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VERDI ISDS TRACER STUDY

JULY 1985



WASHOE COUNTY



DEPARTMENT OF COMPREHENSIVE PLANNING

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TO: JOHN PRESCO
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I'VE CHECKED WITH OUR
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NOT HAD ANYONE REQUEST A
COPY OF THIS REPORT. IT
LOOKS LIKE I DIDN'T MAKE
THE "BEST SELLER LIST".

Don



VERDI ISDS TRACER STUDY

JULY 1985

This document was prepared for the Washoe Council of Governments by the Washoe County Department of Comprehensive Planning.

Funding for this investigation has been provided by Washoe County and the Division of Environmental Protection, State of Nevada Department of Conservation and Natural Resources, through a grant from the U. S. Environmental Protection Agency under Public Law 92-500, Section 205j.

This document is available for \$5.00 from the Washoe County Department of Comprehensive Planning.

FIRST PRINTING, DECEMBER 1985

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SUMMARY

The Truckee River provides more than 80 percent of the municipal water supply for Sierra Pacific Power Company which is the primary water utility in Reno and Sparks. Nondegradation water quality standards have been set for the Truckee River upstream of Reno, reflecting its use for the Reno/Sparks municipal supply and for recreational uses. Existing residential development in Verdi depends primarily upon domestic wells for water supply and Individual Sewage Disposal Systems (ISDS) for wastewater treatment and disposal. At the present time, approximately 600 housing units exist in the Verdi area. The Verdi Area Plan, adopted by the Washoe County Planning Commission and Board of County Commissioners earlier this year, indicates a potential for approximately 3000 dwelling units in the Verdi area (including Verdi, California).

The contamination of shallow groundwater by ISDS effluent in the Verdi area was recognized in 1935 by the Nevada State Department of Health. A United States Geological Survey (USGS) study attributed the bacterial contamination of the groundwater to septic tanks, cesspools, and outhouses. To provide additional information for management of the Verdi area and Truckee River water resources, the Verdi ISDS Tracer Study was proposed to the Nevada Division of Environmental Protection.

The use of tracers was chosen as the method to investigate the groundwater flow system in the Verdi area. Tracers can provide an approximate indication of groundwater velocity, dilution effects, and flow direction. Two tracers were chosen for use in this study. The bromide ion was selected as the primary tracer for the study. Rhodamine WT was used to determine the monitoring program for the bromide tracer. To facilitate the tracer experiments, public cooperation was necessary for allowing the use of sampling and injection sites. None of the residents would allow the use of their septic tanks as injection sites for the tracers. Without public cooperation, it became necessary to

utilize public facilities in the Verdi area as tracer injection sites. The Verdi Justice Court and the Volunteer Fire Department facilities were available for use by virtue of Washoe County ownership of the property.

The travel time from the point of injection to the monitoring locations was much shorter than expected. The peak concentration of Rhodamine WT occurred within the first 12 hours after injection. The bromide tracer experiment indicated a groundwater velocity of about 190 to 350 meters per day.

Many of the ISDS facilities are less than 100 meters from the Truckee River or a water supply source that is derived from the alluvial aquifer. The shorter flow paths may tend to increase the survival of pathogens in the groundwater. At a travel time of approximately four days from central Verdi to the river, time is probably not a significant factor in preventing pathogenic contamination of the river or the water supply systems that depend upon the alluvial aquifer. The pathogenic contamination noted in 1950 probably continues to this date, although it is probably not a problem to most of the present domestic wells.

Approximately 3,700 to 7,300 pounds of nitrogen and 680 to 1200 pounds of phosphorus enters the Truckee River each year as the result of the 220 residences and the natural and agricultural sources in the central Verdi area. Up to 700 pounds of the nitrogen may be from natural and agricultural sources. The flow of groundwater through the alluvial aquifer has been estimated at about 6,750 cubic meters per day (2.75 cfs). This groundwater acts to dilute the ISDS effluent in the central Verdi area. Biologic, chemical, and physical mechanisms remove or retain some of the contaminants and the remainder pass through the aquifer to the Truckee River. The limited removal of nitrogen from the effluent makes the calculation of dilution an academic exercise. Additional dwellings on ISDS systems in the central Verdi area will increase the nitrogen load to the Truckee River and result in a change in the quality of the river. Each dwelling will not result in a significant change in the groundwater quality, but the combined effect will be seen in terms of a degradation of the groundwater and surface water quality.

INTRODUCTION

The Verdi area is an unincorporated settlement along the California/Nevada border, approximately 8 miles west of Reno, Nevada. Verdi lies within Washoe County, Nevada and Sierra County, California. The Truckee River flows through Verdi before flowing on through the Reno/Sparks area.

The Truckee River provides more than 80 percent of the municipal water supply for Sierra Pacific Power Company (SPPCo) which is the primary water utility in Reno and Sparks. Three of the four SPPCo diversions are located downstream from Verdi. Nondegradation water quality standards have been set for the Truckee River upstream of Reno, reflecting its use for the Reno/Sparks municipal supply and for recreational uses.

Existing residential development in Verdi depends primarily upon domestic wells for water supply and Individual Sewage Disposal Systems (ISDS) for wastewater treatment and disposal. The water supply for portions of the Verdi area is provided by several small water utilities that use developed springs and infiltration wells as their primary sources of water. Boomtown and the Glen Meadows Subdivision have wastewater treatment facilities.

At the present time, approximately 600 housing units exist in the Verdi area. The Verdi Area Plan, adopted by the Washoe County Planning Commission and Board of County Commissioners earlier this year, indicates a potential for approximately 3,000 dwelling units in the Verdi area (including Verdi, California).

The geology of the Verdi area affects the fate and quality of ISDS effluent. The rocks exposed in the Verdi area include pre-Tertiary granitics, lake sediments and volcanic rocks of the Miocene Truckee

Formation, and volcanic rocks of post-Pliocene Age (Robinson et al., 1951). Quaternary alluvium covers most of the Truckee River terraces and the present floodplain. The Truckee Formation consists of 2,100 feet or more of diatomaceous earth, clay, sand and gravel, and a basal tuff of questionable age. In the Verdi area, the Truckee Formation contains thin seams of lignite (a form of coal). The Quaternary alluvium is approximately 7 feet to 80 feet thick in the Verdi area and consists of stream-deposited boulders, cobbles, gravel, sand, and some clay. Gravel and cobbles are predominant in the alluvium.

Groundwater flows through gravel and cobbles at a higher velocity than through sands, silts, and clays under the same hydraulic gradient. Gravel and cobbles generally have a much lower cation exchange capacity than sands, silts, or clays. The result of these differences is a lesser level of water quality protection provided by the cobbles and gravels. High velocities and minimal cation exchanges do not provide the water quality protection or enhancement provided by sands, silts, or clays.

The contamination of shallow groundwater by ISDS effluent in the Verdi area was recognized in 1935 by the State of Nevada Department of Health. After heavy rains in November and December of 1950, most of the water samples collected from wells indicated the presence of coliform bacteria. A USGS study in 1951 (Robinson et al., 1951) attributed the bacterial contamination of the groundwater to septic tanks, cesspools, and outhouses. The USGS study did not look at the chemical quality of the groundwater, since there were no adverse reports of color, odor, or taste of the water by residents.

Chemical contamination of the Verdi area groundwater resources, resulting from wastewater disposal practices, should be anticipated as a counterpart of the bacterial contamination. The conditions which allow bacterial contamination are generally favorable to chemical contamination. A spring discharge of approximately 2 cubic feet per second (cfs) flows to the Truckee River from the shallow groundwater system in the alluvium. If chemical contamination of groundwater results from wastewater disposal practices in the Verdi area, the quality of the Truckee River will be affected by the discharge of springs.

Excessive concentrations of iron, manganese, and arsenic have been found in some wells drilled into the volcanic rocks on the north side of the Truckee River. The highest arsenic concentrations are in some of the domestic wells in Verdi, California, at about 3 milligrams per liter (mg/l). The drinking water standard for arsenic is 0.05 mg/l.

To provide additional information for management of the Verdi area and Truckee River water resources, the Verdi ISDS Tracer Study was proposed to the Nevada Division of Environmental Protection. The goals of the study are:

1. To measure travel time from septic tanks to the groundwater system and to the Truckee River as an indicator of potential viral and bacterial contamination;
2. To determine the approximate quantity of nitrogen and phosphorus entering the Truckee River as the result of ISDS systems and agricultural land uses;
3. To determine if ISDS effluent is intercepted by domestic wells in the Verdi area;
4. To determine the dilution of ISDS effluent by the groundwater system; and
5. To obtain information that may be used to assess the need for a wastewater collection and treatment system.



TRACER EXPERIMENTS

The use of tracers was chosen as the method to investigate the groundwater flow system in the Verdi area. Tracers can provide an approximate indication of groundwater velocity, dilution effects, and flow direction. Tracers do not behave exactly like water or the contaminants found in water. The chemical and physical properties of tracers affect their transport through an aquifer system. Tracers move through an aquifer as the result of hydrodynamic dispersion and molecular diffusion. Both of these processes are affected by the chemical and physical properties of the tracers.

An ideal tracer is one that moves through an aquifer with the same velocity as the water. Unfortunately, an ideal tracer does not exist. Tritiated water (HTO) is nearly an ideal tracer, although it is more dense than water and it is subject to radioactive decay. Other tracers are less ideal in their chemical properties. Another practical limit of the use of a tracer is the natural background concentration of the tracer in the system to be studied. High background concentrations can mask the added tracer and alter the molecular diffusion of the tracer in the aquifer.

Two tracers were chosen for use in this study. The bromide ion was selected as the primary tracer for the study. Rhodamine WT was used as a preliminary tracer to determine the monitoring program for the bromide tracer.

Natural background concentrations of bromide are low in most groundwater systems. In the Verdi area, the background concentration of bromide is less than 0.05 mg/l. As an anion, bromide is not directly affected by cation exchanges. Most salts containing the bromide ion are soluble. The silver and mercury salts containing bromide are only slightly soluble. These chemical properties result in a tracer that is

conservative in most natural groundwaters and that moves at a rate closely approximating the groundwater velocity.

Rhodamine WT is a synthetic organic compound that is detectable by sight at concentrations of about 0.1 mg/l. The physical properties of Rhodamine WT allow it to bind to numerous substances. It is not conservative in most natural systems and is difficult to use for precise quantitative determinations. The advantage of Rhodamine WT is its fluorescence when exposed to ultraviolet light. This allows the use of a portable fluorometer to make quantitative measurements of its concentration and to adjust the sampling schedule in the field. Rhodamine WT may be detected at a concentration of 0.01 parts per billion (ppb) using a portable fluorometer.

To facilitate the tracer experiments, public cooperation was necessary for allowing the use of sampling and injection sites. In August 1983, a letter was sent to all of the Verdi residents requesting the use of their wells and septic tanks for the tracer study. A poster was placed in several prominent locations in Verdi requesting cooperation from the residents. Fifteen residents responded to the letters and posters and offered their wells for sampling. None of the residents would allow the use of their septic tanks as injection sites for the tracers. More than half of the residents responding to the request for assistance were California residents seeking a free water analysis for arsenic.

The lack of sufficient volunteers resulted in a modification to the planned design of the tracer experiments. Without public cooperation, it became necessary to utilize public facilities in the Verdi area as tracer injection sites. The Verdi Justice Court and the Volunteer Fire Department facilities were available for use by virtue of Washoe County ownership of the property. These public facilities were used as the tracer injection sites. The modification of the experiment design to limit the injection sites to the public facilities also improved the ability to analyze the data.

RHODAMINE WT :

As a preliminary test to design the monitoring program for the use of a bromide ion tracer, Rhodamine WT was injected into the septic tank

at the Verdi Volunteer Fire Department (VFD). Prior to the injection of any tracers, field measurements of fluorescence were made at 11 sampling sites. The background fluorescence was not significant. Several small doses of Rhodamine WT were used initially to determine the ability to detect Rhodamine WT in spring samples. On November 15, 1983 a 2.0 liter dose of 20 percent Rhodamine WT solution was injected into the VFD septic system and the system was flushed with 140 gallons of water.

Following the injection of the Rhodamine WT, 41 field measurements of fluorescence were made on November 15. A Turner Designs Model 10 Fluorometer was used to monitor the Rhodamine WT concentrations. The monitoring continued on through November 22. Table 1 (pages 10-13) lists the concentration of Rhodamine WT at the various sampling points shown in Figure 1 (page 8). The monitoring sites were chosen on the basis of the direction of groundwater flow as indicated by the elevation of the water table and access to the sites.

The travel time from the point of injection to several of the monitoring locations was much shorter than expected. The peak concentration of Rhodamine WT occurred within the first 12 hours after injection. Figure 2 (page 9) shows the Rhodamine WT concentrations at sites S2 and S3, approximately 250 meters from the injection point. The short travel time indicates a groundwater velocity on the order of 500 meters per day. The actual velocity is probably less, since sites S2 and S3 are sampling points along a flowing stream and the travel time may be partially a function of the travel through the stream.

SODIUM BROMIDE

The original project proposal indicated the use of 50 to 100 septic systems for sodium bromide injection. If the original plan was to be followed, the injections would need to take place during a short period of time. A period of one to two hours would be the maximum amount of time that could be tolerated for the dosing of the septic tanks. If 50 systems were to be dosed in a period of two hours, 12 or more technicians would be required to distribute and inject the sodium bromide. This method of injection was not used because of the lack of sufficient public cooperation.

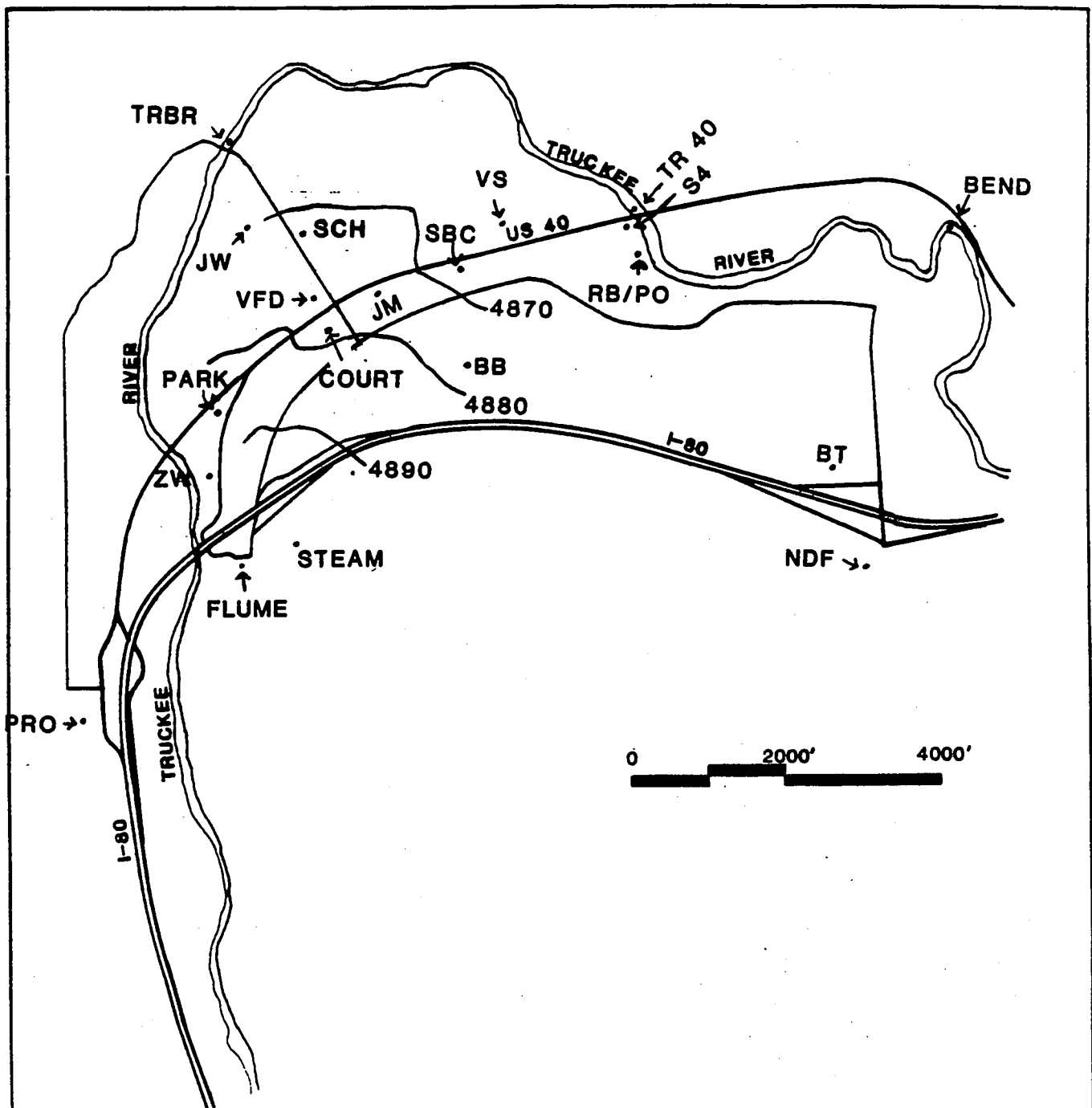
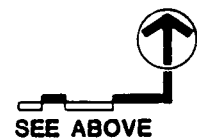


FIGURE 1
STUDY AREA

- Sampling Site
- ~ Water Table Contours Elevation Ft. MSL



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Table 1
RHODAMINE WT DATA

DATE	TIME	SITE	FLUOR	ppb	DAY
02 Nov 83	-	COURT	1.0	0.013	-
07 Nov 83	11.50	COURT	1.0	0.013	-7.98
09 Nov 83	11.50	COURT	0.7	<0.010	-5.98
14 Nov 83	9.85	COURT	1.0	0.012	-1.05
15 Nov 83	10.66	COURT	0.8	0.010	-0.01
16 Nov 83	10.58	COURT	0.8	0.010	0.98
21 Nov 83	13.60	COURT	0.9	0.012	6.11
22 Nov 83	10.33	COURT	0.7	<0.010	6.97
02 Nov 83	-	FLUME	0.7	<0.010	-
07 Nov 83	11.50	FLUME	1.5	0.019	-7.98
14 Nov 83	10.15	FLUME	0.8	0.010	-1.04
15 Nov 83	10.57	FLUME	0.9	0.012	-0.02
15 Nov 83	16.08	FLUME	1.2	0.015	0.21
16 Nov 83	8.25	FLUME	0.5	<0.010	0.89
16 Nov 83	11.05	FLUME	0.5	<0.010	1.00
17 Nov 83	11.48	FLUME	7.0	0.077	2.02
18 Nov 83	11.25	FLUME	1.1	0.014	3.01
02 Nov 83	-	JM	0.5	<0.010	-
14 Nov 83	10.00	PARK	0.4	<0.010	-1.04
07 Nov 83	11.50	S1	10.0	0.108	-7.98
07 Nov 83	11.50	S1E	25.0	0.252	-7.98
09 Nov 83	11.50	S1E	1.3	0.016	-5.98
09 Nov 83	12.50	S1E	0.8	0.010	-5.94
09 Nov 83	13.25	S1E	1.7	0.020	-5.91
10 Nov 83	9.66	S1E	0.9	0.012	-5.06
14 Nov 83	9.92	S1E	1.8	0.021	-1.04
15 Nov 83	10.42	S1E	1.1	0.014	-0.02
15 Nov 83	11.60	S1E	1.9	0.023	0.03
15 Nov 83	11.65	S1E	2.3	0.028	0.03
15 Nov 83	12.80	S1E	2.1	0.025	0.08
15 Nov 83	15.50	S1E	3.1	0.036	0.19
15 Nov 83	18.10	S1E	3.2	0.038	0.30
15 Nov 83	21.85	S1E	1.0	0.012	0.45
15 Nov 83	23.66	S1E	0.7	<0.010	0.53
16 Nov 83	7.46	S1E	0.8	0.010	0.85
16 Nov 83	10.66	S1E	1.1	0.014	0.99
16 Nov 83	11.88	S1E	1.0	0.013	1.04
16 Nov 83	15.57	S1E	0.9	0.012	1.19
17 Nov 83	11.15	S1E	11.4	0.122	2.01
18 Nov 83	10.93	S1E	1.5	0.019	3.00
21 Nov 83	13.56	S1E	1.1	0.014	6.11
02 Nov 83	10.36	S1E	0.8	0.010	6.97
02 Nov 83	-	S2	1.1	0.014	-
07 Nov 83	11.50	S2	15.0	0.157	-7.98
09 Nov 83	11.50	S2	1.3	0.016	-5.98
15 Nov 83	13.00	S2	1.0	0.012	0.08
15 Nov 83	15.80	S2	28.0	0.280	0.20
15 Nov 83	18.34	S2	33.0	0.326	0.31

Table 1 (continued)
RHODAMINE WT DATA

DATE	TIME	SITE	FLUOR	ppb	DAY
15 Nov 83	22.08	S2	5.1	0.057	0.46
15 Nov 83	23.85	S2	8.5	0.093	0.54
16 Nov 83	7.60	S2	1.9	0.023	0.86
16 Nov 83	10.86	S2	1.7	0.021	0.99
16 Nov 83	11.80	S2	1.3	0.016	1.03
16 Nov 83	15.80	S2	1.1	0.014	1.20
18 Nov 83	11.08	S2	1.8	0.022	3.00
21 Nov 83	13.79	S2	1.2	0.015	6.12
22 Nov 83	10.57	S2	1.0	0.012	6.98
02 Nov 83	-	S3	0.9	0.012	-
07 Nov 83	11.50	S3	34.5	0.340	-7.98
09 Nov 83	11.50	S3	9.5	0.102	-5.98
09 Nov 83	12.50	S3	1.9	0.023	-5.94
09 Nov 83	13.00	S3	12.6	0.134	-5.92
09 Nov 83	13.15	S3	6.3	0.071	-5.91
10 Nov 83	9.57	S3	1.1	0.014	-5.06
10 Nov 83	10.15	S3	1.1	0.014	-5.04
14 Nov 83	9.75	S3	1.9	0.023	-1.05
15 Nov 83	10.40	S3	1.1	0.014	-0.02
15 Nov 83	11.77	S3	1.3	0.016	0.03
15 Nov 83	12.94	S3	1.6	0.019	0.08
15 Nov 83	15.70	S3	43.0	0.417	0.20
15 Nov 83	15.73	S3	15.8	0.165	0.20
15 Nov 83	16.00	S3	1.9	0.023	0.21
15 Nov 83	18.25	S3	27.0	0.271	0.30
15 Nov 83	18.30	S3	23.0	0.234	0.30
15 Nov 83	22.00	S3	42.0	0.408	0.46
15 Nov 83	22.15	S3	1.9	0.023	0.46
15 Nov 83	23.80	S3	1.5	0.019	0.53
15 Nov 83	23.92	S3	1.3	0.016	0.54
16 Nov 83	7.55	S3	7.3	0.080	0.86
16 Nov 83	7.66	S3	7.6	0.084	0.86
16 Nov 83	8.07	S3	6.3	0.071	0.88
16 Nov 83	10.80	S3	1.9	0.023	0.99
16 Nov 83	11.78	S3	1.1	0.014	1.03
16 Nov 83	15.75	S3	1.1	0.014	1.20
17 Nov 83	11.25	S3	9.5	0.103	2.01
18 Nov 83	11.06	S3	1.7	0.021	3.00
21 Nov 83	13.75	S3	1.2	0.015	6.11
22 Nov 83	10.54	S3	1.0	0.012	6.98
07 Nov 83	11.50	S3W	66.0	0.621	-7.98
09 Nov 83	11.50	S3W	1.0	0.013	-5.98
09 Nov 83	13.33	S3W	1.6	0.019	-5.90
15 Nov 83	11.68	S3W	1.3	0.016	0.03
15 Nov 83	12.93	S3W	1.1	0.014	0.08
15 Nov 83	15.66	S3W	1.7	0.020	0.19
15 Nov 83	18.20	S3W	1.5	0.019	0.30
15 Nov 83	21.93	S3W	1.1	0.014	0.46

Table 1 (continued)
RHODAMINE WT DATA

DATE	TIME	SITE	FLUOR	ppb	DAY
15 Nov 83	23.75	S3W	1.0	0.012	0.53
16 Nov 83	7.52	S3W	1.2	0.015	0.86
16 Nov 83	10.75	S3W	1.1	0.013	0.99
16 Nov 83	15.73	S3W	0.9	0.012	1.20
17 Nov 83	11.17	S3W	10.7	0.115	2.01
18 Nov 83	11.00	S3W	1.7	0.021	3.00
21 Nov 83	13.67	S3W	1.5	0.019	6.11
22 Nov 83	10.50	S3W	1.0	0.012	6.98
02 Nov 83	-	S4	0.8	0.010	-
07 Nov 83	11.50	S4	23.0	0.234	-7.98
09 Nov 83	11.50	S4	1.1	0.014	-5.98
10 Nov 83	10.25	S4	13.3	0.140	-5.03
14 Nov 83	10.33	S4	1.5	0.019	-1.03
15 Nov 83	10.25	S4	1.2	0.015	-0.03
15 Nov 83	15.90	S4	22.0	0.224	0.20
15 Nov 83	23.98	S4	2.1	0.025	0.54
16 Nov 83	7.88	S4	1.4	0.017	0.87
16 Nov 83	10.95	S4	1.2	0.015	1.00
16 Nov 83	11.98	S4	0.9	0.011	1.04
16 Nov 83	15.93	S4	0.7	<0.010	1.21
17 Nov-83	11.35	S4	1.5	0.019	2.01
18 Nov 83	11.15	S4	0.9	0.012	3.01
21 Nov 83	13.57	S4	0.9	0.012	6.11
22 Nov 83	10.64	S4	0.8	0.010	6.99
07 Nov 83	11.50	S4W	55.0	0.524	-7.98
16 Nov 83	11.67	SBC	0.5	<0.010	1.03
02 Nov 83	-	STEAM	1.0	0.013	-
07 Nov 83	11.50	TR 40	12.0	0.128	-7.98
14 Nov 83	10.66	TR 40	1.0	0.013	-1.01
15 Nov 83	10.15	TR 40	1.4	0.017	-0.04
16 Nov 83	7.94	TR 40	0.7	<0.010	0.87
16 Nov 83	16.00	TR 40	0.7	<0.010	1.21
14 Nov 83	10.50	TR BR	0.8	0.010	-1.02
02 Nov 83	-	VFD	0.8	0.010	-
07 Nov 83	11.50	VFD	0.7	<0.010	-7.98
09 Nov 83	11.50	VFD	0.9	0.011	-5.98
10 Nov 83	9.85	VFD	0.8	0.010	-5.05
14 Nov 83	10.40	VFD	0.7	<0.010	-1.02
15 Nov 83	10.85	VFD	1.0	0.012	-0.01
15 Nov 83	11.43	VFD	1.3	0.016	0.02
15 Nov 83	13.12	VFD	0.7	<0.010	0.09
15 Nov 83	15.60	VFD	0.7	<0.010	0.19
16 Nov 83	7.58	VFD	0.4	<0.010	6.98
16 Nov 83	15.64	VFD	0.5	<0.010	1.19
18 Nov 83	11.43	VFD	0.5	<0.010	3.02

Table 1 (concluded)
RHODAMINE WT DATA

DATE	TIME	SITE	FLUOR	ppb	DAY
22 Nov 83	10.40	VFD	0.4	<0.010	6.98

Source: Washoe County Department of Comprehensive Planning

An alternative injection plan was used for this study. The Verdi Justice Court septic system was used as the injection point for the sodium bromide. This allowed for more control of the bromide dosage and flow of water through the septic system. A single slug of sodium bromide injected through one septic system allows the calculation of travel time with more certainty than if multiple injection points were used.

The initial injection of sodium bromide took place over several days, to allow mixing with the fluid in the septic tank. Table 2 indicates the dosage schedule and the volume of water used to flush the sodium bromide into the septic tank. On May 12, 1984, a dose of 40 kilograms of sodium bromide was injected with 10,850 liters of water. This combination of a gradual dose of tracer without a significant volume of water, followed by a major dose of tracer and a large volume of water, should create a pulse injection of a mass approximately equal to the mass of the tracer added in the major dose. The mass of the bromide dose is estimated in Appendix 1.

Table 2
SODIUM BROMIDE INJECTION SCHEDULE

Starting Date	Starting Time	Mass Added (kg)	Water Added (liters)
5/1/84	12:17	10	110
5/2/84	11:00	6	130
5/3/84	14:55	6	375
5/4/84	09:39	6	375
5/5/84	13:08	6	75
5/6/84	12:07	12	150
5/8/84	11:32	8	100
5/9/84	09:18	8	100
5/10/84	10:15	8	110
5/11/84	10:40	10	110
5/12/84	09:00	40	10,900

Source: Washoe County Department of Comprehensive Planning

The procedure used for bromide sampling was: (1) Rinse the sample container with sample three times; (2) fill sample container; and (3) deliver sample to DRI Laboratory within six hours.

In addition to the above procedures, samples collected for other anions were kept in the shade and delivered to Desert Research Institute (DRI) within two hours. Ammonia/ammonium samples were preserved with 8 drops of 1:1 sulfuric acid per 250 ml sample and delivered to DRI within two hours. All samples from wells were collected after allowing the sampling point (faucet or hydrant) to run for a minimum of two minutes.

Background concentrations of bromide were measured before the dosing of the Court septic system. Samples were collected at the available sampling points (see Figure 1, page 8, and Figure 3, page 30) after the injection until the bromide concentrations returned to the background levels. Samples were also collected for anion and ammonia/ammonium analysis. The results of the chemical sampling are listed in Tables 3a-3j (pages 15-29).

The bromide data from sites VS and S4 indicates the highest observed concentrations. Site VS is the spring (essentially a dug well) used by the Verdi Springs Water Company to supply its water distribution system. Site S4 is a spring near the Truckee River. A plot of the data from sites VS and S4 (Figures 4 and 5, pages 32-33) indicates a similar shape of the breakthrough curve for each site. This shape closely approximates the curve defined by various dispersion equations.

Data from sites other than VS and S4 do not exhibit this shape. Figures 6 through 10 (pages 34-38) indicate the concentrations of bromide at some of the other observation points. The data from site S3 does exhibit an early peak, although it does not follow a regular pattern. The behavior of site S3 may result from the fact that it is a gaining stream and represents several springs.

From the bromide data, the groundwater velocity can be estimated. A basic assumption needed for the analysis of the data is "one-dimensional flow" of the groundwater. This assumption is supported by the bromide data. The shape of the bromide plume is a thin path from the injection point to the discharge point. Data from wells adjacent to the flow path do not indicate a significant change in bromide concentration after the injection of the sodium bromide.

Table 3a
CHEMICAL DATA - MISCELLANEOUS SITES

Date	Time	Site	NO ₃ N	NO ₂ N	NH ₄ N	TOT N	OP P	Br	Cl
12 Apr 85	12.7	BB	1.23	<0.01	<0.01	1.23	0.13	0.03	6.5
03 Apr 85	11.9	BT	1.60	<0.01	<0.01	1.60	0.12	<0.01	13.4
02 Nov 83	-	FLUME	<0.05	<0.01	<0.01	-	<0.10	<0.01	2.41
04 Oct 84	12.3	FLUME	0.03	<0.01	0.009	0.039	<0.10	<0.01	3.8
02 Nov 83	-	JM	<0.05	<0.01	<0.01	-	<0.10	<0.01	1.63
26 Jan 84	11.3	JM	<0.05	<0.01	0.76	0.76	<0.10	<0.01	1.56
12 May 84	13.4	JM	<0.01						
26 Jan 84	9.9	JW	<0.05	<0.01	0.92	0.92	<0.10	<0.01	3.54
12 Apr 85	10.3	JW	0.02	<0.01	1.04	1.06	0.05	<0.01	3.57
02 Apr 85	13.0	NDF	0.79	<0.01	<0.01	0.79	0.20	0.03	4.9
03 Apr 85	10.9	PRO	<0.02	<0.01	3.00	3.00	0.23	<0.01	1.62
26 Jan 84	10.7	RB	1.65	<0.01	<0.01	1.65	0.16	<0.01	6.2
02 Nov 83	-	S1	<0.05	<0.01	<0.01	-	<0.10	<0.01	3.44
02 Nov 83	-	S2	<0.05	<0.01	<0.01	-	<0.10	<0.01	0.32
02 Nov 83	-	STEAM	<0.05	<0.01	<0.01	-	<0.10	<0.01	2.4
12 Apr 85	10.9	SCH	1.25	<0.01	0.509	1.76	0.16	<0.01	6.8
04 May 84	9.5	SEPTIC						305.0	
09 May 84	9.2	SEPTIC						3550.0	
12 May 84	8.9	SEPTIC						1500.0	
12 May 84	11.0	SEPTIC						212.0	
12 May 84	13.0	SEPTIC						154.0	
12 May 84	17.1	SEPTIC						215.0	
13 May 84	9.8	SEPTIC						14.0	
04 Oct 84	12.4	TR 40	0.04	<0.01	0.011	0.05	<0.10	<0.01	5.1
04 Oct 84	12.6	TR BND	0.05	<0.01	0.012	0.06	<0.10	<0.01	5.2
04 Oct 84	12.0	TR BR	0.02	<0.01	0.013	0.03	<0.10	<0.01	5.1
11 May 84	-	UNKNOWN						32800.0	
02 Nov 83	-	VFD	0.07	<0.01	-	0.07	<0.10	<0.01	3.49
14 Nov 83	12.7	VFD	0.08	<0.01	-	0.08	<0.10	<0.01	3.0
12 May 84	12.6	VFD						<0.01	

Table 3a (concluded)
CHEMICAL DATA - MISCELLANEOUS SITES

Date	Time	Site	NO ₃ -N	NO ₂ -N	NH ₄ -N	TOT N	OP P	Br	Cl
04 Oct 84	11.9	VFD	<0.05	<0.01	0.047	0.047	<0.10	<0.01	4.3
12 Apr 85	11.1	VFD	<0.05	<0.01	0.099	0.099	<0.10	<0.01	4.83
26 Jan 84	11.5	ZW	1.45	<0.01	<0.01	1.45	0.12	<0.01	7.00

Note: See notes at bottom of Table 3j.

Source: Washoe County Department of Comprehensive Planning

Table 3b
CHEMICAL DATA - SITE S1E

Date	Time	Site	NO ₃ N	NO ₂ N	NH ₄ N	TOT N	OP P	Br	Cl
07 Dec 83	11.5	S1E	0.12	<0.01	-	0.12	<0.10	<0.01	2.7
04 May 84	10.7	S1E						<0.01	
12 May 84	9.1	S1E						<0.01	
12 May 84	10.1	S1E						0.03	
12 May 84	15.1	S1E						<0.01	
12 May 84	17.5	S1E						<0.01	
12 May 84	18.9	S1E						<0.01	
12 May 84	21.0	S1E						<0.01	
13 May 84	9.2	S1E						<0.01	
13 May 84	17.9	S1E						0.02	
14 May 84	9.2	S1E						<0.01	
15 May 84	10.9	S1E	<0.05	<0.01	<0.01	-	<0.10	<0.01	2.0
16 May 84	11.9	S1E						<0.01	
17 May 84	9.3	S1E						<0.01	
29 May 84	10.7	S1E						<0.01	
08 Jun 84	11.7	S1E						<0.01	
15 Jun 84	11.3	S1E						<0.01	
02 Oct 84	10.7	S1E	<0.05	<0.01	0.014	0.014	0.10	<0.01	5.9

Note: See notes at bottom of Table 3j.

Source: Washoe County Department of Comprehensive Planning

Table 3c
CHEMICAL DATA - SITE SBC

Date	Time	Site	NO ₃ N	NO ₂ N	NH ₄ N	TOT N	OP P	Br	Cl
02 Nov 83	-	SBC	0.25	<0.01	-	0.25	<0.10	<0.01	16.4
07 Dec 83	13.0	SBC	<0.05	<0.01	2.00	2.00	<0.10	0.04	16.2
26 Jan 84	12.5	SBC	<0.05	<0.01	1.90	1.90	<0.10	<0.01	13.4
01 May 84	13.3	SBC						0.03	13.8
02 May 84	12.3	SBC						0.03	
10 May 84	12.0	SBC	<0.05	<0.01	<0.01	-	<0.10	<0.01	15.7
11 May 84	12.1	SBC						<0.01	
12 May 84	12.0	SBC						0.03	
12 May 84	14.9	SBC						0.03	
12 May 84	17.9	SBC						0.03	
12 May 84	21.3	SBC						0.03	
13 May 84	18.9	SBC						0.02	
15 May 84	11.9	SBC	<0.05	<0.0	2.14	2.14	<0.10	0.04	15.2
16 May 84	12.0	SBC						0.02	
19 May 84	12.9	SBC						0.02	
22 May 84	20.6	SBC						0.01	
23 May 84	18.3	SBC						0.01	
24 May 84	12.5	SBC						0.01	
25 May 84	12.0	SBC						0.03	
29 May 84	11.8	SBC						0.03	
05 Jun 84	13.9	SBC						0.01	
08 Jun 84	12.3	SBC						0.01	
13 Jun 84	12.8	SBC						0.02	
15 Jun 84	11.5	SBC						0.03	
21 Jun 84	12.0	SBC						0.05	
04 Oct 84	11.7	SBC	<0.05	<0.01	2.240	2.24	<0.10	0.02	14.3
12 Apr 85	12.0	SBC	<0.05	<0.01	2.320	2.32	<0.10	0.02	8.8

Note: See notes at bottom of Table 3j.

Source: Washoe County Department of Comprehensive Planning

Table 3d
CHEMICAL DATA - SITE P0

Date	Time	Site	NO ₃ -N	NO ₂ -N	NH ₄ -N	TOT N	OP P	Br	Cl
26 Jan 84	10.5	P0	1.32	<0.01	<0.01	1.32	0.19	<0.01	5.3
09 May 84	9.9	P0						<0.01	
10 May 84	10.7	P0	2.09	<0.01	0.18	2.27	<0.10	<0.01	6.29
14 May 84	9.5	P0						<0.01	
15 May 84	11.1	P0	2.10	<0.01	<0.01	2.10	0.15	<0.01	5.2
16 May 84	12.8	P0						<0.01	
17 May 84	9.7	P0						<0.01	
29 May 84	11.0	P0						<0.01	
11 Jun 84	11.4	P0	1.60	<0.01	<0.01	1.60	0.13	<0.01	6.4
12 Apr 85	11.3	P0	1.85	<0.01	<0.005	1.85	0.12	<0.01	12.4

Note: See notes at bottom of Table 3j.

Source: Washoe County Department of Comprehensive Planning

Table 3e
CHEMICAL DATA - SITE S3W

Date	Time	Site	NO ₃ N	NO ₂ N	NH ₄ N	TOT N	OP P	Br	Cl
12 May 84	8.6	S3W						0.01	
12 May 84	9.3	S3W						<0.01	
12 May 84	10.2	S3W						<0.01	
12 May 84	10.8	S3W						<0.01	
12 May 84	11.1	S3W						<0.01	
12 May 84	12.3	S3W						<0.01	
12 May 84	13.2	S3W						<0.01	
12 May 84	15.2	S3W						0.01	
12 May 84	16.1	S3W						<0.01	
12 May 84	17.2	S3W						<0.01	
12 May 84	19.0	S3W						<0.01	
13 May 84	9.3	S3W						<0.01	
14 May 84	9.3	S3W						<0.01	
15 May 84	10.8	S3W	<0.05	<0.01	-	-	<0.10	<0.01	1.90

Note: See notes at bottom of Table 3j.

Source: Washoe County Department of Comprehensive Planning

Table 3f
CHEMICAL DATA - S5

Date	Time	Site	NO ₃ N	NO ₂ N	NH ₄ N	TOT N	OP P	Br	Cl
02 Nov 83	-	S5	<0.50	<0.10	-	-	<1.00	<1.00	267.0
11 May 84	11.1	S5						0.19	
12 May 84	17.4	S5						0.10	
13 May 84	9.6	S5						0.29	
13 May 84	17.9	S5						0.05	
14 May 84	9.4	S5						0.07	
15 May 84	10.6	S5	1.58	0.020	<0.01	1.60	0.11	0.05	34.77
17 May 84	9.5	S5						0.03	
18 May 84	10.0	S5						0.04	

Note: See notes at bottom of Table 3j.

Source: Washoe County Department of Comprehensive Planning

Table 3g
CHEMICAL DATA - SITE COURT

Date	Time	Site	NO ₃ N	NO ₂ N	NH ₄ N	TOT N	OP P	Br	Cl
02 Nov 83	10.3	COURT	<0.05	<0.01	-	-	0.13	<0.01	1.34
07 Dec 83	11.5	COURT	<0.05	<0.01	1.50	1.50	0.16	<0.01	1.20
26 Jan 84	10.3	COURT	<0.05	<0.01	1.40	1.40	0.18	<0.01	1.24
01 May 84	12.3	COURT	<0.05	<0.01	<0.01	-	0.20	<0.01	1.24
02 May 84	11.5	COURT						0.01	
04 May 84	10.0	COURT						<0.01	
08 May 84	11.5	COURT						<0.01	
09 May 84	9.5	COURT						<0.01	
10 May 84	10.5	COURT	<0.05	<0.01	<0.01	-	0.12	<0.01	3.1
11 May 84	10.9	COURT						<0.01	
12 May 84	8.9	COURT						<0.01	
12 May 84	9.5	COURT						0.01	
12 May 84	10.5	COURT						<0.01	
12 May 84	12.9	COURT						<0.01	
12 May 84	13.6	COURT						<0.01	
12 May 84	15.6	COURT						<0.01	
12 May 84	17.0	COURT						0.01	
12 May 84	21.0	COURT						<0.01	
13 May 84	9.0	COURT						<0.01	
13 May 84	18.0	COURT						<0.01	
14 May 84	9.2	COURT						<0.01	
15 May 84	10.9	COURT	<0.05	<0.01	1.61	1.61	0.15	<0.01	1.1
16 May 84	11.9	COURT						<0.01	
17 May 84	9.4	COURT						<0.01	
18 May 84	10.2	COURT						<0.01	
19 May 84	12.3	COURT						<0.01	
20 May 84	11.1	COURT						<0.01	
22 May 84	20.3	COURT						<0.01	
23 May 84	18.1	COURT						<0.01	

Table 3g (concluded)
CHEMICAL DATA - SITE COURT

Date	Time	Site	NO ₃ N	NO ₂ N	NH ₄ N	TOT N	OP P	Br	Cl
24 May 84	12.1	COURT						<0.01	
25 May 84	11.3	COURT						<0.01	
29 May 84	10.8	COURT						0.01	
30 May 84	11.1	COURT						0.02	
31 May 84	12.0	COURT						0.02	
01 Jun 84	10.9	COURT						<0.01	
01 Jun 84	11.3	COURT						<0.01	
04 Jun 84	10.9	COURT						<0.01	
08 Jun 84	11.8	COURT						<0.01	
13 Jun 84	12.7	COURT						<0.01	
15 Jun 84	11.5	COURT						<0.01	
21 Jun 84	11.9	COURT						<0.01	
02 Oct 84	10.8	COURT	<0.05	<0.01	1.56	1.56	0.21	<0.01	1.2
03 Apr 85	10.5	COURT	2.25	<0.01	<0.01	2.25	0.23	0.04	18.9

Note: See notes at bottom of Table 3j.

Source: Washoe County Department of Comprehensive Planning

Table 3h
CHEMICAL DATA - SITE S3

Date	Time	Site	NO ₃ N	NO ₂ N	NH ₄ N	TOT N	OP P	Br	Cl
02 Nov 83	-	S3	<0.05	<0.01	-	-	<0.10	<0.01	3.66
07 Dec 83	11.8	S3	0.13	<0.01	-	0.13	<0.10	<0.01	2.6
01 May 84	13.5	S3						<0.01	2.55
02 May 84	12.0	S3						0.02	
04 May 84	11.0	S3						<0.01	
08 May 84	12.3	S3						<0.01	
09 May 84	9.6	S3						<0.01	
10 May 84	11.0	S3						<0.01	1.46
10 May 84	12.1	S3						<0.01	1.47
11 May 84	11.0	S3						<0.01	
12 May 84	8.5	S3						0.03	
12 May 84	9.3	S3						<0.01	
12 May 84	9.8	S3						0.04	
12 May 84	10.3	S3						<0.01	
12 May 84	10.8	S3						<0.01	
12 May 84	11.2	S3						0.06	
12 May 84	12.3	S3						<0.01	
12 May 84	12.8	S3						0.02	
12 May 84	13.1	S3						0.02	
12 May 84	15.3	S3						0.01	
12 May 84	16.0	S3						0.02	
12 May 84	17.3	S3						<0.01	
12 May 84	17.6	S3						<0.01	
12 May 84	18.8	S3						0.10	
12 May 84	20.9	S3						0.04	
13 May 84	9.3	S3						0.01	
13 May 84	17.9	S3						<0.01	
14 May 84	9.3	S3						<0.01	

Table 3h (concluded)
CHEMICAL DATA - SITE S3

Date	Time	Site	NO ₃ N	NO ₂ N	NH ₄ N	TOT N	OP P	Br	Cl
15 May 84	10.8	S3	<0.05	<0.01	-	-	<0.10	<0.01	1.9
16 May 84	11.8	S3						<0.01	
17 May 84	9.3	S3						<0.01	
18 May 84	10.1	S3						<0.01	
19 May 84	12.2	S3						<0.01	
20 May 84	11.0	S3						<0.01	
22 May 84	20.5	S3						<0.01	
23 May 84	18.1	S3						<0.01	
24 May 84	12.1	S3						<0.01	
25 May 84	11.2	S3						<0.01	
29 May 84	10.7	S3						<0.01	
30 May 84	11.0	S3						<0.01	
31 May 84	11.9	S3						<0.01	
01 Jun 84	11.2	S3						0.02	
08 Jun 84	11.6	S3						<0.01	
11 Jun 84	11.3	S3	<0.05	<0.01	0.01	0.01		<0.01	1.3
13 Jun 84	11.6	S3						<0.01	
15 Jun 84	11.3	S3						<0.01	
21 Jun 84	11.7	S3						<0.01	
02 Oct 84	10.6	S3	<0.05	<0.01	0.010	0.010	0.050	<0.01	5.2
03 Apr 85	12.3	S3	0.24	<0.01	0.012	0.252	0.060	<0.01	5.4

Note: See notes at bottom of Table 3j.

Source: Washoe County Department of Comprehensive Planning

Table 3i
CHEMICAL DATA - MISCELLANEOUS SITES

Date	Time	Site	NO ₃ N	NO ₂ N	NH ₄ N	TOT N	OP P	Br	Cl
02 Nov 83	-	S4	0.72	<0.01	-	0.72	<0.10	<0.01	8.15
07 Dec 83	12.0	S4	1.02	<0.01	<0.01	1.02	<0.10	0.01	6.3
26 Jan 84	12.6	S4	1.95	<0.01	<0.01	1.95	0.21	<0.01	13.8
01 May 84	13.5	S4	0.76	<0.01	<0.01	0.76	0.12	<0.01	6.31
02 May 84	12.4	S4						0.01	
08 May 84	12.3	S4						0.005	
09 May 84	10.0	S4						<0.01	
10 May 84	11.0	S4	0.30	<0.01	<0.01	0.30	<0.10	<0.01	3.26
11 May 84	12.2	S4						<0.01	
12 May 84	8.7	S4						0.06	
12 May 84	9.4	S4						0.04	
12 May 84	10.4	S4						0.06	
12 May 84	12.5	S4						0.03	
12 May 84	13.3	S4						0.03	
12 May 84	15.4	S4						0.09	
12 May 84	17.3	S4						0.03	
12 May 84	19.0	S4						0.05	
12 May 84	21.1	S4						0.02	
13 May 84	9.5	S4						0.03	
13 May 84	17.8	S4						0.05	
14 May 84	9.6	S4						0.10	
15 May 84	12.0	S4	0.37	<0.01	<0.01	0.37	<0.10	1.20	4.2
16 May 84	12.7	S4						0.05	
16 May 84	12.9	S4						0.70	
17 May 84	9.9	S4						0.30	
18 May 84	10.2	S4						0.20	
19 May 84	13.0	S4						0.09	
20 May 84	11.3	S4						0.06	
22 May 84	20.3	S4						0.04	

Table 3i (concluded)
CHEMICAL DATA - SITE S4

Date	Time	Site	NO ₃ N	NO ₂ N	NH ₄ N	TOT N	OP P	Br	Cl
23 May 84	17.9	S4						0.02	
24 May 84	11.9	S4						0.04	
25 May 84	11.1	S4						0.05	
29 May 84	10.6	S4						0.04	
30 May 84	10.9	S4						0.04	
31 May 84	11.8	S4						0.04	
01 Jun 84	11.5	S4						<0.01	
04 Jun 84	11.0	S4						0.05	
07 Jun 84	14.5	S4						0.02	
08 Jun 84	11.5	S4						0.01	
11 Jun 84	11.5	S4	0.60	<0.01	0.02	0.62	<0.10	0.06	6.6
13 Jun 84	12.5	S4						0.02	
14 Jun 84	12.0	S4						0.03	
15 Jun 84	11.2	S4						<0.01	
19 Jun 84	11.0	S4						0.02	
21 Jun 84	11.5	S4						<0.01	
22 Jun 84	11.1	S4						0.02	
27 Jun 84	12.1	S4						0.02	
29 Jun 84	11.7	S4						0.03	
02 Oct 84	10.4	S4	<0.05	<0.01	0.013	0.013	<0.10	<0.01	5.7
12 Apr 85	12.3	S4	0.45	<0.01	0.021	0.471	0.05	<0.01	7.4

Note: See notes at bottom of Table 3j.

Source: Washoe County Department of Comprehensive Planning

Table 3j
CHEMICAL DATA - SITE VS

Date	Time	Site	NO ₃ N	NO ₂ N	NH ₄ N	TOT N	OP P	Br	Cl
12 May 84	8.5	VS						0.07	
12 May 84	10.7	VS						0.08	
12 May 84	12.7	VS						0.08	
12 May 84	17.5	VS						0.07	
12 May 84	21.2	VS	1.42	<0.01	<0.01	1.42	<0.10	0.07	8.7
13 May 84	9.6	VS						0.07	
15 May 84	10.6	VS	1.47	<0.01	<0.01	1.47	0.30	4.10	9.2
17 May 84	9.6	VS						2.10	
18 May 84	10.1	VS						1.50	
19 May 84	12.1	VS						1.10	
20 May 84	10.9	VS						0.84	
22 May 84	20.4	VS						0.50	
23 May 84	18.0	VS						0.42	
24 May 84	12.0	VS						0.35	
25 May 84	11.2	VS						0.38	
29 May 84	10.6	VS						0.35	
30 May 84	11.0	VS						0.24	
31 May 84	11.9	VS						0.22	
01 Jun 84	11.1	VS						0.26	
04 Jun 84	10.9	VS						0.06	
05 Jun 84	13.9	VS						0.05	
07 Jun 84	14.5	VS						0.14	
08 Jun 84	11.6	VS						0.13	
11 Jun 84	11.3	VS	1.34	<0.01	<0.01	1.34	0.20	0.02	7.5
14 Jun 84	12.1	VS						0.03	
15 Jun 84	11.3	VS						0.05	
19 Jun 84	11.1	VS						0.05	
21 Jun 84	11.6	VS						0.05	

Table 3j (concluded)
CHEMICAL DATA - SITE VS

Date	Time	Site	NO ₃ N	NO ₂ N	NH ₄ N	TOT N	OP P	Br	Cl
22 Jun 84	11.0	VS						0.07	
27 Jun 84	12.2	VS						0.08	
29 Jun 84	11.9	VS						0.05	
02 Oct 84	10.5	VS	1.07	<0.01	0.006	1.076	0.22	<0.01	6.2
03 Apr 85	12.1	VS	<0.05	<0.01	1.42	1.420	0.16	<0.01	1.29

Notes for Tables 3a-3j:

1. All concentrations are reported in mg/l.
2. Site locations are indicated on Figures 1 and 3.
3. NO₃N is nitrate expressed as nitrogen.
4. NO₂N is nitrite expressed as nitrogen.
5. NH₄N is ammonia and ammonium expressed as nitrogen.
6. TOT N is the sum of NO₃N, NO₂N, and NH₄N.
7. OP P is orthophosphate expressed as phosphorus.
8. Br is bromide.
9. Cl is chloride.

Source: Washoe County Department of Comprehensive Planning

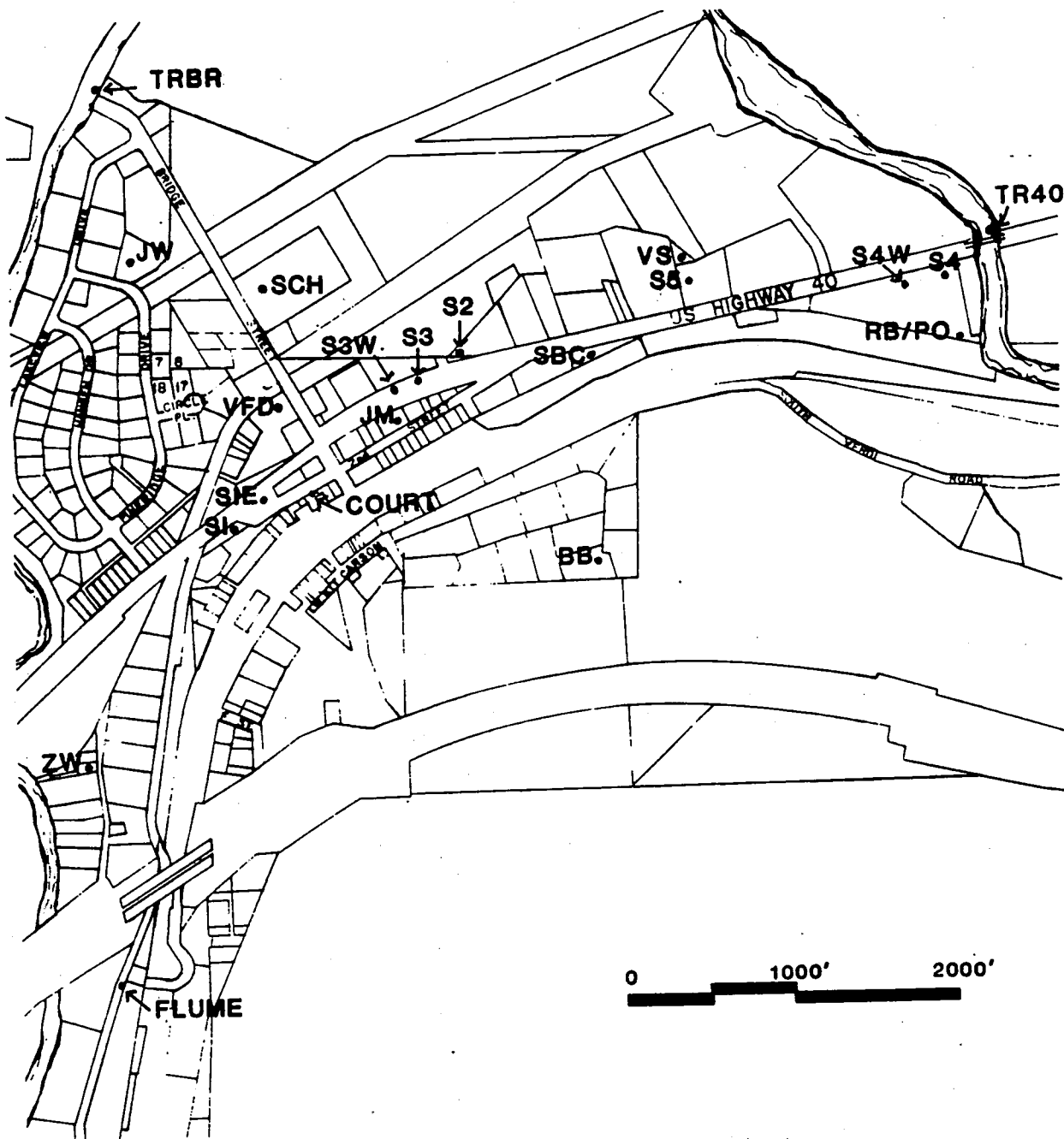


FIGURE 3

CENTRAL VERDI MONITORING SITES

• Monitoring Site



**WASHOE COUNTY
DEPARTMENT OF
COMPREHENSIVE
PLANNING**

A "one-dimensional" analytical model of hydrodynamic dispersion is derived in Appendix 2. The data from sites VS and S4 were used to calibrate the model. The primary use of the model is to determine the groundwater velocity. The travel time to the river or a water supply system may be estimated from the velocity. The results of the model calibration are listed in Table 4. Additional model details may be found in Appendix 2.

Table 4
ONE-DIMENSIONAL MODEL CALIBRATION RESULTS

Site	Average Velocity meters/day	Travel Time days
VS	190	4.3
S4	350	3.5

Source: Washoe County Department of Comprehensive Planning

The estimated travel times represent two relatively long flow paths in the Verdi area. Many of the septic systems are less than 100 meters from the Truckee River or a water supply source that is derived from the alluvial aquifer. The shorter flow paths may increase the chances of survival of pathogens in the groundwater.

Figure 4

Site VS

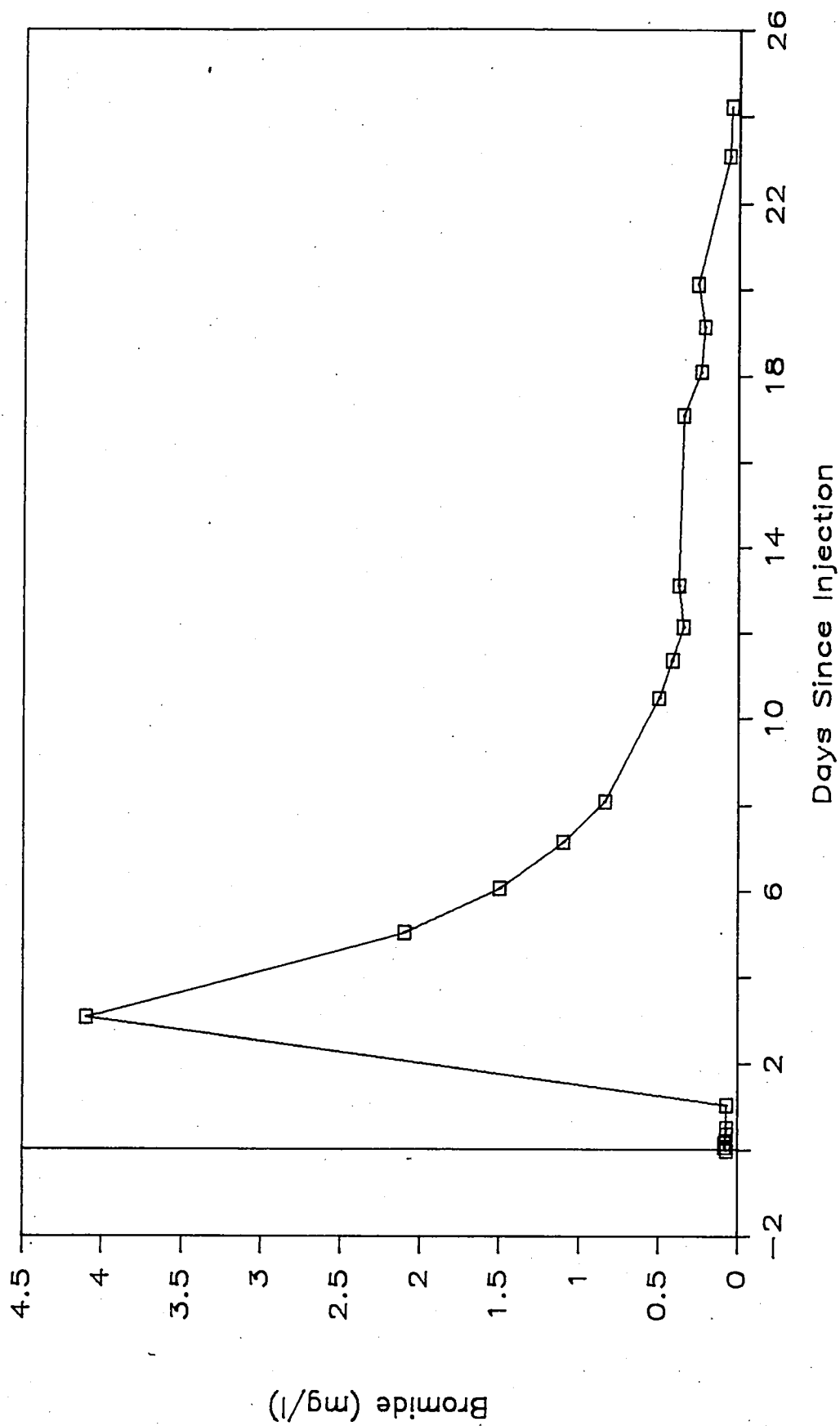


Figure 5

Site S4

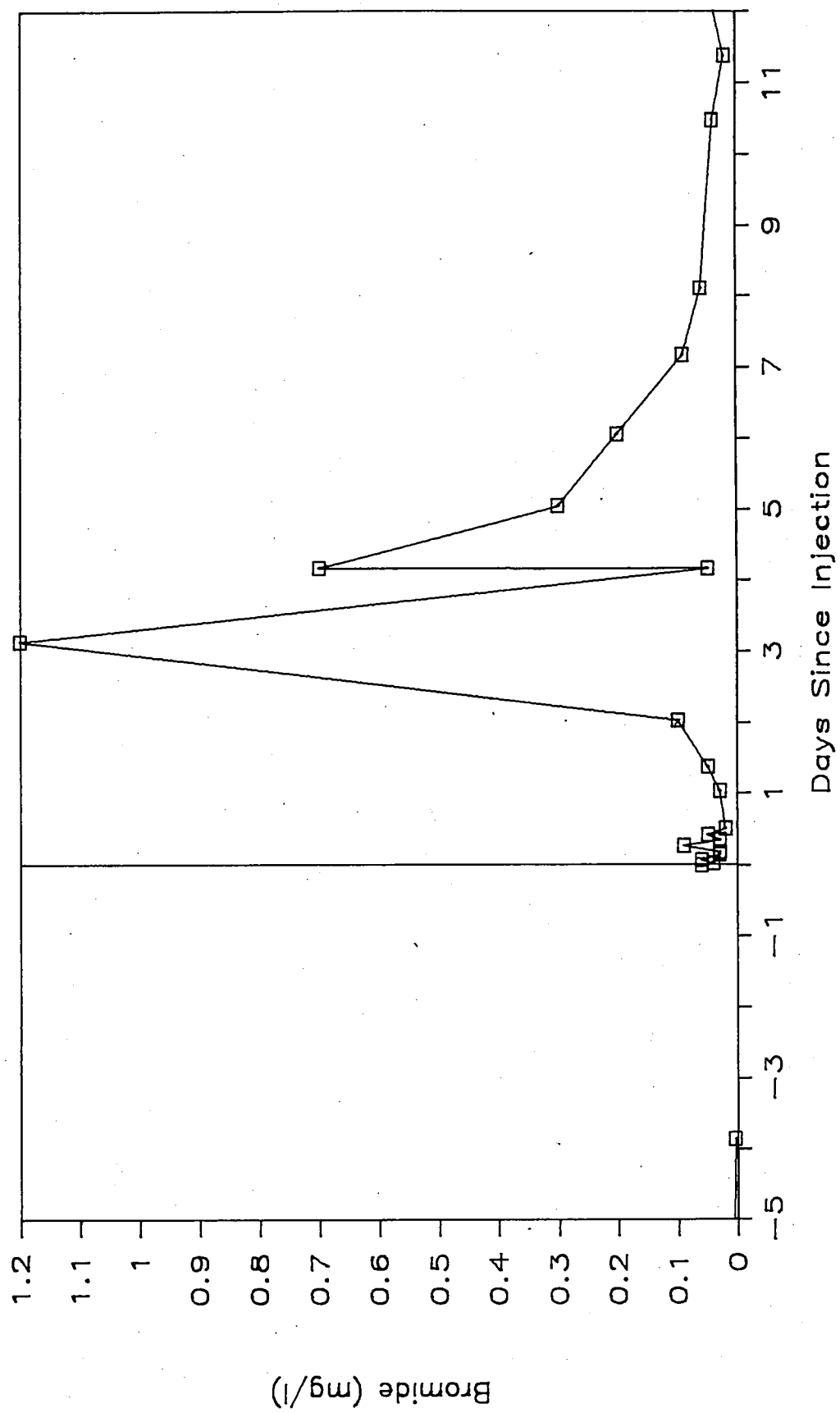


Figure 6

Court House Well

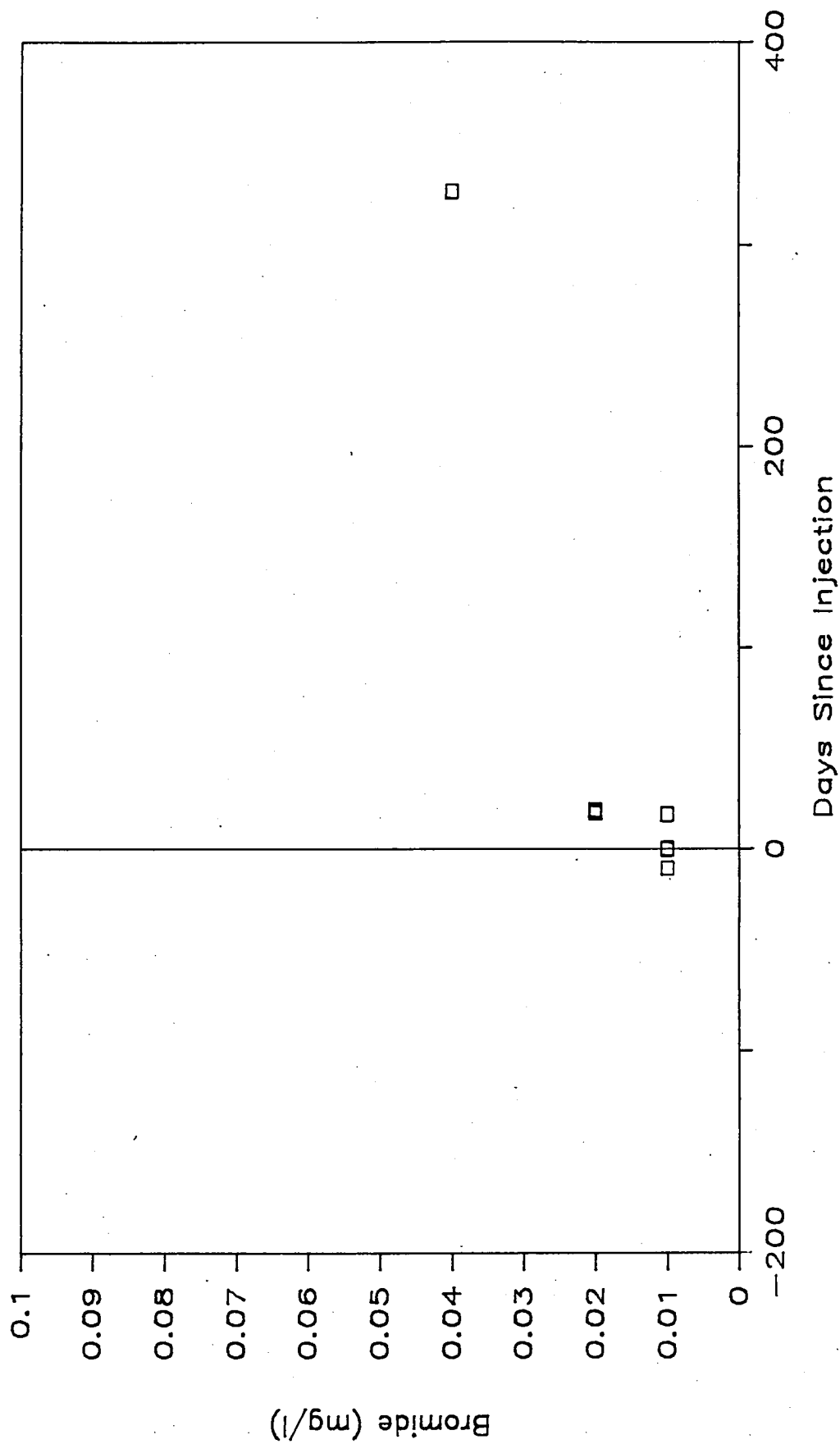


Figure 7
Site S1E

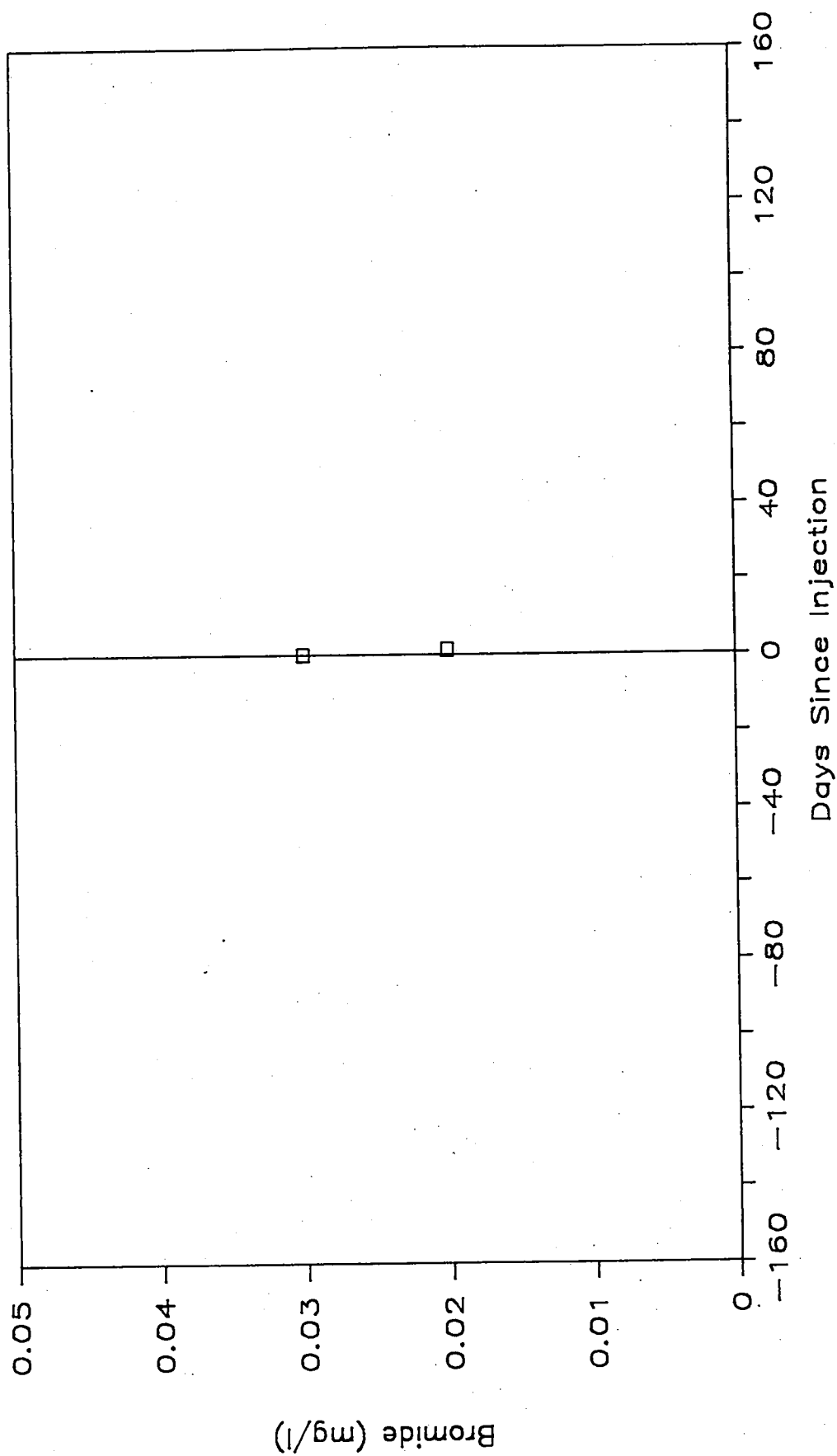


Figure 8
Site S3

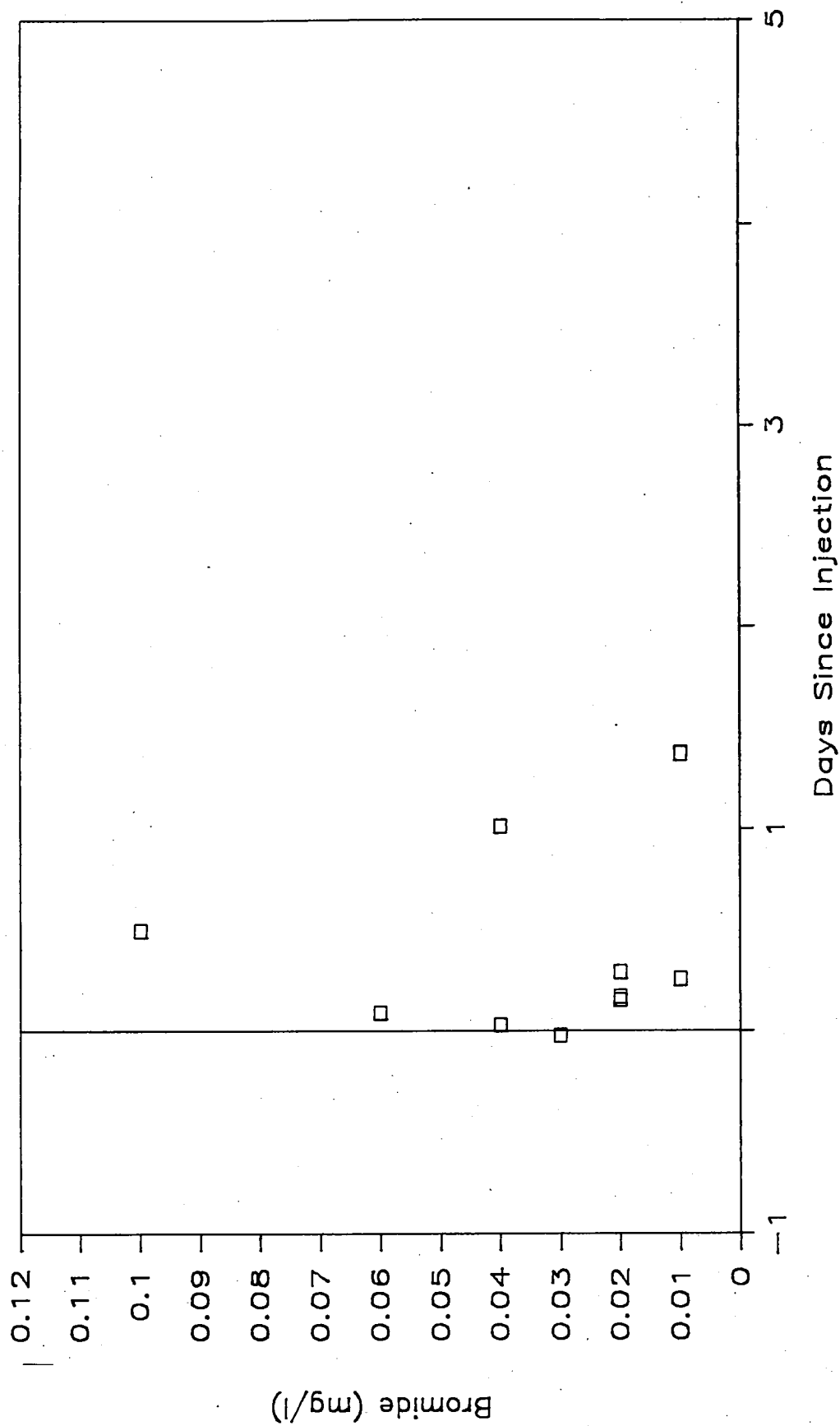


Figure 9
Site S5

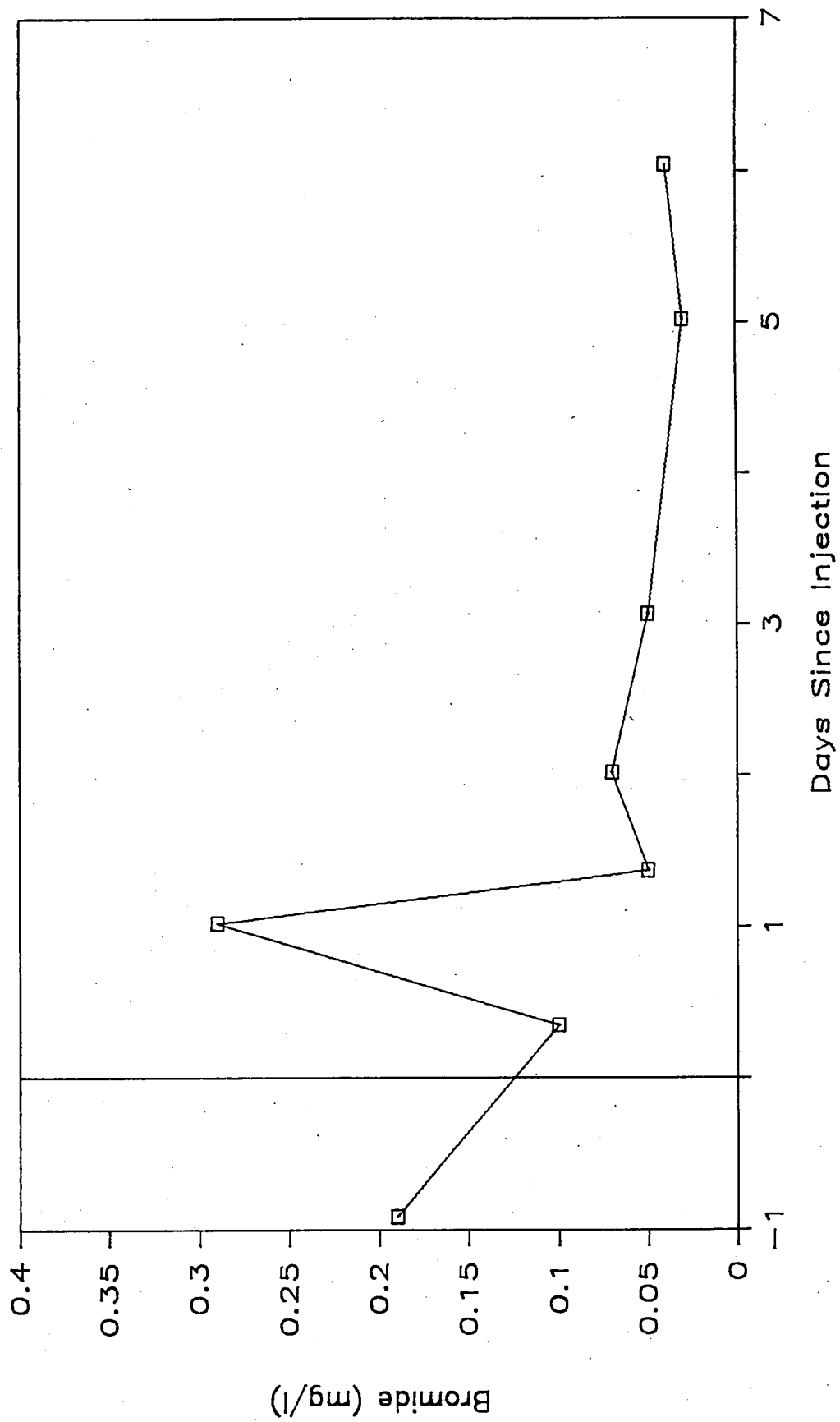
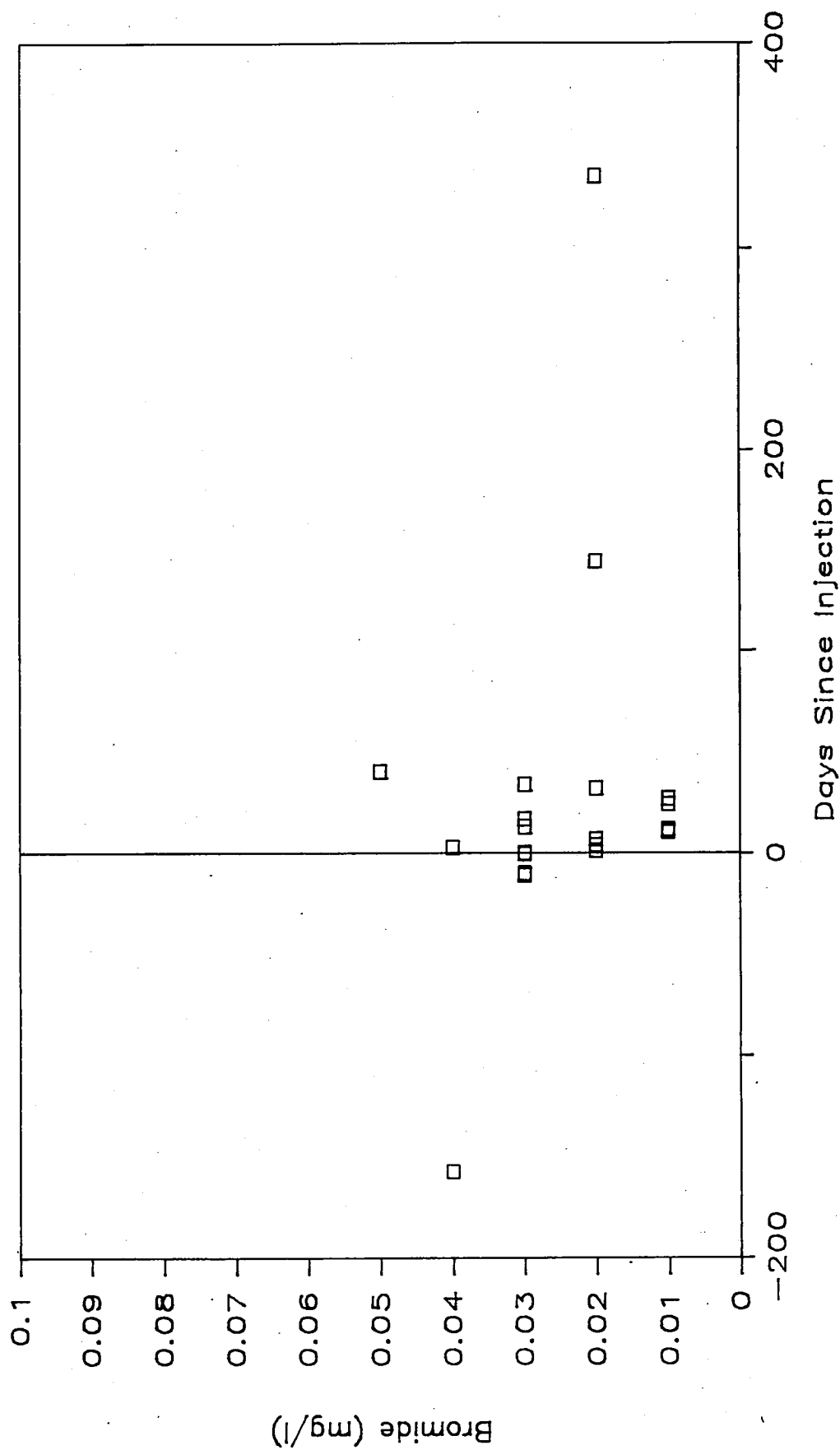


Figure 10
Site SBC



CONCLUSIONS

PATHOGENS

The contamination of groundwater by pathogenic organisms depends upon many factors. The chemistry and hydraulics of the groundwater system are major factors affecting the survival of pathogens. Some of the factors affecting the survival and removal of pathogens are tabulated below.

Table 5
SURVIVAL AND REMOVAL OF PATHOGENS

Factor	Remarks
ENTERIC BACTERIA	
Moisture content	Greater survival time in moist soils.
Temperature	Longer survival at low temperatures.
pH	Shorter survival in acid soils.
Light	Shorter survival when exposed to light.
Organic matter	Increased survival when organic matter is present.
Antagonism from soil microflora	Increased survival time in sterile soil.
VIRUSES	
Flow rate	High flow rates reduce virus removal efficiency.
Cations	Cations can allow negatively charged viruses to be adsorbed onto soil and clay particles.
Clays	Clays can retain viruses by adsorption.

Table 5 (concluded)
SURVIVAL AND REMOVAL OF PATHOGENS

Factor	Remarks
VIRUSES (concluded)	
Soluble organics	Soluble organics compete with viruses for exchange sites and tend to reduce the retention of viruses.
pH	A low pH favors virus adsorption and a high pH favor virus elution.
Chemical composition of soil	Certain metal complexes have been found to adsorb viruses.

Source: Gerba 1975

The most important mechanism of virus removal in soil is by adsorption of viruses onto soil particles. Burge and Enkiri (1978) noted that coarse soils with high pH are less effective in adsorbing viruses. Higher pH values considerably decrease the effectiveness of virus adsorption by soils because of increased ionization of the carboxyl groups of the virus protein and the increasing negative charge of the soils (Canter and Knox, 1985). Viral adsorption can be increased by increasing the concentration of cations in the water. Cations reduce the negative charge on the surface of the viruses and the soil particles, allowing adsorption to occur.

The survival of pathogens in groundwater systems has been studied by several researchers. Gerba (1975) summarized the observed survival times of pathogens. Table 6 is a summary of the information compiled by Gerba (1975).

At a travel time of approximately 4 days from central Verdi to the river, time is probably not a significant factor in preventing pathogenic contamination of the river or the water supply systems that depend upon the alluvial aquifer. The information in Table 6 indicates survival times in excess of 24 days for the pathogens listed. Other factors, such as limited moisture content and the presence of

antagonistic microflora, may play a role in limiting pathogenic contamination in the Verdi area. The pathogenic contamination noted in 1950 probably continues to this date, although it is probably not a problem to most of the present domestic wells. Since the 1950's, most of the shallow domestic wells have been replaced with drilled wells tapping the Truckee Formation. The municipal water supplies that use alluvial aquifer springs are subject to the ISDS induced pathogenic contamination experienced by the shallow wells in the 1950's.

Table 6
SURVIVAL OF BACTERIA AND VIRUSES IN GROUNDWATER

Pathogen	Survival Time	Media
E. coli	63 days	recharge well
E. coli	3-3.5 months	aquifer
E. coli	4-4.5 months	groundwater in lab
Salmonella	44 days	sand columns
Shigella	24 days	sand columns
poliovirus 1	63+ days	sand column with distilled water
poliovirus 1	91+ days	sand column with tap water
poliovirus 1	91+ days	sand column with oxidization pond effluent
f2 bacteriophage	175+ days	sand column with distilled water
f2 bacteriophage	175+ days	sand column with tap water
f2 bacteriophage	175+ days	sand column with oxidization pond effluent

Source: Gerba, 1975

NUTRIENT LOADING TO THE TRUCKEE RIVER

Appendix 3 presents the derivation of the tracer estimated alluvial aquifer discharge to the Truckee River. This estimate, 2.75 cfs, is in

close agreement with the measured discharge of 2 cfs in 1951. The chemistry of water discharged to the river can be estimated from the chemistry of the sampling points (sites VS and S4) near the river. The following calculations indicate the approximate loading to the Truckee River in the Verdi area:

$$Q = 2.75 \text{ cfs} = 6750 \text{ m}^3/\text{day}$$

Average quality (mg/l)	N	P
Site VS	1.35	0.22
Site S4	0.69	0.13
Mass = Q x C (kg/day)	N	P
Site VS	9.11	1.49
Site S4	4.65	0.85

The area upgradient of sampling points VS and S4 has approximately 220 residential units. At an average discharge of 325 gallons per day with 40 mg/l of dissolved nitrogen and 15 mg/l of phosphorus in the effluent, a total mass of 10.84 kg/day of nitrogen and 4.06 kg/day of phosphorus is contained in the effluent. Most of the nitrogen leaving the septic tanks reaches the vicinity of the river. Site S4 is affected by vegetation and indicates a lower concentration of nitrogen than site VS. The composite of all of the springs and subsurface flows to the river is probably within the range of mass loads indicated by sites VS and S4. Approximately 3,700 to 7,300 pounds of nitrogen and 680 to 1200 pounds of phosphorus enters the Truckee River each year as the result of the 220 residences and the natural and agricultural sources in the central Verdi area. Up to 700 pounds of the nitrogen may be from natural and agricultural sources.

"DILUTION" OF ISDS EFFLUENT

The flow of groundwater through the alluvial aquifer has been estimated at about 6,750 cubic meters per day (2.75 cfs). This groundwater acts to dilute the ISDS effluent in the central Verdi area. Biological, chemical and physical mechanisms remove or retain some of the contaminants and the remainder pass through the aquifer to the Truckee River. Assuming a 15 percent removal of nitrogen, as indicated by the data from site VS, a modified estimate of the groundwater flow of

7,940 cubic meters per day (3.24 cfs) can be used for determining concentrations of nitrogen. The ISDS effluent from about 1,600 dwelling units would result in a groundwater concentration of nitrate nitrogen at or above the drinking water standard of 10 mg/l. A lesser number of dwellings may cause the violation of drinking water standards in portions of the area.

The limited removal of nitrogen from the effluent makes the calculation of dilution an academic exercise. Additional dwellings using ISDS facilities in the central Verdi area will increase the nitrogen load to the Truckee River and result in a change in the quality of the River. Each dwelling will not result in a significant change in the groundwater quality, as indicated by the effective flow of 3.24 cfs, but the combined effect will be seen in terms of a degradation of the groundwater and surface water quality.



RECOMMENDATIONS

GENERAL RECOMMENDATIONS

1. The Washoe County District Health Department should monitor additional pathogens in the Verdi area public water supply systems.
2. If a governmental decision is made to allow the permanent use of additional ISDS facilities for new construction in the Verdi area, Washoe county should seek a modification of the water quality standards for the Truckee River.

POLICY RECOMMENDATIONS

1. The use of additional ISDS facilities in the Verdi area shall not be allowed as the permanent method of wastewater treatment and disposal. Temporary ISDS facilities can be used as a short-term treatment alternative during the planning and construction of the Lawton/Verdi interceptor without resulting in significant changes in the quality of the Truckee River. This policy assumes the availability of the interceptor within about 7 years.
2. The use of springs and dug wells for community/public water supplies in the Verdi area shall not be expanded unless the Lawton/Verdi Interceptor has replaced the ISDS facilities in the central Verdi area.
3. If any existing ISDS facilities are replaced by the Lawton/Verdi interceptor, an equal number of new ISDS facilities could be allowed, on a case by case basis, in portions of the Verdi area that cannot be served by the interceptor. The location and density of the new ISDS facilities shall consider the potential impact upon local water supply systems.



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Freeze, R. A., and Cherry, J. A. 1979. Groundwater. Englewood Cliffs, New Jersey: Prentice-Hall, Inc.

Gerba, C. P. 1975. Fate of Waste Water Bacteria and Viruses in Soil, Journal of the Irrigation and Drainage Division. 101, No. IR3:157-173.

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APPENDIX A

ESTIMATION OF INJECTED MASS OF BROMIDE



Appendix A

ESTIMATION OF INJECTED MASS OF Br⁻

Date	Mass NaBr kg	
5/1/84	10	
5/2/84	6	
5/3/84	6	
5/4/84	6	
5/5/84	6	
5/6/84	12	
5/7/84	0	
5/8/84	8	
5/9/84	8	3550 mg/l sample
5/10/84	8	
5/11/84	10	
5/12/84	40	
Total	120	

Assume volume of septic tank = 1,000 gallons
 $\approx 4,000$ l

Mass in tank

$$M = V \cdot C = 4000 \text{ l} \times 3550 \text{ mg/l} = 14,200,000 \text{ mg} \\ = 14.2 \text{ kg}$$

Mass injected: 66 kg added 5/9-5/12
 + 14.2 kg in solution in tank
 = 80.2 kg

Mass Br⁻:

$$\text{Formula wt NaBr}^- = 22.9898 + 79.904 \\ = 102.89$$

$$\text{Percent Br}^- = 100 \times \frac{79.904}{102.89} = 77.66 \text{ percent}$$

$$\text{Mass Br}^- = \text{Total mass} \times \text{Percent Br}^- \\ = 80.2 \times 77.66 \\ = \underline{62.4 \text{ kg Br}^-} \text{ (rounded)}$$

APPENDIX B

ONE-DIMENSIONAL APPROXIMATION OF DISPERSION EQUATION



Appendix B

ONE DIMENSIONAL APPROXIMATION OF DISPERSION EQUATION

3-D EQUATION:

$$C(X,Y,Z,t) = \frac{M}{8(\pi i \cdot t)^{1.5} (D_X D_Y D_Z)^{.5}} \exp - \frac{X^2}{4D_X t} - \frac{Y^2}{4D_Y t} - \frac{Z^2}{4D_Z t}$$

(From: Freeze and Cherry 1979 - Groundwater)

where:

- C = Concentration in excess of background, (M/L^3)
- M = Mass of slug injection, (M)
- X, Y, Z = Coordinates of observation point with respect to center of mass of plume, (L)
- X = $x - \bar{V}_x t$, (L)
 x = position of observation point with respect to injection point, (L)
- \bar{V}_x = specific discharge/effective porosity
 $= V_x/n$, (L/T)
- D_X = $\alpha_x \cdot \bar{V}_x$ = coefficient of hydrodynamic dispersion, (L^2/T)
 α_x = dynamic dispersivity, (L)
- t = time since injection of mass "M," and (T)
- Pi = The constant Pi (3.14159...)

Assuming location of observation points along X axis,

$$Y = Z = 0$$

$$C(X,t) = \frac{M}{8(\pi i \cdot t)^{1.5} (D_X D_Y D_Z)^{.5}} \text{EXP} - \frac{X^2}{4D_X t} \quad (1)$$

let:

$$K = M/(D_X D_Y D_Z)^{.5} \quad (2)$$

then:

$$C(X,t) = \frac{K}{8(\pi i \cdot t)^{1.5}} \text{EXP} - \frac{X^2}{4D_X t} \quad (3)$$

let:

$$X = x - \bar{V}_x t$$

then:

$$C(X,t) = \frac{K}{8(\pi i \cdot t)^{1.5}} \text{EXP} - \frac{(x - \bar{V}_x t)^2}{4D_X t} \quad (4)$$

or

$$C(x,t) = g(t,x,D_X,\bar{V}_x,K)$$

where g = function in computer code equivalent to Equation 4 above

TRIAL AND ERROR CALIBRATION:

x , t , and, to some extent, K , are known quantities. The unknowns are D_X , \bar{V}_x , and K .

\bar{V}_x can be approximated from the arrival time of the contaminant peak.

The model is calibrated by trial and error adjustment of D_X , \bar{V}_x , and K .

Model results are graphically compared to the observed data and then the process is repeated to obtain a close fit to the observed data.

SITE VS

From the trial + error calibration:

$$\bar{V}_x = 190 \text{ M/D}$$

$$D_x = 90,000 \text{ M}^2/\text{D}$$

$$\alpha_x = 470 \text{ M} \quad (\text{By calculation: } \alpha_x = D_x / \bar{V}_x)$$

$$K = 1,000$$

$$x = 820 \text{ M} \quad (\text{from map})$$

$$K = \frac{M}{(D_x D_y D_z)^{.5}} = 1000 = \frac{62,400 \text{ grams}}{(D_x D_y D_z)^{.5}}$$

Find: $D_y D_z$

$$D_y D_z = \frac{M^2}{K^2 D_x} = \frac{0.04}{1} \text{ M}^4/\text{D}^2$$

$$D_z = \alpha_z \bar{V}_z \text{ and}$$

$$D_y = \alpha_y \bar{V}_y \quad \therefore$$

If $\alpha_x \geq \alpha_y \geq \alpha_z > 1\text{M}$

$$\bar{V}_y \cdot \bar{V}_z \leq 0.04 \text{ M}^2/\text{D}^2$$

or \bar{V}_y and \bar{V}_z are small compared to \bar{V}_x

SITE S4

From the trial + error calibration:

$$\bar{V}_x = 350 \text{ M/D}$$

$$D_x = 40,000 \text{ M}^2/\text{D}$$

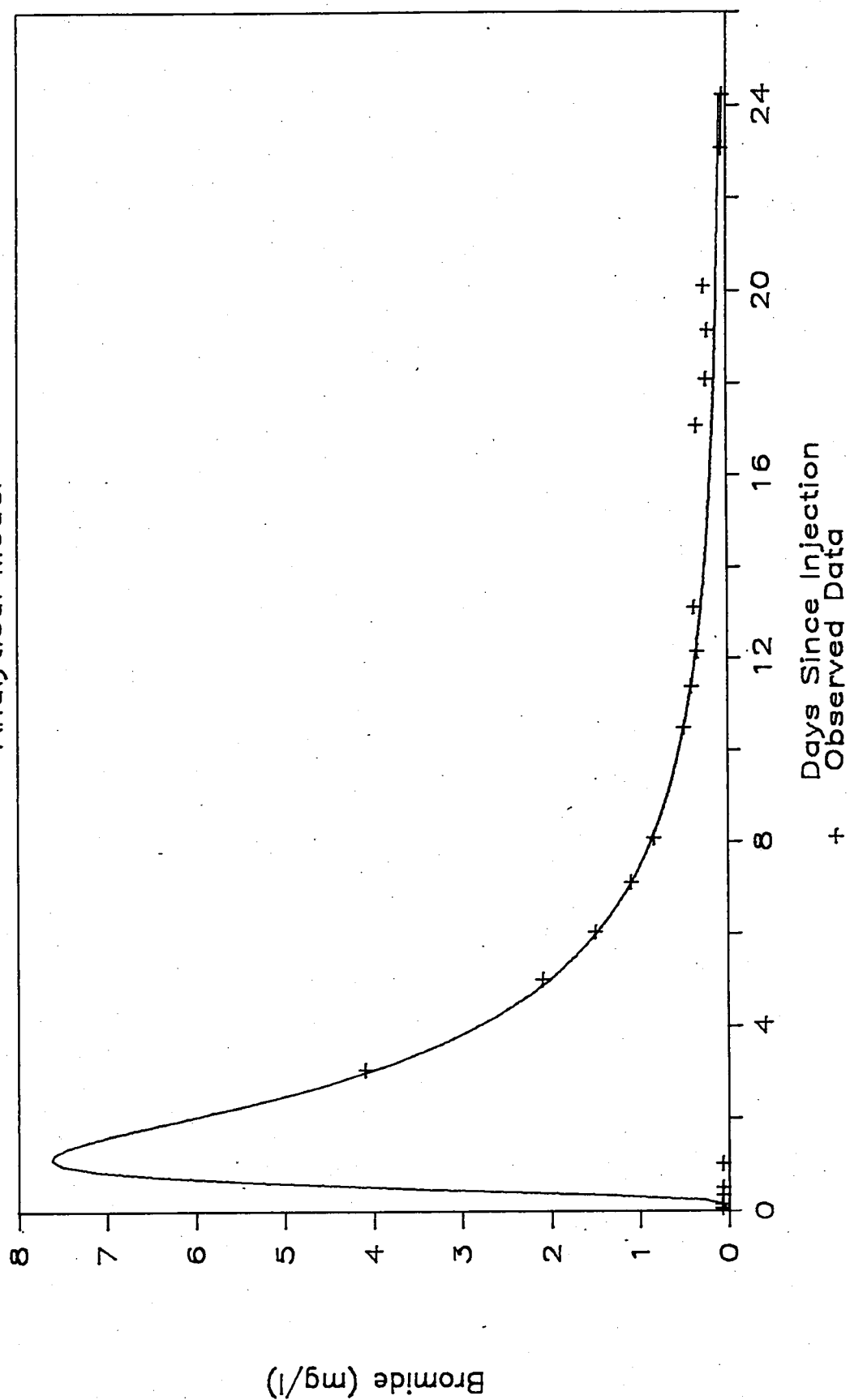
$$= 114 \text{ M} \quad (\text{by calculation: } \alpha_x = D_x / \bar{V}_x)$$

$$K = 360$$

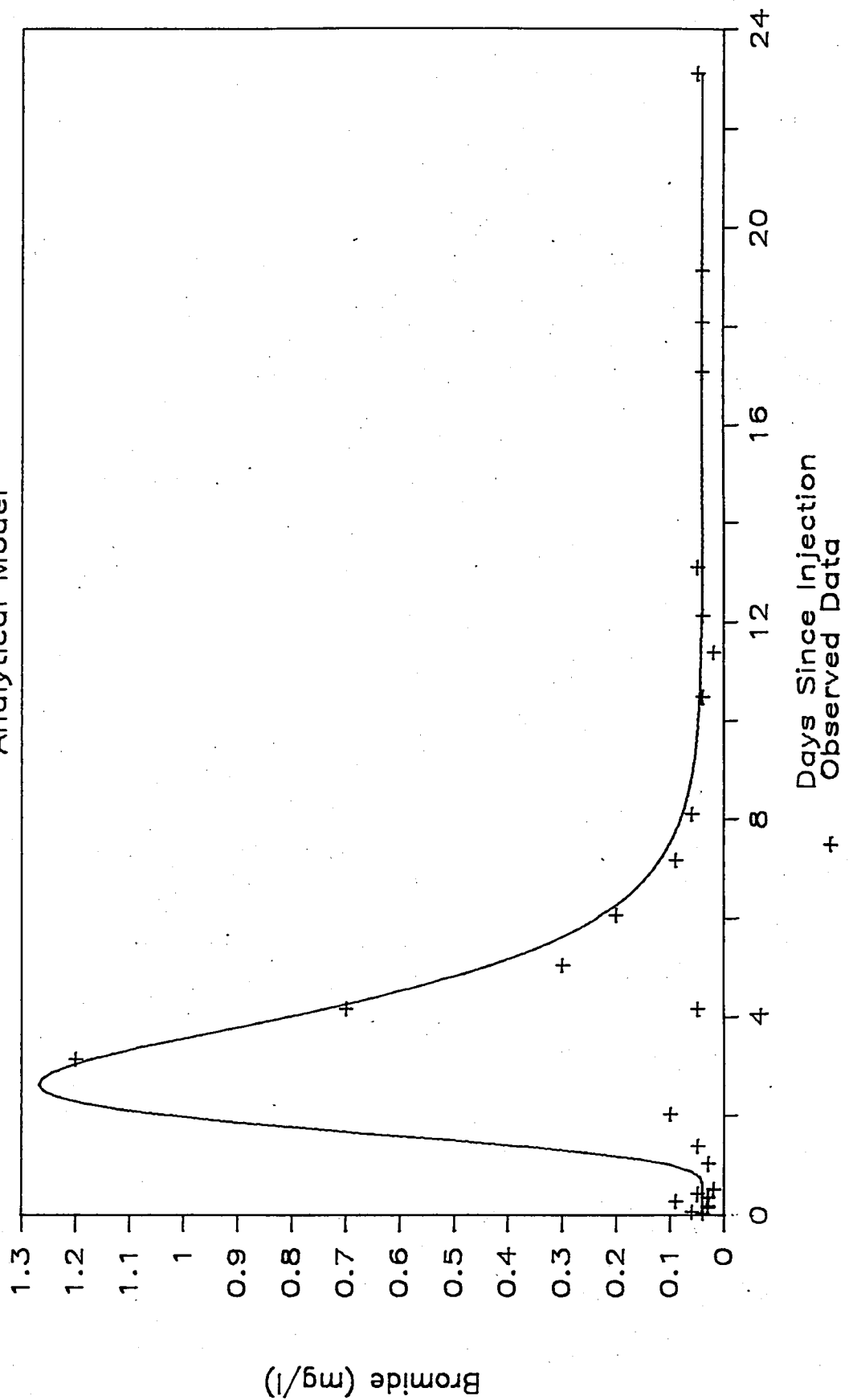
$$x = 1,220 \text{ M} \quad (\text{from map})$$

Calculate: $D_y D_z = 0.75 \text{ M}^4/\text{D}^2$ $\therefore \bar{V}_y$ and \bar{V}_z are small

Site VS Analytical Model



Site S4 Analytical Model



"ONE DIMENSIONAL" MODEL SENSITIVITY ANALYSIS
(SITE VS)

From the equation:

$$C(x,t) = \frac{K}{8(\pi i \cdot t)^{1.5}} \text{EXP} - \frac{x^2}{4D_x t}$$

K = A scaling factor related to the mass injected and the hydrodynamic dispersivity

D_x = A factor controlling the shape of the curve

\bar{V}_x = A factor controlling the shape and position of the curve

SITE VS

Check effect of changing \bar{V}_x at three different time periods and compare to observed data.

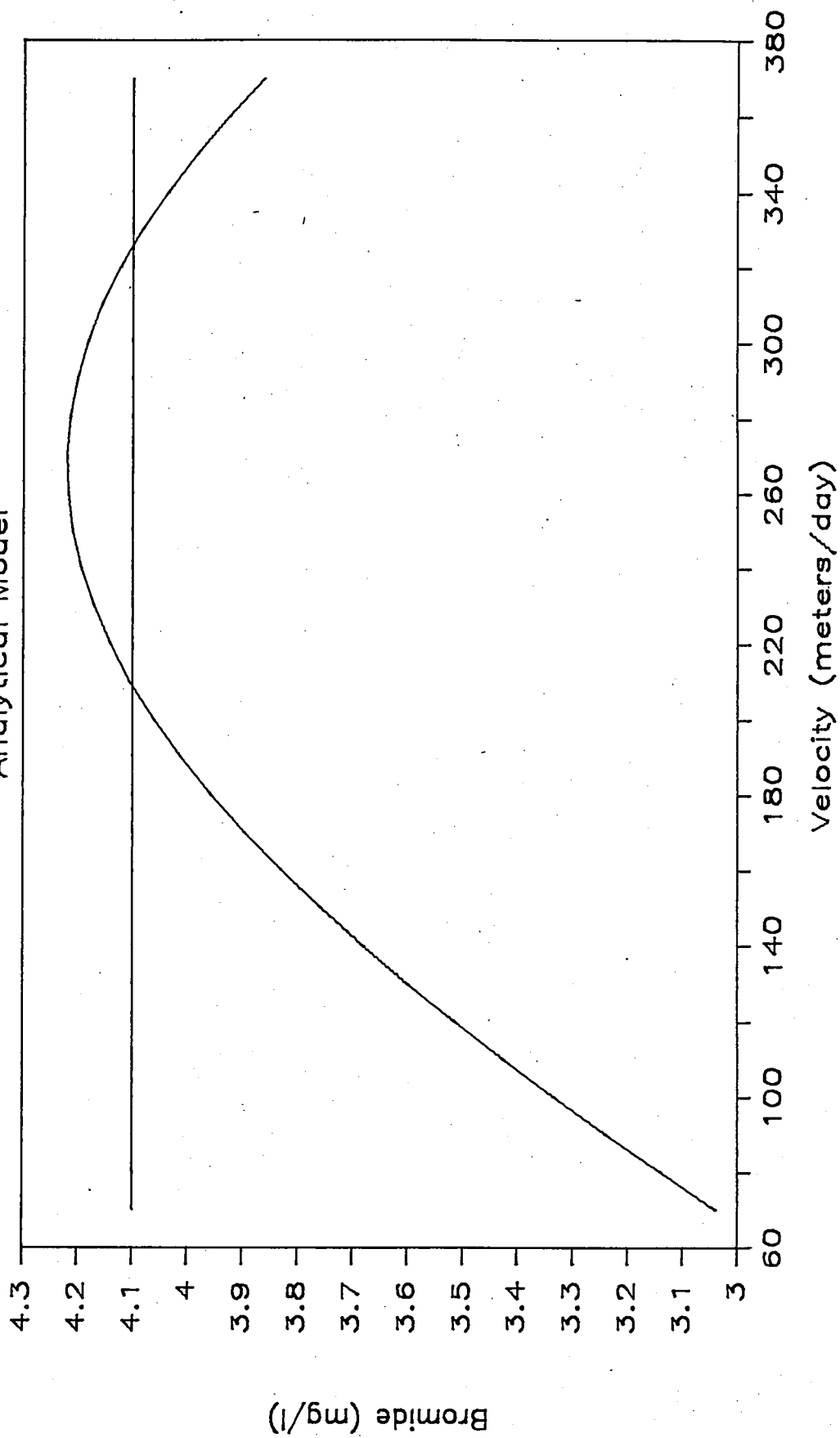
Time (day)	Observed Br mg/l	Velocity of Best Fit \bar{V}_x (M/D)
3.066	4.1	180-360
5.023	2.1	100-230
6.044	1.5	60-220

The attached graphs indicate the calculated Br^- concentrations at various assumed values of \bar{V}_x . A velocity of 180-220 M/D is common to each graph. Outside of this range, concentration changes rapidly with respect to velocity at one or more of the observation times.

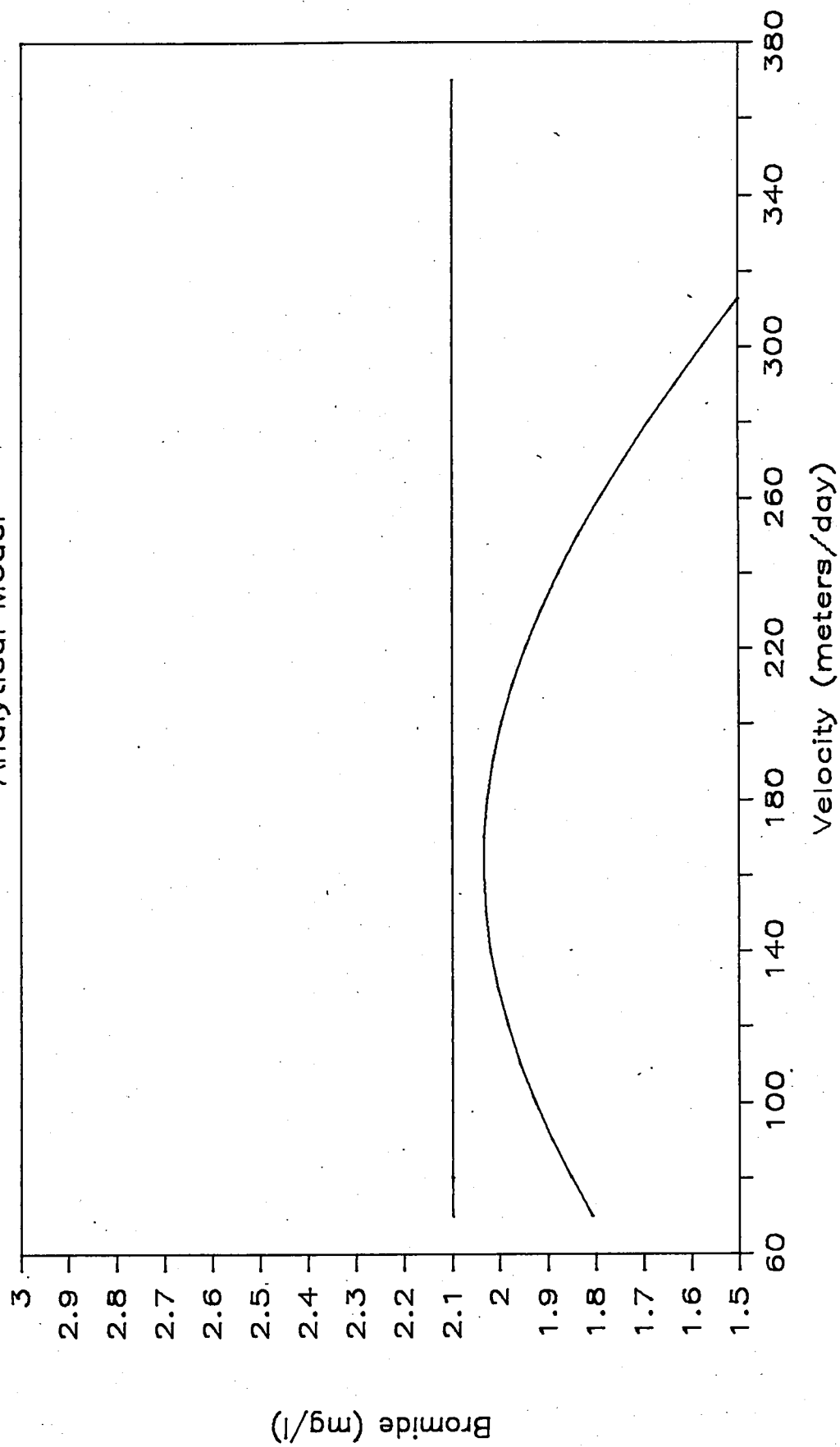
Check effect of altering D_x :

The attached graph indicates a "flat" slope of the concentration versus D_x curve above a value of $D_x = 40,000 \text{ M}^2/\text{D}$.

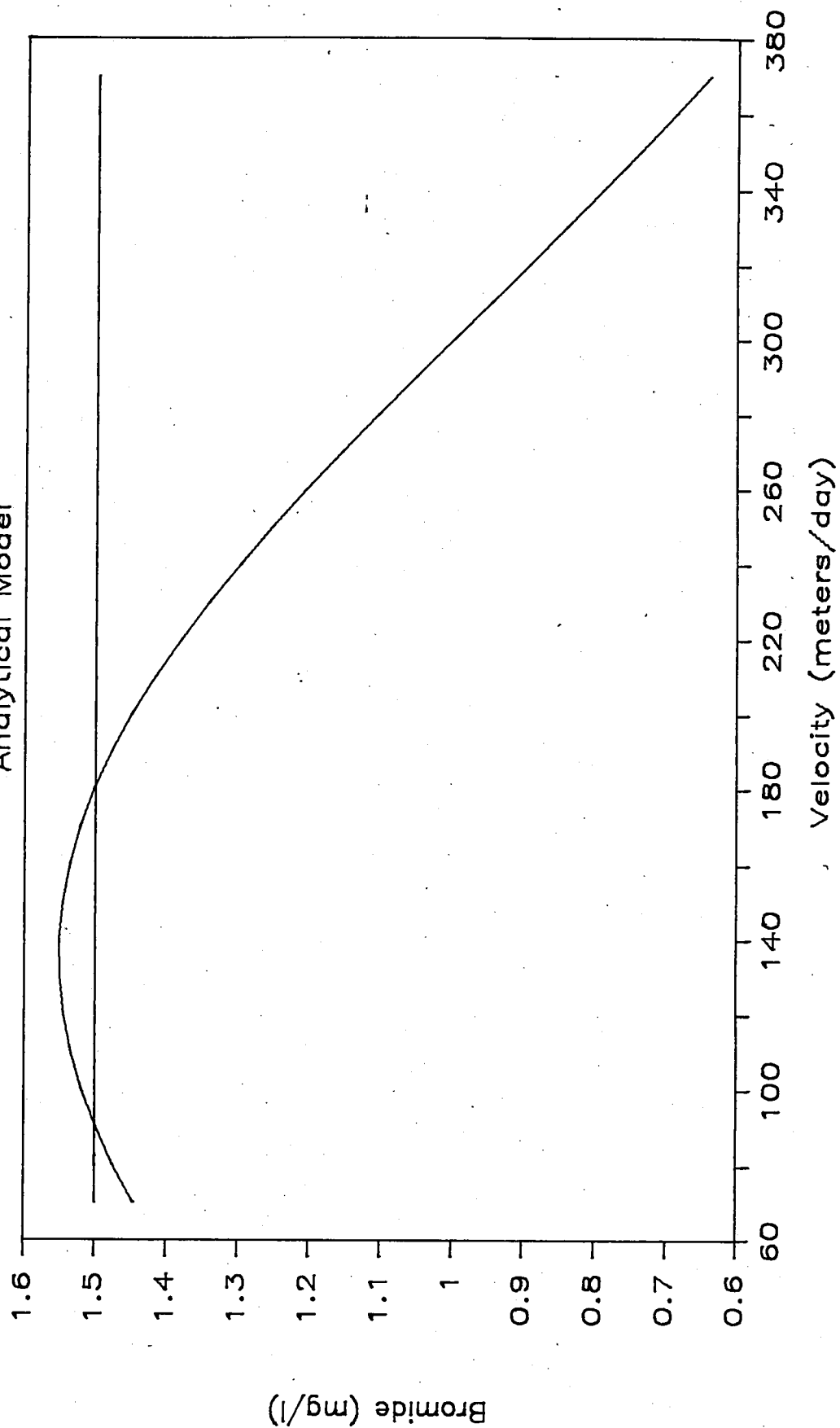
Site VS Analytical Model



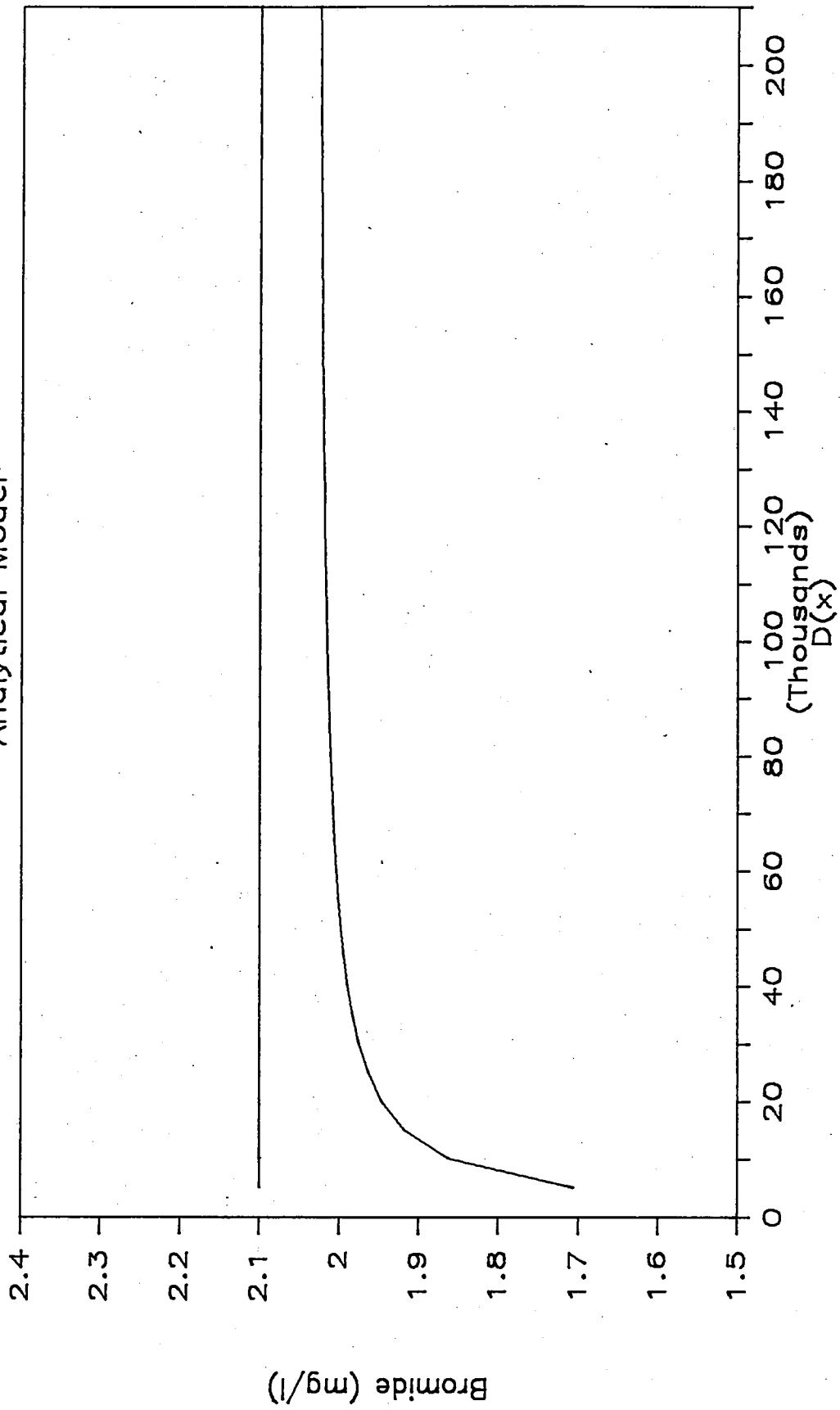
Site VS Analytical Model



Site VS Analytical Model



Site VS Analytical Model



APPENDIX C

ESTIMATION OF DISCHARGE
FROM TRACER EXPERIMENTS



Appendix C

ESTIMATION OF DISCHARGE FROM TRACER EXPERIMENTS

$$\text{Velocity} = \bar{V}_x = 190 \text{ to } 350 \text{ M/D (from tracers)}$$

$$\text{Assume } \bar{V}_x = 200 \text{ M/Day}$$

$$q = \bar{V}_x \cdot n = \text{specific discharge}$$

$$0.10 < n < 0.35$$

$$\text{Assume } n = 0.15$$

$$q = 200 \text{ M/D} \times 0.15 = 30 \text{ M/D}$$

$$Q = q \cdot A$$

$$A = b \cdot w$$

$$w = \text{width} \approx 75 \text{ meters}$$

$$b = \text{thickness} \approx 3 \text{ meters}$$

$$Q = 30 \text{ M/D} \times 3 \text{ M} \times 75 \text{ M}$$

$$= 6750 \text{ M}^3/\text{Day}$$

$$= 0.0781 \text{ M}^3/\text{Second}$$

$$= \underline{2.75 \text{ CFS}}$$

APPENDIX D

FLUOROMETER CALIBRATION - TURNER DESIGNS MODEL 10



Appendix D

FLUOROMETER CALIBRATION - TURNER DESIGNS MODEL 10

Five standards were prepared from the stock solution of 20 percent Rhodamine WT (RWT).

The standards were: 0.020, 0.20, 2.0, 20.0, and 200.0 PPB solutions of RWT.

The standards were prepared and stored in glass containers just prior to the calibration of the fluorometer.

The following equation was fit to the calibration data:

$$F = 110.41 C^{1.0788} \quad R^2 = 0.9999$$

Where F = Fluorescence

C = Concentration RWT (PPB)

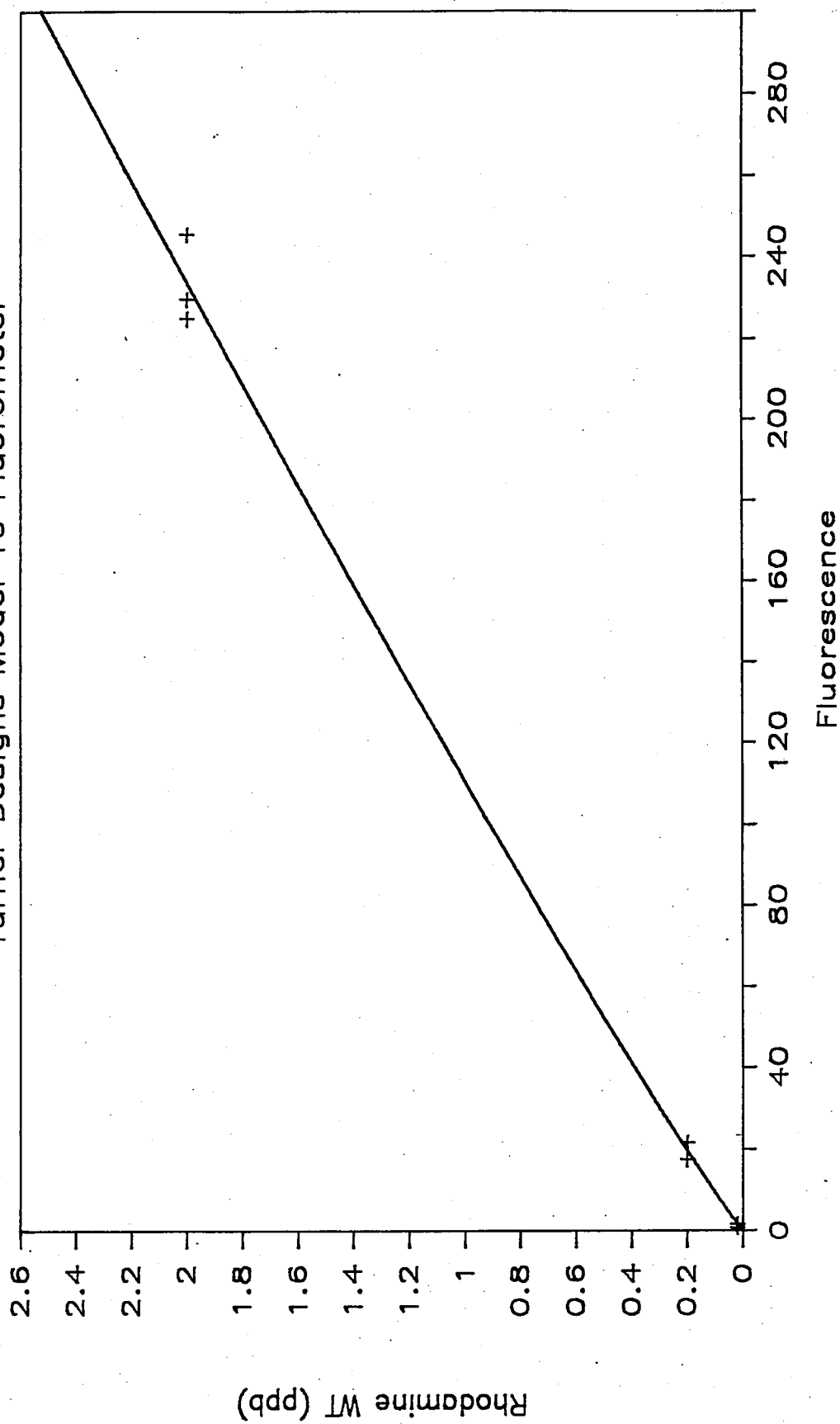
Rearranging terms:

$$C = \text{Exp} \frac{\ln (F/110.41)}{1.0788}$$

The calibration curve defined by this equation is shown on the next page.

Calibration Curve

Turner Designs Model 10 Fluorometer



ACKNOWLEDGEMENTS

WASHOE COUNCIL OF GOVERNMENTS

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James Eardley
Forest Lawson
Shirlee Wedow, WCOG Chairman

The following federal, state, local, and private entities provided input or otherwise assisted in the preparation of the Verdi ISDS Tracer Study. Their cooperation and advice is greatly appreciated.

Desert Research Institute
James C. Heidker, Research Associate

U. S. Geological Survey

Verdi Justice Court

Verdi Post Office

Verdi Volunteer Fire Department

WASHOE COUNTY DEPARTMENT OF COMPREHENSIVE PLANNING

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