET

BY	DATE 8/20/84	PROJECT Lake Meredith Salinity	SHEET ___ OF ___
CHKD BY	DATE	FEATURE DH-3 -water level elevations	
DETAILS Table 1 (continued)		-Surface elev.=3781 ft	

Date	elevation	
9/14/83	3695.86	Just after completion
10/17/83	3694.96	
11/17/83	3695.26	
12/13/83	3695.16	
1/12/84	3695.08	
2/15/84	3695.16	
3/16/84	3695.01	
4/13/84	3695.00	
5/10/84	3694.96	
6/8/84	3694.96	
7/10/84	3694.80	
7/19/84		Pumped well 1 hour. Black fluid,* like drilling mud blown out of hole, then clear water.
8/17/84	3689.67	Hole may not have been properly cleared after drilling. Piezometer should be pumped + tested before using for testing.
9/6/84	3689.10	

*Note: Floating, lighter, materials?

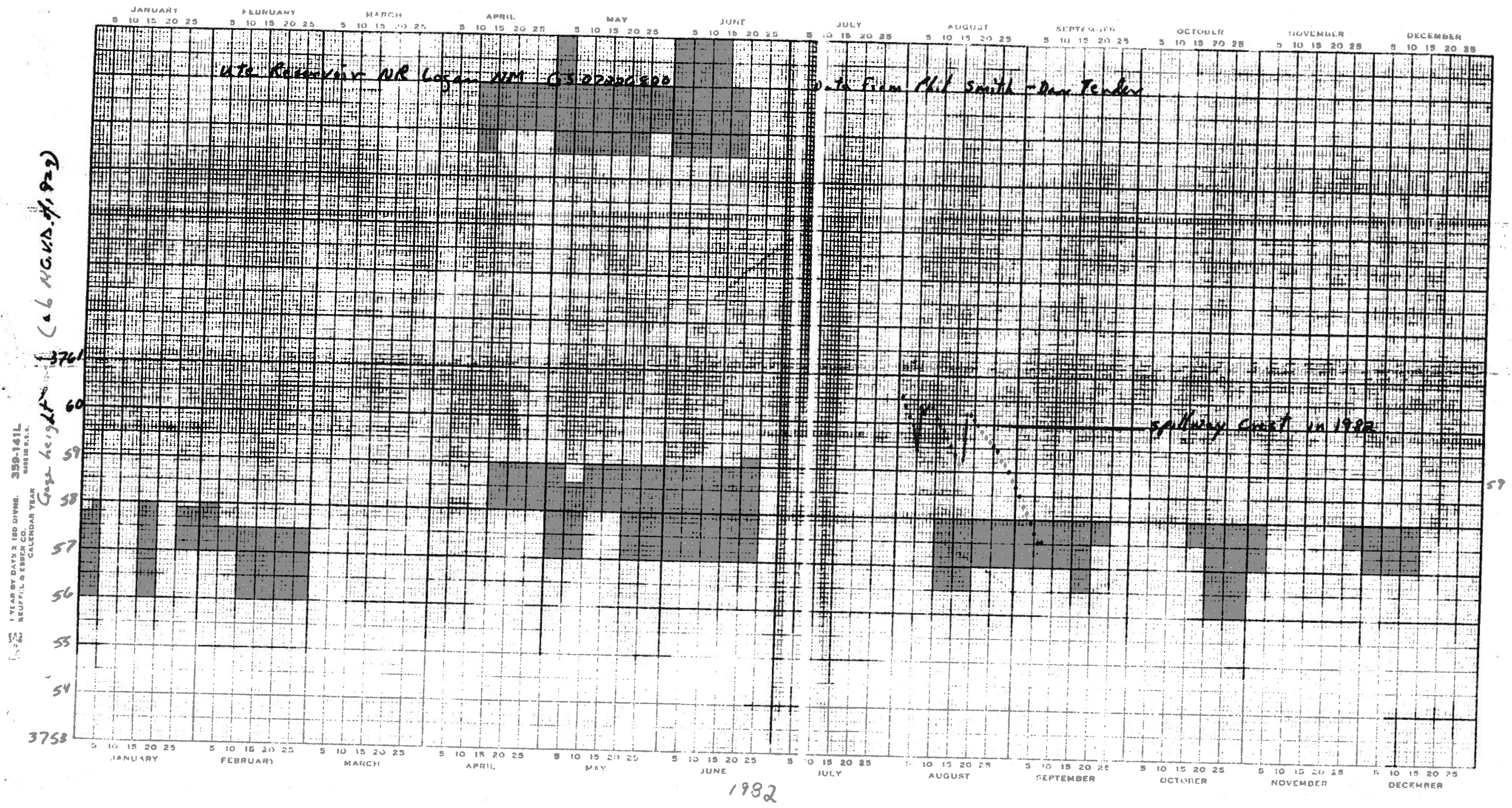


Figure 4 Ute Reservoir near Logan, NM Water Level Elevation Changes

2/3

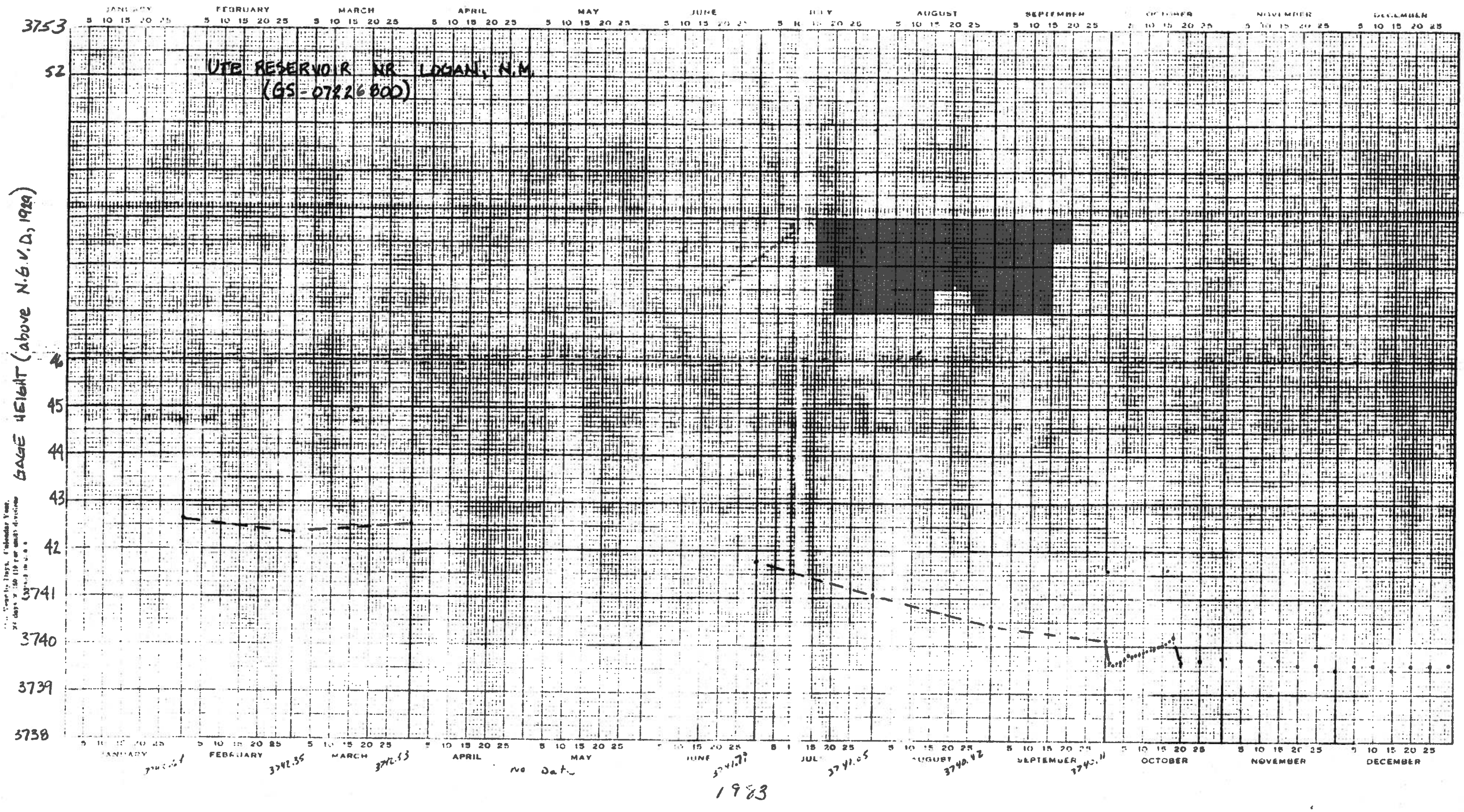


Figure 4 (continued)

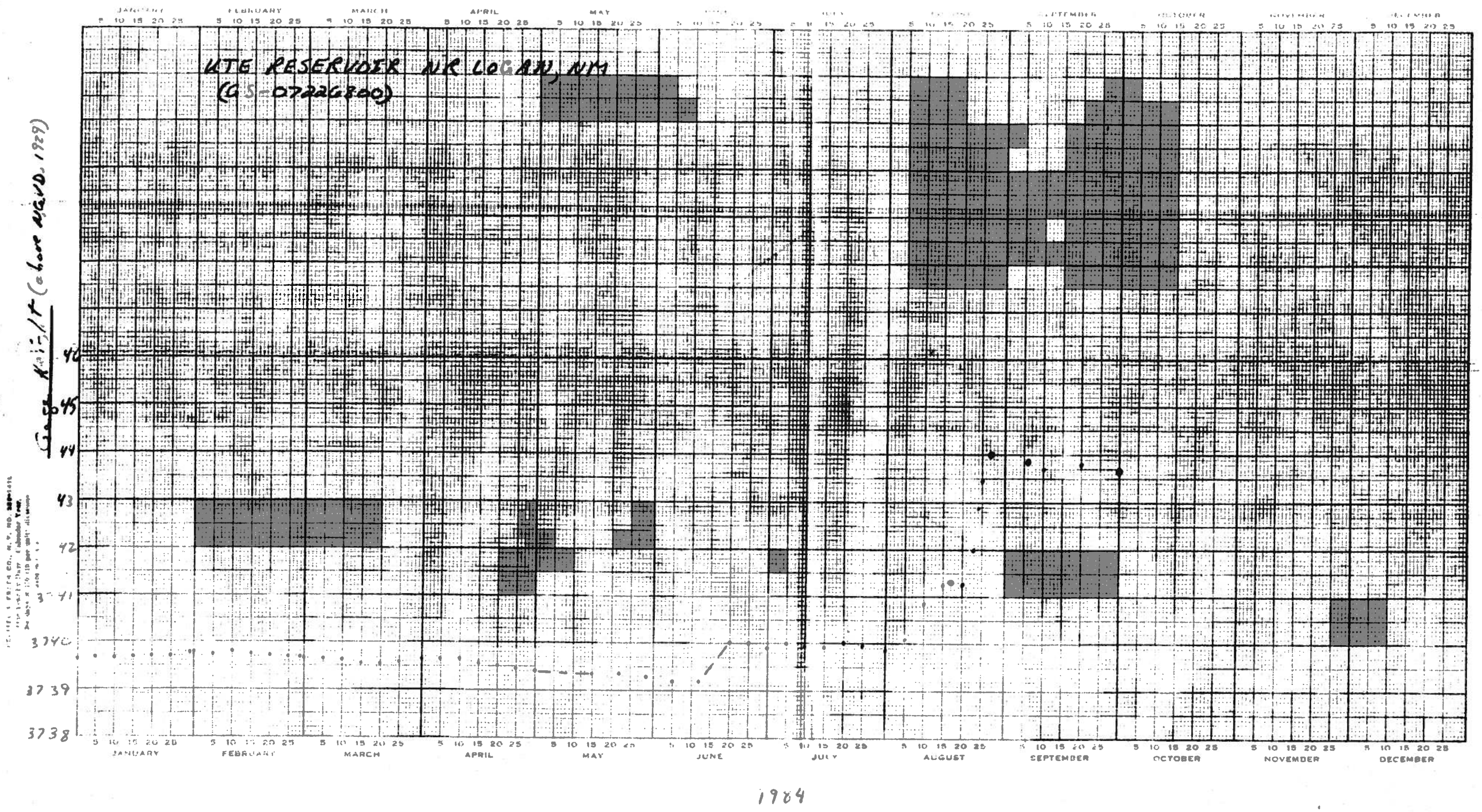


Figure 4 (continued)

Several water samples were collected from wells DH-2, DH-3, and OW-3 for analyses and correlation. Limited isotope data were also collected for age dating and recharge area and water-mixing determinations.

Core Drilling

Information obtained from bore holes completed near Logan during the previous Reclamation investigation had raised questions about the local stratigraphy which could not be adequately resolved due to problems encountered with obtaining reliable samples of the subsurface rocks. It was determined that a core was needed of the Triassic and Upper Permian rocks for proper correlation. This coring operation (hole DH-3) was started in August 1983 and finished about 1 month later using a standard truck-mounted, mud-rotary drilling rig (plate 1 and figure 5). Problems with hole caving slowed the drilling in the shales of the Triassic Formation, which continued until 362 feet of casing was set. The coring then continued to 569.5 feet where the drill stem was twisted off, and the hole had to be abandoned. Core recovery was about 100 percent, which allowed compilation of a very reliable stratigraphic column. A natural gamma log was also obtained from the drill hole (figure 6).

A 147-foot section of grayish-white to bluish-gray sandstone was cored from about 350 feet to 497 feet. It was determined that this sandstone was the Brine Artesian Aquifer identified by earlier drilling. Permian Age rock was first encountered at 514 feet. The hole was completed as an observation well with

GEOLOGIC LOG OF HOLE NO DH-3

SHEET 1 OF 8

PROJECT LAKE MEREDITH SALINITY STUDY FEATURE DEEP CORE HOLE AREA LOGAN AREA STATE NEW MEXICO

COORDS. N. 1509902 E. 770020 GROUND ELEV. 3781.0 ANGLE FROM HORIZ. 90.0 DOWN

BEGUN 8/17/83 FINISHED 9/1?/83 DEPTH TO BEDROCK 11.0 TOTAL DEPTH 569.5 BEARING

DEPTH TO WATER 84.9 FT. 9/9/83 LOGGED BY SHIRLEY SHADIX REVIEWED BY JOE JACKSON

NOTES	FIELD PERMEABILITY TEST (DESIGNATION E-18, EARTH MANUAL): DEPTH (FEET) FROM (P, CS or CM)	TO	DIAMETER (INCHES)	LOSS (GPM)	DIFFERENTIAL PRESSURE (FEET)	LENGTH OF TEST (MIN)	PERMEABILITY (K) FEET/YEAR	PERCENT CORE RECOVERY	DEPTH SCALE (FEET)	CLASSIFICATION INTERVALS: GRAPHIC DEPTHS	ELEVATIONS (FEET)	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION

NOTES

DRILLED USING S+H DRILLING RIG, BEAN PUMP (24 GPM MAXIMUM CAPACITY) AND CORE DRILL OPERATOR FROM BRANTLEY PROJECT, NEW MEXICO.

USED 3-7/8 INCH ROCK BIT 0.0-16.2 FT. USED NQ DIAMOND BIT 16.2-335.9 FT. USED NQ CARBIDE BIT 335.9-370.2 FT. DRILLED 350.0-370.2 AND DRILLED 370.2-569.5 FT. USING NQ DIAMOND BIT. TOP OF ROCK DEPTH BASED ON DRILL ACTION AND CUTTING.

WATER LOSS DURING DRILLING:

INTERVAL (FT.)	PERCENT
48.0- 50.0	50
122.0-160.0	40
273.0-273.5	100
273.5-306.0	40
327.0-332.5 (BEFORE CASING TO 362.0 FT.)	50
350.0-370.2	40
430.0-450.0	80

DRILLED WITH CLEAR WATER EXCEPT IN INTERVALS AS FOLLOWS:

E-Z MUD	DEPTH(FT.)
2 GAL.	61.0
5 GAL.	319.8
5 GAL.	360.0
5 GAL.	370.0
50 LBS REVERT	370.2 FT.
5 GAL.	529.4
8 GAL.	568.2

HOLE BEGAN CAVING AT 335.0 FT. IN RED MUDSTONE AND GREEN SHALE FROM 297.0-340.0 FT. AT 419.3 FT., HOLE CAVED BACK TO APPROX. 366.0 FT. EACH TIME RODS WERE PULLED. AFTER CASING SET TO 362.0 FT., HOLE DEVIATED FROM PREVIOUSLY DRILLED HOLE. CONSOLIDATED CAVING AND FORMATION ROCK FROM SIDE OF HOLE WERE RECOVERED FROM 362.0 TO 409.3 FT. FORMATION ROCK WAS CORED FROM 409.3 TO 569.5 FT.

PERCENT CORE RECOVERY

100

DEPTH SCALE (FEET)

10, 20, 30, 40, 50, 60, 70, 80, 90

ELEVATIONS (FEET)

3700.4
3779.4
3777.0
3770.0
3767.0
3762.7
3754.2
3750.5
3734.0
3727.4
3715.6
3897.8
3895.0
3890.9
3688.7

CLASSIFICATION AND PHYSICAL CONDITION

0.0-11.0 FT.: QUATERNARY ALLUVIUM.

0.0-0.6 FT.: TOPSOIL.

0.6-1.6 FT.: GRAVELLY SAND. NUMEROUS CALICHE FRAGMENTS AND PEBBLES.

1.6-4.0 FT.: SANDY GRAVEL WITH COBBLES.

4.0-11.0 FT.: SILTY SAND.

11.0-514.0 FT.: TRIASSIC DOCKUM GROUP.

11.0-14.0 FT.: SANDSTONE. SILTY, MICACEOUS, MEDIUM GRAINED. BROWN.

14.0-18.3 FT.: CLAYSTONE. CLAYEY, RED TO RED-BROWN, WITH INTERBEDS OF RED-BROWN SILTSTONE (17.1-17.7 FT.) AND FINE GRAINED, MICACEOUS CROSSBEDDED SANDSTONE (16.2-16.7 FT.) AND (17.7-17.9 FT.). STRONG REACTION WITH HCL. TAN.

18.3-30.5 FT.: SANDSTONE. SILTY, MICACEOUS. FINE-GRAINED, CROSSBEDDED. LIGHTLY TO MODERATELY CEMENTED. ONE HAMMER BLOW CRUSHES SMALL PIECE. LONGEST CORE STICK 1.7 FT. STRONG REACTION WITH HCL. TAN TO BROWN, E.PT YELLOW FROM 29.0-30.5 FT.

26.8-26.85 FT.: CLAYSTONE. GREENISH GRAY.

27.3-27.4 FT.: CLAYSTONE. RED.

30.5-47.0 FT.: SHALE. SANDY, MICACEOUS. SLIGHTLY FISSILE TO BLOCKY STRONG REACTION WITH HCL. PREDOMINANTLY RED WITH GREENISH GRAY LAYERS AT 41.7-42.6 FT. AND 43.0-45.0 FT. WITH SOME GREENISH GRAY YELLOW BROWN MOTTLING AND BANDING. CONSIDERABLY LESS SAND IN GRAY COLORED INTERVALS.

47.0-53.6 FT.: SANDSTONE. FINE TO MEDIUM GRAINED, MICACEOUS, CROSSBEDDED. MODERATE TO STRONG REACTION WITH HCL. 70 DEGREES TO VERTICAL FRACTURES WITH IRON AND MANGANESE STAINING. FEW THIN BEDS BELOW 50.6 FT. CONTAIN ROUNDED TO OBLONG FRAGMENTS OF BROWN AND GRAY CLAYSTONE (-1 INCH). TAN TO BROWN.

53.6-65.4 FT.: SHALE. CLAYEY, SLIGHTLY FISSILE TO BLOCKY, MODERATELY WELL-CONSOLIDATED. SLIGHT REACTION WITH HCL. CORE STICKS UP TO 1.1 FT. IN LENGTH BROWN TO REDDISH BROWN WITH THIN GREENISH GRAY LAYERS AND MOTTLING.

65.4-92.3 FT.: SANDSTONE. SILTY TO CLAYEY. MICACEOUS. FINE TO MEDIUM GRAINED. THIN SANDY SILTSTONE LAYERS THROUGHOUT. CARBONACEOUS MATERIAL AND MICA ON BEDDING PLANES. 50-70 DEGREE FRACTURES 72.2-77.5 FT., SLIGHTLY CEMENTED. WEAK TO STRONG REACTION WITH HCL. GRAY TO BROWN WITH LIMONITE STAINING AND SPOTS.

83.2-84.0 FT. SHALE. CLAYEY. FISSILE, WELL CONSOLIDATED. CORE STICK 0.8 FT. LONG. GRAY.

88.0-90.1 FT.: SANDSTONE. MEDIUM GRAINED. THIN TO MEDIUM BEDDED. NEAR VERTICAL FRACTURES THROUGHOUT, BUT STRONGLY FRACTURED 87.6-88.9 FT. SLIGHTLY CEMENTED. YELLOW.

92.3-118.4 FT.: SHALE. CLAYEY. FISSILE. THIN LAYERS (0.7 FT. THICK) OF GREENISH GRAY SHALE AT 92.3 FT., 109.0 FT. AND 118.0 FT. AND 118.0 FT. AND THIN LAYERS OF FINE-GRAINED, WELL CEMENTED GRAY SANDSTONE AT 93.4 FT. AND 97.4 FT. STRONG REACTION TO HCL BECOMING MODERATE BELOW 116.0 FT. RED BROWN.

118.4-149.7 FT.: SANDSTONE. SILTY. MICACEOUS. CARBONIZED WOOD LAYERS AND LAMINATIONS OF MICA AND CARBONACEOUS MATERIAL WITH ASSOCIATED PYRITE AND CHALCOPYRITE ON BEDDING PLANES. FINE GRAINED. MODERATELY TO SLIGHTLY CEMENTED. SLIGHT TO NO REACTION WITH HCL. NEAR VERTICAL FRACTURES AT 121.5-125.0 FT., 132.5-133.0 FT. AND 145.0-146.0 FT. 45 DEGREE FRACTURES

COMMENTS:

SET 14.0 FT. OF 4 INCH SURFACE CASING 8/17/83. SET 18.0 NW CASING TO 18.5 FT. ON 8/18/83. SET ADDITIONAL 343.5 FT. NW CASING TO 362.0 FT. ON 8/31/83. 9/11 THROUGH 9/13/83: GROUTED HOLE FROM T.D. TO 418.5 FT. PLACED 1 FT. SAND FROM 417.5 418.5 FT. SET 49.5 FT. OF 1-1/2 INCH DIAMETER PVC SCREEN AND 371.0 FT SCHEDULE 80 1-1/2 INCH DIAMETER BLANK PVC TO 417.5 FT. PLACED SAND PACK IN HOLE FROM 417.5 TO 381.5 FT. PLACED 3.0 FT. BENTONITE 358.5-381.5 FT. AND NEAT CEMENT GROUT FROM 381.5 FT. TO GROUND LEVEL. PLACED 5 FT. OF 2 INCH STEEL PROTECTIVE CASING WITH 2-FT. STICKUP.

EXPLANATIONS: GENERAL FORMULAS USED TO COMPUTE PERMEABILITY:

$$K = \frac{Q}{2 \pi L H} \log_e \frac{L}{r}$$

WHEN L GREATER THAN OR EQUAL 10r

$$K = \frac{Q}{2 \pi L H} \sinh^{-1} \frac{L}{2r}$$

WHEN L LESS THAN 10r AND GREATER THAN OR EQUAL r

PERMEABILITY VALUES SHOWN ARE COMPUTED FROM THESE THEORETICAL FORMULAS AND DO NOT CONSIDER SYSTEM HEAD LOSSES AND OTHER FACTORS INHERENT IN THE TESTING. THEREFORE, THESE ARE NOT TRUE PERMEABILITIES, MERELY RELATIVE VALUES.

P = PACKER CS = CASING CM = CEMENT

Figure 5 - Geologic Log of Core Hole DH-3 Near Logan, NM

GEOLOGIC LOG OF HOLE NO DH-3

SHEET 2 OF 8

PROJECT LAKE MEREDITH SALINITY STUDY FEATURE DEEP CORE HOLE AREA LOGAN AREA STATE NEW MEXICO
COORDS. N. 1585802 E. 7,020 GROUND ELEV. 3701.0 ANGLE FROM HORIZ 90.0 DOWN
BEGUN 8/17/83 FINISHED 9/14/83 DEPTH TO BEDROCK 11.0 TOTAL DEPTH 569.5 BEARING
DEPTH TO WATER 84.9 FT. 9/9/83 LOGGED BY SHIRLEY SHADIX REVIEWED BY JOE JACKSON

NOTES	FIELD PERMEABILITY TEST (DESIGNATION E-18, EARTH MANUAL) DEPTH (FEET) FROM (P, CS, or CM)	TO	DIAMETER (INCHES)	LOSS (GPM)	DIFFERENTIAL PRESSURE (FEET)	LENGTH OF TEST (MIN)	PERMEABILITY (K) FEET/YEAR	PERCENT CORE RECOVERY	DEPTH SCALE (FEET)	CLASSIFICATION INTERVALS GRAPHIC DEPTHS	ELEVATIONS (FEET)	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
									110 120 130 140 150 160 170 180 190		3862.6 3831.3 3829.9 3813.9 3812.8 3805.4		

AT 147.7 FT. AND 148.2 FT. FRAGMENTS OF GRAY SHALE AND SUBANGULAR TO SUBROUNDED PHOSPHATIC AND QUARTZITIC GRAVEL (1-1/2 INCH) AT 119.7 FT. AND 132.5 FT. GRAY.

149.7-151.1 FT.: CLAYSTONE.
BLOCKY. BLUISH GRAY.

151.1-298.0 FT.: SANDSTONE.
MICACEOUS. FINE TO COARSE-GRAINED. THIN CONGLOMERATIC LAYERS WITH SUBANGULAR TO SUBROUNDED FINE GRAVEL AND ANGULAR FRAGMENTS WITH ASSOCIATED CHALCOPYRITE AND PYRITE (168.2, 171.0, 176.0, 219.0, 234.1 AND 246.9 FT.) GRADING INTO WELL-CEMENTED CONGLOMERATE 274.4 TO 277.0 FT. CARBONACEOUS LAMINATIONS ON HORIZONTAL BEDDING PLANES. MOSTLY THIN BEDDED. SLIGHTLY TO WELL CEMENTED. SLIGHT TO MODERIATE REACTION WITH HCL. 75 DEGREES FRACTURE AT 177.3 FT., VERTICAL FRACTURE AT 223 - FT. VUGS UP TO 1/8 INCH DIAMETER AND .72 INCH DEEP IN WELL CEMENTED CONGLOMERATIC SANDSTONE AT 234.1-238.3 FT. AND 246.9-258.7 FT., GRAY TO LIGHT GRAY.

167.1-168.2 FT.: SHALE.
CLAYEY. GRAY.

175.6-176.0 FT.: SHALE.
CLAYEY. GRAY.

200.6-200.8 FT.: SHALE.
CLAYEY. GRAY.

203.3-203.5 FT.: SHALE.
CLAYEY. GRAY.

205.9-208.1 FT.: SHALE.
CLAYEY. GRAY.

223.8-224.9 FT.: SHALE.
CLAYEY. BLACK LAMINATIONNS ON BEDDING PLANES. GRAY.

298.0-297.0 FT.: SHALE.
CLAYEY. GREENISH-GRAY.

297.0-341.0 FT.: MUDSTONE.
CLAYEY. SANDY. BLOCKY. AIR SLAKES RAPIDLY. STRONG REACTION WITH HCL. PURPLISH RED.

341.0-350.0 FT.: SHALE.
CLAYEY. GREENISH-GRAY.

AQUIFER

418'–361' screen

350.0-496.7 FT.: SANDSTONE.
CLAYEY, MICACEOUS. CARBONACEOUS MATERIAL AND SHALE FRAGMENTS (-1 INCH) OCCUR IN CONGLOMERATIC LAYERS. FINE GRAINED SUBROUNDED TO SUBANGULAR GRAINS. MICA AND CLAY COATED BEDDING PLANES DIP 10 DEGREES. CROSSBEDDED BELOW 462.8 FT. PIN POINT VUGS 449.3-450.5 FT. VERTICAL FRACTURE AT 360.0 FT. AND 415.0 FT.. 70 DEGREES FRACTURE AT 308.0 FT. AND 60 DEGREE FRACTURES AT 410.0 FT. AND 412.0 FT. SLIGHT TO NO REACTION WITH HCL. CORE STICKS UP TO 2.0 FT. GRAYISH WHITE TO BLUISH GRAY.

402.2-404.4 FT.: CLAYSTONE.
SANDY. GREENISH TO BLUISH GRAY.

434.0-435.3 FT.: CLAYSTONE.
SANDY. GREENISH GRAY.

450.5-450.9 FT.: CLAYSTONE.
SANDY. GREENISH GRAY.

472.9-475.0 FT.: CLAYSTONE.
SANDY. GREENISH GRAY.

(NOTE:) EACH CLAYSTONE BED IS OVERLAIN BY CONGLOMERATIC SANDSTONE WHICH BECOMES FINER GRAINED UPWARD.

496.7-514.0 FT.: SHALE.
CLAYEY. FRAGMENTS OF GREENISH LIMESTONE AND WHITE DOLOMITE. INTERBEDS OF HARD WELL CEMENTED LIGHT RED SANDSTONE. HARD. WELL CONSOLIDATED. SLIGHT REACTION WITH HCL. RED

514.0-569.5 FT.: PERMIAN ARTESIA GROUP.

514.0-518.0 FT.: SHALE.
WELL CONSOLIDATED. MODERATE REACTION WITH HCL. SALMON RED.

COMMENTS:

SET 14.0 FT. OF 4 INCH SURFACE CASING 8/17/83. SET 18.0 NW CASING TO 18.5 FT. ON 8/18/83. SET ADDITIONAL 343.5 FT. NW CASING TO 362.0 FT. ON 8/31/83. 9/11 THROUGH 9/13/83: GROUTED HOLE FROM T.D. TO 418.5 FT. PLACED 1 FT. SAND FROM 417.5-418.5 FT. SET 49.5 FT. OF 1-1/2 INCH DIAMETER PVC SCREEN AND 371.0 FT SCHEDULE 80 1-1/2 INCH DIAMETER BLANK PVC TO 417.5 FT. PLACED SAND PACK IN HOLE FROM 417.5 TO 381.5 FT. PLACED 3.0 FT. BENTONITE 358.5-381.5 FT. AND NEAT CEMENT GROUT FROM 381.5 FT. TO GROUND LEVEL. PLACED 5 FT. OF 2 INCH STEEL PROTECTIVE CASING WITH 2-FT. STICKUP.

EXPLANATIONS: GENERAL FORMULAS USED TO COMPUTE PERMEABILITY:

$$K = \frac{Q}{20LH} \mathrm{Log}_e \frac{L}{r}$$ WHEN L GREATER THAN OR EQUAL 10r

$$K = \frac{Q}{20LH} \mathrm{Sinh}^{-1} \frac{L}{2r}$$ WHEN L LESS THAN 10r AND GREATER THAN OR EQUAL r

PERMEABILITY VALUES SHOWN ARE COMPUTED FROM THESE THEORETICAL FORMULAS AND DO NOT CONSIDER SYSTEM HEAD LOSSES AND OTHER FACTORS INHERENT IN THE TESTING. THEREFORE, THESE ARE NOT TRUE PERMEABILITIES, MERELY RELATIVE VALUES.

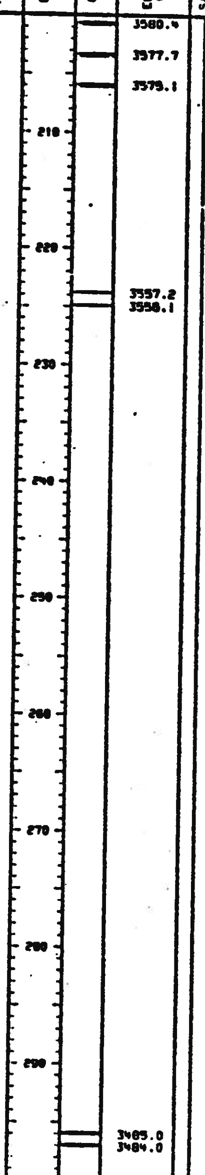
P = PACKER CS = CASING CM = CEMENT

Figure 5(Continued)

GEOLOGIC LOG OF HOLE NO DH-3

SHEET 3 OF 8

PROJECT LAKE MEREDITH SALINITY STUDY FEATURE DEEP CORE HOLE AREA LOGAN AREA STATE NEW MEXICO
COORDS. N. 1505902 E 770020 GROUND ELEV. 3781.0 ANGLE FROM HORIZ 90.0 DOWN
BEGUN 8/17/83 FINISHED 9/14/83 DEPTH TO BEDROCK 11.0 TOTAL DEPTH 569.5 BEARING
DEPTH TO WATER 84.9 FT. 9/9/83 LOGGED BY SHIRLEY SHADIX REVIEWED BY JOE JACKSON



NOTES	FIELD PERMEABILITY TEST (DESIGNATION E-18, EARTH MANUAL) DEPTH (FEET) FROM (P, CS, or CM)	TO	DIAMETER (INCHES)	LOSS (GPM)	DIFFERENTIAL PRESSURE (FEET)	LENGTH OF TEST (MIN)	PERMEABILITY (K) FEET/YEAR	PERCENT CORE RECOVERY	DEPTH SCALE (FEET)	CLASSIFICATION INTERVALS GRAPHIC DEPTHS	ELEVATIONS (FEET)	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
											3580.4 3577.7 3575.1 3557.2 3556.1 3485.0 3484.0		518.0-535.5 FT.: SILTSTONE. SANDY. GREENISH REDUCTION SPOTS. 3-INCH LAYER AT 535.0 FT. CONSISTING OF VERY THIN LAYERS OF GREENISH FINE GRAINED SANDSTONE AND SHALE. HARD. STRONG REACTION WITH HCL. SALMON-RED. 535.5-541.1 FT.: SANDSTONE. GREENISH REDUCTION SPOTS. FINE-GRAINED. MOSTLY ROUNDED GRAINS. HARD. STRONG REACTION WITH HCL. SALMON-RED. 541.1-544.4 FT.: SHALE. SANDY. FEW FRAGMENTS LIMESTONE (-3/4"). WELL CONSOLIDATED. GREENISH TO SALMON-RED. 544.4-569.1 FT.: SILTSTONE. SANDY. GREENISH REDUCTION SPOTS. INTERCALATED WITH LIGHT RED SHALE AND DARK GREENISH GRAY SHALE. FEW CACITE-FILLED FRACTURES. MODERATE REACTION WITH HCL. HARD. WELL CONSOLIDATED. ONE HAMMER BLOW FRAGMENTS SMALL PIECE. LIGHT-RED.

COMMENTS:

SET 14.0 FT. OF 4 INCH SURFACE CASING 8/17/83. SET 18.0 NW CASING TO 18.5 FT. ON 8/18/83. SET ADDITIONAL 343.5 FT. NW CASING TO 362.0 FT. ON 8/31/83. 9/11 THROUGH 9/13/83: GROUTED HOLE FROM T.D. TO 418.5 FT. PLACED 1 FT. SAND FROM 417.5-418.5 FT. SET 49.5 FT. OF 1-1/2 INCH DIAMETER PVC SCREEN AND 371.0 FT SCHEDULE 80 1-1/2 INCH DIAMETER BLANK PVC TO 417.5 FT. PLACED SAND PACK IN HOLE FROM 417.5 TO 381.5 FT. PLACED 3.0 FT. BENTONITE 378.5-381.5 FT. AND NEAT CEMENT GROUT FROM 381.5 FT. TO GROUND LEVEL. PLACED 5 FT. OF 2 INCH STEEL PROTECTIVE CASING WITH 2-FT. STICKUP.

EXPLANATIONS: GENERAL FORMULAS USED TO COMPUTE PERMEABILITY:

$$K = \frac{Q}{2\pi LH} \log_e \frac{L}{r}$$ WHEN L GREATER THAN OR EQUAL 10r

$$K = \frac{Q}{2\pi LH} \sinh^{-1} \frac{L}{2r}$$ WHEN L LESS THAN 10r AND GREATER THAN OR EQUAL r

PERMEABILITY VALUES SHOWN ARE COMPUTED FROM THESE THEORETICAL FORMULAS AND DO NOT CONSIDER SYSTEM HEAD LOSSES AND OTHER FACTORS INHERENT IN THE TESTING. THEREFORE, THESE ARE NOT TRUE PERMEABILITIES, MERELY RELATIVE VALUES.

P = PACKER CS = CASING CM = CEMENT

Figure 5 (continued)

GEOLOGIC LOG OF HOLE NO DH-3

SHEET 4 OF 6

PROJECT LAKE MEREDITH SALINITY STU FEATURE DEEP CORE HOLE .... AREA LOGAN AREA

COORDS. N. 1505902 .... E. 770020 .... GROUND ELEV. ...... 3781.0 ANGLE FROM HORIZ. ... 90.0 DOWN .... STATE NEW MEXICO

BEGUN 8/17/83 ... FINISHED 9/14/83 .... DEPTH TO BEDROCK 11.0 ..... TOTAL DEPTH ...... 580.9 BEARING ....

DEPTH TO WATER 84.9 FT. 9/9/83 LOGGED BY SHIRLEY SHADIX REVIEWED BY JOE JACKSON

NOTES	FIELD PERMEABILITY TEST (DESIGNATION E-18, EARTH MANUAL)							PERCENT CORE RECOVERY	DEPTH SCALE (FEET)	CLASSIFICATION INTERVALS		SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
	DEPTH (FEET)		DIAMETER (INCHES)	LOSS (GPM)	DIFFERENTIAL PRESSURE (FEET)	LENGTH OF TEST (MIN)	PERMEABILITY (K) FEET/YEAR			GRAPHIC DEPTHS	ELEVATIONS (FEET)		
	FROM (P, CS, or CM)	TO											
									310				
									320				
									330				
									340		3440.0		
									350		3431.0		
									360				
									370				
									380				
									390				

COMMENTS:

SET 14.0 FT. OF 4 INCH SURFACE CASING 8/17/83. SET 18.0 NW CASING TO 18.5 FT. ON 8/18/83. SET ADDITIONAL 343.5 FT. NW CASING TO 362.0 FT. ON 8/31/83. 9/11 THROUGH 9/13/83: GROUTED HOLE FROM T.D. TO 418.5 FT. PLACED 1 FT. SAND FROM 417.5-418.5 FT. SET 40.5 FT. OF 1-1/2 INCH DIAMETER PVC SCREEN AND 371.0 FT SCHEDULE 80 1-1/2 INCH DIAMETER BLANK PVC TO 417.5 FT. PLACED SAND PACK IN HOLE FROM 417.5 TO 381.5 FT. PLACED 3.0 FT. BENTONITE 378.5-381.5 FT. AND NEAT CEMENT GROUT FROM 381.5 FT. TO GROUND LEVEL. PLACED 5 FT. OF 2 INCH STEEL PROTECTIVE CASING WITH 2-FT. STICKUP.

EXPLANATIONS: GENERAL FORMULAS USED TO COMPUTE PERMEABILITY:

$$K = \frac{Q}{2\pi LH} \log_e \frac{L}{r}$$ WHEN L GREATER THAN OR EQUAL 10r

$$K = \frac{Q}{2\pi LH} \sinh^{-1} \frac{L}{2r}$$ WHEN L LESS THAN 10r AND GREATER THAN OR EQUAL r

PERMEABILITY VALUES SHOWN ARE COMPUTED FROM THESE THEORETICAL FORMULAS AND DO NOT CONSIDER SYSTEM HEAD LOSSES AND OTHER FACTORS INHERENT IN THE TESTING. THEREFORE, THESE ARE NOT TRUE PERMEABILITIES, MERELY RELATIVE VALUES.

P = PACKER CS = CASING CM = CEMENT

FEATURE ... DEEP CORE HOLE .... AREA .... LOGAN AREA .... SHEET 4 OF 6 HOLE NO. DH-3

Figure 5 (continued).

GEOLOGIC LOG OF HOLE NO DH-3

SHEET 5 OF 6

PROJECT LAKE MEREDITH SALINITY STU FEATURE DEEP CORE HOLE AREA LOGAN AREA

COORDS. N. 1585802 E. 770020 STATE NEW MEXICO

GROUND ELEV. 3781.0 ANGLE FROM HORIZ. 90.0 DOWN

BEGUN 8/17/83 FINISHED 9/19/83 DEPTH TO BEDROCK 11.0 TOTAL DEPTH 500.5 BEARING

DEPTH TO WATER 94.9 FT. 9/9/83 LOGGED BY SHIRLEY SHADIX REVIEWED BY JOE JACKSON

NOTES	FIELD PERMEABILITY TEST (DESIGNATION E-18, EARTH MANUAL) DEPTH (FEET) FROM (P, CS or CM)	TO	DIAMETER (INCHES)	LOSS (GPM)	DIFFERENTIAL PRESSURE (FEET)	LENGTH OF TEST (MIN)	PERMEABILITY (K) FEET/YEAR	PERCENT CORE RECOVERY	DEPTH SCALE (FEET)	CLASSIFICATION INTERVALS GRAPHIC LOGS	ELEVATIONS (FEET)	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
											3378.0		
											3376.6		
									410				
									420				
									430				
											3347.0		
											3345.7		
									440				
									450		3330.5		
									460				
									470				
											3308.1		
											3306.0		
									480				
									490				
											3284.3		

COMMENTS:

SET 14.0 FT. OF 4 INCH SURFACE CASING 8/17/83. SET 18.0 NW CASING TO 18.5 FT. ON 8/18/83. SET ADDITIONAL 343.5 FT. NW CASING TO 362.0 FT. ON 8/31/83. 9/11 THROUGH 9/13/83: GROUTED HOLE FROM T.D. TO 418.5 FT. PLACED 1 FT. SAND FROM 417.5-418.5 FT. SET 49.5 FT. OF 1-1/2 INCH DIAMETER PVC SCREEN AND 371.0 FT SCHEDULE 80 1-1/2 INCH DIAMETER BLANK PVC TO 417.5 FT. PLACED SAND PACK IN HOLE FROM 417.5 TO 361.5 FT. PLACED 3.0 FT. BENTONITE 358.5-361.5 FT. AND NEAT CEMENT GROUT FROM 381.5 FT. TO GROUND LEVEL. PLACED 9 FT. OF 2 INCH STEEL PROTECTIVE CASING WITH 2-FT. STICKUP.

EXPLANATIONS: GENERAL FORMULAS USED TO COMPUTE PERMEABILITY:

$$K = \frac{Q}{2 \pi L H} \log_e \frac{L}{r}$$ WHEN L GREATER THAN OR EQUAL 10r

$$K = \frac{Q}{2 \pi L H} \sinh^{-1} \frac{L}{2r}$$ WHEN L LESS THAN 10r AND GREATER THAN OR EQUAL r

PERMEABILITY VALUES SHOWN ARE COMPUTED FROM THESE THEORETICAL FORMULAS AND DO NOT CONSIDER SYSTEM HEAD LOSSES AND OTHER FACTORS INHERENT IN THE TESTING. THEREFORE, THESE ARE NOT TRUE PERMEABILITIES, MERELY RELATIVE VALUES.

P = PACKER CS = CASING CM = CEMENT

Figure 5 (continued)

GEOLOGIC LOG OF HOLE NO DH-3

SHEET. 8 ... OF 8

PROJECT. LAKE MEREDITH SALINITY STUDY FEATURE. DEEP CORE HOLE .... AREA. LOGAN AREA .... STATE .. NEW MEXICO ......

COORDS. N.. 1505902 .... E.. 770920 .... GROUND ELEV. ...... 3781.0. ANGLE FROM HORIZ... 90.0 .. DOWN

BEGUN .. 8/17/83 ... FINISHED. 9/14/83 ... DEPTH TO BEDROCK .11.0 ..... TOTAL DEPTH .... 569.5.. BEARING ....

DEPTH TO WATER. 84.9 FT. 9/9/83 LOGGED BY SHIRLEY SHADIX .... REVIEWED BY JOE JACKSON ....

NOTES	FIELD PERMEABILITY TEST (DESIGNATION E-18, EARTH MANUAL) DEPTH (FEET) FROM (P, CS, or CM)	TO	DIAMETER (INCHES)	LOSS (GPM)	DIFFERENTIAL PRESSURE (FEET)	LENGTH OF TEST (MIN)	PERMEABILITY (K) FEET/YEAR	PERCENT CORE RECOVERY	DEPTH SCALE (FEET)	CLASSIFICATION INTERVALS GRAPHIC DEPTHS	ELEVATIONS (FEET)	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
									510				
											3267.0		
											3263.0		
									520				
									530				
											3245.5		
									540				
											3239.9		
											3236.0		
									550				
									560				
											3211.9		
									570				
									580				
									590				

COMMENTS:

SET 14.2 FT. OF 4 INCH SURFACE CASING 8/17/83. SET 18.0 NW CASING TO 18.5 FT. ON 8/18/83. SET ADDITIONAL 343.9 FT. NW CASING TO 362.0 FT. ON 8/31/83. 9/11 THROUGH 9/13/83: GROUTED HOLE FROM T.D. TO 418.5 FT. PLACED 1 FT. SAND FROM 417.5-418.5 FT. SET 49.5 FT. OF 1-1/2 INCH DIAMETER PVC SCREEN AND 371.0 FT SCHEDULE 80 1-1/2 INCH DIAMETER BLANK PVC TO 417.5 FT. PLACED SAND PACK IN HOLE FROM 417.5 TO 381.5 FT. PLACED 3.0 FT. BENTONITE 378.5-381.5 FT. AND NEAT CEMENT GROUT FROM 381.5 FT. TO GROUND LEVEL. PLACED 5 FT. OF 2 INCH STEEL PROTECTIVE CASING WITH 2-FT. STICKUP.

EXPLANATIONS: GENERAL FORMULAS USED TO COMPUTE PERMEABILITY:

$$K = \frac{Q}{2\pi LH} \log_e \frac{L}{r}$$ WHEN : GREATER THAN OR EQUAL 10r

$$K = \frac{Q}{2\pi LH} \sinh^{-1} \frac{L}{2r}$$ WHEN L LESS THAN 10r AND GREATER THAN OR EQUAL r

PERMEABILITY VALUES SHOWN ARE COMPUTED FROM THESE THEORETICAL FORMULAS AND DO NOT CONSIDER SYSTEM HEAD LOSSES AND OTHER FACTORS INHERENT IN THE TESTING. THEREFORE, THESE ARE NOT TRUE PERMEABILITIES, MERELY RELATIVE VALUES.

P = PACKER CS = CASING CM = CEMENT

Figure 5 (continued)

9/9/83

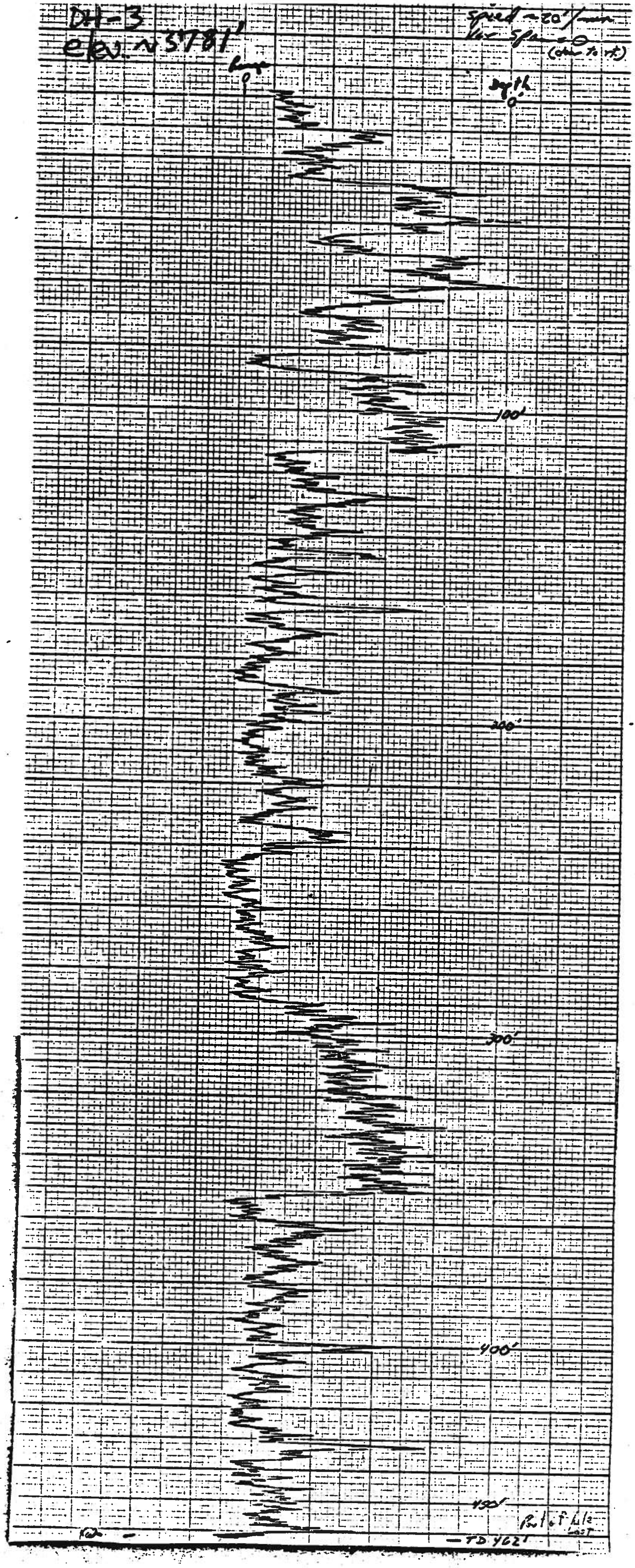


Figure 6 - Natural Gamma Log of Core Hole DH-3 Near Logan, NM

screen set between 418 and 361 feet within the blue-gray sandstone unit. The water level measured just after the observation well completion was 84.9 feet below land surface, a water level considerably above the top of the aquifer. This information, combined with the recorded thick shale sequences, indicated a confined condition.

One significant observation was made during drilling which sheds some light on the questionable stratigraphic log produced for hole DH-2. The shales of the Triassic Formation caved continuously and were recored periodically. This caving and reworking may account for the approximately 350 feet of reddish-brown shale and the 150 feet of white-gray shale logged during DH-2 drilling. Correlation of other well logs to the DH-2 log should be done with caution or maybe not at all.

Seismic Survey

In order to evaluate the subsurface for disposal of brine, a seismic reflection survey was completed during July 20-23, 1984. Approximately 7 miles of full 24-fold subsurface coverage was obtained for two survey lines oriented north-south and east-west and located just south and east of the Canadian River near Logan. The energy source was three to four truck-mounted vibrators, and the geophone spacing was 110 feet. Details of the survey and interpretation are contained in a report entitled "Analysis of Geophysical Data to Examine the Feasibility of Deep-Well Injection of Brine near Logan, New Mexico," prepared by HGC (1984B).

CHAPTER IV - DATA INTERPRETATION

Data for this project was obtained through a cooperative effort between Reclamation, CRMWA, the city of Amarillo, and HGC. Additional supporting data were received from various State, Federal, and private agencies and firms. The HGC has provided, through a contract agreement, summaries of a substantial amount of this data (HGC 1984A and 1984B). This report will attempt to summarize data not included in the HGC reports along with providing some comments about all data collected to date.

Water Quality - Surface Water and Alluvium

Water quality data were collected on surface flows and from the alluvium of the Canadian River between Ute Dam and a point about 10 miles downstream from the dam and the lower 2-1/2 miles of Revuelto Creek. The purpose of the data collection was to establish a good basic understanding of the spatial and temporal variation in the chemical makeup of these waters. The data also provided a baseline to which future water quality information could be compared if a salinity control project was implemented.

Samples collected from piezometers installed in the river alluvium were also intended to provide information on the variations of chemical constituents with depth into the sands and the changes that might occur as a result of surface discharge variations.

Grab samples were collected from surface flows, and discharge measurements were made by standard techniques at sites 1 through 4 and 6 on a regular schedule. Alluvial piezometers were sampled at the same sites and time by air injection lift pumping. These piezometers were generally pumped for 10 to 15 minutes, then sampled.

Samples were collected monthly for these sites after the first month. The water was transported in disposable plastic containers. No preservatives were used. Field parameters such as pH, specific conductance, and temperature were determined for each sample each time. The samples were then delivered to a laboratory for analyses. Every sample was analyzed for chloride, TDS, pH, and specific conductance each time; and every third month an analysis of the major ions was performed. Six sets of complete samples and about 19 sets of partial samples were obtained. The exception was the site 6, 50-foot piezometer which failed in early 1984.

Some problems exist with the data. When ion balances were determined for the complete samples, a considerable deviation from 1 (greater than ± 10 percent of the total of cations plus anions) was sometimes encountered.[1/] Additionally, after regression analyses relating TDS, field-specific conductance, and chlorides were completed, numerous unexplained outliers were recognized. Early analyses for bromide produced totally unacceptable values. An adjustment was

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[1/] When all of the major anions and cations have been determined, the sum of the cations in milliequivalents per liter should equal the sum of the anions expressed in the same units. The difference between the two sums should not be excessive.

made in the laboratory procedure, but the data produced may still be questionable due to the interferences from high chloride concentrations.

Water quality time plots and data tables presented in this report contain corrections made after regression analyses were completed relating chloride, field-specific conductance, and TDS. For these corrections, anomalous values for one of the three parameters were corrected by using relationships established with the other two constituents. Additional chemical constituent values are as reported by the laboratories.

Work was done to try and explain some of the large variations in field-specific conductance. After removing any obviously questionable data, it was observed that most of the anomalous data were occurring when the water contained high concentrations of sodium chloride. It was concluded that since the temperature correction used for the specific conductance meter was based on a potassium-chloride solution, the correction was not entirely valid. No attempt was made to resolve this discrepancy other than using the simple regression analyses.

Oxygenating the samples by airlifting the water from the alluvial piezometers probably had an effect on the pH and alkalinity relationship. No attempt was made to collect a down-hole sample for pH and field alkalinity determinations. Information about these chemical parameters were not considered essential for this study.

Stable and radioactive isotope data were collected from Ute Reservoir and OW-3 so that a determination could be made of the potential mixing of Ute water with

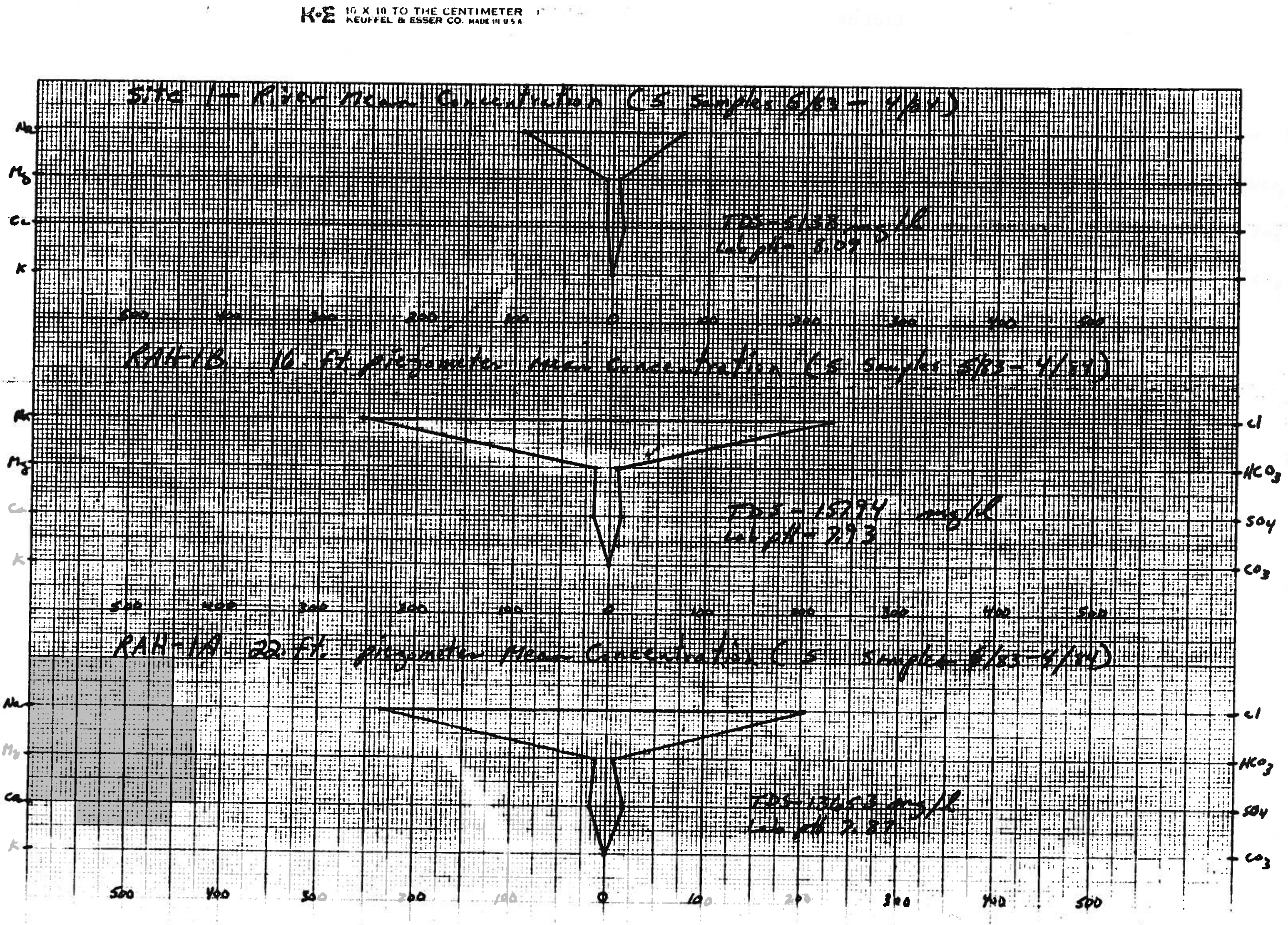


Figure 8 - Stiff Diagrams for Water Samples Collected at Site 1 Near Logan, NM

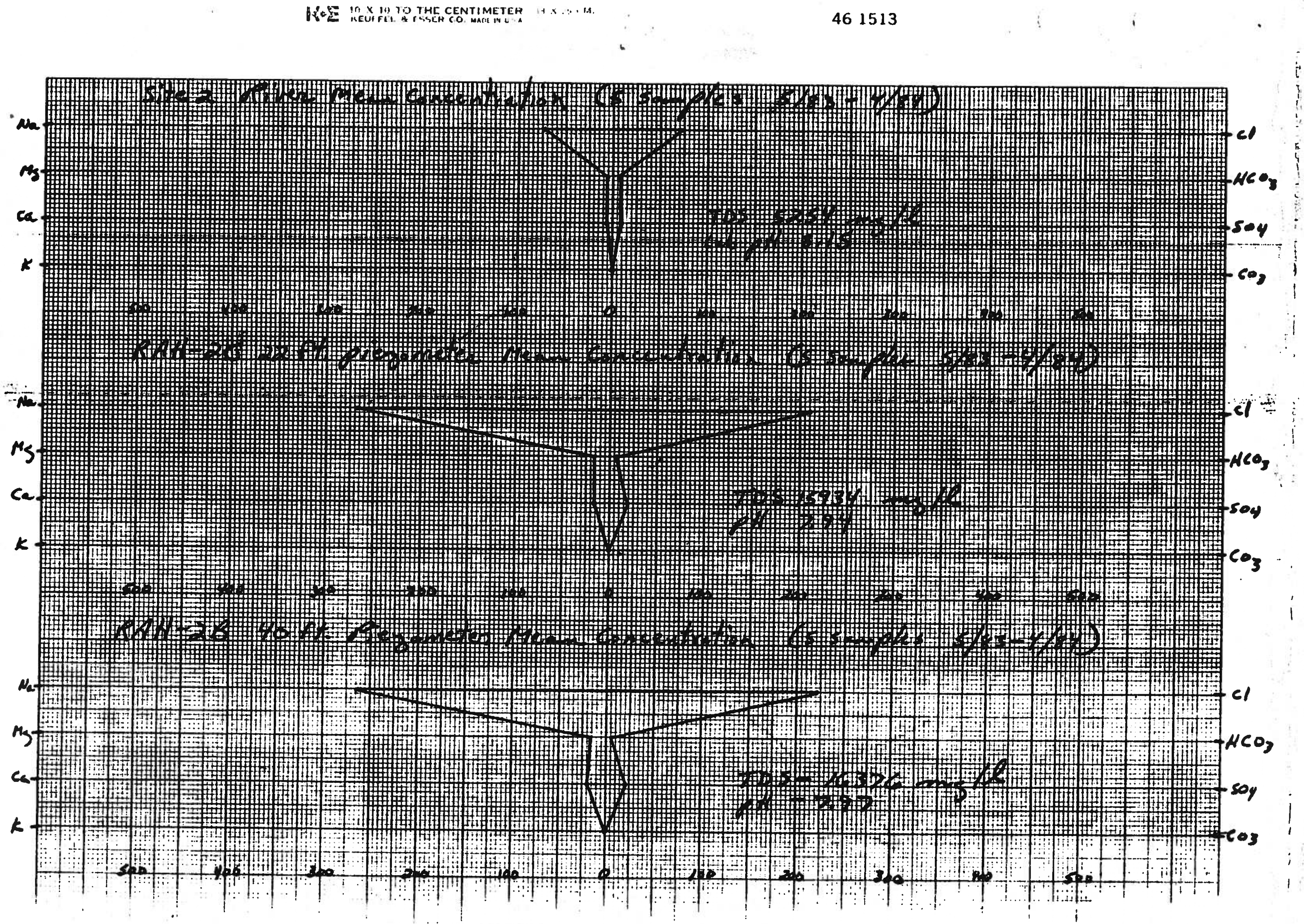
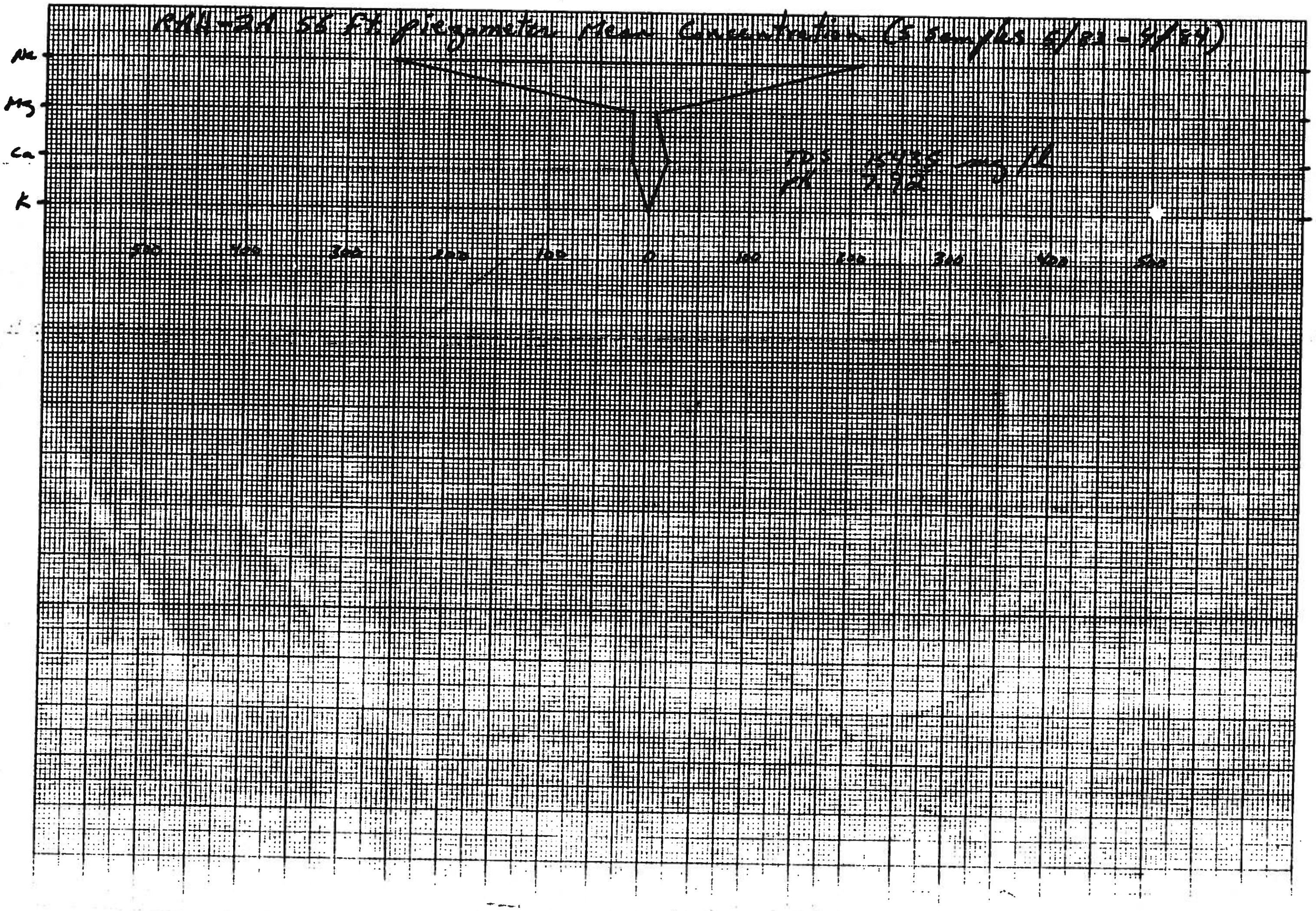


Figure 9. - Stiff Diagrams For Water Samples Collected at Site 2 Near Logan, NM

K&E 10 X 10 TO THE CENTIMETER 18 X 25 CM
KEUFFEL & ESSER CO. MADE IN USA

46 1513


RAH-2A 55 Ft. piezometer Mean Concentration (5 samples 6/83 - 9/84)

TDS 15435 mg/L
pH 7.92

Figure 9 (continued)

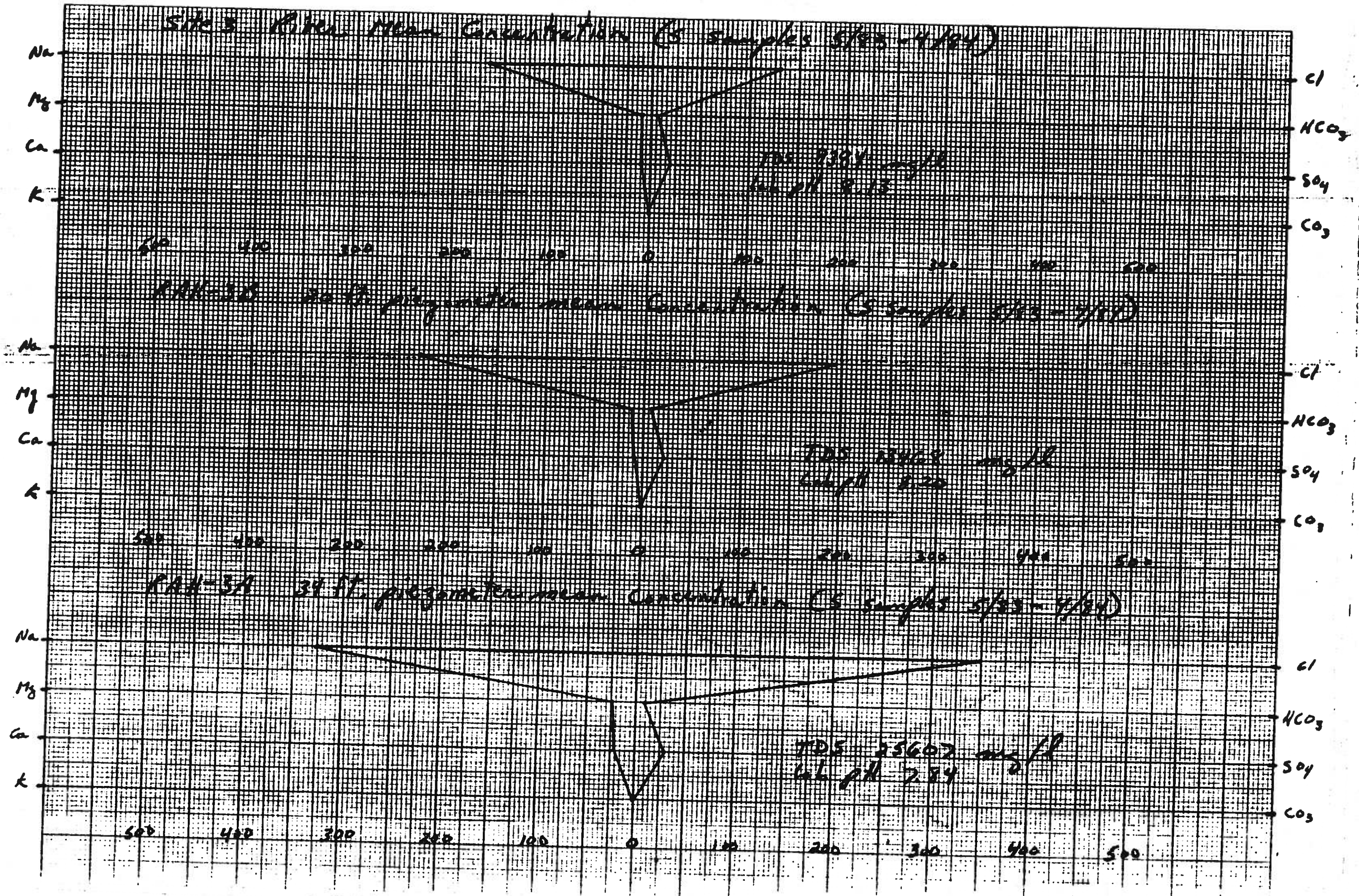


Figure 10 - Stiff Diagrams for Water Samples Collected at Site 3 Near Logan, NM

K+E 10 X 10 TO THE CENTIMETER 18 X 25 CM.
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 1513

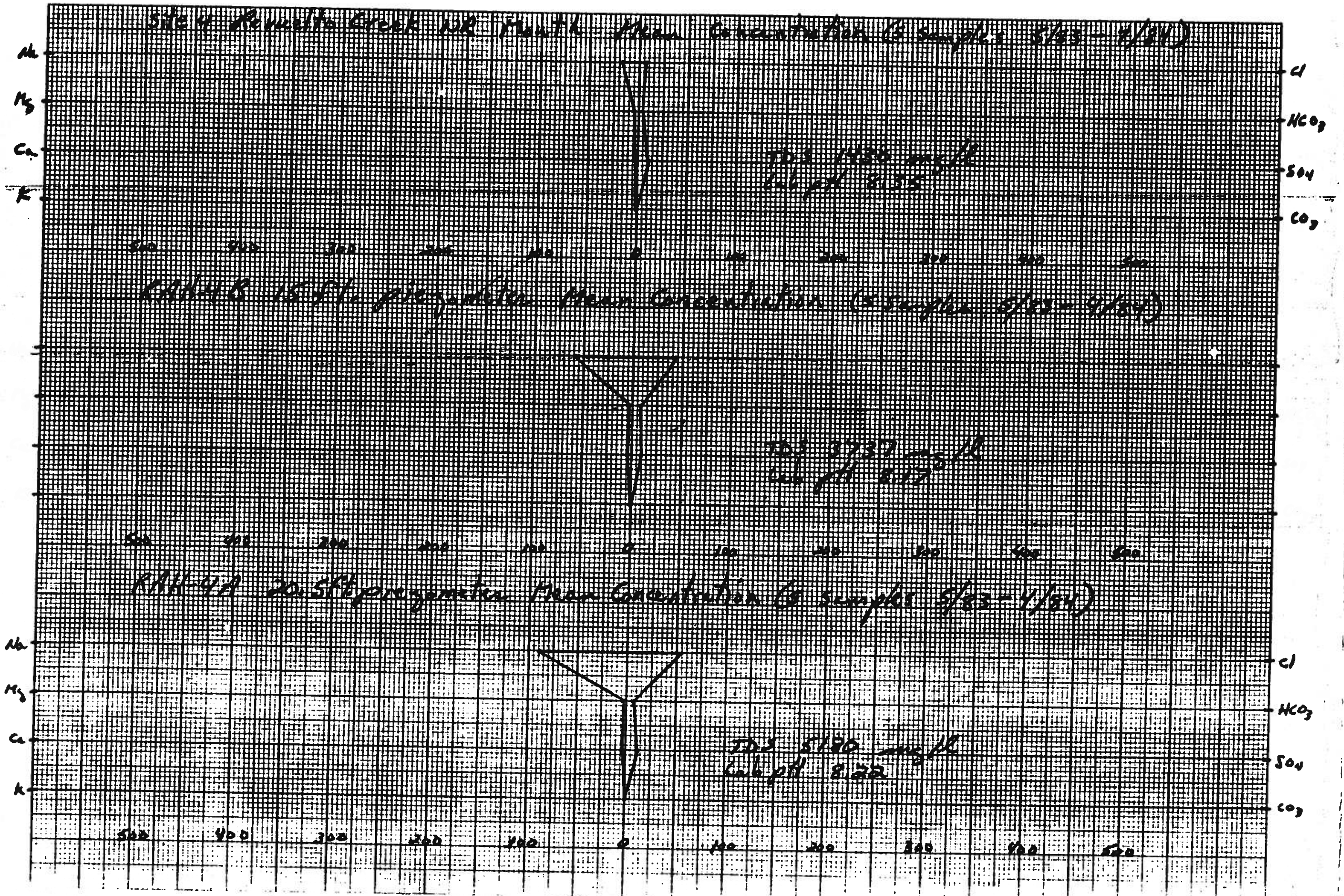


Figure 11 – Stiff Diagrams for Water Samples Collected at Site 4 Near Logan, NM

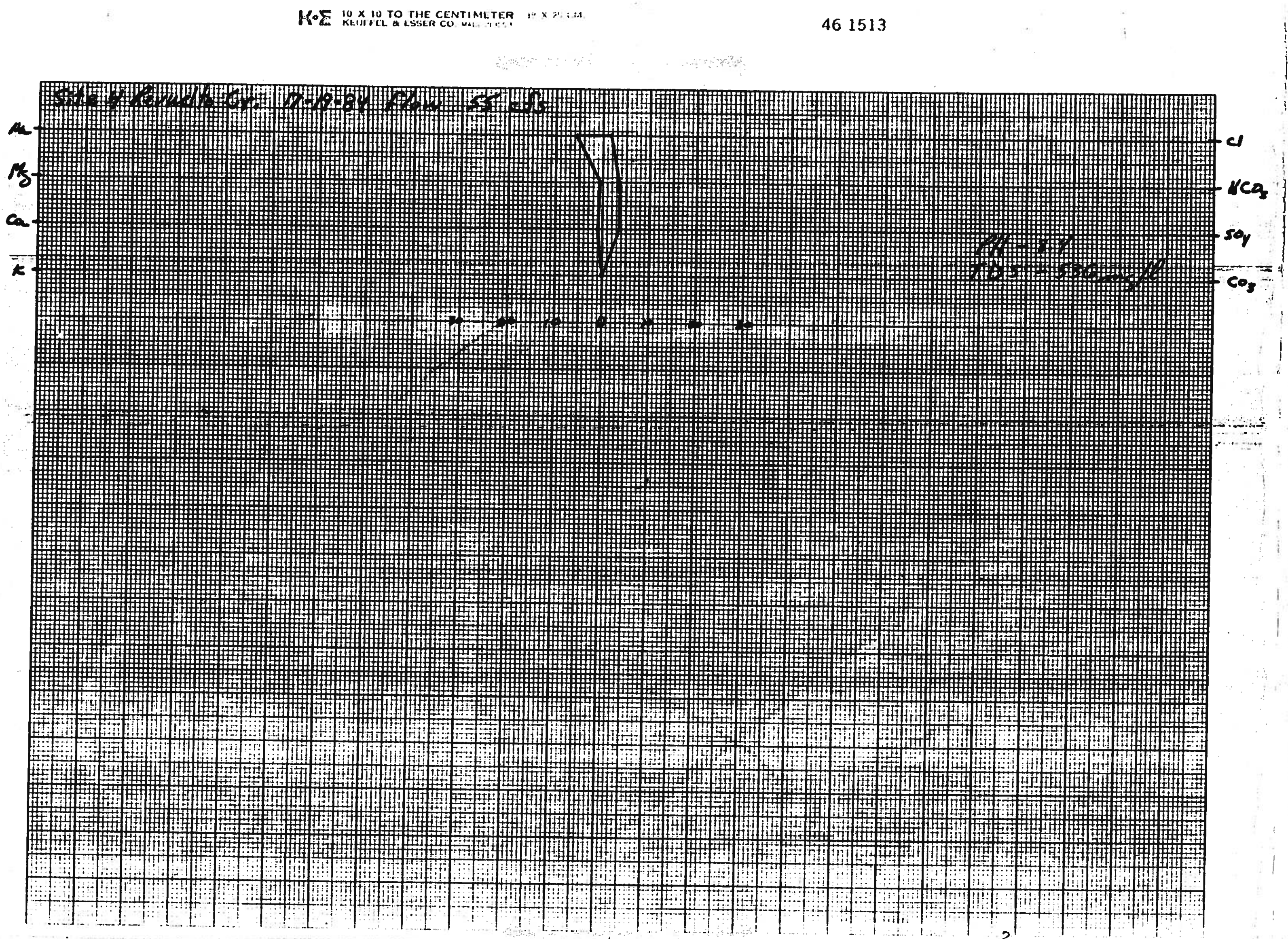
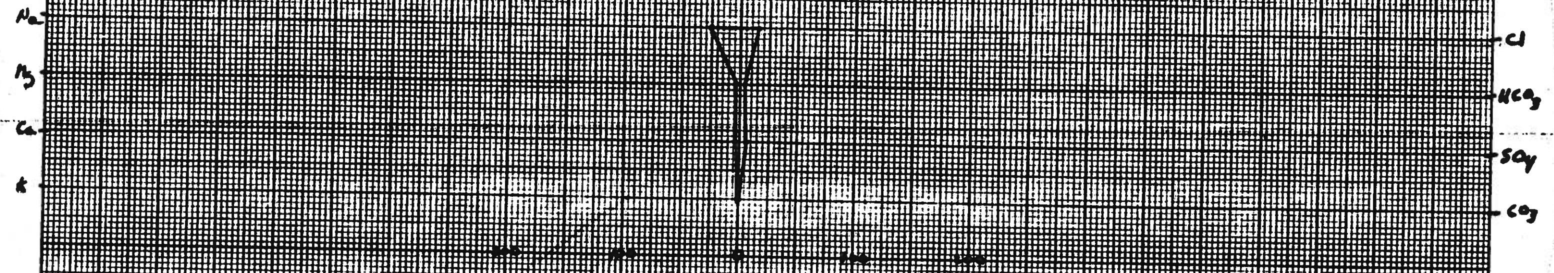


Figure 12 - Stiff Diagram for Water Sample When Creek Flow Was 55 ft³/s at Site 4 Near Logan, NM

K•Σ 10 X 10 TO THE CENTIMETER
KEUFFEL & ESSER CO.

46 1513

U.S.G.S. Revuelto Creek NR Logan, NM 07227100 W.Y. 1981 and W.Y. 1982



Mean of 7 samples as meq/l

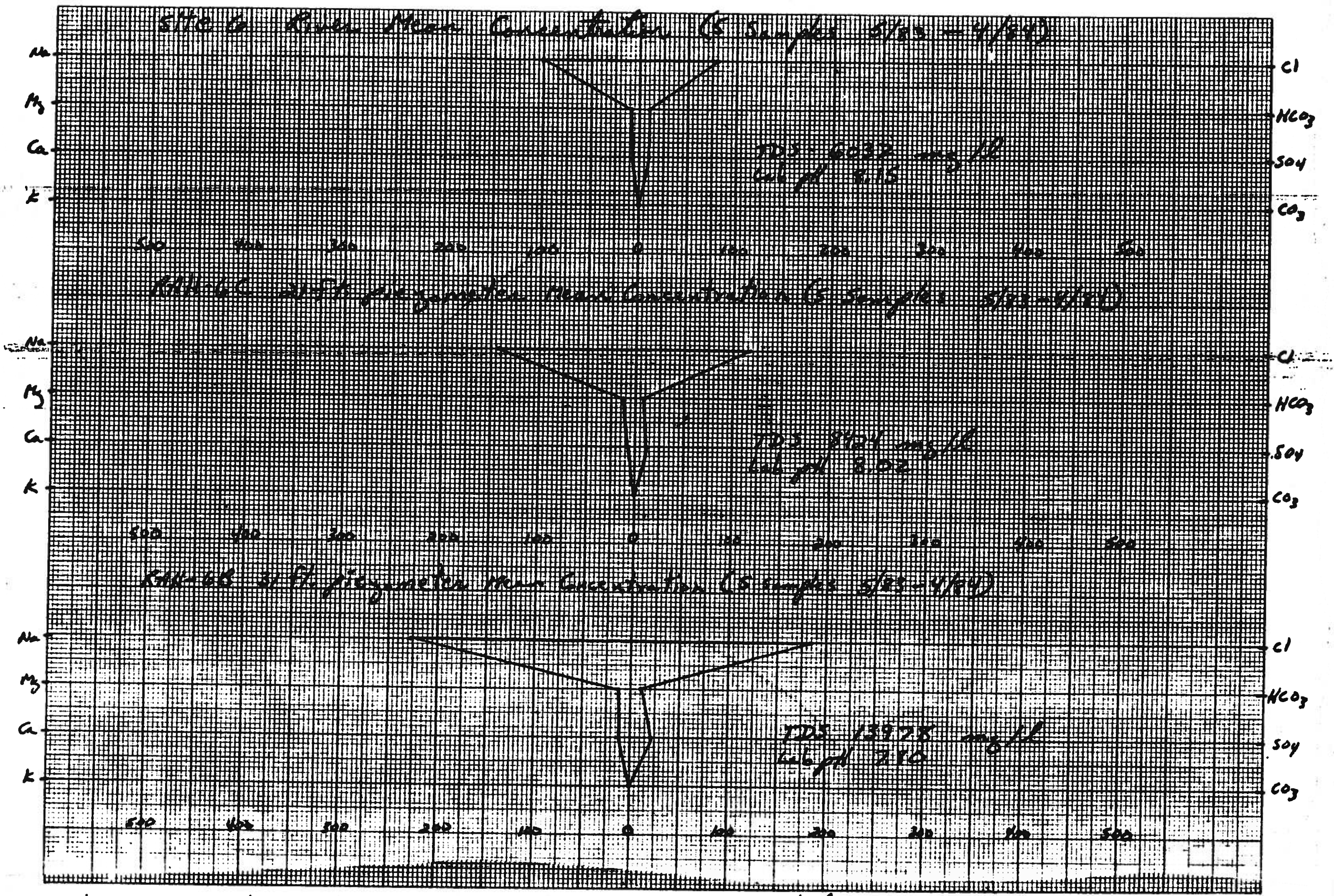
Flow (cfs)	Na	Ca	Mg	K	Cl	HCO3	Sample Alk (as CaCO3)	CO3 (as ?)	SO4	Sample [illegible] TDS (sum)	pH
Min 0.01	160	27	17	1.5	8.3	/	100	/	64	634	8.3
Max 5870	1100	65	80	8.0	1500	/	320	/	570	3520	8.7
Mean /	578	42.9	34.5	4.5	569	~265	217	~0	336	1903	8.5
meq/l /	25	2.5	2.8	0.12	16	~4.3 est.	/	~0 est.	7.0	/	/

only Total Alk. Reported

Figure 13 - Stiff Diagram For Water Samples Collected by USGS at Revuelto Creek Gage Near Logan NM

K•E 10 X 10 TO THE CENTIMETER
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 1513


Site 6 River Mean Concentration (5 Samples 5/83 – 4/84)

KAH-6C 21 ft. piezometer Mean Concentration (5 Samples 5/83 – 4/84)

KAH-6B 31 ft. piezometer Mean Concentration (5 samples 5/83 – 4/84)

Figure 14 – Stiff Diagrams for Water Samples Collected at site 6 New Logan, NM

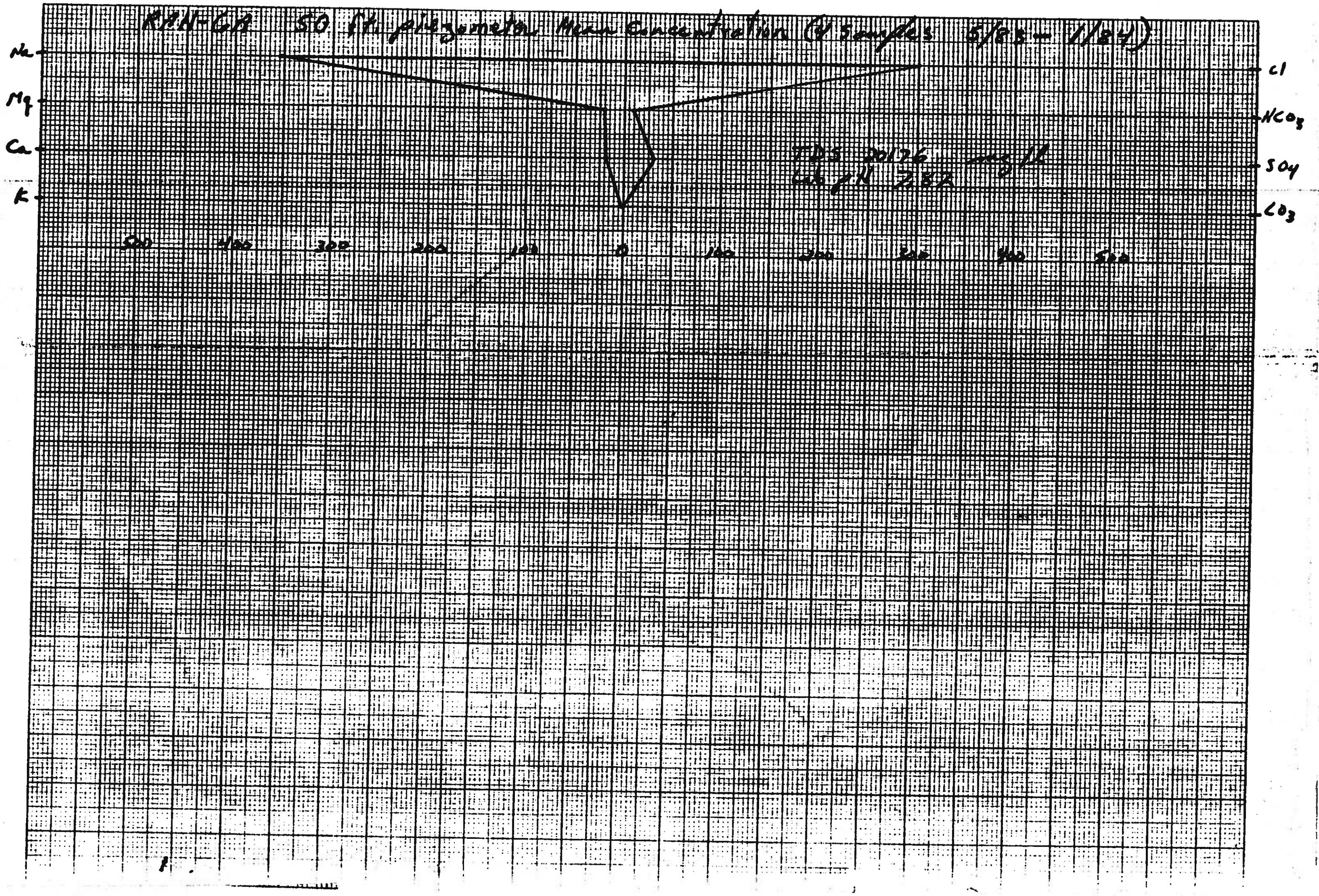
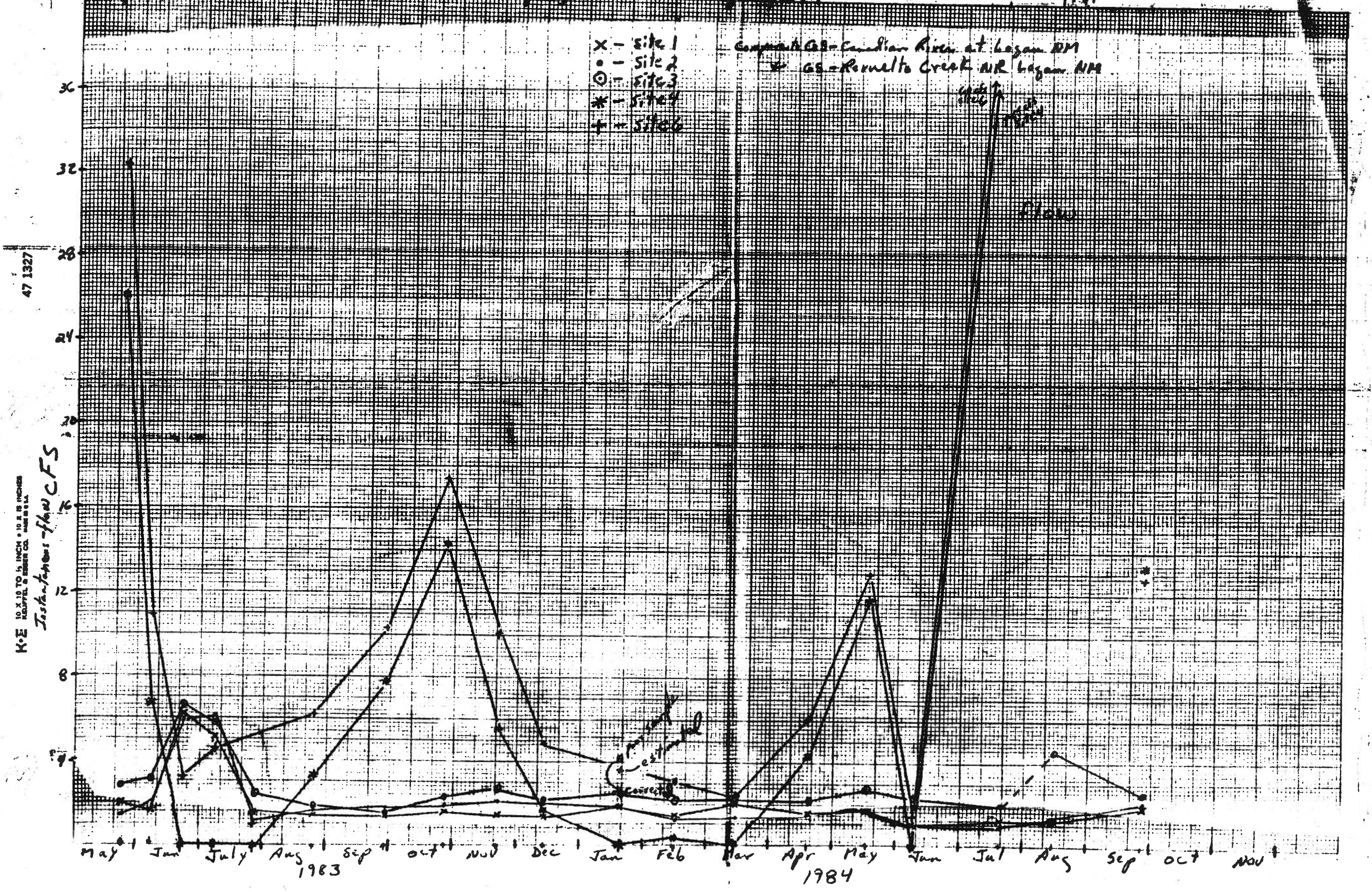


Figure 14 (Continued)

Figure 15 - Monthly Streamflow for Sampling Sites Near Logan NM



1/2

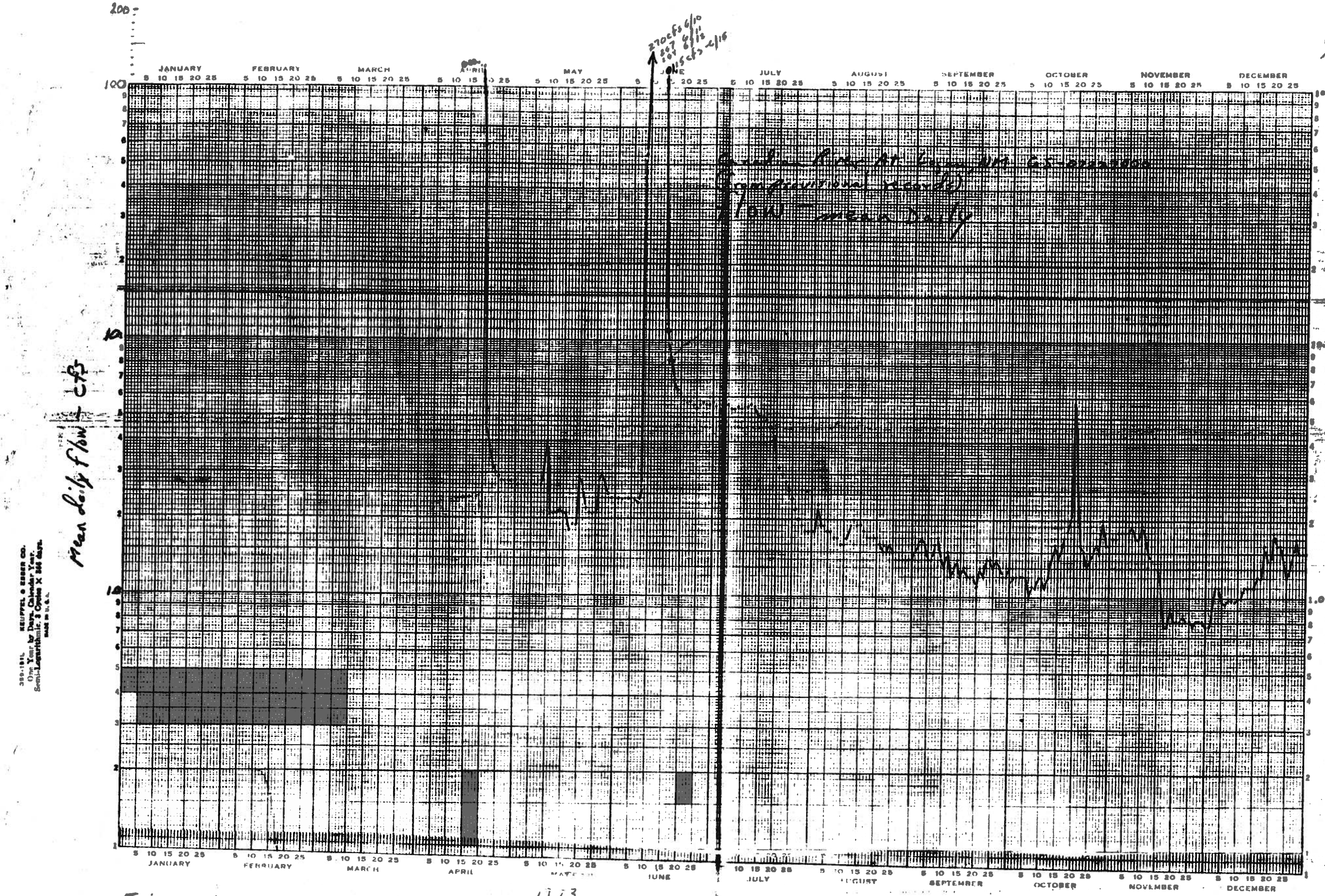


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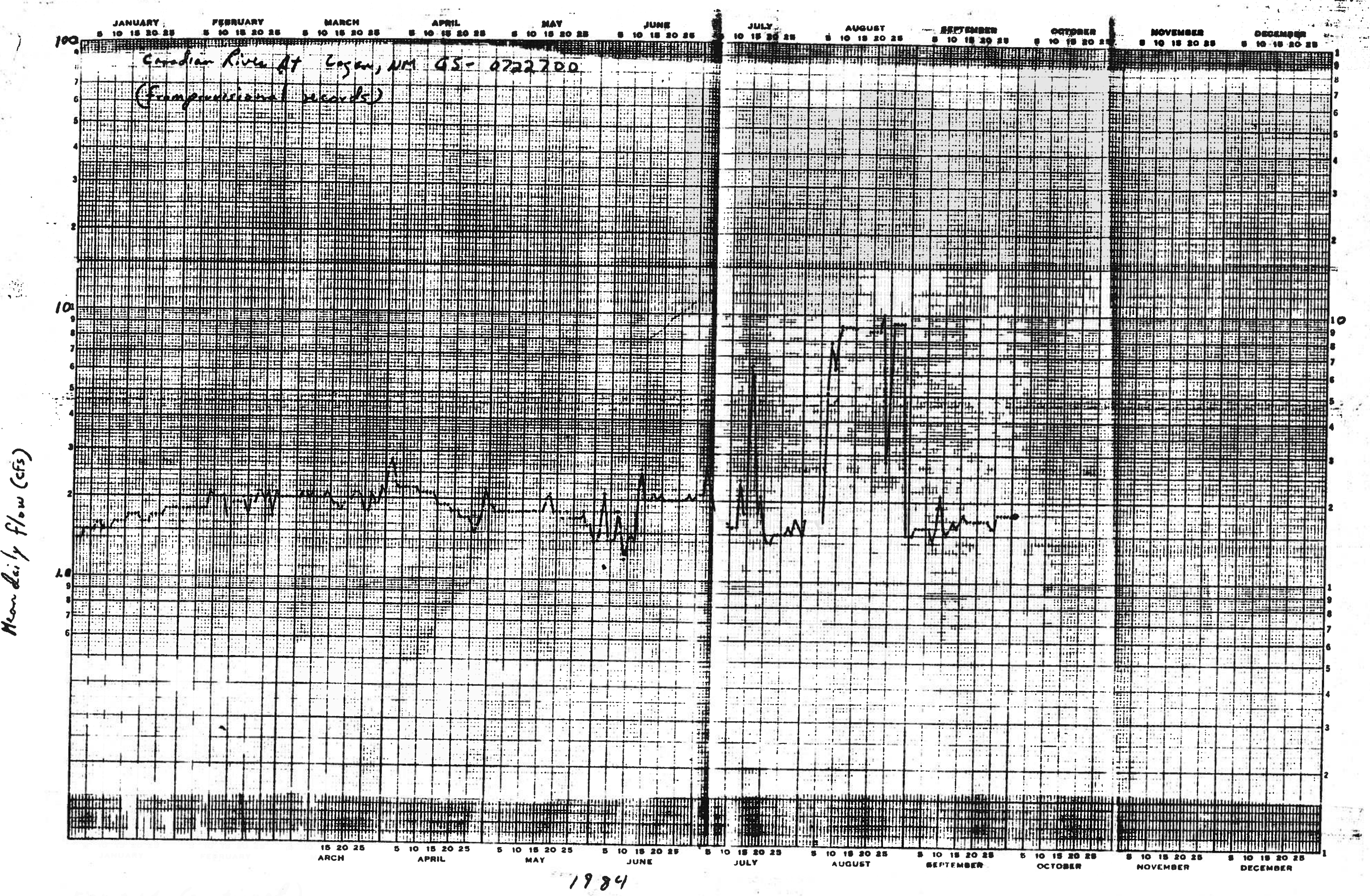
Figure 16 - Continuous Streamflow Record for Canadian River Near Logan, NM

2/2



Canadian River At Logan, NM GS- 0722700

(From provisional records)

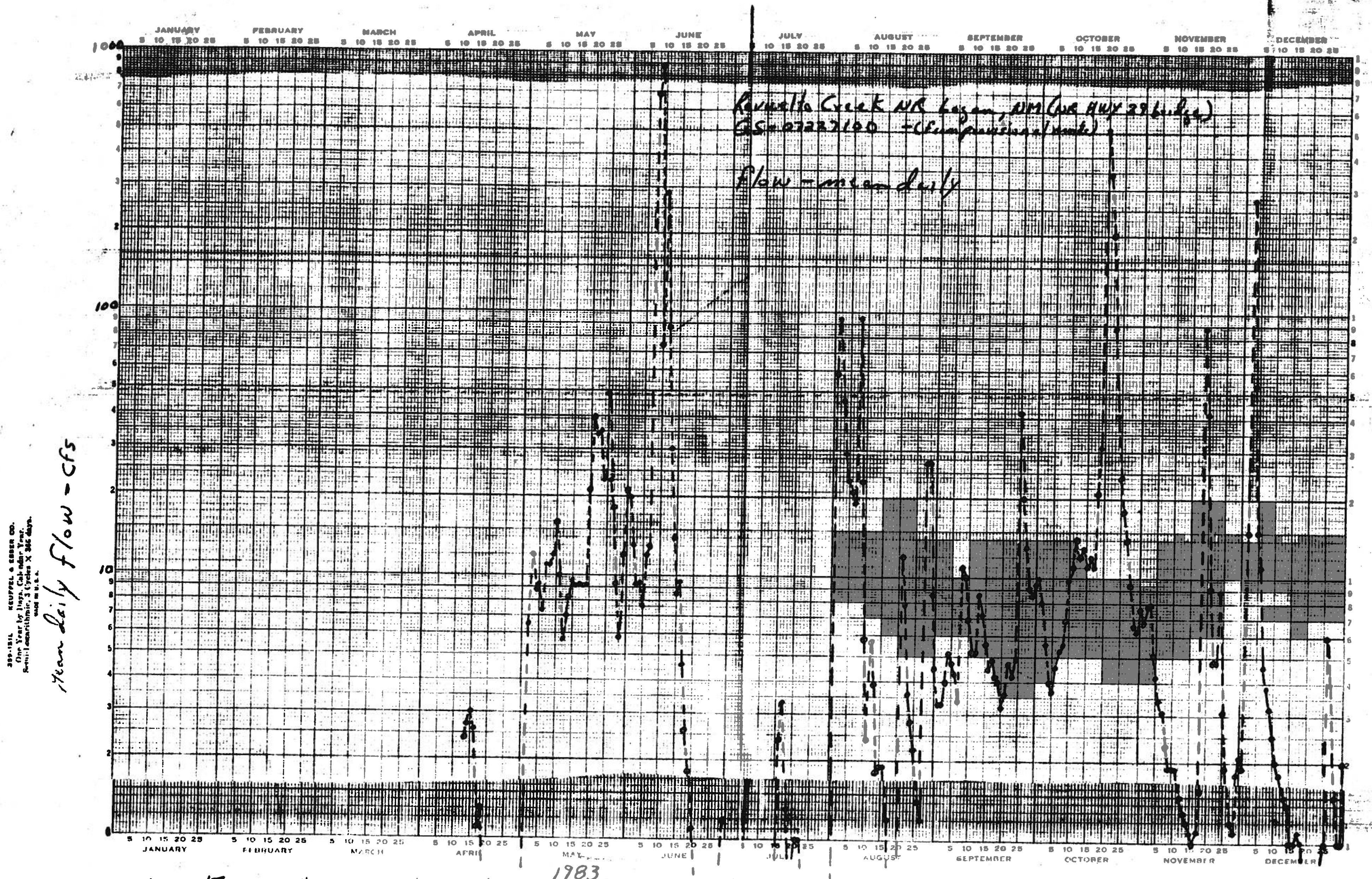


Figure 17- Continuous Streamflow Record for Revuelto Creek Near Logan, NM

2/2

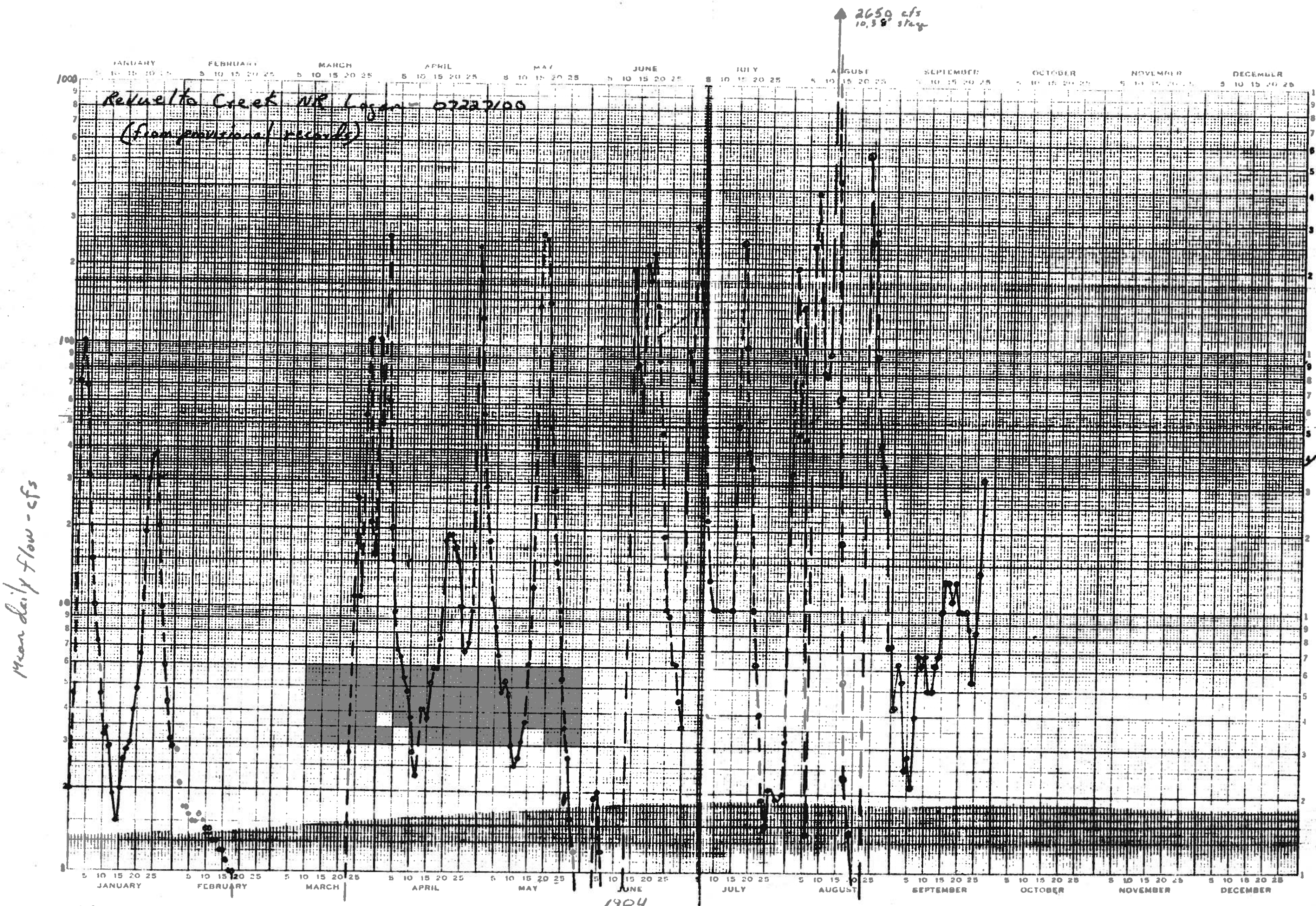


Figure 17 (continued)

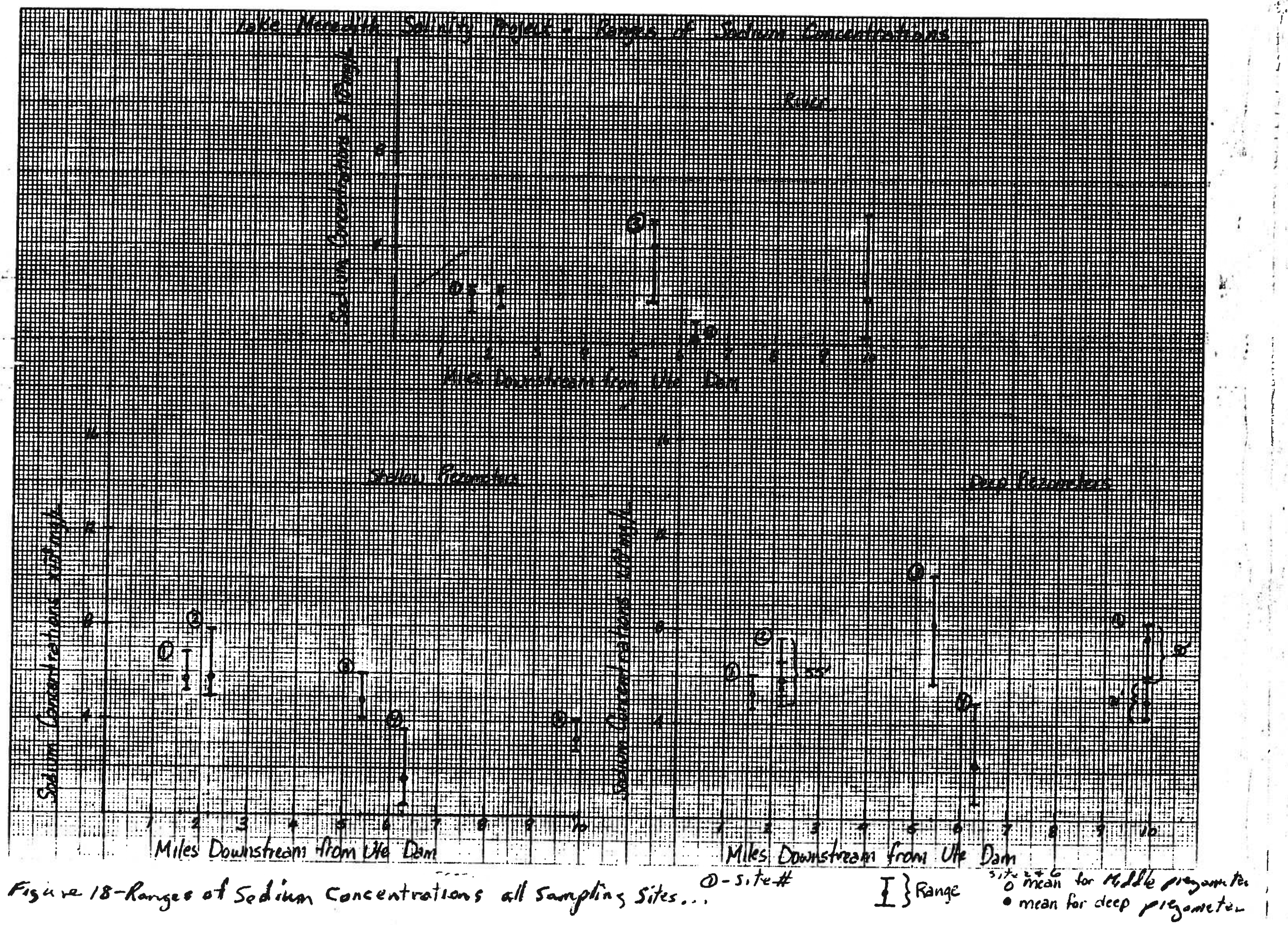


Figure 18-Ranges of Sodium Concentrations all sampling sites...

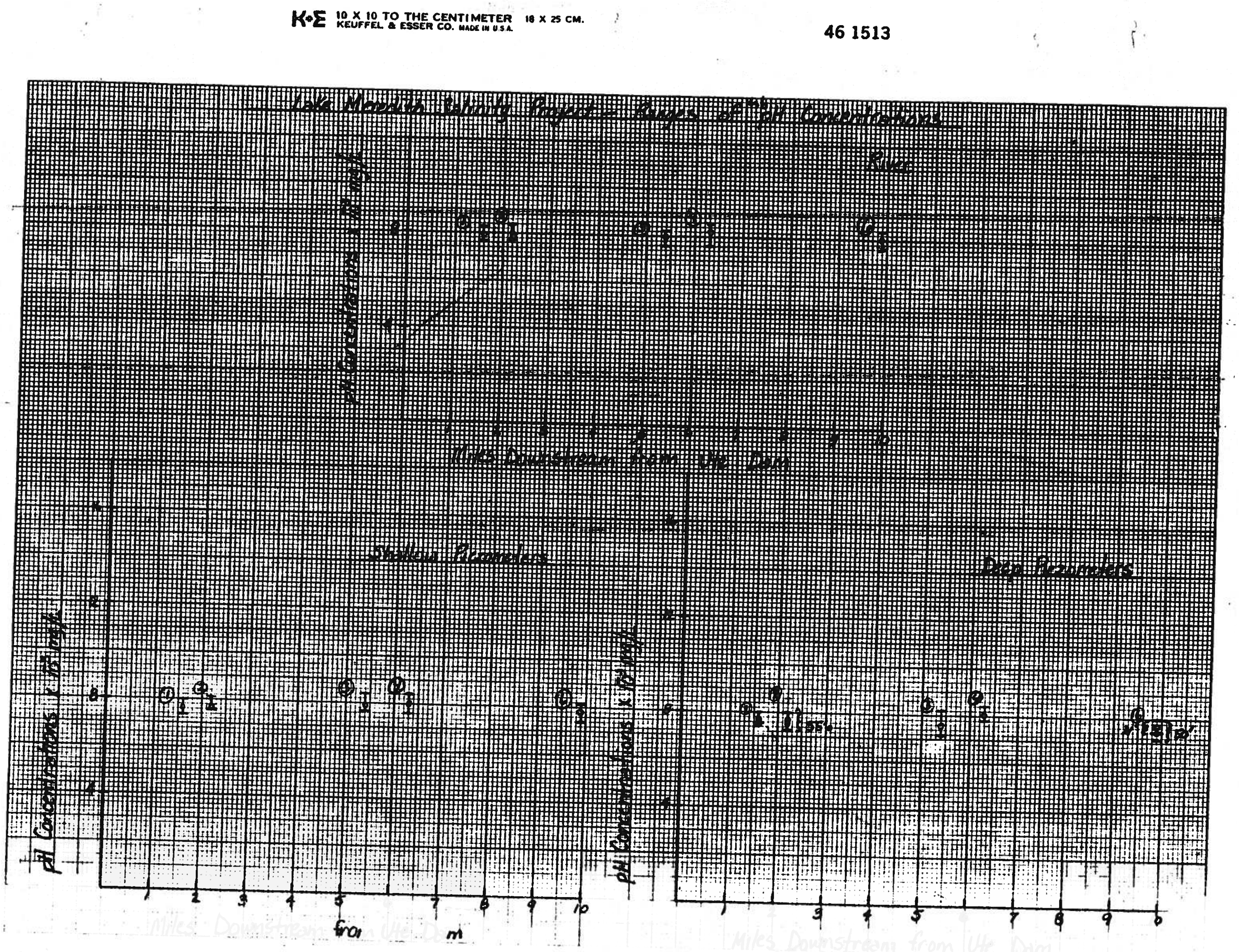


Figure 19-Ranges of Lab pH Determinations

site 2 &
site 6

o mean for Middle piezometer
● mean for deep piezometer

I Range ①-site #

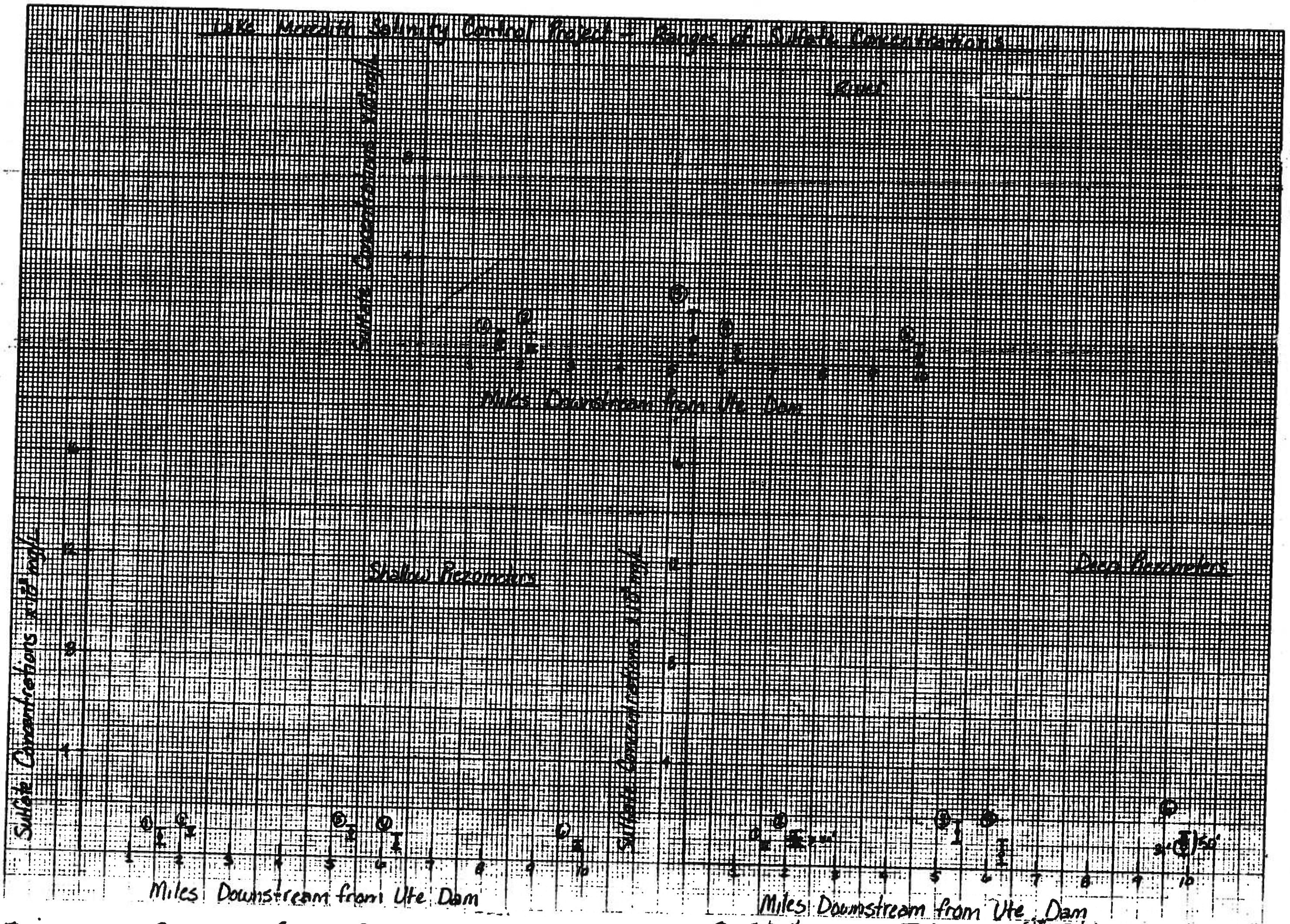


Figure 20 - Ranges of Sulfate Concentrations

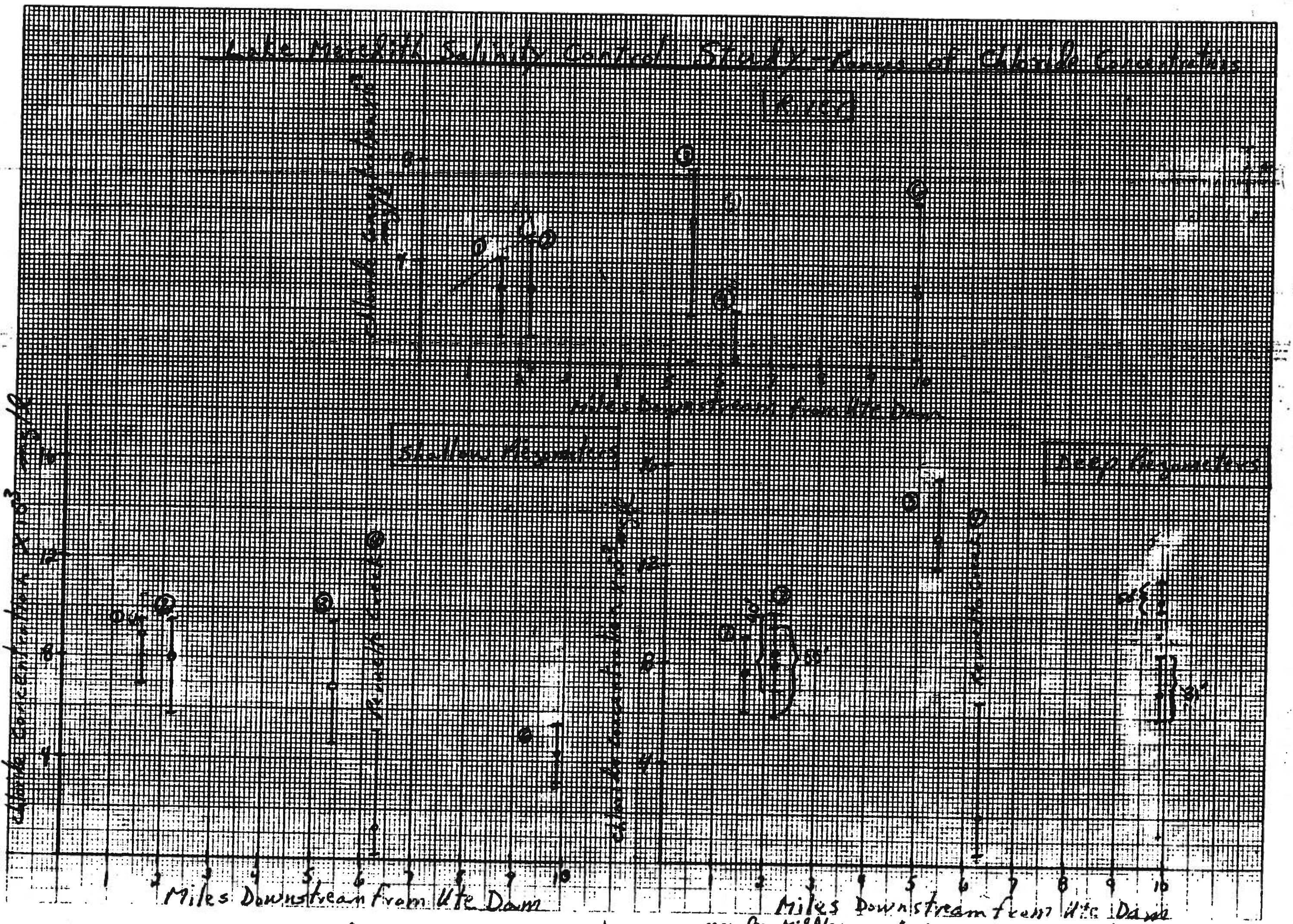


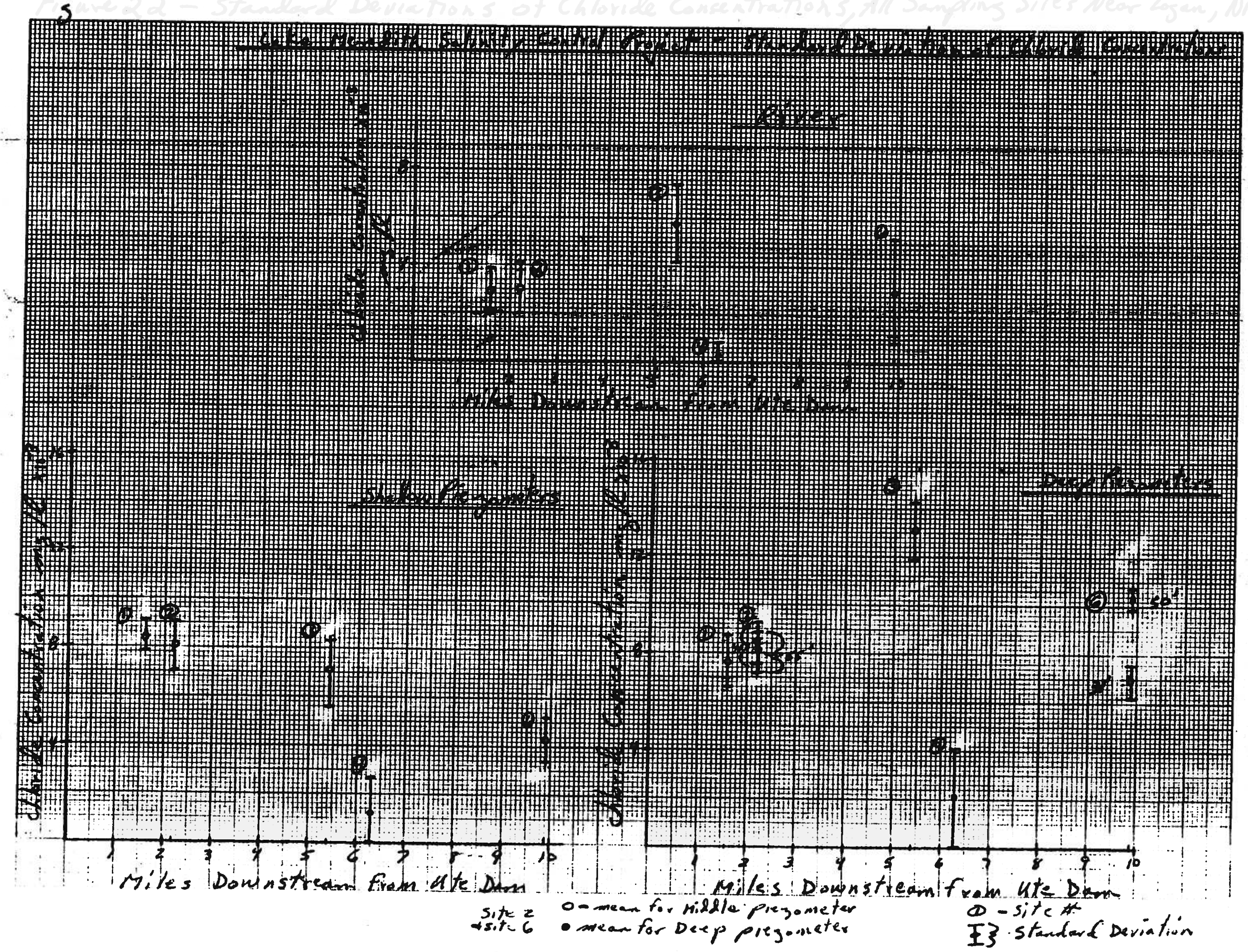
Figure 21-Ranges of Chloride Concentrations...

site 2
+ 6

o mean for Middle piezometer
• mean for deep piezometer
I } Range

①-site #

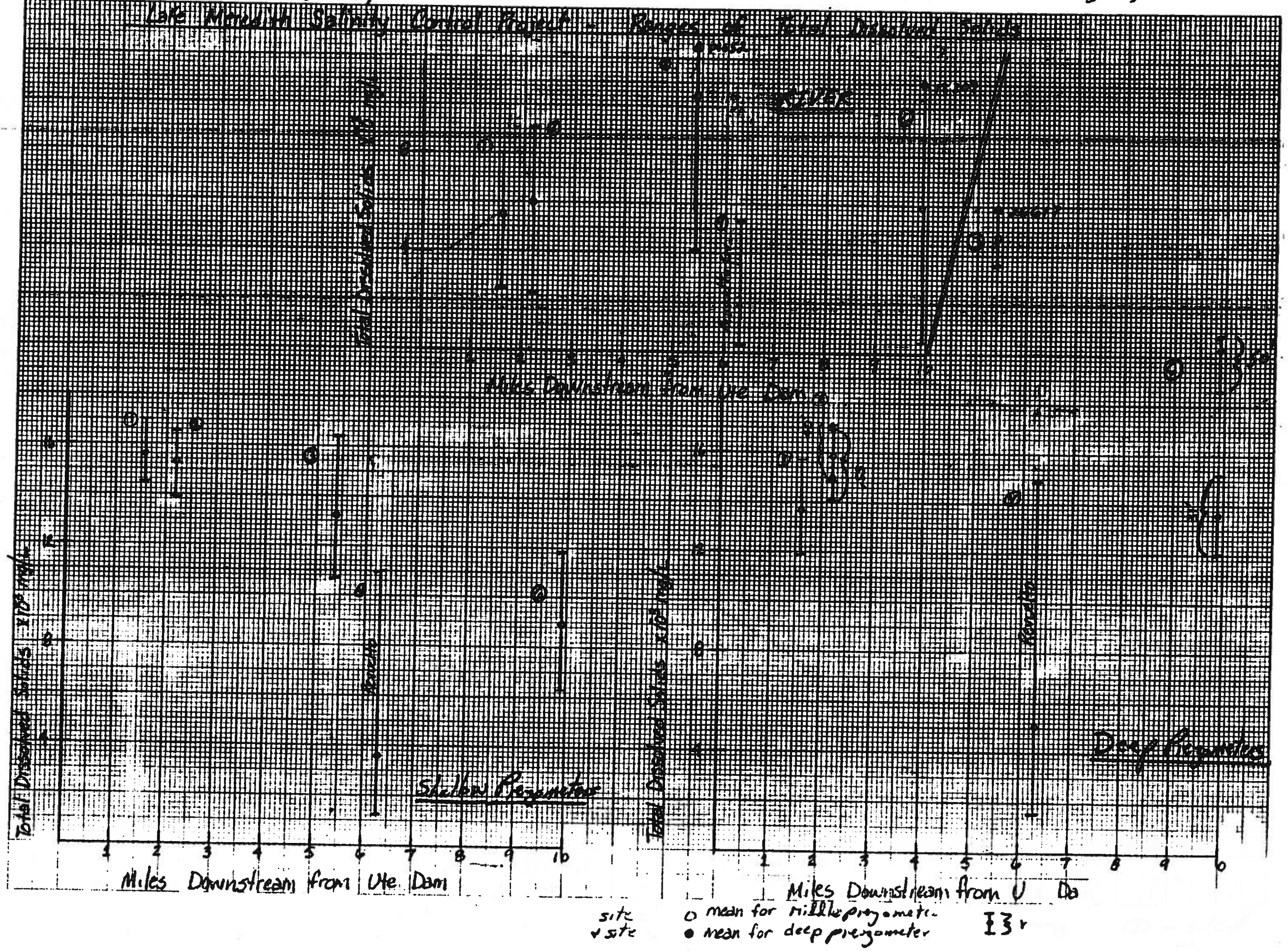
Figure 22 – Standard Deviations of Chloride Concentrations, All Sampling Sites Near Logan, NM



K+E 10 X 10 TO THE CENTIMETER 18 X 25 CM.
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 1513

Figure 23 Ranges of TDS concentrations, All Sampling Sites Near Logan, NM



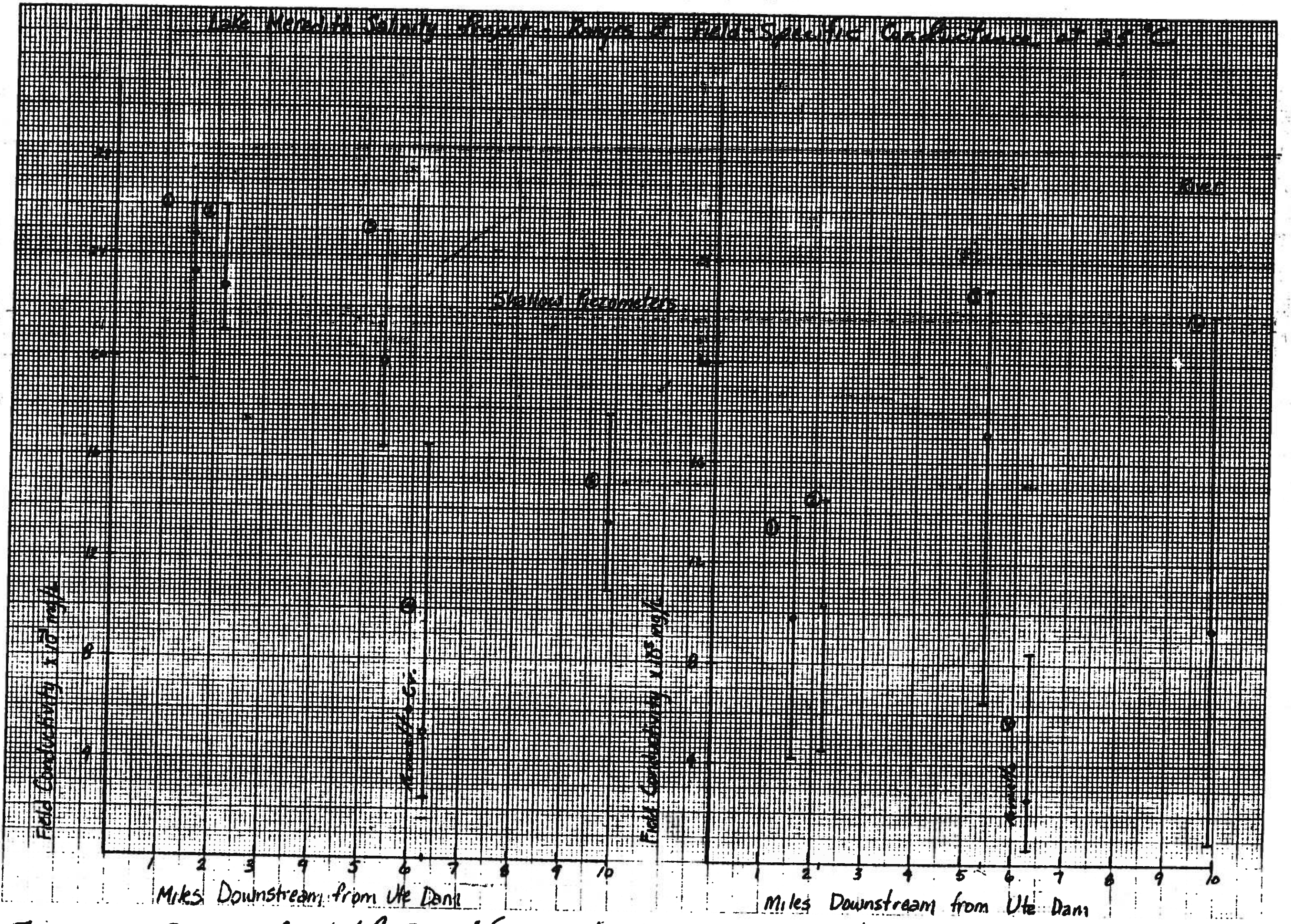


Figure 24—Ranges of Field-Specific Conductance Determinations, All Sampling Sites Near Logan, NM

K•E 10 X 10 TO THE CENTIMETER 18 X 25 CM.
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 1513

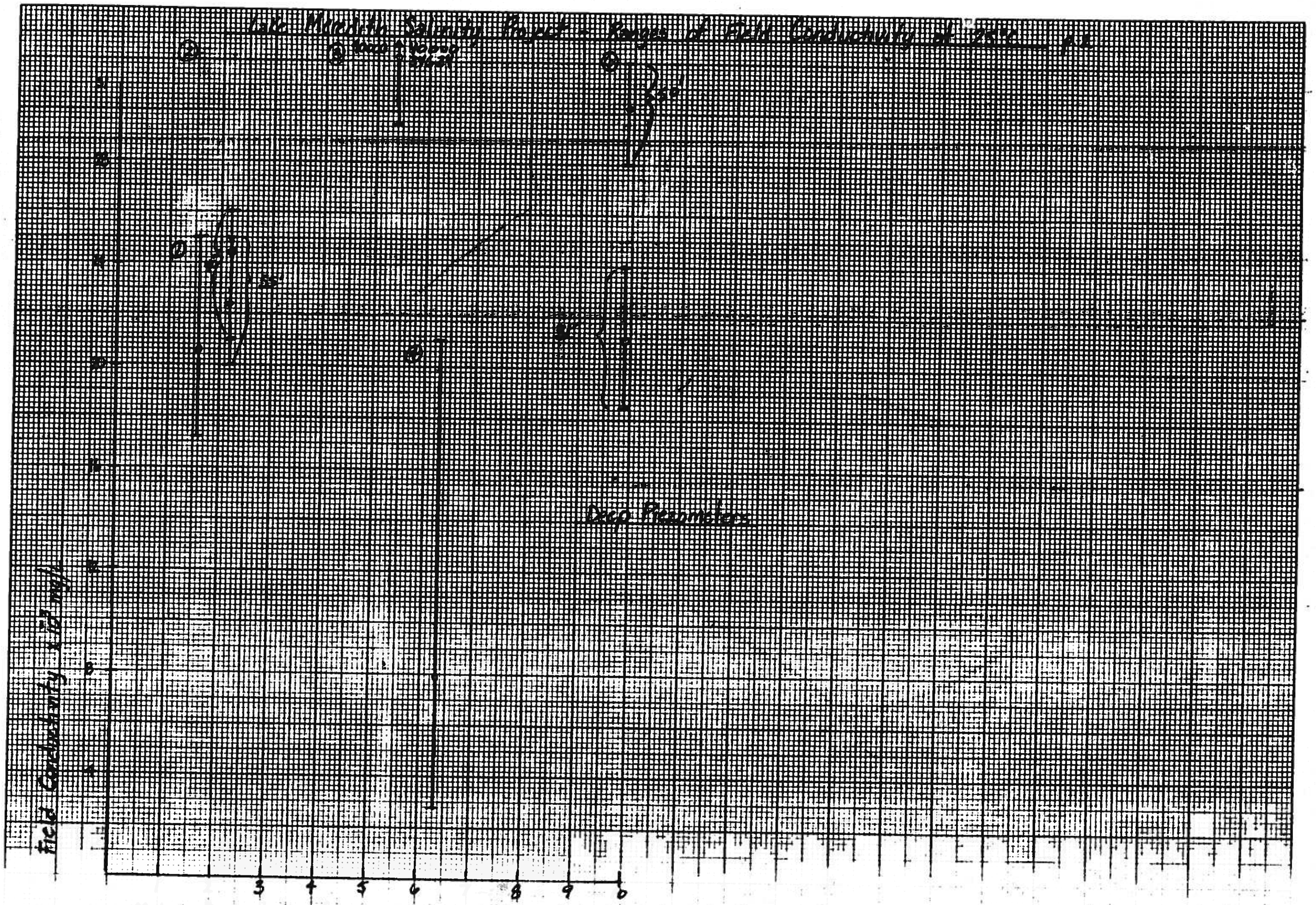

Lake Meredith Salinity Project - Ranges of Field Conductivity at 25°C

Figure 24 (Continued)

7-1654 (7-73)
Water and Power

COMPUTATION SHEET

BY G. G.
DATE 11/13/84
PROJECT Lake Meredith Salinity
SHEET 1 OF 2
CHKD BY
DATE
FEATURE
DETAILS Table 2 – Summary of Chemical Analyses for water Samples Collected at . . .

Site O – (underdrain/Toe Drain) RM 0.0

	Na meq/l	Mg meq/l	Ca meq/l	K meq/l	Cl meq/l	SO_4 meq/l	HCO_3 meq/l
5/23/83	23.49	1.36	2.56	0.15	18.79	4.58	5.76
7/26/83	20.75	1.50	1.28	0.10	14.73	4.91	5.12
mean	22.12	1.43	1.92	0.12	16.76	4.74	5.44

=

Ute Reservoir @ boat ramp

7/26/83	6.40	1.10	2.40	0.13	6.07	5.29	3.66

=

Ute Reservoir outlet works

7/26/83	20.75	1.5	1.28	0.10	14.73	4.91	5.12

7-1654 (7-73)
Water and Power

COMPUTATION SHEET

BY	DATE	PROJECT Lake Meredith	SHEET 2 OF 2
CHKD BY	DATE	FEATURE	
DETAILS Table 2 (continued)			

Site O —

	CO_3 meq/l	TDS mg/l	Lab PH	Field Sp. Cond. @25C	Field Temp °C
5/23/83	0.0	1553	8.20	2400	—
7/26/83	3.0	1057	8.44	1888	16
mean	1.5	1305	8.32	2144	—

=

Ute Reservoir @ boat ramp

7/26/83	0.08	617	8.33	882	26

=

Ute Reservoir outlet works

7/26/83	.12	1057	8.44	1888	16

discharge between sites 0 and 6 may be about 1 ft^3/s creating pools and freshwater zones along the river. These pools and zones are especially noticeable on the north bank of the river.

The spring discharge, combined with about 2 ft^3/s seepage flow from Ute Reservoir, makes up the present freshwater base flow for the Canadian River from sites 1 to 6 (figure 15). Some freshwater runoff occurs intermittently throughout the year from small drainages along the Canadian River. Higher flows in the Canadian River above Revuelto Creek are dependent on releases and spills from Ute Reservoir. During the study period, the highest recorded flow was 270 ft^3/s (figure 16). Revuelto Creek contributes to the freshwater flow of the river also, but on an irregular basis.

Flows in Revuelto Creek have ranged from 0 to thousands of ft^3/s, sometimes reaching these extreme peaks within 24 to 48 hours of a storm and receding just as rapidly (figure 17). These peak flows back water up the Canadian River a considerable distance.

Ranges, means, and standard deviations for selected water quality parameters are presented in the tables and figures which follow (figures 18 through 24). Several of the ranges are quite large. Some extreme values may be due to laboratory errors while others are natural fluctuations in the surface water system. Extreme ranges in the alluvial system are unexplained.

Additional statistical information relating flows, chlorides, field-specific conductance, and TDS are presented. The statistical analyses were performed on the data after several groupings were determined. Groups were composed only of data sets where all of the above four constituents were available for the sample date. Group I includes all the surface water data from sites 1-4 and 6; Group II includes all data from the alluvial piezometers at sites 1, 2, and 3; and Group III includes data from the alluvial piezometers at sites 4 and 6.

The results of these analyses are presented in table 3 and figures 25 through 42. After completing the correlations, it became obvious that the groupings were not necessary. Evaluating all the data as one group would have produced similar correlation coefficients and regression equation variables.

The results show that there is a good correlation between chlorides, TDS, and field-specific conductance for the piezometer and surface water data. They also show that there is a poor linear correlation between streamflow and these same parameters. The correlation did not improve using either the log or inverse of flow versus the three different constituents.

A complete list of the water quality parameter concentrations from sites 1-4 and 6 for the surface and alluvial samples are presented in tables 4 through 20. The minimum, maximum, and means for each constituent were computed, while standard deviations were computed only for certain constituents.

Plots of chloride concentration, TDS, and field-specific conductance versus time are presented for all these alluvial piezometer and surface samples (figures 43-57). Laboratory data are plotted, but the corrected calculated values were used for the graph when it was determined that they were probably

7-1654 (7-73)
Water and Power

COMPUTATION SHEET

BY G.G.	DATE 9/26/84	PROJECT Lk Meredith Project	SHEET 1 OF 4
CHKD BY	DATE	FEATURE Canadian River & Revuelto Cr.	
DETAILS Statistical Analyses - Regression - BR Data 5/83 - 8/84			

Table 3- Summary of Statistical Analyses For Grouped Water Samples, All Sampling Sites Near Logan, NM

Group 1- All Surface Water

y = A + BX

y / x
flow / chlorides

Sample size = 80
Correlation (R) = -0.279
R squared = 0.078
Std. Error of Est. = 22.949
Intercept (A) = 17.061
Slope (B) = -0.003

flow / Field Conductance

Sample size = 80
Correlation (R) = -0.308
R squared = 0.095
Std. Error of Est. = 22.735
Intercept (A) = 20.045
Slope (B) = -0.001

flow / TDS

Sample size = 80
correlation (R) = -0.286
R squared = 0.082
Std. Error of Est. = 22.897
Intercept (A) = 17.966
Slope (B) = -0.002

chlorides / Field Conductance

Sample size = 80
Correlation (R) = 0.936
R squared = 0.877
Std Error of Est. = 775.969
Intercept (A) = -348.662
Slope (B) = 0.352

chlorides / TDS

Sample size = 80
correlation (R) = 0.869
R squared = 0.755
Std. Error of Est = 1095.103
Intercept (A) = 241.498
Slope (B) = 0.471

R - 1 - (-1) - closser to 1 better Linear Relationship; - indicates inverse relationship
R^2 - variance - 0-1 small when variables cluster close to mean
std. Error - std dev of y values from predicted y values

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Water and Power

COMPUTATION SHEET

BY
DATE
PROJECT Lk Meredith Project
SHEET 2 OF 4
CHKD BY
DATE
FEATURE
DETAILS statistical Analyses - Regression y = A + BX

Field Conductance/TDS

Sample size = 80
correlation (R) = 0.877
R squared = 0.768
Std. Error of Est. = 2828.171
Intercept (A) = 2140.874
slope (B) = 1.266

Group II - Alluvial Piezometers Canad. R ab Revuelto Cr.

y x
flow/chlorides

sample size = 119
Correlation (R) = 0.238
R squared = 0.057
std Error of Est. = 1.454
Intercept (A) = 0.842
slope (B) = 0.00017

flow / Field Conductance

sample size = 119
Correlation (R) = 0.209
R squared = 0.044
std. Error of Est. = 1.464
Intercept (A) = 0.883
slope (B) = 0.00006

flow/TDS

sample size = 119
correlation (R) = 0.067
R squared = 0.004
Std. Error of Est. = 1.494
Intercept (A) = 1.935
slope (B) = 0.00002

Table 3 (continued)

Note: Flow data is from the surface stream near the piezometers.

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Water and Power

COMPUTATION SHEET

BY
DATE
PROJECT LK Meredith Project
SHEET 3 OF 4
CHKD BY
DATE
FEATURE
DETAILS Statistical Analyses - Regression Y = A + BX

Chlorides / Field Conductance

Sample size = 119
Correlation (R) = 0.819
R squared = 0.670
Std. Error of Est. = 1235.800
Intercept (A) = 845.918
Slope (B) = 0.338

Chlorides / TDS

Sample size = 119
Correlation (R) = 0.657
R squared = 0.432
Std Error of Est. = 1621.740
Intercept (A) = 3449.926
Slope (B) = 0.348

Field Conductance / TDS

Sample size = 119
Correlation (R) = 0.681
R squared = 0.464
Std Error of Est = 3820.136
Intercept (A) = 10174.063
Slope (B) = 0.874

Group III Alluvial Piezometers, Revuelto Cr. and Canad. R. Below Revuelto Cr. Y = A + BX

Table 3 (Continued)

Y / X
flow / chlorides

Sample size = 67
Correlation R = 0.161
R squared = 0.026
STD ERROR of Est. = 35.181
Intercept (A) = 7.598
Slope (B) = 0.0016

7-1654 (7-73)
Water and Power

COMPUTATION SHEET

BY	DATE	PROJECT Lk Meredith Project	SHEET 4 OF 4
CHKD BY	DATE	FEATURE	
DETAILS Statistical Analyses - Regression Y=A+BX			

Y X
flow/Field Conductance
Sample size = 67
Correlation R = 0.030
R Squared = 0.0009
Std. error of Est. = 35.629
Intercept (A) = 13.441
Slope (B) = 0.0001

flow/TDS
Sample size = 67
Correlation (R) = 0.019
R squared = 0.0004
Std. error of Est. = 35.639
Intercept (A) = 14.014
Slope (B) = 0.0001

chlorides/Field Conductance
Sample size = 67
Correlation (R) = 0.974
R squared = 0.948
Std. Error of Est. = 836.877
Intercept (A) = -533.114
Slope (B) = 0.375

chlorides/TDS
Sample size = 67
Correlation (R) = 0.858
R squared = 0.737
Std Error of Est. = 1892.622
Intercept (A) = 85.511
Slope (B) = 0.471

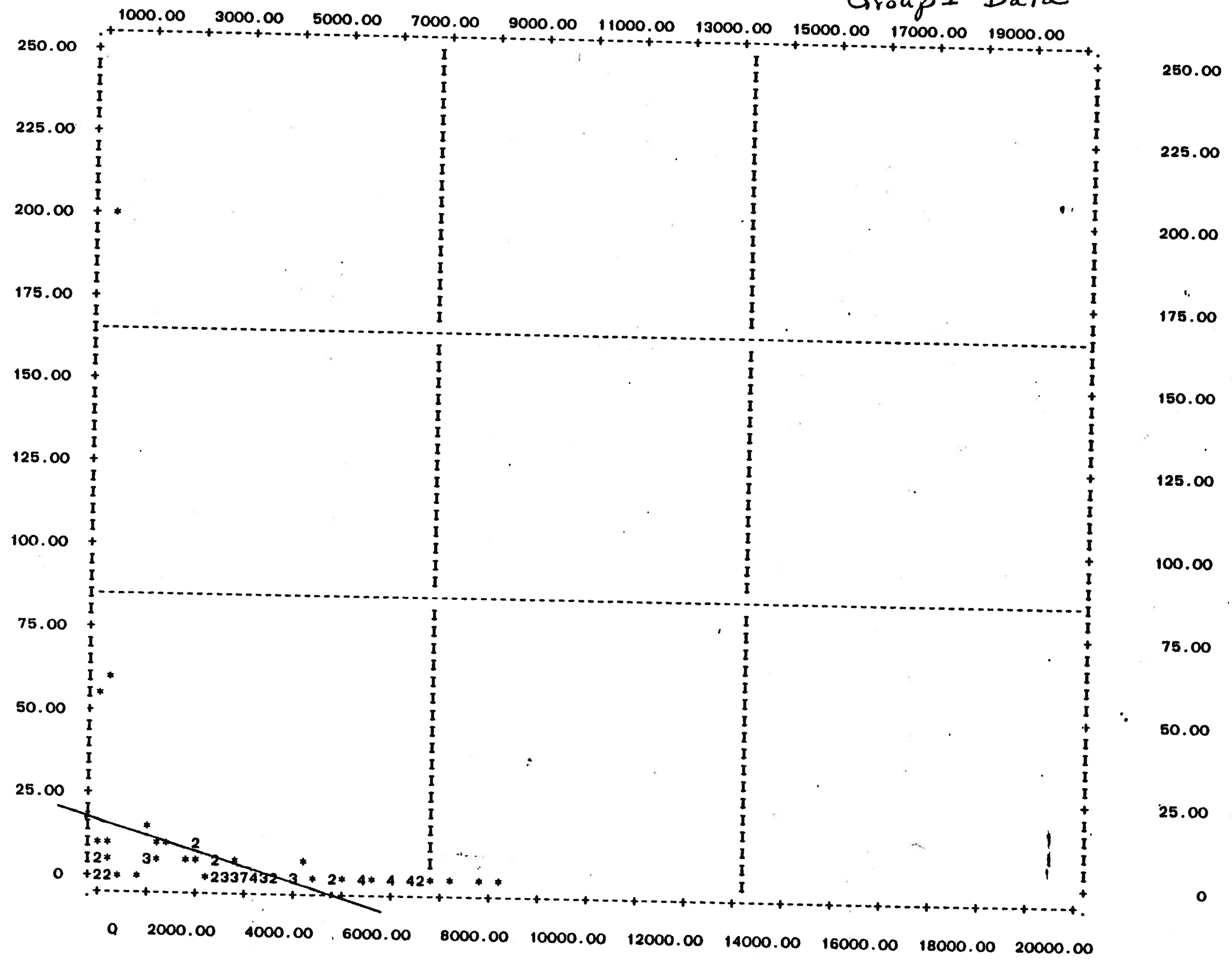
Field Conductance/TDS
Sample size = 67
Correlation (R) = 0.862
R squared = 0.743
Std. Error of Est. = 4851.193
Intercept (A) = 1920.625
Slope (B) = 1.227

Table 3-(continued)

```
CANADIAN RIVER NR LOGAN,NM
SCATTERGRAM-ALL SURFACE WATER-CANADIAN RIVER NR LOGAN,NM                    84/09/23.    16.52.12.    PAGE    3
FILE    NONAME    (CREATION DATE =  84/09/23.)
SUBFILE   S01          S04          S08          S13          S17

SCATTERGRAM OF     (DOWN)  VAR002    FLOW
                  (ACROSS) VAR003    CHLORIDES
```

Figure 25 – Scattergram, Flow VS Chlorides
Group I Data



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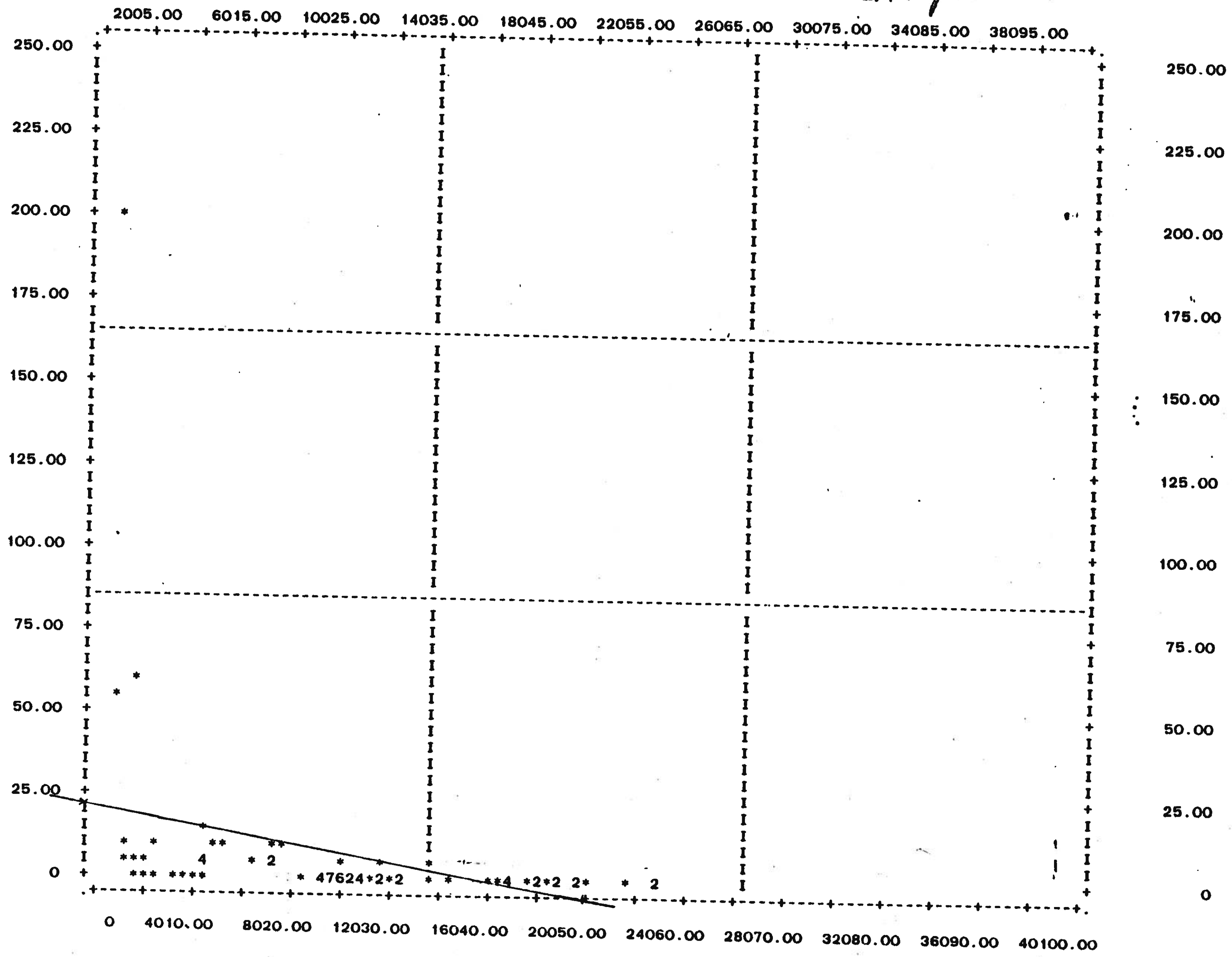
CANADIAN RIVER NR LOGAN,NM                                                          84/09/23.     16.52.12.     PAGE    5
SCATTERGRAM-ALL SURFACE WATER-CANADIAN RIVER NR LOGAN,NM
FILE    NONAME    (CREATION DATE =  84/09/23.)
SUBFILE    S01          S04          S08          S13          S17

SCATTERGRAM OF       (DOWN)  VAR002     FLOW
                     (ACROSS) VAR005    FIELD CONDUCTANCE
```

Figure 26 - Scattergram, Flow VS Field Conductance
Group I Data



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CANADIAN RIVER NR LOGAN,NM
SCATTERGRAM-ALL SURFACE WATER-CANADIAN RIVER NR LOGAN,NM              84/09/23.    16.52.12,    PAGE   7
FILE    NONAME    (CREATION DATE =  84/09/23.)
SUBFILE   S01        S04        S08        S13        S17

SCATTERGRAM OF      (DOWN)  VAR002   FLOW
                    (ACROSS) VAR006   TDS
```
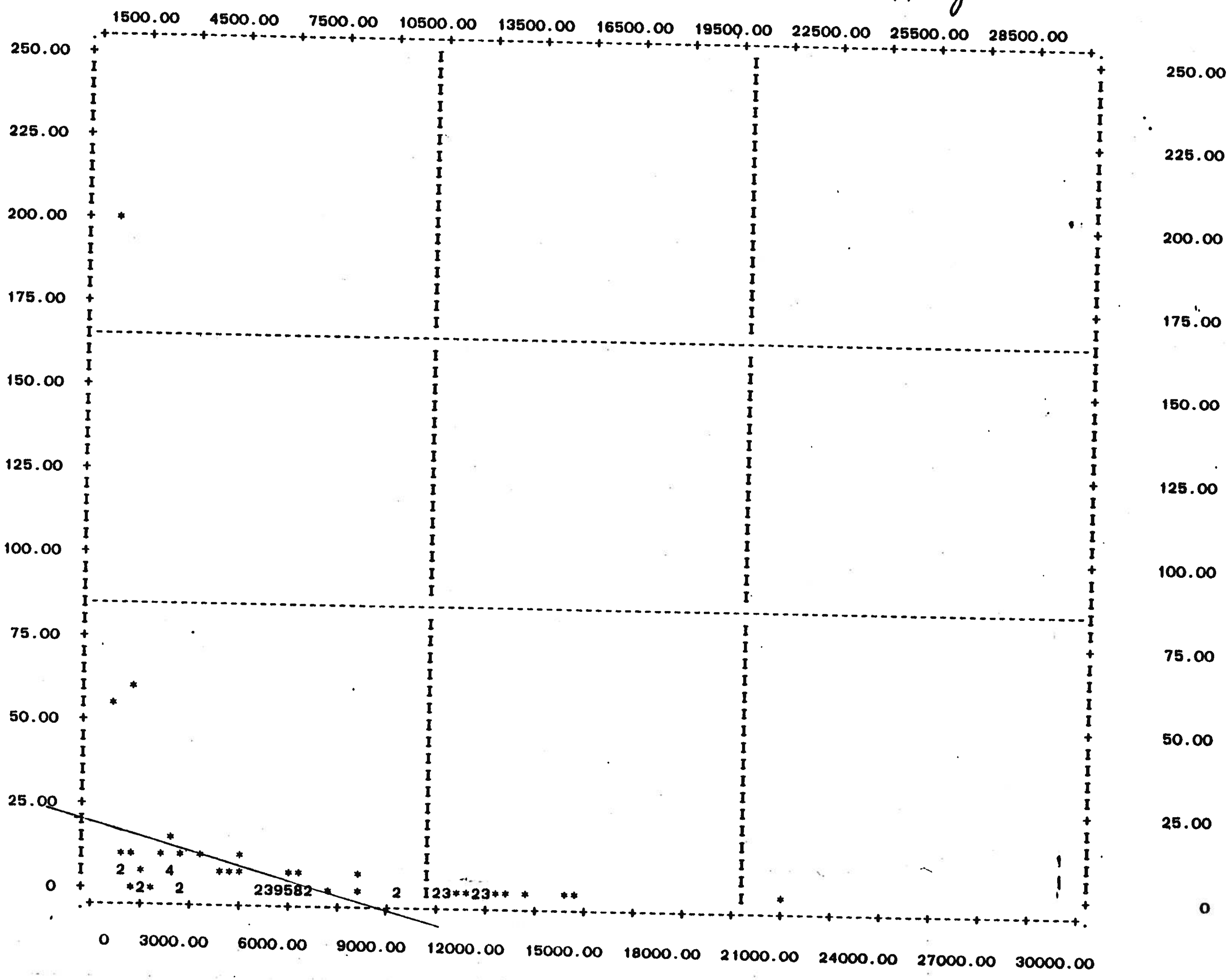

Figure 27 - Scattergram, Flow vs TDS
Group I Data



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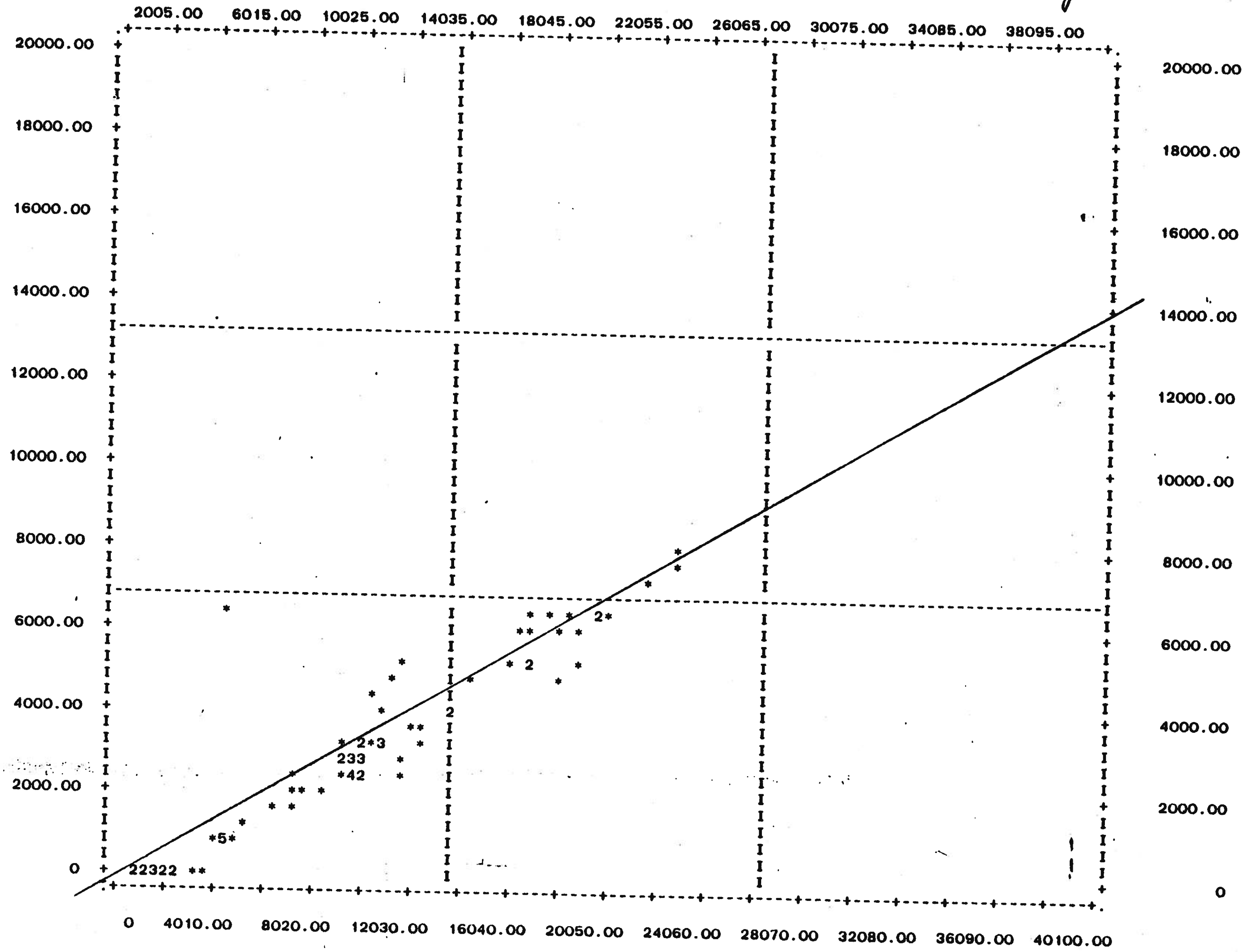
CANADIAN RIVER NR LOGAN,NM
SCATTERGRAM-ALL SURFACE WATER-CANADIAN RIVER NR LOGAN,NM                84/09/23.    16.52.12.    PAGE    9
FILE    NONAME    (CREATION DATE =  84/09/23.)
SUBFILE    S01          S04          S08          S13          S17

SCATTERGRAM OF     (DOWN)  VAR003    CHLORIDES
                  (ACROSS) VAR005    FIELD CONDUCTANCE
```

Figure 28 - Scattergram, Chlorides VS Field Conductance Group I Data



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CANADIAN RIVER NR LOGAN,NM
SCATTERGRAM-ALL SURFACE WATER-CANADIAN RIVER NR LOGAN,NM                  84/09/23.     16.52.12.     PAGE   11
FILE    NONAME    (CREATION DATE =  84/09/23.)
SUBFILE    S01          S04          S08          S13          S17

SCATTERGRAM OF     (DOWN)  VAR003   CHLORIDES
                  (ACROSS) VAR006   TDS
```
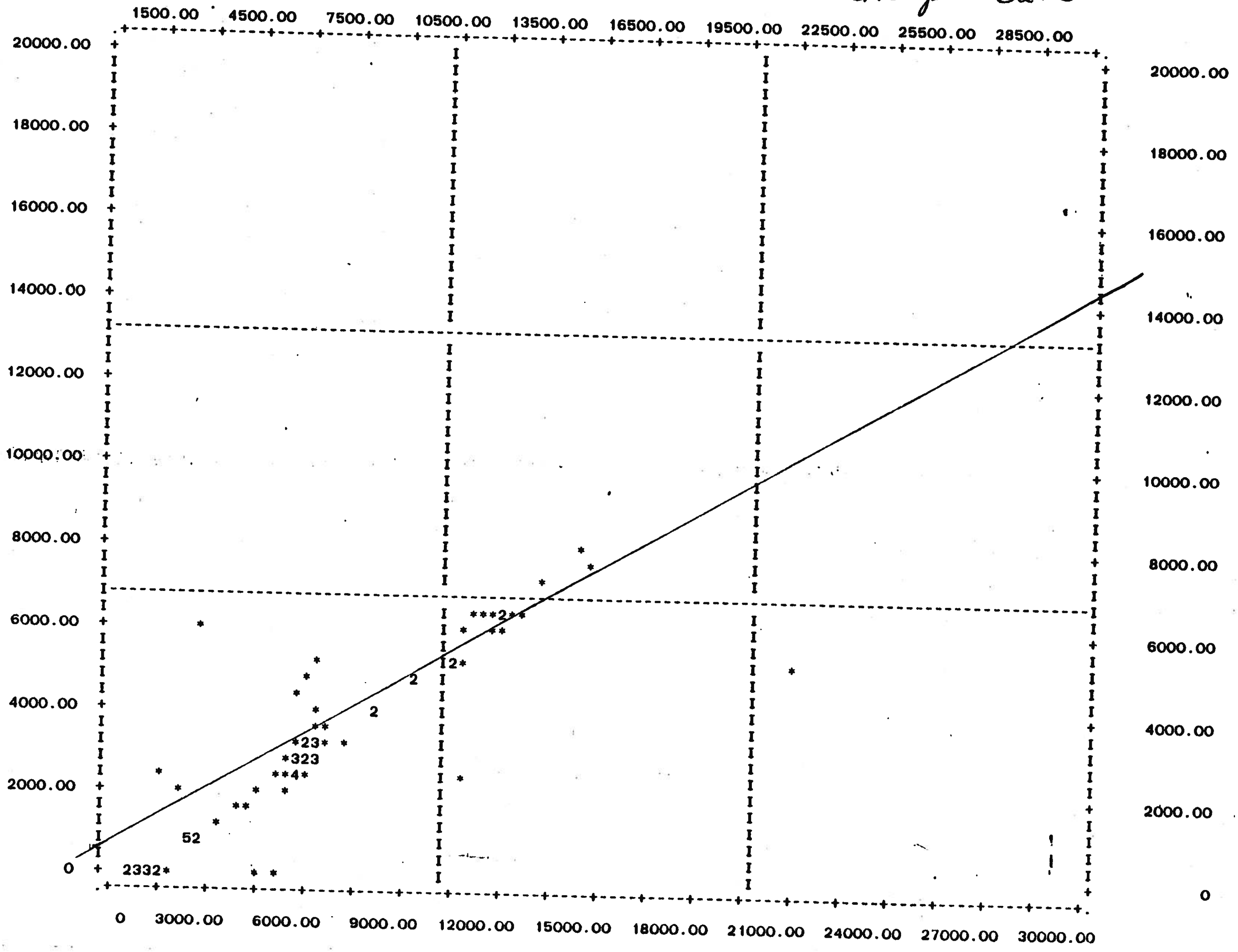

Figure 29 - Scattergram, Chlorides VS TDS
Group I Data



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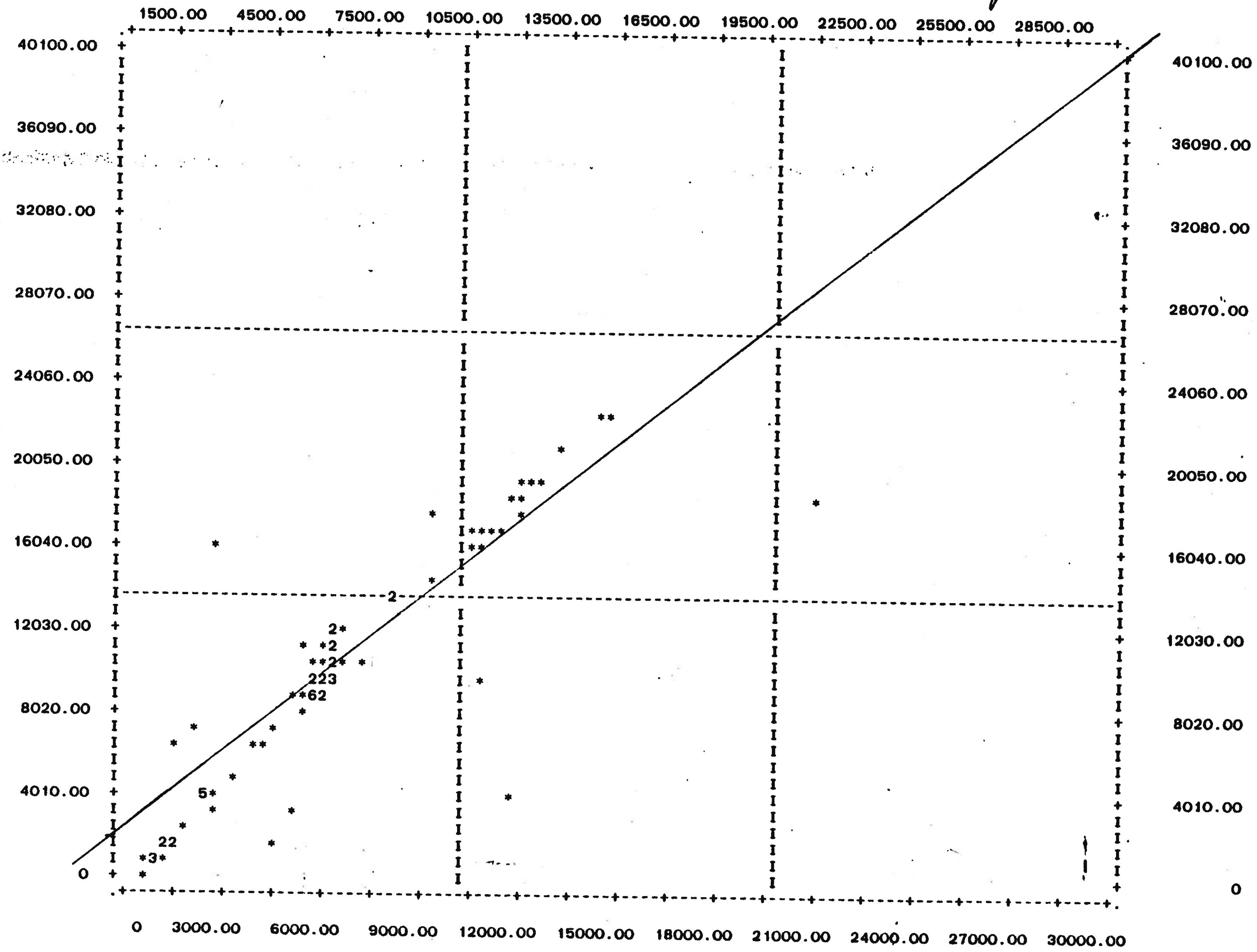
CANADIAN RIVER NR LOGAN,NM                                                       84/09/23.     16.52.12.     PAGE   21
SCATTERGRAM-ALL SURFACE WATER-CANADIAN RIVER NR LOGAN,NM
FILE    NONAME    (CREATION DATE =  84/09/23.)
SUBFILE     S01          S04          S08          S13          S17

SCATTERGRAM OF       (DOWN)  VAR005    FIELD CONDUCTANCE
                     (ACROSS) VAR006   TDS
```

Figure 30 - Scattergram, Field Conductance vs TDS
Group I Data



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CANADIAN RIVER NR LOGAN,NM                                            84/09/23.    16.52.12.     PAGE   37
SCATERGRAM-PIEZOMETERS AB REVUELTO CREEK
FILE    NONAME    (CREATION DATE =  84/09/23.)
SUBFILE   S02         S03         S05         S06         S07         S09         S10

SCATTERGRAM OF     (DOWN)  VAR002    FLOW
                  (ACROSS) VAR003    CHLORIDES
```
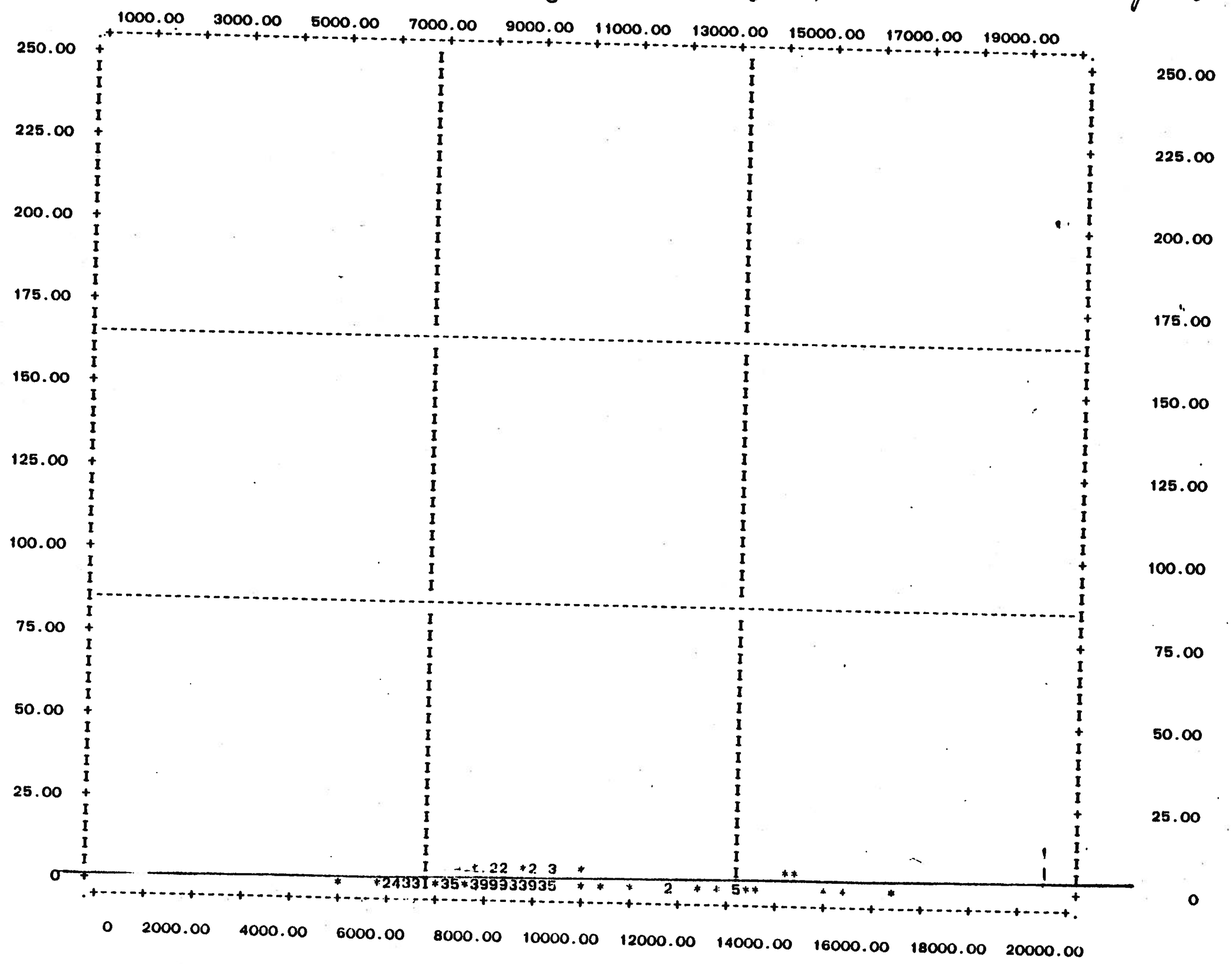

Figure 31 - Scattergram, Flow vs Chlorides   Group II Data



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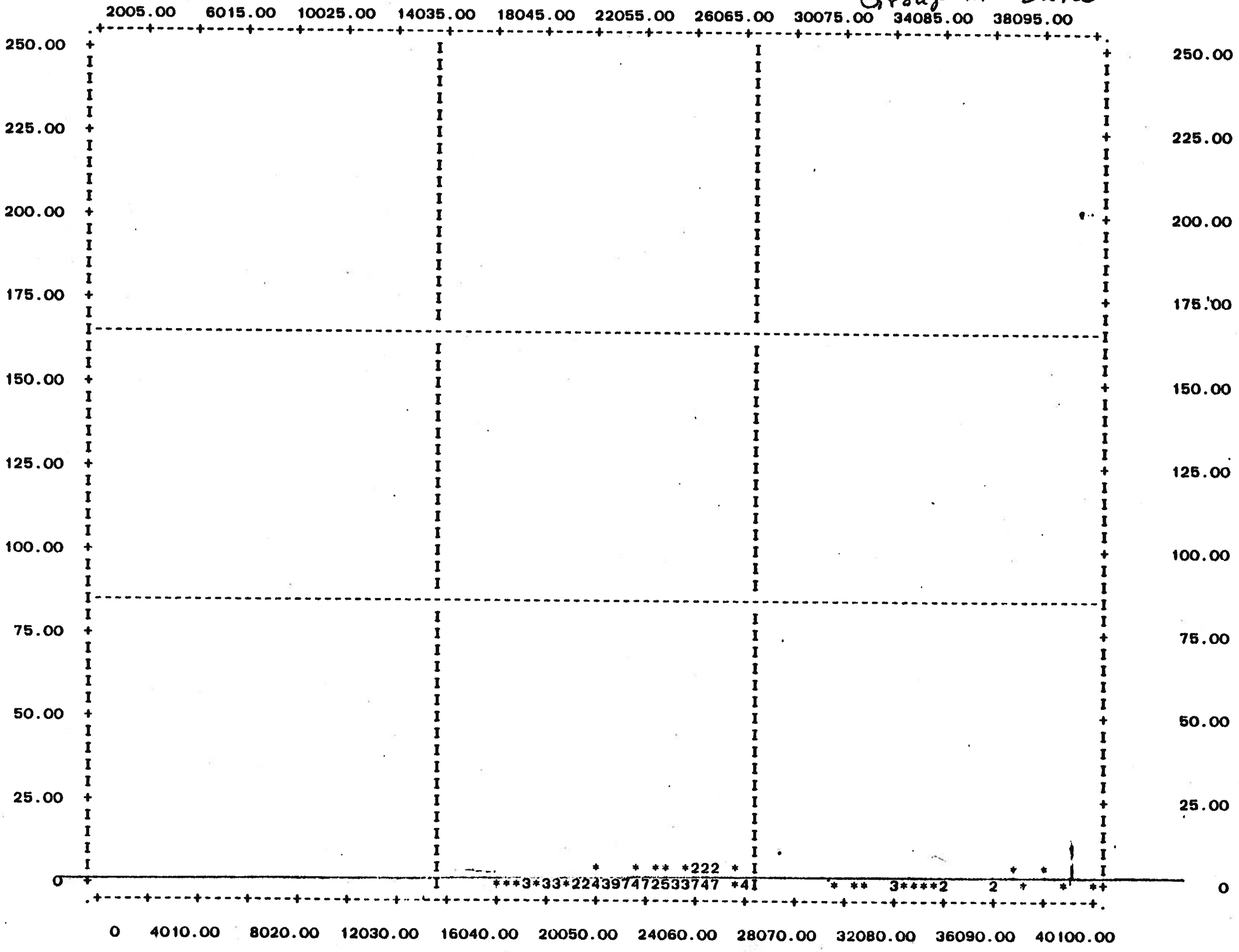
CANADIAN RIVER NR LOGAN,NM                                                      84/09/23.    16.52.12.     PAGE   39
SCATERGRAM-PIEZOMETERS AB REVUELTO CREEK
FILE   NONAME    (CREATION DATE =  84/09/23.)
SUBFILE   S02          S03          S05          S06          S07          S09          S10

SCATTERGRAM OF     (DOWN)  VAR002   FLOW
                   (ACROSS) VAR005  FIELD CONDUCTANCE
```

Figure 32 – Scattergram, Flow VS Field Conductance
Group II Data



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CANADIAN RIVER NR LOGAN,NM                                                         84/09/23.    16.52.12.    PAGE  41
SCATERGRAM-PIEZOMETERS AB REVUELTO CREEK
FILE    NONAME    (CREATION DATE =  84/09/23.)
SUBFILE   S02        S03        S05        S06        S07     S09     S10

SCATTERGRAM OF     (DOWN)  VAR002    FLOW
                   (ACROSS) VAR006   TDS
```
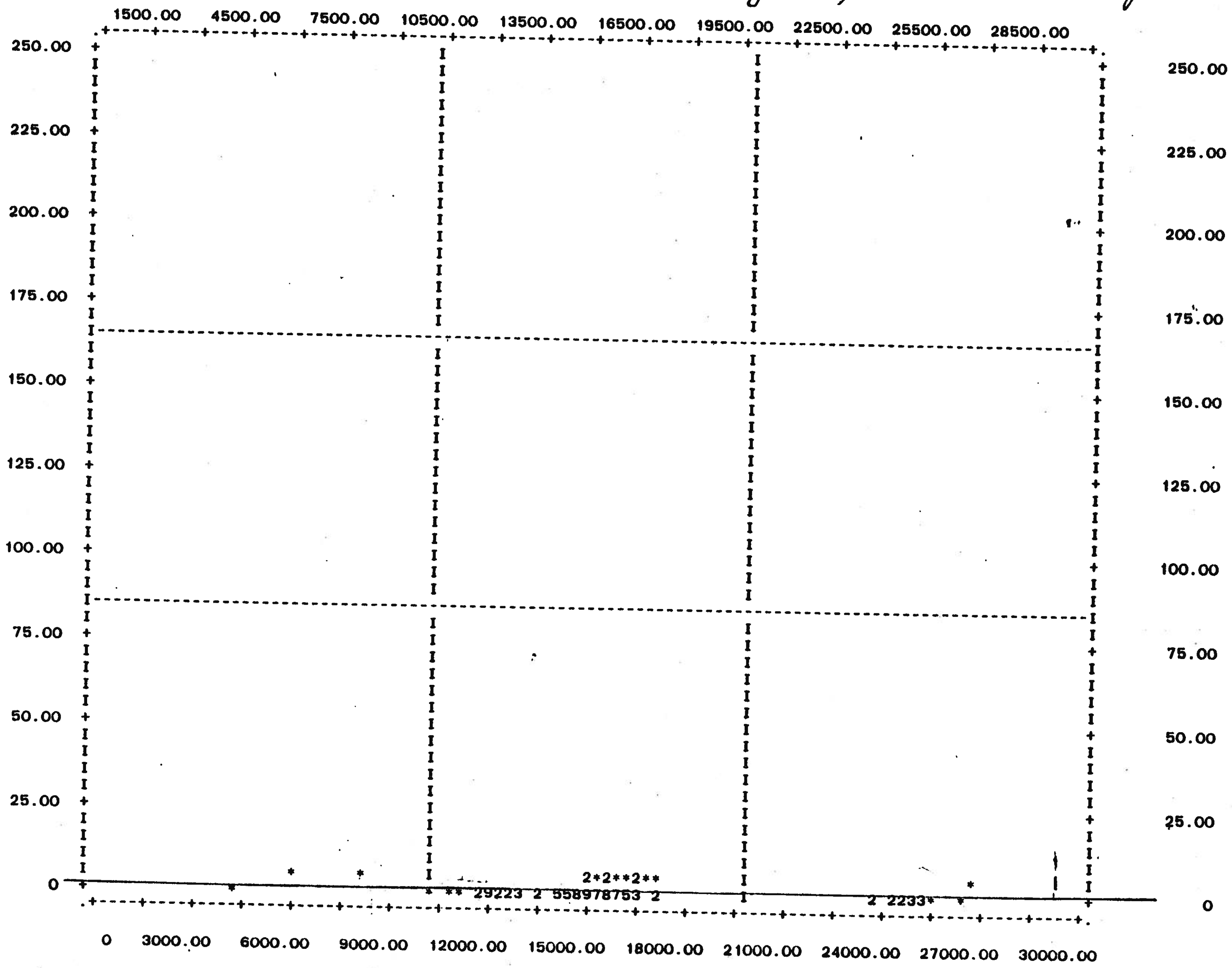

Figure 33 - Scattergram, Flow vs TDS Group II Data



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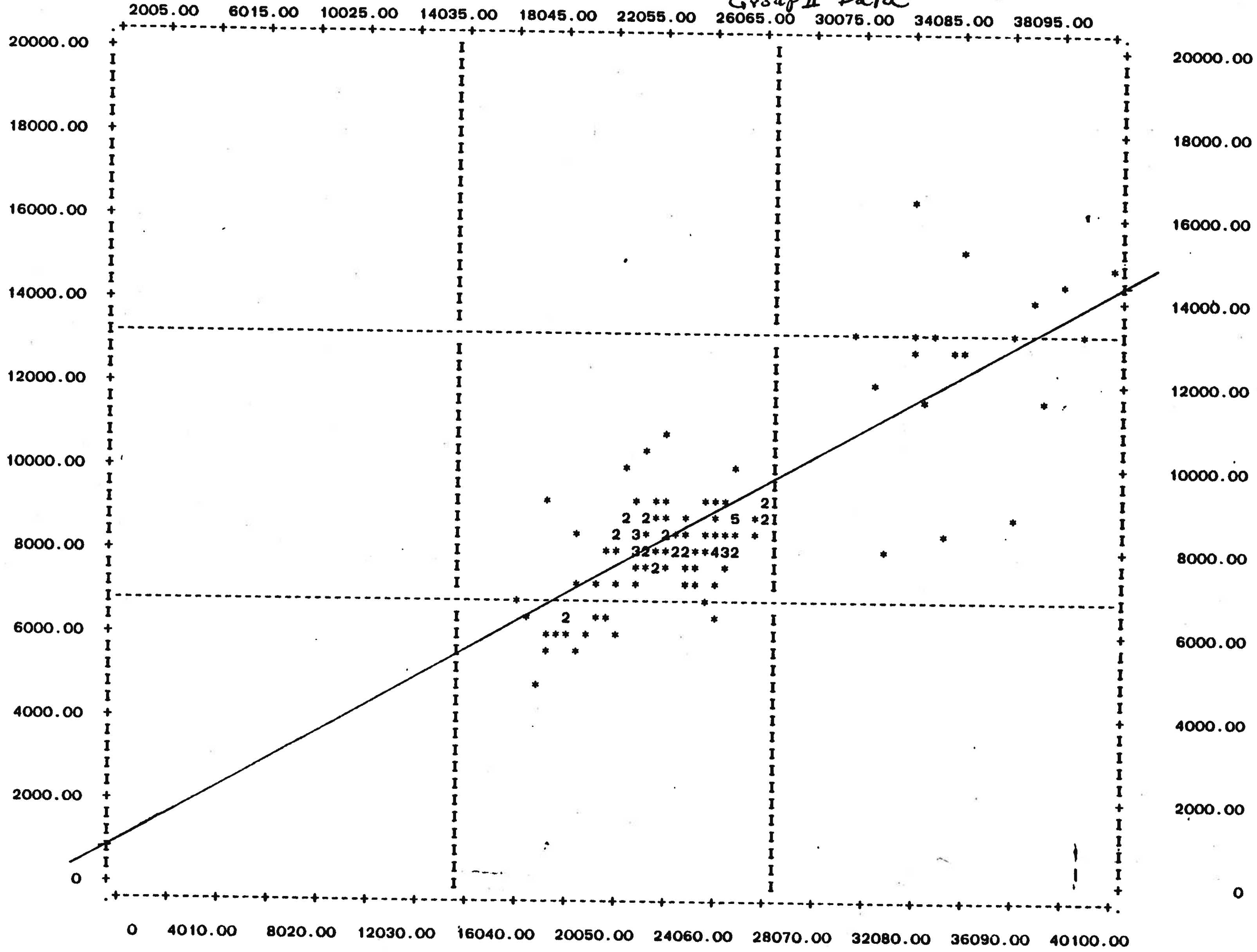
CANADIAN RIVER NR LOGAN,NM                                              84/09/23.    16.52.12.     PAGE   43
SCATERGRAM-PIEZOMETERS AB REVUELTO CREEK
FILE    NONAME    (CREATION DATE =  84/09/23.)
SUBFILE   S02         S03         S05         S06         S07         S09         S10

SCATTERGRAM OF      (DOWN)  VAR003   CHLORIDES
                   (ACROSS) VAR005   FIELD CONDUCTANCE
```

Figure 34 - Scattergram, Chlorides vs Field Conductance
Group II Data



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CANADIAN RIVER NR LOGAN,NM
SCATERGRAM-PIEZOMETERS AB REVUELTO CREEK                         84/09/23.    16.52.12.     PAGE   45
FILE    NONAME    (CREATION DATE =  84/09/23.)
SUBFILE   S02          S03          S05          S06          S07          S09          S10

SCATTERGRAM OF     (DOWN)  VAR003    CHLORIDES
                 (ACROSS)  VAR006    TDS
```
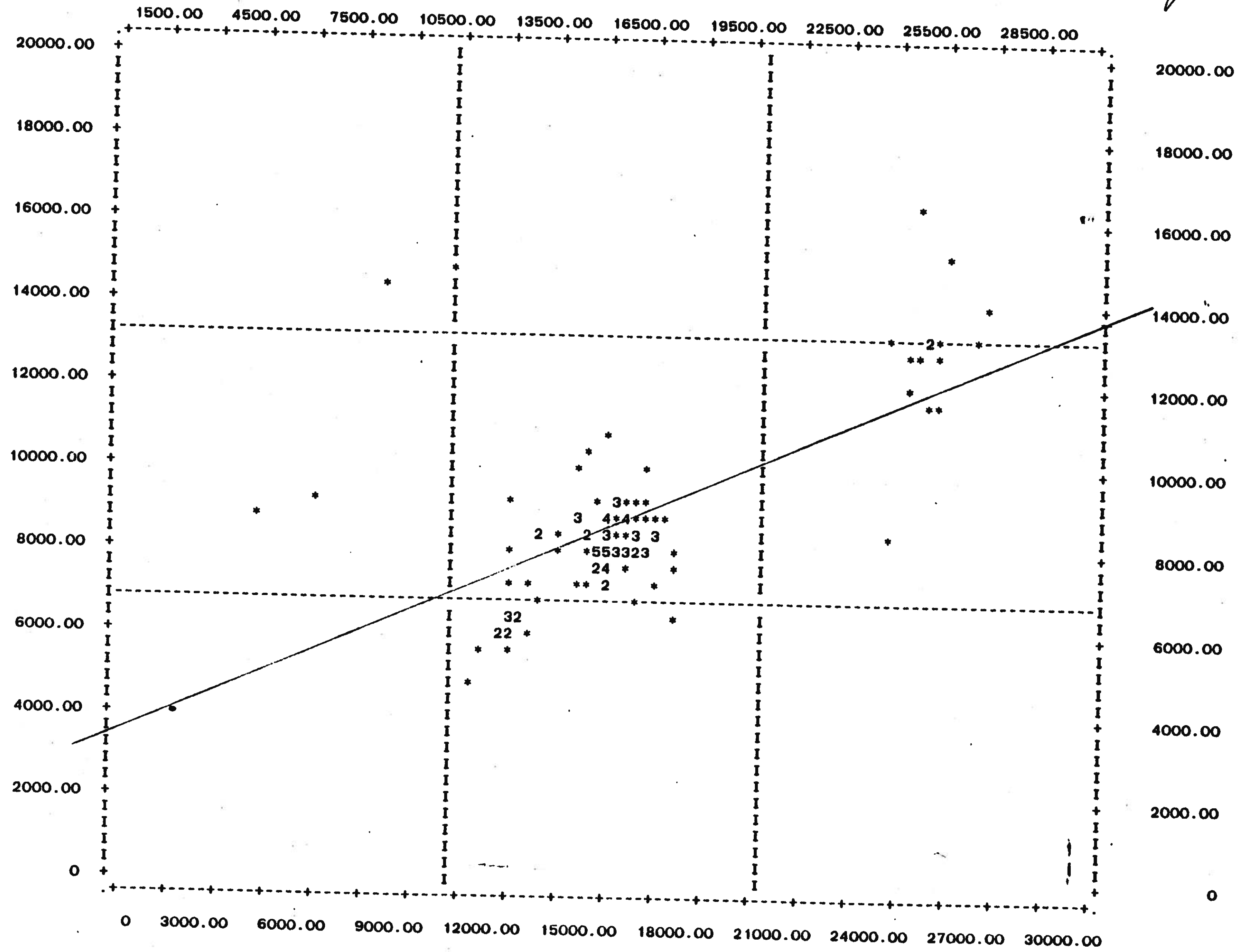

Figure 35 — Scattergram, chlorides vs TDS Group II Data



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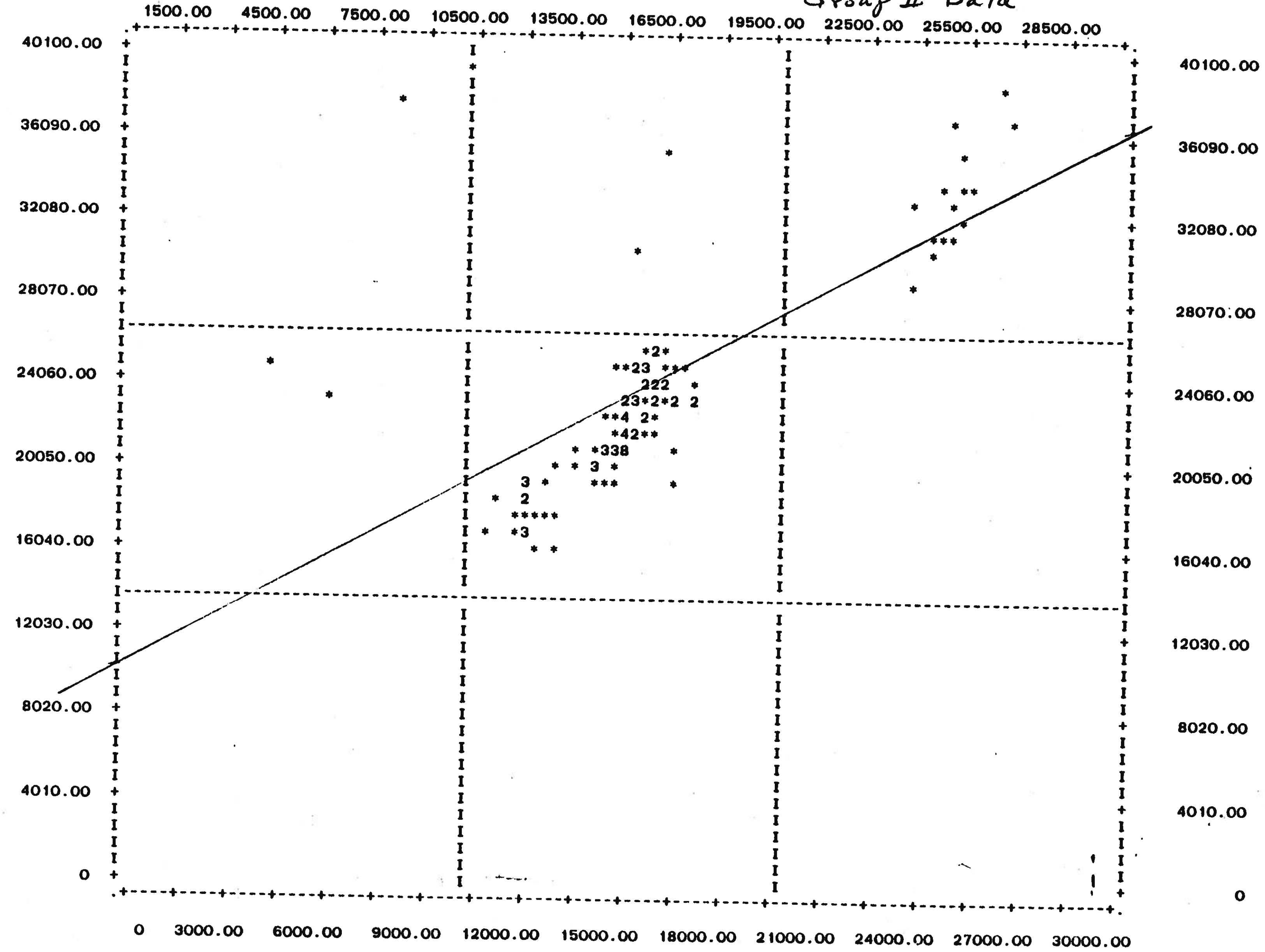
CANADIAN RIVER NR LOGAN,NM                                              84/09/23.   16.52.12.    PAGE   55
SCATERGRAM-PIEZOMETERS AB REVUELTO CREEK
FILE    NONAME    (CREATION DATE =  84/09/23.)
SUBFILE    S02          S03          S05          S06          S07          S09          S10

SCATTERGRAM OF     (DOWN)  VAR005    FIELD CONDUCTANCE
                  (ACROSS) VAR006    TDS
```

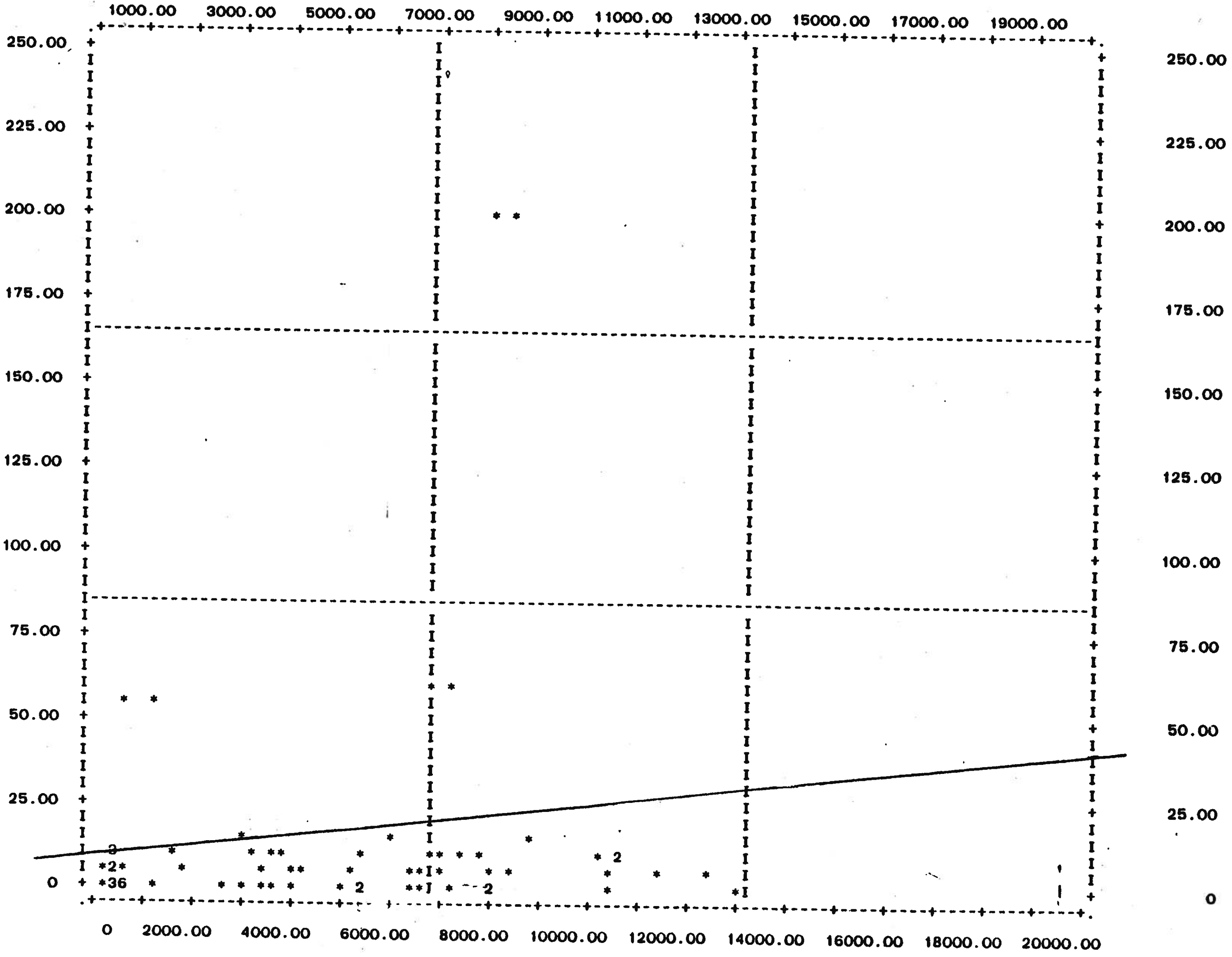
Figure 36 - Scattergram, Field Conductance VS TDS
Group II Data



```
CANADIAN RIVER NR LOGAN,NM                                                          84/09/23.   16.52.12.    PAGE   71
SCATTERGRAM-PIEZOMETERS,REVUELTO CR AND CANAD. R BELOW REV CR
FILE    NONAME    (CREATION DATE =  84/09/23.)
SUBFILE    S11        S12        S14        S15        S16

SCATTERGRAM OF     (DOWN)  VAR002    FLOW
                 (ACROSS)  VAR003    CHLORIDES
```

Figure 37 - Scattergram, Flow vs Chlorides Group III Data



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CANADIAN RIVER NR LOGAN,NM                                              84/09/23.   16.52.12.    PAGE  73
SCATTERGRAM-PIEZOMETERS,REVUELTO CR AND CANAD. R BELOW REV CR
FILE    NONAME    (CREATION DATE =  84/09/23.)
SUBFILE   S11         S12         S14         S15         S16

SCATTERGRAM OF      (DOWN)  VAR002    FLOW
                    (ACROSS) VAR005   FIELD CONDUCTANCE
```
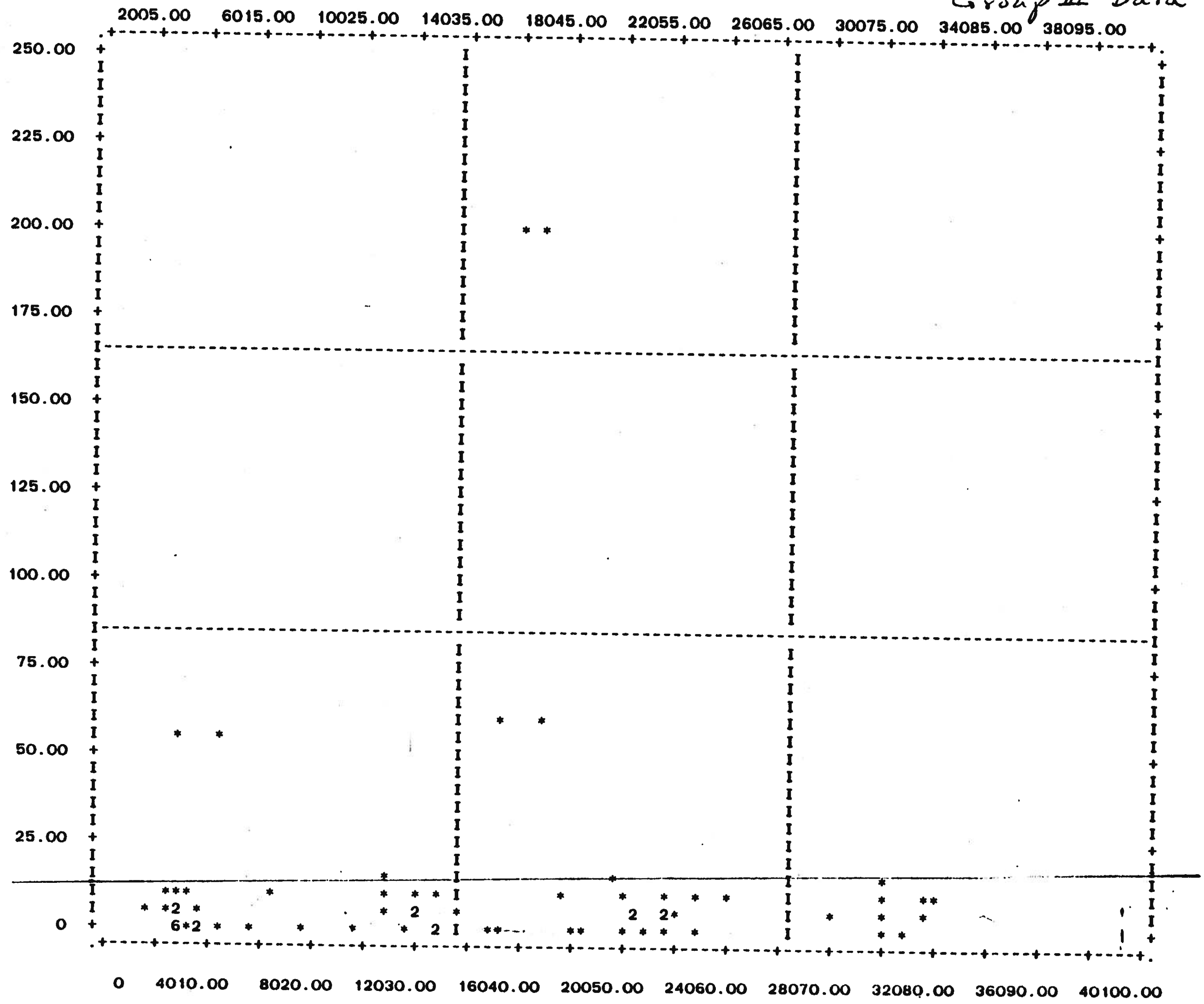

Figure 38 - Scattergram, Flow vs Field Conductance
Group III Data



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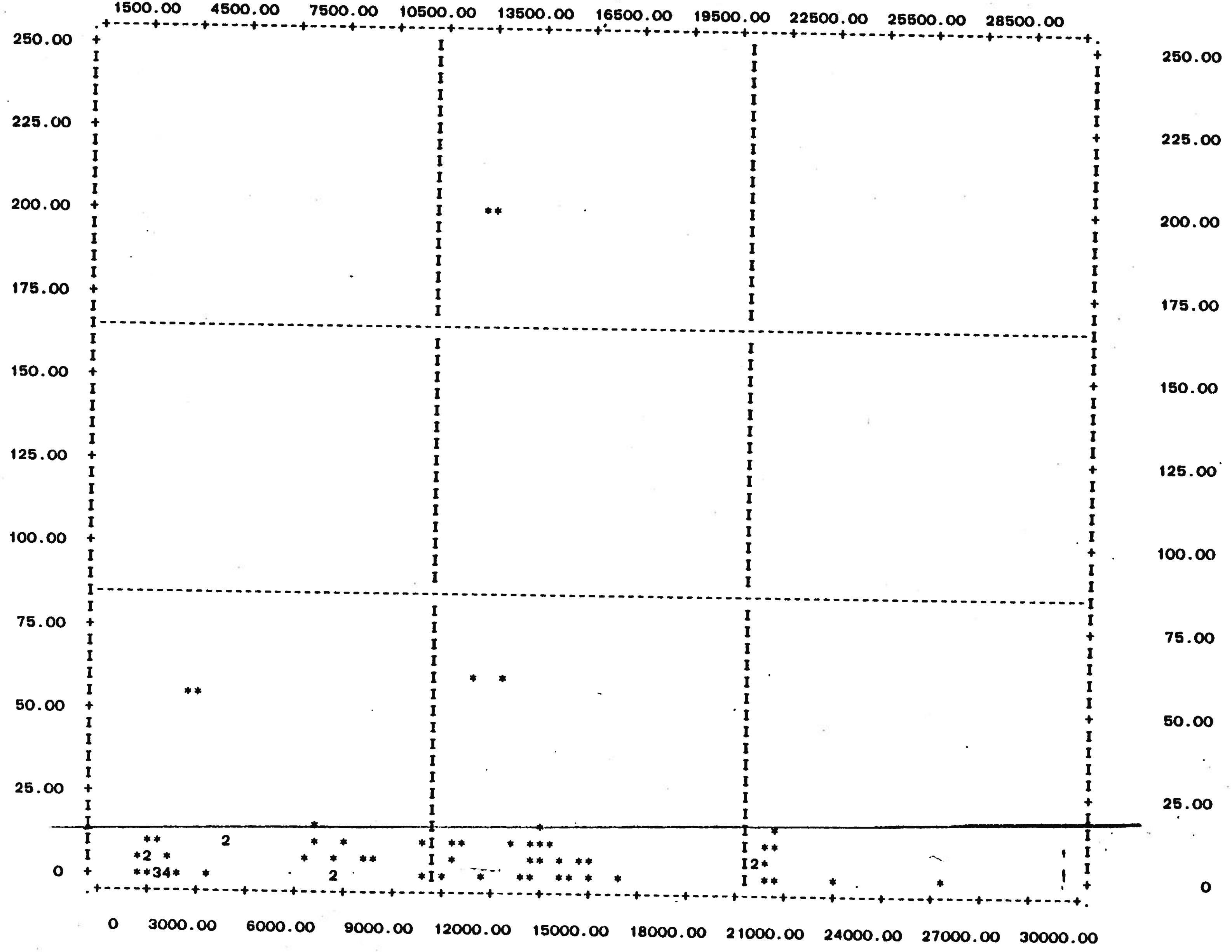
CANADIAN RIVER NR LOGAN,NM                                                84/09/23.    16.52.12.    PAGE  75
SCATTERGRAM-PIEZOMETERS,REVUELTO CR AND CANAD. R BELOW REV CR
FILE   NONAME    (CREATION DATE =  84/09/23.)
SUBFILE   S11         S12         S14         S15         S16

SCATTERGRAM OF      (DOWN)  VAR002    FLOW
                   (ACROSS) VAR006    TDS
```

Figure 39 - Scattergram, Flow vs TDS Group III Data



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CANADIAN RIVER NR LOGAN,NM                                                    84/09/23.    16.52.12.    PAGE   77
SCATTERGRAM-PIEZOMETERS,REVUELTO CR AND CANAD. R BELOW REV CR
FILE   NONAME   (CREATION DATE =  84/09/23.)
SUBFILE   S11        S12        S14        S15        S16

SCATTERGRAM OF    (DOWN)  VAR003   CHLORIDES
                 (ACROSS) VAR005   FIELD CONDUCTANCE
```
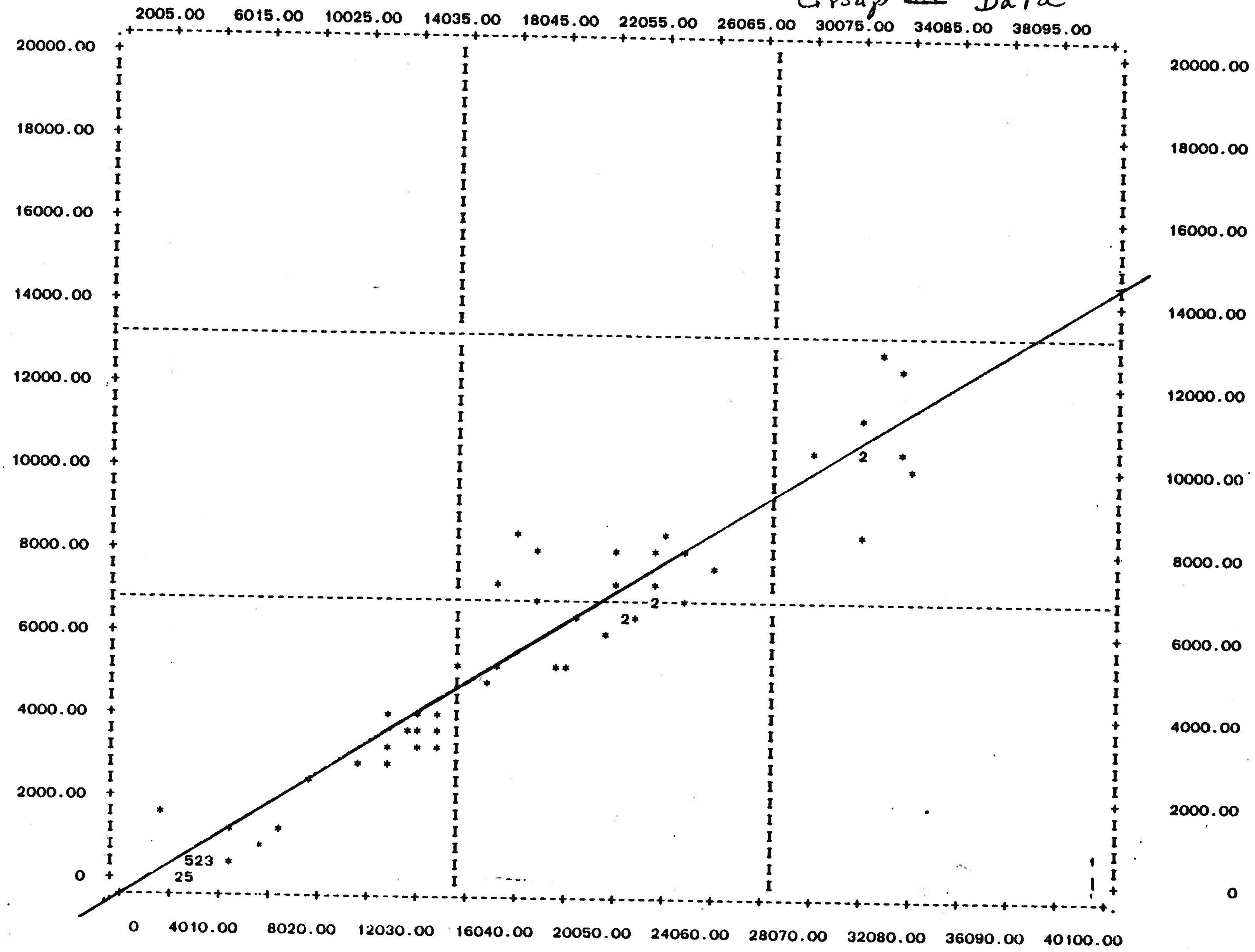

Figure 40 - Scattergram, Chlorides VS Field Conductance
Group III Data



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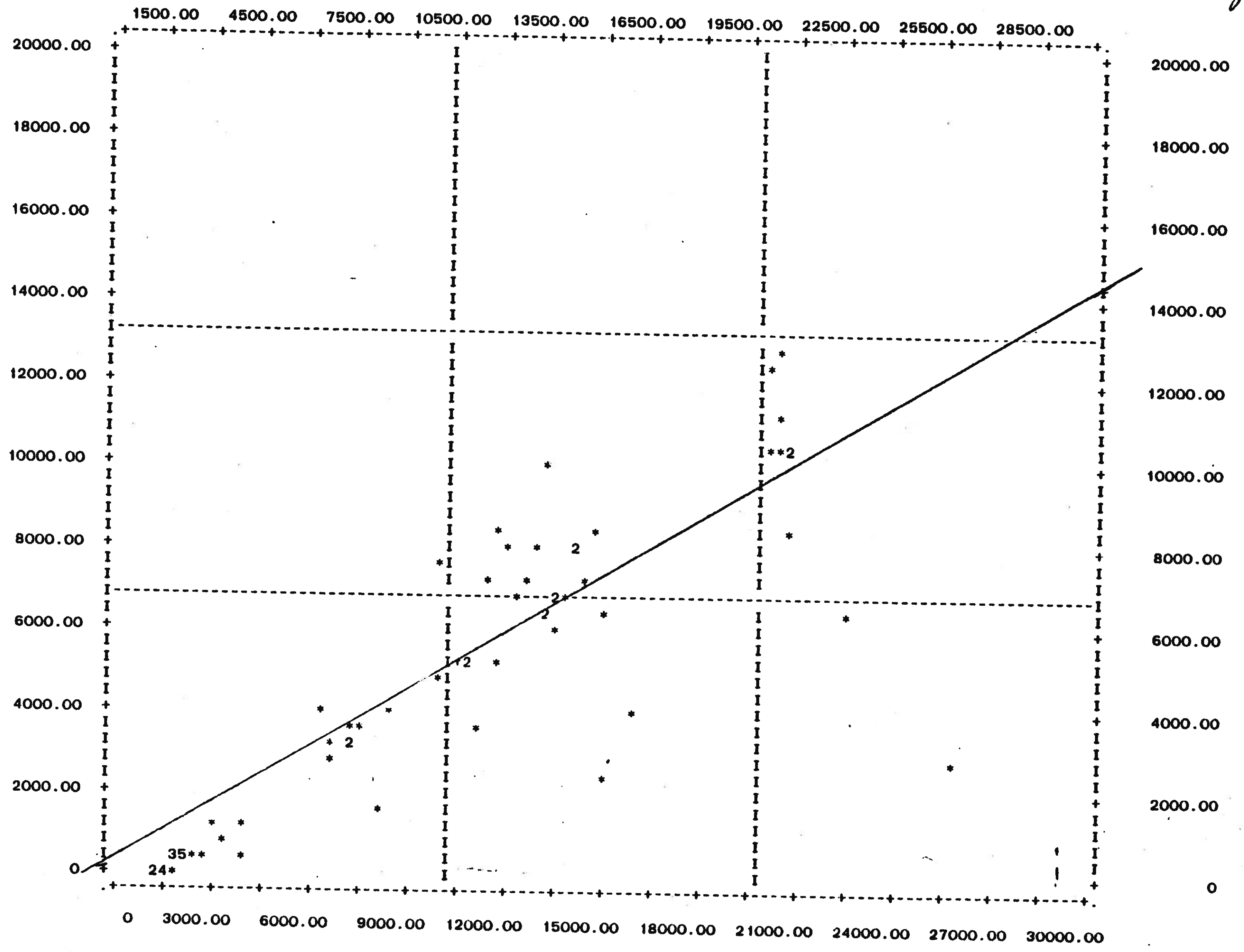
CANADIAN RIVER NR LOGAN,NM
SCATTERGRAM-PIEZOMETERS,REVUELTO CR AND CANAD. R BELOW REV CR          84/09/23.     16.52.12.      PAGE   79
FILE    NONAME    (CREATION DATE =  84/09/23.)
SUBFILE    S11         S12          S14         S15         S16

SCATTERGRAM OF      (DOWN)  VAR003     CHLORIDES
                  (ACROSS)  VAR006     TDS
```

Figure 41 - Scattergram, Chlorides VS TDS Group III Data



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CANADIAN RIVER NR LOGAN,NM                                                    84/09/23.    16.52.12.    PAGE   89
SCATTERGRAM-PIEZOMETERS,REVUELTO CR AND CANAD. R BELOW REV CR
FILE    NONAME    (CREATION DATE =  84/09/23.)
SUBFILE   S11          S12          S14          S15          S16

SCATTERGRAM OF       (DOWN)  VAR005    FIELD CONDUCTANCE
                    (ACROSS) VAR006    TDS
```
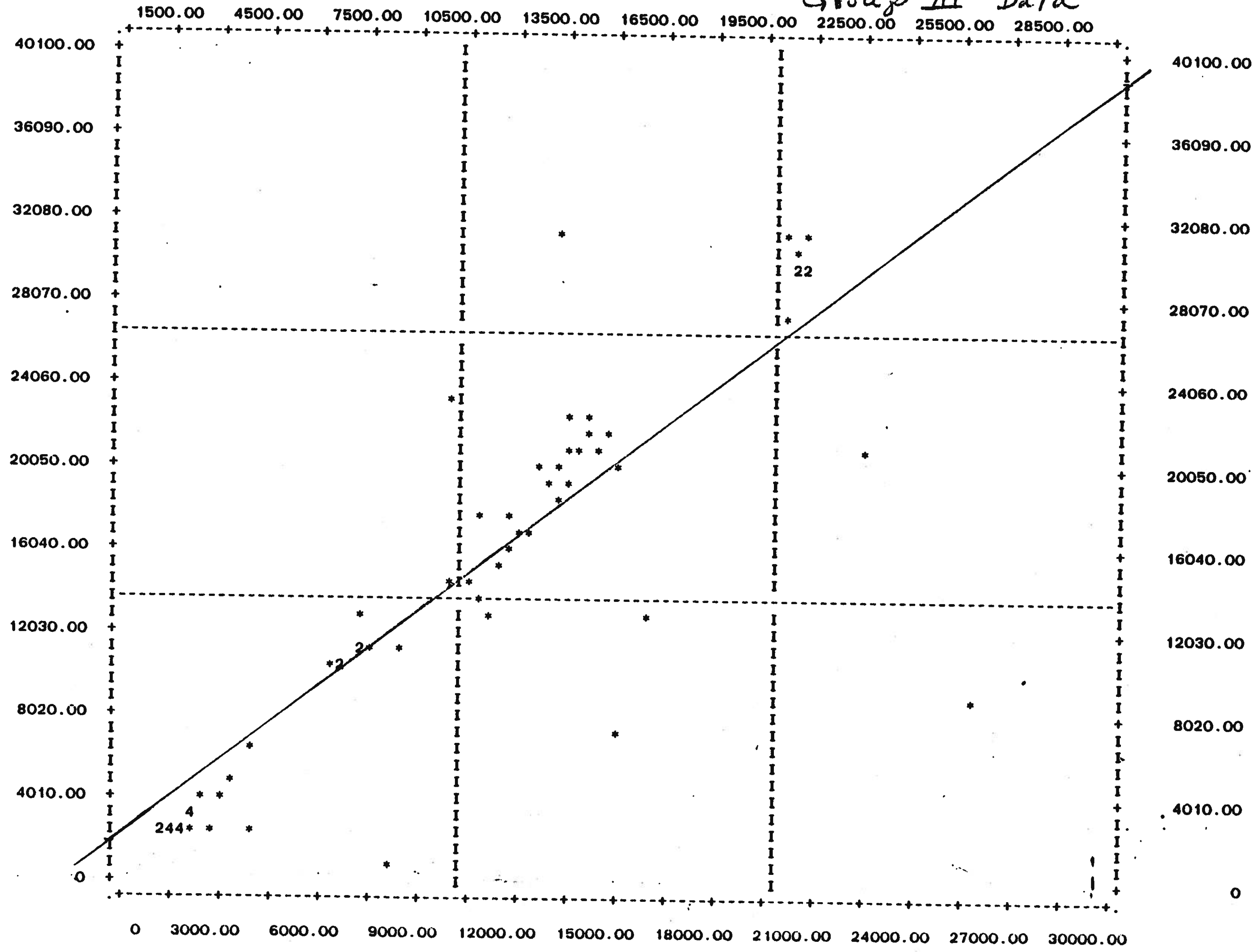

Figure 42 - Scattergram, Field Conductance VS TDS
Group III Data



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COMPUTATION SHEET

BY | DATE | PROJECT | SHEET ____ OF ____
CHKD BY | DATE | FEATURE Table 4 - Water Quality Analyses
DETAILS

SITE 1 - RIVER Mi. 6

DATE	Na		Mg		Ca		K		Cl		SO4		HCO3	
5-13-83	2024	88.04												
5-23									2320	656				
6-7	1984	86.30	53.4	4.39	131.3	6.55	10.2	.26	2880	81.24	830	17.30	396.5	6.5
6-22									2750	77.58				
7-7									1000	28.21				
7-26	1604	69.77	31.2	2.57	80	3.99	6.80	.17	1128	31.82	1120	23.32	304.8	4.99
8-24									3000	84.63				
9-28									~~4500~~ 3350	94.5				
10-26									2950	83.22				
11-21	2172	94.48	84.8	6.97	136	6.78	12.0	.30	2684	95.71	745	15.0	406.26	6.66
12-13									3100	87.45				
									3100	87.45				
1-19-84														
2-15	2304	100.2	95.2	7.83	128	6.35	9.24	.24	2740	77.3	387.6	8.07	431.9	7.08
3-14									4100	115.6				
4-18									3000	84.63				
5/16	2186	95.09	72.0	5.92	148	7.39	14.6	.37	3560	100.43	475	9.89	427.0	7.0
6-8									3500	98.7				
7-19									3000	84.6				
8-14	2281	99.2	5.76	0.47	122.4	6.11	12.0	0.31	3696	104.2	587.5	12.23	378.2	6.2
									~~5000~~ 3680	~~141.0~~ 103.8				
	mg/l	meq/l												
MIN.	1604	69.77	53.4	4.39	80	3.99	6.8	.17	1000	28.2	387.6	8.07	304.8	4.99
MAX.	2304	100.2	95.2	7.8	148	7.39	14.6	.37	4100	115.6	1120	23.3	431.9	7.08
TOTAL MEAN	2079	90.4	57.	4.7	124	6.2	10.8	.28	2923	82.	691	14.4	391	6.4
STD. DEV.	241								780	22	267			
MEAN OF COMPLETES		91		4.7		6.2		.28		78.4		14.4		6.4

Note: All means & ranges were determined with corrected values.

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COMPUTATION SHEET

BY
DATE
PROJECT
SHEET ____ OF ____
CHKD BY
DATE
FEATURE Table 4 (continued)
DETAILS site 1 RIVER

DATE	CO3		TDS	Lab PH	LAB COND.	FIELD COND. @25°C	FIELD H2O T°C	flow (cfs)
5-13-83	—		5828 mg/l	—	— μmhos	9500 μmhos	—	—
5-23	0		5438	8.06	—	10700	— - - -	2.0
6-7			5634	7.84	9500	9500	21	1.6
6-22			2354	8.16	4500	4400	30	6.2
7-7	.6	.02	2500	8.33	4250	4250	29	5.1
7-26			5623	7.85	9000	9500	29	1.6
8-24			5775	7.92	9000	10490	32	1.4
9-28			5857	7.78	9000	9500	26	1.4
c 10-26	0		5643	7.97	8840	9400	19.0	1.6
11-21			6201	7.7	9400	10100	13	1.5
12-13			6222	7.99	11000	10000	8.9	1.4
c 1-19-84	0		5396	7.97	9050	11800	0	1.9
2-15			8000	7.76	11950	13800	10	1.5
3-14			5722	7.93	8500	9200	17	2.0
c 4-18	0		6711	8.13	11080	10780	22	1.6
5-16			5947	7.79	10240	10,000	20	1.7
6-8			5286	7.86	10088	9328	27	1.0
c 7-19	0		6411	8.03	10700	12160	29.0	1.2
8-14			6098	7.72	11540	11348	30.0	1.2
	mg/l	meq/l						

MIN	0		2500	7.70	4250	4250	0.0	1.2
MAX	.6	.02	8000	8.33	11950	13800	32	6.2
TLT MEAN	.10	.003	5613	7.93	9273	9777	21.4	2.0
STD. DEV	-		1275	.17		2254		
Mean of completes		.003	5349	8.17		9848	19.8	2.2

7-1654 (7-73)
Bureau of Reclamation

COMPUTATION SHEET

BY | DATE | PROJECT | SHEET ____ OF ____
CHKD BY | DATE | FEATURE Table 5 - Water quality Analyses..
DETAILS RAH-1B SITE 1 - 16 Piezometer

DATE	mg/l	Na	mg/l	Mg		Co		K		Cl		SO4		HCO3
5-13-83	5600	244								7720	218			
5-23	5920	258	128.2	10.55	357.2	17.83	21.1	.54	6920	195.2	350	7.29	467.2	7.66
6-7									8350	235.5				
6-22									9000	253.89				
7-7	6840	297.54	134.4	11.06	308	15.37	21.4	.55	8880	250.5	352	7.33	487.96	8.00
7-26									9000	253.89				
8-24									9500	268				
9-28									8400	236.96				
10-26	5320	231.42	228.8	18.82	336	16.76	23.7	.60	8360	235.83	950	19.77	529.48	8.68
11-21									8250	232.73				
12-13									8250	232.73				
1-19-84	6220	270.57	200	16.45	324	16.17	21.9	.56	8160	230.19	825	17.18	536.8	8.80
2-15									8100	228.5				
3-14									9500	268				
4-16	5249	228.3	254.4	20.93	380	18.96	23.6	.60	8360	235.84	885	18.43	523.38	8.58
5-16									8500	239.7				
6-8									8500	239.7				
7-19	5417	235.6	226	1.8	325.6	16.2	18.4	.47	8880	250.5	950	19.7	453.84	7.44
8-14									8209 ~~10500~~	231.2				
MIN	5249	228.3	134.4	11.06	308	15.4	18.4	.47	6920	195.2	350	7.29	453.84	7.44
MAX	6840	297.5	254.4	20.9	380	18.9	23.7	.60	9500	268	950	19.7	536.8	8.80
TLT MEAN	5795	252.2	1.95.3	16	338	17	22	.55	8465	238.7	719	15	500	8.2
STD DEV									598	16.9	289			
mean of Completes		254		16		17		.55		233		15		8.2

Note: all means and ranges were determined with corrected values

7-1654 (7-73)
Bureau of Reclamation

COMPUTATION SHEET

BY

DATE

PROJECT

SHEET ____ OF ____

CHKD BY

DATE

FEATURE Table 5 (continued)

DETAILS site 1-16'

DATE	CO3	TDS	LAB pH	LAB COND.	FIELD COND. @ 25°C	WATER TEMP °C
5-13-83	–	16252 mg/l	–	–	19000 μmhos	–
5-23	0	16072	7.92	–	22500	–
6-7	–	15849	7.71	24000	24500	18
6-22	–	15665	7.70	24900	25000	15
7-7	0	16942	8.01	25500	25500	16
7-26	–	15949	7.74	23800	26000	17
8-24	–	15867	7.57	22800	26000	17
9-28	–	15408	7.54	22100	25000	17
10-26	0	16123	7.70	24700	24.000	16
11-21	–	15440	7.54	22500	24000	15
12-13	–	15216	7.50	22250	~~31000~~?	15.6
1-19-84	0	15034	8.01	23700	21500	15
2-15	–	14980	7.60	21000	23400	14
3-14	–	15439	7.42	21500	22000	15
4-18	0	14801	7.99	24700	24880	14
5-16		15123	7.64	13 23700	22080	16
6-8		15030	7.63	~~37600~~	22400	17
7-19	0	16,477	7.66	21,400	21,640	17
8-14		14457	7.51	22200	21084	17
MIN	0	14457	7.42	21000	19000	14.0
MAX	0	16942	8.01	25500	~~31000~~ 26000	18.0
TOTAL MEAN	0	15585	7.6	24021.	23360	16
STD. DEV.		632	.19		1942	
	mg/l	mg/l				
MEAN OF COMPLETES		15908	7.9		23337	16

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Bureau of Reclamation

COMPUTATION SHEET

BY	DATE	PROJECT	SHEET ____ OF ____
CHKD BY	DATE	FEATURE Table 6 – Water Quality Analyses	
DETAILS RAH - 1A SITE 1 - 22' Piezometer			

DATE	Na		Mg		Ca		K		Cl		SO4		HCO3	
5-13-83	5440 mg/l	237 meq/l	—		—		—		6600	186.2				
5-23	6160	268	126.3	10.39	341.2	17.03	19.6	.50	6720	191	830	17.3	634.4	10.4
6-7									7950	224.27				
6-22									9000	253.8				
7-7									7800	222.29				
→ 7-26 →	5800	252.3	122.4	10.07	280	13.97	18.4	.47	9000	253.8	760	15.82	363.56	5.96
8-24									8500	239.7				
9-28									6400	180.54				
10-26	4920	214.02	188.8	15.53	297.6	14.85	19.6	.50	6160	173.77	855	17.80	497.76	8.16
11-21									6200	174.9				
12-13									6700	189.01				
1-19-84	5400	234.9	182.4	15.0	283.2	14.13	18.6	.48	6600	186.17	787.6	16.4	523.3	8.58
2-15									7200	203.11				
3-14									8500	239.79				
4-18	4639	201.8	100.8	8.29	352	17.56	21.9	.56	8760	247.12	795	16.55	509.96	8.36
5-16									8000	225.6				
6-8									7500	211.5				
7-19	4862	211.5	152.6	12.5	304	15.1	16.6	.42	9120	257.2	812.5	16.9	469.7	7.70
8-14									8500	239				

	mg/l	meq/l												
MIN	4639	201.8	100.8	8.29	280	13.9	18.4	.47	6160	173.7	760	15.8	363.56	5.96
MAY	6160	268	188.8	15.5	352	17.5	21.9	.56	9120	257.2	855	17.8	634.4	10.4
TLT MEAN	5317	231	146	12	310	15.4	19	.49	7643	216	807	17	500	8.2
STD. DEV									1041	29.3	33.4			
Mean of Completes		230		12		15.4		.49		213		17		8.2

Note: all means and ranges were determined with corrected values.

7-1654 (7-73)
Bureau of Reclamation

COMPUTATION SHEET

BY	DATE	PROJECT	SHEET ____ OF ____
CHKD BY	DATE	FEATURE Table 6 (continued)	
DETAILS			

Site 1-22'

DATE	CO3	TDS	LAB pH	LAB COND.	FIELD COND. @ 25°C	FIELD H2O TEMP - °C
5-13-83	—	14502 mg/l	—	— μmhos	22500 μmhos	—
5-23	0	15737	7.82	—	24500	—
6-7	—	14738	7.60	23000	22000	15
6-22	—	15029	7.73	23250	23000	15
7-7	0	14948	8.0	21500	21500	16
7-26	–	15248	7.63	22900	25000	16
8-24	–	13411	7.58	19800	21000	17
9-28	–	12025	7.62	16500	19500 18900 calc.	17
10-26	0	12534	7.65	17300	20,000	16
11-21	–	11920	7.52	17000	17200	15
12-13	–	12412	7.70	19000	18000	15.6
1-19-84	0	12150	7.92	19500	17900	15
2-15	–	14131	7.64	19510	20000	15
3-14	–	14923	7.62	20000	20900	15
4-18	0	12897	7.95	22200	20680	15
5-16		13439	7.63	20950	20800	16
6-8		12723	7.62	20000	18348	15
7-19	0	14135	7.84	22,000	20400	17
8-14		12824	7.60	21160	18420	17
MIN	0	11920	7.52	16500	17200	15
MAX	0	15737	8.0	23250	25000	17
TOTAL MEAN	0	13670	7.70	20328	20613	16
STD. DEV		1233	.14		2164	
	mg/l meq/l					
MEAN OF COMPLETES		13734	7.8		20830	16

7-1654 (7-73)
Bureau of Reclamation

COMPUTATION SHEET

BY	DATE	PROJECT	SHEET ____ OF ____
CHKD BY	DATE	FEATURE Table 7 Water Quality Analyses	
DETAILS			

SITE 2 RIVER - Mi 2.2

DATE	Na		Mg		Ca		K		Cl		SO4		HCO3	
	mg/l	meq/l												
5-13-83	1968	86.0	—		—		—		2516	71.0	—		—	
5-23	2120	92.2	53.4	4.40	134.5	6.71	10.6	.27	2990	84.3	375	7.81	381.86	6.26
6-7									2850	80.4				
6-22									1000	16.93				
7-7	1440	62.64	33.6	2.76	68	3.39	6.62	.17	1004	28.32	278	5.79	291.6	4.78
7-26									2500	70.53				
8-24									.3500	98.74				
9-28									.3250	91.68				
10-26	2290	99.61	105.6	8.68	136	6.78	12.5	.31	.2616	73.79	450	9.37	413.58	6.78
11-21									.3200	90.27				
12-13									.3250	91.68				
1-19-84	2276	99.0	100.8	8.29	128	6.39	10.5	.27	2700	76.17	450	9.37	435.54	7.14
2-15									4800	135.41				
3-14									3000	84.63				
4-18	2242	97.53	79.2	6.51	148	7.39	14.8	.38	3420	96.48	450	9.37	422.12	6.92
5-16									4000	112.8				
6-8									2500	70.5				
7-19	2308	100.4	187.7	15.4	123.2	6.15	12.3	.31	3928	110.8	500	10.4	373.32	6.12
8-14									~~5500~~ 3400	95.9				
MIN	1440	62.6	33.6	2.76	68	3.39	6.62	.17	1000	16.93	278	5.79	291.6	4.78
MAX	2308	100.4	187.7	15.4	148	7.39	14.8	.38	4800	135.4	500	10.4	435.54	7.14
TOTAL MEAN	2092	91	93.4	7.7	123.0	6.14	11.2	.29	2970	83.8	417	8.7	386	6.3
STD. DEV									907	25.6				
MEAN OF COMPLETES	2113	91.9	93.4	7.7	123.0	6.14	11.2	.29	2777	79.31	417	8.7	386	6.3

Note: all means and ranges were determined with corrected values.

7-1654 (7-73)
Bureau of Reclamation

COMPUTATION SHEET

BY	DATE	PROJECT	SHEET ____ OF ____
CHKD BY	DATE	FEATURE Table 7 continued	
DETAILS			

2 RIVER

DATE	CO_3		TDS	LAB pH	LAB COND	FIELD COND. @ 25°C	Wat Temp °C	FLOW (cfs)
5-13-83	—		5683 mg/l	—	— µmhos	15000 µmhos	—	—
c 5-23	1.8	.06	5699	8.37	—	9900	—	- +.45
6-7	—		5840	7.85	9250	10000	24	2.0
6-22	—		2422	8.24	4400	4500	30	5.9
c 7-7	1.2	.04	2275	8.33	4500	4500	30.5	6.1
7-26	—		5798	7.94	9500	10000	30	1.1
8-24	—		6110	8.0	9000	10880	32	1.6
9-23	—		6354	7.88	9100	10500	24	1.8
c 10-26	0		5848	8.0	9180	9500	18.0	1.9
11-21	—		6400	7.75	10000	10200	14	2.1
12-13	—		6365	8.06	10000	12500	33	2.0
c 1-19-84	0		5175	8.01	8850	9600	2.0	1.9
2-15	—		9176	7.72	13700	14500	10	1.3
3-14	—		5987	7.90	9400	9600	17.5	1.4
c 4-18	0		7275	8.03	11510	10896	22	1.5
5-16			6395	7.83	10368	10 672	16	1.7
6-8			~~10760~~ 6200	7.91	8656	9798	28	1.0
c 7-19	0		6, 648	7.96	11,300	12484	33.0	.9
8-14			6332	7.81	11980	11820	30	1.3
MIN	0	0.	2275	7.72	4400	4500	2,0	.9
MAX	1.8	.06	9176	8.37	13,700	14500	33.0	6.1
TLT MEAN	.5	.02	5894	7.98	9,453	10361	21.4	2.0
STD. DEV			1496	.18		2603		
MEAN OF COMPLETES			5487	8.1		9480	21	2.3
	mg/l	mg/l						

7-1654 (7-73)
Bureau of Reclamation

COMPUTATION SHEET

BY
DATE
PROJECT
SHEET ____ OF ____
CHKD BY
DATE
FEATURE Table 8 - Water Quality Analyses
DETAILS RAH -2C SITE 2 - 22' Piezometer

DATE	Na		Mg		Ca		K		Cl		SO4		HCO3	
5-13-83	5080	221	—		—		—		5720	161.4	—		—	
5-23	5600	244	147.7	12.15	365.2	18.22	10.6	.27	6600	186.2	925	19.3	559.6	9.17
6-7									8300	234.14				
6-22									9500	268				
7-7	6080	264.48	165.6	13.62	336	16.77	20.4	.52	8480	239.2	790	16.45	352.6	5,78
7-26									9000	253.89				
8-24									9000	253.89				
9-28									8550	241.2				
10-26	7800	339.3	260.8	21.45	352	7.56	18.2	.46	6680	188.4	1025	21.31	428.22	7.02
11-21									8250	232.73				
12-13									8000	225.68				
1-19-84	6220	271.0	238.4	19.61	337.6	16.85	19.9	.51	7720	217.78	995	20.72	341.6	5.60
2-15									7600	214.4				
3-14									8000	225.68				
4-18	5029	218.76	132	10.86	368	18.36	22.6	.58	7800	220.04	855	17.8	470.92	7,72
5-16									8000	225.6				
6-8									8000	225.6				
7-19	4869	211.8	162.2	13.3	276.8	13.8	13.9	.36	9240	260.6	787.5	16.4	425.78	6,98
8-14									9000	253.8				
MIN	5029	218.76	132	10.86	336	13.8	10.6	.27	5720	161.4	790	16.4	341.6	5,60
MAX	7800	339.3	260,8	21.45	368	18.36	22.6	.58	9500	268	102.5	21.31	559.6	9,17
TOTAL MEAN	5811	253	184.	15.0	340	17	18	.45	8076	228	896	19	430	7.0
STD DEV									959	27	102			

mg/l meq/l

	Na		Mg		Ca		K		Cl		SO4		HCO3	
MEAN OF COMPLETES		258		15.0		17		.45		218		19	430	7.0

Note: all means and ranges were determined with corrected values.

7-1654 (7-73)
Bureau of Reclamation

COMPUTATION SHEET

BY	DATE	PROJECT	SHEET ____ OF ____
CHKD BY	DATE	FEATURE Table 8 (continued)	
DETAILS			

Site 2-22'

DATE		CO3	TDS	LAB PH	LAB COND	FIELD COND @ 25°C	FIELD H2O TEMP - °C
5-13-83		—	13902 mg/l	—	— µmhos	21000 µmhos	—
5-23	0		15779	7.83	—	24000	—
6-7		—	15677	7.65	23000	24900	15
6-22		—	15629	7.66	24000	24500	15
7-7	0		16573	7.91	24000	24000	15
7-26		—	15640	7.64	23000	26000	15
8-24		—	15706	7.53	22800	25000	15
9-28		—	15855	7.64	21800	24500	15
10-26	0		17124	7.94	24200	24000	15
11-21		—	15357	7.63	21500	23500	15
12-13		—	14969	7.63	22100	22100	14.4
		—					
1-19-84	0		14892	8.12	23000	21250	14
2-15		—	14786	7.64	20100	21500	15
3-14		—	14778	7.50	20200	21000	17
4-18			~~17224~~ 15300	7.90	24000	23400	14.75
5-16	0		14532	7.56	21720	21000	17
6-8			14619	7.49	22440	19948	17
7-19	0		14,669	7.79	22500	20760	12
8-14			14156	7.48	21480	21080	16
MIN	0		13902	7.63	20,100	21000	14
MAX	0		16573	8.12	24200	26000	17
TOTAL MEAN			15260	7.7	22461	22813	15.1
STD. DEV			800	.18		1826	1.2
	mg/l		mg/l				
MEAN OF COMPLETES			16043	7.9		22902	14.6

7-1654 (7-73)
Bureau of Reclamation

COMPUTATION SHEET

BY
DATE
PROJECT
SHEET ____ OF ____
CHKD BY
DATE
FEATURE Table 9 - Water Quality Analyses
DETAILS RAH-2B SITE 2- 4d Piezometer

DATE	Na		Mg		Ca		K		Cl		SO4		HCO3	
5-13-83	5480	238.4	-		-		-		6960	196.3	-		-	
5-23	5920	257.52	144.8	11.91	418.1	21	23.2	.60	7360	208.0	980	20.4	461.1	7.56
6-7									8600	242.61				
6-22									10,000	282.1				
7-7	5920	257.52	183.6	15.1	342	17.07	20.7	.53	8160	230.19	910	18.95	336.7	4.52
7-26									9000	253.89				
8-24									9500	268				
9-28									8150	229.9				
10-26	6400	278.4	267.2	21.97	377.6	18.84	19.5	.50	7200	203.11	1005	20.92	448.96	7.36
11-21									8400	236.96				
12-13									8500	239.79				
1-19-84	6680	290.58	256	21.06	377.6	18.84	21.2	.54	8680	244.86	1025	21.34	307.44	5.04
2-15									8350	235.5				
3-14									9000	253.89				
4-18	5277	229.5	141.6	11.65	400	19.96	22.6	.58	7960	224.5	1045	21.76	463.6	7.60
5-16									9500	268				
6-8									7500	211.5				
7-19	5223	227.2	150.7	12.4	337.6	16.8	19.1	.49	9120	257.2	1112.5	23.16	416.02	6.82
8-14									8599 ~~11000~~	240				
MIN	5223	227.2	141.6	11.6	337.6	16.8	19.1	.49	6960	196.3	910	18.95	307.44	5.04
MAX	6680	290.5	267.2	21.97	418.1	21.0	23.2	.60	10,000	310.3	1112.5	23	463.6	7.6
TOTAL MEAN	5843	254	191	15.7	382	19	21	.54	8444	238	1013	21	406	6.7
STD. DEV.									818	23	68			

	mg/l	meq/l												
MEAN OF COMPLETES		257		15.7		19		.54		228		21		6.7

Note: All means and ranges were determined with corrected values.

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Bureau of Reclamation

COMPUTATION SHEET

BY	DATE	PROJECT	SHEET ____ OF ____
CHKD BY	DATE	FEATURE Table 9 (continued)	
DETAILS site 2-40'			

DATE	CO3	TDS	LAB pH	LAB COND	FIELD COND @ 25°C	FIELD H2O TEMP - °C
5-13-83	—	15409 mg/l	—	—	23000 µmhos	—
5-23	0	16838	7.89	—	26000	—
6-7	—	16369	7.54	24500	25500	15
6-22	—	16159	7.84	24000	25000	15
7-7	0	17133	7.88	24500	24500	15
7-26	—	16096	7.74	23800	~~36000~~	15
8-24	—	16279	7.51	23600	26000	15
9-28	—	16181	7.60	21700	24500	15
10-26	0	16391	8.00	24700	24000	15
11-21	—	15903	7.59	22100	23500	15
12-13	—	15728	7.32	23100	23000	15.6
1-19-84	— 0	15920	8.06	22000	22200	16
2-15	—	15719	7.58	21600	22500	16
3-14	—	15701	7.46	21400	22000	17
4-18	0	15596	8.0	25200	24400	15
5-16		15219	7.49	22600	21760	16
6-8		15036	7.39	22120	21040	15
7-19	0	15011	8.04	21400	21440	16
8-14		14881	7.6	26040	22160	16
MIN	0	14881	7.32	21400	21040	15
MAX	0	17133	8.06	26040	~~36000~~ 26000	17
TOTAL MEAN		15872	7.7	23198	23395	15.4
STD. DEV.		608	.31		1571	

mg/l mg/l

MEAN OF COMPLETES		16148	7.98		23757	15.4

7-1654 (7-73)
Bureau of Reclamation

COMPUTATION SHEET

BY
DATE
PROJECT
SHEET ____ OF ____
CHKD BY
DATE
FEATURE Table 10 Water Quality Analyses
DETAILS RAH - 2A SITE 2 - 55' Piezometer

DATE	Na		Mg		Ca		K		Cl		SO4		HCO3	
5-13-83	5040	219.2	—		—		—		5920	167.0	—		—	
5-23	5200	226.2	164.24	13.51	352.4	17.59	19.3	.49	6600	186.19	1045	21.76	457.5	7.49
6-7									8000	225.6				
6-22									9500	268				
7-7	5480	238.3	176.4	14.51	302	15.07	19.7	.50	8160	230.19	940	19.57	339.2	5.56
7-26									9000	253.89				
8-24									9000	253.89				
9-28									8300	234.14				
10-26	6160	267.96	259.2	21.32	361.6	18.04	17.4	.44	7180	202.5	962.5	20.04	411.14	6.74
11-21									8200	231.32				
12-13									8150	229.91				
1-19-84	7600	330.6	264	21.72	344	17.17	22.5	.58	7960	224.5	865	18.01	412.36	6.76
2-15									7900	22289				
3-14									8000	225.68				
4-18	4872	211.93	144	11.85	372	18.56	23.8	.61	7440	209.8	990	20.61	445.3	7,30
5-16									8500	239.7				
6-8									8500	239.7				
7-19	4949	215.2	158.4	13.0	315.2	15.7	18.9	.48	8880	250.5	1450	30.19	419.68	6.88
8-14									7700 ~~10,000~~	217				
MIN	4872	211.9	144	11.8	302	15.07	17.4	.44	5920	167	865	18.01	339.2	5.56
MAX	7600	330.6	158	13.0	372	18.56	23.8	.61	9500	268	1450	30.1	457.2	7.49
TOTAL MEAN	5614	244	194	16	341	17	20	.52	8047	227	1042	22	414	6.8
STD. DEV.									851	24	208			

	mg/l	meq/l												
MEAN OF COMPLETES		248		16		17		.52		210		22		6.8

7-1654 (7-73)
Bureau of Reclamation

COMPUTATION SHEET

BY
DATE
PROJECT
SHEET ____ OF ____
CHKD BY
DATE
FEATURE Table 10 (continued)
DETAILS site 2-55'

DATE	CO_3	TDS	LAB pH	LAB COND.	FIELD COND @ 25°C	FIELD H_2O TEMP — °C
5-13-83	—	14296 μmhos	—	— μmhos	21000 mg/l	—
5-23	0	15416	7.96	—	24005	—
6-7	—	14838	7.53	22100	23.000	15
6-22	—	15273	7.84	23000	23500	15
7-7	0	15832	7.85	22500	22500	16
7-26	—	15074	7.69	21900	25000	15
8-24	—	14946	7.54	22200	24000	16
9-28	—	15458	7.48	21000	24000	15
10-26	0	15947	8.05	23900	23500	15
11-21	—	15053	7.48	22000	23000	15
12-13	—	14992	7.28	22000	21,200	15.6
	—					
1-19-84	0	15123	7.95	21700	20900	15
2-15	—	14857	7.47	20200	23000	15
3-14	—	14843	7.38	20000	21100	16
4-18	0	14857	7.78	24100	23.000	16
5-16		14419	7.39	21680	21200	16
6-8		14398	7.62	22200	20044	15
7-19	0	14172	7.98	22600	20560	16
8-14		14249	7.59	21420	20296	16
MIN	0	14172	7.28	21000	20044	15
MAX	0	15947	8.05	24100	25000	16
TOTAL MEANS	0	14950	7.6	22029	22358	15.4
STD. DEV.		503	.24		1499	
MEANS OF COMPLETES	mg/l mg/l	15224	7.9		22410	15.6

7-1654 (7-73)
Bureau of Reclamation

COMPUTATION SHEET

Table 11

BY	DATE	PROJECT	SHEET ____ OF ____
CHKD BY	DATE	FEATURE Table 11 Water Quality Analyses	
DETAILS		SITE 3 - RIVER Mi 5.4	

DATE	Na		Mg		Ca		K		Cl		SO4		HCO3	
5-13-83	4240	184.4							4600	130.0				
5-23	3898	169.5	82.6	6.79	171.4	8.55	16.2	.41	4400	124.12	610	12.7	397.7	6.52
6-7									5550	156.5				
6-22									2500	70.5				
7-7	1752	76.2	48	3.95	88	4.36	8.90	.23	1976	55.7	388	8.08	305.0	5.0
7-26									6000	169.2				
8-24									6000	169.2				
9-28									6000	169.2				
10-26	5040	219.2	203.2	16.7	203.2	10.14	18.6	.48	5320	150.08	2150	44.76	462.38	7.58
11-21									6750	190.4				
12-13									6550	184.78				
1-19-84	4052	176.2	147.2	12.11	206.4	10.3	14.6	.37	4860	137.1	590	12.3	373.3	6.12
2-15									7800	220.0				
3-14									6500	183.37				
4-18	4229	183.96	98.4	8.09	236	11.78	22.4	.57	6560	185.06	895	18.63	483.92	7.92
5-16									6500	183				
6-8									5500	155.1				
7-19	5213	226.7	123.8	10.18	225.6	11.26	20.8	.53	8280	233.5	1150	23.9	434.32	7.12
8-14									7200	203				
MIN	1752	76.2	48	3.95	88	4.39	8.9	.23	1976	55.7	388	8.08	305.0	5.0
MAX	5213	226.7	203.2	16.72	236	11.78	22.4	.57	7800	220	2150	44.76	483.92	7.92
TOTAL MEAN	4061	177	117	9.6	188	9.4	16.9	.45	5728	161.6	964	20	409	6.7
STD. DEV.									1633	46	639			
	mg/l	meq/l												
MEAN OF COMPLETES		175		9.6		9.4		.45		148		20.		6.7

Note: All means and ranges were determined with corrected values.

7-1654 (7-73)
Bureau of Reclamation

COMPUTATION SHEET

BY
DATE
PROJECT
SHEET ____ OF ____
CHKD BY
DATE
FEATURE Table 11 (Cont.)
DETAILS
3- RIVER

DATE	CO_3	TDS	LAB pH	LAB COND	FIELD COND. @25°C	FIELD H_2O TEMP - °C	FLOW (cfs)
5-13-83	—	5674 mg/l	—	— μmhos	7500 μmhos	—	—
5-23	0	10799	8.09	—	20800	—	2.8
6-7	—	10420	7.77	16150	17000	23	3.1
6-22	—	1630	8.19	8250	7100	29	6.6
7-7	0	4109	8.20	6500	6500	25	5.8
7-26	—	~~2681~~ 10,400	7.90	15800	16,250	26	2.4
8-24	—	10740	7.98	16500	17,000	28	1.8
9-28	—	11570	7.81	17000	19000	18	1.5
10-26	0	~~3146~~ 10600	8.14	18300	18800	15	2.3
11-21	—	12665	7.65	18500	20.000	11	2.7
12-13	—	12324	7.82	18000	19500	5.5	2.2
1-19-84	0	9299	8.25	15000	18,000	0	4.2
2-15	—	14652	7.65	20900	22 900	5	2.2
3-14	—	11336	7.82	16100	17500	14	2.3
4-18	0.	12111	7.98	20400	19526	16	2.2
5-16		11895	7.82	18784	18520	17	2.8
6-8		10385	7.91	15836	16168	21	2.4
7-19	0	14294	7.94	20500	22760	25	2.0
8-14		13275	7.74	21340	21640	26	4.5
MIN	0	4109	7.65	6500	6500	0	1.5
MAX	0	14652	8.25	20900	22,900	29	4.5
TOTAL MEAN	0	10430	7.9	16698	17182	17.9	3.0
STD. DEV.		3317	.19		4919		
MEAN OF COMPLETES	mg/l meq/l	10202	8.1		17,731	16.2	3.2

7-1654 (7-73)
Bureau of Reclamation

COMPUTATION SHEET

BY	DATE	PROJECT	SHEET ____ OF ____
CHKD BY	DATE	FEATURE Table 12 Water Quality Analyses	
DETAILS			

RAH-3B SITE 3 - 20' Piezometer

DATE	Na		Mg		Ca		K		Cl		SO4		HCO3	
5-13-83	4080	177.4							4600	130				
5-23	5920	257.5	172	14.15	237	11.83	23.6	.60	6840	192.96	1375	28.63	422.61	6.93
6-7									8200	231.3				
6-22									9500	268				
7-7	6000	261	165.6	13.62	208	10.38	23.1	.59	8480	239.2	1325	27.59	429.4	7.04
7-26									9000	253.89				
8-24									7500	211.58				
9-28									5900	166.4				
10-26	4600	200.1	121.6	10	112	5.59	16.7	.43	4920	138.7	800	16.66	412.36	6.76
11-21									6250	176.31				
12-13									6500	183.37				
1-19-83	5660	246.2	166.4	13.69	188.8	9.44	20.4	.52	5940	167.5	715	14.89	307.44	5.04
2-13									6100	172.08				
3-14									6200	174.9				
4-18	4112	178.8	200.6	16.15	204	10.18	24.7	.63	8360	235.8	860	17.93	444.1	7.28
5-16									7500	211.5				
6-8									6500	183.3				
7-19	4213	183.2	109	8.97	200	9.98	17.1	.44	7040	198.6	987.3	20.5	464.82	7.62
8-14									6640 ~~9500~~	~~268~~ 187.3				
MIN	4080	177.4	109	8.9	112	5.59	16.7	.43	4600	130	715	14.89	307.44	5.04
MAX	6000	261	200.6	16.1	237	11.83	24.7	.63	9500	268	1375	28.63	464.82	7.62
TOTAL MEAN	4941	215	156	12.8	192	9.6	21	.54	6946	196	1010	21	413	6.8
STD. DEV.									1318	37	278			
	mg/l	meq/l												
MEAN OF COMPLETES		221		12.8		9.6		.54		195		21		6.8

Note: All means and ranges were determined with corrected values

7-1654 (7-73)
Bureau of Reclamation

COMPUTATION SHEET

BY	DATE	PROJECT	SHEET ____ OF ____
CHKD BY	DATE	FEATURE Table 12 (continued)	
DETAILS		3-20'	

DATE	CO₂		TDS	LAB pH	LAB COND.	FIELD COND. @ 25°C	FIELD H2O TEMP- °C
5-13-83		—	13415 mg/l	—	— µMhos	20,000 µMhos	—
5-23	7.98	.27	16,348	8.46	—	26000	—
6-7		—	16191	7.76	25000	24200	14
6-22		—	~~6029~~ calc 16250	8.08	25500	24000	14
7-7	0		16414	8.06	20000	20.000	14
7-26		—	~~4343~~ calc 16300	7.95	22900	25000	15
8-24		—	14377	7.73	21500	23100	15
9-28		—	11183	7.86	15200	18500	16
10-26	0		10714	8.18	16100	17000	18
11-21		—	11889	7.76	17000	18800	17
12-13		—	12198	7.73	18000	16400	18.9
1-19-84	0	—	11937	8.29	18700	17250	16
2-15		—	11610	7.83	16600	17500	15
3-14		—	11773	7.73	17100	17900	15
4-18	0		11926	8.02	20100	19568	13
5-16			12050	7.81	18368	19124	13
6-8			11992	7.71	18388	19280	14
7-19	0		12764	7.89	18800	16124	15
8-14			12029	7.81	18798	17152	15
MIN	0		10714	7.73	15200	16400	13
MAX	7.98	.27	16 414	8.46	25500	25 000	18.9
TOTAL MEAN	1.3	.05	13229	7.93	19297	19837	15.2
STD. DEV.			2036	.22		3093	
	mg/l	meq/l					
MEAN OF COMPLETES		.05	13350	8.15		19324	15.2

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Bureau of Reclamation

COMPUTATION SHEET

BY	DATE	PROJECT	SHEET ____ OF ____
CHKD BY	DATE	FEATURE Table 13 Water Quality Analyses	
DETAILS RAH-3A SITE 3 - 34' Piezometer			

DATE	Na		Mg		Ca		K		Cl		SO4		HCO3	
5-13-83	5720	249	—		—		—		~~6960~~	~~196.34~~	—		—	
5-23	8360	363.6	205	16.87	438.9	21.9	31.0	.79	10720	302.4	1720	35.81	580.7	9.51
6-7									13550	382.25				
6-22									14500	409.05				
7-7	9880	429.78	252	20.73	392	19.56	30.8	.79	14240	401.71	1540	32.06	451.4	7.4
7-26									15000	423.15				
8-24									15500	437.26				
9-28									13250	373.7				
10-26	6560	285.3	388	31.92	436.8	21.80	35.8	.92	11880	335.13	1125	23.42	585.6	9.60
11-21									13250	373.78				
12-13									13150	370.96				
1-19-84	10280	447.18	382.4	31.46	448	22.36	36.6	.94	13120	370.12	1525	31.75	594.14	9.74
2-15									13250	373.78				
3-14									12800	361.09				
4-18	8333	362.49	232.4	19.15	428	21.36	32.0	.82	11880	335.13	1435	29.8	553.88	9.08
5-16									~~8500~~ 12100 calc	~~279.7~~ 341				
6-8									13500	~~380.8~~				
7-19	8550	371.9	220	18.10	400	19.9	26	.66	12320	347.5	1875	39.04	485.56	7.96
8-14									NSD ~~16500~~	~~465.4~~ 333				
MIN	5720	249	205	16.87	392	19.5	30.8	.79	11880	335	1125	23.4	451.4	7.4
MAX	10280	447.2	388	31.9	448	22.3	36.6	.94	15500	437	1875	39.0	594.14	9.74
TOTAL MEAN	8241	358	280	23	424	21	32	.82	13100	369	1537	32	542	8.9
STD. DEV.									1215	34	256			
	mg/l	meq/l												
MEAN OF COMPLETES		377		23		21		.82		349		32		8.9

Note: all means and ranges were determined with corrected values.

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Bureau of Reclamation

COMPUTATION SHEET

BY
DATE
PROJECT
SHEET ____ OF ____
CHKD BY
DATE
FEATURE Table 13 (continued)
DETAILS

3-34'

DATE	CO_3	TDS	LAB pH	LAB COND.	FIELD COND. @ 25°C	FIELD H_2O TEMP - °C
5-13-83	—	~~15996~~ mg/l	—	— µmhos	~~23500~~ µmhos	—
5-23	0	26,106	8.23	—	39500	—
6-7	—	26319	7.53	38000	39000	14
6-22		~~8047~~ 23000	7.74	39000	38000	14
7-7	0	26617	7.89	37000	37000	14
7-26	—	~~10281~~ 24000	7.71	32800	40,000	15
8-24	—	25460	7.39	36000	34000	15
9-28	—	25218	7.58	33000	36,000	15
10-26	0	25077	7.68	35900	32500	15
11-21	—	25009	7.62	31600	33000	15
12-13	—	24652	7.17	34000	34100	15.6
1-19-84	0	25231	7.83	35900	33800	16
2-15	—	24919	7.60	32550	32000	16
3-14	—	24426	7.45	33000	32000	16
4-18	0	25004	7.58	38200	37096	14
5-16		23709	7.55	33060	33280	15
6-8		23613	7.52	34080	29560	14
7-19	0	24305	7.73	36000	30520	14
8-14		24569	7.61	29400	31880	15
MIN	0	23613	7.17	29400	29560	14
MAX	0	26617	8.23	39000	40 000	16
TOTAL MEAN	0	24846	7.63	34676	34624	14.9
STD. DEV.		945	.22		3171	

mg/l meq/l

MEAN OF COMPLETES		25390	7.82		35069	14.6

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Bureau of Reclamation

COMPUTATION SHEET

BY
DATE
PROJECT
SHEET ____ OF ____
CHKD BY
DATE
FEATURE Table 14 Water Quality Analyses
DETAILS Canadian R. Mile 6.3 SITE 4 Near Mouth of Revuelto Creek

DATE	Na		Mg		Ca		K		Cl		SO4		HCO3	
- 5-13-83	290	13.0							165	5.0				
- 5-23	210	9.4	24.3	2.0	78.4	3.92	9.2	.24	123	3.47	680	14.16	229.0	3.68
6-7									95	2.68				
6-22									✓ 100	28				
-7-7	NO	DATA			———		———		Creek Dry		———		———	
-7-26									CREEK	DRY				
8-24									20	.56				
9-28									65	1.83				
10-26	163.2	7.1	46.4	3.82	60.8	3.03	6.85	.18	68.5	1.93	345	7.18	240.3	3.94
11-21									100	2.82				
12-13									240	6.77				
- 1-19-84	894	38.8	97.6	8.03	89.6	4.47	5.33	.14	656	18.51	.662	13.78	386.74	6.34
2-15									370	10.44				
3-14									825	23.27				
4-18	3/5	13.70	50.4	4.15	72	1.43	8.7	.22	229	6.46	520	10.83	219.6	0.06
5-16									100	2.82				
6-8									2150	60.6				
7-19	127	5.52	5.28	.43	20	1.0	2.4	.06	54.8	1.55	175.0	3.64	209.84	3.44
- 8-14									200	5.6				
MIN	127	5.52	5.28	.43	20	1.0	2.4	.06	100	28	175	3.64	209.84	3.44
MAX	894	38.8	97.6	8.03	89.6	4.47	9.2	.24	2150	60.6	680	14.16	386.74	6.34
TOTAL MEAN	333	14.5	45	3.7	64	3.2	6.5	.17	327	9.2	476	9.9	256	4.2
STD. DEV.									518	14.6	216			

	mg/l	meq/l						
MEAN OF COMPLETES		14.9	3.7	3.2	.17	6.4	9.9	4.2

Note: All means and ranges were determined with corrected values

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COMPUTATION SHEET

BY	DATE	PROJECT	SHEET ____ OF ____
CHKD BY	DATE	FEATURE Table 14 - Water Quality Analyses	
DETAILS	(mg/l) — SITE 4 Creek —		

DATE	CO3		TDS	LAB pH	LAB COND.	FIELD COND @ 25°C	FIELD H2O TEMP - °C	FLOW (cfs)
5-13-83			1276mg/l	—	— µmhos	2000 µmhos	—	
5-23	3.0	.10	1260	8.56	—	1460	—	26.0
6-7			~~4409~~ 1300	8.14	1750	1900	24	6.7
6-22			~~4973~~ 1250	8.25	1800	~~3700~~	35.5	.01
7-7	NO DATA		CREEK DRY THIS DAY					—
7-26			CREEK DRY THIS DAY					—
8-24			1089	8.34	1000	1500	28	3.3
9-28			829	8.24	1300	1400	21	7.8
10-26	0		767	8.26	1180	1350	16	14.3
11-21			937	8.19	1550	1500	12	5.6
12-13			1492	8.28		2300	10	1.7
1-19-84	0		2294	8.17	3350	4300	0	0 No Flow
2-15			1911	8.25	2800	3200	4	.4
3-14			2618	8.19	4000	4000	17	.1
4-18	1.2	.04	1397	8.39	2430	2068	19	4.3
5-16			1051	8.17	1493	~~2326~~	16	11.7
6-8	concentration in Pool?		5339	7.79	7954	8464	21	0
7-19	1.2	.04	536	8.42	628	No Field	Data	55
8-14			291	7.57	617	568	24	— No measurement
MIN	0	0	291	7.57	617	568	0	0
MAX	3.0	.1	5339	8.56	7954	8464	35.5	55
TOTAL MEAN	1.1	.04	1910	8.2	2275	2572	17.7	9.13
STD. DEV.			1554	.23		1993		

mg/l meq/l

MEAN OF COMPLETES	1251	8.36	2573	~~17~~ not enough Data	21.4

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Bureau of Reclamation

COMPUTATION SHEET

BY	DATE	PROJECT
		SHEET ____ OF ____
CHKD BY	DATE	FEATURE Table 15 Water Quality Analyses
DETAILS RAH-4B SITE 4 - 15' Piezometer		

DATE	Na		Mg		Ca		K		Cl		SO4		HCO3	
5-13-83	3640	158.3							4320	122.0				
5-23	3536	153.8	147.7	12.15	302.7	15.11	15.5	.40	5200	146.69	960	19.9	516.1	8.46
6-7									~~1750~~ 3830	108				
6-22									3000	84.63				
7-7	1676	72.91	3.6	.30	8.4	.42	4.8	.12	1204	33.96	515	10.72	505	8.28
7-26									500	14.11				
8-24									320	9.03				
9-28									360	10.16				
10-26	369.6	16.1	17.6	1.45	27.2	1.36	3.9	.10	306.8	8.65	475	9.89	319.64	5.24
11-21									215	6.07				
12-13									240	6.77				
1-19-84	692	30.10	36.8	3.03	51.2	2.55	4.08	.10	398.8	11.25	485	10.10	306.22	5.02
2-15									435	12.27				
3-14									425	11.99				
4-18	516	22.45	31.2	2.57	72	3.59	5.6	.14	511	14.42	350	7.29	284.26	4.66
5-16									500	14.1				
6-8									650	18.3				
7-19	555	24.1	40.3	3.32	89.6	4.47	5.2	.13	580	16.3	512.5	10.67	303.78	4.98
8-14			No Data											
MIN	516	22.4	3.6	.30	8.4	.42	3.9	.10	215	6.07	350	7.29	284.26	4.66
MAX	3640	158.3	147.7	12.15	302.7	15.1	15.5	.40	5200	146.6	960	19.9	516	8.46
TOTAL MEAN	1569	68	46	3.8	92	4.6	6.5	.17	1278	36	550	11.5	372	6.1
STD. DEV.									1608	45	210	4.4		

mg/l meq/l

	Na		Mg		Ca		K		Cl		SO4		HCO3
MEAN OF COMPLETES	53		3.8		4.6		.17		38.6		11.5		6.1

Note: All means and ranges determined with corrected values.

7-1654 (7-73)
Bureau of Reclamation

COMPUTATION SHEET

BY	DATE	PROJECT	SHEET ____ OF ____
CHKD BY	DATE	FEATURE Table 15 (Continued)	

DETAILS
mg/l meq/l site 4-15'

DATE	CO3		TDS	LAB pH	LAB COND	FIELD COND @ 25°C	FIELD H2O TEMP - °C
- 5-13	—		10955 mg/l	—	—	16500 µmhos	—
- 5-23	0		10452	7.87	—	16500	—
6-7	—		7973	7.65	~~15100~~ 11700	~~1600~~	12
6-22	—		~~28875~~ 7150	8.04	10000	9500	14
- 7-7	1.8	.06	3454	8.46	5250	5250	14
- 7-26			~~15685~~ 4000	8.16	4300	5000	15
8-24	—		1532	8.09	2600	2750	16
9-28	—		1580	8.03	2600	2750	17
10-26	0		1482	8.23	2310	2550	17
11-21	—		1256	7.91	2200	2500	15
12-13	—		1276	7.87	2200	2800	14.4
- 1-19-84	0		1504	8.2	2560	2750	12
2-15	—		1717	7.85	2700	3000	11
3-14	—		1735	7.75	2700	2750	11
4-18	0		1795	8.08	3250	2964	11
5-16			3766	7.78	2874	3132	11
6-8			1999	7.78	3220	2800	13
9-19	0.6	.02	2754	8.37	3,080	2892	14
- 8-14			No Data				
MIN	0		1256	7.65	1510	2500	11
MAX	1.8	.06	10955	8.46	10,000	16500	17
TOTAL MEAN	.4	.01	3688	8.0	3972	5082	13.6
STD. DEV.			3204	,23	2816	4630	
	mg/l	meq/l					
MEAN OF COMPLETES			3574	8.2		5484	13.6

7-1654 (7-73)
Bureau of Reclamation

COMPUTATION SHEET

BY
DATE
PROJECT
SHEET ____ OF ____
CHKD BY
DATE
FEATURE Table 16 Water Quality Analyses
DETAILS RAH-4A SITE 4 - 20.5' Piezometer

DATE	Na		Mg		Ca		K		Cl		SO4		HCO3	
- 5-13-83	4760	207.06							5480	155				
- 5-23	4980	216.63	129.2	10.45	203.4	10.15	19.9	.51	~~5320~~ 6300	183.3	1200	24.98	564.86	9.26
6-7									6550	184.78				
6-22									4000	112.84				
- 7-7	2364	102.83	4.32	.36	12	.60	6.89	.18	2156	60.82	615	12.80	653.9	10.72
- 7-26									1000	28.21				
8-24									700	19.75				
9-28									510	14.39				
10-26	1044	45.41	7.2	.59	12	.60	3.1	.08	~~320~~ 592	~~9.03~~ 16.7	462.5	9.63	374.54	6.14
11-21									~~350~~ 517	~~9.87~~ 14.6				
12-13									570	16.08				
- 1-19-84	726	31.58	10.6	.87	25.6	1.28	3.52	.09	645	18.2	492	10.24	305.0	5.00
2-15									700	19.75				
3-14									600	16.93				
4-18	1075	46.76	36	2.96	88	4.39	7.8	.20	1150	32.4	375	7.81	283.04	4.64
5-16									1550	43.7				
6-8									2550	71.9				
7-19	972	42.2	42	3.4	112	5.59	6.1	.16	1274	35.9	612.5	12.7	322.08	5.28
- 8-14			No Data											
MIN	726	31.5	4.32	.36	12	.60	3.1	.08	510	14.4	375	7.81	283.04	4.64
MAX	4980	216.6	129.2	10.45	203.4	10.15	19.9	.51	6550	184.8	1200	24.98	653.9	10.72
TOTAL MEAN	2274	98.5	38	3.1	75.5	3.8	8.0	.20	2058	58	626	13	417	6.8
STD. DEV.									2106	59.4	296			
	mg/l	meq/l												
MEAN OF COMPLETES		81		3.1		3.8		.20		57.9		13		6.8

7-1654 (7-73)
Bureau of Reclamation

COMPUTATION SHEET

BY	DATE	PROJECT	SHEET ____ OF ____
CHKD BY	DATE	FEATURE Table 16 (Continued)	
DETAILS Site 4-20.5'			

DATE	CO3		TDS	LAB pH	LAB COND	FIELD COND @ 25°C µmhos	FIELD H2O TEMP - °C
5-13-83	—		13378 mg/l	—	— µmhos	21000	—
5-23	0		13787	8.03	—	21000	—
6-7	—		14921	7.68	20250	20600	12
6-22	—		~~15101~~ 9000	8.14	13200	13000	14
7-7	1.2	.04	5291	8.41	8000	8000	14
7-26	—		~~25774~~ 4400	8.18	7000	7000	14
8-24	—		2483	7.96	4000	4400	15
9-28	—		1964	8.06	3100	3500	15
10-26	0		1736	8.30	2720	3000	15
11-21	—		1601	8.04	2650	2800	15
12-13	—		2029	7.99	3300	3300	16.7
1-19-84	.9	.03	1736	8.35	2610	2800	14
2-15	—		2208	7.95	3550	3800	13
3-14	—		2040	7.89	2800	3700	12
4-18	0		3349	8.01	5940	5532	12
5-16			3753	7.79	5982	6452	11
6-8			~~14863~~ 6250	7.69	8694	7464	13
7-19	0		3101	8.30	4570	4280	14
8-14							
MIN	0		1601	7.29	2610	2800	12
MAX	1.2	.04	14921	8.41	20250	21000	16.7
TOTAL MEAN	.35	.01	5168	8.0	6144	7868	13.7
STD. DEV.			4505	.22		6488	
	mg/l	mg/l					
MEAN OF COMPLETES			4833	8.23		7435	13.8

7-1654 (7-73)
Bureau of Reclamation

COMPUTATION SHEET

BY
DATE
PROJECT
SHEET ____ OF ____
CHKD BY
DATE
FEATURE Table 17 Water Quality Analyses
DETAILS SITE 6 RIVER Mi 9.9

DATE	Na		Mg		Ca		K		Cl		SO_4		HCO_3	
5-13-84	1370	59.6	—		—		—		1536	43.3	—		—	
5-23	756	32.89	37	3.04	93	4.64	8.6	.22	900	25.39	395	8.22	230.6	4.60
6-7									2050	57.83				
6-22									- 2500	70.53				
7-7	2196	95.53	62.4	5.13	116	5.79	11.6	.30	- 3244	91.51	514	10.70	305	5,02
7-26									- 6500	183.37				
8-24									1800	50.78				
9-28									1150	32.4				
10-26	1100	47.85	88	7.24	76.8	3.83	8.35	.21	996	28.10	387.5	8.07	273.3	4.48
11-21									2050	57.83				
12-13									4150	117.07				
— 1-19-84	5480	238.38	220.8	18.61	310.4	15.49	19.9	.51	- 6400	180.54	875	18.2	662,46	10,86
2-15									5550	156.57				
3-14									- 6000	169.26				
4-18	2034	88.48	81.6	6.71	148	7.39	16.3	.43	2900	81.81	550	11.45	364.78	5.98
5-16									1500	42.3				
6-3									-6500	183.3				
7-19	296	12.8	9.6	.79	32	1.6	3.8	.10	297.6	8.4	150	3.12	231,8	3.8
8-14									-250	7.05				
MIN	296	12.8	9.6	.79	32	1.6	3.8	.10	250	7.05	150	3.12	231.8	3.8
MAX	5480	238.3	220.8	18.61	310.4	15.4	19.9	.51	6500	183.3	875	18.2	662.46	10,86
TOTAL MEANS	1890	82	83	6.8	129	6.5	11.4	.29	2967	83.4	479	10.0	353	5.8
STD. DEV.									2199	62.0	239			
	mg/l	meq/l												
MEAN OF COMPLETES		86		6.8		6.5		.29		69		10.0		5.8

7-1654 (7-73)
Bureau of Reclamation

COMPUTATION SHEET

BY	DATE	PROJECT
CHKD BY	DATE	FEATURE Table 17 continued
DETAILS		

SHEET ____ OF ____

6 - RIVER

DATE		CO_3	TDS	LAB pH	LAB COND	FIELD COND. @ 25°C µmhos	FIELD H_2O TEMP- °C	FLOW (cfs)
5-13-83		—	4459 mg/l	—	— µmhos	7500	—	—
5-23	0		2383	8.30	—	4235	—	-- 32.3
6-7		—	2038	7.95	7600	7250	18.5	~~10.9~~ 11
6-22		—	+ 5970	8.06	10000	10,000	27	5.5
7-7	0		+ 5696	8.15	9100	9100	22	4.5
7-26		—	+ 11025	7.87	17000	17000	24	1.0
8-24		—	3882	8.12	6200	7200	25	6.2
9-28		—	2685	8.05	4250	4750	17	10.8
10-26	2.4	.08	2549	8.37	3650	4600	11	17.4 17.5
11-21		—	4475	7.98	9000	7800	10	10.1
12-13		—	8243	8.0	12175	13800	3.3	4.9 5.0
— 1-19-84	0		+ 13209	7.80	18880	22000	0	No 0 Flow
2-15		—	10711	7.70	15200	16800	4.0	3.1
3-14		—	+ 11889	7.72	15000	18000	14	2.4 2.5
4-18	0		6321	8.11	10820	11555	12	6.1
5-16			3431	8.05	5536	5228	16	13.0
6-8			+ 11630	7.64	17020	~~4240~~	20	1.4 1.5
7-19	0		1121	8.32	1586	1758	23	60
8-14			- 460	7.57	951	908	24	201
MIN	0		460	7.57	951	908	0	0
MAX	2.4	.08	13209	8.37	18880	22000	27	201
TOTAL MEAN	.4	.01	5904	8.0	9644	9416	15.9	21.7
STD DEV.			4033	.23	5593	5964		

mg/l meg/l

MEAN OF COMPLETES			5213	8.18		8875	13.6	

7-1654 (7-73)
Bureau of Reclamation

COMPUTATION SHEET

Table 18

BY
DATE
PROJECT
SHEET ____ OF ____
CHKD BY
DATE
FEATURE Table 18 Water Quality Analyses
DETAILS RAH-6C SITE 6-21′ Piezometer

DATE	Na		Mg		Ca		K		Cl		SO4		HCO3	
	mg/l	meq/l												
- 5-13-83	2792	121.5							~~2904~~ 4000	~~82.0~~ 113				
- 5-23	2792	121.5	49.5	4.08	91.3	4.56	13.8	.35	3720	104.94	560	11.66	666.1	10.92
6-7									3850	108.61				
6-22									3500	98.74				
7-7	2828	123.02	48	3.95	100	4.20	13.3	.34	3640	102.68	564	11.74	528.3	8.66
7-26									3500	98.74				
8-24									4000	112.84				
9-28									3250	91.6				
10-26	3244	141.11	101.6	8.36	97.6	4.87	13.8	.35	~~2984~~ 3400	~~84.18~~ 96	687.5	14.31	484.34	7.94
11-21									3700	104.38				
12-13									4200	118.48				
- 1-19-84	4120	179.2	376	30.93	244.8	12.2	19.5	.50	4840	136.5	810	16.86	513.62	8.42
2-15									4950	139.64				
3-14									5500	155.16				
4-18	3505	152.47	230	18.92	312	15.57	25.1	.64	5200	146.65	635	13.2	472.14	7.74
5-16									5500	155				
6-8									5500	155				
7-19	3784	164.6	142.1	11.6	337.6	16.8	19.4	.50	~~7300~~ 5300	~~205.9~~ 149	887.5	18.4	447.74	7.34
8-14									~~8500~~ 5500	~~239.7~~ 155				
MIN	2792	121.5	48	3.9	91.3	4.56	13.3	.34	3250	91.6	560	11.6	447.74	7.34
MAX	4120	179.2	376	30.9	337.6	16.8	25.1	.64	5500	155	888	18	666.1	10.92
TOTAL MEAN	3295	143	158	13	197	9.8	17.5	.45	4371	123.3	691	14.4	519	8.5
STD. DEV.									847	23.9	133			
MEAN OF COMPLETES		147		13		9.8		.45		122.6		14.4		

7-1654 (7-73)
Bureau of Reclamation

COMPUTATION SHEET

BY	DATE	PROJECT	SHEET ____ OF ____
CHKD BY	DATE	FEATURE Table 18 continued	
DETAILS site 6-21'			

DATE	CO3	TDS	LAB pH	LAB COND	FIELD COND @ 25°C µmhos	FIELD H2O TEMP °C
-5-13-83		7752 mg/l	—	— µmhos	13600	—
-5-23	0	7694	8.16	—	12800	—
6-7		~~11250~~ 8900	7.65	13000	13000	14
6-22		7197	8.06	11250	12000	14
7-7	0	7246	8.07	11800	11800	14
7-26		7116	7.86	11200	13000	15
8-24		6366	7.7	9250	11000	15
9-28		6483	7.78	9700	11000	15
10-26	0	6669	8.10	9370	10800	16
11-21		7470	7.74	11200	12000	12
12-13		8296	7.49	12000	11900	17.7
-1-19-84	0	9637	8.0	16500	13500	16
2-15		9807	7.74	14000	15000	14
3-14		10.454	7.56	13900	15100	16
4-18	0	10876	7.78	18500	~~13688~~ 15200	14
5-16		10706	7.58	16782	17660	14
6-8		11842	7.42	17048	17852	15
7-19	0	11397	7.9	18000	15260	15
8-14		11598	7.53	18916	16200	17
MIN	0	6366	7.42	9250	10800	12
MAX	0	11842	8.16	18916	17852	17.7
TOTAL MEAN	0	8816	7.78	13668	13583	14.9
STD. DEV.		1889	.23		2175	

		mg/l	mg/l			
MEAN OF COMPLETES	0	8920	8.0		13227	15

7-1654 (7-73)
Bureau of Reclamation

COMPUTATION SHEET

BY
DATE
PROJECT
SHEET ____ OF ____
CHKD BY
DATE
FEATURE: Table 19 - Water Quality Analyses
DETAILS RAH-6B SITE 6 - 31' Piezometer

DATE	Na		Mg		Ca		K		Cl		SO4		HCO3	
- 5-13-93	4920	214							6040	170.4				
- 5-23	5260	228.6	148.6	12.2	254.7	12.71	28.2	.72	5920	167	970	20.2	588.0	9.63
6-7									7750	218.6				
6-22									8500	239.7				
7-7	4360	189.6	151.2	12.4	260	12.97	24	.61	7280	205.3	935	19.47	530.7	8.70
7-26									8000	225.6				
8-24									8000	225.6				
9-28									7050	198.8				
10-26	6160	267.9	67.2	5.53	266.4	13.29	25.6	.65	6600 ~~6040~~	186 ~~170.3~~	1280	26.6	679.54	11.14
11-21									6900	194.6				
12-13									6950	196				
- 1-19-84	5800	252.3	216	17.7	292.8	14.61	24.7	.63	6840	192.9	1170	24.3	707.6	11.60
2-15									6600	186.1				
3-14									6600 ~~8000~~	186 ~~225.6~~				
4-18	4519	196.5	212.2	17.46	276	13.7	27.1	.69	6400	180.5	765	15.9	684.42	11.22
5-16									6500 ~~7500~~	183 ~~211.5~~				
6-8									6500	183.3				
7-19	4365	189.8	128.6	10.58	187.2	9.34	19.3	.49	6864	193.6	1100	2.29	583.16	9.56
8-14									6500 ~~8000~~	183 ~~225.6~~				
MIN	4360	189.6	67.2	5.5	187.2	9.34	19.3	.49	5920	167	765	15.9	530.70	8.70
MAX	6160	267.9	212.2	17.4	292.8	14.61	28.2	.72	8500	239.7	1280	26.6	707.60	11.60
TOTAL MEAN	5055	220	154	12.7	256	12.8	24.8	.63	6936	195.6	1037	21.6	629	10.3
STD. DEV.									689	19.4	-			
MEAN OF	mg/l	meq/l												
COMPLETES		221		12.7		12.8		.63				21.6		10.3

Note: all means and ranges were computed with corrected values.

7-1654 (7-73)
Bureau of Reclamation

COMPUTATION SHEET

BY	DATE	PROJECT	SHEET ____ OF ____
CHKD BY	DATE	FEATURE Table 19 continued	
DETAILS site 6-31'			

DATE	CO3	TDS	LAB pH	LAB COND	FIELD COND @ 25°C µmhos	FIELD H2O TEMP-°C
5-13-83	—	14160 mg/l	—	— µmhos	22000	—
5-23	0	15048	7.93	—	c 23000	—
6-7	—	~~10034~~ 15200	7.58	22500	24000	14
6-22	—	14719	7.73	22250	22000	15
7-7	0	14356	7.92	21500	c 21500	15
7-26	—	14020	7.62	20100	22700	15
8-24	—	14056	7.74	20050	21800	15
9-28	—	13770	7.64	19200	21500	15
10-26	0	13545	7.87	20400	c 19500	15
11-21	—	13511	7.51	19500	22900	10
12-13	—	13618	7.70	19950	21500	10
	—					
1-19-84	0	13740	8.01	22200	c 19000	15
2-15	—	13226	7.65	18300	18500	14
3-14	—	13035	7.74	18000	20000	16
4-18	0	13201	7.69	22400	c 20584	15
5-16		12659	7.58	19204	20100	16
6-8		~~22613~~ 13300	7.63	19376	21004	15
7-19	0	12173	7.76	19350	c ~~16928~~ 19420	15
8-14		12035	7.63	20800	~~16844~~	15
MIN	0	12035	7.51	18000	18500	10
MAX	0	15200	8.01	22500	24000	16
TOTAL MEAN	0	13651	7.72	20299	21167	14.4
STD. DEV.		859	.14		1522	

	mg/l meq/l					
MEAN OF COMPLETES		13677	7.86		20500	15

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Bureau of Reclamation

COMPUTATION SHEET

BY
DATE
PROJECT
SHEET ____ OF ____
CHKD BY
DATE
FEATURE Table 20 Water Quality Analyses
DETAILS RAH-6A SITE 6 - 50′ Piezometer

DATE	Na		Mg		Ca		K		Cl		SO4		HCO3	
- 5-13-83	5920	258	–		–		–		~~7440~~	~~210~~	–		–	
- 5-23	7720	335.8	163.2	13.43	456.5	22.78	43.2	1.10	10750 ~~8160~~	230.19	1285	26.75	555.1	9.1
6-7									10150	286.3				
6-22			?		?				11300 ~~12300~~	352.6				
7-7	8160	354.9	43.2	3.55	75.2	3.75	39.2	1.0	10400	293.3	1365	28.42	570.0	9.36
7-26									11100 ~~13000~~	366.73				
8-24									11500	324.4				
9-29									10550	297.6				
10-26	8360	363.6	383.2	31.5	426.4	21.28	44.2	1.13	10700 ~~8160~~	247.1	1625	33.8	786	12.90
11-21									10700	301.8				
12-13									10450	294.7				
- 1-19-84	8280	360.1	353.6	29	496	24.75	43.5	1.11	10280	290	1612	33.5	812.52	13.32
2-15									NO	DATA				
3-14									NO	DATA				
4-18									NO	DATA				
5-16									NO	DATA				
6-8									"	"				
7-19									"	"				
8-14									"	"				
MIN	5920	258	43.2	3.5	75.2	3.7	39.2	1.0	10280	290	1285	26.7	555.1	9.1
MAX	8360	363.6	383.2	31.5	496	24.7	44.2	1.13	11500	324.4	1625	33.8	812.52	13.32
TOTAL MEAN	7688	334	235.8	19.4	363.5	18.1	42.5	1.09	10716	302	1472	30.6	681	11.2
STD DEV									426	12	173			
	mg/l	meq/l												
MEAN OF COMPLETES		354		19.4		18.1		1.09	10532			30.6		11.2

Note: all means and ranges were computed with corrected values

7-1654 (7-73)
Bureau of Reclamation

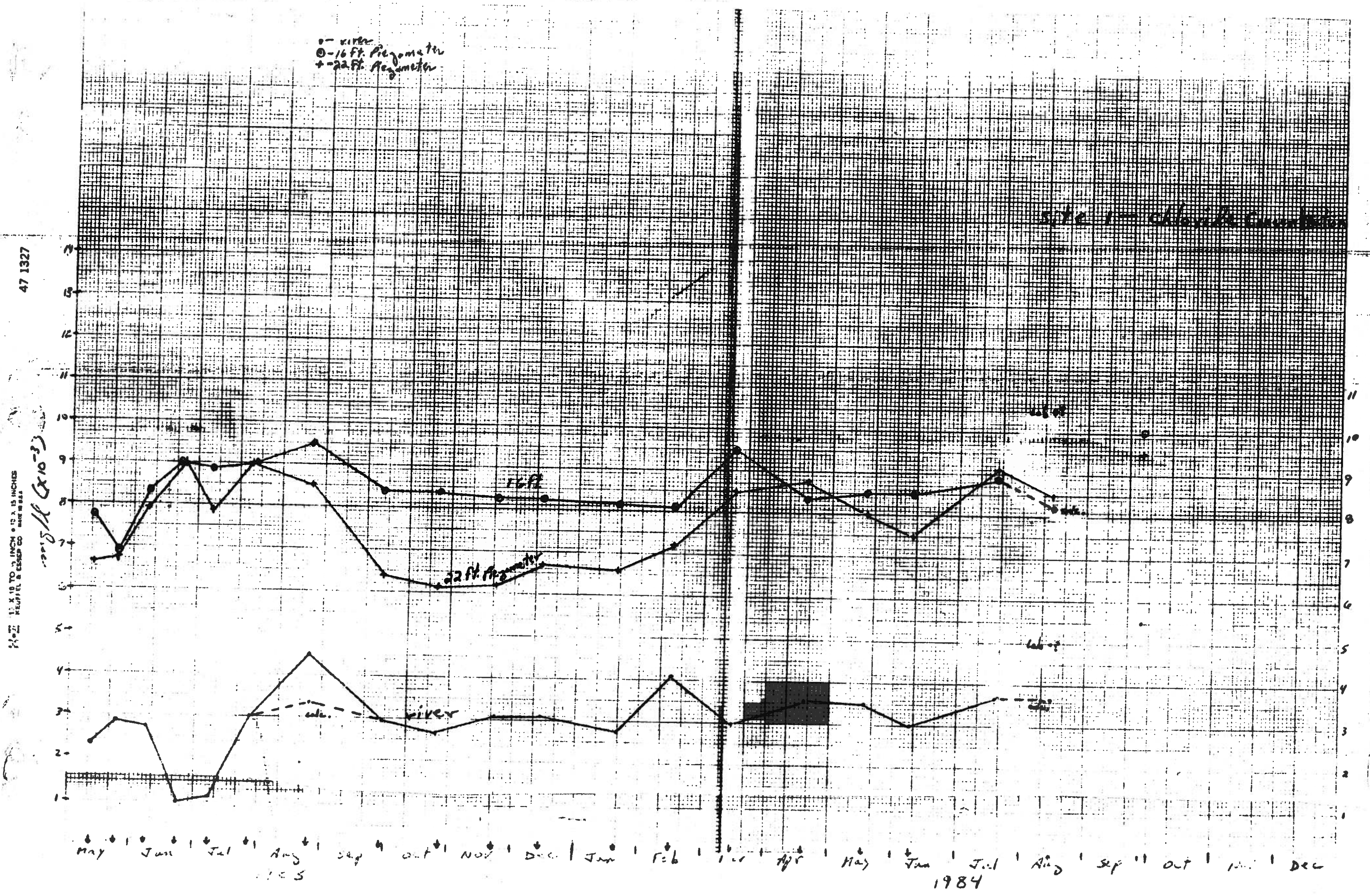
COMPUTATION SHEET

BY
DATE
PROJECT
SHEET ____ OF ____
CHKD BY
DATE
FEATURE Table 20 continued
DETAILS

site 6-50'

DATE	CO_3	TDS	pH	LAB COND.	FIELD COND @ 25°C µmhos	FIELD H_2O TEMP - °C
	—		—			
5-13-83		~~17796~~ mg/l	—	— µmhos	~~25000~~	—
5-23	0	c 20432	7.73	—	30100	—
6-7		~~13115~~ 20800	7.24	30000	32000	14
6-22		20224	7.49	29500	31500	15
7-7	0	c 20846	7.89	30000	30000	15
7-26		20426	7.47	29200	31000	15
8-24		20275	7.18	27500	30000	15
9-28		20418	7.42	27200	30000	15
10-26	0	c 20825	7.76	30300	30000	15
11-21		20590	7.21	28500	31800	10
12-13		20077	7.28	28100	28000	14.4
1-19-84	0	c ~~34558~~ 18600	7.89	32000	~~22500~~ 28000	14
2-15	NO	DATA				
3-14	NO	DATA				
4-18	NO	DATA				
5-16	NO	DATA				
6-8	"	"				
7-19	"	"				
8-14	"	"				
MIN	0	18600	7.18	27200	28000	10
MAX	0	20846	7.89	32000	32000	15
TOTAL MEAN	0	20319	7.50	29230	30218	14.2
STD. DEV		624	.270		1341	
	mg/l	mg/l				
MEAN OF COMPLETES		2017.6	7.82		29525	14.7

Figure 43 - Monthly Chloride Concentration, Site 1 Near Logan, NM



An alternative to drilling more than one well would be to drill to the geologic basement, which is approximately 9,000 feet in this area. Every potential injection zone from the Abo down could be tested, then several thousand feet of slotted casing set. This type of completion may enable a single well to handle a much larger flow than 1 ft^3/s.

The compatibility of the injected water with the receiving formation water is not known at this time. The in situ chemical properties of the receiving formation water and the Brine Artesian Aquifer water will have to be determined.

Tables 23 and 24 list composite values for selected chemical constituents from the Brine Artesian Aquifer and other Permian or deep wells nearby. They may provide enough information for a first estimate of these waters' compatibility.

Operation and maintenance of an injection well system is critical, especially since the proposed disposal zone is a sandstone formation. The potential exists that a chemical and filtering system will be required. Chemicals may have to be added to the injection systems to control clogging and encrustation problems, which would increase pressures and reduce flow rates. Total suspended solids in the brine to be injected will have to be determined and steps taken to remove them if they are too high. Injecting solids into a sandstone formation would cause clogging and reduce the life of the well.

Due to the low seismicity of the area, the low potential for inducing any significant earthquakes, and the remoteness of the area, no seismic monitoring is proposed. Background seismic data are available for the general area. If it is determined that near-site information is needed, a seismic site can also be installed after the project is in operation.

7-1654 (7-78)
Water and Power

COMPUTATION SHEET

BY	DATE 8/16/84	PROJECT Lake Meredith Salinity	SHEET ___ OF ___
CHKD BY	DATE	FEATURE Injection Zone	

DETAILS
Table 23 - Possible In Situ Chemical Concentrations . . .

	mg/l	meq/l
Calcium	1360	
Magnesium	610	
Sodium	29,000	1262
Potassium	64	
Carbonate	0	
Bicarbonate	904	
chloride	43,719	1233
Sulfate	5250	
Nitrate	< 0.4	
Total Dissolved Solids	80,948	
Boron	3.5	
Silica	37	
Hardness as $CaCO_3$	5913	
Specific Conductance (Micromhos @25°C)	70,650	
Lab pH	6.6	
field pH	6.0	
field Temperature (°C)	22.8	
field Alkalinity (as $CaCO_3$)	765	

Chemical Analyses from Dripping Springs well
Sampled from flowing well -
Casing Interval Not known

7-1654 (7-73)
Water and Power

COMPUTATION SHEET

BY	DATE 8/16/84	PROJECT Lake Meredith Salinity	SHEET ____ OF ____
CHKD BY	DATE	FEATURE "Brine Aquifer"	

DETAILS Table 24 Possible In Situ Chemical Concentrations . . .

Sampled from flowing well - Some Changes Could have occured while rising in well

	mg/l	mg/l
Calcium	~1000	
Magnesium	~ 300	
Sodium	~20,000	
Potassium	~ 70	
Carbonate	0	
Bicarbonate (as $CaCO_3$)	~ 800	
Chloride	~ 26000	
Sulfate	~ 28000	
Nitrate	< 0.4	
Total Dissolved Solids	~50,000	
Boron	~ 3	
Silica	—	
Hardness as $CaCO_3$	—	
Specific Conductance (micromhos@25°C)	78,400	
Lab pH	~7.6	
field pH	~6.4	
field temperature (°C)	~19.0	
field Alkalinity (as $CaCO_3$)	836	
Barium	~24	
Strontium	none detected	
Density	~1.03 ?	
Iron	~ 0.5-1	

CO_2 in Solution partial pressure not known
outgassing occures pH ↑, Iron precipitates

Composit Analyses from OW-3

Project monitoring

It will be necessary to establish a stream and alluvial monitoring network to assess the changes to the river system that may occur as a result of depressurizing the Brine Artesian Aquifer. Four sampling sites along the Canadian River are proposed for both levels of this project (plate No. 2). All monitoring sites should be located close together and provisions made to monitor the influences of Revuelto Creek flows. It is desirable to intensively monitor a short reach of the river because of the complexity of brine movement through the alluvial materials and the large area of brine inflow to the river. Most of the time these proposed sites will not be affected by Revuelto Creek; however, during extremely high flows, water is backed at least a mile up the Canadian River.

Each site should have a minimum of three clusters of piezometers completed at three different depths and locations across the river canyon. Some preliminary drilling to determine the cross-sectional depth to bedrock would be useful in locating the piezometers. Each piezometer should be completed with at least 2-inch inside-diameter casing, then pumped for proper development. Water samples should be collected for chemical analyses on a regular basis, preferably by submersible pump or bailing. Also, stream water should be collected and analyzed at each site regularly and flows determined. The TDS concentration was the most stable and reliable constituent measured during this sampling program and may be all that is required. It would be useful to install a continuous specific-conductance meter in the alluvium and river downstream of the last sampling site. If instantaneous surface flow data and specific conductances can be correlated to instantaneous changes in alluvial water specific conductances, then the physical-flushing mechanisms of salt transport from the alluvium could be verified. In addition, brine pools located between the sampling sites should be inventoried and sampled, and areas of freshwater inflow should be determined. These brine pools may represent major sites of contamination of the freshwater system. It has been observed that some of these pools are quite deep and have very high specific conductances. There may be upward leakage of brine into these pools with enough vertical velocity to displace the alluvial materials. (Vertical hydraulic gradients should be determined from water level elevation data collected from the alluvial piezometers.) Correlation of these pools with fractures in the Triassic Formation may be of value in pinpointing actual brine seepage areas from the bedrock to the alluvium.

All preproject chemical data available for this reach of river should be compiled and analyzed as one data set. When a good data set is compiled after the project has been in operation for some time, comparisons should be made. This should be done by treating the pre and postproject data as two different samples and testing to see if there is a significant difference in the means of individual constituents, using a standard "t-test" or other appropriate statistical tests.

An alternative method would be to tabulate all data versus time, fit a regression equation to the entire set, then test to see if the slope of the line is significantly different from 0, which would indicate improvement or no change. These techniques are summarized by E. A. McBean and F. A. Rover (1984).

Water level and quality changes in the upper freshwater, ground water system and the Brine Artesian Aquifer should be monitored on a regular basis. Adequate monitoring of the ground water system will enable changes to be made to the pumping program and potential problems to be anticipated. Water quality monitoring of the brine discharge and then brine injection will also be useful in preventing damage to the disposal formation and piping system.

A detailed three-dimensional ground water model should be constructed for the Brine Artesian Aquifer and upper freshwater system (plate No. 2) since proper design and management of the pumping and monitoring system will be required if a successful project is to be completed. The model should be constructed as a second generation of the model prepared for this evaluation. Additional node points should be used to increase topographic control. As more information becomes available through the drilling program, it should be included and the model updated. Water level information from both the shallow and deep piezometers will be needed for model calibration. Water density determinations from these piezometers should be used for hydraulic head corrections. One or two aquifer tests should be run prior to the actual brine pumpage program; or if that is not possible, detailed records of water level changes should be made during the first few weeks to a month of initial pumping. For proper model calibration, hydraulic conductivities and storage coefficients for both layers, and evidence of any aquifer anisotrophy will have to be determined. Additionally, the leakage coefficient of the confining layer will have to be determined.

Discharge determinations of spring flows from the freshwater system along the Canadian River within the model area should be made. This information will be needed for proper model calibration. Additional water level information may be required from below the Brine Artesian Aquifer because of the complexity of the hydrologic flow system. Several deep piezometers may have to be installed.

If an acceptable computer model can be constructed and calibrated, it will be a very useful tool for proper project direction and control. Proper pumpage rates and locations could then be determined in advance and changes made with some reliable expectation of the results. Also, alternative pumping programs could be tried and evaluated by the model without expending a considerable amount of money.

It may also be desirable to construct a computer model of the alluvial system. A proper understanding of the brine flow through the sands would be useful in predicting time changes in water quality both locally and downstream of the project.

River Alluvium Pumping Plan

The second major brine control plan evaluated was to pump the contaminated alluvial water (plate No. 3). The plan would require one or two collector wells located at the deepest points in the river alluvium (figure 65). The exact location of these pumping sites would be determined after careful examination of the alluvium. This examination was proposed at 10 locations where depth cross sections would be made and hydraulic conductivities of the alluvial material and quality of the alluvial water determined.

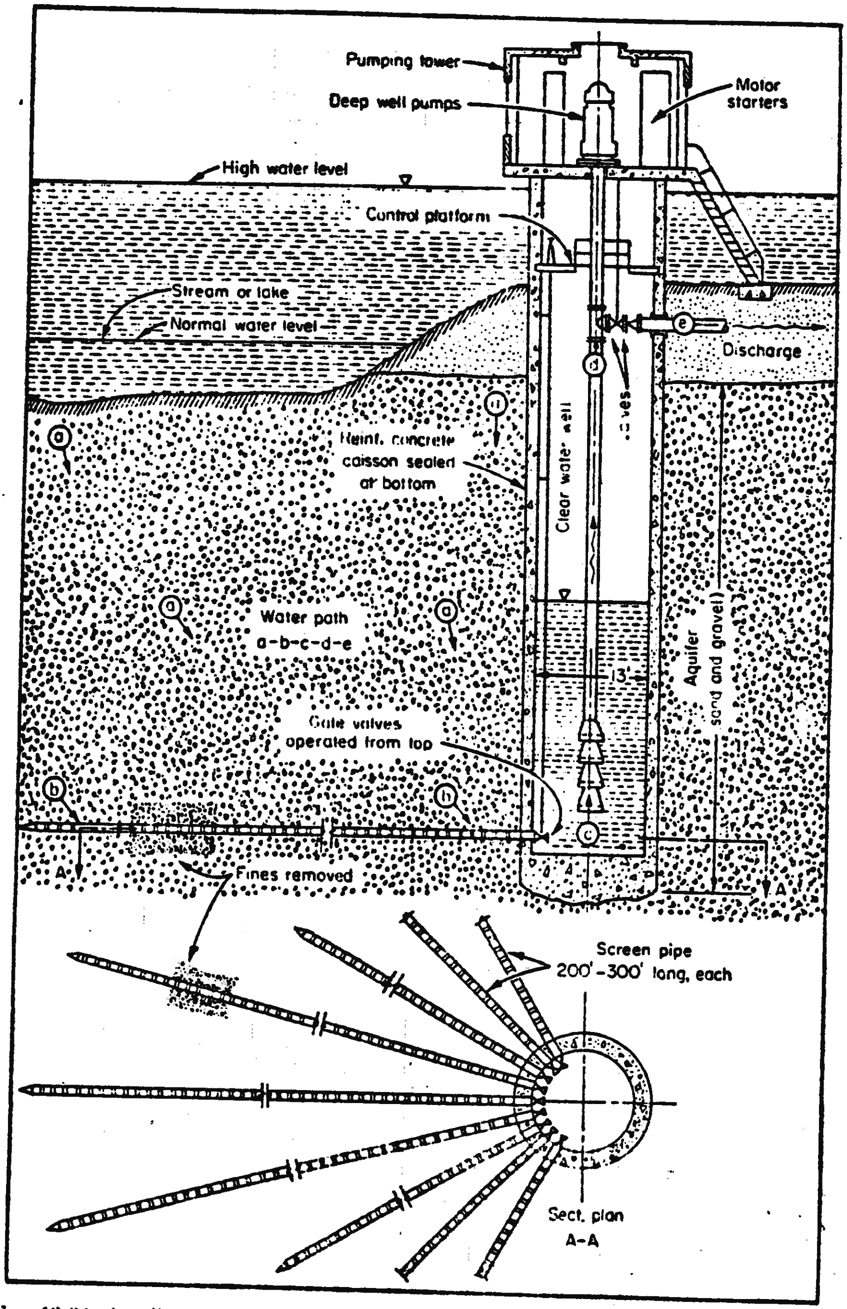


FIG. 13-34. A collector well located near a surface-water body. *(Ranney Method Water Supplies, Inc.)*

Figure 65 - Cross Section of Collector Well System
Evaluated For the Canadian River
Alluvial Material, Near Logan, NM

Ideally, the most concentrated brine would be extracted by controlled pumping from properly placed, screened pipe. These pipes could be installed at different depths and directions, and valves could be used to control which laterals were open for pumping. A computer model was also proposed to evaluate the brine flow within the sands, and water quality samples would be collected at the proposed monitoring sites in the same manner as outlined in the Brine Artesian Aquifer depressurization plan.

This brine control plan was abandoned for several reasons. First, water pumped from the alluvium may contain a high total suspended solids content, which would require a filtering plant to prevent clogging of the injection well. This would increase the cost of pumping substantially. Second, because of the limited extent of the alluvium, this pumping program would probably remove the base flow of the river, leaving a dry streambed for several miles. The associated environmental problems such as wildlife habitat destruction and legal problems with disruption of existing water rights were considered unacceptable.

Because of the considerable brine storage in the river's alluvium, a scaled-down version of this plan may have to be attempted at several points along the channel after the Brine Artesian Aquifer depressurization program is implemented. This would be a temporary situation and may be feasible at this reduced level.

CHAPTER VI - PROJECT ABANDONMENT

Subsurface data collection required the drilling and completion of numerous wells and piezometers near Logan. These include wells DH-1, DH-2, POW-1, OW-2, OW-3, OW-4, and TW-1, and a group of five alluvial piezometers in the Canadian River near State Highway 54 bridge, which were installed during the 1979 Reclamation-CRMWA study. Well DH-3 was completed, and 12 alluvial piezometers and 4 staff gauges were installed at river sites 1 through 4 and 6 during this project.

If this project does not continue beyond this point, some provision will be required to properly clean up the study area. The alluvial piezometers and staff gauges can be removed by pulling them out of the sand with a winch and cable. The deep wells will have to be redrilled to remove the casing, then cemented to the surface. The roads leading to the drill and sampling sites may have to be reseeded, depending upon the wishes of the landowner. These sites have been kept clean of trash so cleanup will be complete once the pipe and casing are removed.

It is important to properly reseal the deeper drill holes. Wells DH-1 and DH-2 were only cased to bedrock so they may presently be providing a route for brine leakage to the alluvium. Other holes may leak in the future if not properly sealed.

Future work in the area will involve drilling many additional wells and piezometers along with a deep disposal well. Provisions should be made at the start of the proposed control project to properly abandon these drill holes when they are no longer of use. This is especially important for the disposal well because of the cost of abandoning such a large structure.

CHAPTER VII - SUMMARY AND CONCLUSIONS

Reports prepared by HGC (1984A and 1984B) present a detailed description of the hydrologic, geologic, and geophysical investigations completed under contract for Reclamation. Additional work completed by Reclamation included sampling of the surface and alluvial water of the Canadian River and Revuelto Creek near Logan, New Mexico, collecting water level and quality of water information from Triassic Formation wells and the Brine Artesian Aquifer in the same area, and analyses of these data. A geologic core-drilling operation was also completed to better define the local stratigraphy.

The hydrogeologic investigations determined that a sodium-chloride brine of natural origin, produced by dissolution of Permian halite beds, flows into the Canadian River near Logan. The brine flows upward from the Permian deposits into a geologic unit in the upper Permian or lower Triassic Formations (the Brine Artesian Aquifer), then upward into the river alluvium. The exact route of movement to the alluvium is not known but is probably through a complex fracture system. The movement of this brine through the alluvial system is not very well understood, but brine appears to discharge into the river at several discreet points. Due to the influences of freshwater springs and floodflows, these sites have not been adequately defined. It is possible that brine seepage may be relatively continuous downriver below Ute Dam.

The investigations further determined that the majority of the chlorides entering Lake Meredith originate in New Mexico between Ute Reservoir and the State line. This brine appears to flow continuously to the river system and floodflows do not appear to affect concentration levels within the alluvium.

Based on the present information and the information obtained from previous investigations, it was concluded that the Brine Artesian Aquifer probably can be pumped to lower its hydraulic head thus reducing upward leakage of brine to the Canadian River alluvium. Disposal of this brine would require completion of a deep well into a formation permeable enough to accept all the water produced. Based on preliminary investigations, an acceptable disposal formation should exist close enough to the project area so that pipeline costs are not excessive. The exact amount of brine which will eventually be produced and the amount each disposal well can accept has not been determined. A brine aquifer depressurization plan and monitoring program were presented.

Some work has been completed evaluating the potential benefits to Lake Meredith and the time it will take to see these benefits under river base flow conditions (HGC 1984A). Additional work needs to be done to verify these conclusions and to expand the interpretations to include floodflows.

CHAPTER VIII - REFERENCES CITED

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ATTACHMENTS

ATTACHMENT A -

WELL NUMBERING SYSTEM USED IN NEW MEXICO

GROUND-WATER LEVELS IN NEW MEXICO, 1961

Well-Numbering System

The system of numbering wells in New Mexico, used in all cases except for the thermal wells in the Hot Springs basin, Sierra County, is based on the common subdivision of public lands into sections. The well number, in addition to designating the well, locates its position to the nearest 10-acre tract in the land network. The number is divided by periods into four segments. The first segment denotes the township north or south of the New Mexico base line; the second denotes the range east or west of the New Mexico principal meridian; and the third denotes the section. In a county such as Roosevelt, where wells are situated both north and south of the base line, an N is added to the first segment of the well number if the well is north of the base line, but no letter is added if the well is south of the base line. Similarly, in a county where wells are located both east and west of the meridian, an E is added to the second segment of the well number of those wells east of the meridian. In counties lying entirely within one quadrant of the principal meridian and base line, the direction north or south of the base line or east or west of the meridian is not given. The fourth segment of the number, which consists of three digits, denotes the 160-, 40-, and 10-acre tracts, respectively, in which the well is situated. For this purpose, the section is divided into four quarters, numbered 1, 2, 3, and 4, in the normal reading order, for the northwest, northeast, southwest, and southeast quarters, respectively. The first digit of the fourth segment gives the quarter section, which is a tract of 160 acres. Similarly, the quarter section is divided into four 40-acre tracts numbered in the same manner, and the second digit denotes the 40-acre tract. Finally, the 40-acre tract is divided into four 10-acre tracts, and the third digit denotes the 10-acre tract. Thus, well 12.36.24.342 in Lea County is in the NE¼SE¼SW¼ sec. 24, T. 12 S., R. 36 E. If a well cannot be located accurately within a 10-acre tract, a zero is used as the third digit, and if it cannot be located accurately within a 40-acre tract, zeros are used for both the second and third digits. If the well cannot be located more closely than the section, the fourth segment of the well number is omitted. When it becomes possible to locate more accurately a well in whose number zeros have been used, the proper digit or digits are substituted for the zeros. Letters a, b, c, etc., are added to the last segment to designate the second, third, fourth, and succeeding wells in the same 10-acre tract.

A modification of this system has been used for wells on grant land in Sunshine Valley in Taos County where land was sectionized according to a system used in Colorado and extended into New Mexico. Within the Sangre de Cristo Grant, townships south of the State line have been designated T. 1 S., and T. 2 S., whereas townships north of the State line are designated T. 1 N., etc.

Figure 2 diagrams the method of numbering wells and tracts in New Mexico.

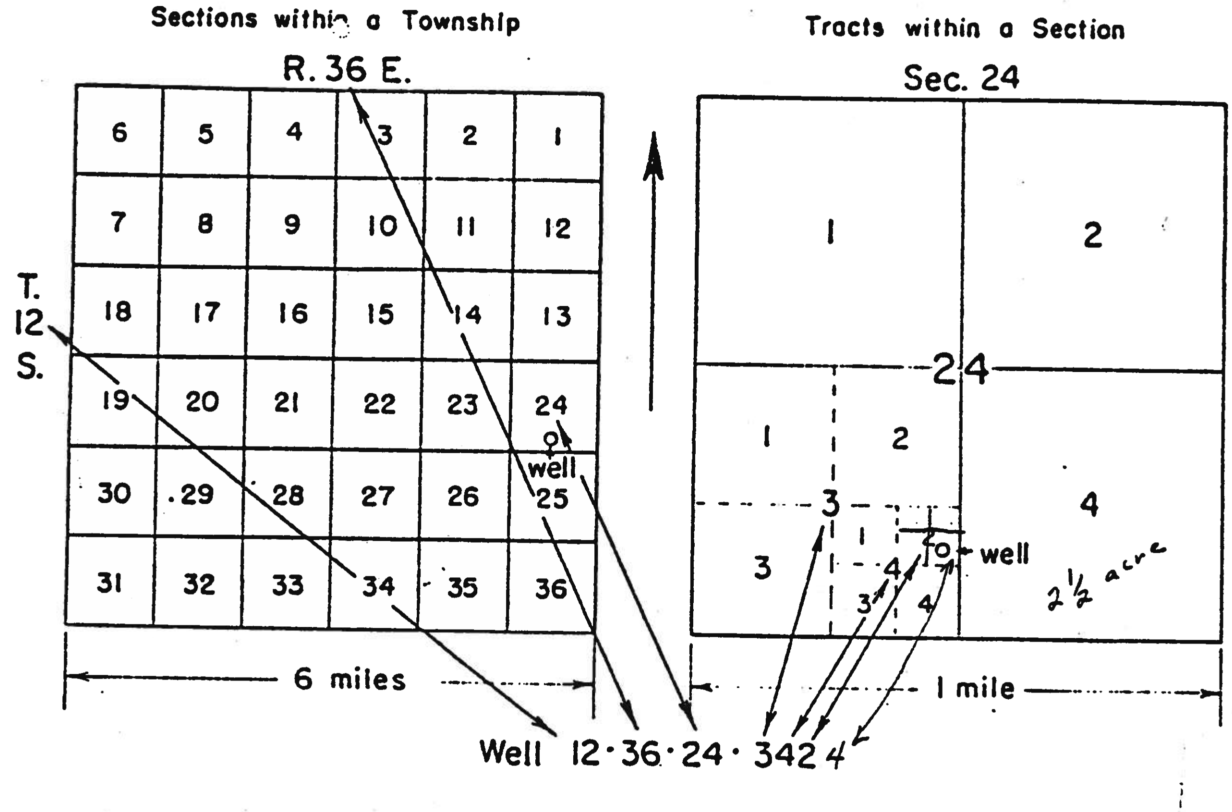


FIGURE 2. -- System of numbering wells in New Mexico.

ATTACHMENT B -

CANADIAN RIVER NEAR LOGAN, NEW MEXICO
STREAM SURVEY - MAY 1983

7-1654 (7-73)
Water and Power

COMPUTATION SHEET

BY G. Gaillot	DATE 5/30/83	PROJECT Lake Meridith Salinity Control	SHEET 1 OF 12
CHKD BY	DATE	FEATURE River miles below Ute Dam	
DETAILS Canadian R. Stream Survey 5/24/83-5/26/83			

Stream Mile 9.9 @ alluvial well site 6

5/24 0945 MDT

clear breezy - few clouds

river stage 0.68" 1-1.5" less than 5/23

redish water

Water T 21.0°C 6" thermometer 22.0°C YSI meter

Sp. Cond. 4250-4300 μmhos S. to N. Banks
Two branches 4250-4280 S. Branch; 4300 N. Branch

Air T 23.0°C

Note: stream T & sp. cond. were taken w/a YSI meter Serial # 8218

Stream Mile 9.7

pool on N. Side w/clear water T- 11.2°C Sp Cond 11500 μmhos

flow Nr S. Bank - Muddy Water

Center Channel - T 21.0°C Sp. Cond. 4320 μmhos

S. Bank T 20.2°C Sp Cond 4450

pool Just upstream T 17.0°C Sp cond 22,108 μmhos

7-1654 (7-73)
Water and Power

COMPUTATION SHEET

BY Gailbt	DATE 5/30/83	PROJECT Lake Meredith	SHEET 2 OF 12
CHKD BY	DATE	FEATURE	
DETAILS Canadian R. Stream Survey			

Stream Mile 9.5 below Ute Dam

S. Bank T 20.2°C sp Cond 4300 µmhos
cloudy water

10' from S. bank T 20.5°C sp Cond 4350 µMhos
30' from S. bank T 20.0°C sp Cond 4350 µMhos
N. side Main channel T 22.0°C sp cond 4350 µMhos
N. Channel NR N Bank T 22.0°C sp cond. 4400 µMhos
Center N. channel T 22.5°C sp Cond. 4420 µMhos

water originating fr. Sand just upstream on N. Bank
T 22.0°C sp Cond 4480 µ Mhos
Clear pool 50' upstream of section T 23.2°C sp Cond 8000 µmhos

3-4' pool 70' upstream on N Bank of section T 22.0°C sp. Cond. 7800 µmhos

Air T 22.5°C —(Thermometer)

Stream Mile 8.8

South side 200' downstream T 23.5°C Sp. Cond 4280 µMhos
South side 300' downstream in hole T 25.5 °C sp cond 16,000 µMhos

~50 ft wide Stream on N side of Channel (cottonwoods in North wash)
N. bank 6' deep cloudy water
T 23.2°C Sp. Cond. 4250

Mid Channel T 23.2°C Sp. Cond. 4200 µMhos
South bank T 23.2°C Sp. Cond. 4,300 µMhos

300 ft upstream on South Bank 26.8 °C Sp Cond 25,000 µMhos

7-1654 (7-73)
Water and Power

COMPUTATION SHEET

BY	DATE	PROJECT	SHEET 3 OF 12
CHKD BY	DATE	FEATURE	
DETAILS Canadian River Stream Survey			

Stream Mile 8.4

pool on North Bank 27.5°C Sp. Cond. 2150 µmhos

yellow growth or deposit on bottom of pool (some of the material is floating. Pool is not connected to main flow.) Cottonwoods on North Bank.

pool 200 ft upstream T 26.8°C Sp Cond 39,000 µmhos

Stream Mile 7.9

North bank (Near large rock) T 20.2 °C Sp. Cond. 4200 µMhos

20 ft from N bank T 25.0°C Sp. Cond. 4090 µmhos

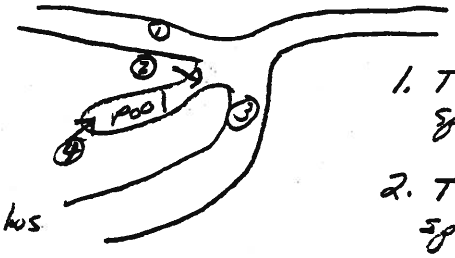
40 ft from N. bank T 16.0°C Sp. cond 4000 µmhos

S. bank T 25.0 °C Sp. cond 4190 µmhos

Air T 26°C (Thermometer)

Stream Mile 7.3

North stream of split channel (very muddy water)



4. Pool
T 28.0 °C
Sp. Cond. 14500 µmhos

1. T 25.8 °C
Sp. Cond. 4350 µMhos

2. T 25.0 °C
Sp. cond. 7900 µmhos

3. T 25.8 °C
Sp. Cond 4250 µMhos

7-1654 (7-73)
Water and Power

COMPUTATION SHEET

BY	DATE	PROJECT	SHEET 4 OF 12
CHKD BY	DATE	FEATURE	
DETAILS Canadian River Stream Survey			

Stream Mile 6.6

North side of alluvial channel

pool	T 30.0 °C	sp. cond. 42,000 μmhos

stream on south side of alluvial channel

North bank	T 28.5 °C	sp. cond. 5800 μmhos
center	T 28.2 °C	sp. cond. 4250 μmhos
South bank	T 28.2 °C	sp. cond 4210 μmhos

Stream Mile 6.2

pool South side channel	T 29.0 °C	sp. cond. 5500 μmhos
South bank	T 29.0 °C	sp cond. 28,00 μmhos
center	T 29.0 °C	sp. cond. 4,500 μmhos
North bank	T 29.0 °C	sp. cond. 4,800 μmhos

Air T 29.0 °C (Thermometer)

Stream Mile 6.1

North bank	T 28.2 °C	sp. cond. 18,300 μmhos
Middle	T 29.5 °C	sp. cond 21,800 μmhos
South bank	T 29.0 °C	sp. cond 22,200 μmhos

Mouth of Revuelto Creek (stream mile 0.1)

10 feet from west bank	29.0 °C	sp. cond 1620 μmhos
10 feet from East bank	29.0 °C	sp. cond 1630 μmhos

Revuelto creek ab Hwy 39 bridge (stream mile 2.1)

West bank	T 29.5 °C	sp. cond. 1630 μmhos
Center	T 29.5 °C	sp. cond. 1610 μmhos
East bank	T 29.5 °C	sp. cond 1580 μmhos

(Muddy water)

7-1654 (7-73)
Water and Power

COMPUTATION SHEET

BY	DATE	PROJECT	SHEET 5 OF 12
CHKD BY	DATE	FEATURE	

DETAILS Canadian River Stream Survey

Stream Mile 5.9   Canadian River 0830 local time 5/25/83

North bank   T 19.0 °C   Sp. Cond. 17,500 µmhos
Center   T 19.0 °C   Sp. Cond 17,500 µmhos
(YSI meter)

Air Temp 22.5°C (Thermometer)
red algal growth along stream edge
black material on bottom in centr stream

Pool   100 ft upstream   T 18.0°C   Sp. Cond. 19,500 µmhos

Stream Mile 5.7

5 ft from South bank
T 18.5°C   Sp. Cond. 17,500 µmhos
5 ft from N. bank   T 18.5 °C   Sp Cond. 17,500 µmhos

pool 200 ft upstream on N. bank
T 19.5 °C   Sp. Cond. 21,800

Stream Mile 5.5   Beaver lodge on North bank

Flow from N. side of channel through beaver lodge area.   T 19.5 °C   Sp. Cond 10,500 µmhos
Main Channel T 19.0 °C   Sp. Cond. 17,500 µmhos

pool S. side – Red algal growth
T 19.0 °C   Sp. Cond. 24,800 µmhos

7-1654 (7-73)
Water and Power

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DETAILS Canadian River Stream Survey

Stream Mile 5.4 (at river sampling site 3)

South bank T 19.0°C sp Cond 17,500 µmhos

pool 600 feet upstream on North Bank

T 19.5°C sp. cond. 17500 µmhos

south side of pool T 20.0°C sp cond 18100 µmhos

pool 750 feet upstream (across from irrigation pipe)

South side T 22.5°C sp. Cond. 47300 µmhos at 2 foot depth

pool ~ 60 feet long 6 feet wide ~ 3 feet deep blue-green water

stream on North side of channel T 20.2°C, sp. Cond. 18,200 µmhos

Pool 900 feet upstream on N bank - red algal growth on bottom

T 28.5°C sp. cond. 46700 µmhos

Stream at this site T 22.0°C sp. Cond. 18,500 µmhos

Stream Mile 5.2 - white deposits on soil and rocks along south bank for ~ 300 feet.

several pools on S. bank have T ~ 19.0°C sp. cond. > 50,000 µmhos

7-1654 (7-73)
Water and Power

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DETAILS Canadian River Stream Survey			

<u>Stream Mile 4.4</u>   10:45 mst

North bank   T 19 °C   sp. cond. 17,000 µmhos
center channel   T 19 °C   sp. cond. 17,000 µmhos
South bank   T 19 °C   sp cond 17,000 µmhos

pool 900 feet upstream on North bank
T 21 °C   sp. Cond 34,800 µmhos
pool 1050 feet upstream of last pool   T 19.5 °C
sp. Cond. 24,500 µmhos

<u>Stream Mile 4.1</u>   Pool N. side of channel
T 20.0 °C   sp. cond. 29500 µmhos
North side stream 50 feet south of pool
T 22.0 °C   sp. cond. 15,200 µmhos
center   T 20.0 °C (1 foot deep)   sp. Cond. 15100 µmhos
south side (2 feet deep)   T 20.0 °C   sp. cond. 15,000 µmhos

<u>Stream Mile 3.5</u>   gravel in channel (placed for telephone line)
center channel — T 25.0 °C   sp. Cond 13,500 µmhos
North side 50 feet upstream   T 25.0 °C   sp. Cond 18,000 µmhos
South side — T 25.0 °C   sp. cond 8,100 µmhos

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DETAILS Canadian River Stream Survey

225 feet upstream Stream Mile 3.5

Center	T 25.0°C	sp. Cond. 14,300
S. Side	T 25.0°C	Sp. Cond. 14,000
N. Side	T 26.0°C	Sp. cond. 14,500

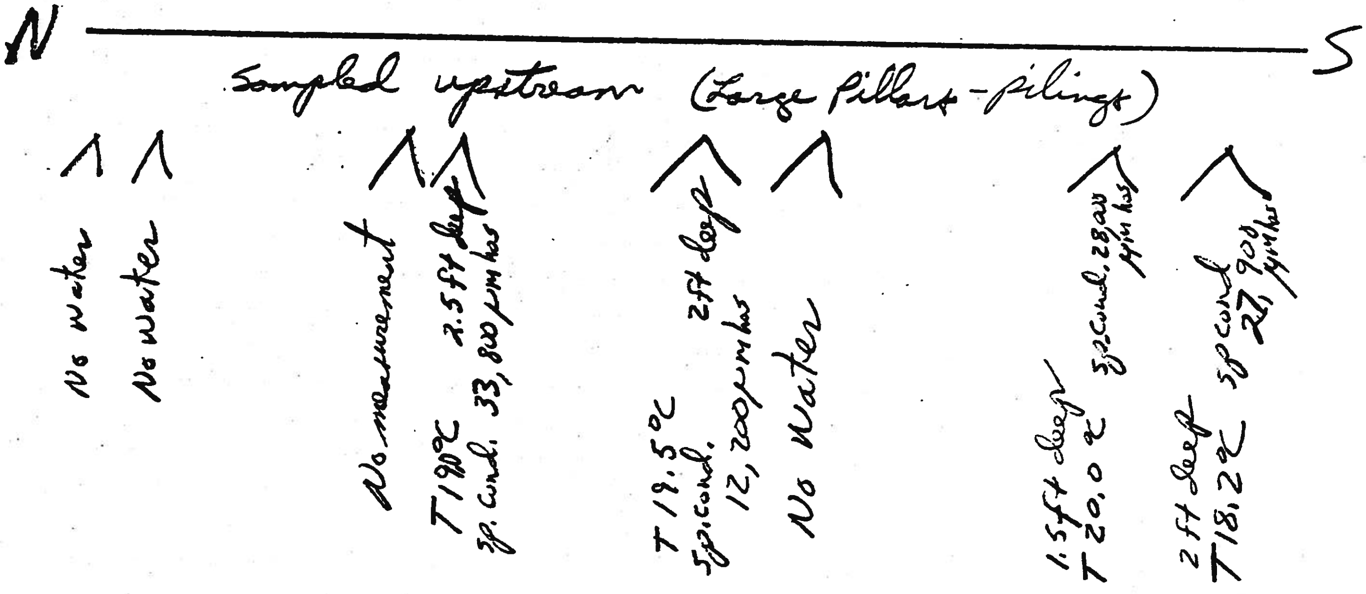
Stream Mile 3.2

40 feet downstream of Rail Road bridge

N. bank	T 24.5°C	Sp. Cond. 12200 µmhos
Center	T 24.5°C	Sp. cond. 13,000 µmhos
S. bank	T 25.0°C	Sp. Cond 13,500 µmhos

Pool – 900 feet upstream from stream Mile 3.2 on south side. Sp. cond. +50,000 µmhos

Rail Road bridge



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Water and Power

COMPUTATION SHEET

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DETAILS Canadian River Stream Survey			

Stream mile 2.8

N. Side T 24.8 °C sp. cond. 11,900 μmhos

Center T 24.8 °C sp. cond. 12,100 μmhos

S. Side T 24.8 °C sp. cond 12,100 μmhos

White deposits on rocks on South bank

Stream Mile 2.2 – (Sample site 2)

river stage 1.02

T 27.0 °C sp cond 10,400 μmhos

Stream Mile 2.0

Pool between Hwy 56 bridge and U.S.G.S. gauge site. Pool not connected to river.

T 27.0 °C sp. cond. 12500 μmhos

River north side T 30.0 °C sp. cond. 11500 μmhos

River south side T 30.0 °C sp. cond 9500 μmhos

Stream Mile 1.9 – River at U.S.G.S. gauge site.

North side T 29.5 °C sp. cond. 11000 μmhos
South side T 29.5 °C sp. cond 11000 μmhos

Stream Mile 1.6 – (Sampling site 1)

North side – T 29.5 °C sp cond 10,700 μmhos
South side – T 30.0 °C sp. cond 9400 μmhos

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Stream Mile 1.4

Pool connected to river upstream from sampling site 1
T 29.5°C   Sp. Cond. 11000 µmhos

Stream Mile 1.3 – River w/ cliff on east side

Northside   T 32.0 °C   Sp. Cond. 10800 µmhos
South side   T 32.0 °C   Sp. Cond. 11200 µmhos

Stream Mile 1.2

Pool connected to stream
T 33.0 °C   Sp. Cond. 15100 µmhos
River right above pool
T 320 °C   Sp. Cond. 10900 µmhos

Stream Mile 1.1   River – below fallen rock – below tallest cliff.

Southside   T 30.0 °C   Sp. Cond. 9800 µmhos
Middle   T 23.5 °C   Sp. Cond 9700 µmhos

Stream Mile 0.9 – at wide section below dam

N side   T 24.0 °C   Sp. Cond. 7200 µmhos
Middle   T 24.0 °C   Sp. Cond. 7200 µmhos
S. side   T 27.0 °C   Sp. Cond 5000 µmhos

Stream Mile 0.8 – River – wide cliffs on North

Measurement taken south side. Springs on north side.
Many cattails
T 27.0 °C   Sp. Cond. 7000 µmhos

7-1654 (7-73)
Water and Power

COMPUTATION SHEET

BY	DATE	PROJECT	SHEET 11 OF 12
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DETAILS Canadian River Stream Survey			

5/26/83 0630 MDT

Air T 16.0°C (Thermometer)

Stream Mile 0.5

S. side channel	T 21.5°C	sp. Cond. 15,400 µMhos
middle	T 18.0°C	sp. Cond. 5400 µMhos
N. side	T 19.0°C	sp Cond. 12500 µMhos

greenish, slightly cloudy water, ~5 feet deep near N. bank

upstream by big rock (in middle) bottom – sp. cond. 5000 µMhos
T 17.9°C

Stream Mile 0.4

S. bank	T 17.5°C	sp. Cond. 5500 µMhos
Center	T 18.0°C	sp. Cond. 5000 µMhos
N. bank	T 18.3°C	sp. Cond. 4800 µMhos

below riffle water greenish fairly clear

Stream Mile 0.35

Beaver Dam in centr channel
stream 1.5' deep – mostly cattails
T 19.0°C sp. Cond 3700 µmhos

Puddle @ N. bank T 18.5°C sp Cond. 3750 µMhos
~1 ft under surface

Stream Mile 0.3 Seep @ Toe (pond) of outlet works
at base of spillway – water milky
color in pond

T 18.5°C Sp Cond 1050 µmhos

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Water and Power

COMPUTATION SHEET

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DETAILS Canadian River Stream Survey			

Stream Mile 0.15 – Ponded area below discharge pipes – ~~deep~~ water – sedges + cattails on bank T 15.0°C
Sp. Cond. 2500 μmhos

Stream Mile 0.1 – discharge pipe from dam underdam drains
T 15.0°C Sp. Cond. 2400 μmhos

7:45 MDT air temp. 19.5°C

ATTACHMENT C -

TRITIUM ANALYSIS, EXPLORATORY WELL OW-3

HYDRO GEO CHEM, INC.

Groundwater Consultants

1430 N. Sixth Avenue
Tucson, Arizona 85705
(602) 623-6981

11 June 1984

Mr. Gary Gaillot
U.S. Bureau of Reclamation
714 S. Tyler, Suite 216
Amarillo, Texas 79101

Dear Gary,

Attached is the analysis for tritium from well OW-3. A value of zero tritium indicates both that the sample was not contaminated during sampling, and that the sources of water that make up the "shallow brine aquifer" have long flow paths. This does not alter the conclusions we made regarding mixing and water types (on pages 93-95 of the final report). However, it shows that OW-3 water is not comprised of any modern water such as that from Ute Reservoir or from recent recharge.

Please call if you would like to discuss the meaning of these isotopic values further. Would you append this analysis to copies of the final report? Thanks.

Sincerely yours,

John J. Ward
Project Chief

Attachment

NEW MEXICO INSTITUTE
OF MINING AND TECHNOLOGY
DEPARTMENT OF GEOSCIENCE

SOCORRO 87801
505-835-563

June 5, 1984

Mr. John J. Ward
Hydrogeologist
Hydro Geo Chem., Inc.
744 N. Country Club
Tucson, AZ 85716

Dear Mr. Ward:

Your groundwater sample yielded the following tritium activity:

Lab #3333....Corrected to 10-17-83....-2.3 +/- 0.5 TU

The sample does not contain measureable tritium activity.

Yours sincerely,

Gerardo Wolfgang Gross.

Gerardo Wolfgang Gross
Professor of Geophysics

GWG/jm

ATTACHMENT D -

ELECTRICAL SURVEYS USEFUL TO DEFINE THE BRINE ARTESIAN AQUIFER

602.

CANADIAN RIVER

HYDRO GEO CHEM, INC.

Groundwater Consultants

1430 N. Sixth Avenue
Tucson, Arizona 85705
(602) 623-6981

September 27, 1984

OCT 1 1984

CODE	OUT	INITIAL
700		
720		
250		
810		
931		

Mr. Gary Gaillot
U.S. Bureau of Reclamation
714 South Tyler
Amarillo, Texas 79101

Dear Gary:

Upon your request, I have written a description of the electrical exploration techniques that should be useful to examine the subsurface distribution of brine in the Canadian River system. This work will complement that done by the Bureau of Reclamation in 1975 and be a logical extension of the hydrogeological work done to date. The enclosed write-up was initially included in the geophysical study, but we believe that it is more appropriate to send it under seperate cover.

Hydro Geo Chem is presently involved in a CSAMT study and we hope to have a full complement of computer modeling programs and analytic techniques for the method by this fall. We also have a numerical inversion program for Schlumberger vertical electrical sounding interpretation. Overall, we are expanding our geophysical efforts and are interested in working with the Bureau of Reclamation in conducting and interpreting surveys for the salinity project.

Please feel free to call if you have any further questions.

Sincerely yours,

Jay Jones

Jay Jones

Enclosure

cc: John Ward

ELECTRICAL SURVEYS USEFUL TO IDENTIFY THE BRINE AQUIFER

Brine entering the Canadian River near Logan originates from dissolution of underlying Permian evaporite deposits. It travels upward through an ill-defined fracture network to the Tertiary Dockum Group sandstones and eventually into the river sediments. An aquifer has been tentatively defined that acts to store the brine. Delineation and monitoring of the brine aquifer is of major importance to the overall scheme of salinity control.

Information regarding the extent and water chemistry of the brine aquifer is primarily from a drilling and hydraulic testing program near and in the Canadian River conducted by the Bureau of Reclamation, and from Schlumberger Vertical Electrical Sounding (VES) data and seismic refraction surveys performed by the Bureau of Reclamation in 1975 (U.S. Bureau of Reclamation, 1976). More geophysical data may be required to adequately delineate this aquifer. Therefore, by request of the Bureau of Reclamation, we have prepared the following description of electrical exploration techniques that we believe may be useful to map the aquifer. The contrast between saltwater and freshwater offers a strong electrical contrast, so we are emphasizing the use of electrical surveys as a cost-effective exploration technique.

DIRECT CURRENT (DC) TECHNIQUES

A limited program of Schlumberger VES has been conducted near Logan. The results showed that a low resistivity zone could be identified within the Dockum Group sediments and a recommendation of further VES and seismic refraction surveys was made. However, no further surveys have been conducted.

Interpretation and field collection of VES data are hindered in the case where lateral variations or rough topography exists. At Logan, both conditions occur and the USBR survey results were useful, although laterally limited. The principal advantage of electromagnetic (EM) soundings is that depth soundings several times the receiver/transmitter spacings can be achieved, in contrast to DC techniques which require electrode spacings 5 - 6 times the depth of penetration. Hence, the necessary array sizes are reduced and lateral restrictions can be minimized. Because of this, we recommend that EM probing techniques be used.

ELECTROMAGNETIC (EM) TECHNIQUES

A more promising approach to the delineation of the brine aquifer is the use of either time or frequency domain electromagnetic exploration methods. Time domain methods (TDEM) examine the temporal response of inductive currents produced by a pulsed EM wave. These methods are relatively new, but have been well-received by explorationists. Frequency domain (FEM) equipment, on the other hand, work by using a fixed series of transmission frequencies and the depth of investigation increases with decreasing frequency. Both types of exploration tools may be applicable to the study of the brine aquifer and are briefly described in the following sections. McNeill (1980) provides a lucid explanation of the theoretical background of the techniques.

Time Domain

Over the past few years there has been a dramatic surge of interest in time-domain EM exploration techniques. A recent special issue of Geophysics (v. 49, no. 7, July, 1984) was devoted to these techniques. In application, a transmitter loop is placed on the ground which provides a pulsed EM signal. A coincident loop within the transmitter loop, or a mobile receiver loop, is used to pick up the transient signal pulse that occurs in response to shutting off the transmitted signal. Two types of measurements are made, depending on the type of survey in use. A low-frequency pulse can be sent into the earth and the induced electrical current that results after the current is turned off is measured. This is referred to as a transient EM survey. A second, less used technique consists of transmitting a series of pulsed signals (transient soundings) over a range of frequencies. Because of a lack of commercially available transient sounding equipment, the following discussion concentrates upon the inductive technique.

Large fixed-loop systems commercially in use include the Geonics EM-37 (Geonics Ltd., Missisauga, Ontario), the Crone PEM (Crone Geophysics, Missisauga, Ontario), the SIROTEM system (Commonwealth Scientific Instrument Research Organization (CSIRO), Australia), and the UTEM III (Lamontague Geophysics, Toronto). There are a number of contractors available that advertise in Geophysics magazine or can be found in the Geophysical Directory, published by the Society of Exploration Geophysicists.

The advantage of the TDEM methods is that they are highly portable, require 2 to 3 people for operation, and have a sufficient depth of investigation for this application. Data interpretation is based upon numerical modeling or theoretical type-curves. The data processing and collection technology is being improved quite rapidly.

Frequency Domain

Non-pulsed, constant fixed frequency transmission of EM energy over a series of set frequencies is the basis of FEM exploration. The most commonly used deep-penetrating technique is the Controlled Source Audio-Frequency MagnetoTelluric (CSAMT) method. A long grounded wire (electric dipole) transmitter antenna is established at a distance from the exploration area. A roving receiver is used in the target area that measures the electric and magnetic fields of the signal that passes into the ground at the measurement point. This measurement, over a range of frequencies, relates to the underlying structure of the ground. Again, like TDEM methods, the measurements can be performed efficiently in the field. Data processing and interpretation procedures are similar in method as well.

Previous application to mapping saltwater-freshwater interfaces is most common in studies of coastal aquifers. TDEM and DC techniques have been used with success to both locate and monitor brine interfaces. Coastal exploration case histories include Fittermon and Hoekstra (1984), Stewart and Gay (1983), and Flathe (1967). The CSAMT technique has been used to map brine pockets at the Waste Isolation Pilot Plant (WIPP) site in southeastern New Mexico (Bartel and others, 1983). This study showed that the FEM technique was sensitive to the lateral variation in electrical conductivity produced by the presence or absence of brine.

In conclusion, the identification and location of brine in the subsurface near Logan, New Mexico should be feasible using electrical exploration techniques. Structural complications are not apparent from the subsurface mapping. Therefore, as was initially advised by the USBR geophysical survey report of 1976, it is recommended that further surveys be implemented to detail the aquifer responsible for delivering brine into the Candian River.

REFERENCES

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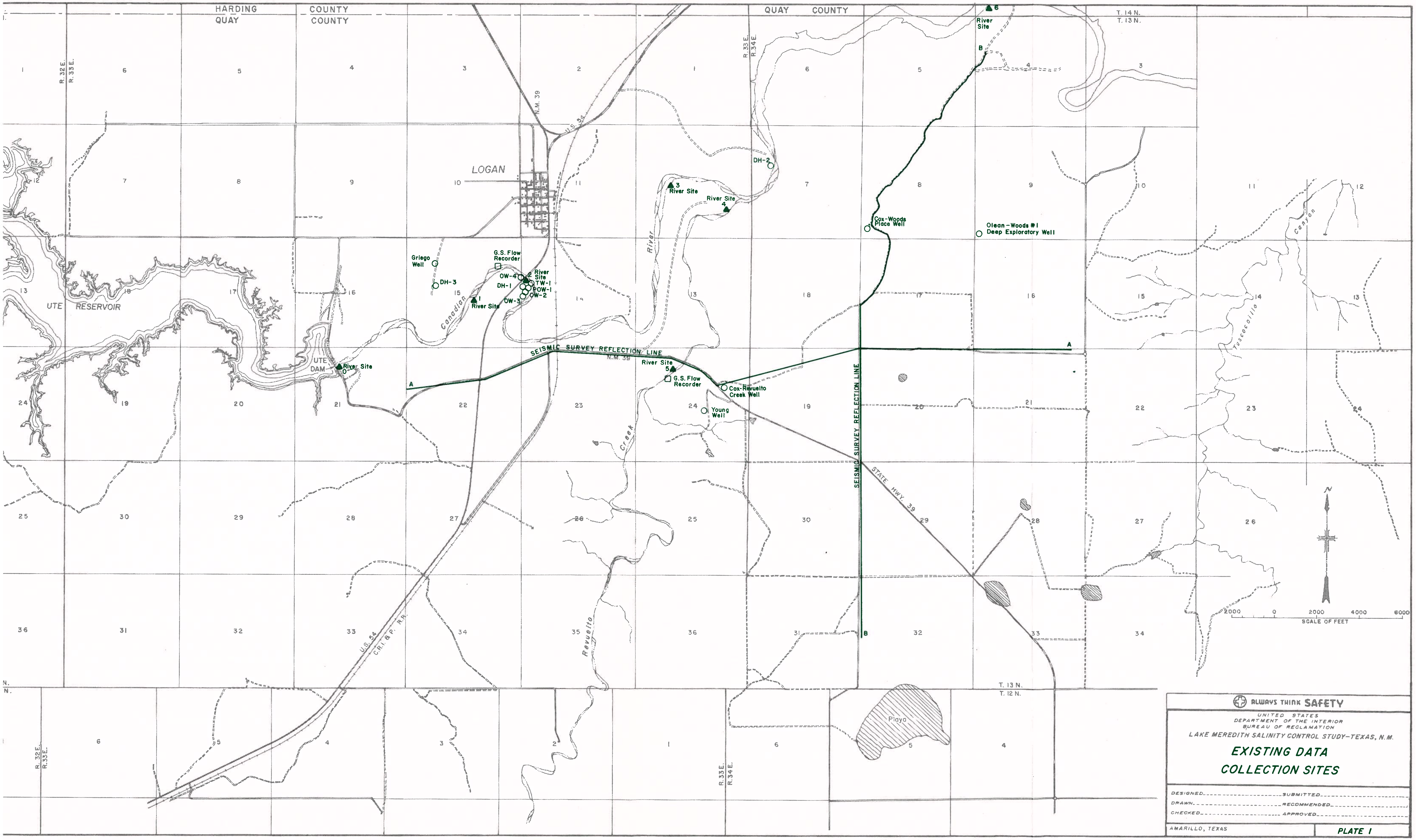
Stewart, M. T., and M. C. Gay, 1983, Evaluation of transient electromagnetic soundings for deep detection of salt-water interfaces. Florida Water Resources Research Center, Pub. 73, Gainesville, FL, 47 p.

U.S. Bureau of Reclamation, 1976, Report on electrical resistivity and seismic refraction surveys, Canadian River, Lake Meredith salinity study. USBR engineering and research center.



ALWAYS THINK SAFETY

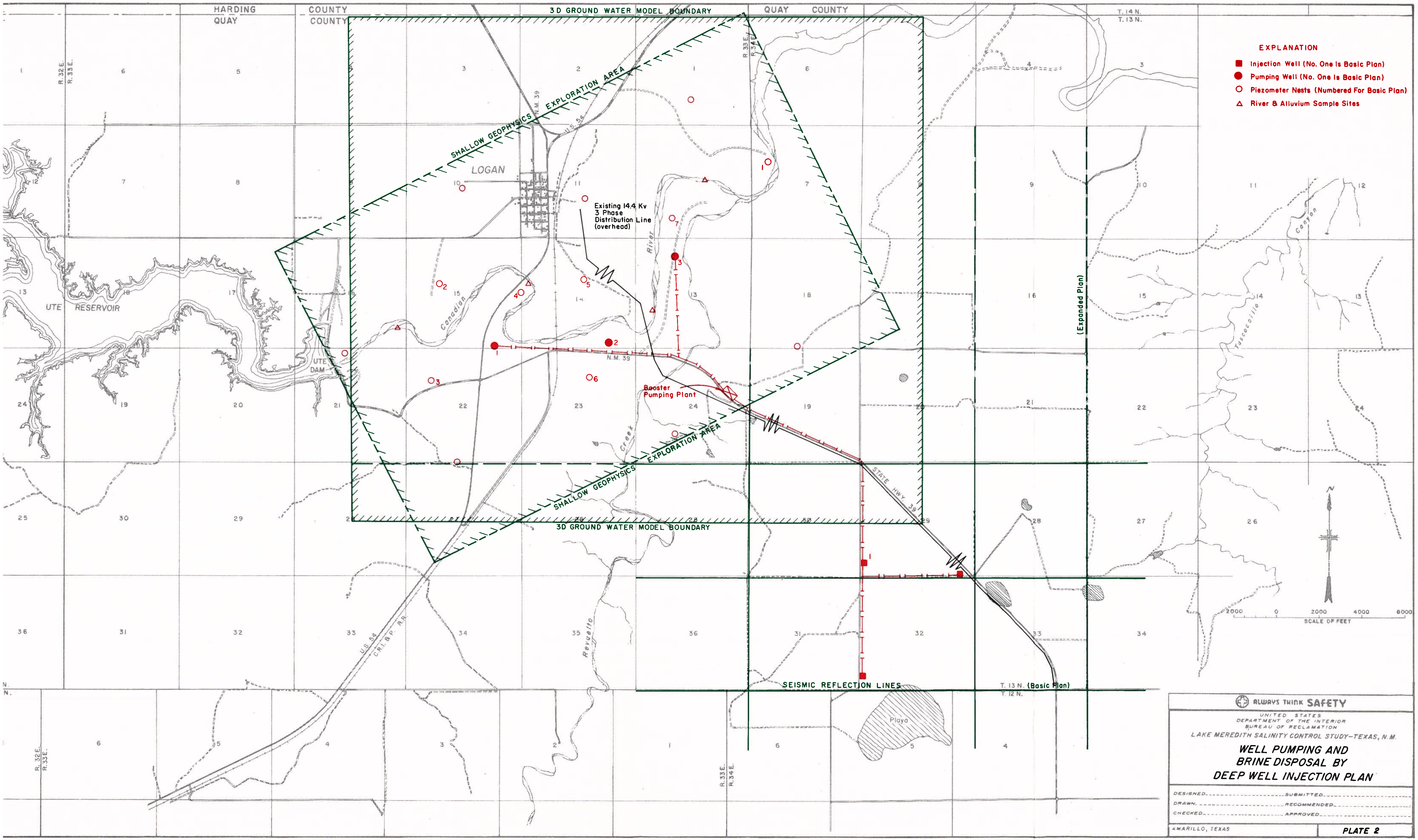
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
LAKE MEREDITH SALINITY CONTROL STUDY—TEXAS, N.M.

EXISTING DATA COLLECTION SITES

DESIGNED............................ SUBMITTED............................
DRAWN............................ RECOMMENDED............................
CHECKED............................ APPROVED............................

AMARILLO, TEXAS

PLATE I



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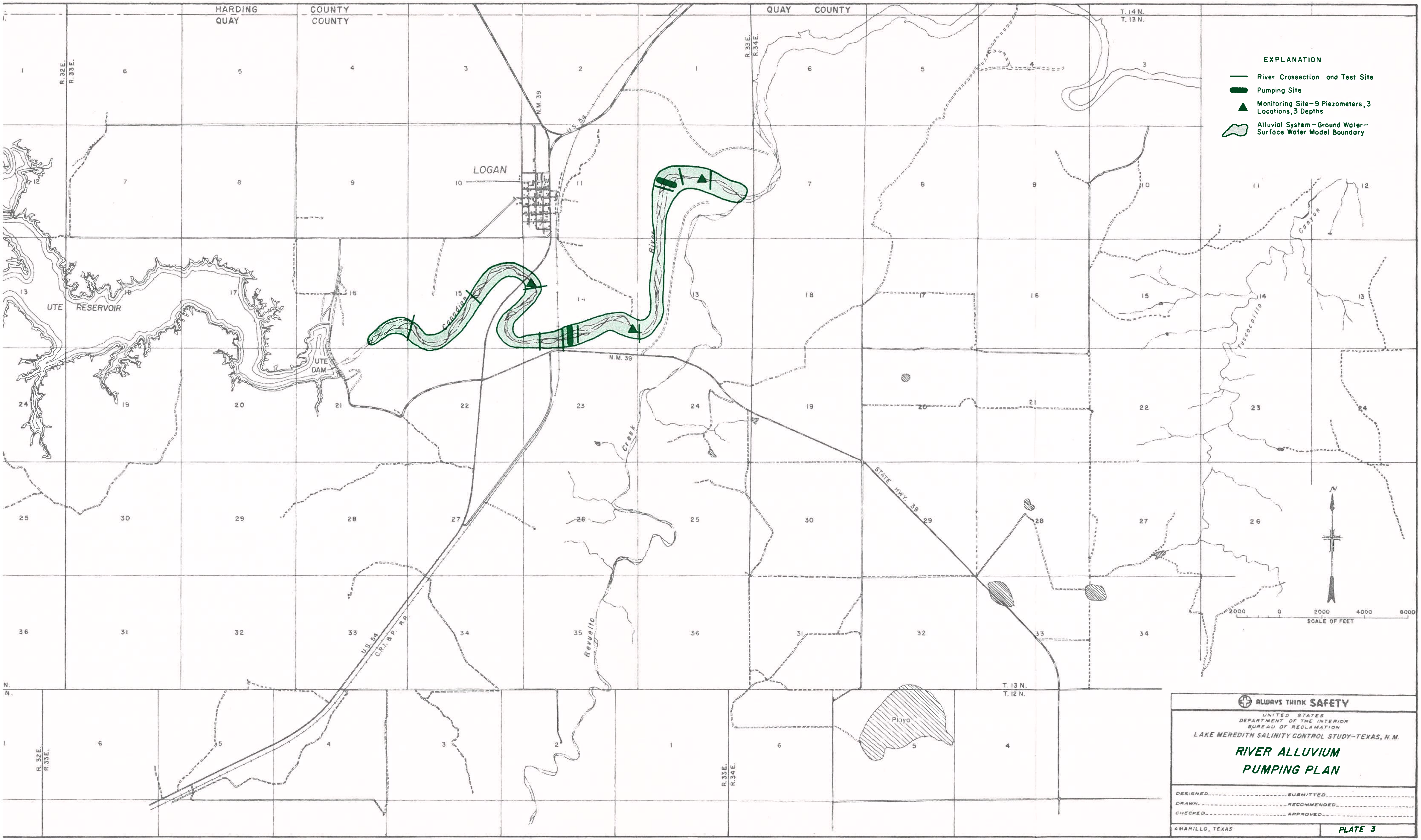
BUREAU OF RECLAMATION
LAKE MEREDITH SALINITY CONTROL STUDY–TEXAS, N.M.

**WELL PUMPING AND
BRINE DISPOSAL BY
DEEP WELL INJECTION PLAN**

DESIGNED.................... SUBMITTED....................
DRAWN.................... RECOMMENDED....................
CHECKED.................... APPROVED....................

AMARILLO, TEXAS

PLATE 2



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BUREAU OF RECLAMATION
LAKE MEREDITH SALINITY CONTROL STUDY–TEXAS, N.M.

RIVER ALLUVIUM
PUMPING PLAN

DESIGNED............ SUBMITTED............
DRAWN............ RECOMMENDED............
CHECKED............ APPROVED............

AMARILLO, TEXAS

PLATE 3