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APPRAISAL OF OIL FIELD BRINE CONTAMINATION IN SHALLOW GROUND WATER AND SURFACE WATER, EASTERN SHERIDAN COUNTY, MONTANA

by

Jon C. Reiten
Hydrogeologist
Montana Bureau of Mines and Geology
Billings, Montana 59101

Terry Tischmak
Geologist
Sheridan County Conservation District
Plentywood, Montana

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APPRAISAL OF OIL-FIELD BRINE CONTAMINATION IN SHALLOW GROUND WATER AND SURFACE WATER, EASTERN SHERIDAN COUNTY, MONTANA

INTRODUCTION

Oil-field development in eastern Sheridan County has caused the transfer of highly concentrated sodium chloride brines from deep oil producing horizons to shallow aquifers and surface-water bodies. The study area covers the eastern one-third of Sheridan County (Figure 1). Several oil fields located in this area are the Flat Lake, Goose Lake, Clear Lake, Brush Lake, Divide, and Comertown oil fields (Plate 1, 2).

Dry land farming and livestock grazing are the traditional land uses in Sheridan County. Irrigation development has grown in the past 10 years; mainly in the southeastern part of the county where the Clear Lake aquifer is being tapped. Sufficient water supplies for irrigation and irrigable soils overlie several of the oil fields. Resource extraction industries including oil production, coal mining, and gravel mining are other land uses in eastern Sheridan County. Reserves of lignite within the Fort Union Formation underlie the glacial and terrace deposits. Several abandoned coal mines are located near the town of Coalridge. Most of the glacial outwash deposits in this area are composed of sand and gravel, and are mined throughout eastern Sheridan County.

Many of these land uses are dependent on adequate supplies of fresh water. In addition, most of these land uses can directly impact the quantity and quality of fresh-water supplies. As a

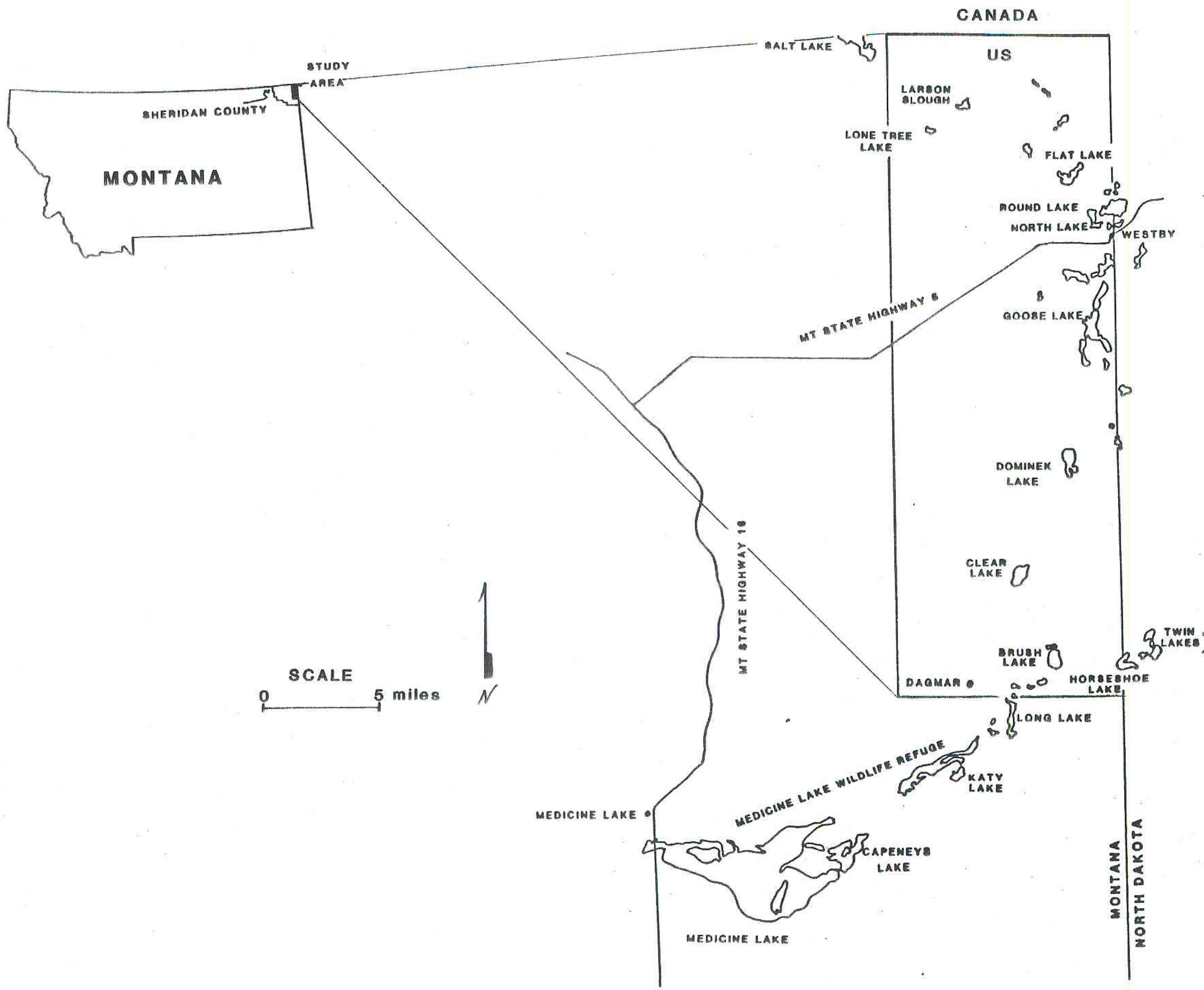


Figure 1. Location of the study area in the eastern one-third of Sheridan County.

result there is increasing pressure on limited water supplies. The potential impact of the oil extraction industry on water supplying these traditional and largely renewable resource industries was the focus of work conducted by the Sheridan County Conservation District and the Montana Bureau of Mines and Geology.

The first oil boom in eastern Sheridan County occurred during the early 1960's when several large fields were developed. Two of the larger fields developed were the Goose Lake and Flat Lake fields. The primary targets for oil extraction were zones in the lower Charles Formation of the Mississippian Madison Group. A second oil boom occurred during the 1970's where smaller, deeper oil pools were targeted, many in the Ordovician Red River Formation. About 700 to 800 oil wells have been drilled in Sheridan County, over half of these in the eastern one-third of the county.

The history of uncontained brine discharges is based on informal reports from local residents and documented investigations by several state agencies (MBMG, File data). Concern over contamination of water supplies was a major reason for organizing the Northeast Montana Land and Mineral Owners Association, Inc. Most of the reports of contamination were originally from members of the association. Several members reported improper disposal of brines into existing sloughs, brine and oil pipeline leaks, brine spills, and overflowing evaporation pits. Investigations by state agencies documented several cases of surface-water and ground-water contamination during the early 1970's.

The problem -- contamination of surface- and ground-water sources by oil-field wastes -- was evaluated by addressing the following questions.

1) What is the extent and severity of shallow groundwater contamination in eastern Sheridan County resulting from the disposal of oil-field wastes, primarily drilling muds, and salt-water brines?

2) Is it possible to develop a broadly applicable, cost-effective methodology for identifying and defining subsurface contamination? The methodology would use existing data or easily collected field data to rank oil-field sites for potential groundwater contamination.

3) Where are areas of existing contamination located?

4) Can future contamination be reduced or eliminated by using alternative disposal practices.

5) What are some of the alternative disposal methods available?

6) What would these alternative disposal methods cost?

BACKGROUND

The potential for contaminating shallow water supplies in eastern Sheridan County are the result of three major factors. First, the physical properties related to the setting; second, the operational methods historically used by industry to develop oil and gas resources; and third, the vulnerability of water resources in the area of oil development.

Influence of Physical Properties on Contamination Potential

The physical properties related to the setting are a result of the geology of both the deeply buried sediments associated with oil and the near-surface sediments associated with water supplies. Oil producing horizons in eastern Sheridan County commonly contain highly concentrated sodium chloride brines. The results of 24 brine analyses from oil producing zones in Sheridan County are shown in Table 1. Salt beds typically overlie target zones and require the use of salt based drilling muds to prevent washouts while drilling through these sediments. Drilling conditions also commonly require using a variety of additives. Many of the additives contain trace metals or other materials that can potentially degrade water supplies and damage soils. These additives are mixed into the drilling fluid to perform specific functions ranging from inhibiting corrosion to increasing mud weight (Table 2) (Murphy and Kehew, 1984).

The near-surface sediments associated with ground-water supplies are typically glacial deposits in Sheridan County. Coarse-grained glacial outwash deposits form the major aquifers. Fine-grained lake clay and glacial till form significant aquitards. Complex stratigraphic relationships and complex areal relationships between outwash deposits, lake clay deposits and glacial till deposits make quantifying and predicting contaminant movement difficult. In addition, surficial outwash deposits have relatively

Table 1. WATER QUALITY ANALYSES FROM OIL PRODUCING ZONES SHERIDAN COUNTY, MONTANA

MBMG SITE NO	OIL FIELD	DATE ANALYZED	LOCATION	GEOLOGIC FORMATION	PRODUCTION INTERVAL	SODIUM (mg/L)	CALCIUM (mg/L)	MAGNESIUM (mg/L)	SULFATE (mg/L)	CHLORIDE (mg/L)	BICARBONATE (mg/L)	pH	DISSOLVED SOLIDS (mg/L)
	SALT LAKE	03/19/71	NE375612CD	NESSON	7900-7900	65828.0	4500.00	1040.00	1650.0	111200.0	195.0	6.30	184314
	WILDCAT	07/27/70	NE375612CD	NISKU	7888-7892	91106.0	6468.00	120.00	388.0	152000.0	60.0	5.40	250111
	WILDCAT	07/30/70	NE375612CD	BAKKEN	7660-7678	93289.0	6170.00	760.00	463.0	156650.0	60.0	5.40	257361
SCB000154	FLAT LAKE	02/08/67	NE375708DX	NISKU	7946-7996	98996.0	7080.00	743.00	1132.0	166500.0	145.0	6.50	274522
SCB000154	FLAT LAKE	01/24/67	NE375708DX	RATCLIFFE	6465-6519	70446.0	4645.00	715.00	2988.0	116660.0	170.0	6.90	195538
SCB000190	FLAT LAKE	01/23/67	NE375721BAX	RATCLIFFE		35231.0	2125.00	560.00	2490.0	57755.0	245.0	7.40	98282
SCB000190	FLAT LAKE	10/09/66	NE375721BAX	RATCLIFFE	6443-6539	50990.0	2730.00	600.00	2602.0	33200.0	190.0	7.10	140216
SCB000190	FLAT LAKE	10/09/66	NE375721BAX	RATCLIFFE	6443-6539	88517.0	4000.00	650.00	2769.0	143400.0	110.0	7.20	239390
SCB000190	FLAT LAKE	10/09/66	NE375721BAX	RATCLIFFE	6443-6539	94522.0	4000.00	650.00	2778.0	152600.0	205.0	7.30	254651
SCB000044	WILDCAT	03/29/61	NE345826ADDB	DWYER	7300-7346	104438.0	11000.00	1980.00	660.0	185744.0	165.0	6.00	303903
	WILDCAT	08/03/70	NE375612CD	NESSON	6690-6704	58408.0	3430.00	590.00	2350.0	95950.0	340.0	6.40	160896
SCB000044	WILDCAT	03/29/61	NE345826ADDB	KIBBEY SAND	6325-6350	21257.0	1300.00	204.00	4045.0	32604.0	165.0	7.00	59491
SCB000044	WILDCAT	03/29/61	NE345826ADDB	KIBBEY SAND	6325-6350	21254.0	1300.00	222.00	4090.0	32604.0	190.0	7.20	59564
SCB000044	WILDCAT	03/29/61	NE345826ADDB	DWYER	7300-7346	105191.0	11000.00	1920.00	658.0	186732.0	165.0	6.00	305582
SCB000044	WILDCAT	03/29/61	NE345826ADDB	DWYER	7300-7346	105076.0	11000.00	1980.00	669.0	186732.0	148.0	6.00	305530
SCB000069	WILDCAT	05/31/63	NE355809CDDB	MISSION CANYON	7260-7306	59820.0	4498.00	677.00	1563.0	101000.0	85.0	5.60	167600
SCB000080	GOOSE LAKE	12/30/64	NE355817BDX	RATCLIFFE	6927-6949	81719.0	4190.00	754.00	2591.0	133600.0	255.0	7.40	222980
	N. GOOSE LKE	01/11/73	NE365828	RATCLIFFE		84728.0	5002.00	331.00	1086.0	139543.0	212.0	6.20	230912
	N. GOOSE LKE	01/11/73	NE365828	RATCLIFFE		73405.0	3575.00	195.00	598.0	119122.0	268.0	6.40	196933
SCB000069	GOOSE LAKE	08/27/63	NE355809CDDB01	MISSION CANYON	7271- 7275	0.0	0.00	0.00	0.0	101530.0	0.0	5.30	166856
SCB000252	WILDCAT	05/26/87	NE345814BDAC01	RED RIVER	11168-11256	90700.0	22040.00	0.00	0.0	173300.0	0.0	6.24	293100
SCB000252	WILDCAT	05/20/87	NE345814BDAC01	RED RIVER	11168-11256	0.0	0.00	0.00	0.0	255550.0	0.0	0.00	0
SCB000080	GOOSE LAKE	08/07/74	NE355817BDX 01	RATCLIFFE	6927- 6932	64500.0	3460.00	830.00	1140.0	107000.0	168.0	6.00	177098
SCB000258	GOOSE LAKE	04/27/89	NE355816BABA01	RATCLIFFE		0.0	0.00	0.00	0.0	190000.0	0.0	6.10	310000

Table 2. Function and general purpose of drilling fluid additives (from Murphy and Kehew, 1984).

Function	General Purpose	Common Additives
Weighting Material	Control formation pressure, check caving facilitate pulling dry pipe, and well completion operations	Barite, lead compounds, iron oxides
Viscosifier	Viscosity builders for fluids for a high viscosity-solids relationship	Bentonite, attapulgite clays, all colloids, fibrous asbestos
Thinner Dispersant	Modify relationship between the viscosity and percentage of solids, vary gel strength, deflocculant	Tannins (quebracho), polyphosphates, lignitic materials
Filtrate Reducer	Cut the loss of the drilling fluids's liquid phase into the formation	Bentonite clays, sodium carboxymethyl cellulose (CMC), pregelatinized starch, various lignosulfonates
Lost Circulation Material	Primary function is to plug the zone of loss	Walnut shells, shredded cellophane flakes, thixotropic cement, shredded cane fiber, pig hair, chicken feathers, etc.
Alkalinity, pH Control	Control the degree of acidity or alkalinity of a fluid	Lime, caustic soda, bicarbonate of soda
Emulsifier	Create a heterogeneous mixture of two liquids	lignosulfonates, and detergent, petroleum sulfonate
Surfactant	Used to the degree of emulsification, aggregation, dispersion, interfacial tension, foaming and defoaming (surface active agent)	Include additives used under emulsifier foamers, defoamers, and flocculators
Corrosion Inhibitor	Materials attempt to decrease the presence of such corrosive compounds as oxygen, carbon dioxide, and hydrogen sulfide	Copper carbonate, sodium chromate, chromate-zinc solutions, chrome lignosulfonates, organic acids and amine polymers, sodium arsenite
Defoamer	Reduce foaming action especially in salt water based muds	Long chain alcohols, silicones, sulfonated oils
Foamer	Surfactants which foam in the presence of water and thus permit air or gas drilling in formation producing water	Organic sodium and sulfonates, alkyl benzene sulfonates
Flocculants	Used commonly for increases in gel strength	Salt, hydrated lime, gypsum, sodium tetraphosphates
Bactericides	Reduce bacteria count	Starch preservative, paraformaldehyde, caustic soda, lime, sodium pentachloraphenate
Lubricants	Reduce torque and increase horsepower at the bit by reducing the coefficient of friction	Graphite powder, soaps, certain oils
Calcium Remover	Prevent and overcome the contamination effects of anhydrite and gypsum	Caustic soda (NaOH), soda ash, bicarbonate of soda, barium carbonate
Shale control Inhibitors	Used to control caving by swelling or hydrous disintegration	Gypsum, sodium silicate, calcium lignosulfonates, lime, salt

high infiltration rates that permit rapid percolation of soluble contaminants.

Influence of Industrial Operation Methods on Contamination Potential

The operational methods used during the drilling and production of hydrocarbons can greatly influence the hazard to water supplies from oil-field wastes. Oil-field wastes include the drilling fluids, cuttings, waste oil, and produced brines. Waste drilling fluids are composed of a viscous phase of waste mud that settles to form a sludge and a less viscous phase of salt water that overlies the sludge. Produced brines are salt water that are co-produced along with the oil. The oil-field wastes and cuttings are contained in a reserve pit that is excavated at the drill site. Typical dimensions of Williston Basin reserve pits are 150 feet long, 60 feet wide, and 10 feet deep. During drilling operations, from 54,000 to 90,000 cubic feet of salt-saturated drilling fluid is maintained in a reserve pit that is excavated at the drill site (Murphy and Kehew, 1984).

Reserve pits are commonly lined with a plastic liner to prevent seepage. Prior to the mid-1970's many of the reserve pits were simply backfilled or were left open and used for storage and disposal of produced brines. This method of backfilling commonly left depressions and a generally unstable land surface. Since the mid-1970's the pits have been reclaimed by a variety of methods. Most commonly, the less viscous portion of the drilling wastes is removed for disposal into an injection well. Then, radial trenches are excavated away from one side of the pit, and fill pushed into the pit, causes the remaining drilling wastes to flow into the radial trenches. The unlined radial trenches are then backfilled and levelled, minimizing the surficial instability. Breaching the liner when the radial trenches are excavated results in a high potential for contaminating shallow aquifers. Other drilling waste disposal methods have been used in the last ten years including off-site disposal or on-site solidification of the waste mud.

Prior to 1975 many of the unreclaimed reserve pits were used as evaporation pits for both temporary storage and final disposal of co-produced brines. Open water-filled pits were identified at a majority of the oil wells in the Goose Lake field on aerial photographs from the late 1960's. Many of these pits were probably being used as evaporation pits.

During the life of an individual oil well or oil field the ratio of brine produced to oil produced typically increases. As an example, the increasing brine to oil ratio can be demonstrated from production records of the Goose Lake field. Total production during 1963 from nine wells in the Goose Lake field was 110,014 barrels of oil and 371,847 barrels of brine for a brine to oil ratio of 3.38. During 1976 nineteen wells produced 252,724 barrels of oil and 1,831,369 barrels of brine for a brine to oil ratio of 7.25. During 1983 thirty wells produced 129,667 barrels of oil and 1,867,709 barrels of brine for a brine to oil ratio of 14.40. Consequently, the volume of brine pumped to the surface and requiring special handling increases through time. Special handling of brines currently includes storage in tank batteries, piping to collection points, injection into disposal wells, and injection into production intervals for enhancing oil recovery.

Influence of Water Supply Proximity to Oil Development on Contamination Potential

The threat of degrading the quality of water supplies within areas of oil development is largely caused by the handling of large volumes of brine above or upgradient of near-surface water supplies. Shallow glacial aquifers are often the best source of water for domestic and stock purposes. In many areas ground water in the underlying bedrock is an unsuitable supply because limited quantities of water can be produced economically or elevated dissolved solids makes the water unuseable. Water supplies tapping shallow aquifers can be highly vulnerable to salt-water contamination when uncontained brine discharges occur at nearby oil-field sites.

Dugouts excavated into shallow aquifers, and stock dams storing excess runoff, are common water supplies used for livestock. Both are highly vulnerable to contamination from uncontained brine discharges. The overall impact of brine contamination to domestic and stock water supplies ranges from minor increases in dissolved solids that do not impact the useability of the water supply to major increases in dissolved solids destroying the useability of the water supply.

Hundreds of lakes and sloughs are located in eastern Sheridan County. These surface-water sources have a very diverse chemistry, with several fold increases in dissolved solids possible between lakes separated by only a few hundred yards. The lakes are used by wildlife, livestock and recreationists. Many of the lakes are important to the water balance of the region both as focused recharge sources and as buffers influencing ground-water levels. The addition of brine to the lakes degrades water quality, although the magnitude of the degradation will vary widely based on background water quality. As a result of the diversity in background water quality and lack of pre-impact data, the overall impact to lakes in eastern Sheridan County due to oil-field brine contamination is difficult to assess.

PREVIOUS STUDIES

Interest in the contamination potential of oil-field wastes developed shortly after the United States Environmental Protection Agency (EPA) began implementing the Resource Conservation and Recovery Act (RCRA) program. Research projects were soon initiated by the EPA (US Environmental Protection Agency, 1987) and the oil industry (Dames and Moore, 1982) evaluating the toxicity of drilling fluids used in North America. The researchers concluded that although potentially hazardous materials are found in oil-field wastes; the concentrations generally do not exceed RCRA guidelines for hazardous wastes.

Case studies documenting contamination from oil-field wastes in the Williston Basin of Montana and North Dakota are discussed in reports by Levings (1984), Murphy and Kehew (1984), Murphy and others (1988), Dewey (1984) and Reiten and others (1991). The most serious threat to water supplies identified in the Williston Basin is the potential damage from sodium chloride salts in both the waste drilling mud and the produced brines.

CLIMATE

Eastern Sheridan County has a semiarid continental climate, characterized by cold, dry winters, moderately hot and dry summers, and cool, dry falls. Cold winters are often interrupted by warming trends, with summers dominated by hot days and cool nights. January is generally the coldest month and July the warmest. Average precipitation at Westby is approximately 14.2 inches/year with about 65 percent of the precipitation falling from May through August. June is typically the wettest month. Monthly precipitation for 1980 to mid 1990 is shown in Table 3. Evaporation is typically much higher than precipitation in this area. The closest station with long-term Class A evaporation pan data is at Sidney. Long-term data from the Sidney site indicates between 25 and 35 inches of water evaporates annually. Evaporation data from a Class A pan of the U.S. Department of Agriculture research farm near Froid indicates significantly higher evaporation rates than at Sidney. The average evaporation at the Froid station was 52 inches per year between 1984 and 1988. In contrast, the Sidney station reported 34 inches of annual evaporation over the same period (Donovan, 1988). Wind and hot temperatures contribute

Table 3. Measured total monthly precipitation in the Westby area.
Data collected by the National Oceanic and Atmospheric Administration

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1980	.66	.31	.43	1.30	.39	2.63	1.14	4.74	1.58	1.06	.26	.55	15.05
1981	.10	.06	.38	.50	1.47	3.97	1.12	2.04	.78	.81	.81	.29	12.33
1982	1.08	.46	.85	.82	3.07	1.14	1.31	1.93	1.85	.82	0	.82	14.15
1983	.26	.07	.73	0	1.16	1.58	2.27	.88	2.00	.01	.29	.30	9.55
1984	.63	.03	.07	0	.59	3.31	.07	.29	1.25	.42	0	.22	6.88
1985*	.06	.22	.78	1.15	1.29	.93	1.02	2.35	1.25	.93	.30	.29	10.57
1986*	.25	.37	.17	.73	3.12	2.56	3.22	.49	4.97	1.41	.44	.06	17.79
1987	.15*	.12*	1.16*	.01*	2.50*	1.20*	5.17	.61	1.04	.18	.11	.01	12.26
1988	.01	.20	.40	.44	1.07	2.33	1.32	.95	1.54	.27	.43	.73	9.69
1989	1.33	.21	.39	1.38	1.30	1.89	.50	.72	.42	1.65	.24	.10	10.13
1990	.10	.01	1.23	.57	2.23	3.01	5.21						
10 Year Average	.45	.21	.54	.63	1.60	2.15	1.71	1.50	1.67	.76	.28	.34	11.84
11 Year Average	.33	.19	.60	.63	1.65	2.23	2.03						
20 Year Average	.46	.45	.44	1.15	1.93	2.89	1.92	2.07	1.42	.69	.34	.43	14.19

* Westby data not available in 1985, 1986, and Jan-Jun of 1987, the station in nearby Plentywood was used for calculations.

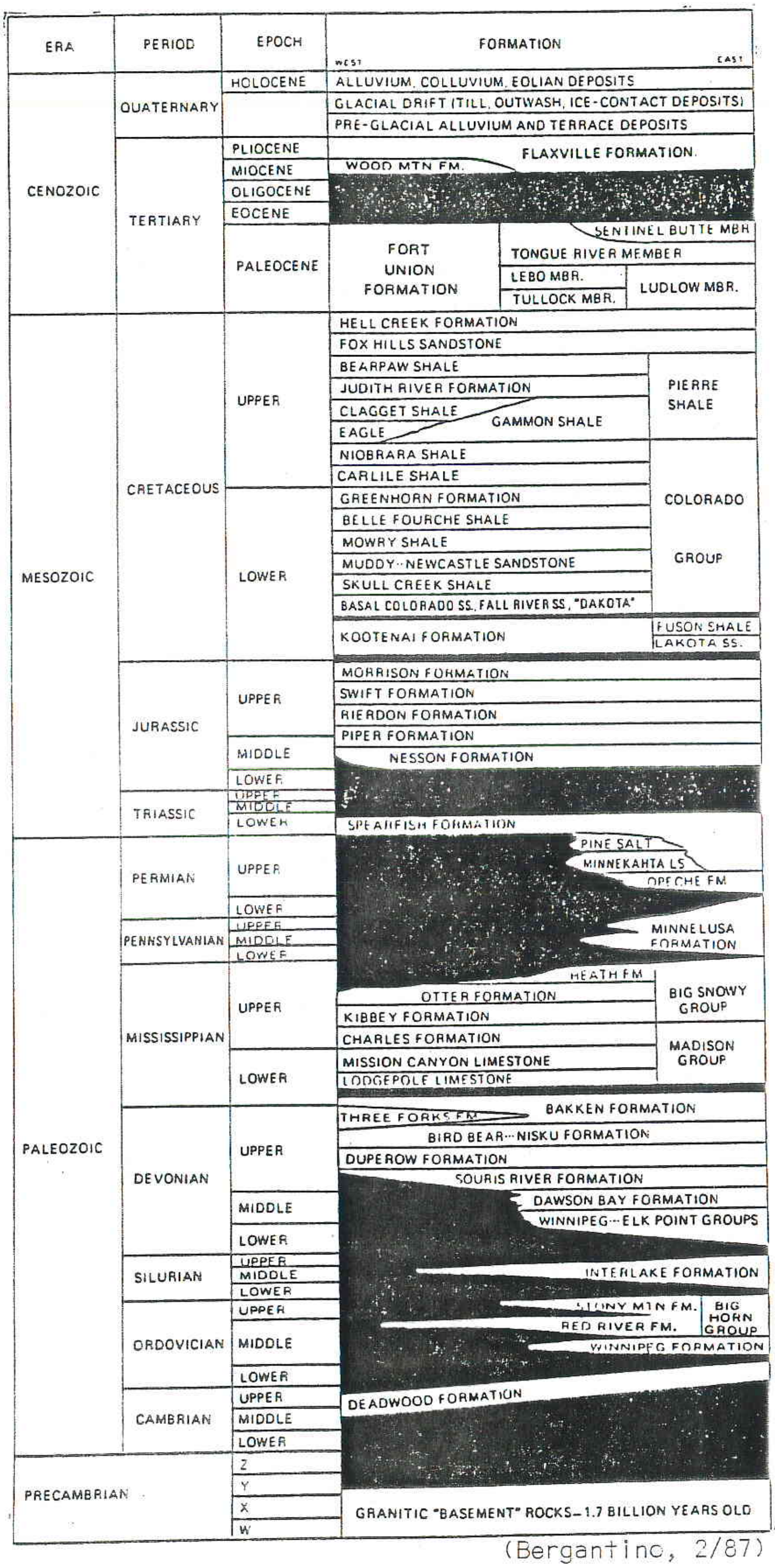
to an average 6 to 12 inches of monthly evaporation from May to August at the Froid site. The Froid climatic station is more representative of conditions in eastern Sheridan County than is the Sidney climatic station because of the proximity and more similar physiography.

Long term climatic trends show a large range of monthly precipitation for individual months (Table 3). This trend is most evident from April through September. A 10-20 year periodicity of below average precipitation is often accompanied by above average temperatures, indicating that cycles of drought are common in this region. The 1980's were drier than average resulting in drought during much of the decade.

REGIONAL HYDROGEOLOGY

The stratigraphic relationships of formations at or below land surface in eastern Sheridan County are shown in Figure 2. Eight major aquifer systems underlie eastern Sheridan County from the Paleozoic Madison Group to the Quaternary alluvium. Aquifers within 200 to 300 feet of ground surface include the Tongue River Member of the Tertiary Fort Union Formation, Tertiary/Quaternary terrace deposits, Quaternary glacial outwash deposits and recent alluvial deposits. The lower Hell Creek-Fox Hills aquifer is the deepest source of potable water in this region. Depth to this aquifer ranges from 700 to 1100 feet.

Deeper aquifers in rocks of Mesozoic and Paleozoic age contain non-potable water but are important aquifers because of an association with oil reservoirs. Water from these aquifers are



(Bergantino, 2/87)

Figure 2. Stratigraphic relationships of Formations at or below land surface in eastern Sheridan County.

commonly pumped to the surface during oil production and can potentially degrade potable supplies if allowed to infiltrate shallow aquifers.

The distribution of surficial glacial deposits of till, outwash, and lake sediments are mapped on Plate 1 and Plate 2. Data for the geological map were obtained from outcrops, drill holes, soil surveys (Richardson and Hanson, 1977), and open-file geologic maps (Bergantino, 1986) of Sheridan County. These sediments were deposited during and after the advance of Late Wisconsinan glaciers into the region. Glacial till is the most widespread surficial geologic unit mapped in the study area. The glacial till consists of unbedded and unsorted gray to light-olive-brown, pebbly clay-loam, and is considered an aquitard. Pebbles, cobbles, and boulders of local and northern sources are common in this unit. Water in the till aquitards is generally under confined conditions. Secondary porosity caused by fractures in the till accounts for most of the water movement.

Glacial outwash deposits are the second most widespread surficial geologic unit mapped in the study area. The outwash consists of light-gray, brown, and reddish-brown, silty sand, sand and gravel. It is composed of a heterogeneous mixture of igneous, metamorphic, and sedimentary rock fragments. Sorting of the outwash ranges from poor to moderate. Glacial outwash was deposited by meltwater streams draining the glaciers. Deposits of glacial outwash typically form aquifers, which if buried by glacial till or other fine-grained materials are commonly under confined or leaky confined conditions.

Glacial lake sediments cover the least area of the surficial geologic units mapped. These lake sediments consist of light-brown to dark-gray interbedded, fine-grained sand, silt, and clay. Lake sediments were deposited by interflow and underflow currents in glacially dammed lakes. All of the surficial lake deposits are restricted to the portion of Plate 1 north and west of McElroy. Due to its fine-grained nature, lake sediments typically form aquitards. As in glacial till, fractures cause secondary porosity, increasing the water transmitting capabilities of this unit. Water in lake deposits is generally under confined conditions.

For simplicity, recent deposits of alluvium, loess, colluvium, and slough sediment were not mapped. These deposits are usually thin (less than 1 meter thick) and where thicker are difficult to distinguish from the older glacial deposits.

Glacial till, glacial outwash, and glacial lake sediments typically have complex stratigraphic and areal inter-relationships. Aquifers developed in glacial deposits can rarely be classified as isotropic, homogeneous and infinite. Consequently, defining the aquifers formed in glacial deposits and defining the properties of these aquifers such as transmissivity, storativity, and boundary conditions are difficult tasks, subject to a wide margin of error.

VERIFICATION OF BRINE CONTAMINATION

A series of investigative steps were used to verify and define brine contamination near oil-field sites. In general, this method employed a system for filtering data from many diverse sources by 1.) identifying the location of over 300 sites, 2.) ranking sites by inspecting and evaluating the brine contamination potential at 99 of these sites, 3.) developing a hydrogeologic overview of the contamination problem at 24 of these sites and, 4.) conducting more detailed hydrogeologic investigations in the Goose Lake field where several sources have contributed to widespread contamination of water resources.

SITE DESIGNATION

Oil-field sites were identified from microfiche copies of Oil and Gas Commission records of oil well drilling in Sheridan County (MBMG file data). The file contains primary information for nearly all oil-field activities through 1984 including oil wells, injection wells, and water supply wells. Additional sites such as tank batteries and pipelines were identified from files at the Oil and Gas Commission office in Billings and from field observations. Table 4 summarizes primary site information for 307 oil-field sites. Primary site information consists of data related to the industrial operations including location, type of site, age, and drilling depth. Site locations are described using the BLM land identification method (Appendix A). Drilling locations were the most common type of site identified. Other types of sites identified are tank batteries for storage of brine and oil, pipelines for transmission of brine and oil, and several lakes and sloughs that are adjacent to areas of intensive oil-field activity.

Table 4. SUMMARY OF PRIMARY OIL FIELD SITE INFORMATION

MBMG NO	LOCATION	OIL FIELD	TYPE OF SITE	DATE WORK STARTED	DEPTH OF WELL	TARGET FORMATION
SCB000001	NE335709DBX	DAGMAR	DRILLING	1967	7577	MISSION CANYON
SCB000002	NE335714DACC	DAGMAR	DRILLING	1969	11396	RED RIVER
SCB000003	NE335728DBCC	DAGMAR	DRILLING	1977	11450	RED RIVER
SCB000004	NE335703DDD	DAGMAR	DRILLING	1983	8000	MADISON
SCB000005	NE335710AAX	DAGMAR	DRILLING	1982	11375	RED RIVER
SCB000006	NE335726BBX	DAGMAR	DRILLING	1960	7671	RATCLIFFE
SCB000007	NE335801BX	BRUSH LAKE	DRILLING	1970	11541	RED RIVER
SCB000008	NE335801CBX	BRUSH LAKE	DRILLING	1969	11758	RED RIVER
SCB000009	NE335801CBAC	BRUSH LAKE	DRILLING	1971	4750	DAKOTA
SCB000010	NE335802DDBB	BRUSH LAKE	DRILLING	1970	11540	RED RIVER
SCB000011	NE335805BACA	CLEAR LAKE	DRILLING	1979	7919	RATCLIFFE
SCB000012	NE335808DDX	CLEAR LAKE	DRILLING	1978	11410	RED RIVER
SCB000013	NE335811ACAA	BRUSH LAKE	DRILLING	1970	11524	RED RIVER
SCB000014	NE335811DDBB	BRUSH LAKE	DRILLING	1971	11509	RED RIVER
SCB000015	NE335813BX	BRUSH LAKE	DRILLING	1971	11480	RED RIVER
SCB000016	NE335814BX	BRUSH LAKE	DRILLING	1972	11550	RED RIVER
SCB000017	NE335816BBDC	CLEAR LAKE	DRILLING	1978	11997	RED RIVER
SCB000018	NE335816CBCD	CLEAR LAKE	DRILLING	1977	11371	RED RIVER
SCB000019	NE335817DABA	CLEAR LAKE	DRILLING	1977	11375	RED RIVER
SCB000020	NE335817ADCA	CLEAR LAKE	DRILLING	1978	8965	MISSION CANYON
SCB000021	NE335824CBBD	BRUSH LAKE	DRILLING	1961	7734	RATCLIFFE
SCB000022	NE335828CBDD	SOUTH CLEAR LAKE	DRILLING	1979	9090	NISKU
SCB000023	NE335828CCAC	SOUTH CLEAR LAKE	DRILLING	1978	11442	RED RIVER
SCB000024	NE335833BACA	SOUTH CLEAR LAKE	DRILLING	1979	11550	RED RIVER
SCB000025	NE335828BCX	SOUTH CLEAR LAKE	DRILLING	1979	9112	NISKU
SCB000026	NE335808DBAC	CLEAR LAKE	DRILLING	1984	11352	RED RIVER
SCB000027	NE345701CDDB	COALRIDGE	DRILLING	1979	8790	MISSION CANYON
SCB000028	NE345702AABD	COALRIDGE	DRILLING	1979	7600	RATCLIFFE
SCB000029	NE345702DX	COALRIDGE	DRILLING	1978	7141	RATCLIFFE
SCB000030	NE345702DAX	COALRIDGE	DRILLING	1979	7500	RATCLIFFE
SCB000031	NE345703CDAC	LOWELL AREA	DRILLING	1979	8910	NISKU
SCB000032	NE345709DBX	LOWELL AREA	DRILLING	1972	7433	RATCLIFFE
SCB000033	NE345711BBX	LOWELL AREA	DRILLING	1963	7370	RATCLIFFE
SCB000034	NE345714ABBD	LOWELL AREA	DRILLING	1962	7345	RATCLIFFE
SCB000035	NE345722BCDA	LOWELL AREA	DRILLING	1979	11262	RED RIVER
SCB000036	NE345807DDX	COALRIDGE	DRILLING	1965	7425	MISSION CANYON
SCB000037	NE345809ADX	DIVIDE	DRILLING	1965	7235	MISSION CANYON
SCB000038	NE345810ACX	DIVIDE	DRILLING	1964	7254	MISSION CANYON
SCB000039	NE345812ABDB	DIVIDE	DRILLING	1968	7341	MISSION CANYON
SCB000040	NE345815ABX	DIVIDE	DRILLING	1976	7300	RATCLIFFE
SCB000041	NE345817DDX	DIVIDE	DRILLING	1968	7330	MISSION CANYON
SCB000042	NE345823ACAC	DIVIDE	DRILLING	1977	11410	RED RIVER
SCB000043	NE345824CD	DIVIDE	DRILLING	1983	7653	MISSION CANYON
SCB000044	NE345826ADDB	DIVIDE	DRILLING	1961	7438	RATCLIFFE
SCB000045	NE345826BX	DIVIDE	DRILLING	1980	7875	MISSION CANYON
SCB000046	NE345827ACDB	DIVIDE	DRILLING	1979	11500	RED RIVER
SCB000047	NE345832CBX	CLEAR LAKE	DRILLING	1979	7903	MISSION CANYON
SCB000048	NE345835AACA	DIVIDE	DRILLING	1979	8106	MISSION CANYON
SCB000049	NE345836BX	BRUSH LAKE	DRILLING	1970	11665	WINNIPEG
SCB000050	NE345836CACC	BRUSH LAKE	DRILLING	1970	11519	RED RIVER
SCB000051	NE355716AA	WEST GOOSE LAKE	DRILLING	1965	7183	RATCLIFFE
SCB000052	NE355724BAX	WEST GOOSE LAKE	DRILLING	1967	7399	MISSION CANYON
SCB000053	NE355726CAX	WEST GOOSE LAKE	DRILLING	1966	7325	MISSION CANYON

Table 4. SUMMARY OF PRIMARY OIL FIELD SITE INFORMATION
(continued)

MBMG NO	LOCATION	OIL FIELD	TYPE OF SITE	DATE WORK STARTED	DEPTH OF WELL	TARGET FORMATION
SCB000054	NE355728ADBD	WEST GOOSE LAKE	DRILLING	1964	7333	MISSION CANYON
SCB000055	NE355734AADB	WEST GOOSE LAKE	DRILLING	1964	7650	MISSION CANYON
SCB000056	NE355801ADX	EAST GOOSE LAKE	DRILLING	1978	6915	RATCLIFFE
SCB000057	NE355801DACD	EAST GOOSE LAKE	DRILLING	1980	7620	MISSION CANYON
SCB000058	NE355804ABBD	GOOSE LAKE	DRILLING	1965	7022	MISSION CANYON
SCB000059	NE355804BBX	GOOSE LAKE	DRILLING	1963	7195	RATCLIFFE
SCB000060	NE355804CBX	GOOSE LAKE	DRILLING	1965	7000	RATCLIFFE
SCB000061	NE355805ABX	GOOSE LAKE	DRILLING	1963	6950	RATCLIFFE
SCB000062	NE355805CBAC	GOOSE LAKE	DRILLING	1968	6960	RATCLIFFE
SCB000063	NE355805DBX	GOOSE LAKE	DRILLING	1965	6960	RATCLIFFE
SCB000064	NE355808ADX	GOOSE LAKE	DRILLING	1965	6982	RATCLIFFE
SCB000065	NE355808BDX	GOOSE LAKE	DRILLING	1966	7049	RATCLIFFE
SCB000066	NE355808CDBD	GOOSE LAKE	DRILLING	1965	7003	RATCLIFFE
SCB000067	NE355808DDX 01	GOOSE LAKE	DRILLING	1963	7320	RATCLIFFE
SCB000068	NE355809BDCA	GOOSE LAKE	DRILLING	1963	7100	RATCLIFFE
SCB000069	NE355809CDDB	GOOSE LAKE	DRILLING	1963	8542	MISSION CANYON
SCB000070	NE355809DDBD	GOOSE LAKE	DRILLING	1963	7357	MISSION CANYON
SCB000071	NE355810BBX	GOOSE LAKE	DRILLING	1979	7450	MISSION CANYON
SCB000072	NE355810BDBD	GOOSE LAKE	DRILLING	1966	7036	RATCLIFFE
SCB000073	NE355811ADBA	EAST GOOSE LAKE	DRILLING	1964	7050	RATCLIFFE
SCB000074	NE355813CABD	EAST GOOSE LAKE	DRILLING	1964	7120	RATCLIFFE
SCB000075	NE355815DDX	EAST GOOSE LAKE	DRILLING	1969	9917	WINNIPEG
SCB000076	NE355816AX	GOOSE LAKE	DRILLING	1974	7000	RATCLIFFE
SCB000077	NE355816BDBD	GOOSE LAKE	DRILLING	1963	7278	RATCLIFFE
SCB000078	NE355816CX	GOOSE LAKE	DRILLING	1974	7010	RATCLIFFE
SCB000079	NE355817ADX 01	GOOSE LAKE	DRILLING	1964	7049	RATCLIFFE
SCB000080	NE355817BDX	GOOSE LAKE	DRILLING	1965	7015	RATCLIFFE
SCB000081	NE355817DX	GOOSE LAKE	DRILLING	1975	7025	RATCLIFFE
SCB000082	NE355818CADB	GOOSE LAKE	DRILLING	1963	7355	RATCLIFFE
SCB000083	NE355819DAX	GOOSE LAKE	DRILLING	1962	7205	CHARLES
SCB000084	NE355820BADB	GOOSE LAKE	DRILLING	1962	7150	RATCLIFFE
SCB000085	NE355820DBCA	GOOSE LAKE	DRILLING	1969	6970	RATCLIFFE
SCB000086	NE355820DBCA	GOOSE LAKE	DRILLING	1970	11040	RED RIVER
SCB000087	NE355821CABD	GOOSE LAKE	DRILLING	1968	7071	RATCLIFFE
SCB000088	NE355821DBX	GOOSE LAKE	DRILLING	1963	7323	MISSION CANYON
SCB000089	NE355822ACAA	GOOSE LAKE	DRILLING	1968	7104	MISSION CANYON
SCB000090	NE355826DCX	SOUTH GOOSE LAKE	DRILLING	1963	11178	RED RIVER
SCB000091	NE355829BACA	GOOSE LAKE	DRILLING	1969	7129	RATCLIFFE
SCB000092	NE355829CAX	GOOSE LAKE	DRILLING	1969	11150	RED RIVER
SCB000093	NE355830BADB	GOOSE LAKE	DRILLING	1966	7520	MISSION CANYON
SCB000094	NE355830DAX	GOOSE LAKE	DRILLING	1969	7185	RATCLIFFE
SCB000095	NE355832BDX	GOOSE LAKE	DRILLING	1961	7194	MISSION CANYON
SCB000096	NE365709DBX	COMERTOWN	DRILLING	1968	4200	SKULL CREEK
SCB000097	NE365713DBDB	COMERTOWN	DRILLING	1983	6945	RATCLIFFE
SCB000098	NE355714BCBD	WEST GOOSE LAKE	DRILLING	1963	7207	MISSION CANYON
SCB000099	NE365714DAX	COMERTOWN	DRILLING	1984	6905	RATCLIFFE
SCB000100	NE355716AAX	WEST GOOSE LAKE	DRILLING	1965	7183	RATCLIFFE
SCB000101	NE365715AADA	COMERTOWN	DRILLING	1983	8350	NISKU
SCB000102	NE365715DAX	COMERTOWN	DRILLING	1983	10630	RED RIVER
SCB000103	NE365725AACA	COMERTOWN	DRILLING	1984	6949	RATCLIFFE
SCB000104	NE365710BCCA	COMERTOWN	DRILLING	1966	6863	RATCLIFFE
SCB000105	NE365710DCX	COMERTOWN	DRILLING	1980	10800	RED RIVER
SCB000106	NE365714BBX	COMERTOWN	DRILLING	1972	10729	RED RIVER

Table 4. SUMMARY OF PRIMARY OIL FIELD SITE INFORMATION
(continued)

MBMG NO	LOCATION	OIL FIELD	TYPE OF SITE	DATE WORK STARTED	DEPTH OF WELL	TARGET FORMATION
SCB000107	NE365721ACCA	COMERTOWN	DRILLING	1963	7090	MISSION CANYON
SCB000108	NE365736DBDB	COMERTOWN	DRILLING	1967	7090	MISSION CANYON
SCB000109	NE365819DBX	GOOSE LAKE	DRILLING	1984	7024	RATCLIFFE
SCB000110	NE365821CBDB	GOOSE LAKE	DRILLING	1967	6915	RATCLIFFE
SCB000111	NE365807CBX	GOOSE LAKE	DRILLING	1976	6825	RATCLIFFE
SCB000112	NE365810BAX	GOOSE LAKE	DRILLING	1974	6910	MISSION CANYON
SCB000113	NE365811DCBD	GOOSE LAKE	DRILLING	1978	7206	MISSION CANYON
SCB000114	NE365821DBX	GOOSE LAKE	DRILLING	1967	6885	RATCLIFFE
SCB000115	NE365821BBX	GOOSE LAKE	DRILLING	1968	6920	RATCLIFFE
SCB000116	NE365821ABX	GOOSE LAKE	DRILLING	1967	6880	RATCLIFFE
SCB000117	NE365822CBDB01	GOOSE LAKE	DRILLING	1967	6889	RATCLIFFE
SCB000118	NE365822DBX	GOOSE LAKE	DRILLING	1967	6817	RATCLIFFE
SCB000119	NE365817CBDA	GOOSE LAKE	DRILLING	1980	10840	RED RIVER
SCB000120	NE365826DBX	GOOSE LAKE	DRILLING	1970	6790	RATCLIFFE
SCB000121	NE365825CBDD	GOOSE LAKE	DRILLING	1968	6840	RATCLIFFE
SCB000122	NE365826CBX	GOOSE LAKE	DRILLING	1970	6818	RATCLIFFE
SCB000123	NE365820BBBD	GOOSE LAKE	DRILLING	1968	6905	RATCLIFFE
SCB000124	NE365827ABCA01	GOOSE LAKE	DRILLING	1967	6805	RATCLIFFE
SCB000125	NE365827BBDB01	GOOSE LAKE	DRILLING	1967	6860	RATCLIFFE
SCB000126	NE365827BAAA01	GOOSE LAKE	DRILLING	1968	4500	MUDDY
SCB000127	NE365827CBCA	GOOSE LAKE	DRILLING	1965	6870	RATCLIFFE
SCB000128	NE365827DBBD	GOOSE LAKE	DRILLING	1968	6947	RATCLIFFE
SCB000129	NE365828ABDB	GOOSE LAKE	DRILLING	1966	6890	RATCLIFFE
SCB000130	NE365828BX	GOOSE LAKE	DRILLING	1967	6914	RATCLIFFE
SCB000131	NE365828CBBD	GOOSE LAKE	DRILLING	1965	6896	RATCLIFFE
SCB000132	NE365828DBCA	GOOSE LAKE	DRILLING	1965	6899	RATCLIFFE
SCB000133	NE365829AX	GOOSE LAKE	DRILLING	1969	6925	RATCLIFFE
SCB000134	NE365829DBDB	GOOSE LAKE	DRILLING	1965	6925	RATCLIFFE
SCB000135	NE365832ABCA	GOOSE LAKE	DRILLING	1964	7048	RATCLIFFE
SCB000136	NE365832CBAD	GOOSE LAKE	DRILLING	1965	6974	RATCLIFFE
SCB000137	NE365832DBDB	GOOSE LAKE	DRILLING	1964	7020	RATCLIFFE
SCB000138	NE365833ABDB	GOOSE LAKE	DRILLING	1964	6942	RATCLIFFE
SCB000139	NE365833BBDB01	GOOSE LAKE	DRILLING	1966	6930	RATCLIFFE
SCB000140	NE365833CBBD	GOOSE LAKE	DRILLING	1965	6972	RATCLIFFE
SCB000141	NE365833DBAC	GOOSE LAKE	DRILLING	1963	7225	RATCLIFFE
SCB000142	NE365834CBX	GOOSE LAKE	DRILLING	1964	6936	RATCLIFFE
SCB000143	NE365834DBBD	GOOSE LAKE	DRILLING	1965	6951	RATCLIFFE
SCB000144	NE365834BBBD	GOOSE LAKE	DRILLING	1965	6938	RATCLIFFE
SCB000145	NE365835DBX	GOOSE LAKE	DRILLING	1968	6895	RATCLIFFE
SCB000146	NE365836ABX	GOOSE LAKE	DRILLING	1974	6840	RATCLIFFE
SCB000147	NE365836BBX	GOOSE LAKE	DRILLING	1968	6916	RATCLIFFE
SCB000148	NE365836DDBD	GOOSE LAKE	DRILLING	1965	6970	RATCLIFFE
SCB000149	NE375701CDX	FLAT LAKE	DRILLING	1966	6600	RATCLIFFE
SCB000150	NE375701DACA	FLAT LAKE	DRILLING	1965	6610	RATCLIFFE
SCB000151	NE375705DDBD01	FLAT LAKE	DRILLING	1963	8092	NISKU
SCB000152	NE375708ADDB	FLAT LAKE	DRILLING	1962	10438	WINNIPEG
SCB000153	NE375708BDCA	FLAT LAKE	DRILLING	1963	8035	NISKU
SCB000154	NE375708DX	FLAT LAKE	DRILLING	1967	8076	NISKU
SCB000155	NE375708DDX	FLAT LAKE	DRILLING	1963	6625	RATCLIFFE
SCB000156	NE375709BDX	FLAT LAKE	DRILLING	1963	8051	NISKU
SCB000157	NE375709CX	FLAT LAKE	DRILLING	1977	8068	NISKU
SCB000158	NE375709DACA	FLAT LAKE	DRILLING	1967	6646	RATCLIFFE
SCB000159	NE375710AAX	FLAT LAKE	DRILLING	1958	10451	WINNIPEG

Table 4. SUMMARY OF PRIMARY OIL FIELD SITE INFORMATION
(continued)

MBMG NO	LOCATION	OIL FIELD	TYPE OF SITE	DATE WORK STARTED	DEPTH OF WELL	TARGET FORMATION
SCB000160	NE375710CAX	FLAT LAKE	DRILLING	1966	6510	RATCLIFFE
SCB000161	NE375710BAX	FLAT LAKE	DRILLING	1970	6557	RATCLIFFE
SCB000162	NE375710DAX	FLAT LAKE	DRILLING	1966	6627	RATCLIFFE
SCB000163	NE375711AABD	FLAT LAKE	DRILLING	1965	6622	RATCLIFFE
SCB000164	NE375711ACX	FLAT LAKE	DRILLING	1980	6650	RATCLIFFE
SCB000165	NE375711CAX	FLAT LAKE	DRILLING	1965	6640	RATCLIFFE
SCB000166	NE375711DAX	FLAT LAKE	DRILLING	1965	6595	RATCLIFFE
SCB000167	NE375712BADB01	FLAT LAKE	DRILLING	1965	6904	RATCLIFFE
SCB000168	NE375713AAX	FLAT LAKE	DRILLING	1964	6619	RATCLIFFE
SCB000169	NE375713BAX	FLAT LAKE	DRILLING	1964	6656	RATCLIFFE
SCB000170	NE375711BAX	FLAT LAKE	DRILLING	1965	6670	RATCLIFFE
SCB000171	NE375712DAX	FLAT LAKE	DRILLING	1965	6847	RATCLIFFE
SCB000172	NE375712AACA	FLAT LAKE	DRILLING	1965	6600	RATCLIFFE
SCB000173	NE375712CAX	FLAT LAKE	DRILLING	1965	6591	RATCLIFFE
SCB000174	NE375713CAX	FLAT LAKE	DRILLING	1969	6588	RATCLIFFE
SCB000175	NE375713DAX	FLAT LAKE	DRILLING	1964	6613	RATCLIFFE
SCB000176	NE375714AACA	FLAT LAKE	DRILLING	1965	6592	RATCLIFFE
SCB000177	NE375714BABD	FLAT LAKE	DRILLING	1965	6560	RATCLIFFE
SCB000178	NE375714CADB	FLAT LAKE	DRILLING	1965	6605	RATCLIFFE
SCB000179	NE375715AACA	FLAT LAKE	DRILLING	1965	6563	RATCLIFFE
SCB000180	NE375715BADB	FLAT LAKE	DRILLING	1966	6507	RATCLIFFE
SCB000181	NE375715CABD	FLAT LAKE	DRILLING	1966	6760	RATCLIFFE
SCB000182	NE375715DAX	FLAT LAKE	DRILLING	1966	6550	RATCLIFFE
SCB000183	NE375716AAX	FLAT LAKE	DRILLING	1966	6620	RATCLIFFE
SCB000184	NE375716BAX	FLAT LAKE	DRILLING	1970	8025	NESSON
SCB000185	NE375716CAX	FLAT LAKE	DRILLING	1966	6650	RATCLIFFE
SCB000186	NE375716DAX	FLAT LAKE	DRILLING	1966	6590	RATCLIFFE
SCB000187	NE375717DDBD	FLAT LAKE	DRILLING	1964	6548	RATCLIFFE
SCB000188	NE375720AAAC	FLAT LAKE	DRILLING	1966	6575	RATCLIFFE
SCB000189	NE375721AADB	FLAT LAKE	DRILLING	1966	6560	RATCLIFFE
SCB000190	NE375721BAX	FLAT LAKE	DRILLING	1966	6590	RATCLIFFE
SCB000191	NE375721DAAC	FLAT LAKE	DRILLING	1966	6560	RATCLIFFE
SCB000192	NE375722AAX	FLAT LAKE	DRILLING	1966	6580	RATCLIFFE
SCB000193	NE375722ABAB	FLAT LAKE	DRILLING	1976	4550	DAKOTA
SCB000194	NE375722BAX	FLAT LAKE	DRILLING	1966	6575	RATCLIFFE
SCB000195	NE375722CAX	FLAT LAKE	DRILLING	1966	6545	RATCLIFFE
SCB000196	NE375722DAX	FLAT LAKE	DRILLING	1966	6575	RATCLIFFE
SCB000197	NE375723AAX	FLAT LAKE	DRILLING	1966	6556	RATCLIFFE
SCB000198	NE375723ADX	FLAT LAKE	DRILLING	1963	6600	RATCLIFFE
SCB000199	NE375724AAX	FLAT LAKE	DRILLING	1970	6528	RATCLIFFE
SCB000200	NE375724BABD	FLAT LAKE	DRILLING	1966	6557	RATCLIFFE
SCB000201	NE375724CAAC	FLAT LAKE	DRILLING	1970	6534	RATCLIFFE
SCB000202	NE375724DACA	FLAT LAKE	DRILLING	1970	6524	RATCLIFFE
SCB000203	NE375725AAX	FLAT LAKE	DRILLING	1977	6512	RATCLIFFE
SCB000204	NE375725DAAB	FLAT LAKE	DRILLING	1977	6476	RATCLIFFE
SCB000205	NE375727BAAC	FLAT LAKE	DRILLING	1966	6500	RATCLIFFE
SCB000206	NE375729CAX	FLAT LAKE	DRILLING	1975	8164	DUPEROW
SCB000207	NE375803AAAC	FLAT LAKE	DRILLING	1965	6430	RATCLIFFE
SCB000208	NE375803BAAD	FLAT LAKE	DRILLING	1965	6450	RATCLIFFE
SCB000209	NE375803CADB	FLAT LAKE	DRILLING	1965	6436	RATCLIFFE
SCB000210	NE375803DADB	FLAT LAKE	DRILLING	1965	6405	RATCLIFFE
SCB000211	NE375804BAX	FLAT LAKE	DRILLING	1965	6500	RATCLIFFE
SCB000212	NE375804AABB	FLAT LAKE	DRILLING	1972	6501	RATCLIFFE

Table 4. SUMMARY OF PRIMARY OIL FIELD SITE INFORMATION
(continued)

MBMG NO	LOCATION	OIL FIELD	TYPE OF SITE	DATE WORK STARTED	DEPTH OF WELL	TARGET FORMATION
SCB000213	NE375804BBAB	FLAT LAKE	DRILLING	1971	6440	RATCLIFFE
SCB000214	NE375804AAAC	FLAT LAKE	DRILLING	1965	6488	RATCLIFFE
SCB000215	NE375804CADA	FLAT LAKE	DRILLING	1971	4500	DAKOTA
SCB000216	NE375804CAX	FLAT LAKE	DRILLING	1965	6450	RATCLIFFE
SCB000217	NE375804DACA	FLAT LAKE	DRILLING	1965	6445	RATCLIFFE
SCB000218	NE375805AAAC	FLAT LAKE	DRILLING	1965	6518	RATCLIFFE
SCB000219	NE375805BACA	FLAT LAKE	DRILLING	1965	6551	RATCLIFFE
SCB000220	NE375805CADB	FLAT LAKE	DRILLING	1964	6780	RATCLIFFE
SCB000221	NE375805DAX	FLAT LAKE	DRILLING	1965	6540	RATCLIFFE
SCB000222	NE375806CAX 01	FLAT LAKE	DRILLING	1965	6545	RATCLIFFE
SCB000223	NE375806DAX	FLAT LAKE	DRILLING	1965	6512	RATCLIFFE
SCB000224	NE375807AABD	FLAT LAKE	DRILLING	1971	4500	DAKOTA
SCB000225	NE375807BABD	FLAT LAKE	DRILLING	1965	6550	RATCLIFFE
SCB000226	NE375807CAX	FLAT LAKE	DRILLING	1965	6532	RATCLIFFE
SCB000227	NE375807AAX	FLAT LAKE	DRILLING	1965	6544	RATCLIFFE
SCB000228	NE375808AAX	FLAT LAKE	DRILLING	1965	6526	RATCLIFFE
SCB000229	NE375810BAAD	FLAT LAKE	DRILLING	1965	6428	RATCLIFFE
SCB000230	NE375818BADB	FLAT LAKE	DRILLING	1964	6839	RATCLIFFE
SCB000231	NE375818BCX	FLAT LAKE	DRILLING	1964	6607	RATCLIFFE
SCB000232	NE375818CAX	FLAT LAKE	DRILLING	1964	6623	RATCLIFFE
SCB000233	NE375818CCX	FLAT LAKE	DRILLING	1980	6610	RATCLIFFE
SCB000234	NE375818DACA	FLAT LAKE	DRILLING	1965	6547	RATCLIFFE
SCB000235	NE375819AACA	FLAT LAKE	DRILLING	1969	6519	RATCLIFFE
SCB000236	NE375819BAX	FLAT LAKE	DRILLING	1970	6490	RATCLIFFE
SCB000237	NE375819CAAC	FLAT LAKE	DRILLING	1970	6480	RATCLIFFE
SCB000238	NE375819DAX	FLAT LAKE	DRILLING	1969	6586	RATCLIFFE
SCB000239	NE375820DAX	FLAT LAKE	DRILLING	1970	6474	RATCLIFFE
SCB000240	NE375820BAX	FLAT LAKE	DRILLING	1970	6532	RATCLIFFE
SCB000241	NE375820CAX	FLAT LAKE	DRILLING	1969	6505	RATCLIFFE
SCB000242	NE375822CAAD	FLAT LAKE	DRILLING	1967	6680	RATCLIFFE
SCB000243	NE375828BBBD	FLAT LAKE	DRILLING	1963	6588	RATCLIFFE
SCB000244	NE375829BAX	FLAT LAKE	DRILLING	1969	6585	RATCLIFFE
SCB000245	NE375830AAX	FLAT LAKE	DRILLING	1968	6800	RATCLIFFE
SCB000246	NE375830BAX	SOUTH FLAT LAKE	DRILLING	1969	6508	RATCLIFFE
SCB000247	NE375830CAX	SOUTH FLAT LAKE	DRILLING	1970	6503	RATCLIFFE
SCB000248	NE375830DAX	SOUTH FLAT LAKE	DRILLING	1966	6637	RATCLIFFE
SCB000249	NE375831BAX	SOUTH FLAT LAKE	DRILLING	1967	6550	RATCLIFFE
SCB000250	NE375834DBA	EAST FLAT LAKE	DRILLING	1966	6705	RATCLIFFE
SCB000251	NE355835DDAB01	SOUTH GOOSE LAKE	DRILLING	1980	11320	RED RIVER
SCB000252	NE345814BDAC01	DIVIDE	DRILLING	1987	11398	RED RIVER
SCB000253	NE345814DBBX01	DIVIDE	DRILLING	1988	11335	RED RIVER
SCB000254	NE365724ABX	COMERTOWN	DRILLING			
SCB000255	NE365830AB	GOOSE LAKE	DRILLING			
SCB000256	NE365721DBDC	SOUTH COMERTOWN	DRILLING			
SCB000257	NE355808DDX 02	GOOSE LAKE	DRILLING	1963	7320	RATCLIFFE
SCB000258	NE355816BABA01	GOOSE LAKE	TANK BATTERY	1963		
SCB000259	NE355819ABDB	GOOSE LAKE	DRILLING			
SCB000260	NE355819BX 01	GOOSE LAKE	DRILLING	1983		RATCLIFFE
SCB000261	NE355816DX	GOOSE LAKE	DRILLING			
SCB000262	NE365832DADD01	GOOSE LAKE	TANK BATTERY	1964		
SCB000263	NE355834AAX	SOUTH GOOSE LAKE	DRILLING	1988		RATCLIFFE
SCB000264	NE365828AADA01	GOOSE LAKE	TANK BATTERY	1970		
SCB000265	NE355829DBD	GOOSE LAKE	DRILLING			

Table 4. SUMMARY OF PRIMARY OIL FIELD SITE INFORMATION
(continued)

MBMG NO	LOCATION	OIL FIELD	TYPE OF SITE	DATE WORK STARTED	DEPTH OF WELL	TARGET FORMATION
SCB000266	NE355819DCDD	GOOSE LAKE	TANK BATTERY			
SCB000267	NE355829DDCD	GOOSE LAKE	DRILLING			
SCB000268	NE365721ABBD01	SOUTH COMERTOWN	DRILLING			
SCB000269	NE365716DCAC	SOUTH COMERTOWN	DRILLING			
SCB000270	NE365715ABAB	COMERTOWN	DRILLING			
SCB000271	NE365710DCX	COMERTOWN	DRILLING			
SCB000272	NE365711CCCA01	COMERTOWN	DRILLING			
SCB000273	NE365711CCCB01	COMERTOWN	DRILLING			
SCB000274	NE365710DDCA01	COMERTOWN	DRILLING			
SCB000275	NE365714ACAB	COMERTOWN	DRILLING			
SCB000276	NE365714BBX 01	COMERTOWN	DRILLING			
SCB000277	NE365714BCBD01	COMERTOWN	DRILLING			
SCB000278	NE365714BC 02	COMERTOWN	DRILLING			
SCB000279	NE365714CBDB	COMERTOWN	DRILLING			
SCB000280	NE375715DCDC01	FLAT LAKE	DRILLING	1966		
SCB000281	NE375721BADD01	FLAT LAKE	DRILLING	1966		
SCB000282	NE365827AADA01	GOOSE LAKE	PIPELINE LEAK			
SCB000283	NE375612CDAC01	FLAT LAKE	DRILLING	1988		
SCB000284	NE375715ABAA01	FLAT LAKE	DRILLING			
SCB000285	NE375714BBAA01	FLAT LAKE	TANK BATTERY			
SCB000286	NE375711DCBC01	FLAT LAKE	DRILLING	1981	6700	RATCLIFFE
SCB000287	NE375711BCX 01	FLAT LAKE	DRILLING			
SCB000288	NE375712DCX 01	FLAT LAKE	DRILLING			
SCB000289	NE345821DDX	DIVIDE	DRILLING			
SCB000290	NE345828AAX	DIVIDE	DRILLING	1988		
SCB000291	NE345827BCX	DIVIDE	DRILLING			
SCB000292	NE345822CCX	DIVIDE	DRILLING			
SCB000293	NE345822DCX	DIVIDE	DRILLING			
SCB000294	NE345820CAX	DIVIDE	DRILLING	1982	7200	
SCB000295	NE345820DAX	DIVIDE	DRILLING	1982	7200	RATCLIFFE
SCB000296	NE345828BBBD	DIVIDE	DRILLING		7200	RATCLIFFE
SCB000297	NE345828ABX	DIVIDE	TANK BATTERY		7200	RATCLIFFE
SCB000298	NE345827DAX	DIVIDE	DRILLING		7200	
SCB000299	NE345827CAX	DIVIDE	DRILLING		7200	
SCB000300	NE345826CBX	DIVIDE	DRILLING			
SCB000301	NE345825BCBA	DIVIDE	DRILLING	1988		
SCB000302	NE335813BCBB	BRUSH LAKE	TANK BATTERY			
SCB000303	NE335808DD 01	CLEAR LAKE	DRILLING			
SCB000304	NE335808ACX	CLEAR LAKE	DRILLING			
SCB000305	NE335821BAX	CLEAR LAKE	DRILLING			
SCB000306	NE365816BBDC	GOOSE LAKE	PIPELINE LEAK	1986		
SCB000307	NE365825DBDC	GOOSE LAKE	LAKE IMPACTS	1965		

Secondary site information was derived from file data and publications on the geology, soils, and water resources (Table 5). Secondary site information consists of data related to the physical properties of the site including soils, near-surface geology, topography, and water resources. The soil survey of Sheridan County (USDA, 1977) describes the soil series and soil mapping units for the entire county. Each soil series and soil mapping unit is determined by the soil profile, that is, the sequence of layers from the ground surface to the underlying bedrock or non-soil material. Physical characteristics are summarized for each soil series providing ranges of values for lithology, texture, and infiltration rates. Grouping soil series by similar parent materials was used to aid geologic mapping. The elevation, distance to surface-water bodies and distance to ground-water supplies for the sites were determined from 7-1/2 minute USGS topographic maps and were verified by field observations.

The site information in Table 5 is summarized on Figure 3 by a series of bar charts showing the distribution of oil-field sites with respect to surficial geology, soils, distance from water wells, distance from surface water, estimated depth to ground water, and age of the site. The surficial geologic unit underlying most oil-field sites is glacial till, followed by glacial outwash, and glacial lake deposits respectively (Figure 3a). Most sites are located on fine-grained soils (Figure 3b). This corresponds to the geologic distribution since fine-grained soils usually develop on glacial till or glacial lake clay parent material. The estimated

Table 5. SUMMARY OF SECONDARY OIL FIELD SITE INFORMATION

MBMG NUMBER	LOCATION OF SITE	ELEVATION OF SITE (FEET)	SOIL* TYPE	SOIL PERMEABILITY (INCHES/HOUR)	UNIFIED SOIL CLASSIFICATION	SOIL TEXTURE (PERCENT FINER THAN FINE SAND)	NEAR ** SURFACE GEOLOGY	ESTIMATED DEPTH TO GROUND WATER (FEET)	CLOSEST WATER WELL (MILES)	CLOSEST SURFACE WATER (MILES)
SCB000001	NE335709DBX	2127	WzC	2	CL	90.0	112TILL	25	0.3	0.6
SCB000002	NE335714DACC	2086	WmB	2	CL	95.0	112TILL	30	0.4	0.6
SCB000003	NE335728DBCC	2103	WmB	2	CL	95.0	112TILL	40	0.6	0.8
SCB000004	NE335703DDD	2152	WmB	2	CL	95.0	112TILL	45	0.8	0.2
SCB000005	NE335710AAX	2146	WmB	2	CL	95.0	112TILL	45	0.7	0.4
SCB000006	NE335726BBX	2044	TuB	20	GW	25.0	112OTSH	5	0.3	0.5
SCB000007	NE335801BX	2042	WmB	2	CL	95.0	112TILL	45	0.3	0.3
SCB000008	NE335801CBX	2027	WaE	20	GM	30.0	112OTSH	35	0.4	0.3
SCB000009	NE335801CBAC	2034	WaE	20	GM	30.0	112OTSH	35	0.4	0.3
SCB000010	NE335802DDBB	2012	ZaE	.4	CL	90.0	112TILL	15	0.4	0.1
SCB000011	NE335805BACA	2027	TuB	20	GW	20.0	112OTSH	10	0.4	0.4
SCB000012	NE335808DDX	2008	MaB	20	GW	25.0	112OTSH	20	0.8	0.5
SCB000013	NE335811ACAA	2009	MaB	20	GW	25.0	112OTSH	15	0.2	0.1
SCB000014	NE335811DDBB	2025	MaB	20	GW	25.0	112OTSH	50	1.0	1.3
SCB000015	NE335813BX	2016	WzB	2	CL	95.0	112TILL	40	1.0	1.8
SCB000016	NE335814BX	2014	MaB	20	GW	25.0	112OTSH	40	0.1	1.0
SCB000017	NE335816BBDC	2012	WaE	20	GW	20.0	112OTSH	30	0.1	0.6
SCB000018	NE335816CBCD	1987	WaE	20	GW	20.0	112OTSH	10	0.1	0.1
SCB000019	NE335817DABA	1998	WaE	20	GW	20.0	112OTSH	20	0.1	0.3
SCB000020	NE335817ADCA	2004	WaE	20	GW	20.0	112OTSH	25	0.2	0.3
SCB000021	NE335824CBBD	2004	DoB	2	SM	65.0	112TILL	40	0.6	0.6
SCB000022	NE335828CBDD	1996	WaE	20	GW	20.0	112OTSH	40	0.4	0.2
SCB000023	NE335828CCAC	1986	WaE	20	GW	20.0	112OTSH	30	0.5	0.3
SCB000024	NE335833BACA	1987	MaB	20	GW	25.0	112OTSH	30	0.6	0.2
SCB000025	NE335828BCX	1986	MaB	20	GW	25.0	112OTSH	30	0.3	0.5
SCB000026	NE335808DBAC	2012	MaB	20	GW	25.0	112OTSH	15	0.6	0.4
SCB000027	NE345701CDDB	2164	WzC	2	CL	90.0	112TILL	50	0.3	1.0
SCB000028	NE345702AABD	2222	ZaE	.4	CL	90.0	112TILL	75	0.7	1.0
SCB000029	NE345702DX	2154	WzC	2	CL	90.0	112TILL	35	0.5	1.0
SCB000030	NE345702DAX	2196	FaA	2	ML	95.0	112OTSH	65	0.7	1.3
SCB000031	NE345703CDAC	2306	WzC	2	CL	90.0	112TILL	50	0.3	2.0
SCB000032	NE345709DBX	2347	WzC	2	CL	90.0	112TILL	65	0.4	1.0
SCB000033	NE345711BBX	2250	LcF	.4	CL	95.0	112TILL	65	1.2	0.8
SCB000034	NE345714ABBD	2157	ZaE	.4	CL	90.0	112TILL	30	0.1	0.2
SCB000035	NE345722BCDA	2213	ZaE	.4	CL	90.0	112TILL	65	0.3	0.5
SCB000036	NE345807DDX	2134	WzC	2	CL	90.0	112TILL	60	0.9	0.5
SCB000037	NE345809ADX	2038	Dm	.06	CH	95.0	112TILL	15	0.4	0.5
SCB000038	NE345810ACX	2038	Mz	.06	CH	90.0	112GLCO	15	0.4	0.5

Table 5. SUMMARY OF SECONDARY OIL FIELD SITE INFORMATION (continued)

MBMG NUMBER	LOCATION OF SITE	ELEVATION OF SITE	SOIL* TYPE (FEET)	SOIL PERMEABILITY (INCHES/HOUR)	UNIFIED SOIL CLASSIFICATION	SOIL TEXTURE (PERCENT FINER THAN FINE SAND)	NEAR ** SURFACE GEOLOGY	ESTIMATED DEPTH TO GROUND WATER (FEET)	CLOSEST WATER WELL (MILES)	CLOSEST SURFACE WATER (MILES)
SCB000039	NE345812ABDB	2067	MaB	20	GW	25.0	112OTSH	30	0.5	1.0
SCB000040	NE345815ABX	2048	MaB	20	GW	25.0	112OTSH	20	0.2	0.4
SCB000041	NE345817DDX	2048	MaB	20	GW	25.0	112OTSH	20	0.4	0.5
SCB000042	NE345823ACAC	2041	DoB	2	SM	65.0	112OTSH	15	0.3	0.1
SCB000043	NE345824CD	2033	WzB	2	CL	90.0	112TILL	30	0.6	0.7
SCB000044	NE345826ADDB	2064	WmB	2	CL	95.0	112TILL	40	0.1	0.3
SCB000045	NE345826BX	2080	ZaD	.4	CL	90.0	112TILL	45	0.4	0.3
SCB000046	NE345827ACDB	2043	WzB	2	CL	95.0	112TILL	20	0.3	0.1
SCB000047	NE345832CBX	2025	MaB	20	GW	25.0	112OTSH	20	0.6	0.8
SCB000048	NE345835AACA	2058	WzC	2	CL	90.0	112TILL	45	0.6	0.7
SCB000049	NE345836BX	2029	WzB	2	CL	90.0	112TILL	30	0.2	0.3
SCB000050	NE345836CACC	2018	WmB	2	CL	95.0	112TILL	20	0.6	0.3
SCB000051	NE355716AA	2314	WmB	2	CL	95.0	112TILL	45	0.5	0.2
SCB000052	NE355724BAX	2179	FaB	2	ML	95.0	112TILL	45	0.6	2.0
SCB000053	NE355726CAX	2328	WzC	2	CL	95.0	112TILL	50	0.5	0.4
SCB000054	NE355728ADBD	2383	WmC	2	CL	95.0	112TILL	50	0.4	0.5
SCB000055	NE355734AADB	2371	ZaE	.4	CL	90.0	112TILL	50	1.0	1.0
SCB000056	NE355801ADX	2061	MaB	20	GW	25.0	112OTSH	15	0.3	0.3
SCB000057	NE355801DACD	2067	WaE	20	GM	30.0	112OTSH	20	0.5	0.1
SCB000058	NE355804ABBD	2185	ZaE	.4	CL	90.0	112TILL	50	0.8	0.4
SCB000059	NE355804BBX	2123	ZwE	2	CL	90.0	112TILL	20	0.5	0.3
SCB000060	NE355804CBX	2110	TuB	20	GW	25.0	112OTSH	15	0.5	0.3
SCB000061	NE355805ABX	2153	WaE	20	GM	30.0	112OTSH	35	1.0	0.7
SCB000062	NE355805CBAC	2139	Dm	.06	CH	99.0	112OTSH	10	0.7	0.2
SCB000063	NE355805DBX	2164	WmB	2	CL	95.0	112TILL	35	0.5	0.5
SCB000064	NE355808ADX	2111	TuB	20	GW	25.0	112OTSH	10	0.4	0.1
SCB000065	NE355808BDX	2175	WmB	2	CL	95.0	112TILL	45	0.4	0.3
SCB000066	NE355808CDBD	2105	WaE	20	GW	20.0	112OTSH	15	0.7	0.1
SCB000067	NE355808DDX 01	2142	WzB	2	CL	90.0	112TILL	20	0.6	0.2
SCB000068	NE355809BDCA	2123	WzB	2	CL	90.0	112TILL	15	0.3	0.2
SCB000069	NE355809CDDB	2122	ZwE	2	CL	90.0	112TILL	10	0.7	0.2
SCB000070	NE355809DDBD	2091	ZaD	.4	CL	90.0	112TILL	15	0.6	0.2
SCB000071	NE355810BBX	2087	TuB	20	GW	25.0	112OTSH	20	0.4	0.3
SCB000072	NE355810BDBD	2083	ZwE	2	CL	90.0	112TILL	10	0.7	0.1
SCB000073	NE355811ADBA	2057	MaB	20	GW	25.0	112OTSH	10	0.3	0.1
SCB000074	NE355813CABD	2065	WaE	20	GW	20.0	112OTSH	20	1.0	0.3
SCB000075	NE355815DDX	2094	WzB	2	CL	90.0	112TILL	30	0.7	0.2
SCB000076	NE355816AX	2113	WzC	2	CL	90.0	112TILL	20	1.0	0.2

Table 5. SUMMARY OF SECONDARY OIL FIELD SITE INFORMATION
(continued)

MBMG NUMBER	LOCATION OF SITE	ELEVATION OF SITE (FEET)	SOIL* TYPE	SOIL PERMEABILITY (INCHES/HOUR)	UNIFIED SOIL CLASSIFICATION	SOIL TEXTURE (PERCENT FINER THAN FINE SAND)	NEAR ** SURFACE GEOLOGY	ESTIMATED DEPTH TO GROUND WATER (FEET)	CLOSEST WATER WELL (MILES)	CLOSEST SURFACE WATER (MILES)
SCB000077	NE355816BDBD	2106	WzC	2	CL	90.0	112TILL	15	0.5	0.1
SCB000078	NE355816CX	2106	ZaD	.4	CL	90.0	112TILL	20	0.5	0.2
SCB000079	NE355817ADX 01	2104	ZaD	.4	ML	95.0	112TILL	15	0.1	0.3
SCB000080	NE355817BDX	2113	WaE	20	GW	20.0	112OTSH	20	0.6	0.4
SCB000081	NE355817DX	2101	FaA	2	ML	95.0	112TILL	15	0.5	0.5
SCB000082	NE355818CADB	2167	WzC	2	CL	90.0	112TILL	35	0.5	0.2
SCB000083	NE355819DAX	2228	WmB	2	CL	95.0	112TILL	55	0.5	0.4
SCB000084	NE355820BADB	2121	ZaD	.4	CL	90.0	112TILL	25	1.0	0.2
SCB000085	NE355820DBCA	2117	ZwE	2	CL	90.0	112TILL	15	0.5	0.1
SCB000086	NE355820DBCA	2117	ZwE	2	CL	90.0	112TILL	15	0.5	0.1
SCB000087	NE355821CABD	2106	TuB	20	GW	25.0	112OTSH	25	0.3	0.3
SCB000088	NE355821DBX	2095	WmB	2	CL	95.0	112TILL	25	0.3	0.3
SCB000089	NE355822ACAA	2101	ZwE	2	CL	90.0	112TILL	40	0.8	0.4
SCB000090	NE355826DCX	2061	MaB	20	GW	25.0	112OTSH	15	0.1	0.1
SCB000091	NE355829BACA	2155	WmB	2	CL	95.0	112TILL	25	0.6	0.2
SCB000092	NE355829CAX	2184	WmB	2	CL	95.0	112TILL	45	0.7	0.2
SCB000093	NE355830BADB	2120	Mz	.06	CH	90.0	112GLCO	10	0.2	0.1
SCB000094	NE355830DAX	2227	WmB	2	CL	95.0	112TILL	50	0.6	0.4
SCB000095	NE355832BDX	2144	ZwE	2	CL	90.0	112TILL	30	0.6	0.2
SCB000096	NE365709DBX	2301	WmB	2	CL	95.0	112TILL	20	0.3	0.4
SCB000097	NE365713DBDB	2277	WzC	2	CL	90.0	112TILL	35	0.7	0.3
SCB000098	NE355714BCBD	2308	WzB	2	CL	90.0	112TILL	65	0.4	1.0
SCB000099	NE365714DAX	2310	WzC	2	CL	90.0	112TILL	15	0.9	0.1
SCB000100	NE355716AAX	2314	WmC	2	CL	95.0	112TILL	15	0.6	0.1
SCB000101	NE365715AADA	2261	WzB	2	CL	90.0	112TILL	15	0.6	0.1
SCB000102	NE365715DAX	2252	WzC	2	CL	90.0	112TILL	15	0.7	0.1
SCB000103	NE365725AACA	2197	WzC	2	CL	95.0	112TILL	15	0.5	0.1
SCB000104	NE365710BCCA	2298	WaE	20	GW	20.0	112OTSH	15	0.6	0.2
SCB000105	NE365710DCX	2279	ZwE	2	CL	90.0	112TILL	25	0.5	0.1
SCB000106	NE365714BBX	2273	DoB	2	SM	80.0	112OTSH	30	0.8	0.1
SCB000107	NE365721ACCA	2453	ZwE	2	CL	90.0	112TILL	20	1.5	0.2
SCB000108	NE365736DBDB	2298	WmB	2	CL	95.0	112TILL	15	0.7	0.1
SCB000109	NE365819DBX	2294	ZwE	2	CL	90.0	112TILL	50	0.6	0.3
SCB000110	NE365821CBDB	2213	WzC	2	CL	90.0	112TILL	35	0.6	0.7
SCB000111	NE365807CBX	2218	ZwE	2	CL	90.0	112TILL	25	0.5	0.4
SCB000112	NE365810BAX	2190	ZwE	2	CL	90.0	112TILL	20	0.4	0.2
SCB000113	NE365811DCBD	2119	WzC	2	CL	95.0	112TILL	15	0.2	0.1
SCB000114	NE365821DBX	2147	WmB	2	CL	95.0	112TILL	20	0.5	0.6

Table 5. SUMMARY OF SECONDARY OIL FIELD SITE INFORMATION (continued)

MBMG NUMBER	LOCATION OF SITE	ELEVATION OF SITE (FEET)	SOIL* TYPE	SOIL PERMEABILITY (INCHES/HOUR)	UNIFIED SOIL CLASSIFICATION	SOIL TEXTURE (PERCENT FINER THAN FINE SAND)	NEAR ** SURFACE GEOLOGY	ESTIMATED DEPTH TO GROUND WATER (FEET)	CLOSEST WATER WELL (MILES)	CLOSEST SURFACE WATER (MILES)
SCB000115	NE365821BBX	2233	ZwE	2	CL	90.0	112TILL	60	1.3	0.3
SCB000116	NE365821ABX	2225	ZwE	2	CL	90.0	112TILL	55	1.2	0.2
SCB000117	NE365822CBDB01	2134	ZwE	2	CL	90.0	112TILL	50	0.6	0.3
SCB000118	NE365822DBX	2117	ZwE	2	CL	90.0	112TILL	40	0.3	0.2
SCB000119	NE365817CBDA	2293	ZwE	2	CL	90.0	112TILL	50	0.5	0.5
SCB000120	NE365826DBX	2057	WaE	20	GW	20.0	112OTSH	15	0.4	0.2
SCB000121	NE365825CBDD	2048	WaE	20	GW	20.0	112OTSH	10	0.2	0.1
SCB000122	NE365826CBX	2078	WaE	20	GW	20.0	112OTSH	25	0.3	0.2
SCB000123	NE365820BBBD	2248	SaB	.2	CH	99.0	112TILL	30	0.5	0.4
SCB000124	NE365827ABCA01	2066	TuB	20	GW	25.0	112OTSH	10	0.3	0.2
SCB000125	NE365827BBDB01	2107	WaE	20	GW	20.0	112OTSH	15	0.1	0.2
SCB000126	NE365827BAAA01	2114	WaE	20	GW	20.0	112OTSH	20	0.2	0.3
SCB000127	NE365827CBCA	2085	WaE	20	GW	20.0	112OTSH	15	0.4	0.1
SCB000128	NE365827DBBD	2101	DoB	2	SM	70.0	112OTSH	35	0.7	0.2
SCB000129	NE365828ABDB	2138	WaE	20	GW	20.0	112OTSH	30	0.1	0.2
SCB000130	NE365828BX	2166	WmB	2	CL	95.0	112TILL	40	0.4	0.3
SCB000131	NE365828CBBD	2157	WmB	2	CL	95.0	112TILL	30	0.4	0.3
SCB000132	NE365828DBCA	2120	WaE	20	GW	20.0	112OTSH	15	0.2	0.2
SCB000133	NE365829AX	2193	WzB	2	CL	90.0	112TILL	45	0.3	1.0
SCB000134	NE365829DBDB	2201	WzC	2	CL	90.0	112TILL	50	0.3	1.0
SCB000135	NE365832ABCA	2266	ZwE	2	CL	90.0	112TILL	60	0.6	0.6
SCB000136	NE365832CBAD	2196	WmB	2	CL	95.0	112TILL	25	0.2	0.2
SCB000137	NE365832DBDB	2208	WzB	2	CL	90.0	112TILL	45	0.5	0.4
SCB000138	NE365833ABDB	2127	WmB	2	CL	95.0	112TILL	20	0.3	0.4
SCB000139	NE365833BBDB01	2132	WmC	2	CL	95.0	112TILL	20	0.4	0.7
SCB000140	NE365833CBBD	2172	ZwE	2	CL	90.0	112TILL	45	0.4	0.4
SCB000141	NE365833DBAC	2178	WzC	2	CL	90.0	112TILL	50	0.5	0.4
SCB000142	NE365834CBX	2109	ZaD	.4	CL	90.0	112TILL	50	0.4	0.2
SCB000143	NE365834DBBD	2114	WmB	2	CL	95.0	112TILL	30	0.4	0.2
SCB000144	NE365834BBBD	2099	WaE	20	GW	20.0	112OTSH	40	0.4	0.2
SCB000145	NE365835DBX	2078	MaB	20	GW	25.0	112OTSH	15	0.6	0.2
SCB000146	NE365836ABX	2050	MaB	20	GW	25.0	112OTSH	30	0.4	0.2
SCB000147	NE365836BBX	2056	Mz	.06	CH	90.0	112GLCO	30	0.2	0.1
SCB000148	NE365836DDBD	2108	MaB	20	GW	25.0	112OTSH	50	0.4	0.5
SCB000149	NE375701CDX	2229	TuB	20	GW	25.0	112OTSH	10	0.2	0.4
SCB000150	NE375701DACA	2201	WaE	20	GW	20.0	112OTSH	15	0.2	0.3
SCB000151	NE375705DDBD01	2287	ZaD	.4	CL	90.0	112TILL	10	0.1	0.1
SCB000152	NE375708ADDB	2289	ZwE	2	CL	90.0	112TILL	50	0.4	0.4

Table 5. SUMMARY OF SECONDARY OIL FIELD SITE INFORMATION (continued)

MBMG NUMBER	LOCATION OF SITE	ELEVATION OF SITE	SOIL* TYPE (FEET)	SOIL PERMEABILITY (INCHES/HOUR)	UNIFIED SOIL CLASSIFICATION	SOIL TEXTURE (PERCENT FINER THAN FINE SAND)	NEAR ** SURFACE GEOLOGY	ESTIMATED DEPTH TO GROUND WATER (FEET)	CLOSEST WATER WELL (MILES)	CLOSEST SURFACE WATER (MILES)
SCB000153	NE375708BDCA	2199	ZwE	2	CL	90.0	112TILL	15	0.3	0.1
SCB000154	NE375708DX	2228	WmC	2	CL	95.0	112TILL	50	0.8	0.3
SCB000155	NE375708DDX	2237	MaB	20	GW	25.0	112OTSH	50	0.9	0.4
SCB000156	NE375709BDX	2303	WzC	2	CL	90.0	112TILL	50	0.6	0.3
SCB000157	NE375709CX	2276	SaC	.2	CH	97.0	112TILL	50	0.7	0.7
SCB000158	NE375709DACA	2287	WzB	2	CL	90.0	112TILL	50	0.5	0.4
SCB000159	NE375710AAX	2264	WmC	2	CL	95.0	112TILL	25	0.8	0.4
SCB000160	NE375710CAX	2183	Mz	.06	CH	90.0	112GLCO	20	0.3	0.2
SCB000161	NE375710BAX	2215	WaE	20	GW	20.0	112OTSH	20	0.8	0.4
SCB000162	NE375710DAX	2265	ZaE	.4	CL	90.0	112TILL	50	0.5	0.3
SCB000163	NE375711AABD	2270	WzC	2	CL	90.0	112TILL	45	0.3	0.3
SCB000164	NE375711ACX	2286	WzC	2	CL	90.0	112TILL	20	0.5	0.2
SCB000165	NE375711CAX	2285	WzB	2	CL	90.0	112TILL	45	0.3	0.3
SCB000166	NE375711DAX	2242	WzC	2	CL	90.0	112TILL	30	0.4	0.2
SCB000167	NE375712BADB01	2263	WzC	2	CL	90.0	112TILL	40	0.1	0.3
SCB000168	NE375713AAX	2226	WzB	2	CL	90.0	112TILL	20	0.5	0.1
SCB000169	NE375713BAX	2252	WzC	2	CL	90.0	112TILL	30	0.6	0.2
SCB000170	NE375711BAX	2297	SaB	.2	CH	97.0	112TILL	45	0.6	0.3
SCB000171	NE375712DAX	2242	WzC	2	CL	90.0	112TILL	45	0.6	0.4
SCB000172	NE375712AACA	2254	WzC	2	CL	90.0	112TILL	50	0.4	0.3
SCB000173	NE375712CAX	2241	WzC	2	CL	90.0	112TILL	40	0.5	0.2
SCB000174	NE375713CAX	2262	WzC	2	CL	90.0	112TILL	50	0.2	0.3
SCB000175	NE375713DAX	2221	WzB	2	CL	90.0	112TILL	35	0.2	0.2
SCB000176	NE375714AACA	2244	ZwE	2	CL	90.0	112TILL	40	0.3	0.2
SCB000177	NE375714BABD	2204	DoC	2	SM	70.0	112OTSH	15	0.2	0.1
SCB000178	NE375714CADB	2257	WzC	2	CL	90.0	112TILL	45	0.6	0.3
SCB000179	NE375715AACA	2208	SaC	.2	CH	97.0	112OTSH	20	0.6	0.5
SCB000180	NE375715BADB	2178	SaB	.2	CH	97.0	112OTSH	15	0.3	0.3
SCB000181	NE375715CABD	2181	SaC	.2	CH	97.0	112GLCO	15	0.6	0.1
SCB000182	NE375715DAX	2202	SaB	.2	CH	97.0	112GLCO	15	0.6	0.4
SCB000183	NE375716AAX	2240	ZaE	.4	CL	90.0	112GLCO	35	0.4	0.2
SCB000184	NE375716BAX	2200	Mr	.06	CH	95.0	112GLCO	15	0.4	0.8
SCB000185	NE375716CAX	2187	Mr	.06	CH	95.0	112GLCO	30	0.3	0.7
SCB000186	NE375716DAX	2208	SaC	.2	CH	97.0	112GLCO	35	0.3	0.2
SCB000187	NE375717DDBD	2164	Dm	.06	CH	95.0	112GLCO	15	1.0	0.2
SCB000188	NE375720AAAC	2159	ZwE	2	CL	90.0	112TILL	15	1.0	0.1
SCB000189	NE375721AADB	2196	Mr	.06	CH	97.0	112GLCO	30	0.7	0.3
SCB000190	NE375721BAX	2184	ZwE	2	CL	90.0	112TILL	25	0.7	0.1

Table 5. SUMMARY OF SECONDARY OIL FIELD SITE INFORMATION
(continued)

MBMG NUMBER	LOCATION OF SITE	ELEVATION OF SITE (FEET)	SOIL* TYPE	SOIL PERMEABILITY (INCHES/HOUR)	UNIFIED SOIL CLASSIFICATION	SOIL TEXTURE (PERCENT FINER THAN FINE SAND)	NEAR ** SURFACE GEOLOGY	ESTIMATED DEPTH TO GROUND WATER (FEET)	CLOSEST WATER WELL (MILES)	CLOSEST SURFACE WATER (MILES)
SCB000191	NE375721DAAC	2173	ZwE	2	CL	90.0	112TILL	30	0.7	0.2
SCB000192	NE375722AAX	2231	WmB	2	CL	95.0	112TILL	50	0.5	0.6
SCB000193	NE375722ABAB	2200	WzC	2	CL	90.0	112TILL	35	0.3	0.2
SCB000194	NE375722BAX	2221	ZwE	2	CL	90.0	112TILL	45	0.1	0.2
SCB000195	NE375722CAX	2184	ZwE	2	CL	90.0	112TILL	30	0.5	0.2
SCB000196	NE375722DAX	2214	ZwE	2	CL	90.0	112TILL	45	0.5	0.3
SCB000197	NE375723AAX	2246	ZwE	2	CL	90.0	112TILL	20	0.5	0.2
SCB000198	NE375723ADX	2233	WzC	2	CL	90.0	112TILL	35	0.5	0.3
SCB000199	NE375724AAX	2216	WmB	2	CL	95.0	112TILL	25	0.5	0.3
SCB000200	NE375724BABD	2221	ZwE	2	CL	90.0	112TILL	20	0.3	0.2
SCB000201	NE375724CAAC	2202	ZwE	2	CL	90.0	112TILL	10	0.3	0.1
SCB000202	NE375724DACA	2194	WmB	2	CL	95.0	112TILL	40	0.6	0.6
SCB000203	NE375725AAX	2177	WzC	2	CL	90.0	112TILL	45	0.3	0.4
SCB000204	NE375725DAAB	2134	ZwE	2	CL	90.0	112TILL	15	0.3	0.1
SCB000205	NE375727BAAC	2150	ZwE	2	CL	90.0	112TILL	25	1.0	0.2
SCB000206	NE375729CAX	2243	BdC	15	SM	65.0	112TILL	30	1.0	0.2
SCB000207	NE375803AAAC	2173	WaE	20	GW	25.0	112OTSH	35	0.4	0.3
SCB000208	NE375803BAAD	2188	ZwE	2	CL	90.0	112TILL	35	0.4	0.2
SCB000209	NE375803CADB	2148	ZwE	2	CL	90.0	112TILL	30	0.3	0.1
SCB000210	NE375803DADB	2146	WaE	20	GW	25.0	112OTSH	15	0.3	0.1
SCB000211	NE375804BAX	2210	WaE	20	GW	25.0	112OTSH	30	0.6	0.2
SCB000212	NE375804AABB	2220	WzC	2	CL	90.0	112TILL	30	1.0	0.2
SCB000213	NE375804BBAB	2207	WzC	2	CL	90.0	112TILL	20	1.0	0.3
SCB000214	NE375804AAAC	2217	WaE	20	GW	25.0	112OTSH	35	1.0	0.3
SCB000215	NE375804CADA	2173	WzC	2	CL	90.0	112TILL	35	0.1	0.2
SCB000216	NE375804CAX	2157	WzC	2	CL	90.0	112TILL	15	0.2	0.1
SCB000217	NE375804DACA	2145	ZwE	2	CL	90.0	112TILL	20	0.4	0.5
SCB000218	NE375805AAAC	2206	WaE	20	GW	25.0	112OTSH	20	0.7	0.2
SCB000219	NE375805BACA	2215	WzC	2	CL	90.0	112TILL	35	0.5	0.4
SCB000220	NE375805CADB	2190	WzC	2	CL	90.0	112TILL	20	0.3	0.1
SCB000221	NE375805DAX	2179	WzB	2	CL	90.0	112TILL	20	0.6	0.2
SCB000222	NE375806CAX 01	2200	WzC	2	CL	90.0	112TILL	20	0.1	0.1
SCB000223	NE375806DAX	2184	WzC	2	CL	90.0	112TILL	20	0.3	0.1
SCB000224	NE375807AABD	2197	WaE	20	GW	25.0	112OTSH	30	0.1	0.2
SCB000225	NE375807BABD	2204	WzC	2	CL	90.0	112TILL	35	0.5	0.2
SCB000226	NE375807CAX	2189	WaE	20	GW	25.0	112OTSH	25	0.6	0.2
SCB000227	NE375807AAX	2200	WaE	20	GW	25.0	112OTSH	30	0.1	0.2
SCB000228	NE375808AAX	2181	WzB	2	CL	90.0	112TILL	30	0.3	0.2

Table 5. SUMMARY OF SECONDARY OIL FIELD SITE INFORMATION
(continued)

MBMG NUMBER	LOCATION OF SITE	ELEVATION OF SITE	SOIL* TYPE (FEET)	SOIL PERMEABILITY (INCHES/HOUR)	UNIFIED SOIL CLASSIFICATION	SOIL TEXTURE (PERCENT FINER THAN FINE SAND)	NEAR ** SURFACE GEOLOGY	ESTIMATED DEPTH TO GROUND WATER (FEET)	CLOSEST WATER WELL (MILES)	CLOSEST SURFACE WATER (MILES)
SCB000229	NE375810BAAD	2135	WzC	2	CL	90.0	112TILL	20	0.7	0.1
SCB000230	NE375818BADB	2180	ZwE	2	CL	90.0	112TILL	15	1.0	0.1
SCB000231	NE375818BCX	2215	ZaD	.4	CL	90.0	112TILL	15	0.5	0.1
SCB000232	NE375818CAX	2203	ZwE	2	CL	90.0	112TILL	25	0.3	0.3
SCB000233	NE375818CCX	2218	ZaD	.4	CL	90.0	112TILL	30	0.3	0.4
SCB000234	NE375818DACA	2199	WzC	2	CL	90.0	112TILL	25	1.0	0.2
SCB000235	NE375819AACA	2185	ZwE	2	CL	90.0	112TILL	25	1.0	0.2
SCB000236	NE375819BAX	2185	ZwE	2	ML	95.0	112TILL	35	0.6	0.4
SCB000237	NE375819CAAC	2163	ZwE	2	CL	90.0	112TILL	15	0.8	0.1
SCB000238	NE375819DAX	2183	WmB	2	CL	95.0	112TILL	40	1.0	0.3
SCB000239	NE375820DAX	2161	WaE	20	GW	25.0	112OTSH	25	0.7	0.2
SCB000240	NE375820BAX	2191	WzB	2	CL	90.0	112TILL	25	1.0	0.3
SCB000241	NE375820CAX	2166	WaE	20	GW	25.0	112OTSH	30	1.0	0.2
SCB000242	NE375822CAAD	2190	ZwE	2	CL	90.0	112TILL	65	1.5	0.3
SCB000243	NE375828BBBD	2133	WaE	20	GW	25.0	112OTSH	15	0.4	0.2
SCB000244	NE375829BAX	2175	ZwE	2	CL	90.0	112TILL	45	1.0	0.2
SCB000245	NE375830AAX	2226	ZwE	2	CL	90.0	112TILL	65	1.0	0.4
SCB000246	NE375830BAX	2161	WzC	2	CL	90.0	112TILL	40	0.7	0.5
SCB000247	NE375830CAX	2140	ZwE	2	CL	90.0	112TILL	10	0.6	0.1
SCB000248	NE375830DAX	2146	ZwE	2	CL	90.0	112TILL	25	0.6	0.3
SCB000249	NE375831BAX	2156	WmC	2	ML	95.0	112TILL	35	0.4	0.2
SCB000250	NE375834DBA	2117	WaE	20	GW	25.0	112OTSH	25	0.1	0.3
SCB000251	NE355835DDAB01	2049	MaB	20	GW	25.0	112OTSH	15	0.3	0.3
SCB000252	NE345814BDAC01	2058	MaB	20	GW	25.0	112OTSH	25	0.2	1.0
SCB000253	NE345814DBBX01	2058	MaB	20	GW	25.0	112OTSH	25	0.2	1.0
SCB000254	NE365724ABX	2275	WzC	2	CL	90.0	112TILL	60	1.0	0.5
SCB000255	NE365830AB	2275	WzC	2	CL	90.0	112TILL	40	0.8	0.4
SCB000256	NE365721DBDC	2400	WzC	2	CL	90.0	112TILL	40	1.0	0.2
SCB000257	NE355808DDX 02	2142	WzB	2	CL	90.0	112TILL	30	0.1	0.2
SCB000258	NE355816BABA01	2125	WmB	2	CL	95.0	112TILL	20	0.1	0.2
SCB000259	NE355819ABDB	2192	ZaE	.4	CL	90.0	112TILL	35	0.8	0.6
SCB000260	NE355819BX 01	2170	WzC	2	CL	90.0	112TILL	35	0.5	0.3
SCB000261	NE355816DX	2130	WzB	2	CL	90.0	112TILL	25	0.8	0.4
SCB000262	NE365832DADD01	2210	ZwE	2	CL	90.0	112TILL	50	0.2	0.1
SCB000263	NE355834AAX	2080	ZwE	2	CL	90.0	112TILL	35	0.3	0.4
SCB000264	NE365828AADA01	2090	WaE	20	GW	25.0	112OTSH	25	0.1	0.4
SCB000265	NE355829DBD	2125	WmB	2	CL	95.0	112TILL	25	0.8	0.3
SCB000266	NE355819DCDD	2200	WmB	2	CL	95.0	112TILL	60	0.2	0.4

Table 5. SUMMARY OF SECONDARY OIL FIELD SITE INFORMATION (continued)

MBMG NUMBER	LOCATION OF SITE	ELEVATION OF SITE (FEET)	SOIL* TYPE	SOIL PERMEABILITY (INCHES/HOUR)	UNIFIED SOIL CLASSIFICATION	SOIL TEXTURE (PERCENT FINER THAN FINE SAND)	NEAR ** SURFACE GEOLOGY	ESTIMATED DEPTH TO GROUND WATER (FEET)	CLOSEST WATER WELL (MILES)	CLOSEST SURFACE WATER (MILES)
SCB000267	NE355829DDCD	2100	ZaD	.4	CL	90.0	112TILL	20	0.5	0.2
SCB000268	NE365721ABBD01	2495	ZwE	2	CL	90.0	112TILL	15	1.0	0.2
SCB000269	NE365716DCAC	2450	ZwE	2	CL	90.0	112TILL	65	1.0	0.2
SCB000270	NE365715ABAB	2250	SaC	2	CL	90.0	112TILL	15	0.2	0.3
SCB000271	NE365710DCX	2280	ZwE	2	CL	90.0	112TILL	25	0.5	0.1
SCB000272	NE365711CCCA01	2291	WaE	20	GW	25.0	112OTSH	40	0.5	0.4
SCB000273	NE365711CCCB01	2283	WaE	20	GW	25.0	112OTSH	40	0.5	0.4
SCB000274	NE365710DDCA01	2265	WaE	20	GW	25.0	112OTSH	10	0.4	0.1
SCB000275	NE365714ACAB	2275	WzC	2	CL	90.0	112TILL	15	0.4	0.1
SCB000276	NE365714BBX 01	2273	DoB	2	SM	65.0	112OTSH	30	0.8	0.1
SCB000277	NE365714BCBD01	2245	WzB	2	CL	90.0	112TILL	15	0.5	0.1
SCB000278	NE365714BC 02	2250	WzB	2	CL	90.0	112TILL	15	0.5	0.1
SCB000279	NE365714CBDB	2245	ZaD	.4	CL	90.0	112TILL	20	0.6	0.1
SCB000280	NE375715DCDC01	2205	ZaD	.4	CL	90.0	112TILL	30	0.2	0.2
SCB000281	NE375721BADD01	2230	ZwE	2	CL	90.0	112TILL	35	0.2	0.2
SCB000282	NE365827AADA01	2050	WaE	20	GW	25.0	112OTSH	1	0.1	0.1
SCB000283	NE375612CDAC01	2195	SaB	.2	CL	95.0	112TILL	5	0.2	0.3
SCB000284	NE375715ABAA01	2210	SaC	.2	CL	95.0	112OTSH	25	0.2	0.3
SCB000285	NE375714BBAA01	2240	DoC	2	SM	65.0	112OTSH	30	0.2	0.2
SCB000286	NE375711DCBC01	2230	SaB	20	GM	30.0	112OTSH	10	0.1	0.1
SCB000287	NE375711BCX 01	2290	WmB	2	CL	90.0	112TILL	50	0.7	0.7
SCB000288	NE375712DCX 01	2240	WzB	2	CL	90.0	112TILL	15	0.4	0.1
SCB000289	NE345821DDX	2065	DoB	2	SM	65.0	112OTSH	30	0.2	0.3
SCB000290	NE345828AAX	2080	DoB	2	SM	65.0	112OTSH	40	0.3	0.4
SCB000291	NE345827BCX	2025	DoB	2	SM	65.0	112OTSH	30	0.5	0.2
SCB000292	NE345822CCX	2045	DoB	2	SM	65.0	112OTSH	15	0.5	0.2
SCB000293	NE345822DCX	2085	DoC	2	SM	65.0	112OTSH	20	0.6	0.1
SCB000294	NE345820CAX	2050	TuB	20	GW	25.0	112OTSH	20	0.4	1.0
SCB000295	NE345820DAX	2035	SaA	.2	CL	95.0	112OTSH	20	0.8	0.7
SCB000296	NE345828BBBD	2050	MaB	20	GW	25.0	112OTSH	20	0.1	0.5
SCB000297	NE345828ABX	2070	DoB	2	SM	65.0	112OTSH	30	0.3	0.2
SCB000298	NE345827DAX	2035	WzB	2	CL	90.0	112TILL	15	0.3	0.2
SCB000299	NE345827CAX	2060	ZaD	.4	CL	90.0	112TILL	30	0.5	0.3
SCB000300	NE345826CBX	2040	WzB	2	CL	90.0	112TILL	20	0.4	0.2
SCB000301	NE345825BCBA	2040	WzB	2	CL	90.0	112TILL	15	0.2	0.1
SCB000302	NE335813BCBB	2005	DoB	2	SM	65.0	112OTSH	40	1.0	1.5
SCB000303	NE335808DD 01	2008	MaB	20	GW	25.0	112OTSH	20	0.3	0.5
SCB000304	NE335808ACX	2010	MaB	20	GW	25.0	112OTSH	20	0.4	0.3

Table 5. SUMMARY OF SECONDARY OIL FIELD SITE INFORMATION
(continued)

MBMG NUMBER	LOCATION OF SITE	ELEVATION OF SITE	SOIL* TYPE (FEET)	SOIL PERMEABILITY (INCHES/HOUR)	UNIFIED SOIL CLASSIFICATION	SOIL TEXTURE (PERCENT FINER THAN FINE SAND)	NEAR ** SURFACE GEOLOGY	ESTIMATED DEPTH TO GROUND WATER (FEET)	CLOSEST WATER WELL (MILES)	CLOSEST SURFACE WATER (MILES)
SCB000305	NE335821BAX	2000	WaE	20	GW	25.0	112OTSH	20	0.2	0.2
SCB000306	NE365816BBDC	2215	ZwE	2	CL	90.0	112TILL	5	0.7	0.1
SCB000307	NE365825DBDC	2049	WaE	20	GW	25.0	112OTSH	20	0.2	0.0

* (USDA, 1972)

** 112TILL - Quaternary Glacial Till
112OTSH - Quaternary Glacial Outwash
112GLCO - Quaternary Glacial Lake Deposits

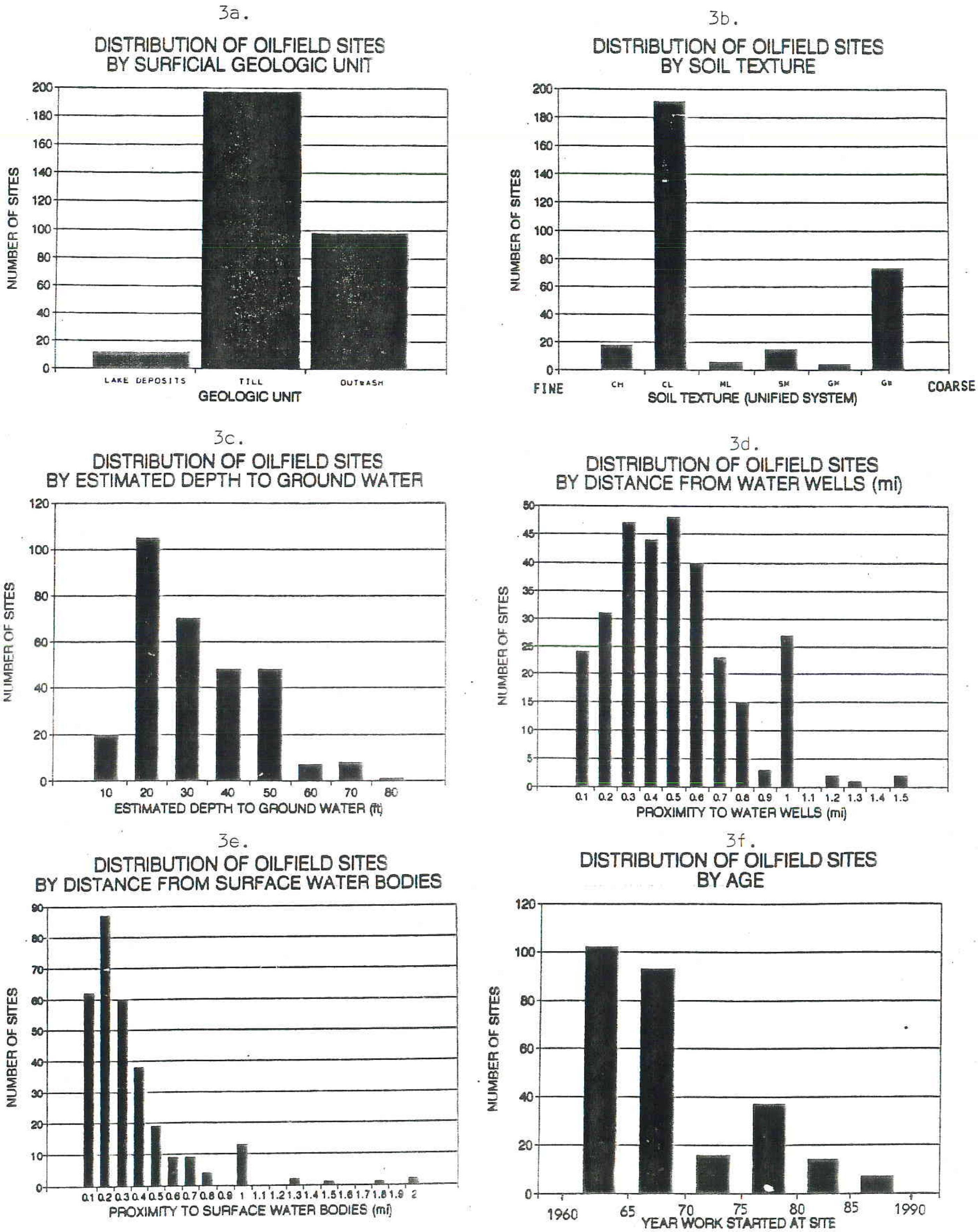


Figure 3. Series of bar charts showing the distribution of oil field sites with respect to a.) surficial geology, b.) soils, c.) distance from water wells, d.) distance from surface water, and e.) estimated depth to ground water, and f.) age.

depth to ground water at a majority of the sites is less than 30 feet (Figure 3c). Nearly all of the oil-field sites are within 1 mile of an existing water well while about 1/3 of the sites are within 0.3 mile of an existing water well (Figure 3d). Most oil-field sites are within 1 mile of a surface-water body such as a lake, slough, or pond while over 2/3 of the sites are within 0.3 mile of a surface-water body (Figure 3e). Most of the oil-field development occurred prior to 1970 (Figure 3f).

INITIAL SITE SURVEY

Visual inspections were conducted at 99 of the oil-field sites identified from the OGC files (Table 6). Selection criteria were designed to sample a diverse group of oil-field sites based on geographic location, surficial geology, and age of the site. The bar charts depicted in Figure 4 illustrate the distribution of surveyed oil-field sites with respect to 4a.) surficial geology, 4b.) soils, 4c.) distance from water wells, 4d.) distance from surface water, 4e.) estimated depth to ground water, and 4f.) age of site. The distribution relationships of the surveyed sites (Figure 4) mirrored those at the original site listing (Figure 3). This similarity shows that the surveyed sites comprise a statistically similar cross-section as indicated by the original site listing.

During the inspections contamination potential was determined based on visible surface damage, near-surface geology, topography, and proximity to existing surface- and ground-water sources. Locations of former leaks, spills, and evaporation pits were

Table 6. LISTING OF OIL FIELD SITES INVENTORIED

MBMG NO	DATE SPILL	AREA OF SURFACE CONTAMINATION (acres)	AREA OF HIGH APPARENT EM CONDUCTIVITY (acres)	ELEVATION (feet)	NEAR* SURFACE GEOLOGY	UNIFIED SOIL CLASSIFICATION	ESTIMATED DEPTH TO GROUNDWATER (feet)	CLOSEST WATER WELL (miles)	CLOSEST SURFACE WATER (miles)
SCB000008	1969			2027	112OTSH	GM	35	0.4	0.3
SCB000009	1971			2034	112OTSH	GM	35	0.4	0.3
SCB000013	1970			2009	112OTSH	GW	15	0.2	0.1
SCB000015	1971			2016	112TILL	CL	40	1.0	1.8
SCB000026	1984			2012	112OTSH	GW	15	0.6	0.4
SCB000027	1979			2164	112TILL	CL	50	0.3	1.0
SCB000046	1979			2043	112TILL	CL	20	0.3	0.1
SCB000059	1963			2123	112TILL	CL	20	0.5	0.3
SCB000064	1965			2111	112OTSH	GW	10	0.4	0.1
SCB000067	1963	1.3	2.5	2142	112TILL	CL	20	0.6	0.2
SCB000069	1963			2122	112TILL	CL	10	0.7	0.2
SCB000070	1963			2091	112TILL	CL	15	0.6	0.2
SCB000079	1964	3.7	6.5	2104	112TILL	ML	15	0.1	0.3
SCB000080	1965	0.0	0.0	2113	112OTSH	GW	20	0.6	0.4
SCB000081	1975			2101	112TILL	ML	15	0.5	0.5
SCB000082	1963	1.0	1.5	2167	112TILL	CL	35	0.5	0.2
SCB000083	1962	1.4	1.5	2228	112TILL	CL	55	0.5	0.4
SCB000092	1969			2184	112TILL	CL	45	0.7	0.2
SCB000101	1983			2261	112TILL	CL	15	0.6	0.1
SCB000103	1984			2197	112TILL	CL	15	0.5	0.1
SCB000114	1967			2147	112TILL	CL	20	0.5	0.6
SCB000117	1967	4.6	5.5	2134	112TILL	CL	50	0.6	0.3
SCB000118	1967			2117	112TILL	CL	40	0.3	0.2
SCB000124	1967	1.7	3.0	2066	112OTSH	GW	10	0.3	0.2
SCB000125	1967	1.0	2.0	2107	112OTSH	GW	15	0.1	0.2
SCB000126	1968	1.7	2.5	2114	112OTSH	GW	20	0.2	0.3
SCB000127	1965			2085	112OTSH	GW	15	0.4	0.1
SCB000134	1965			2201	112TILL	CL	50	0.3	1.0
SCB000135	1964			2266	112TILL	CL	60	0.6	0.6
SCB000137	1964			2208	112TILL	CL	45	0.5	0.4
SCB000139	1966	0.6	2.0	2132	112TILL	CL	20	0.4	0.7
SCB000140	1965			2172	112TILL	CL	45	0.4	0.4
SCB000151	1963	4.2	5.0	2287	112TILL	CL	10	0.1	0.1
SCB000154	1967			2228	112TILL	CL	50	0.8	0.3
SCB000162	1966			2265	112TILL	CL	50	0.5	0.3
SCB000165	1965			2285	112TILL	CL	45	0.3	0.3
SCB000166	1965			2242	112TILL	CL	30	0.4	0.2
SCB000167	1965	2.3	7.0	2263	112TILL	CL	40	0.1	0.3

Table 6. LISTING OF OIL FIELD SITES INVENTORIED (continued)

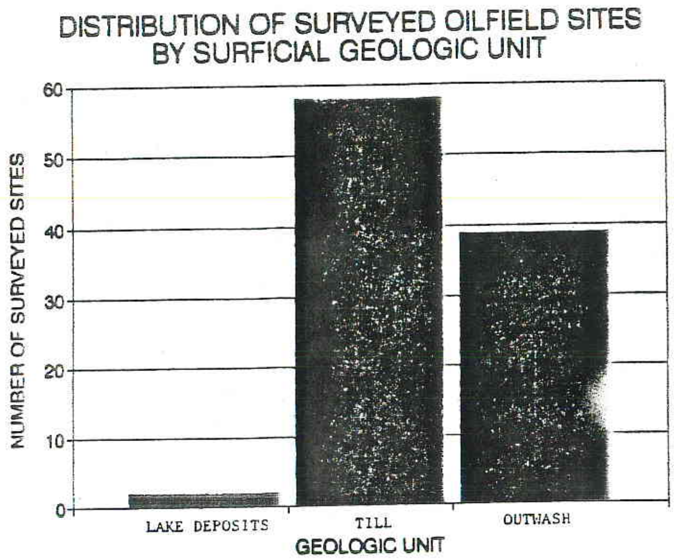
MBMG NO	DATE SPILL	AREA OF SURFACE CONTAMINATION (acres)	AREA OF HIGH APPARENT EM CONDUCTIVITY (acres)	ELEVATION (feet)	NEAR* SURFACE GEOLOGY	UNIFIED SOIL CLASSIFICATION	ESTIMATED DEPTH TO GROUNDWATER (feet)	CLOSEST WATER WELL (miles)	CLOSEST SURFACE WATER (miles)
SCB000177	1965			2204	112OTSH	SM	15	0.2	0.1
SCB000179	1965			2208	112OTSH	CH	20	0.6	0.5
SCB000180	1966			2178	112OTSH	CH	15	0.3	0.3
SCB000183	1966			2240	112GLCO	CL	35	0.4	0.2
SCB000184	1970	1.3	1.5	2200	112GLCO	CH	15	0.4	0.8
SCB000190	1966			2184	112TILL	CL	25	0.7	0.1
SCB000195	1966			2184	112TILL	CL	30	0.5	0.2
SCB000196	1966			2214	112TILL	CL	45	0.5	0.3
SCB000198	1963			2233	112TILL	CL	35	0.5	0.3
SCB000222	1965	1.0	2.0	2200	112TILL	CL	20	0.1	0.1
SCB000251	1980	0.6	1.0	2049	112OTSH	GW	15	0.3	0.3
SCB000252	1987	0.6	1.0	2058	112OTSH	GW	25	0.2	1.0
SCB000253	1988	1.0	0.8	2058	112OTSH	GW	25	0.2	1.0
SCB000256				2400	112TILL	CL	40	1.0	0.2
SCB000258	1963	2.3	8.0	2125	112TILL	CL	20	0.1	0.2
SCB000259				2192	112TILL	CL	35	0.8	0.6
SCB000260	1983			2170	112TILL	CL	35	0.5	0.3
SCB000262	1964	3.8	6.0	2210	112TILL	CL	50	0.2	0.1
SCB000264	1970	2.9	6.0	2090	112OTSH	GW	25	0.1	0.4
SCB000266		1.1	2.0	2200	112TILL	CL	60	0.2	0.4
SCB000267				2100	112TILL	CL	20	0.5	0.2
SCB000268				2495	112TILL	CL	15	1.0	0.2
SCB000269				2450	112TILL	CL	65	1.0	0.2
SCB000270				2250	112TILL	CL	15	0.2	0.3
SCB000271				2280	112TILL	CL	25	0.5	0.1
SCB000272				2291	112OTSH	GW	40	0.5	0.4
SCB000273				2283	112OTSH	GW	40	0.5	0.4
SCB000274				2265	112OTSH	GW	10	0.4	0.1
SCB000275				2275	112TILL	CL	15	0.4	0.1
SCB000276				2273	112OTSH	SM	30	0.8	0.1
SCB000277				2245	112TILL	CL	15	0.5	0.1
SCB000278				2250	112TILL	CL	15	0.5	0.1
SCB000279				2245	112TILL	CL	20	0.6	0.1
SCB000280	1966			2205	112TILL	CL	30	0.2	0.2
SCB000281	1966			2230	112TILL	CL	35	0.2	0.2
SCB000282				2050	112OTSH	GW	1	0.1	0.1
SCB000283	1988			2195	112TILL	CL	5	0.2	0.3
SCB000284				2210	112OTSH	CL	25	0.2	0.3

Table 6. LISTING OF OIL FIELD SITES INVENTORIED (continued)

MBMG NO	DATE SPILL	AREA OF SURFACE CONTAMINATION (acres)	AREA OF HIGH APPARENT EM CONDUCTIVITY (acres)	ELEVATION (feet)	NEAR* SURFACE GEOLOGY	UNIFIED SOIL CLASSIFICATION	ESTIMATED DEPTH TO GROUNDWATER (feet)	CLOSEST WATER WELL (miles)	CLOSEST SURFACE WATER (miles)
SCB000285				2240	112OTSH	SM	30	0.2	0.2
SCB000286	1981	0.5	0.7	2230	112OTSH	GM	10	0.1	0.1
SCB000287				2290	112TILL	CL	50	0.7	0.7
SCB000288		1.0	0.0	2240	112TILL	CL	15	0.4	0.1
SCB000289				2065	112OTSH	SM	30	0.2	0.3
SCB000290	1988			2080	112OTSH	SM	40	0.3	0.4
SCB000291				2025	112OTSH	SM	30	0.5	0.2
SCB000292				2045	112OTSH	SM	15	0.5	0.2
SCB000293				2085	112OTSH	SM	20	0.6	0.1
SCB000294	1982			2050	112OTSH	GW	20	0.4	1.0
SCB000295	1982	0.5	0.0	2035	112OTSH	CL	20	0.8	0.7
SCB000296				2050	112OTSH	GW	20	0.1	0.5
SCB000297				2070	112OTSH	SM	30	0.3	0.2
SCB000298				2035	112TILL	CL	15	0.3	0.2
SCB000299				2060	112TILL	CL	30	0.5	0.3
SCB000300				2040	112TILL	CL	20	0.4	0.2
SCB000301	1988			2040	112TILL	CL	15	0.2	0.1
SCB000302				2005	112OTSH	SM	40	1.0	1.5
SCB000303				2008	112OTSH	GW	20	0.3	0.5
SCB000304				2010	112OTSH	GW	20	0.4	0.3
SCB000305				2000	112OTSH	GW	20	0.2	0.2
SCB000306	1986	6.0	6.0	2215	112TILL	CL	5	0.7	0.1
SCB000307	1965			2049	112OTSH	GW	20	0.2	0.0

112OTSH - Glacial outwash deposits
112TILL - Glacial till deposits
112GLCO - Glacial lake deposits

4a.



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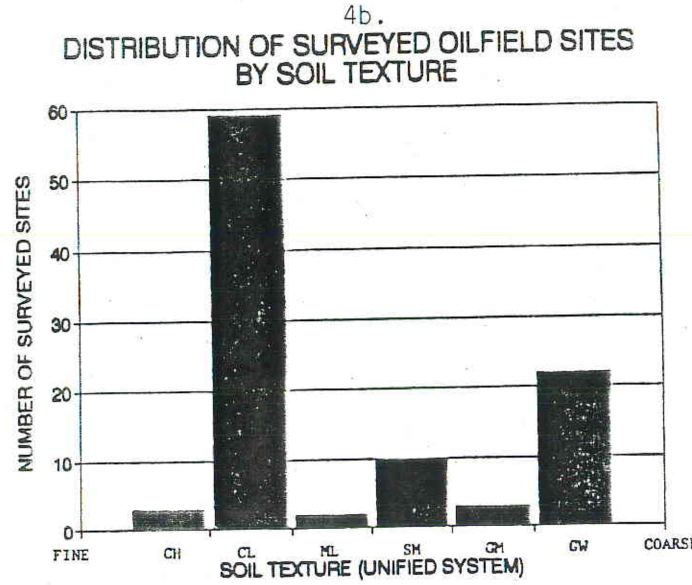

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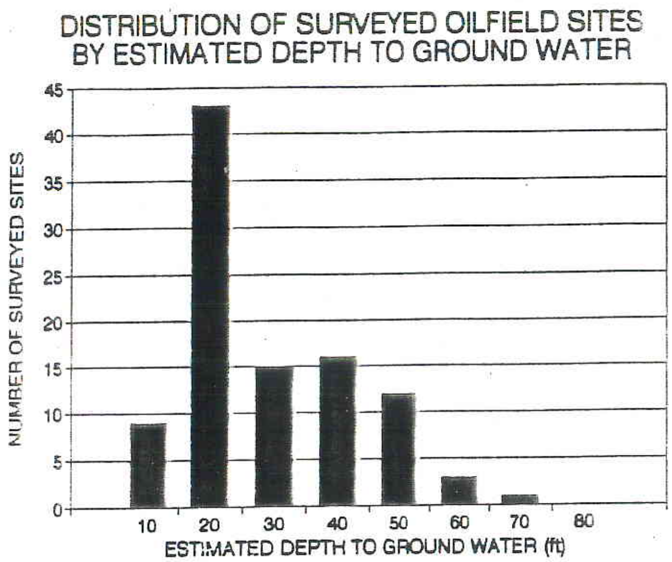

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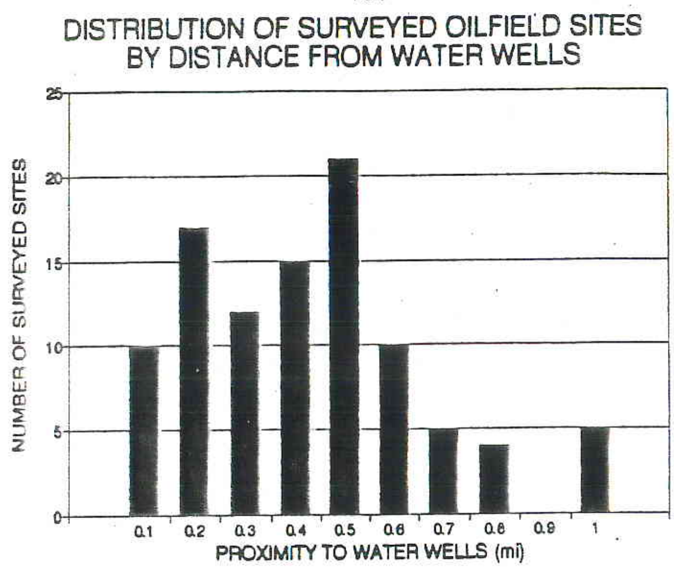

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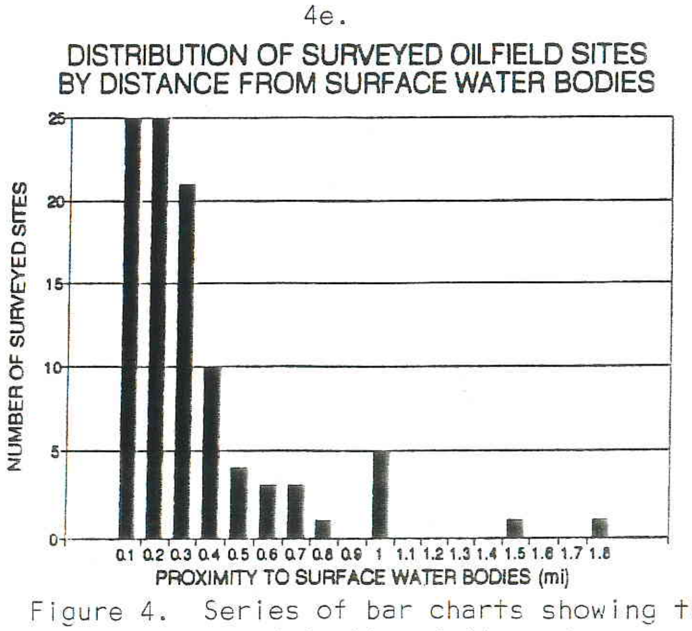


4f.

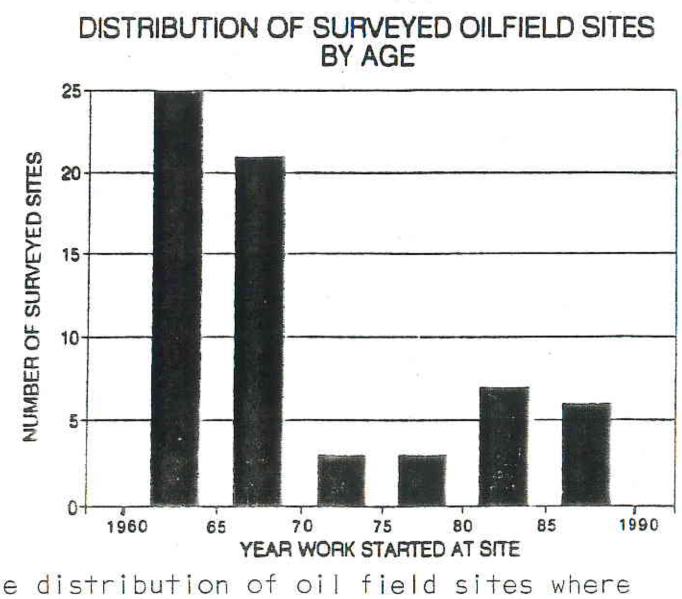


Figure 4. Series of bar charts showing the distribution of oil field sites where initial site visits and surveys were conducted with respect to a.) surficial geology, b.) soils, c.) distance from water wells, d.) distance from surface water, and e.) estimated depth to ground water, f.) age.

compiled during interviews with area residents. Qualitative estimates of the volume of brine discharged, duration of the discharge event, and impacts to soil vegetation, and water resources were determined based on landowner interviews and visible surface damage.

HYDROGEOLOGIC OVERVIEW OF OIL-FIELD SITES IN EASTERN SHERIDAN COUNTY

In order to identify areas of existing ground-water contamination and to assess the extent and severity of contamination, preliminary hydrogeologic investigations were conducted at 24 of the 99 sites that were inspected. Sites previously documented as having contributed to contamination of water supplies or that are associated with severely degraded soils and vegetation were emphasized. Although the severity of degradation was emphasized at this level in the site filtering process, the surficial geology, soils, location with respect to water resources, and age of the sites were considered to provide a representative cross-section of oil-field sites in eastern Sheridan County.

Investigative Process

A four step process was used to determine the hydrogeologic properties and existing contamination at the oil-field sites. 1.) Site visits supplemented by more detailed interviews with area residents were conducted. 2.) An electromagnetic conductivity (EM-31) survey was conducted. 3.) Wells were installed. 4.) Hydrologic parameters were monitored, including measuring water levels, collecting field water quality data, and laboratory analyses of selected water samples. Most of the sites were investigated using all four steps listed above. Several exceptions to the investigative process are listed below. Drilling was not conducted where access was denied. Monitoring was not conducted where test holes were dry. Neither EM surveys nor drilling were conducted near most of the lakes that were sampled.

Results

The hydrogeology and contamination potential of the 24 oil-field sites selected are summarized in Appendix B. The summaries are divided into four parts. 1.) Location and lease information. 2.) Description of the physical properties of the site. 3.) Description of the visible and reported contamination. 4.) A site evaluation summarizing the EM-31 survey, well drilling, monitoring, laboratory analyses, and mapping.

The results of the EM-31 surveys were contoured to define areas of anomolously high apparent conductivities. Holding other electrical properties of the soil constant, the apparent conductivity is a measure of the electrical conductivity of the pore water. When shallow pore water is contaminated with oil-field brines the electrical conductivity of the pore water increases. The resultant apparent conductivity maps are useful for defining the contaminant sources. The EM-31 was operated in a reconnaissance mode designed for rapid surveying. In the reconnaissance mode the depth of penetration is about 2-3 meters. Consequently, the electrical properties of the saturated zone were only measured in areas with very shallow water tables. Lithologic logs of all test holes drilled and monitor wells installed are listed in Appendix C. The results of periodic monitoring of water levels and field water quality are summarized in Table 7. Water levels were measured with either a steel tape or an electronic tape. Chloride concentrations were measured using Quantab chloride titrators. Information about using Quantab chloride titrators is in Appendix D. Water samples with chloride concentrations within the range of the Quantab titrators, about 50 to 5000 mg/L, could be read directly off the test strip. Samples with chloride concentrations above the range of the Quantab titrators required dilution. Field chloride concentrations measured using Quantab chloride titrators compared closely to laboratory determined chloride concentrations. Plots of field chloride values, against lab chloride values showed a nearly 1:1 relationship over a wide range of concentrations (Figure 5). The Quantab titrators proved to be a quick and reliable method for measuring chloride concentrations. Other field water quality parameters measured were pH and specific conductance.

A total of forty-three water samples were analyzed for standard and trace constituents by the MBMG analytical lab in Butte. Twenty-six samples were collected between April 18 and April 22, 1989 as part of the preliminary hydrogeologic investigation. The remaining 17 samples were collected between October 10 and October 13, 1989 as part of the detailed investigation of ground-water degradation in the Goose Lake oil

Table 7. SUMMARY OF FIELD DATA FROM WELLS AND SURFACE WATER SOURCES

SITE NUMBER	LOCATION	TYPE OF SITE	TOTAL DEPTH (FT)	LAND SURFACE ELEVATION (FT)	WATER LEVEL ELEVATION (FT)	SAMPLE DATE	CHLORIDE CONCENTRATION (mg/L)	SPECIFIC CONDUCTANCE (umho/cm)	pH
067A	NE355808DDDB01	WELL	43.00	2134.70	2134.70				
067A	NE355808DDDB01	WELL	43.00	2134.70	2124.60	11/22/88	17660	175170	6.50
067A	NE355808DDDB01	WELL	43.00	2134.70	2123.73	03/10/89	73460	86400	6.84
067A	NE355808DDDB01	WELL	43.00	2134.70	2134.70	03/21/89	76640	81600	
067A	NE355808DDDB01	WELL	43.00	2134.70	2123.85	04/19/89	101240	114110	6.29
067A	NE355808DDDB01	WELL	43.00	2134.70	2124.69	05/15/89	118680	199040	
067A	NE355808DDDB01	WELL	43.00	2134.70	2125.19	07/26/89	107880	202270	
067A	NE355808DDDB01	WELL	43.00	2134.70	2124.19	06/21/90			
067A	NE355808DDDB01	WELL	43.00	2134.70	2124.61	06/27/90	68660	108500	6.41
067B	NE355808DDDA01	WELL	42.00	2128.70	2128.70				
067B	NE355808DDDA01	WELL	42.00	2128.70	2118.00	11/23/88	30780	62930	6.70
067B	NE355808DDDA01	WELL	42.00	2128.70	2120.20	03/10/89	24080	42300	6.98
067B	NE355808DDDA01	WELL	42.00	2128.70	2125.54	04/19/89	43090	58710	6,45
067B	NE355808DDDA01	WELL	42.00	2128.70	2124.83	05/15/89	55010	83850	
067B	NE355808DDDA01	WELL	42.00	2128.70	2122.76	07/25/89	45440	72400	
067B	NE355808DDDA01	WELL	42.00	2128.70	2123.67	06/21/90			
067B	NE355808DDDA01	WELL	42.00	2128.70	2123.36	06/27/90	28140	72000	6.62
067C	NE355809CCCA01	SLOUGH		2106.00	2106.00	04/19/89	<50	260	8.10
067D	NE355808DDDA02	PIT		2135.00	2135.00	04/19/89	275	700	8.24
079A	NE355817ADAC02	WELL	23.00	2103.70	2089.50				
079A	NE355817ADAC02	WELL	23.00	2103.70	2097.60	11/22/88	61160	167670	6.70
079A	NE355817ADAC02	WELL	23.00	2103.70	2096.89	03/10/89	85800	88000	6.67
079A	NE355817ADAC02	WELL	23.00	2103.70	2102.00	04/19/89	67100	101760	6.35
079A	NE355817ADAC02	WELL	23.00	2103.70	2101.22	05/15/89	102480	164350	
079A	NE355817ADAC02	WELL	23.00	2103.70	2098.87	07/25/89	88000	166700	
079A	NE355817ADAC02	WELL	23.00	2103.70	2099.14	06/21/90			
079A	NE355817ADAC02	WELL	23.00	2103.70	2099.13	06/27/90	61160	101300	6.63
079B	NE355817AADC01	WELL	36.00	2109.50	2109.50				
079B	NE355817AADC01	WELL	36.00	2109.50	2071.50	11/22/88			
079B	NE355817AADC01	WELL	36.00	2109.50	2085.02	03/10/89	140	4520	7.85
079B	NE355817AADC01	WELL	36.00	2109.50	2085.96	04/19/89	115	4500	6.64
079B	NE355817AADC01	WELL	36.00	2109.50	2082.44	05/15/89	195	5520	
079B	NE355817AADC01	WELL	36.00	2109.50	2098.31	07/25/89	225	5720	
079B	NE355817AADC01	WELL	36.00	2109.50	2096.41	06/21/90			
079B	NE355817AADC01	WELL	36.00	2109.50	2084.69	06/27/90	185	5700	7.19
079C	NE355817ADAB01	WELL	28.00	2106.60	2106.60				
079C	NE355817ADAB01	WELL	28.00	2106.60	2100.40	11/22/88	59110	148610	6.90
079C	NE355817ADAB01	WELL	28.00	2106.60	2099.83	03/10/89	55360	70200	6.99
079C	NE355817ADAB01	WELL	28.00	2106.60	2103.60	04/19/89	57160	82720	6.70
079C	NE355817ADAB01	WELL	28.00	2106.60	2103.27	05/15/89	64160	134950	
079C	NE355817ADAB01	WELL	28.00	2106.60	2101.89	07/25/89	60700	128600	
079C	NE355817ADAB01	WELL	28.00	2106.60	2101.58	06/21/90			
079C	NE355817ADAB01	WELL	28.00	2106.60	2101.82	06/27/90	56080	87200	6.85
079D	NE355817ADAA01	PIT		2113.00	2113.00	07/20/88	3240	12040	
117A	NE365822CBAC01	WELL	43.00	2117.70	2117.70				
117A	NE365822CBAC01	WELL	43.00	2117.70	2115.00	12/12/88	75	3850	6.90
117A	NE365822CBAC01	WELL	43.00	2117.70	2112.28	03/21/89	75	3030	7.52
117A	NE365822CBAC01	WELL	43.00	2117.70	2113.82	04/21/89	80	4060	6.85
117A	NE365822CBAC01	WELL	43.00	2117.70	2114.08	05/17/89	60	3840	
117A	NE365822CBAC01	WELL	43.00	2117.70	2113.78	06/29/89	<44	3810	
117A	NE365822CBAC01	WELL	43.00	2117.70	2113.57	07/31/89	50	3810	
117A	NE365822CBAC01	WELL	43.00	2117.70	2113.69	10/13/89	135	3970	6.77
117A	NE365822CBAC01	WELL	43.00	2117.70	2113.14	06/19/90			

Table 7. SUMMARY OF FIELD DATA FROM WELLS AND SURFACE WATER SOURCES (continued)

SITE NUMBER	LOCATION	TYPE OF SITE	TOTAL DEPTH (FT)	LAND SURFACE ELEVATION (FT)	WATER LEVEL ELEVATION (FT)	SAMPLE DATE	CHLORIDE CONCENTRATION (mg/L)	SPECIFIC CONDUCTANCE (umho/cm)	pH
117A	NE365822CBAC01	WELL	43.00	2117.70	2112.98	06/26/90	59	3890	6.84
117B	NE365822CBDA01	WELL	38.00	2109.30	2109.30				
117B	NE365822CBDA01	WELL	38.00	2109.30	2109.30	12/12/88	<50	2740	7.10
117B	NE365822CBDA01	WELL	38.00	2109.30	2109.30	04/21/89	<44	2870	6.85
117B	NE365822CBDA01	WELL	38.00	2109.30	2111.38	05/17/89	<44	2820	
117B	NE365822CBDA01	WELL	38.00	2109.30	2109.82	06/29/89	<44	2680	
117B	NE365822CBDA01	WELL	38.00	2109.30	2110.15	07/31/89	<44	2710	
117B	NE365822CBDA01	WELL	38.00	2109.30	2110.88	10/13/89	60	3250	6.98
117B	NE365822CBDA01	WELL	38.00	2109.30	2109.82	06/19/90			
117B	NE365822CBDA01	WELL	38.00	2109.30	2109.65	06/26/90	<44	2830	7.04
117C	NE365822CDBB01	WELL	43.00	2094.40	2094.40				
117C	NE365822CDBB01	WELL	43.00	2094.40	2094.40	11/23/88	130	2470	7.60
117C	NE365822CDBB01	WELL	43.00	2094.40	2094.40	04/21/89	<44	1960	7.10
117C	NE365822CDBB01	WELL	43.00	2094.40	2094.40	05/16/89	<44	1800	
117C	NE365822CDBB01	WELL	43.00	2094.40	2100.90	06/29/89	44	1860	
117C	NE365822CDBB01	WELL	43.00	2094.40	2100.86	07/31/89	<44	1860	
117C	NE365822CDBB01	WELL	43.00	2094.40	2101.59	10/11/89	<44	1880	7.09
117C	NE365822CDBB01	WELL	43.00	2094.40	2194.39	06/19/90			
117C	NE365822CDBB01	WELL	43.00	2094.40	2194.39	06/26/90	<44	1866	7.18
117D	NE365822CDBA01	WELL	8.00	2079.70	2079.70				
117D	NE365822CDBA01	WELL	8.00	2079.70	2075.30	11/23/88	1880	6220	7.30
117D	NE365822CDBA01	WELL	8.00	2079.70	2074.67	03/11/89	1975	5850	6.58
117D	NE365822CDBA01	WELL	8.00	2079.70	2077.48	05/16/89	3380	9200	
117D	NE365822CDBA01	WELL	8.00	2079.70	2077.42	06/29/89	2465	6520	
117D	NE365822CDBA01	WELL	8.00	2079.70	2076.41	07/31/89	2370	6700	
117D	NE365822CDBA01	WELL	8.00	2079.70	2075.53	10/13/89	3040	8020	7.00
117D	NE365822CDBA01	WELL	8.00	2079.70	2076.06	06/19/90			
117D	NE365822CDBA01	WELL	8.00	2079.70	2075.69	06/26/90	2621	7930	7.17
117E	NE365822CDAB01	DUGOUT		2079.10	2079.10	08/10/88	7390	23870	
117E	NE365822CDAB01	DUGOUT		2079.10	2079.10	04/21/89	360	1870	7.91
117E	NE365822CDAB01	DUGOUT		2079.10	2079.10	10/13/89	5120	14700	7.66
117E	NE365822CDAB01	DUGOUT		2019.10	2019.10	06/26/90	5247	14360	8.90
117F	NE365822CDAD01	SLOUGH		2072.00	2072.00	04/21/89	450	2080	
117G	NE365822CADA01	DAM		2110.00	2110.00	04/21/89	100	750	8.00
117H	NE365822DCCB01	WELL		2069.00	2069.00	05/02/89	2025	6450	
117I	NE365823CCCB01	WELL	24.00	2069.00	2051.10	05/29/89	<44	420	
117J	NE365827ABAB01	WELL	15.00	2062.10	2059.40	06/02/89	3430	11000	
117J	NE365827ABAB01	WELL	15.00	2062.10	2059.13	06/28/89	3890	10630	
117J	NE365827ABAB01	WELL	15.00	2062.10	2058.42	07/28/89	3210	9170	
117J	NE365827ABAB01	WELL	15.00	2062.10	2058.07	09/28/89	2850	8470	
117J	NE365827ABAB01	WELL	15.00	2062.10	2058.09	10/12/89	2940	8730	6.96
117J	NE365827ABAB01	WELL	15.00	2062.10	2058.45	06/19/90			
117J	NE365827ABAB01	WELL	15.00	2062.10	2058.45	06/20/90	1704	5760	7.15
117J	NE365827ABAB01	WELL	15.00	2062.10	2058.45	06/20/90	3290	9280	7.15
124A	NE365827ABBD01	WELL	22.00	2075.70	2075.70				
124A	NE365827ABBD01	WELL	22.00	2075.70	2061.10	12/13/88	7400	20100	7.30
124A	NE365827ABBD01	WELL	22.00	2075.70	2061.13	03/11/89	6070	14940	7.18
124A	NE365827ABBD01	WELL	22.00	2075.70	2061.14	04/20/89	8300	20000	6.95
124A	NE365827ABBD01	WELL	22.00	2075.70	2061.47	05/16/89	7960	19990	
124A	NE365827ABBD01	WELL	22.00	2075.70	2061.64	06/28/89	7680	18730	
124A	NE365827ABBD01	WELL	22.00	2075.70	2061.52	07/28/89	7400	18570	
124A	NE365827ABBD01	WELL	22.00	2075.70	2061.52	09/27/89	9070	22450	
124A	NE365827ABBD01	WELL	22.00	2075.70	2061.43	10/12/89	10600	23430	7.31

Table 7. SUMMARY OF FIELD DATA FROM WELLS AND SURFACE WATER SOURCES (continued)

SITE NUMBER	LOCATION	TYPE OF SITE	TOTAL DEPTH (FT)	LAND SURFACE ELEVATION (FT)	WATER LEVEL ELEVATION (FT)	SAMPLE DATE	CHLORIDE CONCENTRATION (mg/L)	SPECIFIC CONDUCTANCE (umho/cm)	pH
124A	NE365827ABBD01	WELL	22.00	2075.70	2061.10	06/19/90			
124A	NE365827ABBD01	WELL	22.00	2075.70	2061.10	06/20/90	5240	13440	7.30
124A	NE365827ABBD01	WELL	22.00	2075.70	2061.10	06/20/90	5610	15470	7.27
124B	NE365827ABAC01	WELL	8.00	2058.30	2058.30				
124B	NE365827ABAC01	WELL	8.00	2058.30	2053.20	12/13/88	8350	24880	7.20
124B	NE365827ABAC01	WELL	8.00	2058.30	2053.17	03/11/89	9110	21600	7.39
124B	NE365827ABAC01	WELL	8.00	2058.30	2054.15	04/21/89	10060	24000	7.28
124B	NE365827ABAC01	WELL	8.00	2058.30	2054.19	05/16/89	11160	23410	
124B	NE365827ABAC01	WELL	8.00	2058.30	2055.06	06/28/89	9090	23400	
124B	NE365827ABAC01	WELL	8.00	2058.30	2054.63	07/28/89	8560	25170	
124B	NE365827ABAC01	WELL	8.00	2058.30	2054.09	09/27/89	10630	27820	
124B	NE365827ABAC01	WELL	8.00	2058.30	2054.08	10/12/89	9850	28530	7.19
124B	NE365827ABAC01	WELL	8.00	2058.30	2054.50	06/19/90			
124B	NE365827ABAC01	WELL	8.00	2058.30	2054.50	06/20/90	8670	24060	7.26
124C	NE365827AABC01	WELL	8.00	2057.70	2057.70				
124C	NE365827AABC01	WELL	8.00	2057.70	2054.00	12/13/88	11210	31900	7.30
124C	NE365827AABC01	WELL	8.00	2057.70	2054.43	03/11/89	11070	24900	7.32
124C	NE365827AABC01	WELL	8.00	2057.70	2054.92	04/21/89	13420	27570	7.26
124C	NE365827AABC01	WELL	8.00	2057.70	2054.78	05/16/89	12150	29330	
124C	NE365827AABC01	WELL	8.00	2057.70	2054.58	06/28/89	12150	26500	
124C	NE365827AABC01	WELL	8.00	2057.70	2053.86	07/28/89	9460	23790	
124C	NE365827AABC01	WELL	8.00	2057.70	2053.45	09/27/89	10630	25200	
124C	NE365827AABC01	WELL	8.00	2057.70	2053.48	10/12/89	9460	24920	7.28
124C	NE365827AABC01	WELL	8.00	2057.70	2053.98	06/19/90			
124C	NE365827AABC01	WELL	8.00	2057.70	2053.98	06/20/90	9870	24340	7.23
124D	NE365827AABD01	SLOUGH		2047.00	2047.00	10/18/88	>6000		
124D	NE365827AABD01	SLOUGH		2047.00	2047.00	04/21/89	5060	11090	9.02
124D	NE365827AABD01	SLOUGH		2047.00	2047.00	07/28/89	53100	103360	
124D	NE365827AABD01	SLOUGH		2047.00	2047.00	06/28/90	59110	101600	7.87
124E	NE365827ADAB01	SLOUGH		2047.00	2047.00	05/02/89	16870	34700	
124E	NE365827ADAB01	SLOUGH		2047.00	2047.00	07/28/89	3080	10640	
124E	NE365827ADAB01	SLOUGH		2047.00	2047.00	06/28/90	37540	46555	7.94
124F	NE365827AACC01	SLOUGH		2047.00	2047.00	05/02/89	12790	27030	
124F	NE365827AACC01	SLOUGH		2047.00	2047.00	06/28/90	49260	89000	8.90
124G	NE365827AAAA01	WELL	27.00	2054.30	2048.71	06/09/89			
124G	NE365827AAAA01	WELL	27.00	2054.30	2048.50	06/28/89	<44	1430	
124G	NE365827AAAA01	WELL	27.00	2054.30	2047.82	07/28/89	65	1500	
124G	NE365827AAAA01	WELL	27.00	2054.30	2047.21	09/29/89	52	1470	
124G	NE365827AAAA01	WELL	27.00	2054.30	2047.24	10/12/89	48	1410	7.17
124G	NE365827AAAA01	WELL	27.00	2054.30	2048.16	06/19/90			
124G	NE365827AAAA01	WELL	27.00	2054.30	2047.97	06/27/90	48	1570	7.29
124H	NE365827AADA01	WELL	17.00	2049.40	2046.36	06/02/89		67000	
124H	NE365827AADA01	WELL	17.00	2049.40	2046.18	06/28/89	41620	95800	
124H	NE365827AADA01	WELL	17.00	2049.40	2045.45	07/28/89	37800	98360	
124H	NE365827AADA01	WELL	17.00	2049.40	2044.84	09/29/89	43400	94600	
124H	NE365827AADA01	WELL	17.00	2049.40	2044.84	09/29/89	33600	93350	
124H	NE365827AADA01	WELL	17.00	2049.40	2044.84	09/29/89	47300	98950	
124H	NE365827AADA01	WELL	17.00	2049.40	2044.90	10/12/89	45340	95690	6.68
124H	NE365827AADA01	WELL	17.00	2049.40	2046.15	06/19/90			
124H	NE365827AADA01	WELL	17.00	2049.40	2045.89	06/26/90	33810	65000	6.90
124H	NE365827AADA01	WELL	17.00	2049.40	2045.89	06/26/90	32440	64800	6.93
124H	NE365827AADA01	WELL	17.00	2049.40	2045.89	06/26/90	33810	66000	6.88
124I	NE365827ABCD01	NOWELL		2072.60	2072.60				

Table 7. SUMMARY OF FIELD DATA FROM WELLS AND SURFACE WATER SOURCES (continued)

SITE NUMBER	LOCATION	TYPE OF SITE	TOTAL DEPTH (FT)	LAND SURFACE ELEVATION (FT)	WATER LEVEL ELEVATION (FT)	SAMPLE DATE	CHLORIDE CONCENTRATION (mg/L)	SPECIFIC CONDUCTANCE (umho/cm)	pH
124J	NE365827ABAC02	WELL	18.00	2059.30	2055.07	06/02/89		46000	
124J	NE365827ABAC02	WELL	18.00	2059.30	2054.98	06/28/89	35500	64360	
124J	NE365827ABAC02	WELL	18.00	2059.30	2054.51	07/28/89	30370	59270	
124J	NE365827ABAC02	WELL	18.00	2059.30	2053.99	09/27/89	12200	31630	
124J	NE365827ABAC02	WELL	18.00	2059.30	2053.99	09/27/89	20080	40920	
124J	NE365827ABAC02	WELL	18.00	2059.30	2053.99	09/27/89	30000	59400	
124J	NE365827ABAC02	WELL	18.00	2059.30	2054.00	10/12/89	25000	46500	6.95
124J	NE365827ABAC02	WELL	18.00	2059.30	2054.41	06/19/90	12000	30320	7.26
124J	NE365827ABAC02	WELL	18.00	2059.30	2054.41	06/20/90	13560	34760	7.24
124J	NE365827ABAC02	WELL	18.00	2059.30	2054.41	06/20/90	23920	59070	6.82
124K	NE365827ABDA01	WELL	14.00	2059.45	2055.07	06/09/89			
124K	NE365827ABDA01	WELL	14.00	2059.45	2054.96	06/28/89	18500	39620	
124K	NE365827ABDA01	WELL	14.00	2059.45	2054.48	07/28/89	18220	39080	
124K	NE365827ABDA01	WELL	14.00	2059.45	2053.98	09/27/89	8290	22800	
124K	NE365827ABDA01	WELL	14.00	2059.45	2053.98	09/27/89	19970	45400	
124K	NE365827ABDA01	WELL	14.00	2059.45	2053.98	09/27/89	28500	63500	
124K	NE365827ABDA01	WELL	14.00	2059.45	2054.00	10/12/89	17160	41430	7.15
124K	NE365827ABDA01	WELL	14.00	2059.45	2054.42	06/19/90			
124K	NE365827ABDA01	WELL	14.00	2059.45	2054.42	06/20/90	8960	26020	7.22
124K	NE365827ABDA01	WELL	14.00	2059.45	2054.42	06/20/90	11730	30880	7.26
124K	NE365827ABDA01	WELL	14.00	2059.45	2054.42	06/20/90	17920	42440	7.15
124L	NE365827ABDB01	WELL	17.00	2060.00	2055.10	06/09/89			
124L	NE365827ABDB01	WELL	17.00	2060.00	2054.92	06/28/89	3380	10280	
124L	NE365827ABDB01	WELL	17.00	2060.00	2054.37	07/31/89	4400	12220	
124L	NE365827ABDB01	WELL	17.00	2060.00	2053.91	09/27/89	2270	7280	
124L	NE365827ABDB01	WELL	17.00	2060.00	2053.91	09/27/89	2810	11400	
124L	NE365827ABDB01	WELL	17.00	2060.00	2053.91	09/27/89	3360	13750	
124L	NE365827ABDB01	WELL	17.00	2060.00	2053.92	10/12/89	2940	8600	7.46
124L	NE365827ABDB01	WELL	17.00	2060.00	2054.42	06/19/90			
124L	NE365827ABDB01	WELL	17.00	2060.00	2054.42	06/20/90	2070	6380	7.52
124L	NE365827ABDB01	WELL	17.00	2060.00	2054.42	06/20/90	3290	9190	7.58
124L	NE365827ABDB01	WELL	17.00	2060.00	2054.42	06/20/90	3812	11240	7.53
124M	NE365827ABDC01	WELL	13.00	2061.40	2055.07	06/03/89		3500	
124M	NE365827ABDC01	WELL	13.00	2061.40	2054.77	06/28/89	830	4430	
124M	NE365827ABDC01	WELL	13.00	2061.40	2053.72	07/31/89	1030	3270	
124M	NE365827ABDC01	WELL	13.00	2061.40	2053.35	09/29/89	600	2080	
124M	NE365827ABDC01	WELL	13.00	2061.40	2053.35	09/29/89	1030	3490	
124M	NE365827ABDC01	WELL	13.00	2061.40	2053.38	10/12/89	600	2670	7.54
124M	NE365827ABDC01	WELL	13.00	2061.40	2054.50	06/19/90	900	2700	7.56
124M	NE365827ABDC01	WELL	13.00	2061.40	2054.50	06/20/90	1404	4210	7.57
124N	NE365827ABBD02	WELL	20.50	2065.90	2065.90	06/03/89		28500	
124N	NE365827ABBD02	WELL	20.50	2065.90	2056.59	06/28/89	13200	29370	
124N	NE365827ABBD02	WELL	20.50	2065.90	2056.26	07/28/89	14650	30340	
124N	NE365827ABBD02	WELL	20.50	2065.90	2055.82	09/27/89	10630	31860	
124N	NE365827ABBD02	WELL	20.50	2065.90	2055.69	10/12/89	12230	31740	7.19
124N	NE365827ABBD02	WELL	20.50	2065.90	2055.57	06/19/90			
124N	NE365827ABBD02	WELL	20.50	2065.90	2055.57	06/20/90	9870	27880	7.24
124N	NE365827ABBD02	WELL	20.50	2065.90	2055.57	06/20/90	11960	30730	7.22
124O	NE365827ADDD01	WELL	23.00	2054.80	2046.98	06/03/89		18000	
124O	NE365827ADDD01	WELL	23.00	2054.80	2048.70	06/28/89	8250	19580	
124O	NE365827ADDD01	WELL	23.00	2054.80	2048.22	07/28/89	8540	20010	
124O	NE365827ADDD01	WELL	23.00	2054.80	2047.86	09/29/89	8560	20280	
124O	NE365827ADDD01	WELL	23.00	2054.80	2047.81	10/12/89	8870	21160	6.79

Table 7. SUMMARY OF FIELD DATA FROM WELLS AND SURFACE WATER SOURCES (continued)

SITE NUMBER	LOCATION	TYPE OF SITE	TOTAL DEPTH (FT)	LAND SURFACE ELEVATION (FT)	WATER LEVEL ELEVATION (FT)	SAMPLE DATE	CHLORIDE CONCENTRATION (mg/L)	SPECIFIC CONDUCTANCE (umho/cm)	pH
124O	NE365827ADDD01	WELL	23.00	2054.80	2048.06	06/19/90			
124O	NE365827ADDD01	WELL	23.00	2054.80	2048.07	06/26/90	10355	25680	6.90
124O	NE365827ADDD01	WELL	23.00	2054.80	2048.07	06/26/90	11270	25800	6.89
124O	NE365827ADDD01	WELL	23.00	2054.80	2048.07	06/26/90	11270	25940	6.88
124P	NE365827ADAA01	WELL	17.00	2057.60	2047.35	06/03/89		26150	
124P	NE365827ADAA01	WELL	17.00	2057.60	2047.34	06/28/89	10620	27660	
124P	NE365827ADAA01	WELL	17.00	2057.60	2047.02	06/28/89	16000	37610	
124P	NE365827ADAA01	WELL	17.00	2057.60	2046.49	09/29/89	18220	42300	
124P	NE365827ADAA01	WELL	17.00	2057.60	2046.38	10/12/89	16230	41850	7.30
124P	NE365827ADAA01	WELL	17.00	2057.60	2046.88	06/19/90			
124P	NE365827ADAA01	WELL	17.00	2057.60	2046.89	06/26/90	14670	33950	7.35
124P	NE365827ADAA01	WELL	17.00	2057.60	2046.89	06/26/90	14940	36780	7.35
124Q	NE365827ABBA01	NOWELL		2075.90	2075.90				
125A	NE365827BBCA01	WELL	27.00	2105.40	2105.40				
125A	NE365827BBCA01	WELL	27.00	2105.40	2091.10	12/12/88	100	1230	7.50
125A	NE365827BBCA01	WELL	27.00	2105.40	2094.70	03/10/89	90	1350	8.25
125A	NE365827BBCA01	WELL	27.00	2105.40	2092.30	04/20/89	<50	1200	7.03
125A	NE365827BBCA01	WELL	27.00	2105.40	2092.43	05/16/89	60	1190	
125A	NE365827BBCA01	WELL	27.00	2105.40	2092.52	06/28/89	<44	780	
125A	NE365827BBCA01	WELL	27.00	2105.40	2092.42	07/26/89	44	930	
125A	NE365827BBCA01	WELL	27.00	2105.40	2092.20	10/03/89	265	1040	
125A	NE365827BBCA01	WELL	27.00	2105.40	2091.04	06/19/90			
125A	NE365827BBCA01	WELL	27.00	2105.40	2091.21	06/19/90	56	1260	7.28
125B	NE365827BBDC01	WELL	33.00	2106.80	2106.80				
125B	NE365827BBDC01	WELL	33.00	2106.80	2090.70	12/12/88	<50	840	7.50
125B	NE365827BBDC01	WELL	33.00	2106.80	2090.37	03/10/89	<50	890	8.37
125B	NE365827BBDC01	WELL	33.00	2106.80	2091.84	04/20/89	50	1200	7.02
125B	NE365827BBDC01	WELL	33.00	2106.80	2092.14	05/16/89	<44	1100	
125B	NE365827BBDC01	WELL	33.00	2106.80	2092.11	06/28/89	<44	860	
125B	NE365827BBDC01	WELL	33.00	2106.80	2092.02	07/26/89	165	1270	
125B	NE365827BBDC01	WELL	33.00	2106.80	2091.72	10/03/89	135	1040	
125B	NE365827BBDC01	WELL	33.00	2106.80	2090.57	06/19/90			
125B	NE365827BBDC02	WELL	33.00	2106.80	2090.47	06/26/90	<44	1255	7.10
125C	NE365827BBX 01	WELL	9.30	2100.60	2091.30	09/08/88	235	2370	
125C	NE365827BBX 01	WELL	9.30	2100.60	2091.85	03/21/89	255	1360	8.18
125D	NE365827BBCA02	WELL	21.70	2106.80	2091.50	09/08/88	225	1270	
125D	NE365827BBCA02	WELL	21.70	2106.80	2091.32	03/21/89	200	1480	7.56
125E	NE365827BBCD01	WELL	23.10	2104.90	2091.70	09/08/88	<50	590	
125E	NE365827BBCD01	WELL	23.10	2104.90	2091.01	03/21/89	<50	570	8.35
125F	NE365827BCAB01	SLOUGH		2086.00	2086.00	04/20/89	430	1800	7.20
126A	NE365827BAAB01	WELL	17.00	2089.60	2089.60				
126A	NE365827BAAB01	WELL	17.00	2089.60	2080.30	12/13/88	3430	10510	7.40
126A	NE365827BAAB01	WELL	17.00	2089.60	2080.22	03/10/89	1310	4660	8.29
126A	NE365827BAAB01	WELL	17.00	2089.60	2080.57	04/20/89	1145	6360	7.25
126A	NE365827BAAB01	WELL	17.00	2089.60	2080.70	05/16/89	4060	8800	
126A	NE365827BAAB01	WELL	17.00	2089.60	2080.65	06/29/89	4060	11590	
126A	NE365827BAAB01	WELL	17.00	2089.60	2080.62	07/31/89	3720	12380	
126A	NE365827BAAB01	WELL	17.00	2089.60	2080.49	09/26/89	2750	9270	
126A	NE365827BAAB01	WELL	17.00	2089.60	2080.46	10/12/89	3430	10160	7.31
126A	NE365827BAAB01	WELL	17.00	2089.60	2080.16	06/19/90			
126A	NE365827BAAB01	WELL	17.00	2089.60	2080.16	06/20/90	1404	4460	7.35
126A	NE365827BAAB01	WELL	17.00	2089.60	2080.16	06/20/90	1704	5060	7.53
126B	NE365827BAAA02	WELL	23.00	2087.80	2087.80				

Table 7. SUMMARY OF FIELD DATA FROM WELLS AND SURFACE WATER SOURCES (continued)

SITE NUMBER	LOCATION	TYPE OF SITE	TOTAL DEPTH (FT)	LAND SURFACE ELEVATION (FT)	WATER LEVEL ELEVATION (FT)	SAMPLE DATE	CHLORIDE CONCENTRATION (mg/L)	SPECIFIC CONDUCTANCE (umho/cm)	pH
126B	NE365827BAAA02	WELL	23.00	2087.80	2073.70	12/13/88	24630	53800	6.80
126B	NE365827BAAA02	WELL	23.00	2087.80	2073.52	03/10/89	24300	48200	7.39
126B	NE365827BAAA02	WELL	23.00	2087.80	2073.68	04/20/89	29480	47840	6.86
126B	NE365827BAAA02	WELL	23.00	2087.80	2074.02	05/16/89	40610	60490	
126B	NE365827BAAA02	WELL	23.00	2087.80	2074.10	06/29/89	30370	60830	
126B	NE365827BAAA02	WELL	23.00	2087.80	2074.13	07/31/89	33800	59970	
126B	NE365827BAAA02	WELL	23.00	2087.80	2074.10	09/27/89	30580	60700	
126B	NE365827BAAA02	WELL	23.00	2087.80	2073.95	10/12/89	30580	59970	6.98
126B	NE365827BAAA02	WELL	23.00	2087.80	2073.59	06/19/90	28440	57900	6.99
126B	NE365827BAAA02	WELL	23.00	2087.80	2073.59	06/20/90	25466	58909	7.05
126B	NE365827BAAA02	WELL	23.00	2087.80	2073.59	06/20/90	26210	59529	7.13
126C	NE365827BAAC01	WELL	18.00	2089.30	2080.99	06/04/89	0	920	
126C	NE365827BAAC01	WELL	18.00	2089.30	2080.99	06/29/89	110	1290	
126C	NE365827BAAC01	WELL	18.00	2089.30	2081.00	07/31/89	<44	1050	
126C	NE365827BAAC01	WELL	18.00	2089.30	2080.89	09/26/89	48	1000	
126C	NE365827BAAC01	WELL	18.00	2089.30	2080.87	10/12/89	<44	1020	7.35
126C	NE365827BAAC01	WELL	18.00	2089.30	2080.50	06/19/90			
126C	NE365827BAAC01	WELL	18.00	2089.30	2080.50	06/20/90	<44	1052	7.18
139A	NE365833BBDA01	WELL	27.00	2120.50	2120.50		0		
139A	NE365833BBDA01	WELL	27.00	2120.50	2111.30	11/23/88	36510	74760	7.00
139A	NE365833BBDA01	WELL	27.00	2120.50	2109.56	03/10/89	38320	55500	7.23
139A	NE365833BBDA01	WELL	27.00	2120.50	2109.29	04/20/89	39160	53920	6.55
139A	NE365833BBDA01	WELL	27.00	2120.50	2109.99	05/16/89	38900	89250	
139A	NE365833BBDA01	WELL	27.00	2120.50	2110.27	07/26/89	45440	72420	
139A	NE365833BBDA01	WELL	27.00	2120.50	2106.88	06/21/90			
139A	NE365833BBDA01	WELL	27.00	2120.50	2108.03	06/27/90	34080	60200	6.93
139A	NE365833BBDA01	WELL	27.00	2120.50	2108.03	06/27/90	34080	61100	6.87
151A	NE375705DDCB01	WELL	13.00	2260.00	2260.00		0		
151A	NE375705DDCB01	WELL	13.00	2260.00	2253.50	12/16/88	16700	97600	6.60
151A	NE375705DDCB01	WELL	13.00	2260.00	2255.00	03/22/89	56840	62200	6.57
151A	NE375705DDCB01	WELL	13.00	2260.00	2257.88	04/21/89	43090	58200	6.66
151A	NE375705DDCB01	WELL	13.00	2260.00	2257.75	05/17/89	55010	122440	
151A	NE375705DDCB01	WELL	13.00	2260.00	2255.58	07/31/89	71000	134100	
151A	NE375705DDCB01	WELL	13.00	2260.00	2256.26	06/21/90			
151A	NE375705DDCB01	WELL	13.00	2260.00	2256.95	06/27/90	49260	80000	6.79
151B	NE375705DCDA01	WELL	18.00	2258.10	2258.10		0		
151B	NE375705DCDA01	WELL	18.00	2258.10	2253.00	12/16/88	10100	81500	6.60
151B	NE375705DCDA01	WELL	18.00	2258.10	2252.45	03/22/89	52700	57600	6.43
151B	NE375705DCDA01	WELL	18.00	2258.10	2254.20	04/22/89	46360	59700	6.40
151B	NE375705DCDA01	WELL	18.00	2258.10	2254.06	05/17/89	56920	114190	
151B	NE375705DCDA01	WELL	18.00	2258.10	2254.15	07/31/89	67600	111800	
151B	NE375705DCDA01	WELL	18.00	2258.10	2251.66	06/25/90			
151B	NE375705DCDA01	WELL	18.00	2258.10	2254.94	06/27/90	49260	83300	6.83
151C	NE375708BAAA01	WELL	198.00	2235.00	2190.00	07/25/86	25	3100	7.99
151D	NE375708DDCB02	SLOUGH		2260.00	2260.00	04/21/89	50	500	8.45
167A	NE375712BABB01	WELL	38.00	2234.60	2234.60		0		
167A	NE375712BABB01	WELL	8.70	2234.60	2234.60	12/16/88	0		
167A	NE375712BABB01	WELL	8.70	2234.60	2229.65	03/11/89	360	1410	8.52
167A	NE375712BABB01	WELL	8.70	2234.60	2228.38	03/22/89	430	1280	7.86
167A	NE375712BABB01	WELL	8.70	2234.60	2228.60	04/22/89	230	1880	
167A	NE375712BABB01	WELL	8.70	2234.60	2234.60	06/27/90	115	1650	7.90
167B	NE375712BBAA01	WELL	13.00	2223.90	2223.90		0		
167B	NE375712BBAA01	WELL	13.00	2223.90	2214.90	12/16/88	11210	27030	7.10

Table 7. SUMMARY OF FIELD DATA FROM WELLS AND SURFACE WATER SOURCES (continued)

SITE NUMBER	LOCATION	TYPE OF SITE	TOTAL DEPTH (FT)	LAND SURFACE ELEVATION (FT)	WATER LEVEL ELEVATION (FT)	SAMPLE DATE	CHLORIDE CONCENTRATION (mg/L)	SPECIFIC CONDUCTANCE (umho/cm)	pH
167B	NE375712BBAA01	WELL	13.00	2223.90	2218.32	03/22/89	2680	6210	7.16
167B	NE375712BBAA01	WELL	13.00	2223.90	2221.06	04/22/89	315	1570	6.95
167B	NE375712BBAA01	WELL	13.00	2223.90	2220.11	05/17/89	135	910	
167B	NE375712BBAA01	WELL	13.00	2223.90	2218.71	06/29/89	135	850	
167B	NE375712BBAA01	WELL	13.00	2223.90	2217.62	07/31/89	70	660	
167B	NE375712BBAA01	WELL	13.00	2223.90	2216.40	06/21/90			
167B	NE375712BBAA01	WELL	13.00	2223.90	2216.37	06/27/90	48	675	7.50
167C	NE375712BBAA02	WELL	21.00	2227.00	2227.00	01/19/76	1125	43130	7.70
167C	NE375712BBAA02	WELL	21.00	2227.00	2227.00	03/22/89	50	620	8.21
167C	NE375712BBAA02	WELL	21.00	2227.00	2227.00	05/11/89	1700	5190	
167C	NE375712BBAA02	WELL	21.00	2227.00	2227.00	06/01/89	2270	6850	
167C	NE375712BBAA02	WELL	21.00	2227.00	2227.00	07/05/89	1700	4850	
167D	NE375701CX 01	WELL	15.00	2226.30	2226.30	03/11/89	110	770	8.24
167E	NE375806CCCB01	SLOUGH		2196.00	2196.00	05/12/89	44	1050	
167F	NE375806CBCC01	WELL	17.00	2199.70	2188.65	06/20/89			
167F	NE375806CBCC01	WELL	17.00	2199.70	2188.58	06/29/89	155	1040	
167F	NE375806CBCC01	WELL	17.00	2199.70	2188.21	07/31/89	115	940	
167F	NE375806CBCC01	WELL	17.00	2199.70	2187.84	06/21/90			
167F	NE375806CBCC01	WELL	17.00	2199.70	2187.82	06/27/90	135	1043	7.73
167G	NE375712CBCC01	NOWELL		2229.10	2229.10				
167H	NE375712BBDB01	WELL	8.00	2223.30	2218.71	06/01/89	<50	420	
167H	NE375712BBDB01	WELL	8.00	2223.30	2218.54	06/29/89	<44	450	
167H	NE375712BBDB01	WELL	8.00	2223.30	2217.67	07/31/89	<44	460	
167H	NE375712BBDB01	WELL	8.00	2223.30	2216.74	06/21/90			
167H	NE375712BBDB01	WELL	8.00	2223.30	2216.18	06/27/90	<44	539	7.82
167I	NE375712BACB01	NOWELL		2222.80	2222.80	06/01/89	<50	650	
167J	NE375712BBDA01	NOWELL		2226.90	2226.90				
167K	NE375712BBAD01	WELL	12.00	2223.50	2218.79	06/01/89	1310	5310	
167K	NE375712BBAD01	WELL	12.00	2223.50	2218.52	06/29/89	1600	4500	
167K	NE375712BBAD01	WELL	12.00	2223.50	2217.42	07/31/89	1125	3460	
167K	NE375712BBAD01	WELL	12.00	2223.50	2216.34	06/21/90			
167K	NE375712BBAD01	WELL	12.00	2223.50	2216.32	06/27/90	570	2720	7.63
167L	NE375712BBAA03	WELL	13.00	2227.30	2218.81	06/01/89	505	2300	
167L	NE375712BBAA03	WELL	13.00	2227.30	2218.55	06/29/89	515	1860	
167L	NE375712BBAA03	WELL	13.00	2227.30	2217.46	07/31/89	400	1650	
167L	NE375712BBAA03	WELL	13.00	2227.30	2216.23	06/21/90			
167L	NE375712BBAA03	WELL	13.00	2227.30	2216.04	06/27/90	338	1590	7.40
167M	NE375712BBAC01	WELL	13.00	2223.90	2218.82	06/01/89	275	1180	
167M	NE375712BBAC01	WELL	13.00	2223.90	2218.56	06/29/89	265	1220	
167M	NE375712BBAC01	WELL	13.00	2223.90	2217.47	07/31/89	265	1170	
167M	NE375712BBAC01	WELL	13.00	2223.90	2216.46	06/21/90			
167M	NE375712BBAC01	WELL	13.00	2223.90	2216.52	06/27/90	460	1950	7.68
222A	NE375806CAAC01	WELL	43.00	2188.20	2188.20				
222A	NE375806CAAC01	WELL	43.00	2188.20	2172.00	12/16/88	275	6090	7.10
222A	NE375806CAAC01	WELL	43.00	2188.20	2178.45	03/11/89	315	6050	7.27
222A	NE375806CAAC01	WELL	43.00	2188.20	2176.83	04/21/89	170	6450	6.84
222A	NE375806CAAC01	WELL	43.00	2188.20	2177.07	05/17/89	580	9270	
222A	NE375806CAAC01	WELL	43.00	2188.20	2177.68	07/31/89	1125	11000	
222A	NE375806CAAC01	WELL	43.00	2188.20	2177.19	06/21/90			
222A	NE375806CAAC01	WELL	43.00	2188.20	2170.79	06/27/90	195	5940	7.02
222A	NE375806CAAC01	WELL	43.00	2188.20	2170.79	06/27/90	400	7800	7.18
222A	NE375806CAAC01	WELL	43.00	2188.20	2170.79	06/27/90	440	8130	7.16
222B	NE375806CADA01	WELL	48.00	2183.60	2183.60				

Table 7. SUMMARY OF FIELD DATA FROM WELLS AND SURFACE WATER SOURCES (continued)

SITE NUMBER	LOCATION	TYPE OF SITE	TOTAL DEPTH (FT)	LAND SURFACE ELEVATION (FT)	WATER LEVEL ELEVATION (FT)	SAMPLE DATE	CHLORIDE CONCENTRATION (mg/L)	SPECIFIC CONDUCTANCE (umho/cm)	pH
222B	NE375806CADA01	WELL	48.00	2183.60	2158.20	12/16/88	50	3110	7.70
222B	NE375806CADA01	WELL	48.00	2183.60	2171.89	03/11/89	<50	2860	7.43
222B	NE375806CADA01	WELL	48.00	2183.60	2176.02	04/21/89	450	5750	7.16
222B	NE375806CADA01	WELL	48.00	2183.60	2174.96	05/17/89	1170	6110	
222B	NE375806CADA01	WELL	48.00	2183.60	2175.39	07/31/89	980	5940	
222B	NE375806CADA01	WELL	48.00	2183.60	2177.05	06/21/90			
222B	NE375806CACA01	WELL	48.00	2183.60	2154.32	06/27/90	500	4830	7.28
222C	NE375806DBCC01	WELL	14.00	2182.50	2171.50	08/18/88	>600		
222C	NE375806DBCC01	WELL	14.00	2182.50	2172.50	04/14/89	80	1710	
222D	NE375806DBCX01	WELL	82.00	2193.80	2182.80	10/20/88	6.5	2800	
222D	NE375806DBCX01	WELL	82.00	2193.80	2193.80	03/22/89	<50	2530	6.71
222E	NE375806DBCC01	WELL	85.00	2188.20	2188.20				
222F	NE375806CADA02	SLOUGH		2178.00	2178.00	04/21/89	<44	410	7.24
222F	NE375806CADA02	SLOUGH		2178.00	2178.00	05/12/89	<44	530	
222G	NE375806DCCC01	SLOUGH		2175.00	2175.00	05/12/89	<44	870	
222H	NE375806DCBD01	SLOUGH		2175.00	2175.00	05/12/89	550	6280	
222I	NE375806DDAA01	SLOUGH		2175.00	2175.00	05/12/89	1270	16340	
251A	NE345802DCDA01	WELL	15.00	2045.00	2036.58	04/18/89	<50	1350	
251B	NE345802DCDD01	LAKE		2039.00	2039.00	04/18/89	255	13000	
252A	NE345814BDAC01	WELL	32.00	2059.10	2034.00	11/03/88	275	1670	
252A	NE345814BDAC01	WELL	32.00	2059.10	2034.00	11/22/88	460	2220	7.10
252A	NE345814BDAC01	WELL	32.00	2059.10	2034.45	03/20/89	830	3160	6.63
252A	NE345814BDAC01	WELL	32.00	2059.10	2034.66	04/18/89	830	3500	6.70
252A	NE345814BDAC01	WELL	32.00	2059.10	2035.24	05/15/89	830	3510	
252A	NE345814BDAC01	WELL	32.00	2059.10	2031.74	07/25/89	400	2230	
252A	NE345814BDAC01	WELL	32.00	2059.10	2032.49	06/21/90			
252A	NE345814BDAC01	WELL	32.00	2059.10	2032.22	06/28/90	473	2690	7.30
252B	NE345814BDBD01	WELL	32.00	2060.80	2034.10	11/03/88	<50	1690	
252B	NE345814BDBD01	WELL	32.00	2060.80	2034.10	11/22/88	<50	1690	7.60
252B	NE345814BDBD01	WELL	32.00	2060.80	2034.55	03/10/89	<50	1520	
252B	NE345814BDBD01	WELL	32.00	2060.80	2034.74	04/18/89	<50	1380	7.10
252B	NE345814BDBD01	WELL	32.00	2060.80	2034.43	05/15/89	<44	1410	
252B	NE345814BDBD01	WELL	32.00	2060.80	2032.03	07/25/89	<44	1410	
252B	NE345814BDBD01	WELL	32.00	2060.80	2032.65	06/21/90			
252B	NE345814BDBD01	WELL	32.00	2060.80	2032.41	06/28/90	147	2250	7.24
252C	NE345814BDDD01	WELL	150.00	2056.45	2032.11	03/20/89			
252C	NE345814BDDD01	WELL	150.00	2056.45	2032.42	04/18/89			
252C	NE345814BDDD01	WELL	150.00	2056.45	2056.45	07/25/89	<44	1150	
253A	NE345814DBBD01	WELL	31.00	2057.70	2033.80	11/02/88	<50	390	
253A	NE345814DBBD01	WELL	31.00	2057.70	2034.00	11/22/88	<50	400	8.00
253A	NE345814DBBD01	WELL	31.00	2057.70	2034.55	03/10/89	<50	360	6.99
253A	NE345814DBBD01	WELL	31.00	2057.70	2034.74	04/18/89	<50	380	7.26
253A	NE345814DBBD01	WELL	31.00	2057.70	2034.34	05/15/89	<44	370	
253A	NE345814DBBD01	WELL	31.00	2057.70	2031.29	07/25/89	<44	440	
253A	NE345814DBBD01	WELL	31.00	2057.70	2032.04	06/28/90	48	525	7.82
253B	NE345814DBBD02	WELL	30.00	2059.30	2033.80	11/02/88	1360	4370	
253B	NE345814DBBD02	WELL	30.00	2059.30	2033.90	11/22/88	3430	10090	7.30
253B	NE345814DBBD02	WELL	30.00	2059.30	2034.40	03/10/89	3810	9220	7.29
253B	NE345814DBBD02	WELL	30.00	2059.30	2034.60	04/18/89	2560	9000	7.00
253B	NE345814DBBD02	WELL	30.00	2059.30	2034.24	05/15/89	3550	9840	
253B	NE345814DBBD02	WELL	30.00	2059.30	2031.27	07/25/89	33800	58900	
253B	NE345814DBBD02	WELL	30.00	2059.30	2032.31	06/21/90			
253B	NE345814DBBD02	WELL	30.00	2059.30	2031.99	06/28/90	4609	14790	7.08

Table 7. SUMMARY OF FIELD DATA FROM WELLS AND SURFACE WATER SOURCES (continued)

SITE NUMBER	LOCATION	TYPE OF SITE	TOTAL DEPTH (FT)	LAND SURFACE ELEVATION (FT)	WATER LEVEL ELEVATION (FT)	SAMPLE DATE	CHLORIDE CONCENTRATION (mg/L)	SPECIFIC CONDUCTANCE (umho/cm)	pH
253C	NE345814DBCA01	WELL	32.00	2059.90	2033.70	11/02/88	<50	510	
253C	NE345814DBCA01	WELL	32.00	2059.90	2033.90	11/22/88	<50	580	7.90
253C	NE345814DBCA01	WELL	32.00	2059.90	2034.44	03/10/89	<50	740	7.70
253C	NE345814DBCA01	WELL	32.00	2059.90	2034.62	04/18/89	<50	520	6.70
253C	NE345814DBCA01	WELL	32.00	2059.90	2034.35	05/15/89	<44	520	
253C	NE345814DBAC01	WELL	32.00	2059.90	2031.25	07/25/89	44	660	
253C	NE345814DBAC01	WELL	32.00	2059.90	2032.34	06/21/90			
253C	NE345814DBAC01	WELL	32.00	2059.90	2032.00	06/28/90	<44	550	7.37
258A	NE355809CDCD01	WELL	32.00	2122.30	2115.60				
258A	NE355809CDCD01	WELL	32.00	2122.30	2115.60	11/23/88	73890	241700	6.70
258A	NE355809CDCD01	WELL	32.00	2122.30	2114.75	03/10/89	70280	87600	6.73
258A	NE355809CDCD01	WELL	32.00	2122.30	2115.82	04/19/89	79820	120670	6.50
258A	NE355809CDCD01	WELL	32.00	2122.30	2116.58	05/15/89	145620	202710	
258A	NE355809CDCD01	WELL	32.00	2122.30	2114.82	07/26/89	107880	193500	
258A	NE355809CDCD01	WELL	32.00	2122.30	2113.28	06/21/90			
258A	NE355809CDCD01	WELL	32.00	2122.30	2113.37	06/27/90	61160	102500	6.61
258B	NE355809CDCA01	WELL	28.00	2114.00	2107.80				
258B	NE355809CDCA01	WELL	28.00	2114.00	2107.80	11/23/88	85590	261850	6.80
258B	NE355809CDCA01	WELL	28.00	2114.00	2106.65	03/10/89	79820	89700	6.93
258B	NE355809CDCA01	WELL	28.00	2114.00	2107.27	04/19/89	89570	125190	6.50
258B	NE355809CDCA01	WELL	28.00	2114.00	2107.98	05/15/89	97080	192950	
258B	NE355809CDCA01	WELL	28.00	2114.00	2107.81	07/26/89	92600	186700	
258B	NE355809CDCA01	WELL	28.00	2114.00	2106.63	06/21/90			
258B	NE355809CDCA01	WELL	28.00	2114.00	2106.78	06/27/90	90000	180000	6.70
258C	NE355809ADCB01	WELL	60.00	2112.00	2082.00	10/18/88	60	2190	
258C	NE355809ADCB01	WELL	60.00	2112.00	2082.00	03/21/89	75	1810	6.97
258D	NE355809BABD01	WELL	86.00	2131.00	2100.70	04/19/89	130	1440	6.02
258E	NE355809CDCD02	SLOUGH		2122.00	2122.00	04/19/89	120	630	8.85
258F	NE355816BABA02	LEAK		2132.00	2132.00	04/19/89	190000	100000	6.10
258G	NE355809CDBC01	SLOUGH		2112.00	2112.00	04/19/89	140	610	8.80
262A	NE365832DDAB01	WELL	33.00	2176.60	2150.80				
262A	NE365832DDAB01	WELL	33.00	2176.60	2150.80	11/23/88	39360	125550	6.60
262A	NE365832DDAB01	WELL	33.00	2176.60	2153.00	03/10/89	19580	39800	7.17
262A	NE365832DDAB01	WELL	33.00	2176.60	2152.86	04/20/89	55360	66340	6.43
262A	NE365832DDAB01	WELL	33.00	2176.60	2153.05	05/16/89	60740	101930	
262A	NE365832DDAB01	WELL	33.00	2176.60	2153.35	07/26/89	43530	84800	
262A	NE365832DDAB01	WELL	33.00	2176.60	2152.48	06/21/90			
262A	NE365832DDAB01	WELL	33.00	2176.60	2152.47	06/27/90	36420	67000	6.82
262B	NE365832DDDB01	NOWELL	43.00	2157.70	2157.70				
262C	NE365832DDAB02	DAM		2195.00	2195.00	07/20/88	2500	8020	
262C	NE365832DDAB02	DAM		2195.00	2195.00	04/19/89	430	1130	8.64
262C	NE365832DDAB02	DAM		2195.00	2195.00	06/27/90	835	2800	1.13
262D	NE365833CCDC01	WELL	50.00	2117.50	2081.50	08/10/88	<50	1250	
262D	NE365833CCDC01	WELL	50.00	2117.50	2080.46	03/21/89	50	1030	7.33
262E	NE365833CCCC01	WELL	68.50	2158.00	2158.00	07/01/73	12770	33100	7.44
262E	NE365833CCCC01	WELL	68.50	2158.00	2095.20	04/19/89	345	1370	6.52
264A	NE365828AADA02	WELL	23.00	2116.20	2116.20				
264A	NE365828AADA02	WELL	23.00	2116.20	2100.40	12/12/88	72400	106800	6.30
264A	NE365828AADA02	WELL	23.00	2116.20	2099.90	03/10/89	67100	94600	6.91
264A	NE365828AADA02	WELL	23.00	2116.20	2100.36	04/20/89	87320	95520	6.69
264A	NE365828AADA02	WELL	23.00	2116.20	2100.95	05/16/89	88060	167800	
264A	NE365828AADA02	WELL	23.00	2116.20	2100.81	06/28/89	91000	183000	
264A	NE365828AADA02	WELL	23.00	2116.20	2100.77	07/26/89	92570	186700	

Table 7. SUMMARY OF FIELD DATA FROM WELLS AND SURFACE WATER SOURCES (continued)

SITE NUMBER	LOCATION	TYPE OF SITE	TOTAL DEPTH (FT)	LAND SURFACE ELEVATION (FT)	WATER LEVEL ELEVATION (FT)	SAMPLE DATE	CHLORIDE CONCENTRATION (mg/L)	SPECIFIC CONDUCTANCE (umho/cm)	pH
264A	NE365828AADA02	WELL	23.00	2116.20	2100.49	09/29/89	61160	178600	
264A	NE365828AADA02	WELL	23.00	2116.20	2100.35	10/13/89	79890	180500	6.70
264A	NE365828AADA02	WELL	23.00	2116.20	2099.72	06/19/90			
264A	NE365828AADA02	WELL	23.00	2116.20	2099.65	06/26/90	54600	106600	6.75
264B	NE365828AADD01	WELL	8.00	2102.30	2102.30				
264B	NE365828AADD01	WELL	8.00	2102.30	2099.90	12/12/88	50200	81400	6.70
264B	NE365828AADD01	WELL	8.00	2102.30	2101.98	03/21/89	46360	51500	6.82
264B	NE365828AADD01	WELL	8.00	2102.30	2101.27	04/20/89	42760	66390	6.79
264B	NE365828AADD01	WELL	8.00	2102.30	2101.36	05/16/89	41620	87920	
264B	NE365828AADD01	WELL	8.00	2102.30	2100.85	06/28/89	49280	100600	
264B	NE365828AADD01	WELL	8.00	2102.30	2099.89	07/26/89	53100	104400	
264B	NE365828AADD01	WELL	8.00	2102.30	2099.38	09/29/89	57060	117450	
264B	NE365828AADD01	WELL	8.00	2102.30	2099.45	10/13/89	53160	120700	6.81
264B	NE365828AADD01	WELL	8.00	2102.30	2102.30	06/19/90			
264B	NE365828AADD01	WELL	8.00	2102.30	2100.20	06/26/90	48740	83300	6.71
264C	NE365828AADD02	NOWELL	18.00	2106.00	2106.00				
264D	NE365827BCBC01	WELL	13.00	2094.60	2094.60				
264D	NE365827BCBC01	WELL	13.00	2094.60	2090.60	12/13/88	21760	52360	6.50
264D	NE365827BCBC01	WELL	13.00	2094.60	2094.19	03/21/89	25000	32700	6.74
264D	NE365827BCBC01	WELL	13.00	2094.60	2093.52	04/20/89	17640	41000	6.92
264D	NE365827BCBC01	WELL	13.00	2094.60	2093.04	05/16/89	24640	45630	
264D	NE365827BCBC01	WELL	13.00	2094.60	2093.53	06/28/89	22700	41570	
264D	NE365827BCBC01	WELL	13.00	2094.60	2090.55	07/28/89	18770	44590	
264D	NE365827BCBC01	WELL	13.00	2094.60	2089.55	10/03/89	22670	52300	
264D	NE365827BCBC01	WELL	13.00	2094.60	2089.78	10/13/89	24630	55220	6.65
264D	NE365827BCBC01	WELL	13.00	2094.60	2092.55	06/19/90			
264D	NE365827BCBC01	WELL	13.00	2094.60	2091.84	06/27/90	18150	39660	6.85
264E	NE365828ADAA01	SLOUGH		2104.80	2104.80	07/21/88	>6000	50000	
264E	NE365828ADAA01	SLOUGH		2104.80	2104.80	10/18/88	30120	79180	
264E	NE365828ADAA01	SLOUGH		2104.80	2104.80	04/20/89	15000	22880	8.69
264F	NE365828AACA01	DUGOUT		2106.70	2106.70				
264F	NE365828AACA01	DUGOUT		2106.70	2106.70	04/20/89	80	450	8.20
264F	NE365828AACA01	DUGOUT		2106.70	2106.70	10/13/89	1510	5050	8.38
264G	NE365827BCCD01	SLOUGH		2078.00	2078.00	04/20/89	115	1600	7.16
264G	NE365827DBBA01	SLOUGH		2078.00	2078.00	05/01/89	335	1370	
264H	NE365828AAAA01	SLOUGH		2116.00	2116.00	05/01/89	<44	290	
264I	NE365828ABDD01	WELL	16.00	2117.50	2108.50	05/01/89	80	1700	
264J	NE365827CBAA01	SLOUGH		2078.00	2078.00	05/01/89	350	1740	
264K	NE365827CBDC01	SLOUGH		2077.00	2077.00	05/01/89	2190	6800	
264L	NE365827CBDD01	SLOUGH		2076.00	2076.00	05/01/89	800	3100	
264M	NE365827CBDD02	DUGOUT		2074.00	2074.00	05/01/89	140	890	
264M	NE365827CBDD02	DUGOUT		2074.00	2074.00	10/13/89	2560	7270	9.23
264M	NE365827CBDD02	DUGOUT		2074.00	2074.00	06/26/90	5946	8190	8.72
264N	NE365828ACAA01	DUGOUT		2114.00	2114.00	05/02/89	<44	320	
264O	NE365828ADBD01	SLOUGH		2123.00	2123.00	05/02/89	<44	210	
264P	NE365827DBDB01	SLOUGH		2066.00	2066.00	05/02/89	80	840	
264Q	NE365827BCBD01	WELL	23.00	2087.60	2081.76	06/09/89			
264Q	NE365827BCBD01	WELL	23.00	2087.60	2081.40	06/28/89	11380	27130	
264Q	NE365827BCBD01	WELL	23.00	2087.60	2079.82	07/28/89	10240	28970	
264Q	NE365827BCBD01	WELL	23.00	2087.60	2078.19	10/03/89	11410	29000	
264Q	NE365827BCBD01	WELL	23.00	2087.60	2078.19	10/13/89	10630	28690	7.13
264Q	NE365827BCBD01	WELL	23.00	2087.60	2080.32	06/19/90			
264Q	NE365827BCBD01	WELL	23.00	2087.60	2080.12	06/26/90	11330	26300	7.25

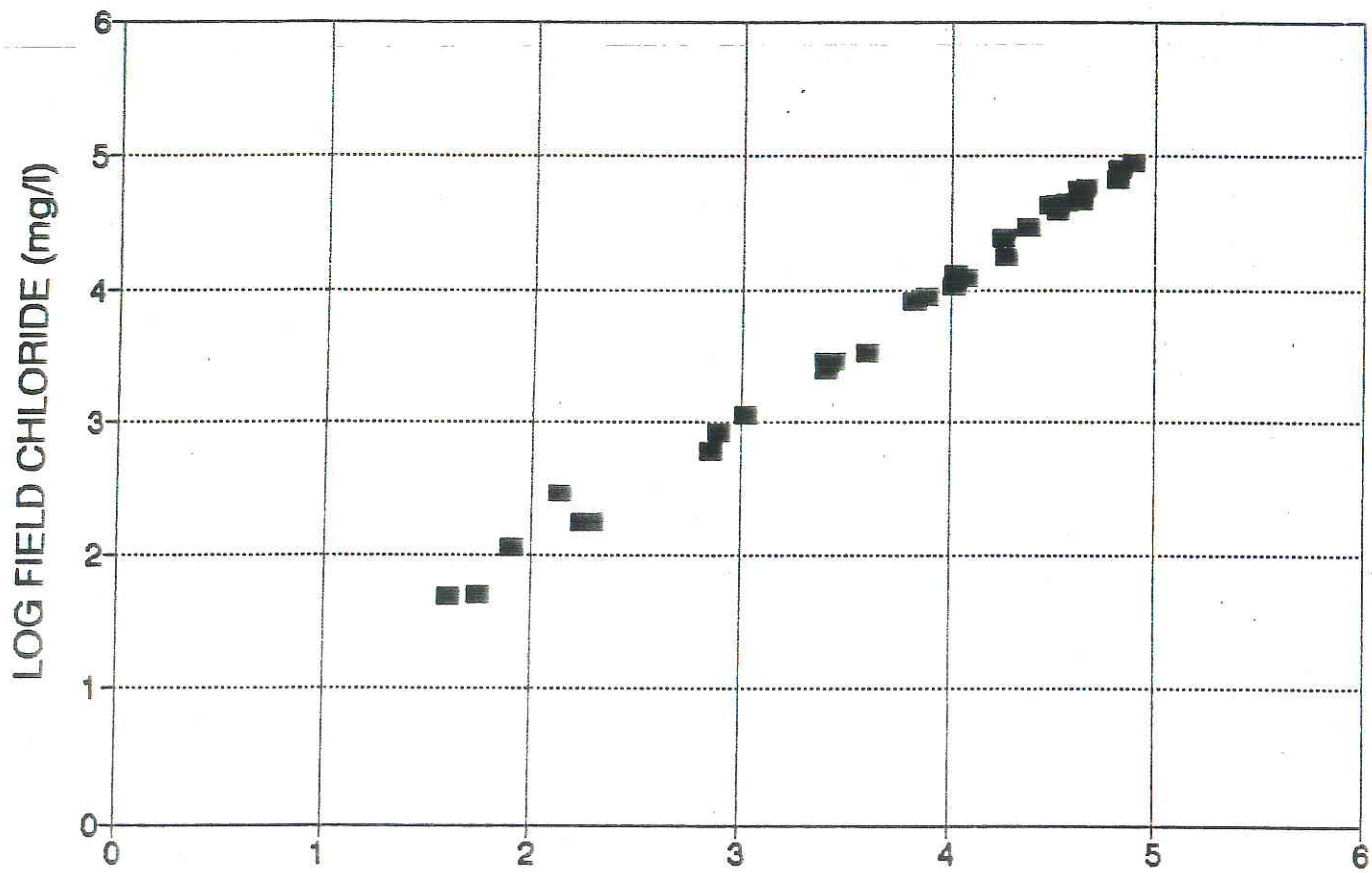
Table 7. SUMMARY OF FIELD DATA FROM WELLS AND SURFACE WATER SOURCES (continued)

SITE NUMBER	LOCATION	TYPE OF SITE	TOTAL DEPTH (FT)	LAND SURFACE ELEVATION (FT)	WATER LEVEL ELEVATION (FT)	SAMPLE DATE	CHLORIDE CONCENTRATION (mg/L)	SPECIFIC CONDUCTANCE (umho/cm)	pH
264R	NE365827DAAD01	WELL	22.00	2062.00	2056.11	06/04/89	275	2100	
264R	NE365827DAAD01	WELL	22.00	2062.00	2055.95	06/28/89	140	1860	
264R	NE365827DAAD01	WELL	22.00	2062.00	2055.72	07/28/89	110	1830	
264R	NE365827DAAD01	WELL	22.00	2062.00	2055.56	09/29/89	140	1860	
264R	NE365827DAAD01	WELL	22.00	2062.00	2055.44	10/13/89	175	1980	7.25
264R	NE365827DAAD01	WELL	22.00	2062.00	2055.11	06/19/90			
264R	NE365827DAAD01	WELL	22.00	2062.00	2055.16	06/26/90	122	1764	7.40
264S	NE365827CX 01	WELL	18.00	2075.40	2072.28	06/04/89	4000	10000	
264S	NE365827CX 01	WELL	18.00	2075.40	2072.84	06/28/89	3040	8630	
264S	NE365827CX 01	WELL	18.00	2075.40	2071.60	07/28/89	3380	8460	
264S	NE365827CX 01	WELL	18.00	2075.40	2070.97	10/03/89	2850	8470	
264S	NE365827CX 01	WELL	18.00	2075.40	2070.90	10/13/89	2940	8640	7.00
264S	NE365827CX 01	WELL	18.00	2075.40	2072.04	06/19/90			
264S	NE365827CX 01	WELL	18.00	2075.40	2071.72	06/26/90	4182	10930	7.15
264T	NE365827DBCC01	WELL	23.00	2074.00	2071.75	06/04/89	50	1800	
264T	NE365827DBCC01	WELL	23.00	2074.00	2071.44	06/28/89	<44	710	
264T	NE365827DBCC01	WELL	23.00	2074.00	2070.56	07/28/89	<44	700	
264T	NE365827DBCC01	WELL	23.00	2074.00	2069.84	10/03/89	<44	710	
264T	NE365827DBCC01	WELL	23.00	2074.00	2069.84	10/13/89	<44	755	7.30
264T	NE365827DBCC01	WELL	23.00	2074.00	2070.42	06/19/90			
264T	NE365827DBCC01	WELL	23.00	2074.00	2070.21	06/26/90	<44	754	7.11
266A	NE355830ABAB01	NOWELL		2195.00	2195.00				
266B	NE355830ABBD01	WELL	150.00	2180.00	2120.00	09/09/88	<50	850	
270A	NE365710DCDC02	LAKE		2245.00	2245.00	05/18/89	85	2390	
286A	NE375711DCAC01	WELL	13.00	2212.40	2212.40				
286A	NE375711DCAC01	WELL	13.00	2212.40	2202.80	12/16/88	410	2100	7.40
286A	NE375711DCAC01	WELL	13.00	2212.40	2203.08	03/11/89	345	1760	7.65
286A	NE375711DCAC01	WELL	13.00	2212.40	2204.45	04/22/89	300	1790	
286A	NE375711DCAC01	WELL	13.00	2212.40	2204.96	05/17/89	350	1910	
286A	NE375711DCAC01	WELL	13.00	2212.40	2203.53	07/31/89	340	2040	
286A	NE375711DCAC01	WELL	13.00	2212.40	2203.78	06/21/90			
286A	NE375711DCAC01	WELL	13.00	2212.40	2203.84	06/27/90	542	2540	7.64
286B	NE375711DCCD01	WELL	30.00	2229.30	2202.30	10/20/88	<50	870	
286C	NE375714ABBA01	SLOUGH		2211.00	2211.00	04/21/89	2230	8810	8.91
286C	NE375714ABBA01	SLOUGH		2211.00	2211.00	05/11/89	5400	18560	
286D	NE375714BAX 01	SLOUGH		2204.00	2204.00	05/10/89	420	2790	
286E	NE375715CABD01	SLOUGH		2175.00	2175.00	05/11/89	<44	920	
286F	NE375715ACCB01	SLOUGH		2175.00	2175.00	05/11/89	<44	940	
286G	NE375714BCCD01	SLOUGH		2212.00	2212.00	05/11/89	<44	430	
286H	NE375711DCDC01	SLOUGH		2211.00	2211.00	05/11/89	170	1990	
286I	NE375715ABBB01	WELL	21.00	2192.00	2174.74	05/18/89	<44	1200	
286J	NE375710CDCA01	WELL	40.00	2192.00	2192.00	05/18/89	50	3670	
288A	NE375612CDBD01	WELL	8.00	2193.50	2188.00	08/12/88	5250	21870	
288B	NE375613ABBC01	WELL	15.00	2181.20	2170.00	05/18/89	340	2750	
288C	NE375613BAAB01	WELL	13.00	2185.20	2176.82	05/18/89	<44	1150	
288D	NE375613ABCB01	SEEP		2170.00	2170.00	05/18/89	33790	72060	
307A	NE365825DBCD01	LAKE		2049.00	2049.00	04/21/89	1300	27630	9.89
307A	NE365825DBCD01	LAKE		2049.00	2049.00	10/13/89	3380	66400	9.25
307A	NE365825DBCD01	LAKE		2049.00	2039.65	06/28/90	3620	63500	9.35
307B	NE365826BBCD01	LAKE		2044.00	2044.00	04/21/89	4480	41680	7.33
307B	NE365826BBCD01	LAKE		2044.00	2035.67	06/28/90	26240	103000	8.33
307C	NE365836BBBB01	SLOUGH		2057.00	2057.00	05/02/89	<44	1070	
307D	NE365825CCBD01	SLOUGH		2047.00	2047.00	05/02/89	3610	17940	

Table 7. SUMMARY OF FIELD DATA FROM WELLS AND SURFACE WATER SOURCES (continued)

SITE NUMBER	LOCATION	TYPE OF SITE	TOTAL DEPTH (FT)	LAND SURFACE ELEVATION (FT)	WATER LEVEL ELEVATION (FT)	SAMPLE DATE	CHLORIDE CONCENTRATION (mg/L)	SPECIFIC CONDUCTANCE (umho/cm)	pH
307E	NE365825DBCB01	SLOUGH		2053.00	2053.00	05/02/89	<<44	330	
307F	NE365825DBBD01	SLOUGH		2048.00	2048.00	05/02/89	2010	37500	
307G	NE365824DDAA01	LAKE		2046.00	2046.00	05/02/89	1070	73700	
307H	16210314CCCC01	SLOUGH		2055.00	2055.00	05/08/89	1040	29200	
307I	16210315DADD01	SLOUGH		2064.00	2064.00	05/08/89	130	3810	
307J	16210322ACBD01	SLOUGH		2056.00	2056.00	05/08/89	390	10130	
307K	16210313CCCC01	SLOUGH		2056.00	2056.00	05/10/89	200	9220	
307L	16210314AADB01	SLOUGH		2056.00	2056.00	05/10/89	570	23100	
307M	NE365826CDCD01	WELL	10.00	2087.00	2087.00	06/13/89	290	1210	
307N	NE365825CCDD01	WELL	40.00	2060.00	2062.00	06/13/89	<44	1870	
307O	NE365834BCBD01	SLOUGH		2067.00	2067.00	07/26/89	28320	136700	

COMPARISON OF QUANTAB FIELD CHLORIDE VALUES WITH LABORATORY CHLORIDE VALUES



REGRESSION OUTPUT:

Constant		0.029342
Std err of Y est		0.080347
R squared		0.993906
X coefficient(s)	1.01	
Std err of coef.	0.01	

Figure 5. Comparison of Quantab field chloride values to laboratory chloride values.

field. Samples were filtered through 0.45 micron filters in the field and acidified in the lab. The results of these water analyses are listed in Table 8 and discussed in the following section.

Discussion

All of the oil-field sites in the hydrogeologic overview are classified as either till sites or outwash sites. This classification is based on interpretations of the dominant near-surface geology. Outwash sites are areas where aquifers have developed in glacial outwash deposits. Till sites are areas where saturated conditions occur in fine-grained deposits of till or lake clay. Another complicating factor in classifying the sites is where water contaminated at an oil-field site has migrated and is manifested by degraded water quality in an aquifer or water body away from the original oil-field site. Two examples of off-site contamination are at sites #117 and #167. In both cases the actual oil-field sites were set in glacial till deposits but subsequent brine discharges have impacted downslope outwash aquifers.

The potential for impacting regional water sources from multiple source, variable volume discharges of brines can be assessed by using a three step process. The first step is to determine the magnitude of contamination in surface- and ground-water sources by collecting and interpreting water quality data. The second step is to determine the extent a contaminant can be traced in surface- or ground water downgradient of the source of contamination. The third step is to determine the number of water

Table 8. WATER QUALITY OF SELECTED WELLS AND LAKES, SHERIDAN COUNTY, MONTANA
(units are milligrams/litre except where indicated)
(negative values are below detection limits)

SITE ID	DATE SAMPLED	LAB NUMBER	CALCIUM	MAGNESIUM	SODIUM	POTASSIUM	IRON	MANGANESE	SILICA SIO2	BICARBONATE	CHLORIDE	SULFATE	NITRATE as N	FLUORIDE	TOTAL PHOSPHATE as P
067B	04/19/89	89Q0485	4120.00	6120.00	3920.0	66.6	-0.002	4.890	13.50	397.0	30200.0	2030.0	1.70	2.0	0.500
079A	04/19/89	89Q0486	7270.00	6250.00	23000.0	219.0	-0.002	0.058	14.20	256.7	65800.0	540.0	14.00	2.0	-0.100
079B	04/19/89	89Q0487	514.00	276.00	496.0	18.2	-0.002	1.170	15.20	697.0	81.0	2700.0	0.35	0.1	-0.100
079C	04/19/89	89Q0488	3230.00	4370.00	20200.0	216.0	-0.002	3.000	13.60	325.0	46400.0	2840.0	6.51	1.0	-0.100
117B	04/21/89	89Q0489	405.00	122.00	157.0	11.4	7.870	0.970	24.30	626.0	10.2	1330.0	0.04	0.3	-0.100
117C	04/21/89	89Q0490	226.00	76.50	119.0	9.5	0.770	0.860	22.50	591.5	17.1	633.0	0.05	0.4	-0.100
117C	10/11/89	89Q1376	200.00	83.60	132.0	11.0	-0.004	0.028	25.10	605.0	13.9	612.0	0.12	0.1	-0.100
117J	10/13/89	89Q1390	469.00	457.00	745.0	52.6	9.465	2.376	31.40	311.0	2560.0	859.0	0.89	0.2	-0.100
124A	04/20/89	89Q0491	988.00	412.00	2640.0	45.1	0.018	3.800	16.40	252.3	6680.0	144.0	2.22	-1.0	0.200
124C	04/21/89	89Q0492	501.00	193.00	6180.0	110.0	0.015	0.008	15.40	304.0	10600.0	234.0	12.00	-1.0	0.100
124G	10/12/89	89Q1383	173.00	74.60	46.2	7.7	-0.004	0.640	25.70	395.0	40.1	430.0	0.08	0.1	-0.100
124H	10/12/89	89Q1384	1900.00	1340.00	18800.0	340.0	-0.004	0.380	20.80	425.0	36500.0	268.0	13.60	0.0	0.200
124J	10/12/89	89Q1377	1190.00	410.00	9420.0	202.0	1.279	5.710	20.00	325.0	18000.0	268.0	27.43	0.0	0.260
124L	10/12/89	89Q1379	180.00	62.54	1590.0	54.5	-0.004	0.421	23.80	353.0	2650.0	183.0	9.70	0.9	0.100
124M	10/12/89	89Q1380	92.92	40.66	447.0	19.5	-0.004	0.013	26.80	262.0	718.0	110.0	15.70	0.3	0.140
124N	10/17/89	89Q1378	790.00	240.00	6500.0	154.0	-0.004	0.754	22.80	270.0	12000.0	177.0	0.07	0.9	-0.100
124O	10/12/89	89Q1381	1970.00	1120.00	1410.0	44.5	0.509	2.698	22.50	314.0	7840.0	1220.0	1.10	1.0	0.300
124P	10/12/89	89Q1382	945.00	1400.00	7500.0	123.0	-0.004	0.220	22.20	299.0	16300.0	1450.0	2.40	0.2	-0.110
125A	04/21/89	89Q0493	142.00	66.50	27.6	6.0	0.930	0.570	23.20	344.0	26.0	370.0	0.05	0.3	-0.100
125B	04/20/89	89Q0494	128.00	46.40	57.0	7.7	0.260	1.440	22.70	381.0	56.5	258.0	0.03	0.3	-0.100
126A	04/20/89	89Q0495	66.90	31.70	719.0	12.0	0.002	0.170	19.40	325.0	1060.0	111.0	3.12	0.3	-0.100
126B	04/20/89	89Q0496	2120.00	1120.00	11100.0	162.0	0.009	3.950	16.30	258.7	23600.0	116.0	32.00	-2.0	0.100
126C	10/12/89	89Q1391	116.00	57.05	26.9	9.0	0.980	0.832	27.20	375.0	6.6	257.0	0.06	0.3	-0.010
139A	04/20/89	89Q0497	3330.00	4290.00	10600.0	74.9	-0.002	3.960	15.30	204.5	33200.0	2840.0	1.60	1.0	-0.100
151B	04/22/89	89Q0498	8940.00	3080.00	12800.0	275.0	-0.002	0.048	12.20	259.6	44300.0	121.0	9.70	0.2	-0.100
167B	04/22/89	89Q0499	58.60	18.80	14.3	8.3	-0.002	0.004	8.50	237.2	35.1	20.5	0.87	0.2	-0.100
222A	04/21/89	89Q0500	452.00	287.00	879.0	18.5	0.430	1.590	22.70	893.0	177.0	3140.0	0.03	0.1	-0.100
252A	04/18/89	89Q0501	311.00	150.00	161.0	7.2	1.260	0.110	28.90	335.0	773.0	291.0	26.90	0.3	-0.100
252B	04/18/89	89Q0502	140.00	88.10	29.3	3.3	0.061	0.007	26.60	355.0	18.6	343.0	29.20	0.2	-0.100
253A	04/18/89	89Q0503	52.70	14.50	5.6	2.1	-0.002	0.002	19.90	195.7	14.0	10.0	2.81	0.0	-0.100
253B	04/18/89	89Q0504	488.00	84.80	1060.0	39.3	0.032	0.590	20.90	209.8	2570.0	24.0	16.10	0.1	-0.100
258A	04/19/89	89Q0505	5380.00	2910.00	32500.0	395.0	-0.002	1.620	11.00	290.0	68000.0	1890.0	1.00	1.0	-0.100
258B	04/19/89	89Q0506	3720.00	4080.00	39500.0	301.0	-0.002	1.840	11.10	240.1	78600.0	1630.0	0.40	1.0	-0.100
262A	04/20/89	89Q0507	3630.00	1090.00	21600.0	60.8	0.370	1.960	14.40	276.2	42300.0	197.0	17.00	-5.0	-0.100
264A	10/13/89	89Q1389	2770.00	859.00	39000.0	860.0	0.962	11.320	10.10	320.0	66900.0	669.0	34.60	0.3	0.400
264B	04/20/89	89Q0508	2420.00	1420.00	15900.0	272.0	0.003	6.080	9.20	320.0	32800.0	250.0	24.00	-5.0	0.300
264D	04/20/89	89Q0509	1500.00	853.00	9590.0	110.0	0.073	9.530	11.90	547.0	18600.0	1210.0	7.00	-1.0	-0.100
264Q	10/13/89	89Q1388	1010.00	596.00	5060.0	56.9	-0.004	3.108	15.70	273.0	10300.0	1060.0	5.02	0.1	0.300
264R	10/13/89	89Q1385	178.00	122.00	99.9	19.1	-0.004	0.636	22.90	427.0	195.0	538.0	0.00	0.1	-0.100
264S	10/13/89	89Q1387	406.00	318.00	956.0	30.9	7.840	2.374	30.60	351.0	2810.0	182.0	0.06	0.1	0.300
264T	10/13/89	89Q1386	80.80	39.44	20.3	5.8	1.354	0.694	23.00	321.0	12.3	130.0	0.06	0.3	-0.100
295A	04/22/89	89Q0510	68.20	47.80	131.0	4.5	-0.002	-0.001	20.30	341.0	138.0	142.0	11.90	0.4	-0.100
307A	10/13/89	89Q1375	11.99	656.00	27600.0	724.0	0.147	0.009	0.30	5490.0	4070.0	47600.0	2.94	0.2	0.540

Table 8 (cont). WATER QUALITY ANALYSES OF SELECTED WELLS AND LAKES, SHERIDAN COUNTY, MONTANA
(units are milligrams/litre except where indicated)
(negative values are below detection limits)
* DIS=dissolved BIO=biologically available

LAB NUMBER	TRACE METALS TYPE*	ALUMINUM	SILVER	BORON	CADMIUM	CHROMIUM	COPPER	LITHIUM	MOLYBDENUM	BARIUM	BROMIDE	NICKEL	STRONTIUM	TITANIUM	VANADIUM
89Q0485	DIS	-0.03	-0.002	0.33	0.066	-0.002	0.092	1.800	0.03		-1.00	0.25	13.60	-0.001	0.005
89Q0486	DIS	-0.03	0.006	0.29	0.096	-0.002	0.110	7.780	-0.02		-1.00	0.18	73.60	-0.001	-0.001
89Q0487	DIS	-0.03	-0.002	0.41	-0.002	-0.002	-0.002	0.510	-0.02		0.70	0.01	2.73	0.004	-0.001
89Q0488	DIS	-0.03	-0.002	9.76	0.063	-0.002	0.066	8.080	-0.02		-1.00	0.17	68.90	-0.001	0.009
89Q0489	DIS	0.11	-0.002	0.57	-0.002	-0.002	-0.002	0.190	-0.02		-0.10	-0.01	1.94	0.004	-0.001
89Q0490	DIS	-0.03	-0.002	0.53	-0.002	-0.002	-0.002	0.120	-0.02		0.20	-0.01	0.99	0.002	-0.001
89Q1376	DIS	-0.04	-0.004	0.49	-0.005	-0.005	-0.004	0.143	-0.04	0.03	0.30	-0.02	1.05	-0.004	-0.004
89Q1390	DIS	-0.04	0.004	0.31	-0.005	-0.005	-0.004	0.267	-0.04	0.16	2.10	0.02	2.11	-0.004	-0.004
89Q0491	DIS	0.10	-0.002	5.75	0.013	0.022	0.034	1.070	-0.02		-1.00	0.05	7.12	0.012	0.036
89Q0492	DIS	-0.03	-0.002	17.50	-0.002	-0.002	0.012	2.080	-0.02		-1.00	-0.01	9.81	0.014	0.006
89Q1383	DIS	-0.04	-0.004	0.08	-0.005	-0.005	-0.004	0.034	-0.04	0.06	-0.10	-0.02	0.46	-0.004	-0.004
89Q1384	DIS	0.09	0.014	34.20	0.012	0.007	0.031	9.230	-0.04	0.30	12.30	0.02	24.80	-0.004	0.027
89Q1377	DIS	0.16		28.50	0.008	0.007	0.023	4.440	-0.04	0.33	65.40	0.04	18.70	-0.004	0.020
89Q1379	DIS	0.12	-0.004	5.47	-0.005	-0.005	0.004	0.730	-0.04	0.14	4.40	-0.02	3.58	-0.004	0.007
89Q1380	DIS	0.05	-0.004	1.39	-0.005	-0.005	-0.004	0.196	-0.04	0.09	1.70	-0.02	1.01	-0.004	-0.004
89Q1378	DIS	0.10	0.007	17.80	-0.005	-0.005	0.016	2.840	-0.04	0.49	-0.10	0.02	13.80	-0.004	0.013
89Q1381	DIS	0.10	0.007	0.26	0.011	0.006	0.026	0.447	-0.04	0.11	15.90	0.06	5.60	-0.004	0.022
89Q1382	DIS	-0.04	0.006	1.84	0.012	-0.005	0.020	2.780	-0.04	0.17	-0.10	-0.02	12.80	0.009	0.014
89Q0493	DIS	-0.03	-0.002	0.08	-0.002	-0.002	0.003	0.110	-0.02		0.10	-0.01	0.60	0.003	-0.001
89Q0494	DIS	-0.03	-0.002	0.20	-0.002	-0.002	-0.002	0.120	-0.02		-0.10	-0.01	0.58	0.001	-0.001
89Q0495	DIS	-0.03	-0.002	1.59	-0.002	-0.002	-0.002	0.280	-0.02		-0.10	-0.01	0.70	-0.001	-0.001
89Q0496	DIS	-0.03	-0.002	1.57	0.023	0.023	0.066	3.950	0.06		-1.00	0.07	25.70	-0.001	0.057
89Q1391	DIS	-0.04	-0.004	0.15	-0.005	-0.005	-0.004	0.069	-0.04	0.10	-0.10	-0.02	0.47	-0.004	-0.004
89Q0497	DIS	-0.03	0.017	0.93	0.046	-0.002	0.066	3.410	-0.02		-1.00	0.11	26.70	-0.001	0.010
89Q0498	DIS	-0.03	0.026	4.22	0.067	-0.002	0.110	4.200	0.04		-1.00	0.13	3.21	-0.001	0.034
89Q0499	DIS	-0.03	-0.002	-0.02	-0.002	-0.002	-0.002	0.009	-0.02		-0.10	-0.01	0.11	-0.002	-0.001
89Q0500	DIS	-0.03	-0.002	0.56	-0.002	-0.002	-0.002	0.480	-0.02		1.40	-0.01	2.82	0.008	-0.001
89Q0501	DIS	0.38	-0.002	-0.02	-0.002	-0.002	0.005	0.044	-0.02		-1.00	-0.01	0.65	0.038	0.012
89Q0502	DIS	-0.03	-0.002	0.11	-0.002	-0.002	-0.002	0.018	-0.02		-0.10	-0.01	0.25	0.006	-0.001
89Q0503	DIS	-0.03	-0.002	0.08	-0.002	-0.002	-0.002	0.019	-0.02		-0.10	-0.01	0.09	0.001	-0.001
89Q0504	DIS	-0.03	-0.002	0.29	-0.002	0.002	0.014	0.540	-0.02		-1.00	-0.01	9.68	0.019	0.011
89Q0505	DIS	-0.03	0.047	24.70	0.120	-0.002	0.096	13.100	-0.02		-1.00	0.14	95.10	0.140	0.034
89Q0506	DIS	-0.03	0.034	11.90	0.073	-0.002	0.078	12.400	-0.02		-1.00	0.15	78.90	0.110	0.014
89Q0507	DIS	0.10	0.019	14.80	0.039	0.030	0.078	5.840	-0.02		-1.00	0.07	22.40	-0.001	0.061
89Q1389	DIS	0.10	0.018	89.70	0.025	0.009	0.039	22.200	-0.04	0.80	2.20	0.04	80.10	-0.004	0.030
89Q0508	DIS	0.04	0.015	20.60	0.071	0.024	0.077	6.280	0.03		-1.00	0.12	25.40	-0.001	0.051
89Q0509	DIS	-0.03	0.003	12.20	0.011	0.010	0.047	3.280	-0.02		-1.00	0.08	16.60	-0.001	0.029
89Q1388	DIS	0.12	0.010	6.20	0.012	0.005	0.015	2.030	-0.04	0.36	7.10	0.04	7.75	0.017	0.019
89Q1385	DIS	0.07	-0.004	0.15	-0.005	-0.005	0.006	0.081	-0.04	0.08	0.20	-0.02	0.59	0.004	0.007
89Q1387	DIS	0.23	0.005	1.21	-0.005	-0.005	0.006	0.339	-0.04	0.82	2.80	0.02	1.64	0.031	0.008
89Q1386	DIS	0.04	-0.004	0.11	-0.005	-0.005	-0.004	0.028	-0.04	0.05	-0.10	-0.02	0.23	0.004	0.006
89Q0510	DIS	-0.03	-0.002	0.48	-0.002	-0.002	-0.002	0.100	-0.02		-0.10	-0.01	0.29	-0.001	-0.001
89Q1375	DIS	-0.04	-0.004	17.20	-0.005	-0.005	-0.004	3.340	-0.04	-0.01	8.50	-0.02	0.08	-0.004	-0.004

Table 8 (cont). WATER QUALITY ANALYSES OF SELECTED WELLS AND LAKES SHERIDAN COUNTY, MONTANA
(units are milligrams/litre except where indicated)
(negative values are below detection limits)

LAB NUMBER	ZINC	ZIRCONIUM	ORTHO-PHOSPHATE	ARSENIC	LEAD	CALCULATED DISSOLVED SOLIDS	SUM OF DISSOLVED CONSTITUENTS	LAB SPECIFIC CONDUCTIVITY (microsiemens/cm) (at 25 degrees C)	LAB pH (units)	SODIUM ADSORPTION RATIO	FIELD SPECIFIC CONDUCTIVITY (microsiemens/cm) (at 25 degrees C)	FIELD pH (units)	FIELD TEMPERATURE (degrees C)	FIELD CHLORIDE	CONTAMINATION INDEX
89Q0485	0.017	-0.010	0.4			46674.2	46875.7	61872.9	6.88	9.05	58710.0	6.45	5.5	43090.0	0.730
89Q0486	0.013	-0.004	-1.0			103235.5	103366.0	108790.0	6.76	47.78	101760.0	6.35	4.5	67100.0	0.660
89Q0487	0.009	-0.004	-0.1			4445.7	4799.0	4599.0	7.67	4.38	4500.0	6.64	10.0	115.0	0.026
89Q0488	0.013	-0.004	-1.0			77465.0	77630.1	71781.6	7.00	54.46	82720.0	6.70	6.0	57160.0	0.690
89Q0489	-0.003	0.029	-0.1			2377.4	2695.1	3250.0	7.31	1.75	2870.0	6.85	9.0	<44.0	0.003
89Q0490	-0.003	-0.004	-0.1			1397.0	1697.2	1829.7	7.55	1.74	1960.0	7.10	8.7	<44.0	0.009
89Q1376	-0.007	-0.006				1375.9	1682.8	2213.3	7.73	1.97	1883.0	7.09	11.4	<44.0	0.007
89Q1390	0.008	-0.006			0.130	5340.2	5498.0	9211.4	7.09	5.86	8730.0	6.96	10.3	2942.0	0.340
89Q0491	0.009	0.033	-0.1			11055.8	11183.8	18850.3	7.36	17.80	20000.0	6.96	9.0	8300.0	0.420
89Q0492	0.004	-0.004	-0.1			17995.2	18149.4	29096.4	7.30	59.46	27570.0	7.26	6.9	13420.0	0.490
89Q1383	0.007	-0.006			-0.050	992.7	1193.2	1596.4	7.55	0.73	1413.0	7.17	13.7	48.0	0.034
89Q1384	0.009	0.018			0.400	59472.0	59688.0	78617.0	7.47	0.00	95690.0	6.68	12.9	45340.0	0.474
89Q1377	0.013	0.011			0.220	29704.5	29869.4	44480.0	7.44	60.05	46500.0	6.95	14.2	25000.0	0.540
89Q1379	0.007	-0.006			-0.050	4928.8	5107.9	8817.1	7.67	26.02	8600.0	7.46	15.9	2942.0	0.340
89Q1380	-0.007	-0.006			-0.050	1599.9	1732.9	2968.0	7.79	9.73	2670.0	7.54	16.3	604.0	0.230
89Q1378	0.007	0.007			0.140	20018.5	20155.5	2255.7	7.49	51.98	31740.0	7.19	15.9	12232.0	0.390
89Q1381	0.014	0.007			0.310	13787.0	13946.3	21375.0	7.51	6.28	21160.0	6.79	14.0	8866.0	0.420
89Q1382	-0.006	-0.006			0.270	27890.0	28042.0	40603.0	7.70	36.21	41850.0	7.30	14.3	16228.0	0.388
89Q0493	-0.003	-0.004	-0.1			832.6	1007.1	1202.6	7.65	0.47	1200.0	7.03	8.2	<50.0	0.022
89Q0494	-0.003	-0.004	-0.1			766.0	959.3	1111.6	7.34	1.09	1200.0	7.02	8.9	50.0	0.042
89Q0495	-0.003	-0.004	-0.1			2183.7	2348.6	6232.7	7.45	18.13	6360.0	7.25	8.2	1145.0	0.180
89Q0496	0.015	0.014	-1.0			38397.5	38529.0	59537.8	7.08	48.54	47845.0	6.86	8.5	29475.0	0.620
89Q1391	-0.007	-0.006				686.7	877.0	1203.0	7.51	0.51	1018.0	7.35	13.9	<44.0	0.007
89Q0497	0.006	-0.004	-1.0			54457.3	54561.3	71208.0	7.14	28.62	54535.0	6.55	7.0	39160.0	0.720
89Q0498	0.014	-0.004	-1.0			69391.8	69522.7	88377.0	7.40	29.77	89490.0	6.40	7.7	46360.0	0.520
89Q0499	0.003	-0.004	-0.1			282.0	402.4	500.8	7.81	0.41	500.0	7.00	7.6	<44.0	0.070
89Q0500	0.007	-0.004	-0.1			5418.2	5871.3	6280.2	7.52	7.95	6450.0	6.84	9.8	173.0	0.027
89Q0501	0.009	-0.004	0.1			1915.7	2085.7	3540.6	7.87	1.87	3500.0	6.70	8.2	829.0	0.240
89Q0502	-0.003	-0.004	-0.1			853.2	1033.4	1581.4	7.93	0.47	1380.0	7.10	7.9	<50.0	0.014
89Q0503	-0.003	-0.004	-0.1			218.1	317.4	412.0	7.90	0.17	380.0	7.26	7.8	<50.0	0.037
89Q0504	0.005	-0.004	-0.1			4407.2	4513.6	8425.3	6.97	11.65	8900.0	7.00	7.8	2560.0	0.290
89Q0505	0.012	-0.004	-1.0			111232.2	111379.6	70990.4	6.93	88.72	120670.0	6.50	5.0	79820.0	0.660
89Q0506	0.050	-0.004	-1.0			127963.4	128085.4	69230.0	6.92	106.43	125192.0	6.50	5.0	89570.0	0.720
89Q0507	0.036	0.050	-1.0			69047.3	69187.7	95260.5	7.10	80.75	66340.0	6.43	9.0	55360.0	0.830
89Q1389	0.011	0.025			0.680	111467.0	111629.0		7.18	15.40	180500.0	6.70	8.8	79890.0	0.440
89Q0508	0.017	0.029	-1.0			53258.6	53421.3	78625.5	6.95	13.00	66394.0	6.79	6.0	43760.0	0.660
89Q0509	0.014	-0.004	-1.0			32161.0	32438.5	48105.0	6.70	48.98	41000.0	6.92	5.0	17640.0	0.430
89Q1388	0.016	0.009			0.180	18241.3	18379.8	28810.0	7.03	31.21	28690.0	7.13	13.7	10632.0	0.370
89Q1385	-0.007	-0.006				1386.1	1602.7	2181.5	7.67	1.41	1984.0	7.25	10.7	175.0	0.090
89Q1387	0.008	-0.006			0.070	4916.8	5094.9	8800.1	7.50	8.63	8640.0	7.00	13.4	2942.0	0.340
89Q1386	0.007	-0.006				472.4	635.2	760.5	7.70	0.46	755.0	7.30	11.7	<44.0	0.017
89Q0510	-0.003	-0.004	-0.1			732.0	905.1	1898.9	7.89	2.97	1786.0		7.7	295.0	0.165
89Q1375	0.018	0.006		0.109	0.140	86564.0	89355.0		10.09		66395.0	9.25	12.4	3379.0	0.051

sources that have been impacted, including existing privately owned water wells and surface-water bodies.

Magnitude of Brine Contamination

The magnitude of brine contamination is best indicated by the chloride concentration, as determined by either a field or laboratory analysis of a water sample. The effectiveness of this indicator is the result of naturally low background chloride concentrations in both surface- and ground water in this area. Occasionally chloride levels along with TDS concentration and SC values are elevated due to evaporation in surface-water bodies or due to sluggish flow conditions of groundwater in fine-grained deposits. To distinguish between naturally-elevated chloride concentrations and those elevated by brine, a contamination index (CI) was designed. The best index was determined to be the ratio of the field chloride concentration to the field specific conductance. For example, the average chloride values measured at surface-water samples 258E, 251B, and 307G were 120 mg/L, 355 mg/L, and 1070 mg/L respectively. Based solely on the magnitude of chloride this indicates an increasing trend of oil field brine. The specific conductance values for these samples were 630 umhos/cm, 13,000 umhos/cm, and 73,700 umhos/cm. By comparing the CI from 258E (CI=.190), 251B (CI=.020), and 307G (CI=.015) a more realistic decreasing trend of brine contamination is indicated. This index was devised using field measurements of chloride and conductivity to enable a quick estimate of the magnitude of brine contamination in a water sample. Chloride concentrations below detection levels of the field titrators result in an inaccurate CI. Laboratory values of conductivity and chloride can be substituted for field values extending the range of the CI. Although the absolute lower limit of brine contamination indicated by the index is not well defined, it appears that in eastern Sheridan County a CI between 0.035 and 0.050 reflects degradation to water quality due to oil field brines. The average value of field parameters measured at monitoring wells and surface-water monitoring sites are summarized in Table 9.

There is a wide range of brine impacts to water in all geologic sources within the study area based on the CI (Figure 6). The CI ranges between near zero to greater than 0.50 for all geologic sources. The magnitude of brine contamination tends to be higher at sampling sites associated with glacial till than at sampling sites associated with glacial outwash based on the CI.

The field parameters and the CI are effective methods for assessing the presence or absence of oil field brines in both surface- and ground-water sources. Laboratory analyses provide a more detailed evaluation of the major and minor chemical constituents in a water sample. Using the more detailed evaluation, water samples can be grouped by similar hydrogeologic sources, relative concentration of major ions, and

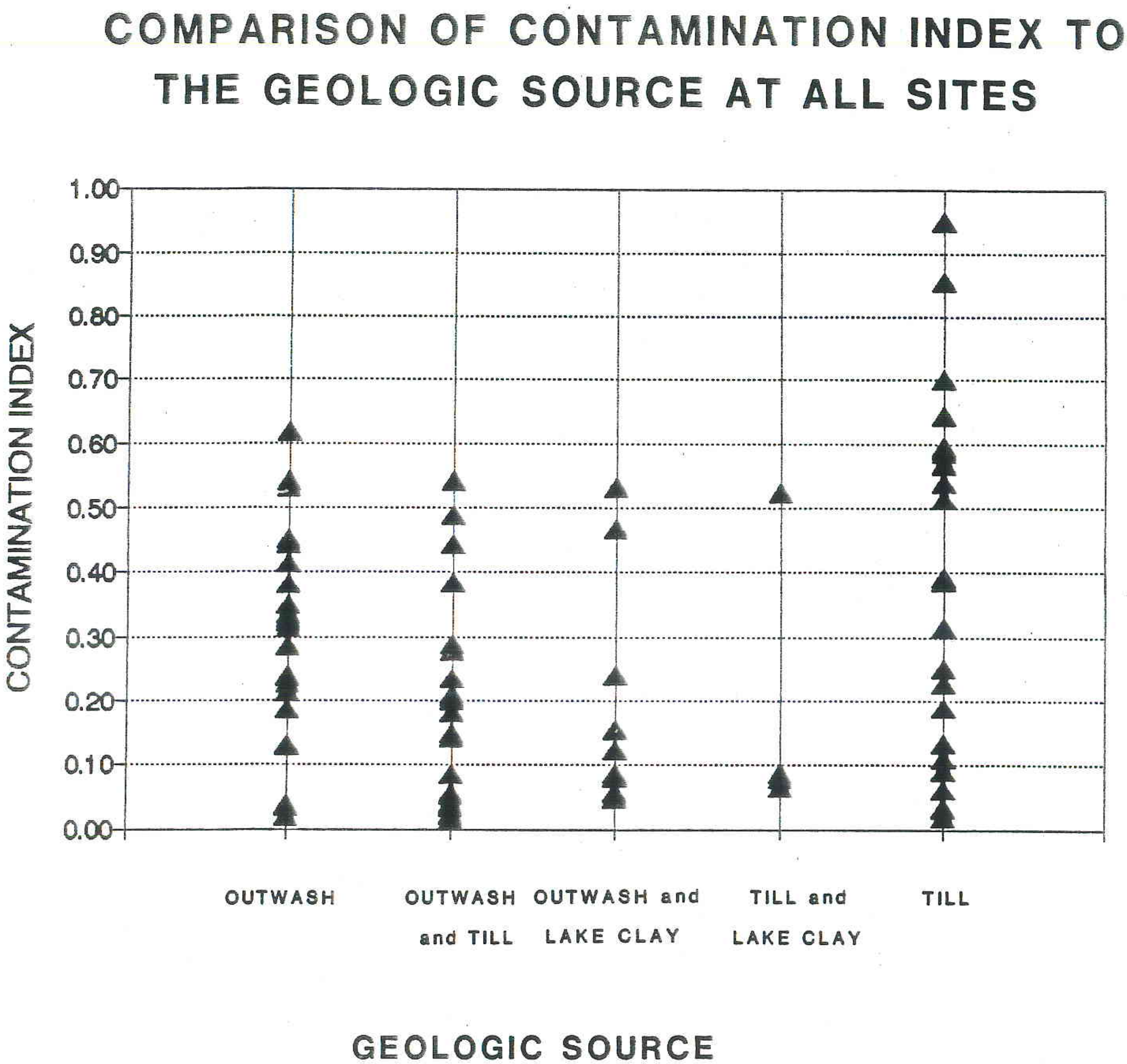


Figure 6. Comparison of contamination index to the geologic source at all sites listed in Table 9.

TABLE 9. AVERAGE VALUE OF FIELD PARAMETERS
(continued)

Site Number	Site Type	Distance from Contamination Source (ft)	Geologic Code	Total Depth (ft)	Depth to(1) Water Level (ft)	Field Chloride Content (mg/L)	Field Specific Conductance (umhos/cm)	Contamination Index
067A	WELL	50	5	43	10	91000	130000	0.7
067B	WELL	135	5	42	6	38000	65000	0.59
067C	SLOUGH	325	5			50(2)	260	0.19(3)
067D	PIT		5			275	700	0.39
079A	WELL	250	5	23	4	78000	132000	0.59
079B	WELL	220	5	36	12	170	5200	0.03
079C	WELL	50	5	28	5	59000	109000	0.54
079D	PIT		5			3240	3780	0.86
117A	WELL	125	5	43	4	72	3780	0.02
117B	WELL	515	5	38	-1	45(2)	2840	0.02(3)
117C	WELL	1015	5	43	-7	45(2)	1960	0.02(3)
117D	WELL	1720	1	8	4	2530	7200	0.35
117E	DUGOUT	1800	1			4530	13700	0.33
117F	SLOUGH	1850	1			450	2080	0.22
117G	DAM	250	5			100	750	0.13
117H	WELL		2			2025	6450	0.31
117I	WELL		1			44(2)	420	0.1(3)
124A	WELL	300	1	23	14	7530	16900	0.45
124B	WELL	250	1	8	4	9500	24800	0.38
124C	WELL	450	1	8	4	11050	26500	0.42
124D	SLOUGH	530	1			39090	72000	0.54
124E	SLOUGH	700	1			19160	31000	0.62
124F	SLOUGH	550	1			31000	58000	0.53
125A	WELL	150	3	27	12	90	1120	0.08
125B	WELL	100	4	33	15	70	1060	0.07
125C	WELL	260	1	9		245	1865	0.13
125D	WELL	290	3	22		212	1375	0.15
125E	WELL	250	3	23		50(2)	580	0.09(3)
125F	SLOUGH	800	1			430	1800	0.24
126A	WELL	190	1	17	9	2830	8720	0.32
126B	WELL	115	1	23	14	26705	58780	0.45
126C	WELL	400	3	18	8.5	60	1055	0.06
139A	WELL	250	5	27	11	38700	67800	0.57
151A	WELL	370	5	13	4	55040	92420	0.6
151B	WELL	720	5	18	5	54568	84680	0.64
151C	WELL		7	198	45	25	3100	0.01
151D	SLOUGH		5			50	500	0.1
167A	WELL	360	2	6		284	1560	0.18
167B	WELL	700	2	13	6	2085	5415	0.39
167C	WELL	850	1	21		1369	4365	0.31
167D	WELL	1800	2	15		110	770	0.14
167E	SLOUGH	6000	2			44	1050	0.04
167F	WELL	6000	1	17	11.5	135	1043	0.13
167H	WELL	850	2	8	6	45(2)	467	0.1(3)
167K	WELL	800	1	11.5	6	1150	4000	0.29
167L	WELL	800	2	13	10	440	1860	0.24
167M	WELL	850	1	10	6	316	1380	0.23
222A	WELL	120	5	43	12.5	468	7692	0.06
222B	WELL	300	5	48	8.5	532	4770	0.11
222C	WELL	1040	3	14	10.5	80	1710	0.05
222D	WELL	1040	7	82	11	50(2)	2715	0.02(3)
222E	WELL	980	7	85				

TABLE 9. AVERAGE VALUE OF FIELD PARAMETERS
(continued)

Site Number	Site Type	Distance from Contamination Source (ft)	Geologic Code	Total Depth (ft)	Depth to(1) Water Level (ft)	Field Chloride Content (mg/L)	Field Specific Conductance (umhos/cm)	Contamination Index
222F	SLOUGH	500	4			44(2)	470	0.09(3)
222G	SLOUGH	1800	4			44(2)	870	0.05(3)
222H	SLOUGH	1800	4			550	6280	0.09
222I	SLOUGH	2700	4			1270	16340	0.08
251A	WELL	1500	1	15	9.4	50(2)	1350	0.04(3)
251B	LAKE	1500	1			255	13000	0.02
252A	WELL	60	1	32	26	585	2711	0.22
252B	WELL	50	1	32	27	62	1620	0.04
252C	WELL	1000	1	150	24	44(2)	1150	0.04(3)
253A	WELL	70	1	31	24	50(2)	409	0.12(3)
253B	WELL	20	1	30	26	3220	9550	0.34
253C	WELL	210	1	32	27	50(2)	583	0.09(3)
258A	WELL	100	5	32	7	89775	158111	0.57
258B	WELL	450	5	28	7	89110	172732	0.52
258C	WELL	3900	5	60	30	68	2000	0.03
258D	WELL	4500	5	86	30	130	1440	0.09
258E	SLOUGH		5			120	630	0.19
258F	LEAK		5			190000	200000	0.95
258G	SLOUGH		5			140	610	0.23
262A	WELL	150	4	33	24	42500	80900	0.53
262C	DAM		5			1250	3980	0.31
262D	WELL	900	5	50	36.5	50(2)	1140	0.04(3)
262E	WELL	800	5	68		6558	17235	0.38
264A	WELL	150	3	23	16	77122	144460	0.53
264B	WELL	380	2	8	2	49140	90407	0.54
264D	WELL	1000	2	13	3	21540	43909	0.49
264E	SLOUGH	800	2			22560	50687	0.45
264F	DUGOUT	500	2			795	2750	0.29
264G	SLOUGH		2			225	1485	0.15
264H	SLOUGH		2			45(2)	290	0.16(3)
264J	SLOUGH		2			350	1740	0.2
264K	SLOUGH		2			2190	6800	0.32
264L	SLOUGH		2			800	3100	0.26
264M	DUGOUT		2			2880	5450	0.53
264N	DUGOUT		2			44(2)	320	0.14(3)
264O	SLOUGH		2			44(2)	210	0.21(3)
264P	SLOUGH		2			80	840	0.1
266A	TEST	140	4					
266B	WELL	800	7	150	60	50(2)	850	0.06(3)
286A	WELL	130	1	13	9	380	2020	0.19
286B	WELL		2	30	27	50(2)	870	0.06(3)
286C	SLOUGH		2			3815	13685	0.28
286D	SLOUGH		2			420	2790	0.15
286E	SLOUGH		2			44(2)	920	0.05(3)
286F	SLOUGH		2			44(2)	940	0.05(3)
286G	SLOUGH		2			44(2)	430	0.1(3)
286H	SLOUGH		2			170	1990	0.09
286I	WELL		2	21	17	44(2)	1200	0.04(3)
286J	SLOUGH		2	40		50	3670	0.01
288A	WELL		3	8	5.5	5250	21870	0.24
288B	WELL		3	15	11.2	340	2750	0.12
288C	WELL		3	13	9.6	44(2)	1150	0.04(3)

TABLE 9. AVERAGE VALUE OF FIELD PARAMETERS
(continued)

Site Number	Site Type	Distance from Contamination Source (ft)	Geologic Code	Total Depth (ft)	Depth to(1) Water Level (ft)	Field Chloride Content (mg/L)	Field Specific Conductance (umhos/cm)	Contamination Index
288D	SEEP		3			33790	72060	0.47
306	SLOUGH		5					
307A	LAKE		2			2770	52500	0.05
307B	LAKE		2			15360	72340	0.21
307C	SLOUGH		5			44(2)	1070	0.04(3)
307D	SLOUGH		5			3610	17940	0.2
307E	SLOUGH		2			44(2)	330	0.13(3)
307F	SLOUGH		2			2010	37500	0.05
307G	LAKE		2			1070	73700	0.02
307H	SLOUGH		2			1040	29200	0.04
307I	SLOUGH		2			130	3810	0.03
307J	SLOUGH		2			390	10130	0.04
307K	SLOUGH		2			200	9220	0.02
307L	SLOUGH		2			570	23100	0.03
307M	WELL		1	10		290	1210	0.24
307N	WELL		1	40		44(2)	1870	0.02(3)
307O	SLOUGH		2			28320	136700	0.21

(1) Negative values indicate feet above land surface
(2) CL concentration below detection limit
(3) Index is less than value indicated because CL concentration was below detection limit

GEOLOGIC CODES: 1 - Outwash; 2 - Till/Outwash; 3 - Outwash/Lake Clay; 4 - Till/Lake Clay: 5 - Till; 6 - Lake Clay
7 - Fort Union Formation

degree of brine impacts. In addition, concentrations of trace constituents can be compared to established standards (Table 10).

The results of the 43 water quality analyses can be placed into 5 different categories based upon the hydrogeologic source of the water and the value of the CI. Trilinear diagrams clearly indicate changes in water quality as a result of the brine impacts in both till and outwash settings (Figure 7). The 5 categories used to group the results of the water quality analyses are uncontaminated ground water in glacial outwash, contaminated ground water in glacial outwash, uncontaminated ground water in glacial till, contaminated ground water in glacial till, and contaminated surface water (Goose Lake) associated with both till and outwash. For calculating the CI the laboratory value of the chloride concentration can be substituted for field chloride concentration when levels were below detection levels of the titrators. Samples with the CI below .035 were considered uncontaminated.

Analyses of water samples from uncontaminated outwash form a group along the left side of the trilinear diagram (Figure 7a). Calcium, sulfate and bicarbonate are the dominant ions. Calculated dissolved solids (CDS) are low ranging from 220 mg/L to 990 mg/L. The pH of these samples are slightly alkaline ranging from 7.03 to 7.35. The ranges of percent reacting values for the cations are:

Table 10. Recommended limits and maximum levels of constituents in drinking water, stock water and irrigation water

Parameter	Drinking Water *Maximum Contaminant Levels (Mg/L)	Drinking Water ** USPHS Recommended Limits (Mg/L)	***Stock Water Limits (Mg/L)	***Irrigation Water Limits, Water Used Continuously On All Soils (Mg/L)
Aluminum			5	5
Arsenic	.05	.01	.2	.1
Beryllium				.1
Barium	1.0			
Boron			5	1.0
Bromide				
Cadmium	.01		.05	.01
Chloride		250		
Chromium	.05		1.0	.1
Cobalt			1.0	.05
Copper		1.0	.5	.2
Cyanide		.2		
Fluoride	2.4	.8-1.7	2.0	1.0
Iron		.3		5.0
Lead	.05		.1	5.0
Lithium				2.5
Manganese		.05		.2
Mercury	.002		.01	
Molybdenum				.01
Nickel				.2
Nitrate				
(No_3 as N)	10	10	100	
(as No_3)	44			
Selenium	.01		.05	.02
Silver	.05			
Strontium				
Sulfate		250		
Tin				
Titanium				
Total dissolved solids		500	10,000	
Vanadium			.1	.1
Zinc		5	24	2
Zirconium				

* National Primary Drinking Water Regulations from Safe Drinking Water Act (Public Law 93-523)

** U.S. Public Health Service (1962)

*** Environmental Studies Board: Nat. Acad. of Sci., Nat. Acad. of Eng. Water Quality Criteria

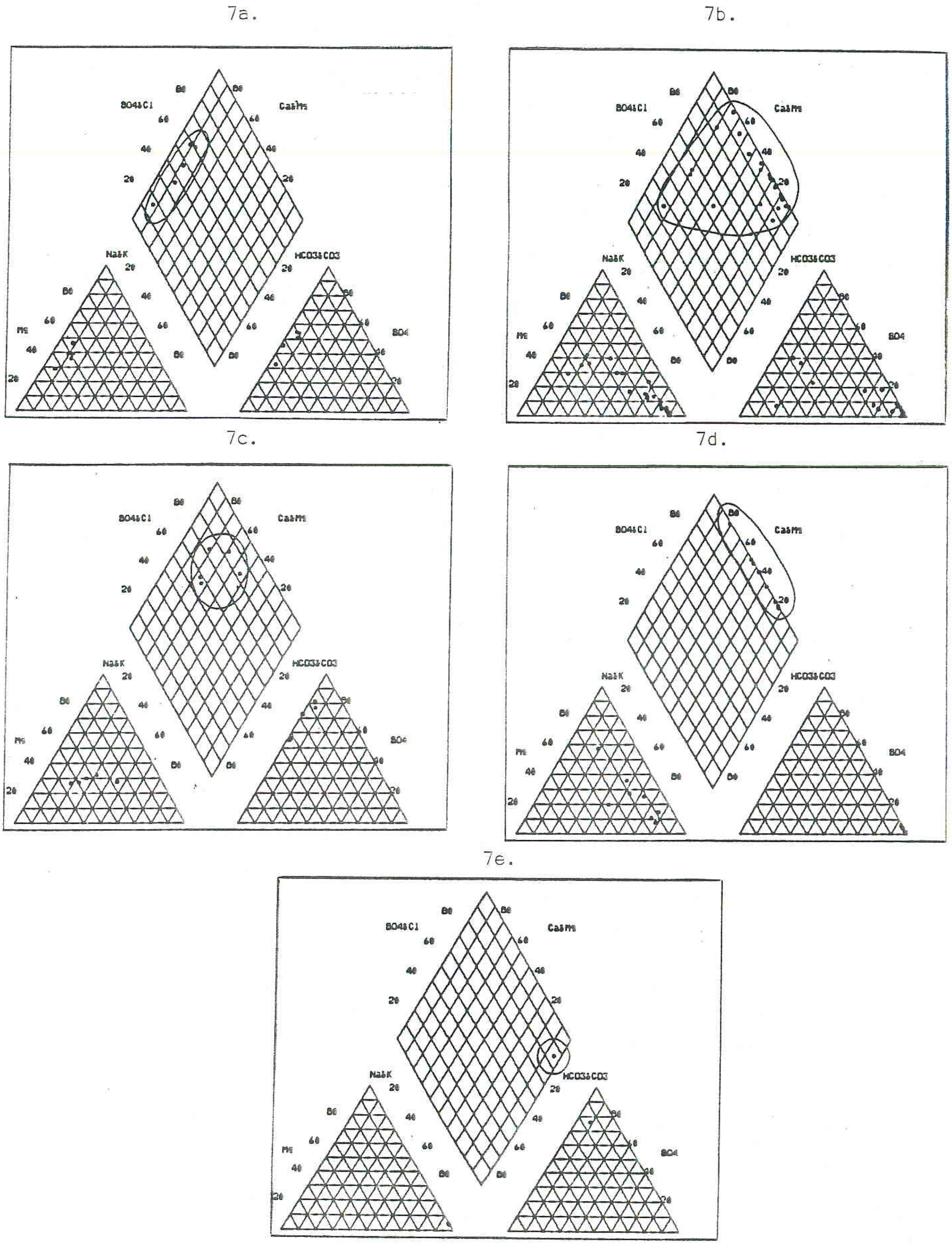


Figure 7. Trilinear diagrams developed from 43 water quality analyses indicating percent reacting values of major ions in ground water from a.) uncontaminated outwash, b.) contaminated outwash, c.) uncontaminated till, d.) contaminated till; and for surface water from (e.) Goose Lake.

calcium 44-64%, magnesium 29-47%, and sodium plus potassium 7-13%. The ranges of percent reacting values of the anions are: chloride 1-12%, sulfate 5-55%, and bicarbonate 38-83%. The ranges of sulfate and bicarbonate percent-reacting values are much tighter if the results from well #253A are omitted, 32-55% and 38-64% respectively. Sulfate-reducing bacteria may have impacted water in this well decreasing the sulfate concentration while increasing the bicarbonate concentration. Nitrate concentrations are above drinking water standards in one sample from uncontaminated outwash (Table 3). Trace constituents were low in these samples with levels generally below detection limits (Table 10).

Analyses of 23 water samples from contaminated outwash, plot as a group to the right of the samples from uncontaminated outwash on the trilinear diagram (Figure 7b). The magnitude of the shift towards the right corresponds to the degree of chloride degradation with the most impacted water samples plotting near the right margin. Sodium and chloride are typically the dominant ions although relatively large proportions of calcium magnesium, and bicarbonate occur in the less impacted samples. CDS values are very diverse ranging from 288 to 110,000 mg/L. The pH of contaminated outwash samples are also diverse ranging from 6.43 to 7.54. The ranges of percent-reacting values of the cations are: calcium 7-50%, magnesium 3-40%, and sodium plus potassium 15-70%. The ranges of percent reacting values of the anions are: chloride 12-99%, sulfate 0.5-41%, and bicarbonate 0.6-73%. Nitrate concentrations are above the drinking water standard in about half of the contaminated outwash samples. Several trace constituents are at higher concentrations than in the uncontaminated outwash samples. Concentrations of boron are above the stock watering limit of 5 mg/L in 6 of the 23 contaminated outwash samples. Concentrations of cadmium are above drinking water standards in 6 of the 23 samples. Concentrations of lithium are above recommended irrigation limits of 2.5 mg/L in 6 of the 23 samples. Concentrations of lead are above drinking water standards in 9 of the 11 brine-contaminated outwash samples that were tested for lead.

Analyses of 5 water samples from uncontaminated till, plot as a group near the center of the trilinear diagram (Figure 7c). Calcium, magnesium, and sulfate are the dominant ions. Calculated dissolved solids are moderately high ranging from 1375 to 5420 mg/L. The pH of uncontaminated till samples are slightly acidic to neutral ranging from 6.64 to 7.10. The ranges of percent reacting values for the cations are: calcium 26-54%, magnesium 26-33%, and sodium plus potassium 19-46%. The ranges of percent reacting values of the anions are: chloride 0-6%, sulfate 55-82% and bicarbonate 15-43%. Nitrate concentrations are above drinking water standards in one sample from uncontaminated till. Trace constituents are generally slightly above detection limits but are below all recommended limits or maximum levels set for drinking, stock watering, and irrigation.

Analyses of 8 water samples from contaminated till plot as a group near the right side of the trilinear diagram (Figure 7d). Sodium and chloride are typically the dominant ions although relatively high proportions of calcium and magnesium are identified in a few samples. CDS are very high ranging from 47,000 to 128,000 mg/L. The pH of these samples is slightly acidic ranging from 6.40 to 6.70. The ranges of percent-reacting values of the cations are: calcium 8-35%, magnesium 7-57%, and sodium plus potassium 19-78%. The ranges of percent reacting values of the anions are: chloride 93-100%, sulfate 0-6%, and bicarbonate 0-0.5%. Nitrate concentrations are above drinking water standards in one of the contaminated till samples. As in the outwash samples, trace constituents are generally higher in the brine contaminated till water samples than in the uncontaminated till water samples. Concentrations of boron are above the stock watering limit of 5 mg/L in four of the eight contaminated till samples. Concentrations of cadmium are above the drinking water standard in all eight of the samples. Concentrations of lithium are above the irrigation standard of 2.5 mg/L in five of the eight samples.

One sample was analyzed from Goose Lake. Based on the contamination index of .051, water in Goose Lake is slightly impacted by chloride brines. The Goose Lake sample plots towards the right side of the trilinear diagram. Sodium and sulfate are the dominant ions. CDS of the Goose Lake sample are 89,600 mg/L.

The pH of water in Goose Lake is very alkaline and was measured at 9.25 in the field. Most trace constituents are relatively low in the lake water with the following exceptions. Concentrations of boron (17.20 mg/L) are above the stock watering limit of 5 mg/L. Concentrations of lithium (3.34 mg/L) are above the irrigation water limit of 2.5 mg/L. Concentrations of arsenic (0.109 mg/L) are above the drinking water standard of 0.05 mg/L. Concentrations of lead (0.140 mg/L) are above the drinking water standard of 0.05 mg/L.

Extent of Brine Contamination

Determining the extent of brine contamination is very important for assessing the degradation of a water supply. However, it is difficult to determine due to the number of variables involved: the volume of waste brine discharged; timing of the discharge; concentration of the discharge; soil texture; near-surface geology; slope of the land; direction of ground-water flow; and direction of vertical ground water gradients. Multiple contaminant sources can also complicate evaluating the extent of contamination.

The total extent of contaminant movement in the ground water was not defined at any of the sites studied during the hydrogeologic overview. All sites sampled indicated significant contaminant levels extended beyond the furthest downgradient monitor wells. Contamination indexes in brine-impacted ground water were typically higher in glacial till than in glacial outwash. A contaminant plume is likely to move faster and farther through permeable outwash deposits than through tighter till deposits. As a result, plumes within till deposits approach the concentrations of the original contaminant while greater ground water flux within outwash deposits causes a more dilute contaminant plume.

Contamination in Surface-Water Bodies and Private Wells

Water quality degradation was evaluated at several existing surface- and ground-water sources during the hydrogeologic overview. The degradation was detected by measuring field water quality parameters. The most significant parameters for identifying brine contamination are chloride concentration and specific conductance. The derived contamination index (CL^-/SC) was used as the primary indicator of brine contamination. As previously used, a contamination index value of 0.035 and larger is assumed to indicate brine contamination.

Water sources that were tested included an uncontrolled leak from a tank battery, water filled pits at oil well sites, surface seeps, existing water wells, small dams, dugouts, sloughs and lakes. The highest brine concentrations were measured at the tank battery leak near Site #258. The CI of the discharging water was 0.95. Two water-filled pits at Site #67 and Site #79 had contamination indexes averaging 0.39 and 0.86 respectively. A surface seep at Site #288 had a CI of 0.47. Nine existing water wells had contamination indexes ranging from 0.035 to 0.38 and averaging 0.18. These wells are associated with oil-field sites

#117, #125, #167, #122, #258 and #262. Water use at five of these wells had been abandoned (125C, 125D, 167C, 222C and 262E) or restricted because of degraded water quality prior to this study. Water from three of the remaining wells identified as impacted by brines is currently still being used for domestic and/or stock purposes. Water in those wells had concentrations below the maximum recommended limit of chloride concentration in drinking water. Water in two small dams (117G and 262C) had contamination indexes averaging 0.13 and 0.31 respectively. Water in three dugouts at Sites #117 and #264, constructed for stock water, had contamination indexes ranging from 0.33 to 0.53. Water quality has been degraded to below stock watering limits at 2 of the dugouts. Water in 27 sloughs had average contamination indexes ranging from 0.035 to 0.62 and averaging 0.22. The sloughs are all ephemeral water bodies ranging in size from small ponds having a surface area less 1 acre to large lake-sized water bodies having a surface area of hundreds of acres. Water in Goose Lake (307A) had an average CI of 0.05 and a large lake northwest of Goose Lake (307B) had an average CI of 0.21.

The most serious damage to existing water sources is the degradation of water quality in several of the wells and dugouts. Data from monitor wells identified many contaminated outwash aquifers, but the low population density in this area has fortunately resulted in only a few cases of actual negative impacts to existing water supplies. Impacts to water quality in lakes and sloughs due to brine contamination is more difficult to assess.

These surface-water bodies already have a diverse water quality. The significance of the degradation of the surface water due to the addition of chloride salts is unclear.

IMPACT NEAR THE GOOSE LAKE OIL FIELD

The hydrogeologic overview of sites in eastern Sheridan County identified high concentrations of chloride contamination adjacent to several oil-field sites in the Goose Lake Field. Drilling wastes and production water from several oil-field sites located in T. 36 N., R. 58 E., sections 22, 27, and 28 have contaminated surface- and ground water in this area. This part of the Goose Lake Field was selected for a more detailed hydrogeologic investigation because water quality in several water supply wells and dugouts had been degraded, and a high potential for contaminant migration existed in the shallow outwash aquifer. The location of this part of the Goose Lake Field is outlined and identified as the detailed study area on Plate 1.

Hydrogeology

The topography within the detailed study area is expressed by gently rolling hills with land surface sloping towards the east (Figure 8). A broad hill covers the central and northern part of section 27. Surface drainages surround this hill with all coulees emptying into the lake on the east edge of the study area. Several small ephemeral sloughs are located within the drainages. Ground water is tapped by dugouts and shallow wells within the drainages.

The hydrogeology of surface deposits in the Goose Lake field is mapped on Figure 8. The map was constructed using information

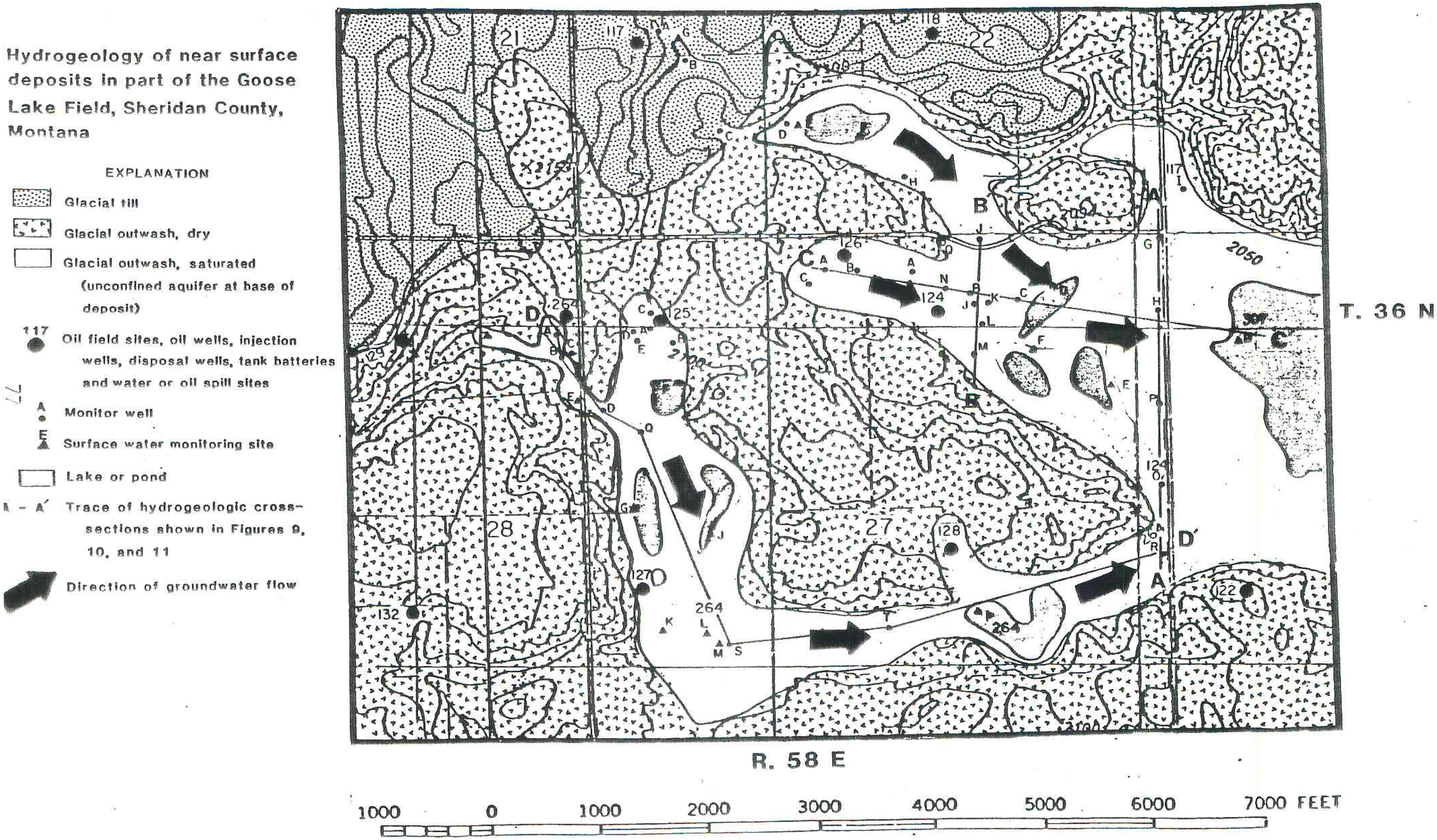


Figure 8. Hydrogeologic map of detailed study area located in T. 36 N., R. 58 E., in part of the Goose Lake oil field.

from air photos (USDA, 1967), soil maps (USDA, 1977), field checks, and logs from test holes (Appendix B). The map depicts the distribution of three hydrogeologic units: glacial till; dry glacial outwash; and saturated glacial outwash. Other features mapped include oil-field sites, test borings, monitor wells, lines of cross-sections, surface-water monitoring sites, and surface-water bodies. A contact between surficial deposits of glacial till and surficial deposits of glacial outwash is located in the northern one-third of the study area. South of the contact, glacial outwash mantles the underlying till with a relatively uniform thickness of sand and gravel averaging about 15 feet thick.

The outwash aquifer is composed of moderately well-sorted to very poorly sorted silty sand and gravel. The basal confining bed under the aquifer is composed of relatively impermeable pebbly clay loam (glacial till). These outwash deposits are unsaturated beneath the hills. Under low-lying areas associated with the drainages the outwash deposits are saturated forming an unconfined aquifer.

A series of cross-sections are shown in figures 9-11 depicting the major hydrogeologic relationships. Cross-section A-A' and cross-section B-B' were constructed perpendicular to the drainage located in the northeast part of section 27 (Figure 9). Cross-section C-C' is constructed along the axis of the drainage (Figure 10). Cross-section D-D' is constructed along the axis of the drainage located in the south and west part of section 27 (Figure 11). As previously described, a relatively uniform thickness of

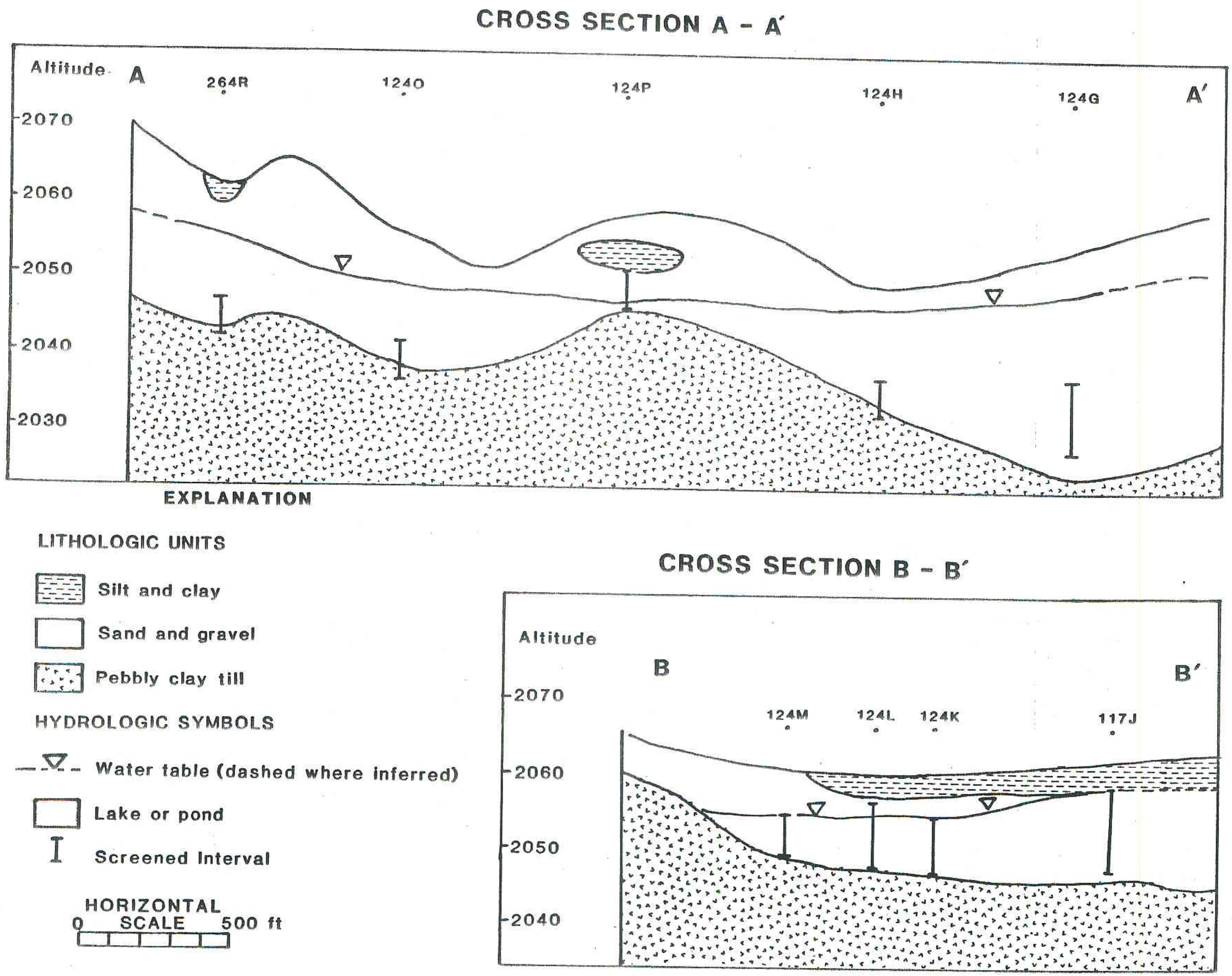


Figure 9. Hydrogeologic cross-sections A-A' and B-B' depicting hydrogeologic relationships underlying the drainage located in the northeast part of section 27.

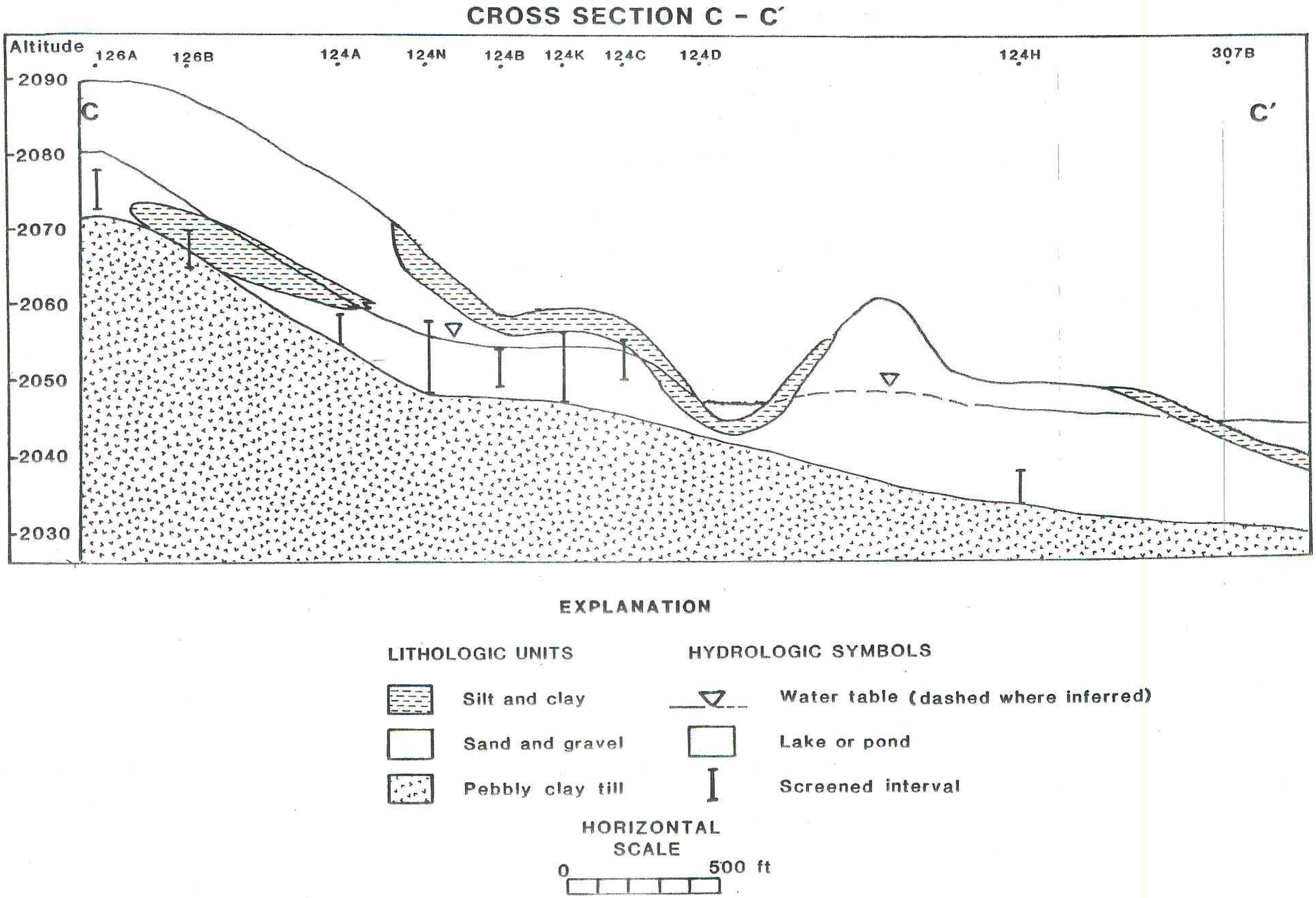


Figure 10. Hydrogeologic cross-section C-C' depicting hydrogeologic relationships underlying the axis of the drainage located in the northeast part of section 27.

CROSS SECTION D - D′

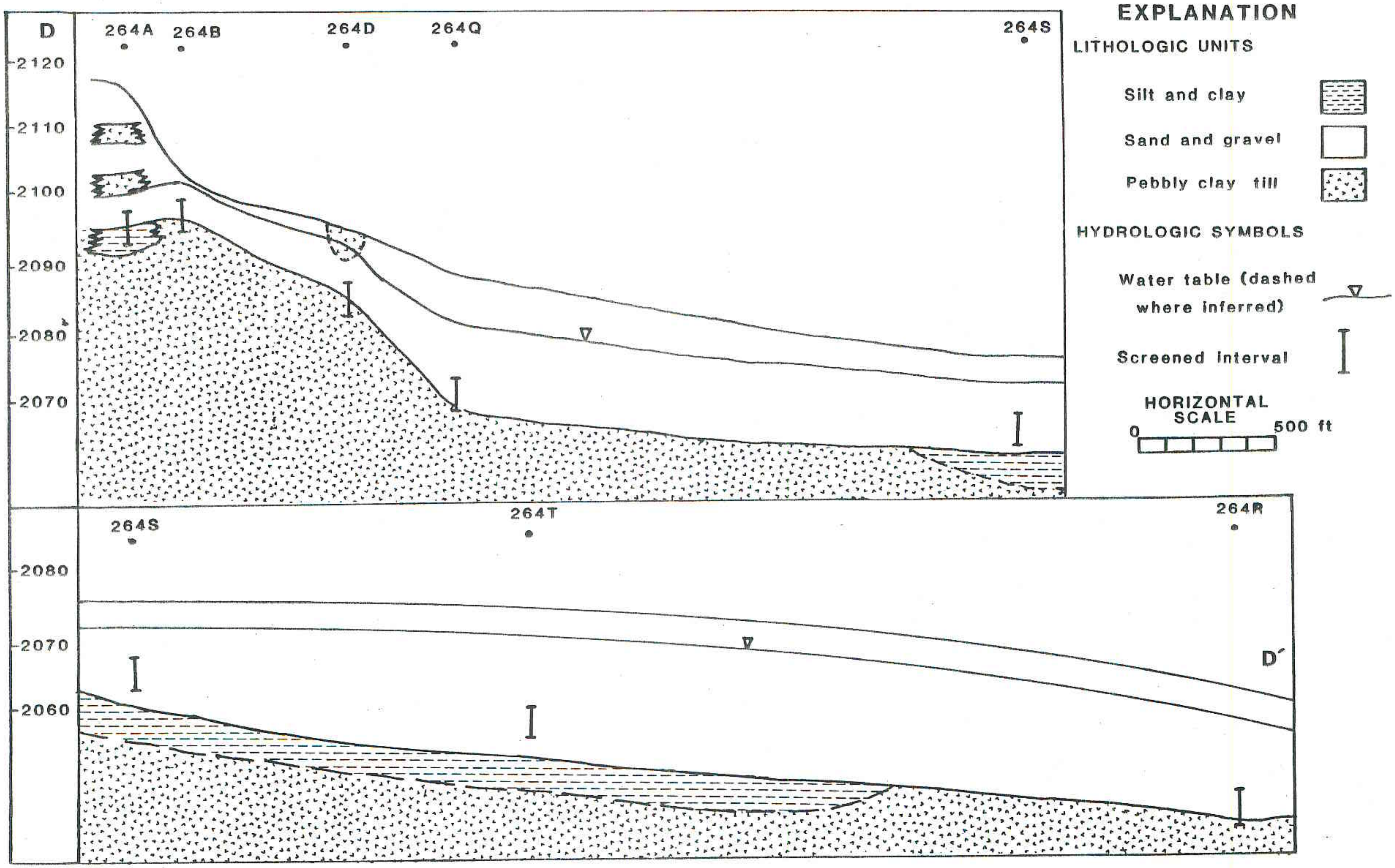


Figure 11. Hydrogeologic cross-section D-D' depicting hydrogeologic relationships underlying the axis of the drainage located in the south and west part of section 27.

outwash sand and gravel mantles the underlying till. The saturated thickness of the unconfined outwash aquifer is controlled by topography of both the land surface and the glacial till surface. Examples of variations in saturated thickness of the aquifer are shown on cross-section A-A' (Figure 9). At monitor well 124P a knob of glacial till produces a very thin saturated zone; while at monitor well 124G a depression in the till surface produces a much thicker saturated zone.

Hydraulic properties of the unconfined outwash aquifer were determined by a short-term aquifer test conducted at site #124 (MBMG file data). Based on a 200-minute aquifer test the transmissivity was calculated at 1400 ft^2/day. The storage coefficient was estimated at 0.20. The hydraulic conductivity was calculated to be 100 ft/day based on a saturated thickness of 14 feet.

Extent of Brine Contamination

Brine plumes were identified adjacent to and downslope from all of the oil-field sites in the detailed study area that were surveyed. The positions of brine plumes were located by conducting electromagnetic induction surveys and by collecting surface-water and ground-water samples. The EM-31 surveys that were conducted during the overview were supplemented by EM-34 surveys conducting during the investigation of the detailed study area. The EM-34 surveys used a 10 meter spacing and measured apparent terrain conductivity to a depth of about 7.5 meters below land surface. The EM-34 surveys were conducted within the drainages below oil-field sites #117, #124, #127, and #128. The results of EM-31 and EM-34 surveys were combined on Figure 12, showing areas of high, moderate, and background apparent conductivity. Apparent conductivity anomalies could be caused by a variety of conditions including: highly mineralized ground water; fine-grained soils; saline seeps; and high water tables. The close association of the conductivity anomalies with the oil-field sites that were surveyed supported the interpretation that near-surface materials had been contaminated by brine discharges. In this case, results of water sampling confirmed that the conductivity anomalies were caused by sodium chloride salts. The only potential sources of these salts are from oil-field brines.

An area of high apparent conductivity at site #117 covered several acres surrounding the abandoned oil well. The source of this anomaly appears to be from a combination of surface brine spills, reclaimed reserve pits, pipeline leaks, and a small containment dam. Water samples from wells 117A and 117B underlying this anomaly indicate little to no brine contamination. Several conductivity anomalies are present downslope of Site #117. The area of high conductivity near well 117C appears to be associated with the development of a saline seep, not brine contaminated groundwater. Chloride concentrations are very low in samples from this well and static water levels are above the land surface restricting the infiltration of any surficial brine discharges. Apparent conductivity anomalies downslope of the geologic contact between till and outwash near Site #117 are directly associated

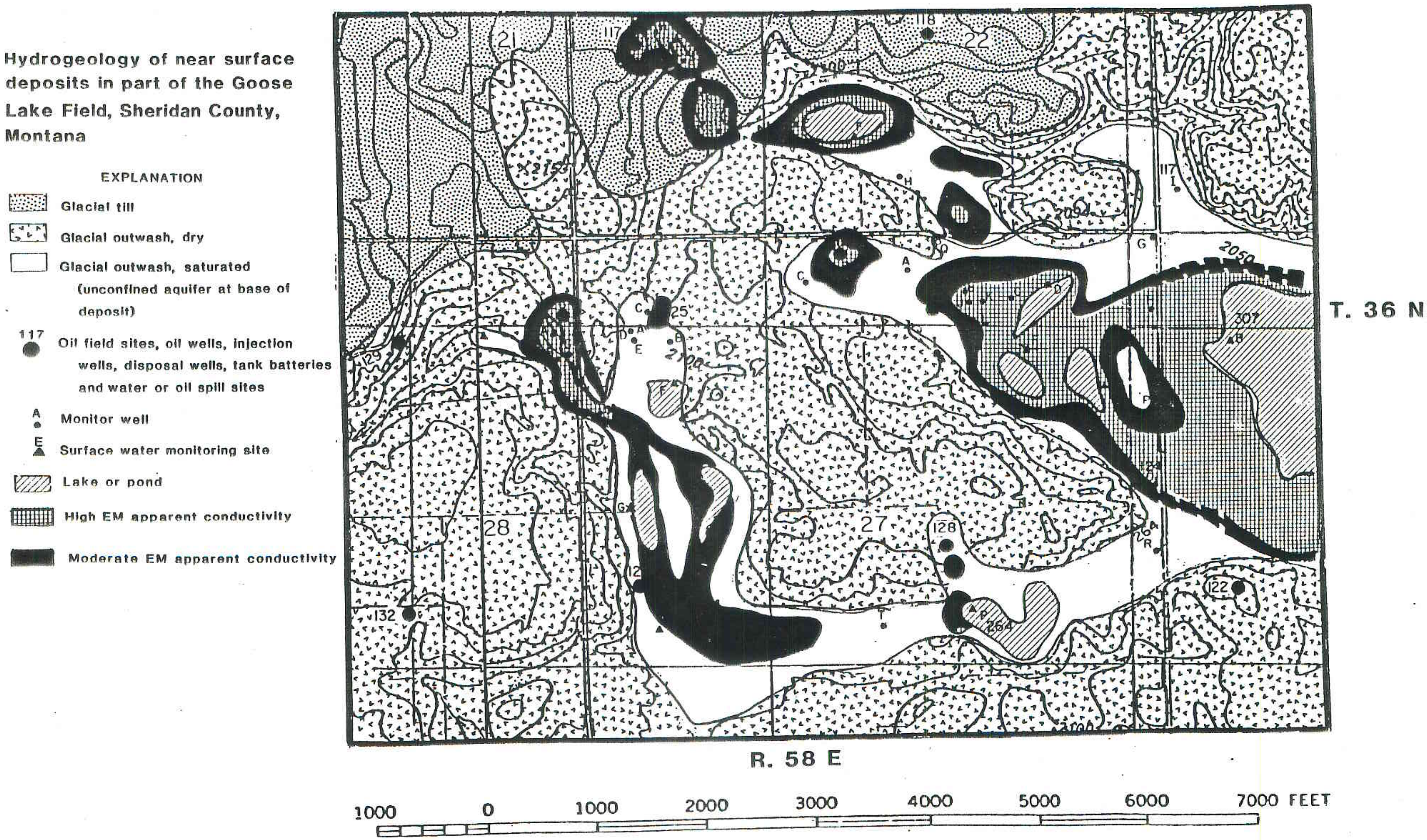


Figure 12. Extent of contamination based on electromagnetic conductivity.

with elevated chloride concentrations in the ground water. Brine contamination at outwash wells 117D and 117J was probably the result of uncontained surface spills near the oil well at Site #117 located 1700 feet and 3500 feet respectively, upslope from these wells. The low-permeability and upward flow gradients in the glacial till prevented infiltration of salt water flowing over the land surface. When the salt water flowed over the more permeable outwash deposits, the water percolated to the water table contaminating the aquifer.

The plume of salt water coming from site #117 crosses into the northeast part of section 27 near well 117J where it mixes with another brine plume associated with oil-field sites #124 and #126. As salt water from these three sources mix a large area of high apparent conductivity develops along the east boundary of section 27. Background water-quality is associated with outwash well 126C which is about 400 feet upgradient of the source at Site #126. High concentrations of sodium chloride salts are associated with all of the outwash wells downgradient of Site #126.

Brine plumes in the drainage along the south and west parts of section 27 are also identified by apparent conductivity anomalies. The highest apparent conductivities are adjacent to or downslope of individual oil-field sites. Wells underlying conductivity anomalies contain brine-contaminated ground-water. Water in wells underlying areas of background conductivity is either fresh (264T) or only slightly contaminated (264R).

The discontinuous nature of apparent-conductivity anomalies was observed over much of this part of the Goose Lake Field. Typically, high conductivities are found adjacent to or downslope of oil-field sites. Small surface spills, reclaimed reserve pits, and holding ponds are likely causes of these anomalies. A saline seep produces a conductivity anomaly below Site #117. Storage of brine in ponds and pits upgradient of the seep, and brine flowing over the seep, may have enhanced this anomaly. The surficial topography above an unconfined aquifer can also produce discontinuous apparent conductivity anomalies. An undulating topographic surface will alter the depth to the water table. Consequently, the apparent conductivity readings will be significantly higher over topographic lows. This appears to be the cause of discontinuous anomalies underlying the drainage in the northern part of section 27. A brine plume underlies the entire area but the plume is only expressed as a conductivity anomaly where the depth to the water is within the depth of investigation of the EM device. The drainage in the south and west part of section 27 contains an outwash aquifer that has also been impacted by several contamination sources. Groundwater at well 264S is contaminated by chloride salts but downgradient at well 264T ground water is uncontaminated. Apparently the brine plume has been diluted to background conditions between these two wells.

Vertical density gradients occur in several outwash wells within the contamination plume. The density gradients are manifested by increasing concentrations of sodium chloride salts with depth (Figure 13). As the concentration of sodium chloride increases in water the density of the water/salt mixture increases. The gradients are probably related to an optimal hydraulic conductivity of the aquifer. At hydraulic conductivities greater than optimal, the brine is flushed laterally and diluted before it can develop a well-defined density gradient. At hydraulic conductivities smaller than optimal, dilution or mixing with fresh groundwater is reduced and brine concentrations remain uniform with depth. Vertical density gradients complicate any description of contaminant movement, because defining the vertical position within a plume is of equal importance as defining the horizontal position within a plume. As a result of these complications, a map view of a plume must also refer to a third dimension perpendicular to the plane of the map. Within a density gradient, chloride concentrations of a sample collected at the water table would be significantly less than chloride concentrations at the base of the aquifer.

The sampling points available for mapping contamination plumes included wells completed at the water table, wells completed at the base of the aquifer, and surface-water bodies. Because of the density gradients, there is no practical method of directly comparing chloride concentrations from such diverse sampling points.

It was observed that the contamination index (CL/SC) remained relatively stable in vertically integrated samples from wells screened in contaminant plumes characterized by vertical density gradients (Figure 13). The greatest contrast in the CI was in well

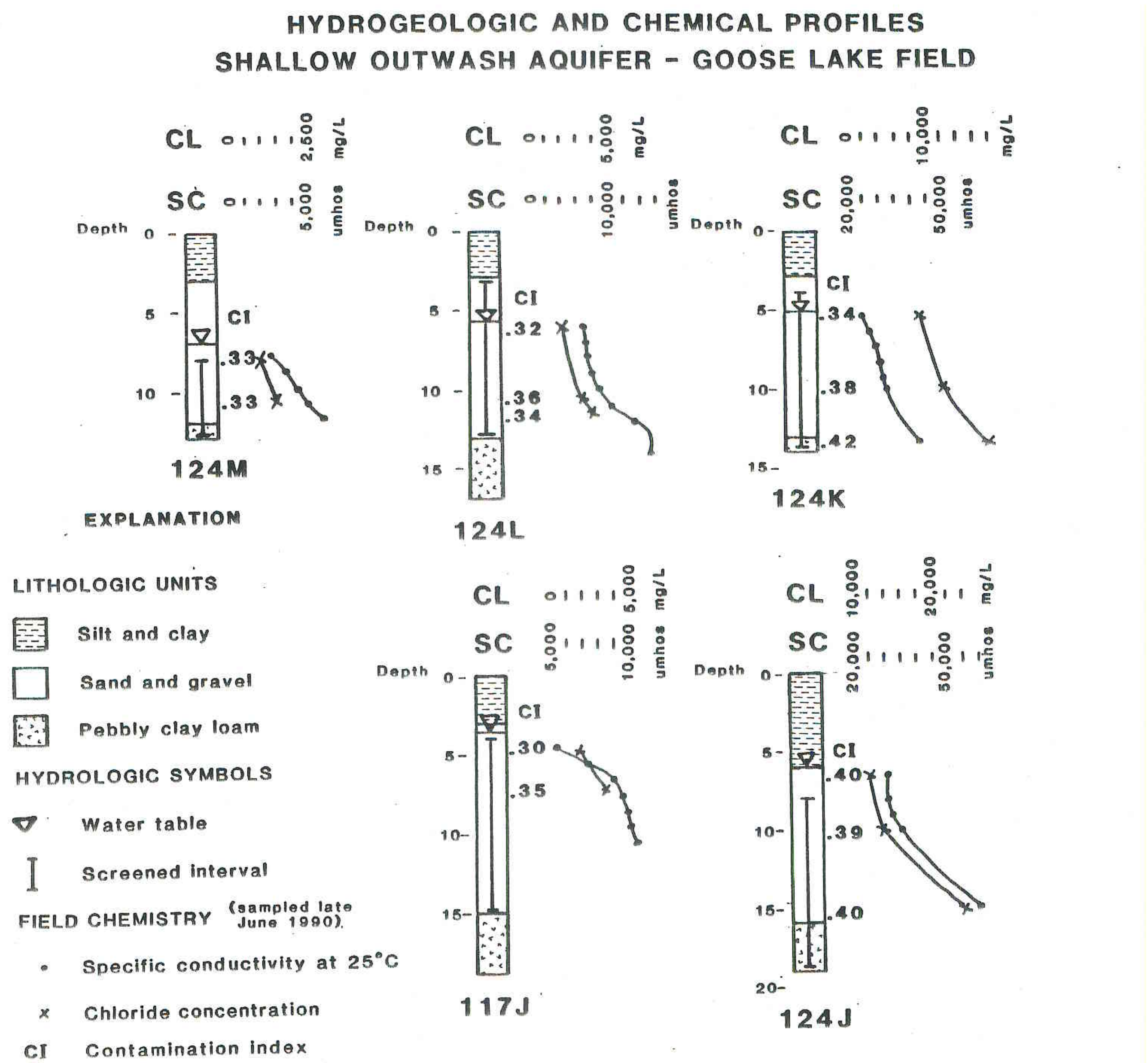


Figure 13. Vertical salinity gradients in selected outwash wells. Variations in salinity create density gradients that influence ground-water flow.

124K where the value ranged from 0.34 at the water table to 0.42 at the bottom. This variation was relatively small especially when compared to the chloride concentration where the value ranged from 8960 mg/L at the water table to 17,920 mg/L at the bottom of the well. All of the other examples on Figure 13 showed a more consistent relationship. Based on the relative consistency of the CI regardless of sample depth, it was used to construct a map of the brine plume (Figure 14).

The brine plume is fairly well defined up to the east border of section 27. The greatest level of ground-water degradation based on the CI underlies several small sloughs east of site #124. Water in most of the outwash aquifer underlying section 27 contains levels of chloride concentrations above the drinking water standard. The extent that the brine plume has spread through the outwash aquifer east of section 27 is yet undefined but chloride contamination has been identified in several surface-water bodies. Relatively high concentrations of chloride were identified in the lake at sample point 307B. If the plume continues to be characterized by vertical density gradients, higher salt concentrations would be expected at the base of the aquifer than were measured in the lake. There is additional evidence that water in Goose Lake is slightly impacted by oil field brines about 2-1/2 miles farther east. Several other oil-field sites could also be sources of this brine. The impact to lakes is probably much less than to aquifers. The shallow outwash aquifer identified as contaminated overlies the deeper more productive Clear Lake aquifer

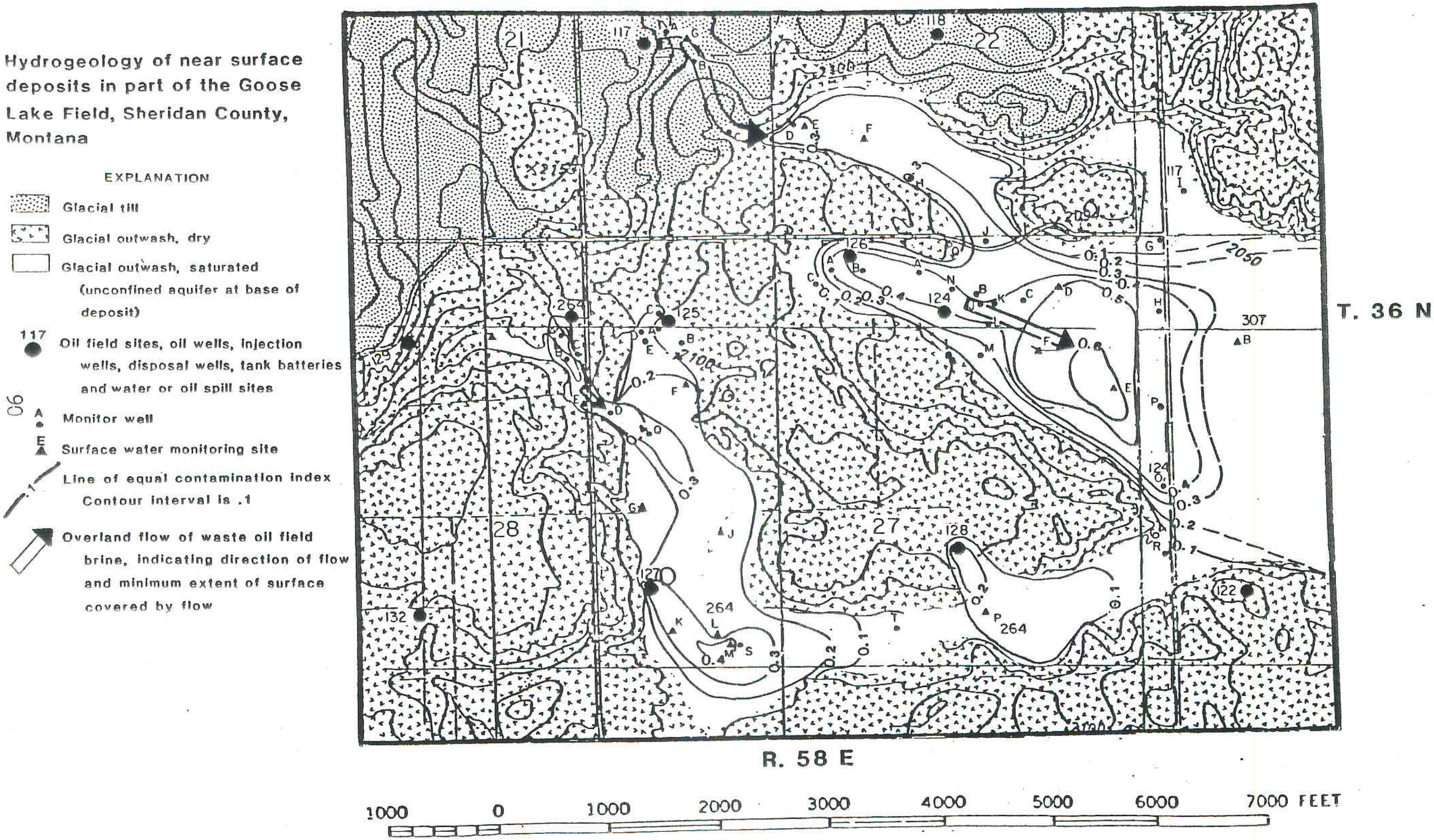


Figure 14. Extent of contamination based on the contamination index (chloride, mg/L: Specific Conductance, umhos).

near Goose Lake (Donovan, 1988). Nearly all of the irrigation development in the Clear Lake aquifer is downgradient of the existing contamination. The hydraulic connection between the shallow outwash aquifer and the Clear Lake aquifer is poorly defined. Consequently, the potential threat to this water supply is unclear.

The obvious sources of contamination in the Goose Lake oil field are the individual oil-field sites. Environmentally unsound methods of brine disposal that were commonly used at these sites prior to 1975 are the main causes of the existing contamination. The use of evaporation pits, trenching of reserve pits, and pipeline leaks all have contributed to the brine contamination. It is unlikely that the large extent and high level of surface-water and ground-water contamination existing in the Goose Lake Field could be derived from these relatively small volume sources of brine. Much of the existing contamination appears to confirm landowner reports that large volumes of brine were disposed of by simply allowing the brine to flow onto the ground surface.

POSSIBLE APPROACHES TO RANK CONTAMINATION POTENTIAL

The potential for oil-field sites to contaminate ground water resources could be ranked using several different approaches. At old sites a ranking system could be designed to determine which sites are likely to degrade or have degraded ground-water quality. This prioritization would reduce the workload required to assess contamination potential by eliminating a large number of low ranking sites. At new sites a ranking system could be used to develop a reclamation plan designed to minimize contamination. The goal of any approach would be to minimize the high expenses of field work while adequately assessing the problem.

RANKING CONTAMINATION POTENTIAL BASED ONLY ON AVAILABLE DATA

Sites could be ranked for contamination potential, filtering sites exclusively on physical data available from published reports, file data from county, state or federal agencies, topographic maps, geologic maps, soils maps, hydrologic maps, and land use maps. This approach is equally applicable at old oil-field sites or at new drilling locations.

A stepwise multiple regression analysis was used to test the influence of several physical variables to the existing contamination. A valid regression model would identify a constant and necessary coefficients to develop an equation to predict the magnitude of ground-water contamination. In a stepwise multiple regression, independent variables are inserted or deleted until the greatest amount of variability of the dependent variable is accounted for. A monitor well was selected at each site to represent the magnitude of the existing contamination. The existing contamination was identified by the contamination index derived from the ratio of the average chloride concentration to the average specific conductance. The contamination index was set as the dependent variable. Physical data including age of site, near-surface geology index, soil permeability, soil texture index, depth to ground water, and distance from the key well to the source of contamination were set as the independent variables (Table 11).

Table 11a. Matrix of correlation coefficients used to develop Equation 1.

	CI	SWL	DIST	LOG	PERM	GEO	YEAR	UNICODE
CI	1.0000	-.2468	-.0176	-.4893	-.4463	.4172	-.4622	-.3257
SWL	-.2468	1.0000	-.4422	.2636	.2445	-.2605	.6264	.3352
DIST	-.0176	-.4422	1.0000	.1823	.1942	-.2456	-.2549	-.3206
LOG	-.4893	.2636	.1823	1.0000	.9558	-.8955	.5529	.6997
PERM	-.4463	.2445	.1942	.9558	1.0000	-.9215	.5997	.7706
GEO	.4172	-.2605	-.2456	-.8955	-.9215	1.0000	-.6499	-.6944
YEAR	-.4622	.6264	-.2549	.5529	.5997	-.6499	1.0000	.6197
UNICODE	-.3257	.3352	-.3206	.6997	.7706	-.6944	.6197	1.0000

CI - Contamination Index (dependent variable)

SWL - Static Water Level (independent variable)

DIST - Distance from the key well to the contamination source (independent variable)

LOG - Log of the soil permeability (independent variable)

PERM - Soil permeability (independent variable)

GEO - Geologic source index (independent variable)

YEAR - Age of site, year drilled (independent variable)

UNICODE - Soil texture index based on the SCS Unified System (independent variable)

Table 11b. Matrix of correlation coefficients used to develop Equation 2.

	SURFCON	EM	LOG	CI	YEAR	PRELIMCI
SURFCON	1.0000	.7835	-.3307	.5304	-.4899	.2623
EM	.7835	1.0000	-.2868	.5998	-.6004	.2122
LOG	-.3307	-.2868	1.0000	-.4893	.5529	-.2581
CI	.5304	.5998	-.4893	1.0000	-.4622	.4589
YEAR	-.4899	-.6004	.5529	-.4622	1.0000	-.3683
PRELIMCI	.2623	.2122	-.2581	.4589	-.3683	1.0000

SURFCON - Estimate of the area of surface contamination (independent variable)

EM - Measurement of the area of higher than background apparent terrain conductivity (independent variable)

LOG - Log of the soil permeability (independent variable)

CI - Contamination index (dependent variable)

YEAR - Year oil well was drilled (independent variable)

PRELIMCI - Contamination index calculated from field measurements at existing water sources near the oil field site (independent variable)

Correlation coefficients were calculated for the dependent and independent variables listed above. A matrix of correlation coefficients was examined to check for interdependence between independent variables and negligible correlation with the dependent variable (Table 11a). The independent variables, PERM, GEO, and UNICODE were eliminated based on a high degree of correlation between these variables and the independent variable LOG. The independent variable DIST was eliminated based on negligible correlation with the dependent variable. The original list of 7 independent variables was reduced to 3 (YEAR, LOG, and SWL). Based on these 3 variables, the regression analyses was used to calculate constants and coefficients expressed in Equation 1.

$$\text{Equation 1:} \quad CI = 13.1475 + (-0.006442 * YEAR) + (-0.091397 * LOG) + (.000558 * SWL).$$

Results of the multiple regression indicated that the physical data could only account for 29 percent of the variation in the contamination index (Appendix E). In addition to accounting for only a small percent of the variation in the contamination index, the analysis of variance for the full regression indicated the results were not statistically significant at the 0.05 level based on the F-ratio (Steele and Torrie, 1960). Consequently, a rating system based exclusively on these independent variables will not adequately predict ground-water contamination near existing oil-field sites. Other variables including the volume of brine discharged, timing of the discharge, and whether the brine was discharged on the land surface or leached out of a reserve pit probably are more directly related to the magnitude of ground-water contamination. The volume, timing, and method of brine discharge are usually not known adequately for quantification. Usually, landowner reports are the only historic information available concerning brine discharges. These reports were proven to be useful for confirming high levels of brine contamination at several sites.

The physical data is probably more useful for developing adequate reclamation methods at new drill sites. The soil permeability, soil texture, surficial geology, and depth to groundwater should all be considered before final disposal of oil-field wastes. Other factors to consider are the distance and relationship of the oil well site to existing surface- and ground-water sources.

RANKING CONTAMINATION POTENTIAL BASED ON PRELIMINARY SITE SURVEYS

Sites could also be ranked for contamination potential based on a combination of available physical data plus field data that are easily collected during a site visit. This approach is most applicable at old oil-field sites.

A stepwise multiple regression analysis was again used to test the influence of several independent variables to the existing contamination. The contamination index from a representative monitor well at each site was set as the dependent variable. The two independent variables (LOG, YEAR) which showed the greatest influence on the regression analysis in the previous section were again used in this analysis. Several possible additional independent variables derived by collecting field data included SURFCON (estimate of the area of surface contamination), EM (measurement of the area of higher than background apparent terrain conductivity), and PRELIMCI (contamination index calculated from field measurements of existing water sources near the oil-field site).

A matrix of correlation coefficients from the dependent and independent variables was examined to test for interdependence between independent variables (Table 11b). The independent variable SURFCON was eliminated based on a high degree of correlation with the independent variable EM. The original list of 5 independent variables was reduced to 4 (YEAR, LOG, EM, PRELIMCI). The final step of the regression analysis was based on these 4 variables, and was used to calculate the constants and coefficients expressed in Equation 2.

$$\text{EQUATION 2:} \quad CI = -6.93566 + (0.23948 * PRELIMCI) + (-0.09490 * LOG) + (0.03842 * EM) + (0.003652 * YEAR)$$

Results of this multiple regression indicate that by combining the physical data with observations from preliminary site visits could account for about 56% of the variation in the contamination index. The analysis of variance for the full regression indicates that the results were statistically significant at the 0.05 level based on the F-ratio (Steel and Torrie, 1960). Consequently, a rating system can predict ground-water contamination at oil-field sites if the independent variables in Equation 2 are determined.

The implications of using this predictive tool are that site specific field data are necessary to estimate ground-water contamination near the oil-field site.

ASPECTS OF RANKING METHODS APPLICABLE TO OTHER AREAS

The predictive equations tested as methods of ranking oil-field sites are valid conceptually but are probably not directly applicable to other areas of oil-field activity. The derived constant and coefficients from the multiple regression are likely to change significantly, even within eastern Sheridan County, as the number of observations are increased.

The approaches that were used for ranking the contamination potential of oil-field sites emphasized locations having reported contamination or visible evidence of surficial contamination. This bias was necessary because the intent to assess the severity of brine contamination in this area required defining the worst sites. Consequently, the results of the field work are probably also biased towards the more contaminated oil-field sites. Bias towards the more contaminated sites is also manifested in Equation 2. Results of Equation 2 will indicate moderately high to high levels of contamination even when little evidence of contamination is indicated by the independent variables. Although the constants and coefficients in the predictive equations are not directly applicable, many of the variables in the regression analysis are probably transferable to other areas. Factors that appear to correlate best with groundwater contamination based on the previous statistical evaluation are variables related to physical properties of near-surface materials, and variables related to methods of waste disposal, and variables related to existing near-surface contamination.

An indicator of the magnitude of ground-water contamination is required in order to rank oil-field sites for contamination potential. The contamination index (field Cl^-/field SC) was used as an indication of brine contamination in order to rank oil-field sites for contamination potential. Other indexes including lab chloride concentration, lab Cl^-/lab SC, lab Cl^-/dissolved solids, lab Cl^-/lab SO_4- would probably have adequately assessed the magnitude of contamination. Many oil fields produce fresh water or brackish water along with the oil. The ratio of field Cl^- to field SC may not be the best indicator of ground-water contamination in both fresh and brackish water oil fields. Naturally elevated chloride concentrations in shallow aquifers may also diminish the value of this ratio as an indicator of contamination. The chemistry and toxicity of the specific oil-field wastes in the area of interest must be understood prior to developing ranking methods. Specific oil-field wastes may include drilling fluids and cuttings, waste hydrocarbons and produced water.

A variable that relates to the physical properties of the near-surface materials is required to rank oil-field sites for contamination potential. Examples of these variables include mapped values of soil permeability (PERM,LOG), soil classification (UNICODE) and geologic source (GEO). If maps are unavailable, on-site description of the near-surface materials could be used to develop a classification system.

A variable that relates to the method of waste disposal commonly used when the oil-field site was active is required to rank oil-field sites for contamination potential. An example of this variable is the year a site was drilled (YEAR). The variable YEAR relates to disposal method because prior to 1975 there were few regulations addressing oil-field waste disposal. As a result, brine discharges and poor methods of waste disposal were more common before 1975 than after 1975.

One or more variables that assess the existing contamination at the oil-field site is necessary to develop a site ranking system. Examples of these variables are the area of surface contamination based on soil and vegetation damage (SURFCON), the area of higher than background apparent terrain conductivity (EM), and a contamination index (PRELIMCI) based on samples from water sources adjacent to the oil-field site.

Other variables including depth to ground water, vertical flow gradient (both direction and magnitude), volume of waste discharged, and timing of waste discharge may be significant indicators of ground-water contamination. All of these variables are difficult to quantify especially for screening a large number of sites.

RECLAMATION, MITIGATION, AND IMPROVED DISPOSAL MANAGEMENT

Several options are available for reclaiming some of the more contaminated sites, mitigating impacts of future brine disposal, and in general making environmentally sound decisions to improve the methods of oil-field waste disposal.

RECLAMATION OPTIONS FOR EXISTING SITES

Reclamation strategies should be developed at sites that have a high potential for contaminating water resources. The available options can only be developed on the basis of detailed hydrogeologic investigations. The variability of site specific hydrogeologic conditions prevents the development of generic reclamation methods that can be universally applied at all sites. Possible reclamation options include:

1. Determine Significance of Contamination

Assess the potential for migration of contaminants into water supplies. If the potential for contamination is low, additional reclamation may not be warranted. Field inspections test drilling, and water sampling may be required to determine the significance of contamination.

2. Limit Recharge

Install a clay cap or revegetate the land surface overlying a reserve pit or other source of salts. The purpose of this option is to isolate the contamination source above the water table by preventing infiltration of precipitation. Preventing infiltration of precipitation would be most effective at sites underlain by low-permeability materials. Lateral ground-water flow rates at these sites are low. Preventing infiltration through the pits would effectively isolate salts from being mobilized.

3. Construct Grout Curtains

Construct grout curtains around the site to prevent off-site migration of the salts. Grout curtains would be most effective at sites underlain by relatively high-permeability materials dominated by lateral ground-water flow. Grout curtains would form "underground dams" downgradient of the site preventing off-site migration of salt-laden ground water.

4. Install Recovery Wells

Install a series of recovery wells to remove contaminated ground water. Recovery wells would be most effective at sites underlain by relatively high-permeability materials capable of supplying adequate quantities of water to the collector wells. Contaminated water pumped from the recovery wells would be injected into salt-water disposal wells. The removal of salt could be enhanced by flood irrigating the land surface overlying source areas of salts.

5. Excavate and Wash Salt-Saturated Materials

Salt would be removed from the waste materials by washing with fresh water and centrifuging to separate the salt water from the sediment. The waste water would be injected into salt-water disposal wells and the inert waste solids would be reburied at the site.

6. Backfill Existing Water-Filled Pits

Open pits filled with water and waste oil are located at several oil-field sites. Many of these pits are unlined or have ripped liners. The apparent but ineffective purpose of these pits is to contain accidental discharges of brine or hydrocarbons. In addition, precipitation and runoff accumulates in the pits increasing recharge potential through salt-saturated materials. Backfilling and capping these pits will prevent off-site migration of salts by reducing the recharge potential.

7. Test the Integrity of Collector Pipelines

Many miles of salt-water pipelines collect production water and transport it to tank batteries and disposal wells. Integrity tests are periodically conducted by the EPA on the disposal wells. The collector pipelines are not tested for leaks and create a potential for large volume brine discharges.

8. Centralized Disposal

Remove salt-saturated solids from critical sites and dispose waste material at a centralized disposal facility. Critical sites can be identified by existing contamination or high potential for producing contamination. Sites could be designated critical based on site specific properties such as a large volume of salts confined in a relatively small area, high water table, proximity to water wells, proximity to irrigated land, proximity to surface-water bodies, proximity to springs or seeps, and proximity to shallow outwash aquifers.

Centralized disposal is currently not a viable option for site cleanup because no appropriate disposal facilities have been developed in Montana.

DISPOSAL OPTIONS FOR NEW SITES

Possible disposal options at new drilling sites should be developed on the basis of surface conditions and the physical properties of near-surface materials to a depth of 10 feet to 15 feet. Many of these factors can be determined by evaluating existing data, but the adequacy of an oil well site for on-site disposal should be based on an inspection of either bore hole cuttings or a backhoe pit examining the texture and stratigraphy of materials at least as deep as the projected base of the reserve pit. Layers of sand, gravel or other permeable materials would trigger consideration of alternative disposal methods and may prohibit final disposal of oil-field wastes at the drilling location.

Reducing the volume of salt-saturated oil-field wastes may be a possible method of preventing future contamination while minimizing reclamation costs (Lal and Thurber, 1989). Fresh-water drilling fluids could be disposed of prior to the conversion to salt-water drilling fluids. Surface runoff could be diverted to prevent flow into reserve pits. Drilling fluids could be recycled by reusing the fluids at another drilling location.

Reserve pits should all be lined with a heavy plastic liner. The liner should be intact throughout the drilling and completion of the oil well. Care should be taken to prevent damage to the liner during the operation and reclamation of the reserve pit.

Disposal Options for Sites Underlain by High-Permeability Materials

At drilling sites that are underlain by high-permeability materials several disposal options are available to reduce or prevent off-site salt-water contamination. In all cases, the decanted fluids are separated from the waste solids and injected into disposal wells. Possible reclamation options for the remaining waste includes:

1. Haul the waste to a centralized disposal facility. This is the best option at critical sites but is not viable today because no disposal facilities are operating in the state.
2. Use above ground tanks and containers to isolate drilling fluids. Reserve pits are not required using this method. Drilling fluids could be recycled for use at another drilling location, disposed of at a centralized facility, if available, or washed prior to on-site burial.
3. Solidify pit by mixing mud with fly ash, lime, and small amounts of portland cement. The pit liner is left in place during this process but it is easily breached while mixing the solidifying materials with the pit mud. Following mixing the liner is folded over the top of the pit to reduce recharge into the solidified drilling mud. Solidification is best suited at sites with deep water tables and limited recharge.
4. Wash salt out, de-water (centrifuge) and bury drilling waste solids. Several washings may be required to reach adequately low salt concentrations in the waste

materials. The waste water would be disposed of in injection wells.

Disposal Options for Sites Underlain by Low-Permeability Materials

At drilling sites that are underlain by low-permeability materials the lower ground-water flow rates help to reduce the potential for contamination. The decanted fluids must be separated and injected into a disposal well. Possible reclamation options for the remaining wastes include:

1. Dilute by blowing in dry inert soil and covering with the plastic liner and cover with topsoil.
2. Construct trenches radially away from the pit and push the pit mud into the trenches. Trenching is the typical method of reclamation used in this area. There probably are many locations underlain by low-permeability materials and deep water tables where this method remains a viable disposal option.

ESTIMATED COSTS OF OIL-FIELD WASTE DISPOSAL

The actual cost of oil-field waste disposal depends on the volume of both the liquid and the solid wastes and the specific disposal method(s) selected. Estimated costs of several methods of reserve pit reclamation are listed in Table 12.

Trenching and levelling a reserve pit is usually preferred by most oil companies because of relatively low costs, familiarity of local service companies with this disposal method, and relatively short amount of time required for reclamation.

Table 12. Estimated costs of oil field waste disposal and reclamation.

Reclamation Method	Estimated Costs
Trench and level pit (1)	$2,500-$3,000
Blow in pit (1)	$2,600
Central disposal (1)	$13,000-70,000
Hauling	$10,000-60,000+
Disposal	$3,000-8,000
Solidify Pit (1)	$19,000
Dewater drilling mud (1)	$2,000-8,000
Capping with clay (2) (.90/cu. yd. if fill is available)	
1 acre covered with 2 ft	$2,904
1 acre covered with 3 ft	$4,356
Salt water disposal (3)	$0.25/barrel

Sources:

(1) Ed Murphy, North Dakota Geological Survey, Bismarck, ND
(2) Sheridan County Conservation District, Plentywood, MT
(3) Charles Devaney, Big M Oil Field Service, Plentywood, MT

Trenching and levelling a reserve pit typically costs between $2,500 and $3,000.

Liquid phase wastes are separated from the solid phase wastes prior to reserve pit reclamation to reduce the volume and salt concentration of the waste solids. Disposal of liquid phase wastes into salt-water-disposal wells costs about $0.25 per barrel (42 US gallons), not including hauling charges.

Other reserve pit reclamation methods are typically more expensive and as a result are used less frequently. Blowing sediment into the pit has been successfully tested in western North Dakota and costs about $2,600.00. Solidifying pits has been tested in both Montana and North Dakota and costs about $19,000.00. De-watering drilling mud by using a centrifuge system has been tested in western North Dakota and costs range from $2,000 to $8,000 per well.

Central disposal sites have been operated in North Dakota since 1984. Hauling and disposing drilling wastes to a central disposal site ranges from $13,000 to more than $70,000. The wide range of estimated costs are largely a result of trucking costs. No central disposal sites are currently being operated in Montana. Establishing a central disposal facility would require site approval by the State Department of Health Solid and Hazardous Waste Bureau and by the US EPA. The estimated costs of constructing a 20 acre disposal site would be about $275,000 and annual operations would cost about $52,340.00 (Table 13).

Table 13. Estimated construction and operation costs for a 20-acre central disposal site. (Interstate, Engineering, 1990)

Capital Costs

Land Acquisition	20 Acres	@	$ 500.00/AC	=	$ 10,000.00
Surface Drainage Modification	6,500 C.Y	@	$ 2.00/CY	=	$ 13,000.00
Security Fencing	3,800 FT.	@	$ 3.50/FT	=	$ 13,300.00
Groundwater Well Construction	5 Each	@	$1,200.00/EA	=	$ 6,000.00
Final Reclamation Material	64,500 C.Y.	@	$ 1.00/CY	=	$ 64,500.00
	Estimated Total Improvements				$106,800.00
	Estimated Site Engineering, Geotechnical & Hydrology Study				$ 18,200.00
	Subtotal				$125,000.00

* Equipment

Track Dozer	1 Each	@			$150,000.00
	Estimated Equipment				$150,000.00
	ESTIMATED TOTAL				$275,000.00

* Assumes Independent Hauling to Site

Disposal Site Annual Operation and Maintenance

Site Maintenance	$ 1,000.00
Groundwater Testing	$ 5,000.00
Gate Attendant (4 hrs @ 5 days @ $7.00/hr)	$ 7,280.00
Equipment Operator (312 hrs @ $15.00/hr)	$ 4,680.00
Equipment Depreciation (312 hrs @ $70.00/hr)	$ 21,840.00
Capital Recovery	$ 12,540.00
TOTAL OF O & M	$ 52,340.00

SUMMARY AND CONCLUSIONS

A series of six questions were initially posed focusing on problems related to brine contamination of shallow aquifers by salt-saturated oil-field wastes in eastern Sheridan County. Based on our results these questions can be directly addressed.

1) What is the extent and severity of shallow groundwater contamination in eastern Sheridan County resulting from the disposal of oil-field wastes, primarily drilling muds, and salt-water brines?

There is a wide range of brine contamination in all geologic sources within the study area. The magnitude of brine contamination tends to be higher at sampling sites associated with glacial till than at sampling sites associated with glacial outwash. The contamination is generally expressed by elevated concentrations of all major constituents. Since the brines are typically highly concentrated sodium-chloride solutions, chloride concentration and a contamination index based on the ratio of chloride concentration to specific conductance were used to assess the severity of contamination. The highest chloride concentration measured in till wells was 145,000 mg/L. The highest chloride concentration measured in outwash wells was 92,000 mg/L.

Several trace constituents were significantly higher in water samples contaminated with chloride salts than in uncontaminated water samples. Specific trace constituents that were commonly higher in the contaminated samples includes lead, cadmium, boron, and lithium.

Brine contamination at all oil-field sites extended beyond the furthest downgradient monitoring point. Highly contaminated ground water was identified over 2,000 feet downgradient of one of the sites. This contaminant plume probably extends several thousand feet past this point.

2) Is it possible to develop a broadly applicable, cost-effective methodology for identifying and defining subsurface contamination? The methodology would use existing data or easily collected field data to rank oil-field sites for potential ground-water contamination.

Site ranking methods were tested based on existing data, and easily collected field data using a step-wise multiple regression. The regression analysis based on existing data accounted for only 29% of the variability in the magnitude of contamination. Adding easily collected field data increased the effect of predicting the magnitude of contamination to 56%.

The easily collected field data includes EM surveys and field sampling of existing sources of water. The EM surveys have proven to be a very effective way to define impacts of improperly disposed highly conductive wastes such as oil field brines. These surveys are quick and effective methods for mapping brine plumes in both the vadose zone and in shallow aquifers.

The CI is also a quick and effective method for assessing brine impacts to a source of water. Measurements of specific conductance using a field conductivity meter and chloride concentration using Quantab titrators can be obtained in a few minutes. The resultant ratio of CL/SC (CI) will indicate the level of chloride salts impacting the water sample. In many areas this will directly relate to impacts of oil field brines. In addition, the CI proved to be a very useful means to assess brine plumes in aquifers characterized by increases of salinity with depth (density gradients). The CI tended to remain relatively stable in vertically integrated samples from wells screened in this type of brine plume. As a result of this stability the CI can be used to map the extent of brine contamination using data collected from diverse sampling points with the plumes.

Consequently, site specific field data are necessary to estimate ground-water contamination near an oil-field site. Knowledge of the volume of brine discharged, method of brine discharge, and timing of the brine discharge would probably greatly aid in predicting the magnitude of ground-water contamination. This information is rarely quantified but can often be qualitatively assessed by interviewing local residents. Interviews with local residents resulted in identifying many of the most highly contaminated sites in eastern Sheridan County.

The predictive methods are probably not directly applicable to other areas of oil-field activity but are useful in defining several variables that appear to help predict the magnitude of contamination. Important factors that correlate best with ground-water contamination are variables related to physical properties of near-surface materials, variables related to methods of waste disposal, and variables related to existing near-surface contamination.

3) Where are areas of existing contamination located?

Areas of existing contamination are generally located near facilities that have handled large volumes of brine. Sites that were active prior to 1975 are typically contaminated to a greater extent than sites that were constructed after 1975. Disposal of large volumes of produced water on the land surface and in unlined disposal ponds prior to 1975 caused much of the contaminated ground water. Aerial photos taken in the late 1960's identified water filled pits near a majority of drilling locations in the Goose Lake Field. The average reserve pit size in the air photos is estimated to be 50 feet wide, 100 feet long, and 10 feet deep. Based on a conservative average chloride concentration of 100,000 mg/L, approximately 260 tons of sodium chloride salts would have been dissolved in each pit.

The volume of brine currently being disposed at oil well sites is relatively small. Trenching reserve pits continues to be the most common method of drilling mud disposal. This disposal method can greatly increase the potential for ground-water contamination.

Another potentially large volume source of uncontrolled discharges of produced water is from pipeline leaks. Tens to hundreds of miles of salt-water pipelines are located in eastern Sheridan County. The US EPA currently tests the integrity of disposal wells but the pipelines transmitting the salt water to tank batteries and disposal wells are not tested.

4) Can future contamination be reduced or eliminated by using alternative disposal practices?

Environmentally sound disposal methods must be developed and routinely used to prevent future contamination. Several possible alternative disposal methods are proposed. All of the methods are based on an assessment of potential ground water contamination from field tests at each drilling site.

Field tests should emphasize examining the texture and stratigraphy of materials at least as deep as the projected base of the reserve pit. Layers of sand, gravel or other permeable materials would trigger consideration of alternative disposal methods and may prohibit final disposal of oil-field wastes at the drilling location.

5) What are some of the alternative disposal methods available?

Reclaiming reserve pits by trenching continues to be the most common method of waste mud disposal, although this method can increase the potential for ground-water contamination. Several alternative methods for disposing of spent drilling fluids have been tested in the North Dakota portion of the Williston Basin (Murphy, 1991 written communication). Alternative disposal methods include blowing inert sediment into the pit, hauling waste drilling mud to a central disposal site, pit solidification, and dehydration of drilling wastes using a centrifuge system. Blowing sediment into the pit is preferred over trenching for two reasons: the liner is left intact; and the dry inert sediment dilutes the volume of salt-saturated drilling mud. Hauling the mud to a centralized disposal facility removes the salt hazard from the drilling site by transferring the wastes to a properly controlled location. No centralized disposal facilities currently exist in Montana but local interest is growing to develop a properly engineered central disposal site that could handle large volumes of waste muds without causing environmental damage. Pit solidification produces hard irregular blocks that resist salt dissolution. Leaching of salts from the waste material is reduced but not eliminated. One drawback of this method is that mixing is typically conducted using the bucket of a track hoe and the plastic liners are frequently damaged. Drilling wastes can be de-watered using a centrifuge system to separate the solid phase from the liquid phase. Liquid wastes can be disposed of down an injection well and the solid wastes buried at the drilling site. Further washing with freshwater would remove additional salts from the waste mud. This process would both reduce the volume of salt-saturated sludge and remove the salt-saturated liquid that is likely to migrate into the ground water.

6) What would these alternative disposal methods cost?

Estimated costs of alternative disposal methods are shown in Table 12. The costs of disposal methods such as blowing sediment into the pits, and de-watering the muds are similar to the cost of trenching a reserve pit. Pit solidification costs are approximately an order of magnitude higher than trenching costs. Central disposal costs range from about 6 times to more than 30 times trenching costs depending on the hauling distance.

Conditioning drilling muds by alternative mud systems that use additional filters to clean the mud can potentially reduce drilling costs and reduce the volume of drilling wastes (Murphy, written communication, 1991). Conventional mud systems require periodic dumping of drilling fluid in the reserve pit when it becomes too sandy or silty. Waste volumes are significantly reduced by this process leaving only mud coated drill cuttings for disposal. The remaining drilling fluids can be recycled potentially saving the operator from $35,000 to $100,000 a well by reducing costs of mud additives and salt-water transportation.

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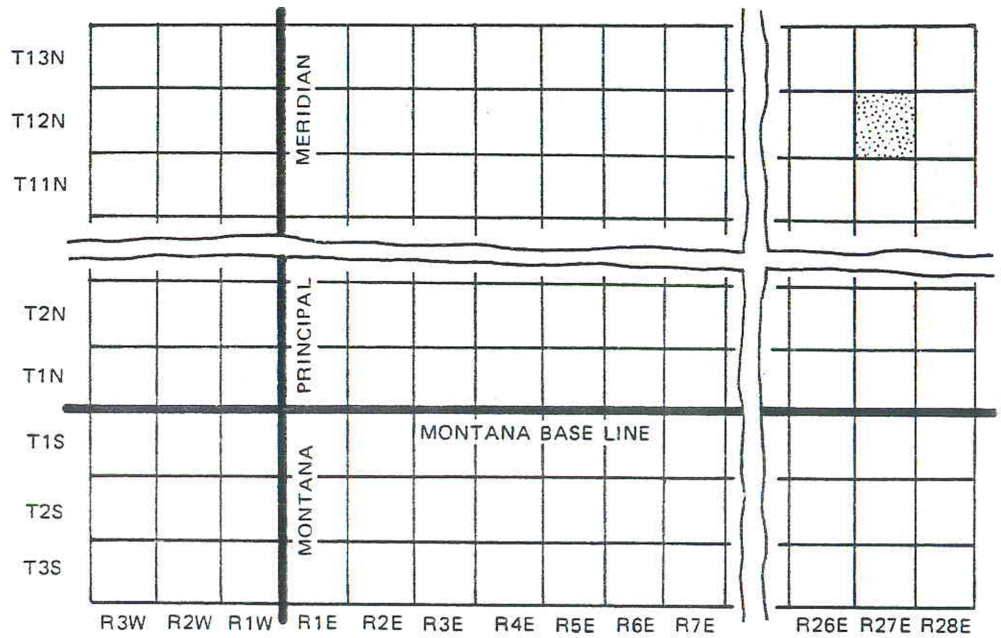
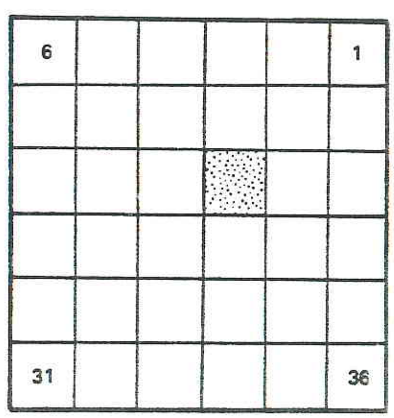
APPENDIX A

The Site Location System described below is taken from an informal publication of the Montana Bureau of Mines and Geology and acknowledgment of the source of this information is hearby made.

The location of objects in Montana (such as wells, springs, ponds, etc) is referenced to the legal subdivisions of public lands by township, range, section and quarters of sections. Thus a site description of T. 12 N., R. 27 E. designates a particular township, 6 miles on a side, that lies 12 townships north of the Montana Base Line and 27 townships east of the Montana Principal Meridian.

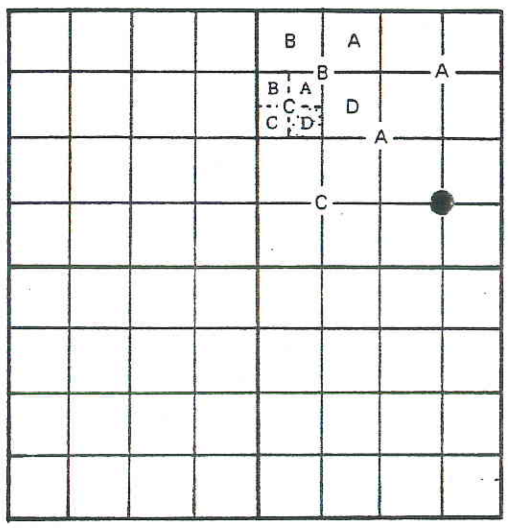


Each township is subdivided into 36 sections as follows:



T. 12 N., R. 27 E. Section 15 describes a tract of land one mile square.

The subdivision of a particular section into quarters, however, departs from legal usage in that the letters A, B, C, and D are used for the NE, NW, SW, and SE quarters respectively. Additionally the quartering of a section in the Site Location System begins with the largest quarter (the 160-acre tract) then proceeds to the 40-acre tract, the 10-acre tract, and the 2.5-acre tract. If, for example, a well site is described as Section 15ABCD T. 12 N., R. 27 E., the location of that well is in the SE of the SW of the NW of the NE quarter of section 15, township 12 north, range 27 east. In the sequence ABCD, the first letter (A) describes the NE quarter, the second letter (B) calls out the NW quarter of the NE quarter, the third letter (C) calls out the SW quarter of the NW quarter of the NE quarter, and the fourth letter (D) calls out the SE quarter of the SW quarter of the NW quarter of the NE quarter. An example is illustrated below. The oil and gas industry commonly locates drilling sites in the center of a tract designating the center as X.



T. 12 N., R. 27 E. Section 15 ABCD describes a tract of land containing 2.5 acres.

T. 12 N., R. 27 E., Section 15 ADX describes a point in the center of the NE quarter of Section 15.

APPENDIX B

EXPLANATION FOR MAPS IN APPENDIX B

ORIGINAL SITE OF OIL WELL OR INJECTION WELL

TANK BATTERY

MONITOR WELL

TEST HOLE

SURFACE WATER MONITORING SITE

EM CONDUCTIVITY GRID POINT

X CENTER OF CONTAMINATION SOURCE

100 ISOCONDUCTIVITY LINE; DASHED WHERE INFERRED

CI CONTOUR INTERVAL

AXIS OF SURFACE DRAINAGE

APPROXIMATE LOCATION OF RECLAIMED OR BACKFILLED RESERVE/EVAPORATION

GROUND WATER FLOW DIRECTION

LOCATION AND LEASE INFORMATION

SITE #67
H. OSKSA #1
TOWNSHIP 35N., RANGE 58E., SECTION 08DDDB01
ELEVATION = 2142 FEET
TADPOLE LAKE QUAD
OGC #63PO3182

SITE DESCRIPTION

The site is an oil well drilled in 1963 to a depth of 7320 feet in the Goose Lake Field. The production interval is from 6935 to 6942 feet in the Ratcliffe zone of the Charles Formation. It has been reported that over 1 million barrels of oil have been produced from this well operated by Sun Oil Company. The site includes an active pumper, storage tanks, flare pit, and two reclaimed evaporation pits. Currently, it serves as a collection point for several other wells. The site is on a flat knob in hummocky terrain. Near surface materials are glacial till. Ground water within the till is under confined conditions. The soil type is Williams-Zahill loam; SCS permeability ranges from .2 to 2 inches per hour; the grain size of more than 90% of a soil sample is less than .42 mm; the soil is classified CL in the SCS Unified system.

CONTAMINATION REPORT

Evidence of saltwater damage includes bare patches of ground, salt tolerant vegetation and salt crystals on the soil surface. Two evaporation pits were used for brine disposal from initial production in 1963 until about 1975. One of the evaporation pits was reported to be located to the east of the current flare pit. Contamination was reported to have occurred since the early 1960's consisting mostly of seepage from unlined pits, pit overflow and spillage of saltwater. Area of visible surface damage covers about 1.3 acres.

SITE EVALUATION

An EM-31 conductivity survey identified an elliptical shaped region of high apparent conductivity, trending WNW to ESE. The area of higher than background apparent conductivity covers about 2.5 acres. The highest conductivity value measured was 380 mmhos/m located near the fence line east of the flare pit, possibly identifying a reclaimed evaporation pit. The region of high conductivity follows the axis of a minor drainage to the east across the county road. The site is bounded by background apparent conductivities ranging from 50 to 90 mmhos/m (average 80 mmhos/m). Background conductivity readings were low over a down-gradient slough, implying little impact away from the site.

Two monitor wells were installed and screened in glacial till. Well 67A is 43 feet deep and well 67B is 42 feet deep. The bottom 5 feet of each well was screened. Ground water in the till is under confined conditions. The potentiometric surface is about 6 to 10 feet below land surface and the direction of groundwater flow is towards the east.

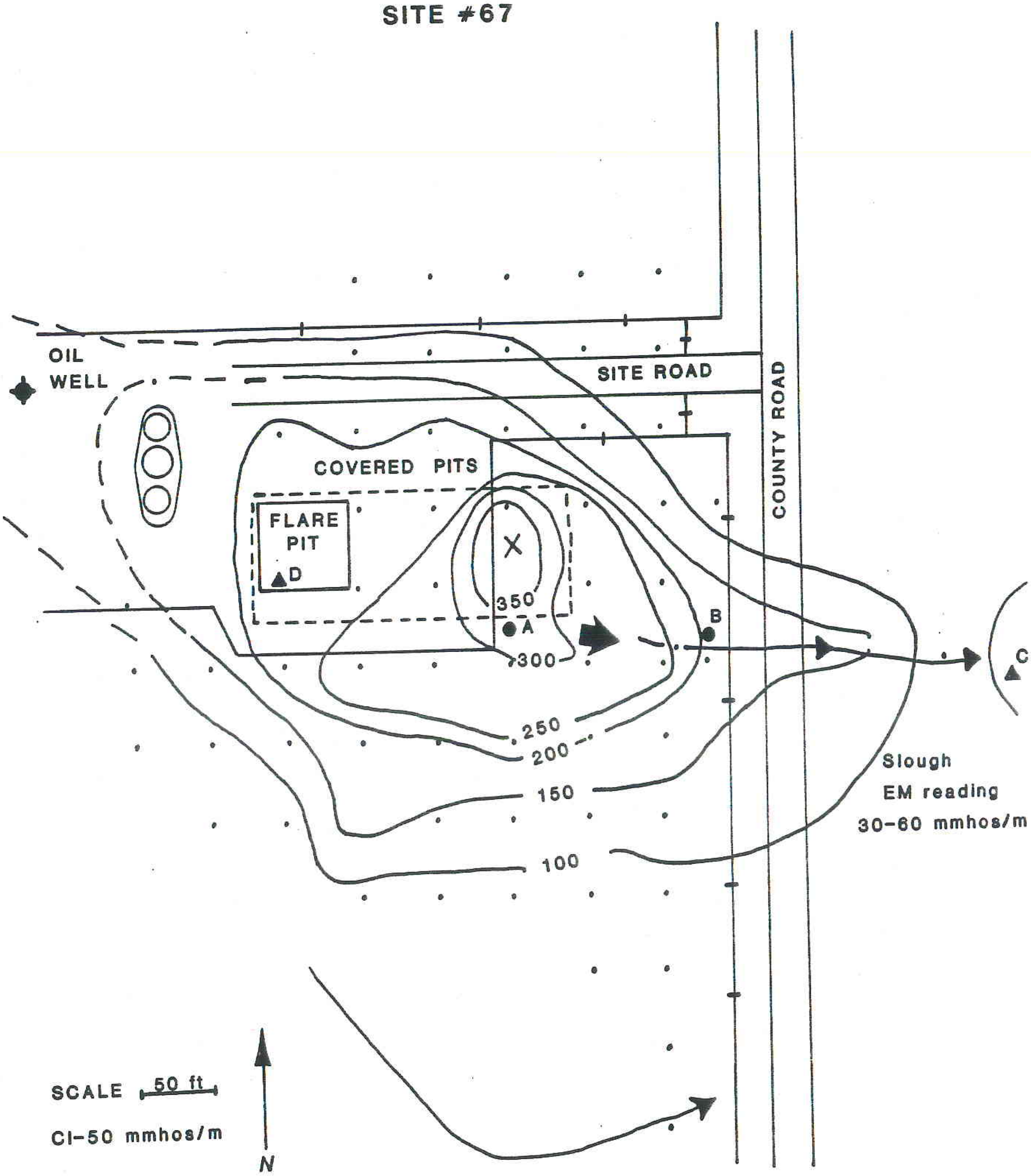
Both monitor wells are located in areas of high apparent terrain conductivity. Well 67A is located close to a reclaimed evaporation pit and well 67B is about 135 feet downgradient of well 67A. The values of field parameters at this site are listed in Table 7 and the average values are summarized below.

Site Number	Type of site	Distance from Contamination Source (ft)	Depth to Potentiometric Surface (ft)	Chloride Concentration (mg/L)	Specific Conductance umhos/cm	Chloride Salt Contamination Index
67A	Well	50	10	91,000	130,000	.700
67B	Well	135	6	38,000	65,000	.585
67C	Slough	325		<50	260	.192
67D	Pit			275	700	.393

A water quality analysis from well 67B (Lab No. 89Q0485) reported dissolved solids of 46,700 mg/L and chloride concentration 30,200 mg/L (Table 8).

The observed contamination appears to verify reports of brine overflowing pits, brine seeping out of unlined pits and numerous brine spills. Although the extent of ground-water contamination was not determined, high salt concentrations were identified more than 100 feet downgradient of the original evaporation pits.

SITE #67



OIL
WELL
SITE ROAD
COUNTY ROAD
COVERED PITS
FLARE
PIT
D
X
350
A
300
B
C
250
200
150
100
Slough
EM reading
30-60 mmhos/m
SCALE
50 ft
Cl-50 mmhos/m
N

LOCATION AND LEASE INFORMATION

SITE #79
C.W. NELSON #1
TOWNSHIP 35N., RANGE 58E., SECTION 17ADAC
ELEVATION = 2104 FEET
TADPOLE LAKE QUAD
OGC #64P03187

SITE DESCRIPTION

The site is an oil well drilled in 1964 to a depth of 7049 feet in the Goose Lake Field. The production interval is from 6925 to 6927 feet in the Ratcliffe zone of the Charles Formation. Signal Oil Company drilled this well and it is currently operated by Apache Oil Company. The site includes an active pumper, a lined emergency pit, an unlined emergency pit, and a tank battery. The well is located in a shallow swale. A dike was constructed upgradient of the well and pipe set to transmit water across the swale and avoid ponding at the well site. Topography is hummocky sloping towards the south. Near surface materials are glacial till. The soil type is Zahill clay-loam; SCS permeability ranges from .6 to 2 inches per hour; the grain size of more than 90% of this soil is less than 0.42 mm; the soil is classified CL in the SCS unified system.

CONTAMINATION REPORT

Evidence of saltwater damage includes bare patches of ground, salt tolerant vegetation, salt crystals on the soil surface, and dead trees. The dead trees were part of a shelterbelt south of the site. It appears that a combination of surface spills and seepage has killed trees in a swath about 150 feet wide covering about 1/3 acre. Two large pits were used for saltwater disposal from 1964 until the mid-1970's. Contamination was reported to have consisted mostly of seepage of saltwater from unlined pits, pit overflow, and spills. Evidence of surface damage to soils and vegetation covers about 3.7 acres.

SITE EVALUATION

An EM-31 conductivity survey identified an irregular shaped area of higher than background conductivity covering about 6.5 acres. The highest conductivity measured was 460 mmhos/m about 150 feet northeast of the oil well, possibly over a reclaimed evaporation pit. The site is bounded by background conductivities ranging from 50 to 100 mmhos/m (average = 90 mmhos/m). A tongue of high conductivity readings extends from the existing pits down slope towards the dead trees southwest of the pits.

Three monitor wells were installed in glacial till. Well 79A is 23 feet deep, well 79B is 36 feet deep, and well 79C is 28 feet deep. Well screen was set in the bottom 5 feet of each well. Ground water in the till is under confined conditions. The potentiometric surface is about 4 to 12 feet below land surface and the direction of ground-water flow is towards the south.

Well 79C and 79A are located in areas of high apparent terrain conductivity. Well 79B is located in an area with background apparent terrain conductivity of about 50 mmhos/m. Wells 79B and 79E are about 220 feet and 50 feet upgradient of the reclaimed pits and well 79A is about 250 feet downgradient from the pits.

The values of field parameters measured at this site are listed in Table 7 and the average values are summarized below.

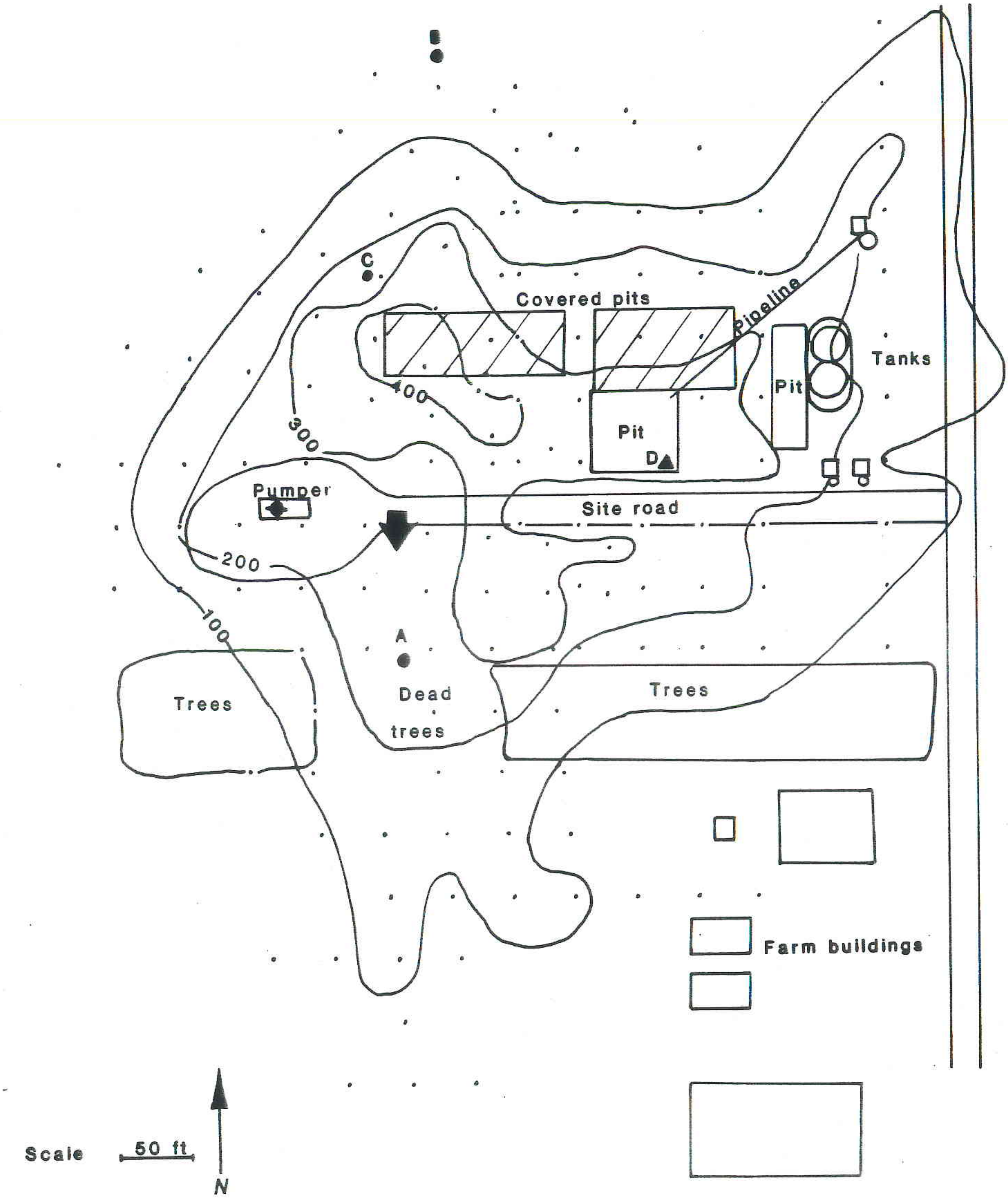
Site Number	Type of site	Distance from Contamination Source (ft)	Depth to Potentiometric Surface (ft)	Chloride Concentration (mg/L)	Specific Conductance umhos/cm	Chloride Salt Contamination Index
79A	Well	250	4	78,000	132,000	.591
79B	Well	220	12	170	5,200	.032
79C	Well	50	5	59,000	109,000	.541
79D	Pit			3,240	3,780	.857

Results of water quality analyses from wells at this site are listed in Table 8 and are summarized below.

Well Number	Lab Number	Dissolved Solids (Mg/L)	Chloride Concentration (Mg/L)
79A	89Q0486	103,000	65,800
79B	89Q0487	4,800	81
79C	89Q0488	77,630	46,400

The observed contamination appears to verify reports of brine overflowing pits, brine seeping out of unlined pits, and numerous brine spills. The extent of ground-water contamination was not determined but strongly contaminated ground water was identified 250 feet downgradient of the original evaporation pits.

SITE #79



Cl-100 mmhos/m

LOCATION AND LEASE INFORMATION

SITE #82
HEREIM #1
TOWNSHIP 35N., RANGE 58E., SECTION 18CADB01
ELEVATION = 2162
TADPOLE LAKE QUAD
OGC #63P03187

SITE DESCRIPTION

Site is an abandoned injection well that was drilled in 1963 to a depth of 7355 feet in the Goose Lake Field. Production intervals were from 6988 to 6991 feet and 7001 to 7003 feet in the Ratcliffe zone of the Charles Formation. The well was converted into an injection well in July, 1967. Signal Oil Company operated the well until it was plugged and abandoned on 5/16/88. The site is abandoned and reclaimed. The topography is gently rolling, sloping north towards an outwash channel. Near surface materials are glacial till. Soil type is Williams-Zahill loam; SCS permeability ranges from .2 to 2 inches per hour; the grain size of more than 90% of a soil sample is less than .42 mm; the soil is classified CL in the SCS unified system.

CONTAMINATION REPORT

Very little evidence of saltwater damage is apparent at this site. Surface damage was difficult to assess because the land was in summer fallow. Soil discoloration and salt crusts were visible over about 1 acre. Contamination was reported to have been leakage from damaged casing of the injection well. The leak was reportedly about 50 feet below ground level. In 1983 the Environmental Protection Agency shut down the injection well because of the casing leak.

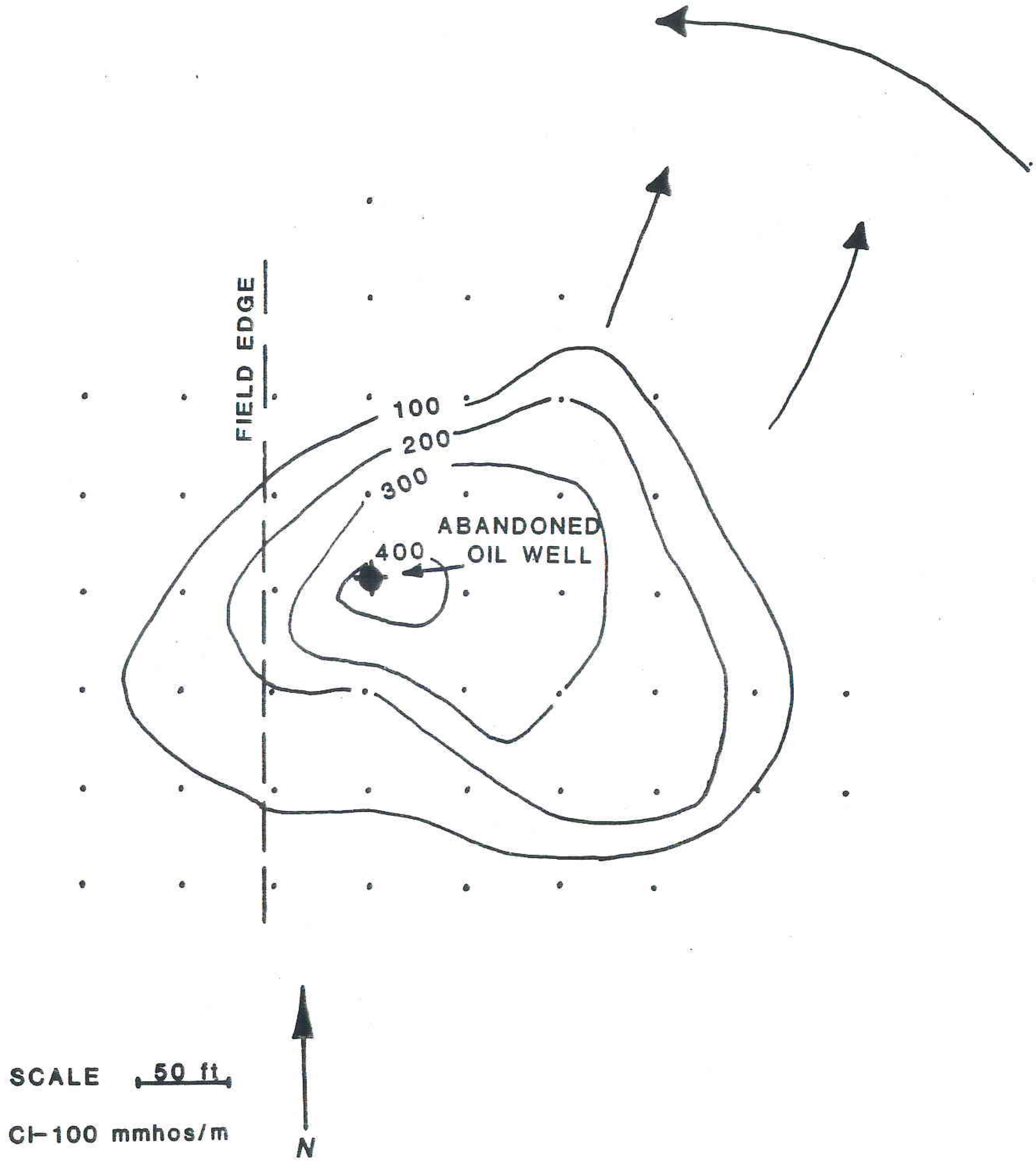
SITE EVALUATION

An EM-31 conductivity survey identified a roughly circular area of higher than background apparent conductivities covering about 1.5 acres. The highest conductivity value was 400 mmhos/M near the middle of the site, probably centered over the abandoned well. The site is bounded by background apparent conductivities ranging from 50 to 90 mmhos/m (average = 70 mmhos/m).

No wells were installed or water samples collected near this site.

The circular shape of the terrain conductivity anomaly is consistent with a saltwater plume moving radially away from a leaky injection well.

SITE #82


FIELD EDGE
100
200
300
400
ABANDONED
OIL WELL
SCALE
50 ft
Cl-100 mmhos/m
N

LOCATION AND LEASE INFORMATION

SITE #83
PETERSEN #1
TOWNSHIP 35N., RANGE 58E., SECTION 19ADAC
ELEVATION = 2228 FEET
TADPOLE LAKE QUAD
OGC #62P03177

SITE DESCRIPTION

Site is an oil well drilled in 1962 to a depth of 7205 feet in the Goose Lake Field. The production intervals are from 7084 to 7086 feet and 7105 to 7107 feet in the Charles Formation. Signal Oil Company operates the well. The site includes an inactive pumper, a water filled flare pit, and a tank pad with the storage tanks removed. Topography is undulating with an irregular gully draining towards the southeast. Near surface materials are glacial till. The soil type is Williams-Zahill loam; SCS permeability ranges from 0.6 to 2.0 inches per hour; grain size of more than 95% of this soil is less than 0.42 mm; the soil is classified CL in the SCS unified system.

CONTAMINATION REPORT

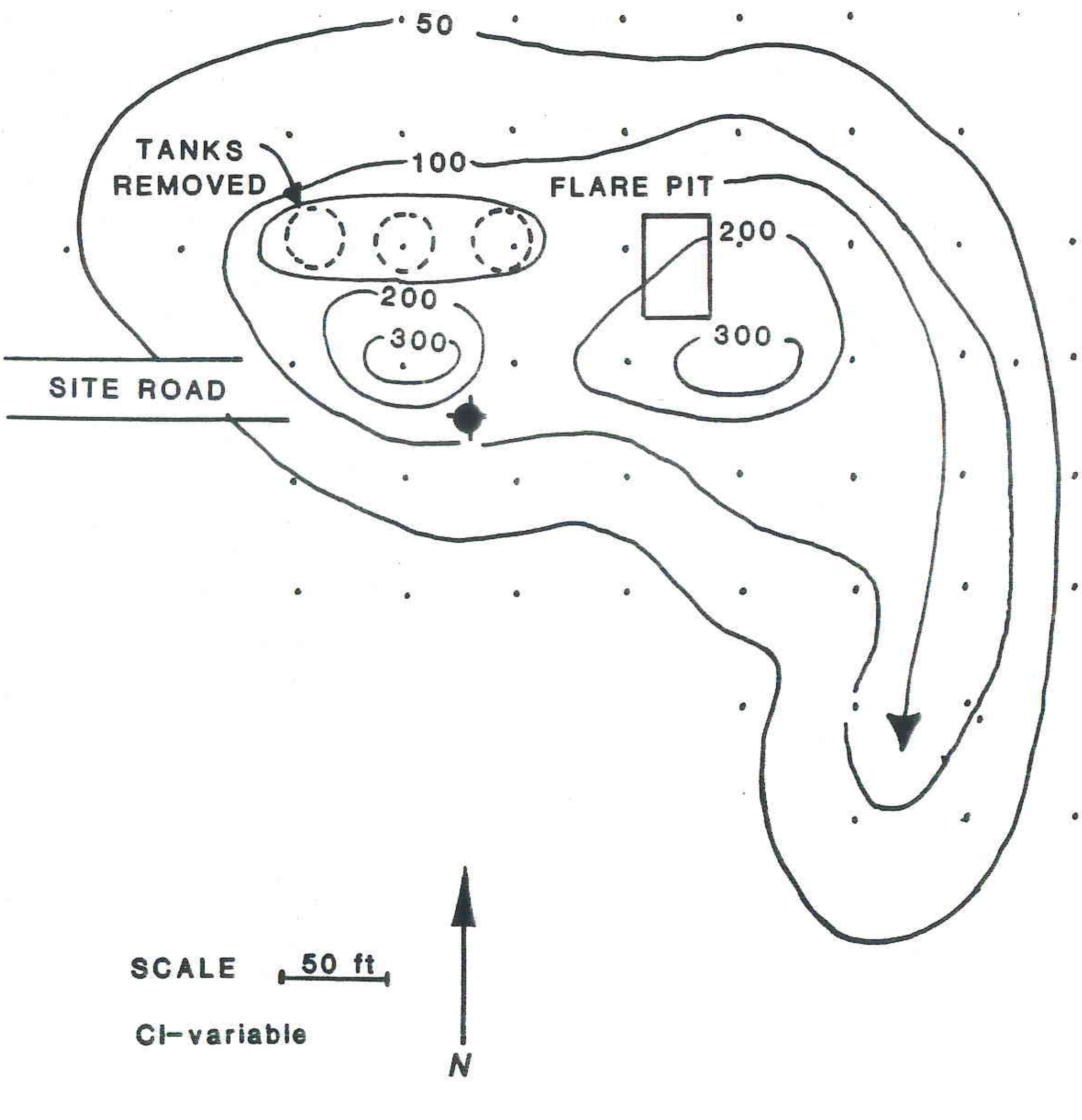
Evidence of saltwater damage includes bare patches of ground, salt crystals on the soil surface, and dead trees 1/4 mile downgradient of the site. Leakage and overflow of evaporation pits and storage tanks were reported to have occurred in the late 1960's and early 1970's. About 1.4 acres of land has been damaged near this site.

SITE EVALUATION

An EM-31 conductivity survey identified an L-shaped area of higher than background apparent conductivity covering about 1-1/2 acres. Two areas of very high conductivity (>300 mmhos/m) were identified; one northwest of the well pad and another larger area about 60 feet east of the well pad. The site is bounded by background apparent conductivities ranging from 40 to 50 mmhos/m (average = 50 mmhos/m).

No wells were installed or water samples collected near this site. The elongate down slope shape of the conductivity anomaly is consistent with the reported saltwater spills.

SITE #83



50
100
200
300
200
300
TANKS REMOVED
FLARE PIT
SITE ROAD
SCALE 50 ft
Cl–variable
N

LOCATION AND LEASE INFORMATION

SITE #117
CARL HAMMER #4
TOWNSHIP 36N., RANGE 58E., SECTION 22CBDB
ELEVATION = 2134 FEET
WESTBY SOUTH QUAD
OGC #67PO2526

SITE DESCRIPTION

Site is an oil well drilled in 1967 to a depth of 6889 feet in the Goose Lake Field. The production interval is from 6778 to 6780 feet in the Ratcliffe zone of the Charles Formation. Signal Oil Company operated this site until it was abandoned and reclaimed in about 1986. The main site is near the top of a hill in hummocky terrain. It is drained by a coulee towards the southeast ending in an outwash channel containing several small sloughs. A small earth filled dam immediately below the site was apparently constructed to hold waste water from flowing towards the first slough nearly 1/2 mile away. Near surface materials are glacial till at the old well site with outwash sand and gravel overlying till near the slough. At the main site the soil type is Zahill-Williams loam; SCS permeability is 0.2 to 2.0 inches per hour; the grain size of more than 90% of the soil is less than 0.42 mm; the soil is classified CL in the SCS unified system. Soils near the downgradient slough are Wabek gravelly sandy loam; SCS permeability is greater than 20 inches per hour; the grain size of between 15 to 40% of the soil is less than 0.42 mm; the soil is classified GM by the SCS unified system. The well was converted to injection in 1973.

CONTAMINATION REPORT

Evidence of saltwater damage includes bare patches of ground, salt crystals on the soil surface, gumbo soils, and high chloride levels in a down-gradient dugout. About 4.6 acres of land nearby and down slope of the site appears to have been contaminated. The source of contamination has been reported to be from a leaking saltwater pipeline, seepage of brine from evaporation pits and breaching a small earth-filled dam. A saline seep below the main site may have been impacted by brines degrading the soil structure. In appears that much of the saltwater flowed overland until more permeable soils near the downgradient slough allowed infiltration to the water table.

SITE EVALUATION

An EM-31 conductivity survey identified an area of higher than background conductivities covering about 5.5 acres. Several areas of high apparent conductivities at the main site may overlie reclaimed evaporation pits. The highest terrain conductivity was measured within the dry reservoir. A swale about 500 feet south of the main site appears to indicate impacts of a saline seep combined with impacts of overland flow of brines. The main site is bounded by background apparent conductivity values ranging from 25 to 60 mmhos/m.

Four monitor wells were installed at this site. Well 117A (43 feet deep), well 117B (38 ft deep) and well 117C (43 ft deep) were installed in glacial till. Well 117D (8 ft deep) was installed in thin glacial outwash. Water from a dugout (117E), an intermittent slough (117F), and a small dam (117G) were also monitored during the study. An additional monitor well, 117J (15 feet deep) was installed in outwash 3,500 downgradient of the former oil well as part of a more detailed investigation of brine contamination in the Goose Lake field. Field water samples were also collected from two private wells 117H and 117I.

Well screen was set in the bottom 5 feet of each well. Water in the till is under confined conditions. The average potentiometric surface was above ground level in 117B and 117C and was 4 feet below land surface at 117A. Water in the outwash is under unconfined conditions. The average depth to water at 117D was about 4 feet during the study. The direction of ground-water flow is towards the southeast and east.

All of the wells were installed in areas having high apparent terrain conductivity. The values of field parameters measured at this site are listed in Table 7 and the average values are summarized below.

Site Number	Type of site	Distance from Contamination Source (ft)	Depth to Potentiometric Surface (ft)	Chloride Concentration (mg/L)	Specific Conductance umhos/cm	Chloride Salt Contamination Index
117A	Well	125	4	72	3,780	.019
117B	Well	515	-1*	<45	2,840	.016
117C	Well	1,015	-7*	<45	1,960	.023
117D	Well	1,720	4	2,530	7,200	.351
117E	Dugout	1,800		4,530	13,700	.331
117F	Slough	1,850		450	2,080	.216
117G	Dam	250		100	750	.133

* (-) indicates feet above land surface

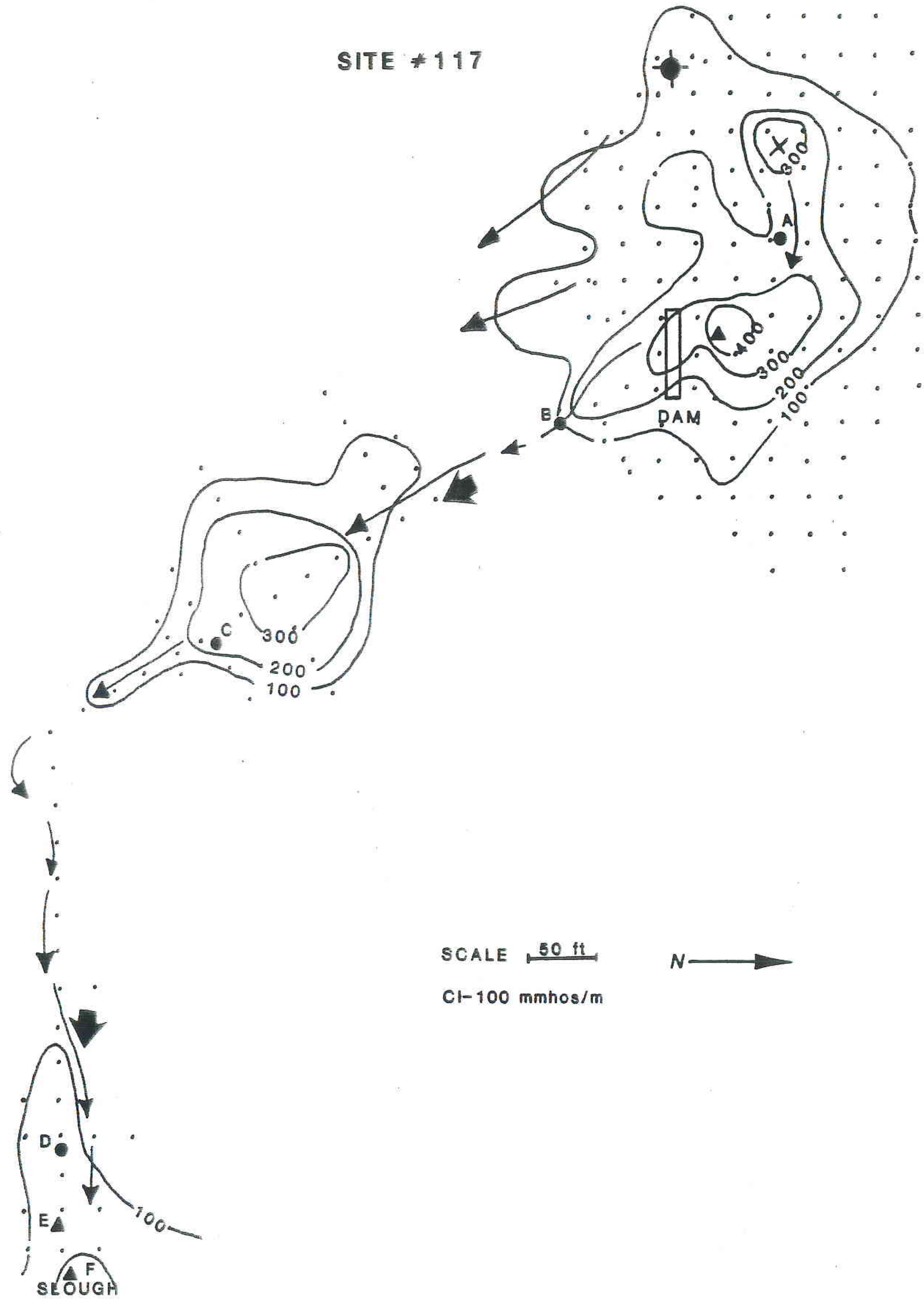
Results of water quality analyses from wells at this site are listed in Table 8 and are summarized below.

Well Number (sample date)	Lab Number	Dissolved Solids (Mg/L)	Chloride Concentration (Mg/L)
117B (04/21/89)	89Q0489	2,377	10.2
117C (04/21/89)	89Q0490	1,397	17.1
117C (10/11/89)	89Q1376	1,376	13.9

Saltwater contamination has impacted ground water 1700 feet downgradient and surface water 1900 feet downgradient of the original well site. Water in an abandoned domestic well (117H) and a stock watering dugout (117E) have been degraded by chlorides to concentrations much higher than the recommended drinking water standards.

The hydrogeologic evidence supports the previously reported saltwater pipeline breaks and brine pit overflows. Low chloride concentrations in groundwater near the focus of contamination at this site are the result of upward flow gradients preventing significant infiltration. Consequently, salt contamination of groundwater is most significant more than 1500 feet downgradient of the original contamination site. Contaminant plumes from this site and several other nearby sites have coalesced.

SITE #117



SCALE 50 ft

Cl-100 mmhos/m

LOCATION AND LEASE INFORMATION

SITE #124
A.E. LAGERQUIST #1
TOWNSHIP 36N., RANGE 58E., SECTION 27ABCA
ELEVATION = 2066 FEET
WESTBY SOUTH QUAD
OGC #67P02528

SITE DESCRIPTION

Site is an oil well drilled in 1967 to a depth of 6805 feet in the Goose Lake Field. The production interval is from 6717 to 6720 feet into the Ratcliffe zone of the Charles Formation. Signal Oil Company originally operated the well and it was later operated by Apache Oil Company. The site consists of an abandoned oil well, tanks, and reclaimed evaporation pits. The site is near a northwest extension of Goose Lake and the land slopes gently towards the lake through a series of sloughs. In the fall of 1988 this arm of Goose Lake was dry although the small sloughs contained a small volume of water. The near surface materials are glacial outwash overlying lake sediments overlying glacial till. The soil type is Turner sandy loam; SCS permeability is greater than 20 inches per hour; the grain size of less than 25% of this soil is smaller than 0.42 mm; the soil is classified GW by the SCS unified system.

CONTAMINATION REPORT

Evidence of saltwater damage covers about 1.7 acres and includes bare patches of ground, salt tolerant vegetation, and salt crystals on the soil surface. Prior to excavation of evaporation pits saltwater was allowed to flow overland into nearby sloughs. Overflow and seepage were reported to have continued after the pits were installed. An injection well (site #126) may have contributed to contamination near this site.

SITE EVALUATION

An EM-31 conductivity survey identified an area of higher than background conductivities covering about 3 acres. The site is bounded by background values on 3 sides. Values increase from background readings of 30 to 50 mmhos/m near the well pad to 200 mmhos/m near the dry slough bed. A combination of high natural salinities associated with the sloughs together with surface flows and seepage of saltwater from the evaporation pits appear to have impacted the apparent conductivity readings. Elevated chloride and conductivity values of ground-water samples point towards brine contamination contributing a significant part of the high apparent conductivities.

Several monitor wells were drilled to define and map the contaminant plume. Well 124A (23 feet deep), well 124B (8 feet deep) and well 124C (8 feet deep) were installed for the initial assessment. All three wells were drilled in glacial outwash with well screen set in the bottom 5 feet. Water from three sloughs was also monitored during the study. Nine additional monitor wells and two test holes were drilled for a more detailed site evaluation.

Water in the outwash aquifer is under unconfined conditions. The average depth to water ranges from 4 feet at 124C to 14 feet at 124A. The direction of ground-water flow is towards the east.

Well 124A was installed in an area having background apparent conductivity. Apparent terrain conductivity values were above background levels at 124B and 124C. The values of field parameters measured at this site are listed in Table 7 and the average values are summarized below.

Site Number	Type of site	Distance from Contamination Source (ft)	Depth to Potentiometric Surface (ft)	Chloride Concentration (mg/L)	Specific Conductance umhos/cm	Chloride Salt Contamination Index
124A	Well	300(up)	14	7,530	16,900	.445
124B	Well	250	4	9,500	24,800	.383
124C	Well	450	4	11,050	26,500	.417
124D	Slough	530		39,090	72,000	.543
124E	Slough	700		19,160	31,000	.618
124F	Slough	550		31,000	58,000	.534

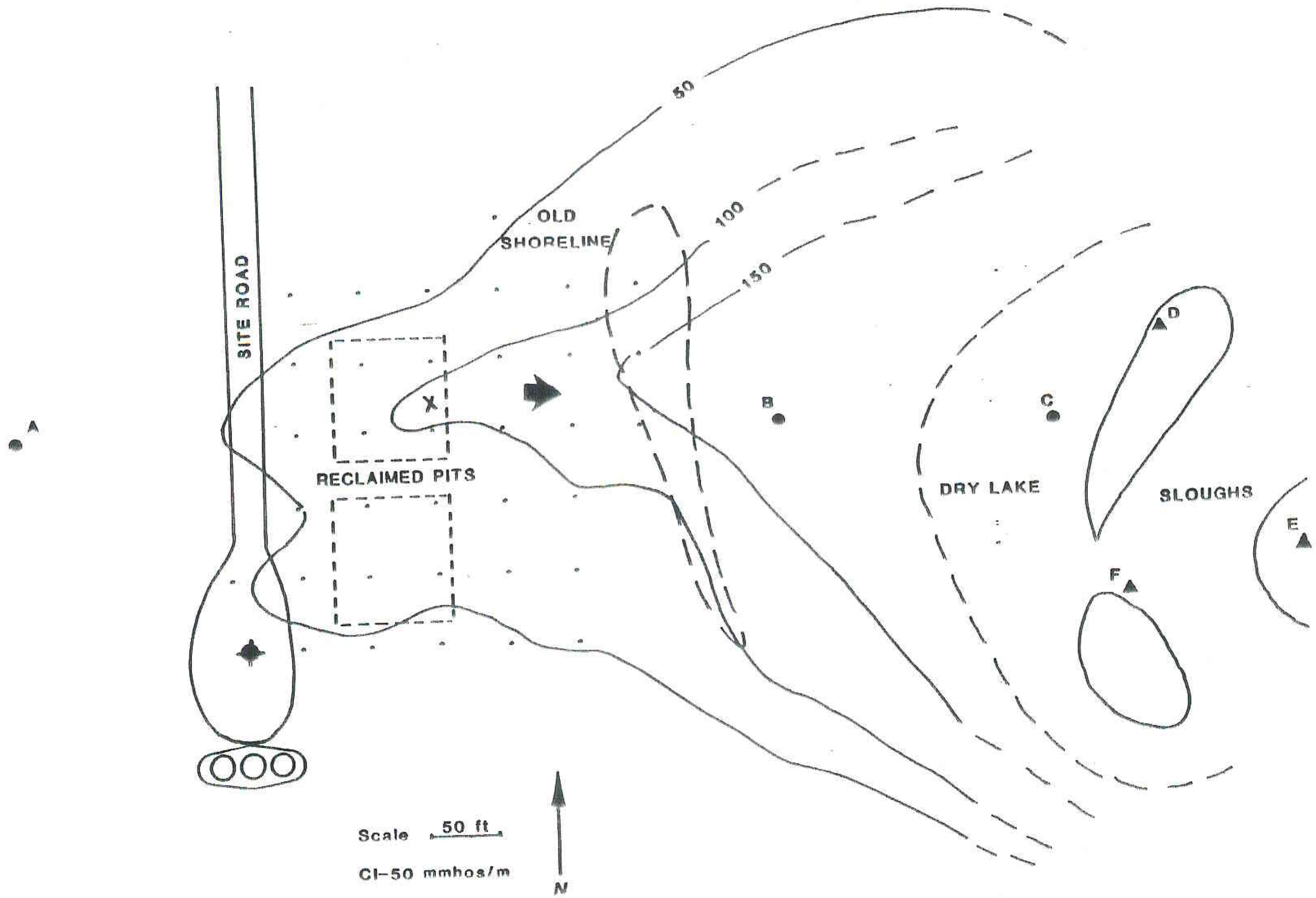
Results of water quality analyses from wells at this site are listed in Table 8 and are summarized below.

Well Number (sample date)	Lab Number	Dissolved Solids (Mg/L)	Chloride Concentration (Mg/L)
124A (04/20/89)	89Q0491	11,060	6,680
124C (04/21/89)	89Q0497	18,000	10,600

Brine contamination was identified at well 124A 300 feet upgradient of the contamination source. This contamination is the result of brine seepage from site #126. Brine contamination was also identified in ground water (124C) 450 feet downgradient of the contamination source and surface water (124E) over 700 feet downgradient of the source. Further investigation traced the contaminant plume over 2,500 feet downgradient in groundwater and 3,000 feet downgradient in surface water.

The hydrogeologic evidence supports the previously reported brine seepage and saltwater overflows from evaporation pits. An undetermined large volume of brine was disposed at this site. Both overland flow and infiltration of brine water into the outwash has caused the surface and groundwater contamination. Rapid movement of ground water contamination can be caused by allowing contaminated water to flow overland. Rather than limiting contaminant movement to relatively slow ground water velocities, overland flow of contaminated water allows rapid contaminant transport at much higher velocities. In addition, the entire area underlying the overland flow can be a potential infiltration site. Because of the potential of widespread contamination, this site was the focus of a more detailed assessment of brine contamination in the Goose Lake Field discussed later in this report.

SITE #124



50
100
150
OLD SHORELINE
SITE ROAD
RECLAIMED PITS
X
A
B
C
D
E
F
DRY LAKE
SLOUGHS
Scale 50 ft
CI-50 mmhos/m
N

LOCATION AND LEASE INFORMATION

SITE #125
ROBERT LAGERQUIST #1
TOWNSHIP 36N., RANGE 58E., SECTION 27BBDB
ELEVATION = 2107 FEET
WESTBY SOUTH QUAD
OGC #67P02527

SITE DESCRIPTION

Site is an oil well drilled in 1967 to a depth of 6860 feet in the Goose Lake Field. The production interval is from 6723-6726 feet in the Ratcliffe zone of the Charles Formation. The original operator was Signal Oil Company and later Apache Oil Company operated the well. The site is near an abandoned farmstead. An oil well pad and a pumper are currently at the site. All pits have been levelled. The near surface materials are glacial outwash overlying lake sediments and glacial till. The soil type is Turner loam; SCS permeability is greater than 20 inches per hour; the grain size of 20% of the soil is less than 0.42; the soil is classified as GW by the SCS unified system.

CONTAMINATION REPORT

Bare patches of ground and heavy soils are surface evidence of saltwater contamination. Surface damage from brines covers about 1 acre. Water wells at the adjacent farmstead were reported to have been contaminated by high levels of chlorides making the water unfit for garden irrigation. Spills and infiltration of brine water are probable sources of contamination. Heavy soils in the field north of the site may be in part caused by spills but this area appears to be a natural saline seep.

SITE EVALUATION

An EM-31 survey identified an area of higher than background apparent conductivities covering about 2.0 acres at the site. Highest apparent conductivities were south of the well pad, probably the site of the reserve pit. High conductivities and gumbo soils are found about 300 feet north of the well pad. Background level apparent conductivity readings separate these two high conductivity areas. Wells containing elevated chloride concentrations underlie areas having background apparent conductivities, implying that perhaps the contamination is beyond the useable depth of the EM-31.

Two monitor wells, 125A (27 feet deep) and 125B (33 feet deep) were drilled near this site. Three existing wells 125C (9 feet deep), 125D (22 feet deep), and 125E (23 feet deep) were also monitored to assess the extent of ground-water contamination. The outwash deposits were dry at both monitor well locations. Saturated lake deposits of clayey silt and fine sand were screened from 22 ft to 27 feet in well 125A. Saturated glacial till was screened from 28 ft to 33 ft in well 125B. The average depth to water was 12 feet at 125A and 15 feet at 125B. The direction of ground water flow is toward the southeast.

Both wells were drilled in areas with background or nearly background apparent terrain conductivity. The values of field parameters measured at this site are listed in Table 7 and the average values are summarized below.

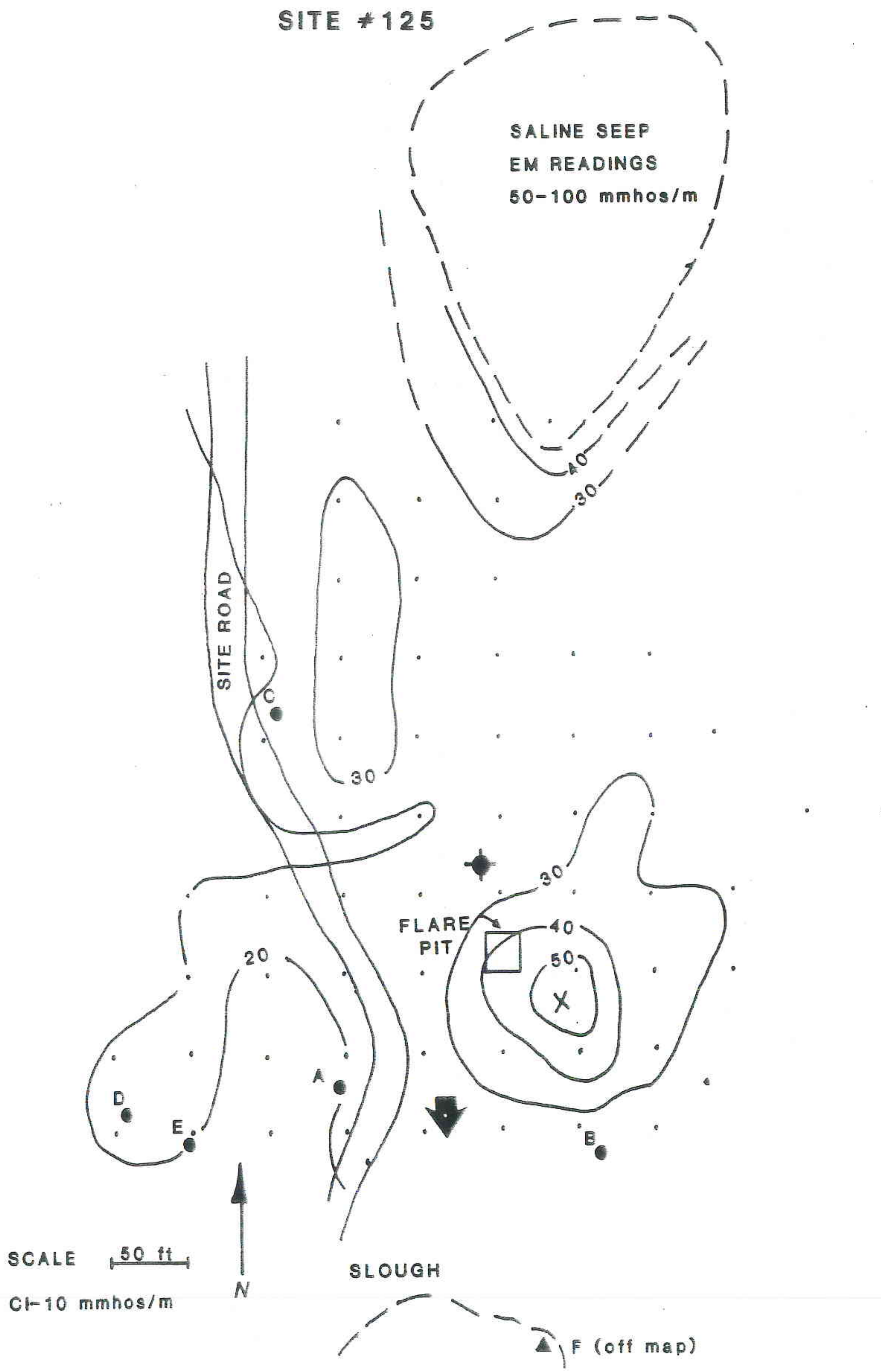
Site Number	Type of site	Distance from Contamination Source (ft)	Depth to Potentiometric Surface (ft)	Chloride Concentration (mg/L)	Specific Conductance umhos/cm	Chloride Salt Contamination Index
125A	Well	150	12	90	1,120	.080
125B	Well	100	15	70	1,060	.066
125C	Well (private)	260	9	245	1,865	.131
125D	Well (private)	290	15	212	1,375	.154
125E	Well (private)	250	135	<50	580	.086
125F	Slough	800		430	1,800	.239

Results of water quality analyses from wells at this site are listed in Table 8 and are summarized below.

Well Number (sample date)	Lab Number	Dissolved Solids (Mg/L)	Chloride Concentration (Mg/L)
125A (04/21/89)	89Q0493	833	26
125B (04/20/89)	89Q0494	766	56

The hydrogeologic evidence generally indicates low levels of brine contamination at this site. Although contamination levels are low, two existing, but currently unused wells (125C, 125D) have degraded water quality due to high chloride concentrations. Down slope degradation of a slough (125F) is also evident.

The history of spills or leaks of brine are sketchy at this site. The relatively low level of soil contamination and ground water contamination indicate relatively minor amounts of saltwater were disposed of at this site.


SITE #125
SALINE SEEP
EM READINGS
50-100 mmhos/m
40
30
SITE ROAD
C
30
30
FLARE
PIT
40
50
X
20
D
E
A
B
SCALE
50 ft
Cl-10 mmhos/m
N
SLOUGH
F (off map)

LOCATION AND LEASE INFORMATION

SITE #126
ROBERT LAGERQUIST #2
TOWNSHIP 36N., RANGE 58E., SECTION 27BAAA
ELEVATION = 2114 FEET
WESTBY SOUTH QUAD
OGC #68PO2516

SITE DESCRIPTION

Site is an injection well drilled in 1968 to a depth of 4500 feet in the Goose Lake Field. The injection interval is from 4318 to 4378 feet into the Big Muddy Member of the Dakota Formation. The injection well and former evaporation pit have been reclaimed. The near surface materials are glacial outwash overlying lake sediments overlying glacial till. The soil type is Wabek gravelly sandy loam; SCS permeability is greater than 20 inches per hour; the grain size of between 15 to 40% of the soil is less than 0.42 mm; the soil is classified GM by the SCS unified system.

CONTAMINATION REPORT

Bare patches of ground and salt tolerant vegetation covering about 1.7 acres near the site are the only evidence of saltwater contamination. Casing leaks from the injection well and surface spills of saltwater were reported to have occurred at this site. Seepage from reserve pits has also contributed to site contamination.

SITE EVALUATION

An EM-31 survey identified an area of higher than background apparent conductivity covering 2.5 acres at the site. Apparent conductivity readings decrease away from the central part of the site which likely was the well site. The shape of the high conductivity anomaly suggests either a leaky casing in the injection well or seepage from an evaporation pit was the main source of contamination. Multiple pit locations and reclamation by trenching may have caused the odd shape of the high conductivity anomaly. Background values ranging from 40 to 60 mmhos/m bound the site.

Three monitor wells 126A (17 feet deep), 126B (23 feet deep) and 126C (18 feet deep) were installed at this site. Ground water in outwash was tapped by well 126A and 126C. The outwash was dry at 126B and the well was screened in the underlying lake and till deposits.

Water in the outwash is under unconfined conditions. The till/lake deposit ground water is probably also unconfined. The direction of ground water flow is towards the east.

Apparent terrain conductivity values were above background readings at wells 126A and 126B. Background terrain conductivity readings were measured at 126C. The average value of field parameters are listed in Table 7 and the average values are listed below.

Site Number	Type of site	Distance from Contamination Source (ft)	Depth to Potentiometric Surface (ft)	Chloride Concentration (mg/L)	Specific Conductance umhos/cm	Chloride Salt Contamination Index
126A	Well	190(up)	9	2,830	8,720	.324
126B	Well	115	14	26,705	58,780	.454
126C	Well	400(up)	8.5	60	1,055	.057

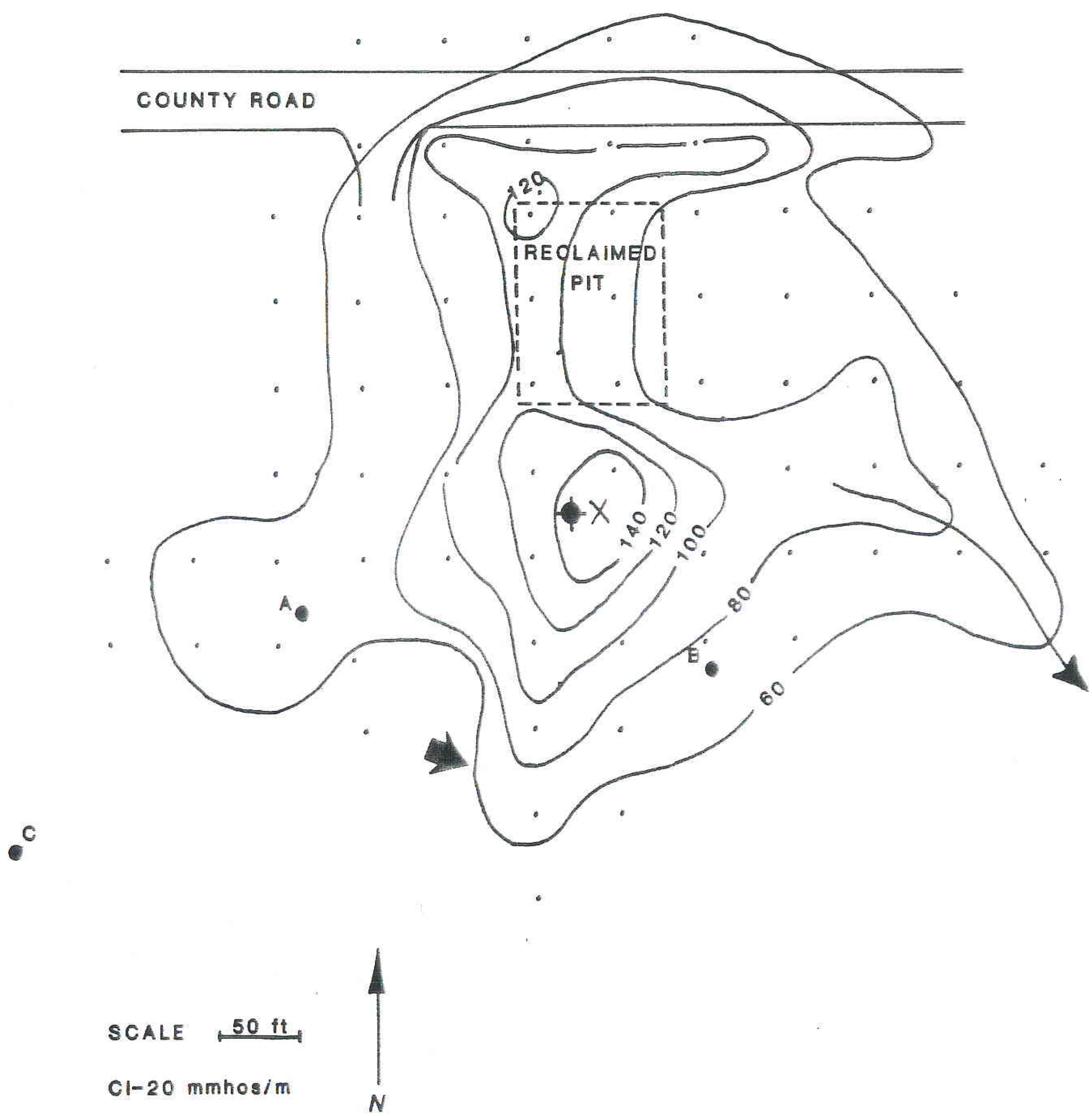
Results of water quality analyses from wells at this site are listed in Table 8 and are summarized below.

Well Number (sample date)	Lab Number	Dissolved Solids (Mg/L)	Chloride Concentration (Mg/L)
126A (04/20/89)	89Q0495	2,180	1,060
126B (04/20/89)	89Q0496	38,400	23,600
126C (10/12/89)	89Q1391	690	6.6

Little or no brine contamination was observed at well 126C, located 400 feet upgradient from the source. Well 126A showed significant contamination even though it is located 190 feet upgradient of the source. Water in well 126B, located 115 feet downgradient was highly contaminated. Designating a specific point as the source is subject to interpretation and reported information that may not match the actual source. Contamination sources were often identified as the center of a large area of contamination so relative distances between surface and ground water monitoring sites could be compared. Consequently, upgradient wells that are found to be impacted may result from a larger source than originally indicated.

The hydrogeologic evidence supports brine seepage from evaporation pits, surface spills, and possibly brine leaking through casing breaks in an injection well. Saltwater is moving downgradient and combining with the brine plume at Site 124.

SITE #126


COUNTY ROAD
120
RECLAIMED
PIT
140
120
100
80
60
A
B
C
SCALE
50 ft
Cl-20 mmhos/m
N

LOCATION AND LEASE INFORMATION

SITE #139
KELDSEN "B" #1
TOWNSHIP 36N., RANGE 58E., SECTION 33BBDB
ELEVATION = 2107 FEET
TADPOLE LAKE QUAD
OGC #66P02506

SITE DESCRIPTION

Site is an oil well drilled in 1963 to a depth of 6930 feet in the Goose Lake Field. The production interval is from 6799-6802 feet in the Ratcliffe zone of the Charles Formation. The original operator was Signal Oil Company and later Apache Oil Company. The site is surrounded by cropland and consists of the well pad with an active pumper. All pits have been levelled. Popcorn-textured soils are found east of the well pad and may represent the location of the reserve pit. Near surface materials consist of a thin colluvial layer overlying glacial till. The soil type is Williams loam; SCS permeability ranges from .6 to 2 inches per hour; the grain size of more than 95% of a soil sample is less than 0.42 mm; the soil is classified CL in the SCS unified system.

CONTAMINATION REPORT

The contamination report indicated little evidence of contamination at the surface. The area of soil degradation was estimated at .6 acre. Since the site was surrounded by summer fallow when surveyed, the extent of soil contamination was difficult to assess. Popcorn textured soils near the site may be an indication of bentonite drilling muds. An evaporation pit, located just east of the site, was in use until the early 1970's. Brine from another site was reported to have been dumped into this pit at least once.

SITE EVALUATION

An EM-31 survey identified a circular area of higher than background apparent conductivities covering about 2 acres at the site. Highest apparent conductivities were on the east side of the well pad, probably overlying the reclaimed reserve pit. Background apparent conductivity values ranging from 18 to 70 mmhos/m bound the site.

The large range in background conductivities is probably caused by changes in the properties of soil and near surface sediments.

One monitor well (139A, 27 feet deep) was drilled down slope (east) of the reclaimed reserve pit in an area of background terrain conductivity. The well was screened from 22 to 27 feet below land surface in glacial till.

Ground water in the till is under confined conditions. The average potentiometric surface was 11 feet below land surface. The value of field parameters measured at this site are listed in Table 7 and the average values are summarized below.

Site Number	Type of site	Distance from Contamination Source (ft)	Depth to Potentiometric Surface (ft)	Chloride Concentration (mg/L)	Specific Conductance umhos/cm	Chloride Salt Contamination Index
139A	Well	250	11	38,700	67,800	.571

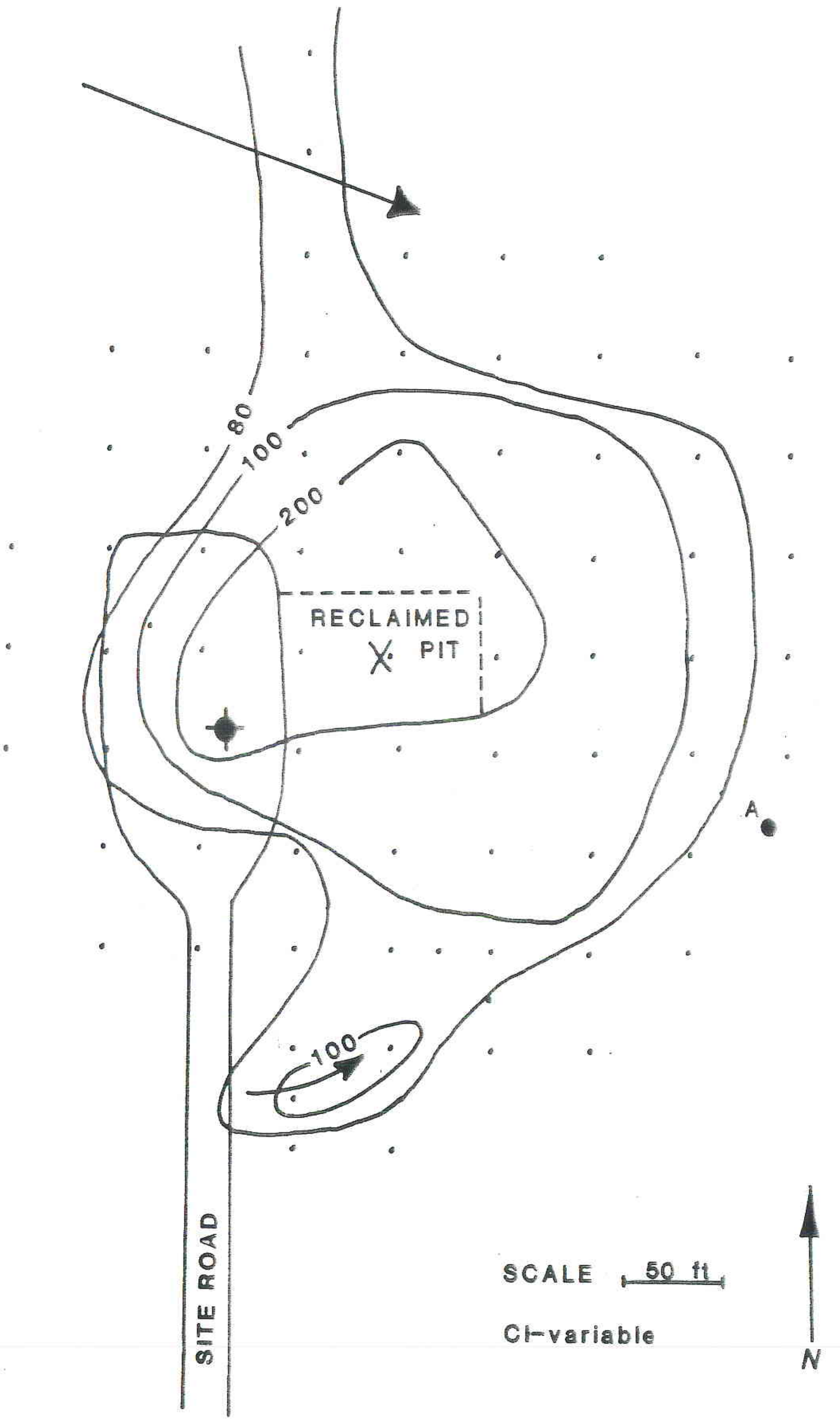
Results of water quality analyses from wells at this site are listed in Table 8 and are summarized below.

Well Number (sample date)	Lab Number	Dissolved Solids (Mg/L)	Chloride Concentration (Mg/L)
139A (04/20/89)	89Q0497	54,500	33,200

Contaminated soil covers a relatively small area at this site. This observation implies only minor spills or surface discharges. High chloride concentrations in the groundwater at this location are probably the result of seepage from an evaporation pit.

Although ground water contamination was confirmed at this site, the extent of contamination both vertically and areally was not determined.

SITE #139



80
100
200
RECLAIMED
PIT
A
100
SITE ROAD
SCALE
50 ft
Cl-variable
N

LOCATION AND LEASE INFORMATION

SITE #151
M. HELLEGAARD #3
TOWNSHIP 37N., RANGE 57E., SECTION 05DDBD
ELEVATION = 2287 FEET
LONE TREE LAKE QUAD
OGC #63P01024

SITE DESCRIPTION

Site is an oil well drilled to a depth of 8,092 feet in the Flat Lake Field. The production interval was in the Nisku Formation. The well was converted to an injection well and is currently operated by Sun Oil Company. Storage tanks, a reclaimed evaporation pit, and the oil/injection well make up the site. Drainage from the site is to the north into a slough and then west into a closed lake basin. The site is in hummocky terrain composed of glacial till. The soil type is Zahill clay loam; SCS permeability ranges from .2-.6 inches per hour; the grain size of more than 90% of the soil sample is less than 0.42 mm; the soil is classified CL by the SCS unified system.

CONTAMINATION REPORT

Evidence of saltwater damage includes bare ground, heavy soils, and salt crystals on the soil surface. Underground seepage and pit overflow were reported to have caused off-site contamination. The area of surface damage covers about 4.2 acres. Spills and leaks from a second site northeast of the slough appears to have contributed to surface and ground water contamination.

SITE EVALUATION

An EM-31 survey identified an area of higher than background apparent conductivities covering about 5 acres. Highest conductivities are immediately below the well pad and over the nearby slough. High conductivities over the slough may be a combination of natural saline conduction and spill or leak related salinity. Background apparent conductivity values ranging from 60-180 mmhos/m bound most of the site. Higher conductivity values trend from the slough northeast towards a different oil well site and from the slough west towards a closed lake basin.

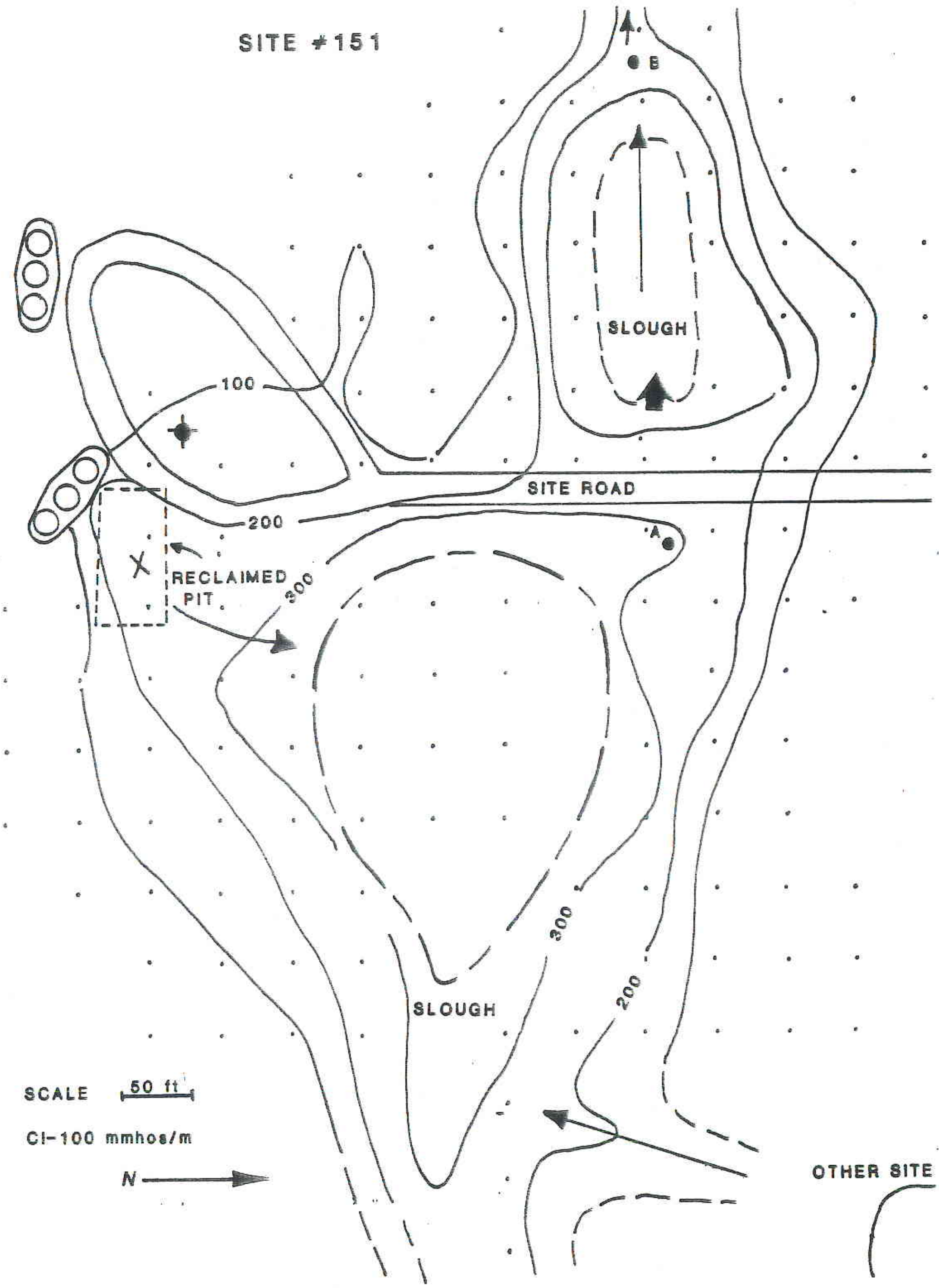
Two monitor wells were installed in glacial till at this site. Both well 151A (13 feet deep) and well 151B (18 feet deep) were constructed in areas of very high apparent terrain conductivity. Well screen was set in the bottom 5 feet of each well. Down slope of the site a domestic well (151C) and a slough were also monitored. Groundwater in the till is under confined conditions. The values of field parameters measured at this site are listed in Table 7 and the average values are summarized below.

Site Number	Type of site	Distance from Contamination Source (ft)	Depth to Potentiometric Surface (ft)	Chloride Concentration (mg/L)	Specific Conductance umhos/cm	Chloride Salt Contamination Index
151A	Well	370	4	55,040	92,420	.595
151B	Well	720	5	54,568	84,680	.644

Results of water quality analyses from wells at this site are listed in Table 8 and are summarized below.

Well Number (sample date)	Lab Number	Dissolved Solids (Mg/L)	Chloride Concentration (Mg/L)
151B (04/22/90)	89Q0498	69,400	44,300

Both monitor wells contain very high concentrations of sodium chloride salts. Brine contamination of the shallow ground water has spread over 700 feet downgradient from the original source. The hydrogeologic evidence supports the previously reported brine seepage and brine overflows from an evaporation pit. The slough at the site was probably used for disposal of an undetermined large volume of brine. Seepage of saltwater into the ground water system probably occurred under the entire area of overland flow. The total vertical and areal extent of brine contamination was not defined by the monitor wells.


SITE #151
B
SLOUGH
100
SITE ROAD
200
A
RECLAIMED PIT
300
300
200
SLOUGH
SCALE 50 ft
Cl-100 mmhos/m
N
OTHER SITE

LOCATION AND LEASE INFORMATION

SITE #167
NELS WARD #1
TOWNSHIP 37N., RANGE 57E., SECTION 12BADB
ELEVATION = 2263 FEET
LONE TREE LAKE QUAD
OGC #65P01050

SITE DESCRIPTION

Site is an oil well drilled in 1965 to a depth of 6904 feet in the Flat Lake Field. The production intervals are 6528 to 6542 feet and 6546 to 6564 feet, both in the Ratcliffe zone of the Charles Formation. The original operator was California Oil Company and the well is currently operated by Chevron. The site is on a glacial till covered hillside sloping towards a glacial outwash channel. Currently a pumper is located in the southeast corner of the site, all pits have been levelled. Near surface material consists of slope wash overlying glacial till on the hillslope and glacial outwash overlying glacial till in the channel. The soil type is Williams-Zahill loam; SCS permeability ranges from .2-2 inches per hour; the grain size of more than 90% of a soil sample is less than 0.42 mm; the soil is classified CL in the SCS unified system.

CONTAMINATION REPORT

Surficial evidence of brine contamination consisting of bare patches of ground, salt tolerant vegetation, and salt crystals on the soil are visible over about 2.3 acres. Water wells in the outwash channel had become unusable, according to the landowner. The reserve pit had overflowed at least once, contaminating the ground water. Well 167C was first contaminated during the early 1970's. The operator drilled several test holes trying to find an alternative water supply but was unsuccessful. Before groundwater in the outwash channel was contaminated it represented the only nearby reliable water supply.

SITE EVALUATION

An EM-31 survey identified an area of higher than background apparent conductivities covering about 7 acres on a hillside sloping towards an outwash channel. Highest conductivities are associated with sparse vegetative cover overlying reclaimed evaporation pits. Background terrain conductivity values ranging from 20 to 60 mmhos/m bound all but the northwest corner of the site.

The anomaly on the northwest corner of the site is down slope of reclaimed evaporation pits and appears to correlate with overland flow of the brine.

Two monitor wells were originally installed to assess the extent of ground water contamination. Well 167A was installed to monitor the water quality of recharge water moving through thin outwash gravels. This well was constructed with slots from 3-6 feet across the gravel/till contact and has a blank drop pipe to collect the recharge water. Well 167B was installed to monitor water levels and water quality in the outwash aquifer. Several other test holes and wells were drilled to define the brine plume in the outwash channel from about 4,000 feet upgradient to about 6,000 feet downgradient of the source. Additional water data was collected from a slough and two existing water wells.

Groundwater in the outwash is under unconfined conditions. Depth to water level ranges from 6 to 12 feet below ground surface. The direction of ground water flow is down the outwash channel towards the north and east. The values of field parameters measured at this site are listed in Table 7 and the average values are summarized below.

Site Number	Type of site	Distance from Contamination Source (ft)	Depth to Potentiometric Surface (ft)	Chloride Concentration (mg/L)	Specific Conductance umhos/cm	Chloride Salt Contamination Index
167A	Well (perched)	360		284	1,560	.182
167B	Well	700	6	2,085	5,415	.385
167C	Well (private)	850		1,369	4,365	.314
167D	Well (private)	1,800		110	770	.143
167E	Slough	6,000		44	1,050	.042
167F	Well	6,000	11.5	135	1,043	.129
167G	Test Hole	3,500(up)				
167H	Well	850	6	<45	467	.096
167I	Test Hole	590				
167J	Test Hole	700				
167K	Well	800	6	1,150	4,000	.287
167L	Well	800	10	440	1,860	.236
167M	Well	850	6	316	1,380	.229

Results of water quality analyses from wells at this site are listed in Table 8 and are summarized below.

Well Number (sample date)	Lab Number	Dissolved Solids (Mg/L)	Chloride Concentration (Mg/L)
167B (04/22/89)	89Q0499	282	35

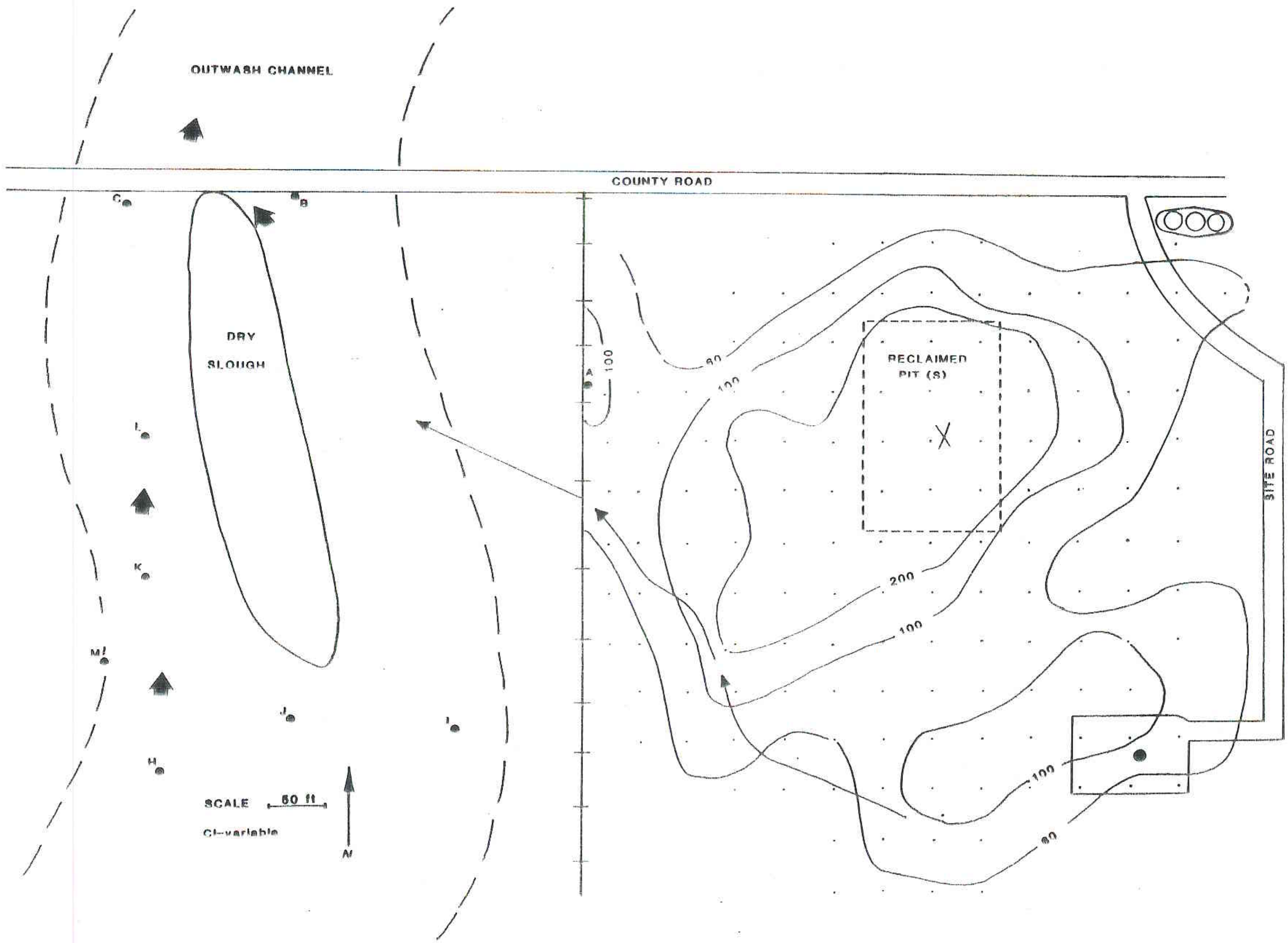
The water analyses from 167B differs significantly from field values measured when the sample was collected. This is probably because the water sample analyzed was from higher in the water column than the water sample measured in the field. Strong vertical density gradients were commonly observed in wells completed in outwash deposits.

Contamination from chloride salts has spread throughout a large part of this outwash channel. Because of the low background levels of CL^- in the contaminated ground water, fairly low CL^- concentrations indicate brine contamination.

Water quality has been degraded in two existing wells and water in the outwash aquifer has elevated chloride concentrations over 6000 feet downgradient of the original site. The outwash aquifer is very thin, probably discontinuous, and very susceptible to contamination. The topography of the underlying glacial till appears to control the saturated thickness of the outwash aquifer and movement of the contaminant plume. Depressions in the till are filled with saturated outwash and ridges in the till are covered with thin unsaturated outwash. Vertical density gradients produce the greatest contamination in deeper portions of the aquifer.

Fluctuations in concentrations of field parameters could be the result of sampling different horizons in the water column rather than representing lateral movement of brine plumes. Ground water in thin outwash aquifers is often a reliable source of continuous small volume water supplies such as stock and domestic purposes. Thin outwash aquifers are very susceptible to contamination from surface or near surface sources. Defining and mapping those aquifers is usually difficult and predicting contaminant movement nearly impossible.

SITE #167



OUTWASH CHANNEL
COUNTY ROAD
SITE ROAD
DRY
SLOUGH
RECLAIMED
PIT (S)
200
100
A
B
C
H
I
J
K
L
M
SCALE 50 ft
Cl-variable
N

LOCATION AND LEASE INFORMATION

SITE #184
JOYES STATE #4
TOWNSHIP 37N., RANGE 57E., SECTION 16BAx
ELEVATION = 2200 FEET
LONE TREE LAKE QUAD
OGC #70P01041

SITE DESCRIPTION

Site is an injection well drilled in 1970 to a depth of 8025 feet in the Flat Lake Field. Two production intervals were perforated in the Charles Formation from 6672-6696 ft in the Nesson zone and from 6455-6499 ft in the Ratcliffe zone. The original operator was Sun Oil Company and the current operator is Chevron Oil Company. The site is in gently rolling terrain. A well house is the only structure at the site. Near surface material consists of lake clay overlying glacial till. The soil type is Marias clay; SCS permeability is .06 inches per hour; the grain size of more than 95% of this material is less than 0.42 mm; the soil is classified CH in the SCS unified system.

CONTAMINATION REPORT

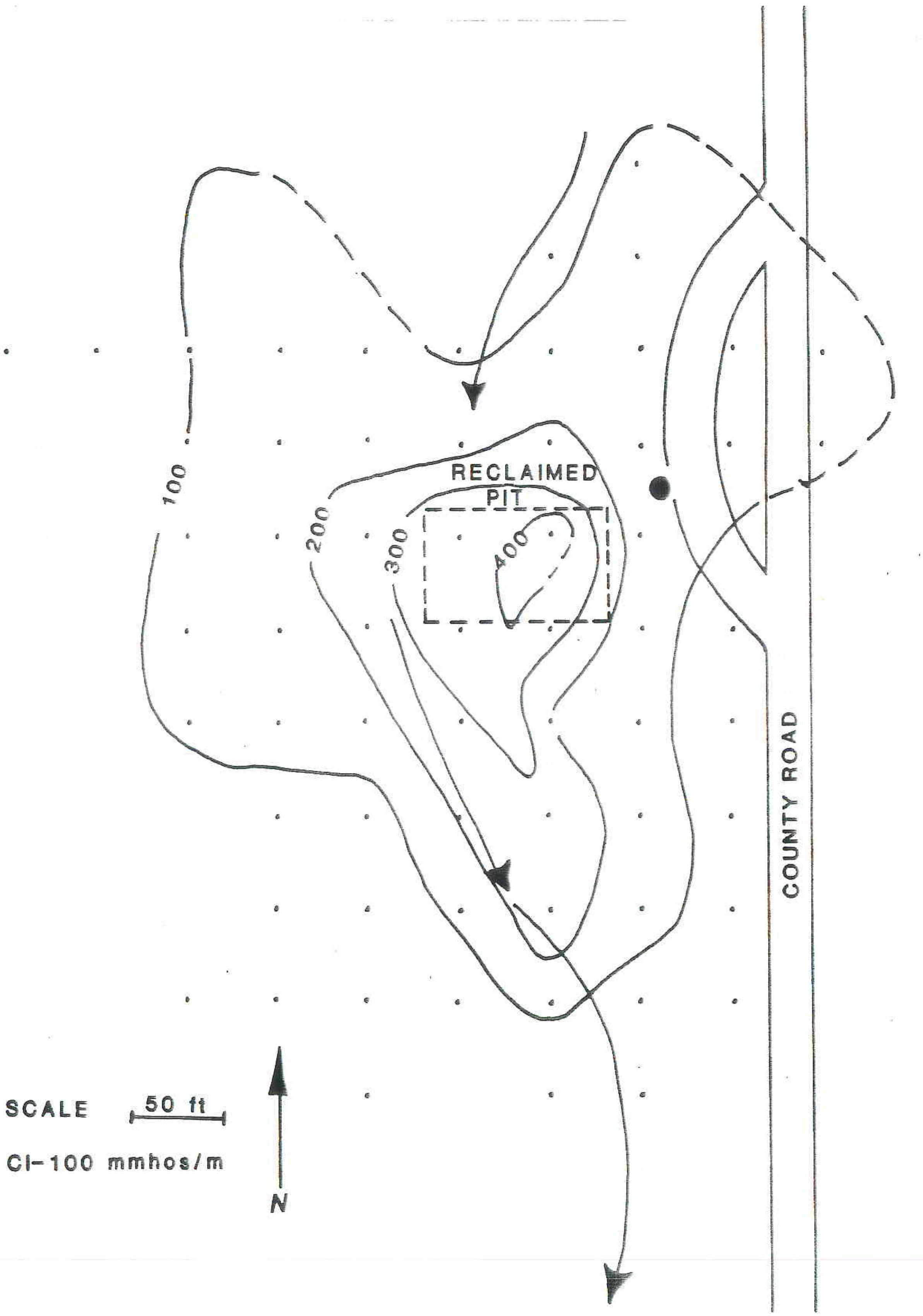
Damaged vegetation, salt crystals on the soil surface, and degraded soil structure are visible over about 1.3 acres near the injection well. Most of the obvious contamination appears to be from surface spills. Determining source of contamination may be difficult to separate from natural or cropping related saline seeps.

SITE EVALUATION

An EM-31 survey identified an area of higher than background apparent conductivities covering about 1.5 acres. Highest conductivities are associated with sparse vegetation and salt crystals on the soil surface. Background conductivities are higher than normal and erratic surrounding the site probably caused by variations in soil moisture. Higher terrain conductivities spread down slope south of the probable source of contamination.

No wells were installed or water samples collected near this site. Most of the surficial contamination appears to be from surface spills.

SITE #184



RECLAIMED PIT
100
200
300
400
COUNTY ROAD
SCALE 50 ft
Cl-100 mmhos/m
N

LOCATION AND LEASE INFORMATION

SITE #222
IDA METVEDT #1
TOWNSHIP 37N., RANGE 58E., SECTION 06CAx
ELEVATION = 2199.9 FEET
LONE TREE LAKE QUAD
OGC #65PO1068

SITE DESCRIPTION

Site is an oil well drilled in 1965 to a depth of 6545 feet in the Flat Lake Field. The production interval is from 6464 to 6502 feet in the Ratcliffe zone of the Charles Formation. The well was operated by the California Oil Company. The site is on a hill slope next to a small lake. A well shack is the only structure left at site. Former evaporation pits have been reclaimed. Near surface material consists of glacial till with lake clay and outwash gravels occurring near the lake. The soil type is Williams-Zahill loam; SCS permeability ranges from .2-2.0 inches per hour; more than 90% of a soil sample will pass through a No. 40 sieve (<.42); the soil is classified CL in the SCS unified system.

CONTAMINATION REPORT

Bare patches of ground, salt crystals on the soil surface, and dead trees downgradient of the site are evidence of saltwater contamination. Evidence of surface damage covers about 1 acre. A nearby domestic well was reported to have been contaminated with sodium chloride. The evaporation pit associated with this site used to overflow into the slough below the site.

SITE EVALUATION

An EM-31 survey identified an area of higher than background apparent conductivities covering about 2 acres. Highest conductivities are east of the well shack probably overlying levelled evaporation pits. Background conductivities are erratic around the site ranging from 30 mmhos/m on the hillside above the site to over 80 mmhos/m below the site near the slough.

Two monitor wells were installed in glacial till down slope from the reclaimed evaporation pits. Both wells are located in areas of higher than background apparent terrain conductivity. Well 222A (43 feet deep) and well 222B (48 feet deep) both had screen set in the bottom 5 feet. Ground water in the till is under confined conditions. The potentiometric surface ranges from 8.5 feet below ground surface at 222B to 12.5 feet below ground surface at 222A. Water samples were tested for field parameters at three private wells and four nearby sloughs.

The values of field parameters measured at this site are listed in Table 7 and the average values are summarized below.

Site Number	Type of site	Distance from Contamination Source (ft)	Depth to Potentiometric Surface (ft)	Chloride Concentration (mg/L)	Specific Conductance umhos/cm	Chloride Salt Contamination Index
222A	Well	120	12.5	468	7,692	.061
222B	Well	300	8.5	532	4,770	.111
222C	Well (private)	1,040	10.5	80->600	1,710-N/A	.047-N/A
222D	Well (private)	1,040	11	<50	2,715	.018
222E	Well (private)	980				

Site Number	Type of site	Distance from Contamination Source (ft)	Depth to Potentiometric Surface (ft)	Chloride Concentration (mg/L)	Specific Conductance umhos/cm	Chloride Salt Contamination Index
222F	Slough	500		<44	470	.094
222G	Slough	1,800		<44	870	.050
222H	Slough	1,800		550	6,280	.087
222I	Slough	2,700		1,270	16,340	.078

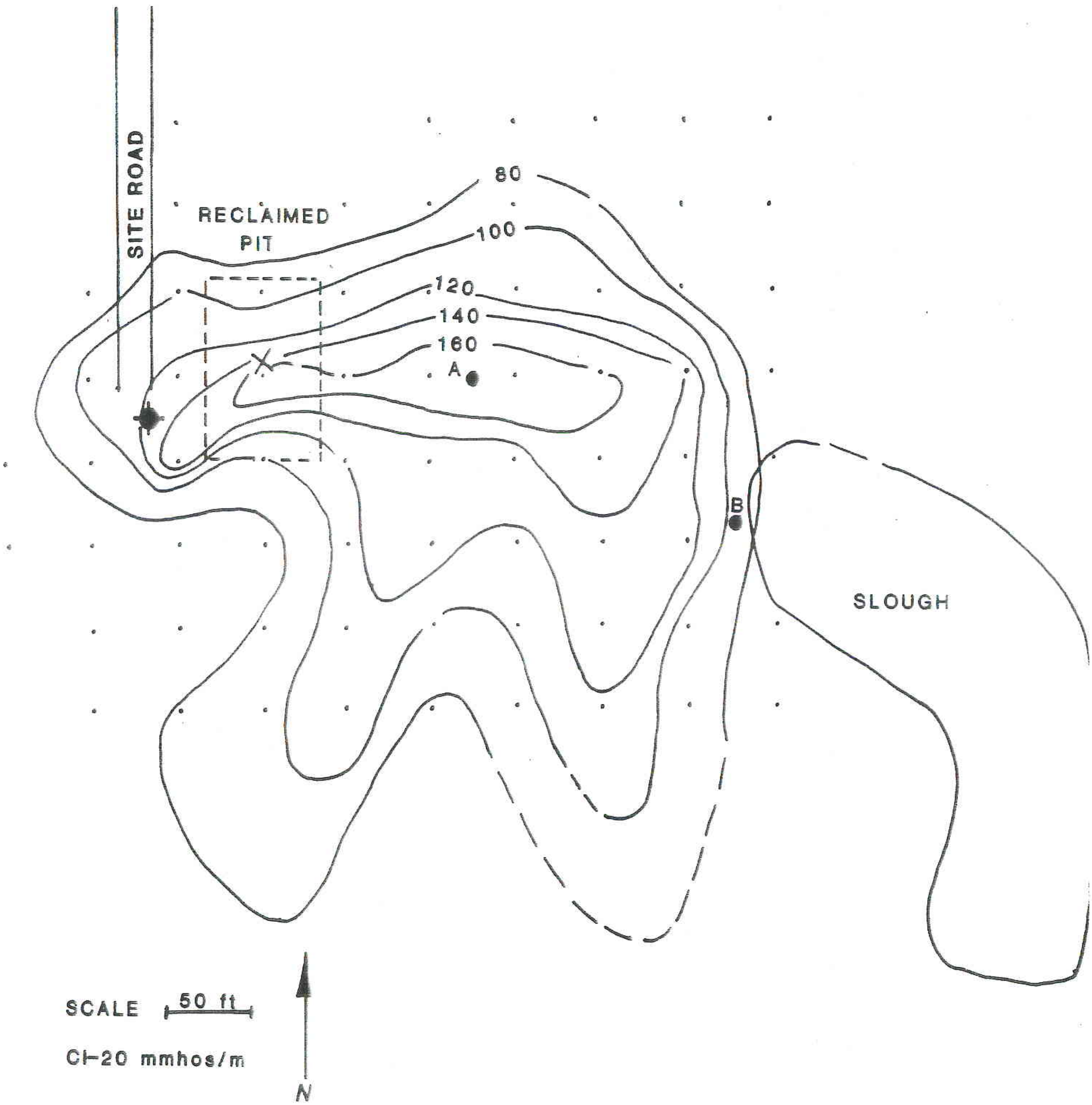
Results of water quality analyses from wells at this site are listed in Table 8 and are summarized below.

Well Number (sample date)	Lab Number	Dissolved Solids (Mg/L)	Chloride Concentration (Mg/L)
222A (04/21/89)	89Q0500	5,418	177

Chloride contamination from oil field brines was detected in one domestic well, two research wells and two nearby sloughs. Other oil drilling sites in the vicinity may have also contributed to the contamination. Strong vertical density gradients were measured in well #222A. The lab analyses from this well appears to be from the top of the water column. Levels of contamination were significantly lower than at other sites in glacial till.

Ground water in glacial till at this site appears to have relatively high permeability which has resulted in more dilution of the contaminant plume than at other glacial till sites. The extent of the plume was not determined but it appears that ground water contamination associated with this site is declining.

SITE #222



SCALE 50 ft

Cl–20 mmhos/m

LOCATION AND LEASE INFORMATION

SITE #251
YARASLASKI 1-35
TOWNSHIP 35N., RANGE 58E., SECTION 35DDx
ELEVATION = 2049 FEET
DOMINEK LAKE QUAD
OGC # NOT LISTED

SITE DESCRIPTION

Site is oil well drilled in 1981 to a depth of 11,320 in the South Goose Lake Field. Problems were encountered during drilling and well was never completed. The well was drilled by Patrick petroleum targeting the Red River Formation. The site is adjacent to an extension of Dominek Lake. The well was plugged and abandoned on 3/7/81. It is currently marked by a pipe sticking out at the ground at the well site. Near surface material consists of lake sediments and glacial outwash. The soil type is Manning coarse sandy loam; SCS permeability is over 20 inches per hour. The grain size of about 25% of a soil sample is less than 0.42 mm. The soil is classified GW in the SCS unified system.

CONTAMINATION REPORT

Minor bare patches of ground are the only visible evidence of surface contamination. Visible surface damage covers about 0.6 of an acre. Inadequate reclamation of a reserve pit was reported at this site. The pit was trenched and squeezed with trenches dug into the water table. Dominek Lake was at a high level when work was done, aggravating reclamation.

SITE EVALUATION

An EM-31 survey identified an area of higher than background apparent conductivities covering about 1 acre. Highest conductivities are east of the well site probably overlying the reclaimed reserve pit. Background conductivity values less than 10 mmhos/m surround the site. Ratio of maximum EM conductivity to background EM conductivity is 35:1.

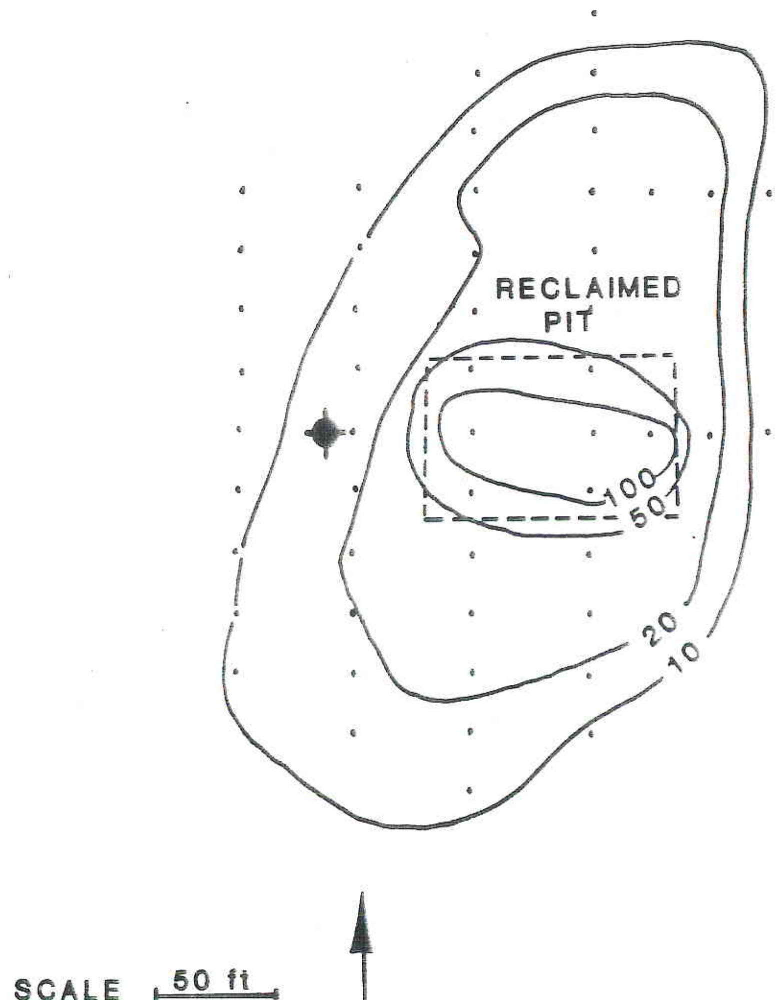
No wells were installed at this site. Field water samples were collected about 1/4 mile southwest of this site from an abandoned well and from Dominek Lake. The results of the field analyses are shown below.

Site Number	Type of site	Distance from Contamination Source (ft)	Depth to Potentiometric Surface (ft)	Chloride Concentration (mg/L)	Specific Conductance umhos/cm	Chloride Salt Contamination Index
251A	Well	1,500	9.42	<50	1,350	.037
251B	Lake	1,500		255	13,000	.020

Brine contamination appears to have impacted only a small area near site 251. The high apparent terrain conductivity anomaly is consistent with the reported problems associated with the mud disposal.

Samples collected at 251A and 251B do not indicate brine contamination.

SITE #251



LOCATION AND LEASE INFORMATION

SITE #252
ONSTAD 22-14
TOWNSHIP 34N., RANGE 58E., SECTION 14BD
ELEVATION = 2058 FEET
DOMINEK LAKE QUAD
OGC # NOT LISTED

SITE DESCRIPTION

Site is an oil well drilled in 1987 to a depth of 11,398 feet in the South Goose Lake Field. The production interval is from 11,168 to 11,256 feet in the Red River Formation. The site is an active oil well operated by Meridian Oil Company. The initial production of this well was 334 barrels of oil per day and 117 barrels of saltwater per day. The site is located on an irrigated field. Near surface materials are glacial outwash. The soil type is Manning coarse sandy loam; SCS permeability is 12-35 inches per hour; the grain size of about 25% of a soil sample is less than 0.42 mm; the soil is classified GW in the SCS unified system.

CONTAMINATION REPORT

The site was reclaimed in 1987 by pit solidification. Little evidence of surficial contamination is visible and the damage covers only about .6 acre at this well and is limited to the immediate vicinity of the well. Because the site is under a center pivot irrigation system, there. is a high potential for salt leaching into the ground water. Samples of the production water had chloride concentrations of 173,300 mg/L and dissolved solid concentrations of 293,100 mg/L.

SITE EVALUATION

An EM-31 survey identified an area of higher than background apparent conductivities covering about 1.0. Highest conductivities are about 50 feet north of the well site. Low background conductivities bound all but the northwest side of the site. The movement of the center pivot towards the site prevented expanding the survey to the northwest. The higher background values may be caused by higher clay content in the soil profile or other natural variabilities in physical properties of the near surface materials.

Two wells were installed in shallow glacial outwash at this site. Well 252A (32 feet deep) and well 252B (32 feet deep) were both constructed with 5 ft of well screen set in the bottom of each well. Both wells were located over areas of high to moderately high terrain conductivity relatively close to the edge of the solidified reserve pit. A deeper outwash aquifer is used at this site for an irrigation supply (well 252C-150 feet deep). The two outwash aquifers are separated by 40 to 80 feet of low permeability deposits of glacial till and lake clay.

Water in the shallow outwash aquifer is under unconfined conditions. The depth to water ranges from 26 to 27 feet below land surface. Water in the deep outwash aquifer is under confined conditions. The depth to the potentiometric surface is about 24 feet below land surface. The values of field parameters measured at this site are listed in Table 7 and the average values are summarized below.

Site Number	Type of site	Distance from Contamination Source (ft)	Depth to Potentiometric Surface (ft)	Chloride Concentration (mg/L)	Specific Conductance umhos/cm	Chloride Salt Contamination Index
252A	Well	60	260	585	2,711	.216
252B	Well	50	27	62	1,620	.038
252C	Irrigation Well (private)	1,000	24	<44	1,150	.038

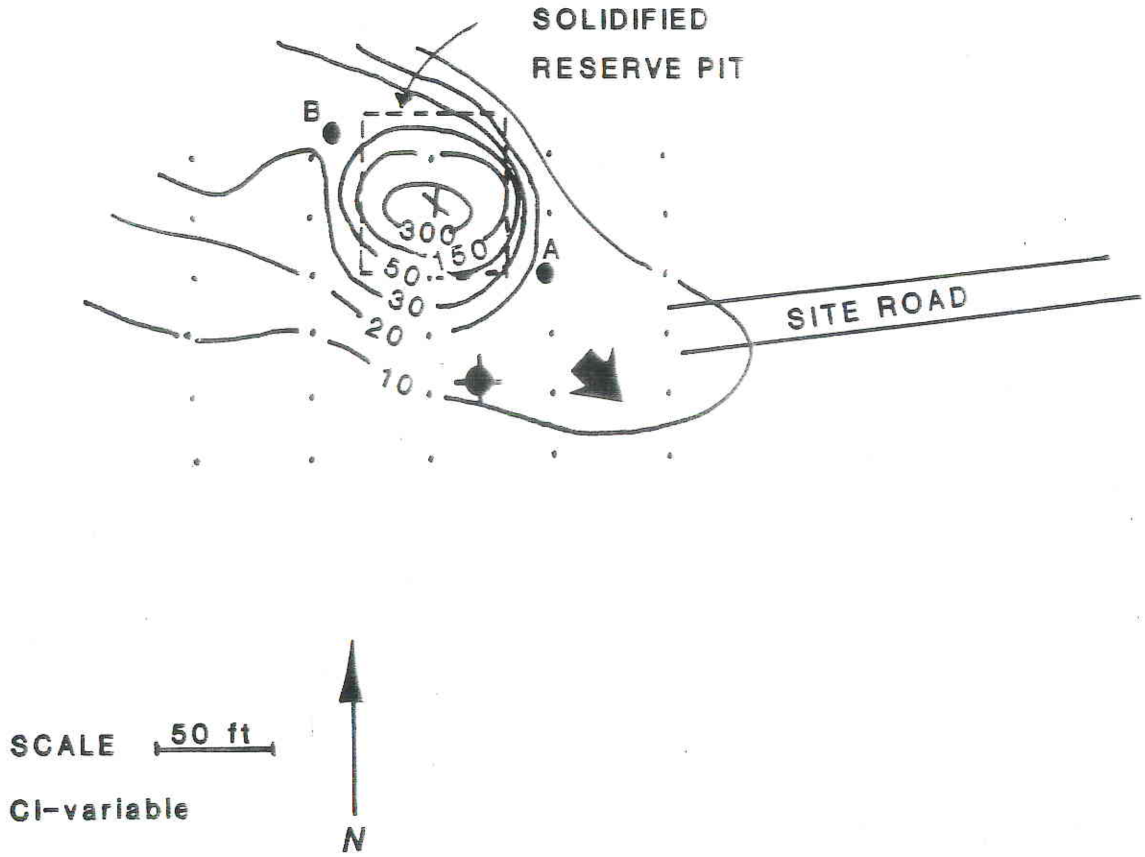
Results of water quality analyses from wells at this site are listed in Table 8 and are summarized below.

Well Number (sample date)	Lab Number	Dissolved Solids (Mg/L)	Chloride Concentration (Mg/L)
252A (04/18/89)	89Q0501	1,920	773
252B (04/18/89)	89Q0502	850	19

Solidification of this pit has apparently concentrated the contamination below a relatively small area of land. Contamination from oil field brines was identified in ground water below the solidified reserve pit. The greatest contamination was found near the southeast corner of the reclaimed pit. Since the monitor wells tapped only the top of the shallow outwash aquifer, vertical density gradients may have developed with greater contamination deeper in the water column.

Brine contamination of the shallow aquifer was identified below the solidified pits. The extent of contamination is unknown but probably covers a small area. The concentration of salt in the ground water is at relatively low but still undesirable levels. No contamination has been detected in the deeper outwash aquifer used as an irrigation water supply.

SITE #252


SOLIDIFIED
RESERVE PIT
B
A
300
150
50
30
20
10
SITE ROAD
SCALE 50 ft
Cl-variable
N

LOCATION AND LEASE INFORMATION

SITE #253
SULLIVAN 33-14
TOWNSHIP 34N., RANGE 58E., SECTION 14DB
ELEVATION = 2058 FEET
DOMINEK LAKE QUAD
OGC # NOT LISTED

SITE DESCRIPTION

Site is an oil well drilled in 1988 to a depth of 11,335 feet in the South Goose Lake Field. The production interval is 11,142 to 11,170 feet in the Red River Formation. The initial production was 310 barrels of oil per day and 2 barrels of water per day. The site is an active oil well operated by Meridian Oil Company. The well is next to an irrigated field. Near surface materials are glacial outwash. The soil type is Manning coarse sandy loam. SCS permeability is 12-35 inches per hour; about 25% of a soil sample will pass through a No. 40 sieve (<.42 mm); the soil is classified GW in the SCS unified system.

CONTAMINATION REPORT

Poor vegetative cover marks surface contamination at the site. The reserve pit was reclaimed by trenching followed by levelling of the surface. Visible surface damage consisting of poor vegetative cover, pieces of pit liner on the surface, and salt crystals on the soil cover about 1 acre.

SITE EVALUATION

An EM-31 survey identified an area of higher than background apparent conductivities covering about .8 acre. Highest conductivities are about 100 feet northwest of the well site.

Background conductivities are very low ranging from 0 to 9.

Three monitor wells were installed in the shallow outwash aquifer at this site. Well 253A (31 feet deep), well 253B (30 feet deep) and well 253C (32 feet deep) were constructed with 5 feet of well screen tapping the top of the aquifer. High apparent terrain conductivities were measured at well 253B. Background apparent terrain conductivities were measured at well 253A and well 253C. A deeper outwash aquifer is separated by 40 to 80 feet of low permeability deposits of glacial till and lake clay based on nearby test holes. The deep outwash aquifer was not monitored at this site.

Water in the shallow outwash aquifer is under unconfined conditions. The depth to water ranges from 24 to 27 feet below land surface. Water level elevations were very similar at all three wells and the direction of ground water flow could not be accurately determined. Heads were generally slightly lower than at Site 252. The values of field parameters measured at this site are listed in Table 7 and the average values are summarized below.

Site Number	Type of site	Distance from Contamination Source (ft)	Depth to Potentiometric Surface (ft)	Chloride Concentration (mg/L)	Specific Conductance umhos/cm	Chloride Salt Contamination Index
253A	Well	70	24	<50	409	.122
253B	Well	20	26	3,220	9,550	.337
253C	Well	210	27	<50	583	.086

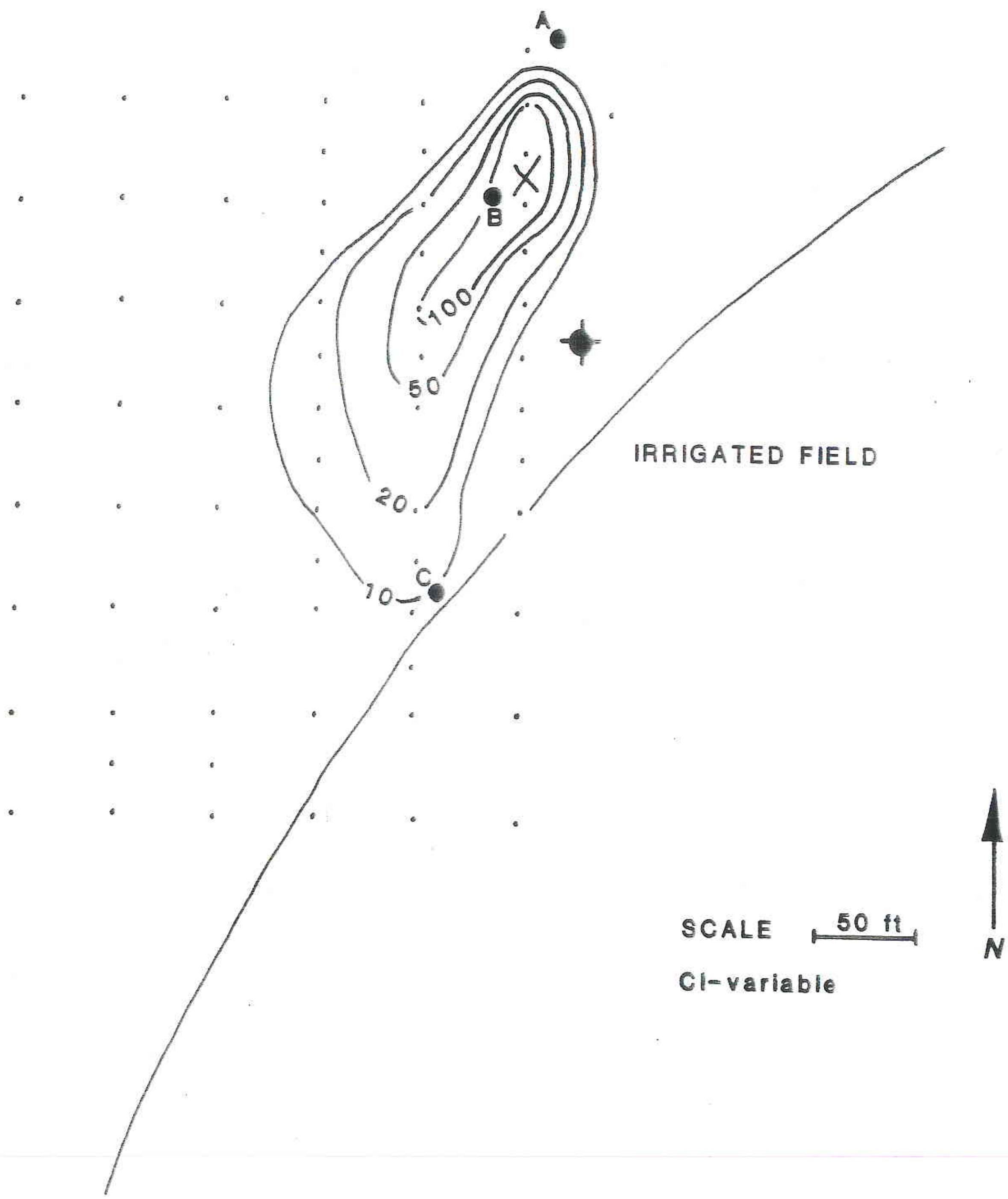
Results of water quality analyses from wells at this site are listed in Table 8 and are summarized below.

Well Number (sample date)	Lab Number	Dissolved Solids (Mg/L)	Chloride Concentration (Mg/L)
253A (04/18/89)	89Q0503	218	14
253B (04/18/89)	89Q0504	4,407	2,570

The only evidence of ground water contamination was detected at well 253B which was installed very close to the reserve pit. At well 253B sand saturated with saltwater was encountered from 6 to 13 feet. This layer probably represents brine leachate moving towards the water table. The other wells are either screened above the contaminated zone, or not downgradient from the contamination source.

The extent of brine contamination is unknown. Contaminant levels were higher at this site than at Site 252 which was in a similar hydrogeologic setting. The higher concentrations may indicate differences between sites reclaimed by solidification and sites reclaimed by trenching.

SITE #253



LOCATION AND LEASE INFORMATION

SITE #258 and #69
STATE A2 AND A3 BATTERY
TOWNSHIP 35N., RANGE 58E., SECTION 16BABA and 9CDCD
ELEVATION = 2125 FEET
TADPOLE LAKE QUAD
OGC # NOT LISTED

SITE DESCRIPTION

Site is a tank battery used for temporary water and oil storage in the Goose Lake Field. Several storage tanks, pipelines, and small out buildings currently make up the site. Three evaporation pits were once located here but have been levelled. An oil well (#69) was drilled about 500 ft north of the site. The well was drilled in 1967 to the Ratcliffe Zone. Another injection well (#68) was located 3/4 mile north of the site but has been reclaimed. The site is being operated by Apache Oil Company. Near surface materials are glacial till forming a level to undulating land surface. The soil type is Williams loam; SCS permeability is .6-2 inches per hour; the grain size of about 95% of a soil sample is less than 0.42 mm. The soil is classified CL in the SCS unified system.

CONTAMINATION REPORT

A large part of this site is covered by evidence of saltwater contamination including bare ground, popcorn soil structure, mottled oil stained soil, damaged vegetation, and salt crystals on the surface. The surface contamination covers about 2.3 acres. Two evaporation pits were reported to have been used for about 10 years. These pits have been reclaimed, probably by trenching and levelling. A third pit was reclaimed by the landowners when the oil company refused to do so. A small pothole is about 1/4 mile to the north down slope of the site. Saltwater was reported to have regularly overflowed from the upper pit into both the lower pit and the pothole. Brine contaminations had also been reported from two private wells located about 3/4 mile north of the site. Complaints regarding contamination of this site resulted in field investigations by the State Department of Health in 1974 and 1975 which documented several sources of contamination.

SITE EVALUATION

An EM conductivity survey identified an area of higher than background conductivities covering about 8 acres. Highest conductivities are over what appears to be reclaimed evaporation pits on the west side of the site and a slough 1/4 mile north of the site. The site is bounded by background apparent conductivities ranging from 40 mmhos/m to 70 mmhos/m on all but the north side.

Two monitor wells were installed at this site. Well 258A (32 feet deep) and well 258B (28 feet deep) were installed in glacial till with 5 feet of screen set at the bottom of each well. Black, sticky, tar-saturated sediment was penetrated while drilling from 1 to 4 feet in well 258B. Traces of hydrocarbon contaminated sediment were encountered to depths of 8 feet in this well. Water from a small temporary pond (258E), a pipeline leak from an oil/water separator (258F), and a slough (258G) were also monitored during the study. Two existing private wells, 258C (60 feet deep) and 258D (86 feet deep) were monitored because of reported contamination.

Ground water in the till was under confined conditions at this site. The average depth to the potentiometric surface was 7 feet during the study in both monitor wells. The direction of ground water flow is towards the north.

Both wells were installed in areas having high apparent terrain conductivity. The values of field parameters measured at this site are listed in Table 7 and the averages are summarized below.

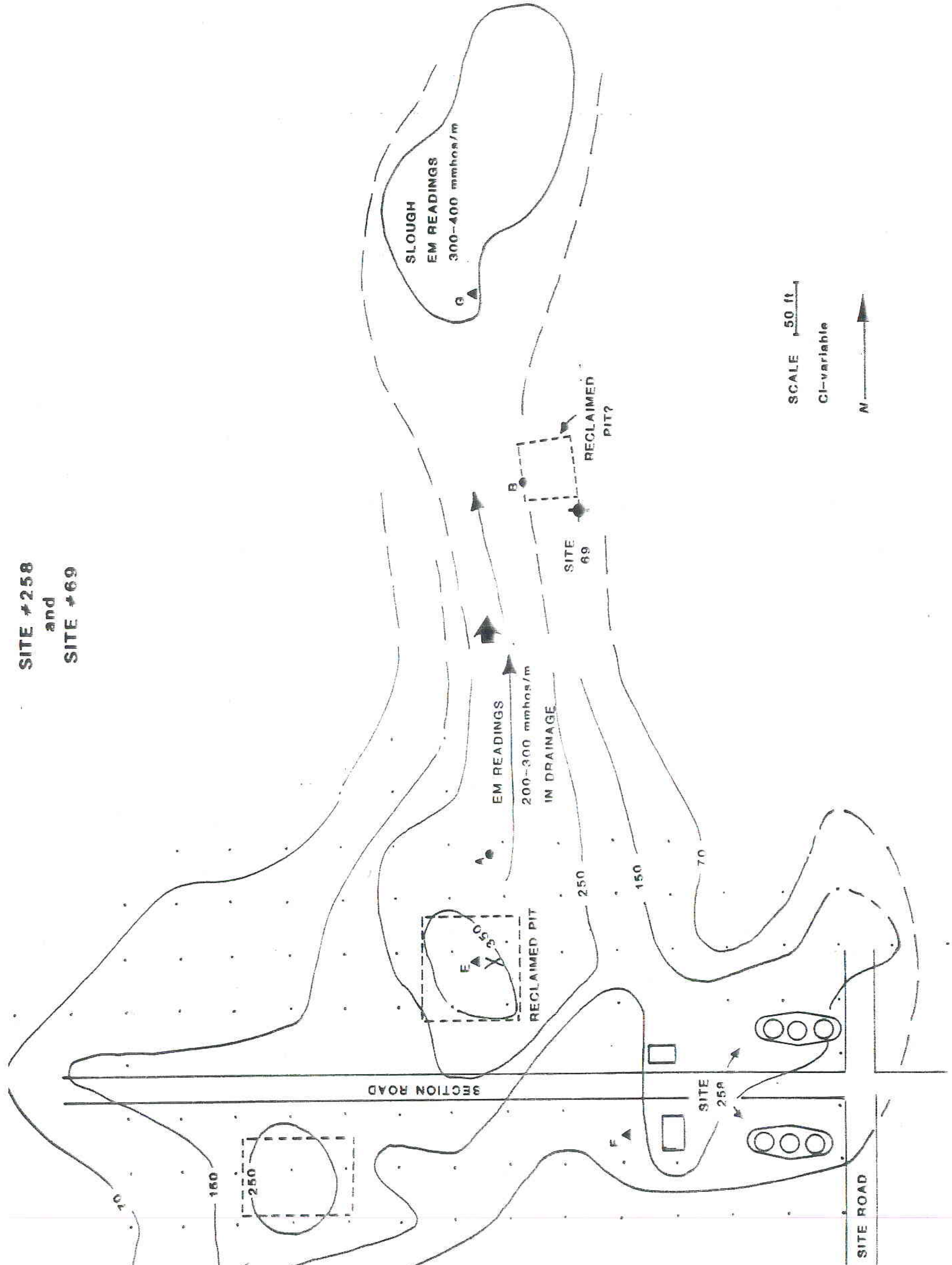
Site Number	Type of site	Distance from Contamination Source (ft)	Depth to Potentiometric Surface (ft)	Chloride Concentration (mg/L)	Specific Conductance umhos/cm	Chloride Salt Contamination Index
258A	Well	100	7	89,775	158,111	.568
258B	Well	450	7	89,110	172,732	.516
258C	Well (private)	3,900	30	68	2,000	.034
258D	Well (private)	4,500	30	130	1,440	.090
258E	Pond			120	630	.190
258F	Leak			190,000	200,000	.950
258G	Slough			140	610	.229

Results of water quality analyses from wells at this site are listed in Table 8 and are summarized below.

Well Number (sample date)	Lab Number	Dissolved Solids (Mg/L)	Chloride Concentration (Mg/L)
258A (04/19/89)	89Q0505	111,200	68,000
258B (04/19/89)	89Q0506	128,000	32,800

Ground water at this site is contaminated with highly concentrated sodium chloride brines. Uncontained leaks of oil and brine were observed during the study. Lower concentrations of contaminants were measured in the seasonal surface water sources at this site. Low to moderate levels of salt contamination were identified in the private wells 258C (3900 feet northeast of site) and 258D (4500 feet north of site).

The hydrogeologic evidence indicates that uncontained brine discharges has contaminated ground water at this site. The extent of the brine plumes was not determined. Contamination of ground water by hydrocarbons was not measured but is a potential problem near well 258B. The low-level contamination of wells north of the site is unlikely to have been derived from this site. Other potential contaminant sources are closer to these wells.


SITE #258
and
SITE #69
SLOUGH
EM READINGS
300-400 mmhos/m
G
RECLAIMED
PIT?
B
SITE
69
SCALE 50 ft
CI-variable
N
EM READINGS
200-300 mmhos/m
IN DRAINAGE
A
250
150
70
E
350
RECLAIMED PIT
SECTION ROAD
SITE
258
F
250
150
70
SITE ROAD

LOCATION AND LEASE INFORMATION

SITE #262
HJELM #1 BATTERY
TOWNSHIP 36N., RANGE 58E., SECTION 32DADD
ELEVATION = 2210 FEET
TADPOLE LAKE QUAD
OGC # NOT LISTED

SITE DESCRIPTION

Site is a tank battery used for temporary water and oil storage in the Goose Lake Field. Several storage tanks, pipelines, pits, and dikes, make up the site. A small dam ponds brine water from flowing down a drainage to the south. The tank battery is being operated by Apache Oil Company. Near surface materials are glacial till. Topography is rolling to steep. The soil type is Zahill loam; SCS permeability is 0.2-2.0 inches per hour; about 90% of a soil sample will pass through a No. 40 sieve (<.42 mm); the soil is classified CL in the unified system.

CONTAMINATION REPORT

Evidence of saltwater contamination includes bare ground, pits and reservoirs containing brine, gullies eroded into the hillside, and salt crystals at the land surface. Visible surface damage covers about 3.8 acres. A water well located about 1/8 mile southeast of the site is reported to have been contaminated by saltwater from this site. Little additional information was reported concerning spills and leaks at this site.

SITE EVALUATION

An Em conductivity survey identified an area of higher than background conductivities covering about 6 acres. Highest conductivities are near the brine ponds. The site is bounded by background conductivities ranging from 45 to 80 mmhos/m on all but the east side.

One monitor well (262A, 33 feet deep) was drilled down slope from the dam. This well was completed into lake clay and glacial till with 5 feet of well screen set in the bottom of the hole. A test hole (262B) was drilled several hundred feet down slope from 262A but there was little evidence of water and a monitor well was not installed. Field water samples were collected from a pond (262C) below the tank battery. Water from private wells 262D and 262E were monitored during the study.

Water in the till is under confined conditions. The potentiometric surface was 24 feet below land surface at well 262A. The direction of ground water flow was not determined but is probably towards the south based on surface topography.

Well 262A was installed in an area having high apparent terrain conductivity. Field parameters measured at this site are listed in Table 7 and the average values are summarized below.

Site Number	Type of site	Distance from Contamination Source (ft)	Depth to Potentiometric Surface (ft)	Chloride Concentration (mg/L)	Specific Conductance umhos/cm	Chloride Salt Contamination Index
262A	Well	150	24	42,500	80,900	.525
262B	Test Hole	750				
262C	Dam			1,250	3,980	.314
262D	Well (private)	900	36.5	<50	1,140	.044
262E (1973)	Well (private)	800		12,770	33,100	.386
262E (1989)	Well (private)	800	67.8	345	1,370	.252

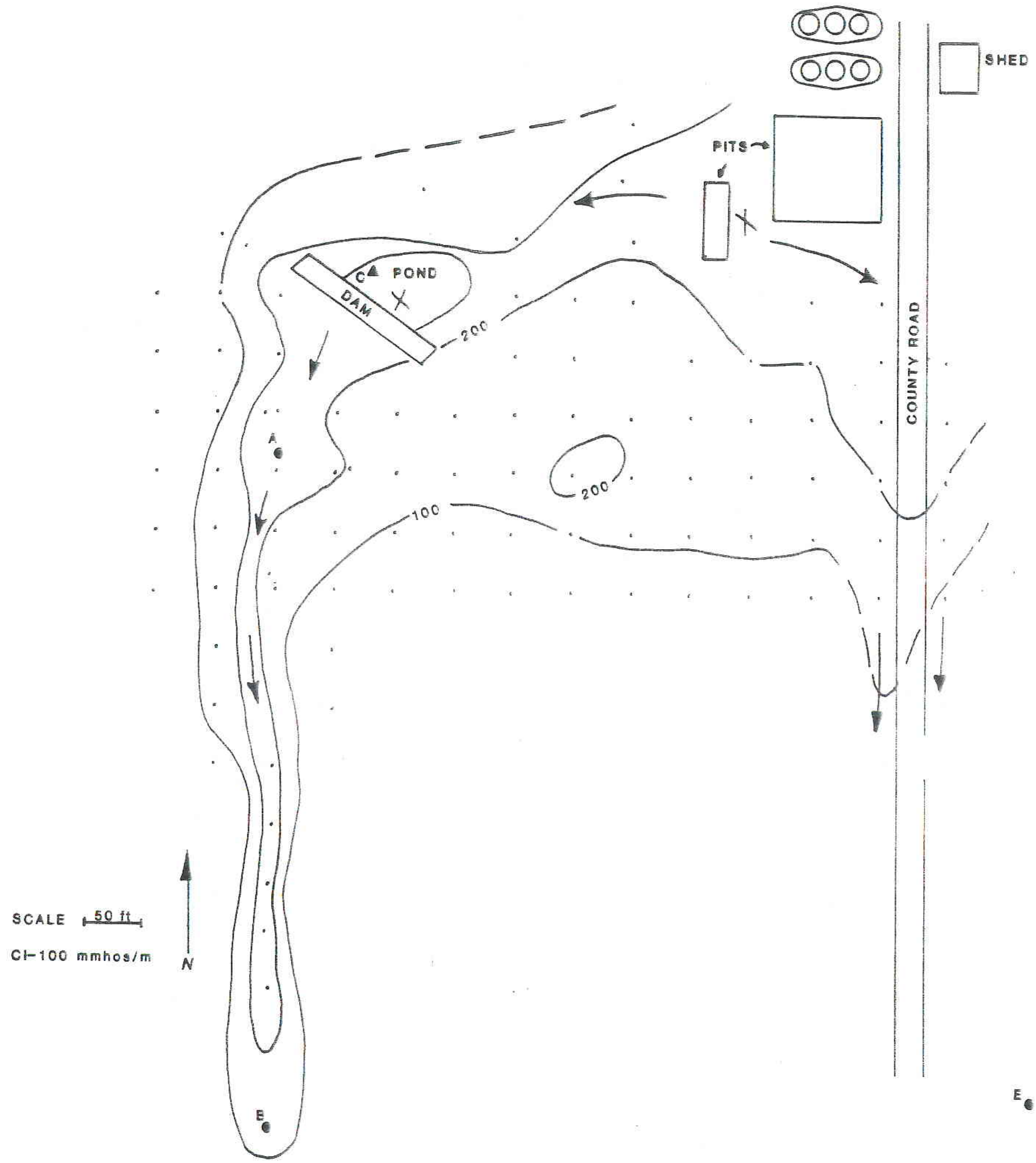
Results of water quality analyses from wells at this site are listed in Table 8 and are summarized below.

Well Number (sample date)	Lab Number	Dissolved Solids (Mg/L)	Chloride Concentration (Mg/L)
262A (04/20/89)	89Q0507	69,050	42,300

Saltwater contamination has impacted ground water in a private well (262E) over 800 feet downgradient of the tank batteries. Several sources appear to have contributed to the contamination including reclaimed pits, unreclaimed pits, surface spills and saltwater storage reservoirs. The chloride concentration measured at well 262E has decreased from 12,770 in 1973 to 345 in 1989. This decrease may not be representative of ground water conditions because the well could not be purged adequately when sampled in 1989.

The hydrogeologic evidence indicates large volumes of saltwater have been released to the surface and subsurface at this site. The extent of the contaminant plume was not determined but was identified 800 feet from the source of contamination.

SITE #262


SHED
PITS
POND
C
DAM
200
200
100
COUNTY ROAD
A
B
E
SCALE 50 ft
CI-100 mmhos/m
N

LOCATION AND LEASE INFORMATION

SITE #264
HAMMER M BATTERY
TOWNSHIP 36N., RANGE 58E., SECTION 28AADA
ELEVATION = 2090 FEET
WESTBY SOUTH QUAD
OGC # NOT LISTED

SITE DESCRIPTION

Site is a tank battery used for temporary oil and water storage in the Goose Lake Field. The site is made up of tanks, pipelines, pits, and dikes. A small intermittent stream drains the site. The tank battery is operated by Apache Oil Company. Near surface materials are glacial till and outwash deposits. The topography is rolling to steep. The soil type is Wabek gravelly sandy loam; SCS permeability is greater than 20 inches per hour; less than 25% of a soil sample will pass through a No. 40 sieve (<.42 mm); the soil is classified as GW in the SCS unified system.

CONTAMINATION REPORT

Evidence of contamination includes bare ground, gravel covering oil leaks, pits containing brine, gullies eroded in the hillside, and salt crystals on the ground surface. Surface contamination covers about 2.9 acres. This tank battery has been operated for about 25 years and is reported to have been the destination for produced brines from a number of oil wells in the area. One large disposal pit was reported to have been excavated into outwash gravel deposits. Landowner reports also indicate frequent oil and brine pipeline leaks. There is potential for saltwater to move towards a larger outwash aquifer east of the site. A coulee immediately below the tank battery was once used for stock watering before uncontained brine spills contaminated the water supply. Down slope water samples from dugouts below the site were collected in July, 1975. All samples showed elevated chloride levels. The most distant sampling point, a dugout about 2/3 mile southeast of the site, contained 940 mg/L chloride.

SITE EVALUATION

An EM-conductivity survey identified an area of higher than background conductivities covering about 6 acres. Highest conductivities are over bare spots in the bottom of the NW-SE trending coulee and near existing brine pits. The site is bounded by background apparent conductivities ranging from 20 to 60. Erratic background values probably are because of the complex intermixing of till and outwash deposits at the surface.

Three monitor wells were installed during the initial site investigation. Well 264A (23 feet deep), was installed in glacial outwash and lake clay deposits with 5 feet of screen set at the bottom of the well. Well 264B (8 feet deep) and well 264D (13 feet deep) were installed in glacial outwash with 5 feet of screen set at the bottom of each well. A test hole (264C) was drilled to 18 ft and no water bearing zones were encountered. Water from a small temporary pond (264E) and from a dugout (264F) was also monitored during the study. Several other monitoring wells, dugouts, and sloughs were monitored down slope of site

#264 as part of a more detailed investigation of brine contamination in the Goose Lake Field.

Water in the outwash is under unconfined conditions. The average depth to water ranged from 2 feet in the coulee bottom (264B and 264D) and 16 feet on the hillside (264A). The direction of groundwater flow is towards the southeast.

All of the monitor wells were located in areas of high apparent terrain conductivity. The field parameters measured at this site are listed in Table 7 and the average values are summarized below.

Site Number	Type of site	Distance from Contamination Source (ft)	Depth to Potentiometric Surface (ft)	Chloride Concentration (mg/L)	Specific Conductance umhos/cm	Chloride Salt Contamination Index
264A	Well	150	16	77,122	144,460	.534
264B	Well	380	2	49,140	90,407	.543
264C	Test Hole	440	Dry			
264D	Well	1,000	3	21,540	43,909	.490
264E	Pond	800		22,560	50,687	.445
264F	Dugout	500		795	2,750	.289

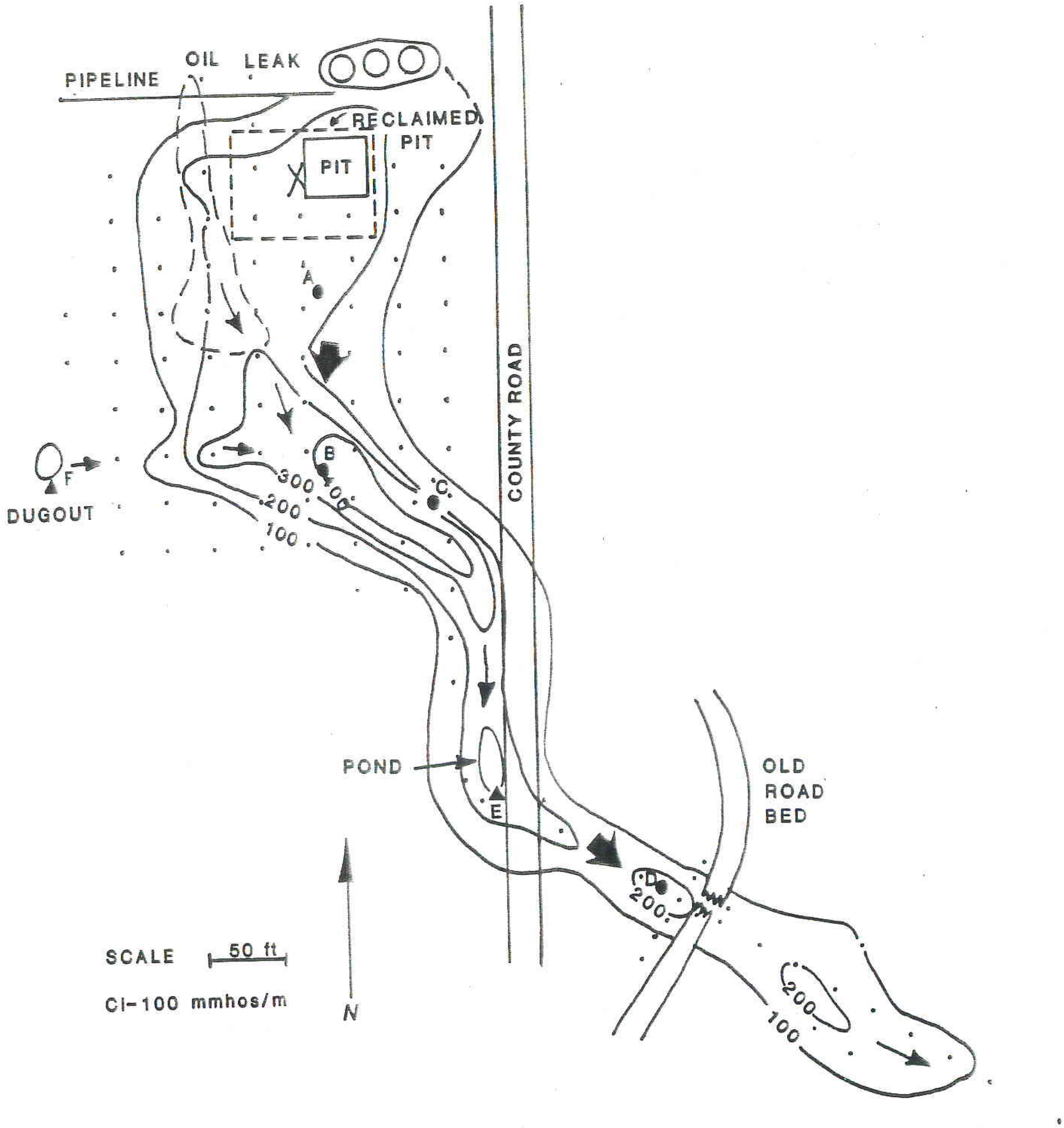
Results of water quality analyses from wells at this site are listed in Table 8 and are summarized below.

Well Number (sample date)	Lab Number	Dissolved Solids (Mg/L)	Chloride Concentration (Mg/L)
264A (10/13/89)	89Q1389	111,500	66,900
264B (04/20/89)	89Q0508	53,300	32,800
264D (04/20/89)	89Q0509	32,200	18,600

Saltwater contamination has impacted ground water over a thousand feet downgradient of the tank battery. Water in a temporary pond and a dugout have been degraded by chlorides to concentrations much higher than drinking water standards.

The hydrogeologic evidence supports the previously reported uncontained discharges of saltwater. Further investigation of this site indicated impacts to outwash aquifers nearly a mile downgradient from the tank battery.

SITE #264



OIL LEAK
PIPELINE
RECLAIMED PIT
PIT
A
B
C
300
100
200
100
F
DUGOUT
COUNTY ROAD
POND
E
OLD ROAD BED
D
200
200
100
SCALE 50 ft
Cl-100 mmhos/m
N

LOCATION AND LEASE INFORMATION

SITE #266
PETERSEN BATTERY
TOWNSHIP 35N., RANGE 58E., SECTION 19DCDD
ELEVATION = 2200 FEET
TADPOLE LAKE QUAD
OGC # NOT LISTED

SITE DESCRIPTION

Site is a tank battery located in the Goose Lake field that has been used for temporary oil and water storage for about 25 years. Storage tanks, an unlined emergency pit, pipelines, reclaimed disposal pits, and dikes make up the site. Apache Oil Company operates the tank battery. Near surface materials are thin glacial till overlying interbedded sand and clay of the Fort Union Formation. Topography is flat to undulating. The soil type is Williams loam; SCS permeability is 0.6 to 2.0 inches per hour; 95% of a soil sample will pass through a No. 40 sieve (<.42 mm). The soil is classified CL in the SCS unified system.

CONTAMINATION REPORT

Evidence of saltwater damage includes bare ground, salt crystals on the surface, poorly drained soils, unlined emergency pits. Surface damage covers about 1.1 acres. Overflow and seepage from pits and leakage from trucks, tanks, and pipelines are the reported sources of saltwater contamination. Brine may be seeping to the surface at the base of the slope below the tank battery. Further down the slope are outwash deposits of the Coalridge Channel.

SITE EVALUATION

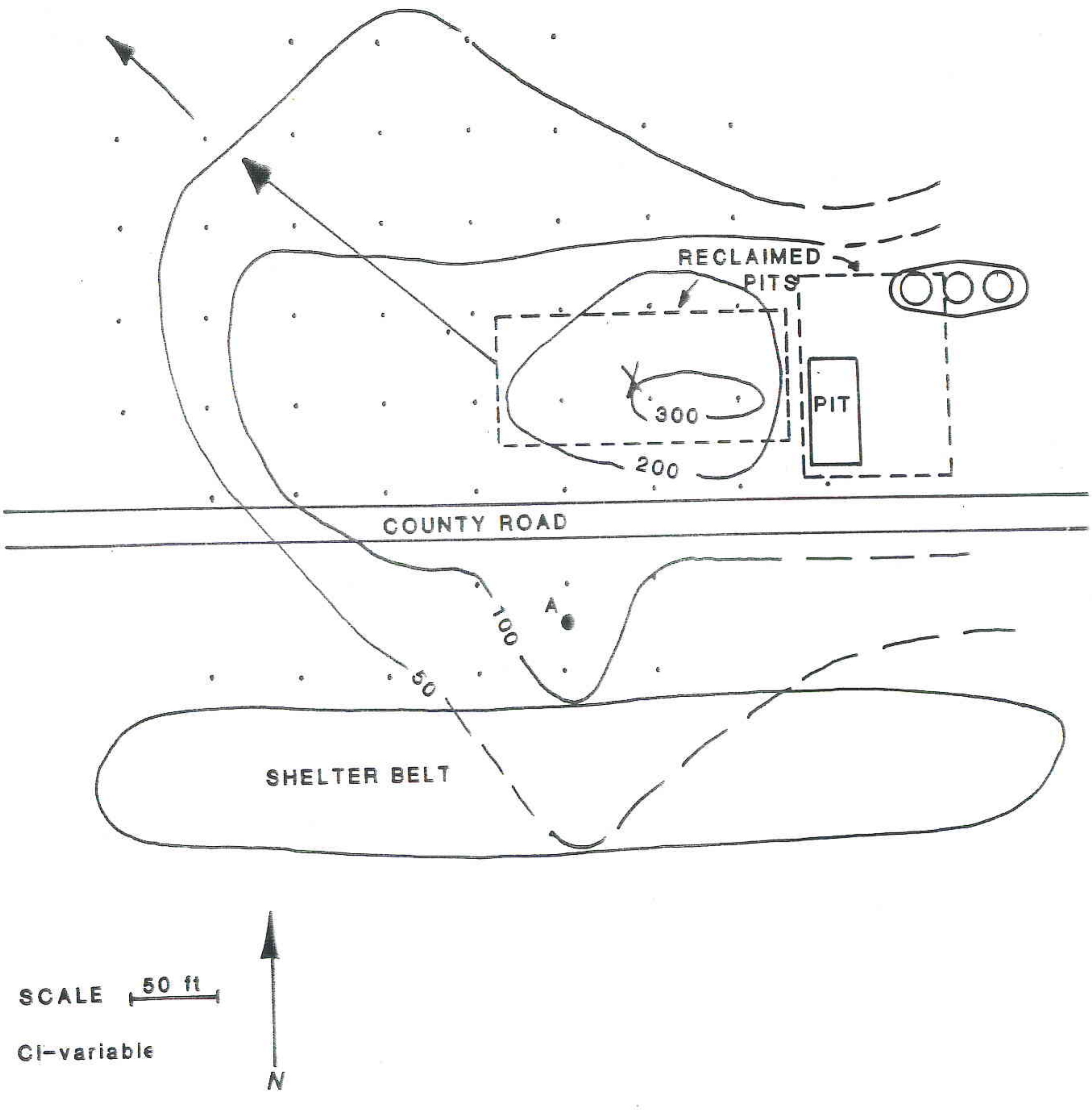
An EM conductivity survey identified an area of higher than background apparent conductivities covering about 2 acres. Highest conductivities are over poorly drained soils next to the tank battery. The site is bounded by background conductivities ranging from 20 to 45 on all but the east side which was outside the boundary of the EM survey.

One test hole was drilled at this site (266A, 38 feet deep). A well was not installed because ground water was not encountered. Logs from the test hole reported 6 feet of glacial till overlying interbedded very fine sand and silty clay of the Fort Union Formation. A private well was monitored 800 feet southwest of the tank battery. The results of field monitoring are listed in Table 7 and are also listed below.

Site Number	Type of site	Distance from Contamination Source (ft)	Depth to Potentiometric Surface (ft)	Chloride Concentration (mg/L)	Specific Conductance umhos/cm	Chloride Salt Contamination Index
266A	Test Hole	140	Dry			
266B	Well (private)	800	60	<50	850	<.059

The surface conditions and EM survey indicate shallow saltwater contamination. No ground water contamination was detected at this site.

SITE #266



RECLAIMED PITS
PIT
300
200
COUNTY ROAD
A
100
50
SHELTER BELT
SCALE 50 ft
Cl-variable
N

LOCATION AND LEASE INFORMATION
SITE #286
HANSEN 2-3
TOWNSHIP 37N., RANGE 57E., SECTION 11DCBD
ELEVATION = 2220 FEET
LONE TREE LAKE QUAD
OGC # NOT LISTED

SITE DESCRIPTION

Site is an oil well drilled in 1981 to a depth of 6700 feet in the Flat Lake Field. The production interval is from 6492 to 6530 feet in the Ratcliffe Zone of the Charles Formation. The initial production was 50 barrels of oil per day and 451 barrels of water per day. Chevron Oil Company is the original and current operator of this oil well. The site is on the west edge of a slough that occupies an outwash channel. Near surface materials are alluvium, glacial till, and outwash deposits. The soil type is Savage silty clay loam; SCS permeability is less than .2 inches per hour, 95% of a soil sample will pass through a No. 40 sieve (<.42 mm); the soil is classified CL in the SCS unified system.

Several private wells, lakes, and sloughs located in the Flat Lake field were included in this site assessment.

CONTAMINATION REPORT

No obvious evidence of saltwater contamination exists at this site. The well pod covered about 1/2 acre. The reserve pit was trenched and squeezed increasing the potential for salts moving off site.

SITE EVALUATION

An EM-31 conductivity survey identified an area of higher than background conductivities covering about 2/3 acre. Highest readings were west of the oil well. Background readings surrounded the site ranging from 11 to 50 mmhos/m. Highest background readings were next to the slough.

One monitor well was installed in glacial outwash deposits east of the oil well. Well 286A is 13 feet deep with well screen set in the bottom 5 feet of the well. Ground water in the outwash is under unconfined conditions. The average depth to the water table during the study period was 9 feet. The direction of ground water flow was not determined but based on topography, it is towards the east. This outwash deposit forms a discontinuous poorly defined aquifer referred to as the Border Channel aquifer. Parts of Site 167 and Site 222 also overlie this aquifer. The value of field parameters measured at this site are listed in Table 7 and the averages are summarized below.

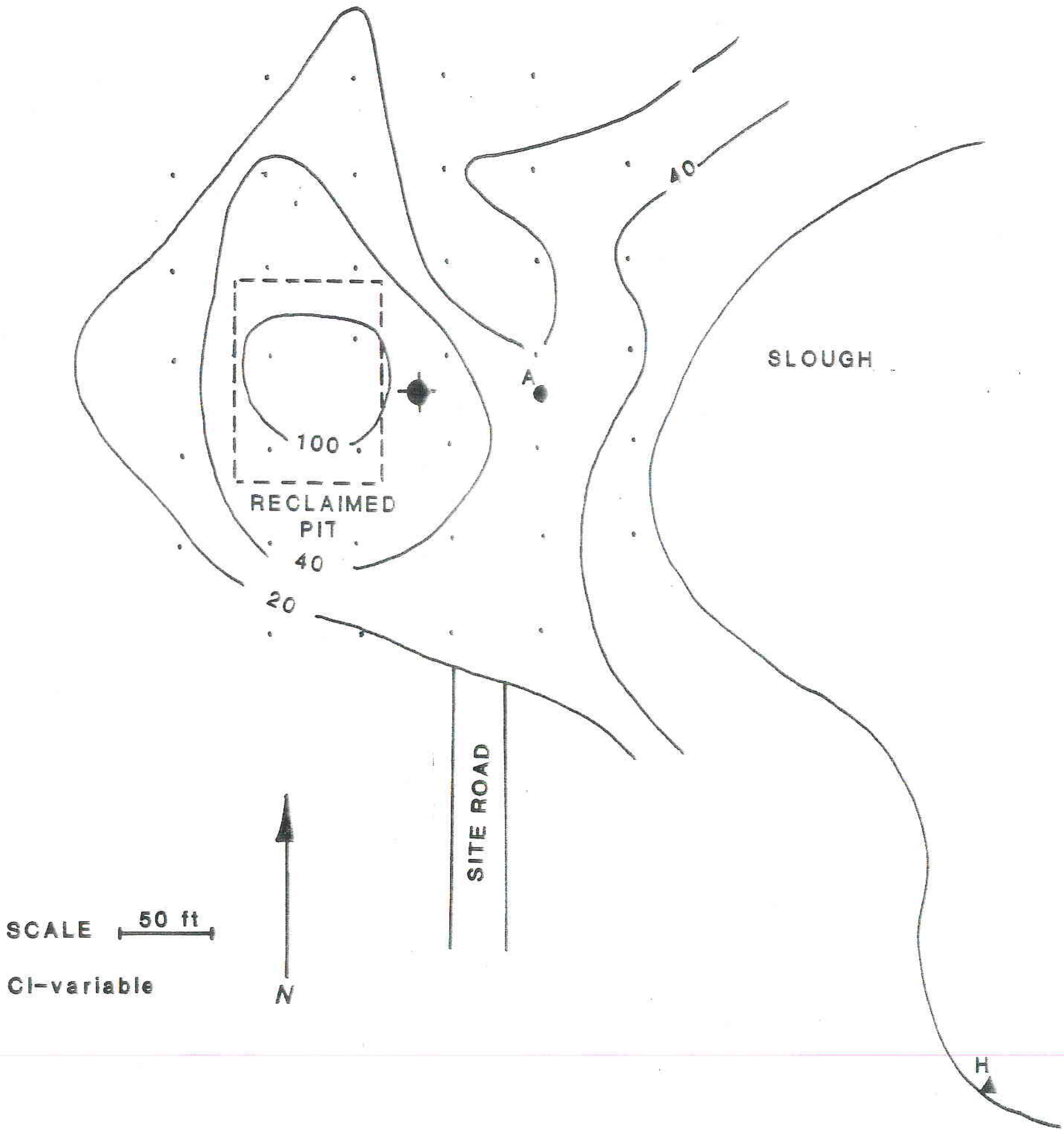
Site Number	Type of site	Distance from Contamination Source (ft)	Depth to Potentiometric Surface (ft)	Chloride Concentration (mg/L)	Specific Conductance umhos/cm	Chloride Salt Contamination Index
286A	Well	130	9	380	2,020	.188
286B	Well (private)		27	<50	870	.057
286C	Slough			3,815	13,685	.279
286D	Slough			420	2,790	.150
286E	Slough			<44	920	.048
286F	Slough			<44	940	.047
286G	Slough			<44	430	.102

Site Number	Type of site	Distance from Contamination Source (ft)	Depth to Potentiometric Surface (ft)	Chloride Concentration (mg/L)	Specific Conductance umhos/cm	Chloride Salt Contamination Index
286H	Slough			170	1,990	.085
286I	Well		17	<44	1,200	.037
286J	Well			50	3,670	.014

The average chloride concentration at well 286A indicates a brine plume is moving east of this site. The level of contamination is relatively low. The source of the contaminant plume appears to be the reserve pit that was reclaimed by trenching. Brine contamination was not evident in any of the private wells monitored in this area.

Elevated chloride levels in several of the nearby sloughs are probably the result of uncontained saltwater discharges from adjacent oil field sites.

SITE #286



40
SLOUGH
A
100
RECLAIMED PIT
40
20
SITE ROAD
SCALE
50 ft
Cl-variable
N
H

LOCATION AND LEASE INFORMATION
SITE #288
SMITHSON/JOYES
TOWNSHIP 37N., RANGE 56E., SECTION 12CDAC01
ELEVATION = 2195 FEET
PARK LAKE QUAD
OGC # NOT LISTED

SITE DESCRIPTION

Site is an oil well drilled to an unknown depth and two nearby tank batteries. The site was investigated by Montana Salinity Control Association regarding reclamation of several saline seeps in the area. Near surface materials are composed of lake clay and glacial outwash deposits. The soil type is Savage silty clay loam; SCS permeability is less than .2 inches per hour; 95% of a soil sample will pass through a No. 40 sieve (<.42 mm); the soil is classified CL in the SCS unified system.

CONTAMINATION REPORT

Little information was available on reported spills, leaks, or other uncontained brine discharges at this site. Barren ground, salt crystals on the soil, and salt tolerant vegetation covered about 1 acre.

SITE EVALUATION

An EM-31 conductivity survey identified an area of higher than background conductivity surrounding the oil well and patch of barren ground. The area of high EM conductivity was not determined because of the few number of readings measured at this site. High background conductivities caused by natural or cropping related high soil salinities complicated the conductivity survey.

Three shallow monitor wells were installed by MSCA into the glacial outwash deposits. Well 288A (8 feet deep), well 288B (15 feet deep), and well 288C (13 feet deep) were monitored during this study.

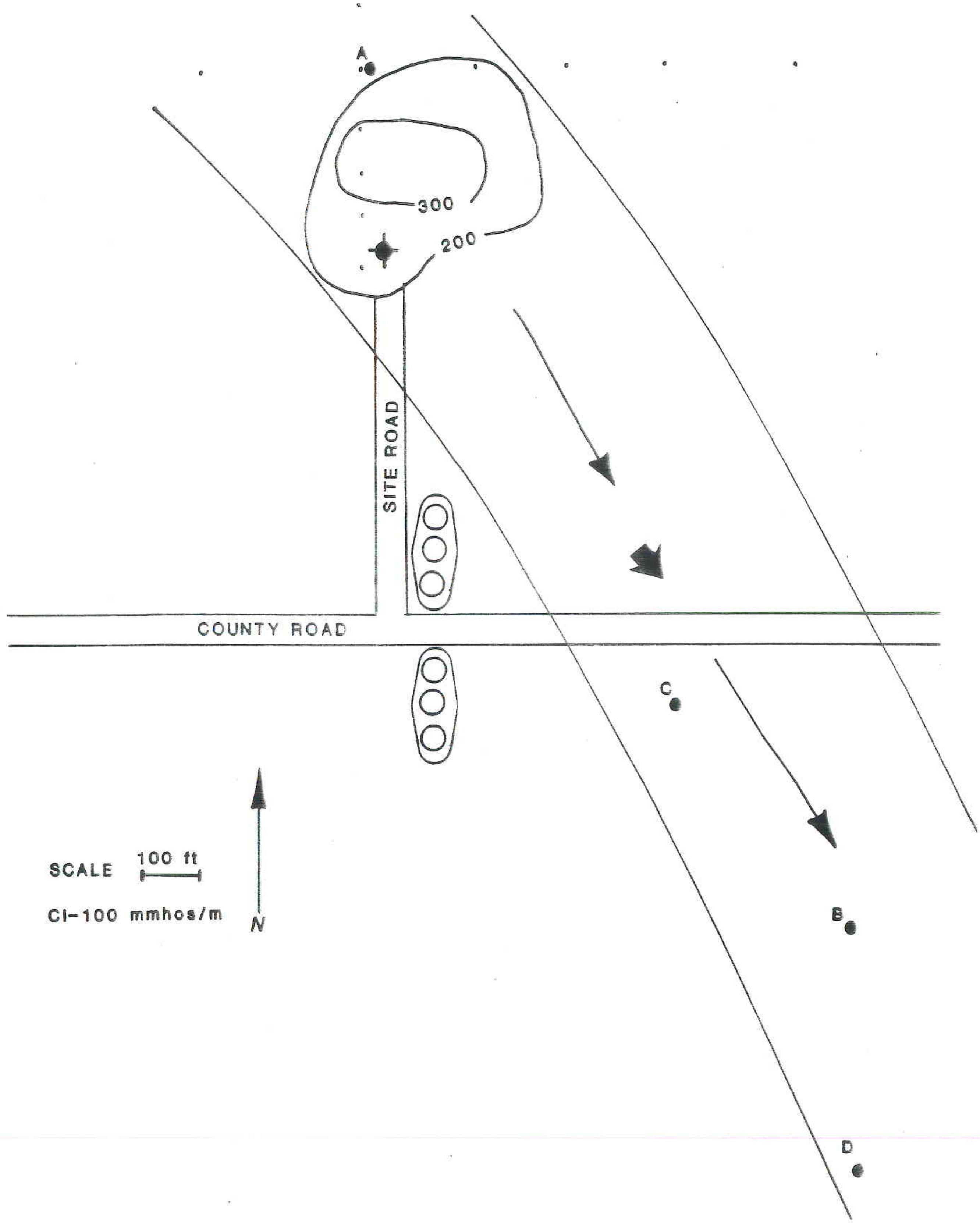
Ground water in the outwash was under unconfined conditions. The depth to water ranged from 5 to 11 feet below land surface. The direction of ground water flow was towards the southeast.

The value of field parameters measured at the site are listed in Table 7 as well as in the following listing.

Site Number	Type of site	Distance from Contamination Source (ft)	Depth to Potentiometric Surface (ft)	Chloride Concentration (mg/L)	Specific Conductance umhos/cm	Chloride Salt Contamination Index
288A	Well		5.5	5,250	21,870	.240
288B	Well		11.2	340	2,750	.124
288C	Well		9.6	<44	1,150	.038
288D	Seep			33,790	72,060	.469

The observed high terrain conductivity values associated with the drilling site indicates uncontained surface discharges of saltwater. High chloride concentrations measured in well 288A, well 288B, and the seep at 288D indicate the source of contamination is from oil field brines. This site is complicated by several natural or cropping related saline seeps. Discharging large volumes of oil field brine in a seep area can combine to increase the degradation of soil and water quality.

SITE #288


A
300
200
SITE ROAD
COUNTY ROAD
C
B
D
SCALE 100 ft
Cl-100 mmhos/m
N

LOCATION AND LEASE INFORMATION

SITE #306
PORTAL PIPELINE BREAK
TOWNSHIP 36N., RANGE 58E., SECTION 16BBDC
ELEVATION =
LONE TREE LAKE QUAD
OGC # NOT LISTED

SITE DESCRIPTION

Site is a slough where an oil pipeline broke leaking 17,000 bbl's (714,000 gallons) of oil into the slough. The spill was reported on 3/20/86. Portal Pipeline Company operates the pipeline. Near surface materials are colluvium, slough deposits, and glacial till. The soil type is Dimmick silty clay; SCS permeability is <.06 inches per hour; more than 95% of a soil sample is less than 0.42 mm; the soil is classified CL in the SCS unified system.

CONTAMINATION REPORT

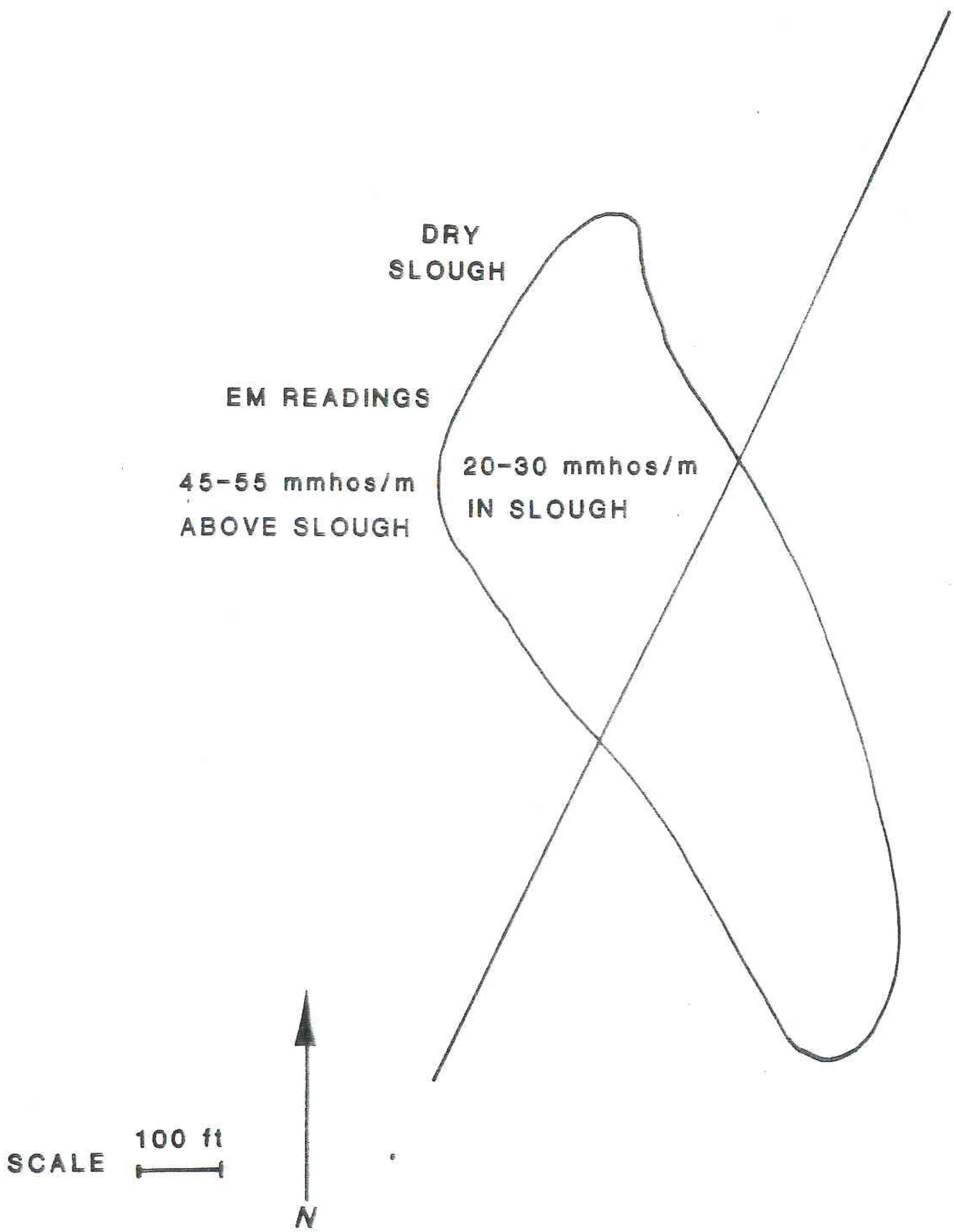
The soil on the dry slough bed was mottled and stained with oil. Following the leak the oil was vacuumed into tanks and the remaining oil was burned. The spill occurred when the ground was frozen.

SITE EVALUATION

An EM-31 conductivity survey was conducted over the spill site. Apparent conductivities were lower over the slough (20 to 30 mmhos/m) than the surrounding slopes (45 to 55 mmhos/m). The low reading may reflect the low conductivity of the oil remaining in the soil.

Ground water or surface water samples were not collected at this site. There remains a potential for hydrocarbon contamination of the slough water if wetter conditions cause the slough to fill.

SITE #306


DRY
SLOUGH
EM READINGS
45-55 mmhos/m
ABOVE SLOUGH
20-30 mmhos/m
IN SLOUGH
SCALE
100 ft
N

LOCATION AND LEASE INFORMATION

SITE #307
EAST PART OF GOOSE LAKE FIELD
SE1/4 OF T. 36 N., R. 58 E. (MT)
and ADJACENT PARTS of T. 162 N. R. 103W. (ND)
ELEVATION = 2040 TO 2100
WESTBY SOUTH QUAD
OGC # NOT LISTED

SITE DESCRIPTION

The site encompasses several sections near the east part of the Goose Lake oil field. Water from several lakes, sloughs, and private wells was monitored during the study. The near surface materials are largely glacial outwash deposits with minor deposits of glacial till.

CONTAMINATION REPORT

Small areas of saltwater contaminated soils are associated with individual oil field sites. Oil wells, tank batteries, and several miles of pipelines are potential contamination sources located in this area. The western part of the map includes the Goose Lake Field detailed brine contamination study area. Most of the lakes and wells are downgradient from this area of brine contaminated surface and ground water.

SITE EVALUATION

One private well and several of the lakes and sloughs in this area appear to be contaminated by oil field brines. The field parameters measured at this site are listed in Table 7 and the average values are summarized below.

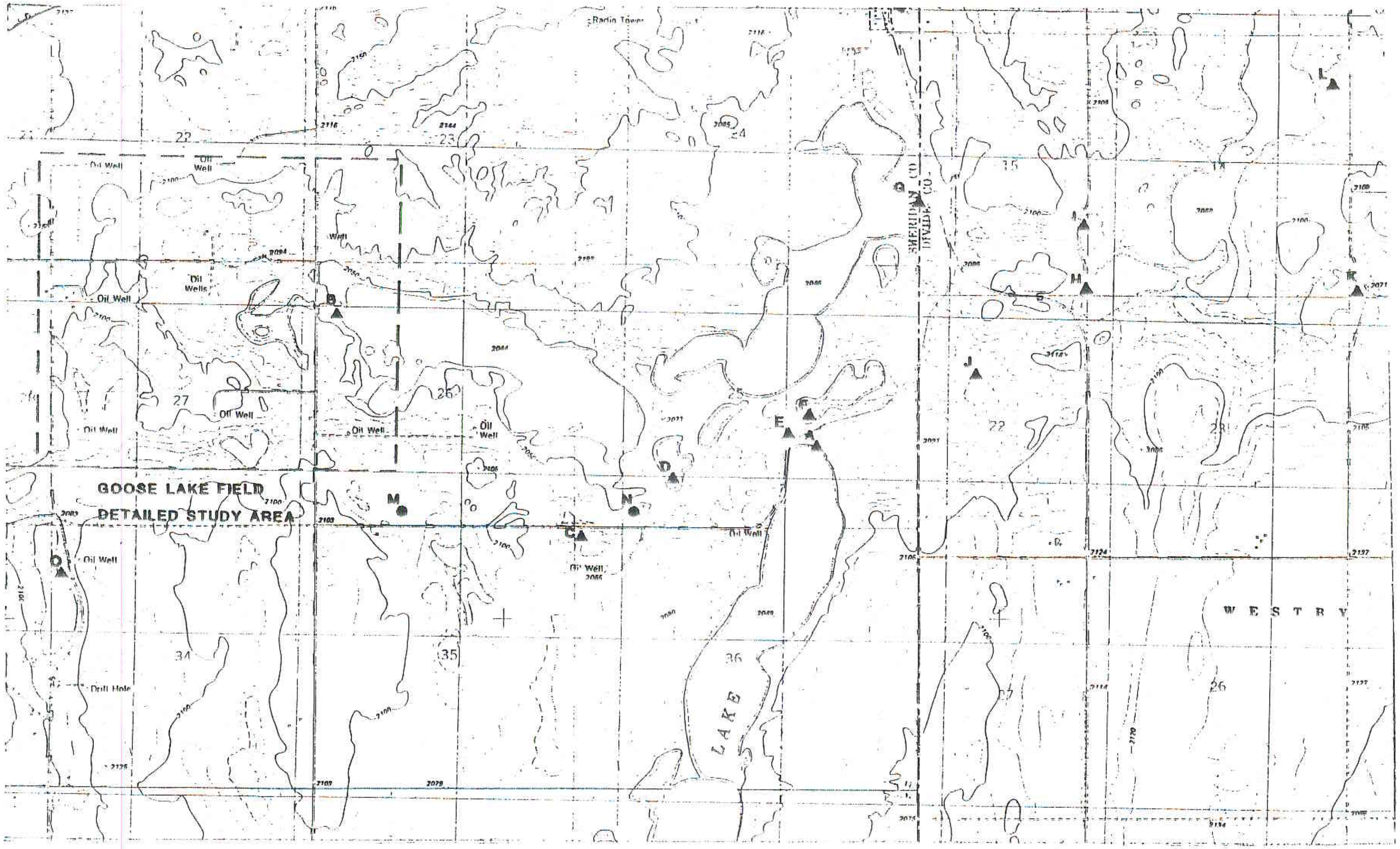
Site Number	Type of site	Distance from Contamination Source (ft)	Depth to Potentiometric Surface (ft)	Chloride Concentration (mg/L)	Specific Conductance umhos/cm	Chloride Salt Contamination Index
307A	Lake			2,770	52,500	.053
307B	Lake			15,360	72,340	.212
307C	Slough			<44	1,070	.041
307D	Slough			3,610	17,940	.201
307E	Slough			<44	330	.133
307F	Slough			2,010	37,500	.054
307G	Lake			1,070	73,700	.015
307H	Slough			1,040	29,200	.036
307I	Slough			130	3,810	.034
307J	Slough			390	10,130	.038
307K	Slough			200	9,220	.022
307L	Slough			570	23,100	.025
307M	Well			290	1,210	.240
307N	Well		Flows	<44	1,870	
307O	Slough			28,320	136,700	.207

Results of water quality analyses from wells at this site are listed in Table 8 and are summarized below.

Well Number (sample date)	Lab Number	Dissolved Solids (Mg/L)	Chloride Concentration (Mg/L)
307A (10/13/89)	89Q1375	86,504	4,070

Uncontained brine discharges to both surface water and ground water are the likely cause of the observed contamination. Dilution and high natural concentrations of sodium sulfate salts in many of the lakes makes evaluation of brine contamination difficult to assess.

SITE #307


GOOSE LAKE FIELD
DETAILED STUDY AREA
Oil Well
Oil Wells
Drill Hole
Radio Tower
SHERIDAN CO.
DIVIDE CO.
LAKE
WESTBY

APPENDIX C

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Sheridan Location: T. 35N R. 58E Sec. 08 Tract: DDDB01 Hole name or Number 67A

Hole location: East of tank battery in fenceline corner

Recorded by: JR Date hole Started: 11/04/88 Date hole Completed: 11/04/88 Driller: F. Schmidt Drilling Company MBMG

Total well depth (ft) 43 Well diameter: 6" Solid Stem Casing diameter(s) and length (s): 2" PVC

Type of casing(s): Weight or gage of casing: Method-perforated or screened:

Interval-perforated or screened: SI = 38-43" #10 Slot screen

Has well been test pumped?: No Were material samples taken?: No Was a water sample taken?: Yes

Remarks: Gravel packed 30-43', backfilled with clay cuttings 5-30', bentonite seal to surface

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	1	Pebbly loam, dark brown, (topsoil)
1	33	Pebbly clay loam, light olive-brown (oxidized till)
33	36	Pebbly clay loam, dark olive-brown (transition till)
36	43	Pebbly clay loam, dark bluish-gray (unoxidized till)

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Sheridan Location: T. 35N R. 58E Sec. 08 Tract: DDDA01 Hole name or Number 67B

Hole location: 100' SE of 67A, in bottom of drainage

Recorded by: JR Date hole Started: 11/04/88 Date hole Completed: 11/04/88 Driller: F. Schmidt Drilling Company MBMG

Total well depth (ft) 43' Well diameter: 6" Solid Stem Casing diameter(s) and length (s): 2" PVC

Type of casing(s): ______ Weight or gage of casing: ______ Method-perforated or screened: ______

Interval-perforated or screened: SI = 37-42' #10 slot screen

Has well been test pumped?: No Were material samples taken?: No Was a water sample taken?: Yes

Remarks: Gravel pack 21-42', clay cuttings 3-21', bentonite seal to surface

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	2	Silty loam topsoil, very dark brown (slopewash)
2	25	Pebbly clay loam, light olive-brown, cohesive, hard (oxidized till)
25	37	Pebbly clay loam, dark olive-brown, cohesive, soft, pliable (transition till)
37	43	Pebbly clay loam, dark bluish-gray (unoxidized till)

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Sheridan Location: T. 35N R. 58E Sec. 17 Tract: ADAC02 Hole name or Number 79A

Hole location: Nelson battery in gap where trees died

Recorded by: JR Date hole Started: 11/03/88 Date hole Completed: 11/03/88 Driller: F. Schmidt Drilling Company MBMG

Total well depth (ft) 23 Well diameter: 6" Solid Stem Casing diameter(s) and length (s): 2" PVC

Type of casing(s): ______ Weight or gage of casing: ______ Method-perforated or screened: ______

Interval-perforated or screened: SI = 18-23' #10 slot screen

Has well been test pumped?: No Were material samples taken?: No Was a water sample taken?: Yes

Remarks: Gravel pack 9-23', cuttings 3-9', bentonite seal to surface

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	3	Silt loam, very dark brown (topsoil)
3	20	Pebbly clay loam, light olive-brown, salt stringers, cohesive, stiff (oxidized till)
20	23	Pebbly clay loam, dark olive-brown, cohesive, stiff (transition till)

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Sheridan Location: T. 35N R. 58E Sec. 17 Tract: AADC01 Hole name or Number 79E

Hole location: 350' north of location road in waterway

Recorded by: TT Date hole Started: 11/03/88 Date hole Completed: 11/03/88 Driller: F. Schmidt Drilling Company MBMG

Total well depth (ft) 38 Well diameter: 6" Solid Stem Casing diameter(s) and length (s): 2" PVC

Type of casing(s): ______ Weight or gage of casing: ______ Method-perforated or screened: ______

Interval-perforated or screened: SI = 31-36' #10 slot screen

Has well been test pumped?: No Were material samples taken?: No Was a water sample taken?: Yes

Remarks: Gravel pack 10-36', cuttings, 3-10', bentonite seal to surface

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	3	Silt loam, very dark brown (topsoil)
3	20	Pebbly clay loam, light olive brown, cohesive, stiff, gypsum stringers, (oxidized till)
20	33	Pebbly clay loam, dark olive brown, (transition till)
33	38	Pebbly clay loam, dark bluish gray (unoxidized till)

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Sheridan Location: T. 35N R. 58E Sec. 17 Tract: ADAB01 Hole name or Number 79C

Hole location: 150' north of location road next to 12" PVC pipeline

Recorded by: JR Date hole Started: 11/03/88 Date hole Completed: 11/03/88 Driller: F. Schmidt Drilling Company MBMG

Total well depth (ft) 28 Well diameter: 6" Solid Stem Casing diameter(s) and length (s): 2" PVC

Type of casing(s): Weight or gage of casing: Method-perforated or screened:

Interval-perforated or screened: SI = 23-28' #10 slot screen

Has well been test pumped?: No Were material samples taken?: No Was a water sample taken?: Yes

Remarks: Gravel pack 6-28', bentonite seal to surface

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	3	Silty clay, dark yellowish-brown, laminated dark brown with light brown (slopewash)
3	18	Pebbly clay loam, light olive-brown, (oxidized till)
18	25	Pebbly clay loam, dark olive-brown, (transition till)
25	28	Pebbly clay loam, dark bluish-gray, (unoxidized till)

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Sheridan Location: T. 36N R. 58E Sec. 22 Tract: CBAC01 Hole name or Number 117A

Hole location: 20' north of rockpile in waterway above small dam

Recorded by: TT Date hole Started: 11/07/88 Date hole Completed: 11/07/88 Driller: F. Schmidt Drilling Company MBMG

Total well depth (ft) 48 Well diameter: 6" Solid Stem Casing diameter(s) and length (s): 2" PVC

Type of casing(s): Weight or gage of casing: Method-perforated or screened:

Interval-perforated or screened: SI = 38-43' #10 slot screen

Has well been test pumped?: No Were material samples taken?: No Was a water sample taken?: Yes

Remarks: Gravel pack 20-43', cuttings 5-20', bentonite seal to surface, bottom 5' of hole collapsed

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	1	Silty sand, medium brown, loose, (topsoil)
1	12	Pebbly clay loam, light olive-brown, hard, cohesive (oxidized till)
12	20	Pebbly clay loam, dark olive-brown, (transition till)
20	40	Clay loam, dark gray (unoxidized till/lake clay)
40	48	Pebbly clay loam, light gray with sand and lignite stringers (unoxidized till)

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Sheridan Location: T. 36N R. 58E Sec. 22 Tract: CBDA01 Hole name or Number 117B

Hole location: In waterway 100' south of small dam

Recorded by: TT Date hole Started: 11/07/88 Date hole Completed: 11/07/88 Driller: F. Schmidt Drilling Company MBMG

Total well depth (ft) 38 Well diameter: 6" Solid Stem Casing diameter(s) and length (s): 2" PVC

Type of casing(s): Weight or gage of casing: Method-perforated or screened:

Interval-perforated or screened: 33-38' #20 slot screen

Has well been test pumped?: No Were material samples taken?: No Was a water sample taken?: Yes

Remarks: Gravel pack 15-38', cuttings 5-15', bentonite seal to surface

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	1	Sandy silt, dark brown, loose, dry (topsoil)
1	5	Pebbly silty loam, light brownish-gray, loose, dry (slopewash)
5	15	Pebbly clay loam, dark olive-brown, cohesive, hard, fractured (transition till)
15	30	Pebbly clay loam, bluish-gray, cohesive, moderately hard (unoxidized till)
30	38	Pebbly clay loam, light gray, cohesive, moderately hard (unoxidized till)

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Sheridan Location: T. 36N R. 58E Sec. 22 Tract: CDBB01 Hole name or Number 117C

Hole location: South end of saline seep area south of small dam

Recorded by: TT Date hole Started: 11/07/88 Date hole Completed: 11/07/88 Driller: F. Schmidt Drilling Company MBMG

Total well depth (ft) 43 Well diameter: 6" Solid Stem Casing diameter(s) and length (s): 2" PVC

Type of casing(s): Weight or gage of casing: Method-perforated or screened:

Interval-perforated or screened: SI = 38-43' #40 slot screen

Has well been test pumped?: No Were material samples taken?: No Was a water sample taken?: Yes

Remarks: Gravel pack 20-43', bentonite seal to surface

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	15	Pebbly clay loam, dark olive-brown, cohesive, hard, large salt crystals in fractures (oxidized till)
15	30	Pebbly clay loam, dark bluish-gray, cohesive, hard (unoxidized till)
30	43	Silty clay loam, medium gray (unoxidized till)

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Sheridan Location: T. 36N R. 58E Sec. 22 Tract: CDBA01 Hole name or Number 117D

Hole location: 75' west of dugout in marshy area, west end of slough

Recorded by: TI Date hole Started: 11/07/88 Date hole Completed: 11/07/88 Driller: F. Schmidt Drilling Company MBMG

Total well depth (ft) 8 Well diameter: 6" Solid Stem Casing diameter(s) and length (s): 2" PVC

Type of casing(s): Weight or gage of casing: Method-perforated or screened:

Interval-perforated or screened: SI = 3-8' #20 slot screen

Has well been test pumped?: No Were material samples taken?: No Was a water sample taken?: Yes .

Remarks: Natural pack (collapse) 5-8', gravel pack 3-5', bentonite seal to surface

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	4	Silt loam, cohesive, soft, black with organics (outwash/slough deposits)
4	8	Coarse pebbly sand, with clay lenses (outwash)

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Sheridan Location: T. 36N R. 58E Sec. 27 Tract: ABAB01 Hole name or Number 117J

Hole location: In low spot north of bend in county road

Recorded by: JR Date hole Started: 06/02/89 Date hole Completed: 06/02/89 Driller: F. Schmidt Drilling Company MBMG

Total well depth (ft) 18 Well diameter: 7-1/2" Casing diameter(s) and length (s): 2" PVC

Type of casing(s): Weight or gage of casing: Method-perforated or screened:

Interval-perforated or screened: 4.5 - 14.5 #20 slot screen

Has well been test pumped?: No Were material samples taken?: No Was a water sample taken?: Yes

Remarks: Installed 2" well natural pack, bentonite seal to surface

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	3	Silt, very dark grayish-brown, clayey, rich in organics (slough sediment)
3	4	Pebbly clay loam, light gray, soft, non cohesive (transition till)
4	6	Sand and gravel, olive-green, silty, very poorly sorted (wet) (outwash)
6	17	Sand and gravel, gray, silty, very poorly sorted (outwash)
17	18	Till, dark blue-gray, bit sample (unoxidized till)

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Sheridan Location: T. 36N R. 58E Sec. 27 Tract: ABBD01 Hole name or Number 124A

Hole location: 100' west of site road NW of pumper

Recorded by: JR Date hole Started: 11/06/88 Date hole Completed: 11/06/88 Driller: F. Schmidt Drilling Company MBMG

Total well depth (ft) 23 Well diameter: 7" hollow stem Casing diameter(s) and length (s): 2" PVC

Type of casing(s): Weight or gage of casing: Method-perforated or screened:

Interval-perforated or screened: SI = 18-23' #40 slot screen

Has well been test pumped?: No Were material samples taken?: No Was a water sample taken?: Yes

Remarks: Natural pack, bentonite seal to surface

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	1	Sandy loam, dark brown (topsoil)
1	3	Sand and gravel, poorly sorted, pale brown (outwash)
3	14	Sand and gravel, poorly sorted, light yellowish-brown, gravel layer at 12' (outwash)
14	16	Silt, sandy, clayey, gray, soft, mod. cohesive (outwash)
16	18	Sand and gravel, yellowish-brown, poorly sorted, gravel layer 16-17' (outwash)
18	22	Sand, silty, clayey, gray (outwash)
22	23	Pebbly clay loam, dark bluish-gray (unoxidized till)

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Sheridan Location: T. 36N R. 58E Sec. 27 Tract: ABAC01 Hole name or Number 124B

Hole location: North east of pumper about 350' in tall grass

Recorded by: JR Date hole Started: 11/06/88 Date hole Completed: 11/06/88 Driller: F. Schmidt Drilling Company MBMG

Total well depth (ft) 8 Well diameter: 7" hollow stem Casing diameter(s) and length (s): 2" PVC

Type of casing(s): Weight or gage of casing: Method-perforated or screened:

Interval-perforated or screened: SI = 3-8' #20 slot screen

Has well been test pumped?: No Were material samples taken?: No Was a water sample taken?: Yes

Remarks: Natural pack, bentonite seal to surface

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	3	Silt, clayey, dark brown, (slough deposits)
3	8	Sand and gravel, yellowish-brown, poorly sorted (outwash)

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Sheridan Location: T. 36N R. 58E Sec. 27 Tract: AABC01 Hole name or Number 124C

Hole location: Edge of slough 200' east of 124B near small rise

Recorded by: JR Date hole Started: 11/06/88 Date hole Completed: 11/06/88 Driller: F. Schmidt Drilling Company MBMG

Total well depth (ft) 8 Well diameter: 7" hollow stem Casing diameter(s) and length (s): 2" PVC

Type of casing(s): Weight or gage of casing: Method-perforated or screened:

Interval-perforated or screened: SI = 3-8' #20 slot screen

Has well been test pumped?: No Were material samples taken?: No Was a water sample taken?: Yes.

Remarks: Natural pack, bentonite seal to surface

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	1	Silt, clayey, dark brown, (topsoil)
1	3	Silt, clayey, light gray, wet, noncohesive (slough deposits)
3	8	Sand and gravel, yellowish-brown, poorly sorted (outwash)

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Sheridan Location: T. 36N R. 58E Sec. 27 Tract: AAAA01 Hole name or Number 124G

Hole location: NE corner of section 27 near road intersection

Recorded by: JR Date hole Started: 06/02/89 Date hole Completed: 06/02/89 Driller: F. Schmidt Drilling Company MBMG

Total well depth (ft) 31 Well diameter: 7-1/2" Casing diameter(s) and length (s): 2" PVC 20'

Type of casing(s): Weight or gage of casing: Method-perforated or screened:

Interval-perforated or screened: 17-27 #10 slot screen

Has well been test pumped?: No Were material samples taken?: No Was a water sample taken?: Yes

Remarks: Installed 2" well Natural pack, bentonite seal to surface

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	1	Sandy loam, dark grayish-brown, (topsoil)
1	10	Sand and gravel, yellowish-brown, silty, poorly sorted, wet @ 6' (outwash)
10	30	Sand and gravel, grayish-brown, silty, poorly sorted (outwash)
30	31	Pebbly clay loam, dark bluish-gray, moderately cohesive (unoxidized till)

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Sheridan Location: T. 36N R. 58E Sec. 27 Tract: AADA01 Hole name or Number 124H

Hole location: 1/4 mile south of 124G near low spot in ditch

Recorded by: JR Date hole Started: 06/02/89 Date hole Completed: 06/02/89 Driller: F. Schmidt Drilling Company MBMG

Total well depth (ft) 17 Well diameter: 7-1/2" Casing diameter(s) and length (s): 2" PVC 14'

Type of casing(s): ______ Weight or gage of casing: ______ Method-perforated or screened: ______

Interval-perforated or screened: 12-17 #10 slot screen

Has well been test pumped?: No Were material samples taken?: No Was a water sample taken?: Yes

Remarks: Installed well natural pack, bentonite seal to surface

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	1	Sandy loam, dark brown (topsoil)
1	10	Sand and gravel, yellowish-brown, silty, poorly sorted (outwash)
10	16	Sand and gravel, grayish-brown, silty, poorly sorted (outwash)
16	18	Pebbly clay loam, bluish-gray, moderately cohesive (unoxidized till)

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Sheridan Location: T. 36N R. 58E Sec. 27 Tract: ABCD01 Hole name or Number 124I

Hole location: South of well pad at site #124 (300')

Recorded by: JR Date hole Started: 06/02/89 Date hole Completed: 06/02/89 Driller: F. Schmidt Drilling Company MBMG

Total well depth (ft) 18 Well diameter: No well Casing diameter(s) and length (s): ____

Type of casing(s): ____ Weight or gage of casing: ____ Method-perforated or screened: ____

Interval-perforated or screened: ____

Has well been test pumped?: ____ Were material samples taken?: ____ Was a water sample taken?: ____

Remarks: No well -- channel is north of here

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	1	Sandy loam, dark grayish-brown (topsoil)
1	5	Sand and gravel, pale brown, silty, poorly sorted, dry (outwash)
5	14	Sand and gravel, yellowish-brown, silty, poorly sorted, dry (outwash)
14	18	Pebbly clay loam, dark bluish-gray, cohesive (unoxidized till)

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Sheridan Location: T. 36N R. 58E Sec. 27 Tract: ABAC02 Hole name or Number 124J

Hole location: 30' SE of 124E

Recorded by: JR Date hole Started: 06/02/89 Date hole Completed: 06/02/89 Driller: F. Schmidt Drilling Company MBMG

Total well depth (ft) 18 Well diameter: 7-1/2" Casing diameter(s) and length (s): 2" PVC 10'

Type of casing(s): ______ Weight or gage of casing: ______ Method-perforated or screened: ______

Interval-perforated or screened: SI = 8-18" #10 Slot screen

Has well been test pumped?: ______ Were material samples taken?: ______ Was a water sample taken?: ______

Remarks: Installed well natural pack, bentonite seal to surface

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	5	Clay, dark grayish-brown, silty, organic rich, (slough deposits)
5	15	Sand and gravel, yellowish-brown, silty, poorly sorted, rock at 15' (outwash)
15	18	Pebbly clay loam, dark bluish-gray, cohesive (unoxidized till)

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Sheridan Location: T. 36N R. 58E Sec. 27 Tract: ABDA01 Hole name or Number 124K

Hole location: 25' SE of 124V

Recorded by: JF Date hole Started: 06/03/89 Date hole Completed: 06/03/89 Driller: F. Schmidt Drilling Company MBMG

Total well depth (ft) 14 Well diameter: 10-1/4 hollow Stem Casing diameter(s) and length (s): 4-1/2" x 6' 2' out of ground

Type of casing(s): Weight or gage of casing: Method-perforated or screened:

Interval-perforated or screened: (4-14) 4-9' 4-1/2" #20 slot screen 9-14 4" #20 slot screen

Has well been test pumped?: Yes Were material samples taken?: No Was a water sample taken?: Yes

Remarks: Installed well 5' of 4-1/2" 20 slot screen 1 foot blank and 4 feet 4" #20 slot screen and 6' of blank 4-1/2" PVC on top, natural pack, bentonite seal to surface

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	3	Clay, dark grayish-brown, silty, organics (slough deposits)
3	13	Sand and gravel, yellowish-brown, silty, poorly sorted (outwash)
13	14	Pebbly clay loam, bluish-gray, cohesive (unoxidized till)

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Sheridan Location: T. 36N R. 58E Sec. 27 Tract: ABDB01 Hole name or Number 124L

Hole location: About 200' south of 124K

Recorded by: JR Date hole Started: 06/03/89 Date hole Completed: 06/03/89 Driller: F. Schmidt Drilling Company MBMG

Total well depth (ft) 17 Well diameter: 7-1/2" Casing diameter(s) and length (s): 2" PVC

Type of casing(s): --- Weight or gage of casing: Method-perforated or screened:

Interval-perforated or screened: 3-13

Has well been test pumped?: No Were material samples taken?: No Was a water sample taken?: Yes

Remarks: Installed 2" well, 10' #20 slot screen, 4' drop pipe, 5' casing, 2' out of ground, bentonite seal to surface

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	3	Clay, dark grayish-brown, silty, organics (slough sediments)
3	13	Sand and gravel, yellowish-brown to grayish brown, silty, poorly sorted (outwash)
13	17	Pebbly clay loam, dark bluish-gray, cohesive (unoxidized till)

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Sheridan Location: T. 36N R. 58E Sec. 27 Tract: ABDC01 Hole name or Number 124M

Hole location: South of 4" well about 600' next to junk pile

Recorded by: JR Date hole Started: 06/03/89 Date hole Completed: 06/03/89 Driller: F. Schmidt Drilling Company MBMG

Total well depth (ft) 13 Well diameter: 7-1/2" Casing diameter(s) and length (s): 2" PVC

Type of casing(s): Weight or gage of casing: Method-perforated or screened:

Interval-perforated or screened: 8-13 #10 slot screen

Has well been test pumped?: No Were material samples taken?: No Was a water sample taken?: Yes

Remarks: Installed well natural pack, topped with gravel pack, backfilled with cuttings, bentonite seal 0-3'.

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	1	Sandy loam, dark grayish-brown, (topsoil)
1	12	Sand and gravel, yellowish-brown, to grayish brown, silty, poorly sorted (outwash)
12	13	Pebbly clay loam, dark bluish-gray, moderately cohesive (unoxidized till)

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Sheridan Location: T. 36N R. 58E Sec. 27 Tract: ABBD02 Hole name or Number 124N

Hole location: Next to oil well access road east side

Recorded by: JR Date hole Started: 06/03/89 Date hole Completed: 06/03/89 Driller: F. Schmidt Drilling Company MBMG

Total well depth (ft) 20.5 Well diameter: 7-1/2" Casing diameter(s) and length (s): 2" PVC

Type of casing(s): Weight or gage of casing: Method-perforated or screened:

Interval-perforated or screened: 8-18' #10 slot screen

Has well been test pumped?: No Were material samples taken?: No Was a water sample taken?: Yes

Remarks: Installed well natural pack, bentonite seal to surface

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	2	Silt, dark brown, clayey (slopewash)
2	4	Silt, grayish-brown, clayey (slopewash)
4	18	Sand and gravel, yellowish-brown, silty, poorly sorted (outwash) "Most outwash in this area is largely medium sand -- typical composition -- 10-20% gravel -- 5-10% coarse sand, 50-70% medium sand -- 10-20% silt
18	20.5	Pebbly clay loam, dark bluish-gray, moderately cohesive (unoxidized till)

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Sheridan Location: T. 36N R. 58E Sec. 27 Tract: ADDD01 Hole name or Number 1240

Hole location: 150' north of oil well access road to site #128

Recorded by: JR Date hole Started: 06/03/89 Date hole Completed: 06/03/89 Driller: F. Schmidt Drilling Company MBMG

Total well depth (ft) 23 Well diameter: 7-1/2" Casing diameter(s) and length (s): 2" PVC

Type of casing(s): ________ Weight or gage of casing: ________ Method-perforated or screened: ________

Interval-perforated or screened: 14-19 #20 slot screen

Has well been test pumped?: No Were material samples taken?: No Was a water sample taken?: Yes

Remarks: Installed 2" well natural pack, bentonite seal to surface

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	1	Sandy loam, dark grayish-brown (topsoil)
1	3	Sand and gravel, pale brown, poorly sorted, silty (outwash)
3	8	Sand and gravel, reddish-brown, silty, poorly sorted (outwash)
8	17	Fine to medium sand, silty, gravelly, moderately well-sorted (outwash)
17	19	Silt, gray, clayey, sticky, soft (lake deposits)
19	23	Clay, dark bluish-gray, sticky, moderately hard, cohesive, massive (lake deposits)

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Sheridan Location: T. 36N R. 58E Sec. 27 Tract: ADAA01 Hole name or Number 124F

Hole location: 1/4 mile north of 124A west of county road

Recorded by: JF Date hole Started: 06/03/89 Date hole Completed: 06/03/89 Driller: F. Schmidt Drilling Company MBMG

Total well depth (ft) 17 Well diameter: 7-1/2" Casing diameter(s) and length (s): 2" PVC 5' drop pipe below screen

Type of casing(s): Weight or gage of casing: Method-perforated or screened:

Interval-perforated or screened: 7-12

Has well been test pumped?: No Were material samples taken?: No Was a water sample taken?:

Remarks: Installed 2" well natural pack, bentonite seal to surface

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	1	Sandy loam, dark brown (topsoil)
1	3	Sand, pale brown, silty, poorly sorted, (outwash)
3	7	Silty, gray, dry with sand layers, very hard drilling (Lake deposits)
7	12	Sand and gravel, yellowish-brown to grayish-brown, silty, poorly sorted (outwash)
12	15	Pebbly clay loam, light olive-brown, and brownish-gray, hard, cohesive (oxidized till)
15	17	Pebbly clay loam, dark olive-gray (transition till)

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Sheridan Location: T. 36N R. 58E Sec. 27 Tract: ABBA01 Hole name or Number 1240

Hole location: Next to intersection of road to site #124 and county road

Recorded by: JR Date hole Started: 06/04/89 Date hole Completed: 06/04/89 Driller: F. Schmidt Drilling Company MBMG

Total well depth (ft) 18 Well diameter: 7-1/2" Casing diameter(s) and length (s): None

Type of casing(s): Weight or gage of casing: Method-perforated or screened:

Interval-perforated or screened: None

Has well been test pumped?: No Were material samples taken?: No Was a water sample taken?: No

Remarks: No well--backfilled

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	1	Sandy and gravel loam, dark grayish-brown (topsoil)
1	3	Sand and gravel, very pale brown, silty, poorly sorted, dry, gravel coated with caliche (outwash)
3	8	Sand and gravel, yellowish-brown, silty, poorly sorted (outwash)
8	15	Sand and gravel, grayish-brown, silty, poorly sorted (outwash)
15	18	Pebbly clay loam, dark bluish-gray, cohesive, massive (unoxidized till)

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Sheridan Location: T. 36N R. 58E Sec. 27 Tract: BBCA01 Hole name or Number 125A

Hole location: Next to fence SW of pumper, 1/2 way between contam well and pumper

Recorded by: JR Date hole Started: 11/06/88 Date hole Completed: 11/06/88 Driller: F. Schmidt Drilling Company MBMG

Total well depth (ft) 27 Well diameter: 6" Solid Stem Casing diameter(s) and length (s): 2" PVC

Type of casing(s): Weight or gage of casing: Method-perforated or screened:

Interval-perforated or screened: SI = 22-27 #40 slot screen

Has well been test pumped?: No Were material samples taken?: No Was a water sample taken?: Yes

Remarks: Gravel pack 4-24, bentonite seal to surface, bottom of hole collapsed, had to shove into place

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	1	Gravelly sand loam, dark brown (topsoil)
1	15	Sand and gravel, reddish-brown, poorly sorted (outwash)
15	20	Sand and gravel, dark yellowish-brown (outwash)
20	23	Silty clay, gray, massive, cohesive (lake deposits)
23	32	Clayey silt, gray, massive, noncohesive, wet, with fine sand and lignite stringers (lake deposits)
32	33	Silty clay, gray, soft (lake deposits)

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Sheridan Location: T. 36N R. 58E Sec. 27 Tract: BBDC01 Hole name or Number 125B

Hole location: 100' East of junk pile, south of reserve pit location

Recorded by: JR Date hole Started: 11/06/88 Date hole Completed: 11/06/88 Driller: F. Schmidt Drilling Company MBMG

Total well depth (ft) 33 Well diameter: 6" Solid Stem Casing diameter(s) and length (s): 2" PVC

Type of casing(s): ______ Weight or gage of casing: ______ Method-perforated or screened: ______

Interval-perforated or screened: SI = 28-33 #20 slot screen

Has well been test pumped?: No Were material samples taken?: No Was a water sample taken?: Yes

Remarks: Natural pack (collapse) 28-33', Gravel pack 15-28, cuttings 3-15, bentonite seal to surface

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	1	Gravelly sand loam, dark brown (topsoil)
1	20	Sand and gravel, yellowish-brown, poorly sorted (outwash)
20	25	Silty clay, gray, massive, cohesive, sticky (lake deposits)
25	32	Pebbly clay loam, brownish-gray, hard, cohesive, sticky (transition till)
32	43	Silty and silty clay, blue-grey (poor returns), interbedded with silty fine sand (lake deposits)

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Sheridan Location: T. 36N R. 58E Sec. 27 Tract: BAAB01 Hole name or Number 126A

Hole location: West edge of site in small depression

Recorded by: JR Date hole Started: 11/06/88 Date hole Completed: 11/06/88 Driller: F. Schmidt Drilling Company MBMG

Total well depth (ft) 17 Well diameter: 7" hollow stem Casing diameter(s) and length (s): 2" PVC

Type of casing(s): Weight or gage of casing: Method-perforated or screened:

Interval-perforated or screened: SI = 12-17' #20 slot screen

Has well been test pumped?: No Were material samples taken?: No Was a water sample taken?: Yes

Remarks: Natural pack, bentonite seal to surface, drilled with solid stem, hole would not stay open, redrilled with hollow stem

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	1	Gravelly sand loam, dark brown (topsoil)
1	12	Sand and gravel, yellowish-brown, poorly sorted (outwash)
12	18	Medium to coarse sand, multi-colored (outwash)

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Sheridan Location: T. 36N R. 58E Sec. 27 Tract: BAAA02 Hole name or Number 126B

Hole location: SE corner of site next to fenceline

Recorded by: JR Date hole Started: 11/06/88 Date hole Completed: 11/06/88 Driller: F. Schmidt Drilling Company MBMG

Total well depth (ft) 23 Well diameter: 7" hollow stem Casing diameter(s) and length (s): 2" PVC

Type of casing(s): ______ Weight or gage of casing: ______ Method-perforated or screened: ______

Interval-perforated or screened: SI = 18-23 #40 slot screen

Has well been test pumped?: No Were material samples taken?: No Was a water sample taken?: Yes

Remarks: Natural pack, bentonite seal to surface

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	1	Gravelly sand loam, dark brown (topsoil)
1	2	Sand and gravel, white to light gray (caliche layer)
2	10	Sand and gravel, yellowish-brown, poorly sorted (outwash)
10	11	Coarse gravel (outwash)
11	15	Sand and gravel, dark yellowish-brown, poorly sorted, interbedded with clayey silt (outwash)
15	20	Silty clay, gray, soft, sticky, cohesive, with very fine sand and clayey silt stringers (lake deposits)
20	23	Pebbly clay loam, dark bluish-gray (unoxidized till)

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Sheridan Location: T. 36N R. 58E Sec. 27 Tract: BAAC01 Hole name or Number 126C

Hole location: SW of site #126

Recorded by: JR Date hole Started: 06/04/89 Date hole Completed: 06/04/89 Driller: F. Schmidt Drilling Company MBMG

Total well depth (ft) 18 Well diameter: 7-1/2" Casing diameter(s) and length (s): 2" PVC

Type of casing(s): Weight or gage of casing: Method-perforated or screened:

Interval-perforated or screened: 11-16' #10 slot screen

Has well been test pumped?: No Were material samples taken?: No Was a water sample taken?: Yes

Remarks: Installed 2" well, natural pack, backfilled with cuttings and washed gravel, bentonite seal to surface

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	1	Sandy loam, dark brown, gravelly (topsoil)
1	15	Sand and gravel, reddish-brown, slightly silty, poorly sorted (outwash)
15	18	Silt, bluish-gray, clayey, moderately soft, moderately cohesive, sticky (lake deposits)

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Sheridan Location: T. 36N R. 58E Sec. 33 Tract: BBDA01 Hole name or Number 139A

Hole location: 125' due east of pumper in bottom of waterway

Recorded by: JR Date hole Started: 11/05/88 Date hole Completed: 11/05/88 Driller: F. Schmidt Drilling Company MBMG

Total well depth (ft) 27 Well diameter: 6" Solid Stem Casing diameter(s) and length (s): 2" PVC

Type of casing(s): Weight or gage of casing: Method-perforated or screened:

Interval-perforated or screened: S1 = 22-27' #10 slot screen

Has well been test pumped?: No Were material samples taken?: No Was a water sample taken?: Yes

Remarks: Gravel pack 10-27', cuttings 3-10', bentonite seal to surface

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	3	Silty clay, dark brownish-gray (slopewash)
3	4	Clayey silt, black, organic rich (slough deposits)
4	18	Pebbly clay loam, light olive-brown, strong iron stain on fractures (oxidized till)
18	23	Pebbly clay loam, dark olive-brown, mixed with pebbly clay loam, olive-brown (transition till)
23	28	Pebbly clay loam, dark olive brown (unoxidized till)

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Sheridan Location: T. 37N R. 57E Sec. 05 Tract: DDCB01 Hole name or Number 151A

Hole location: East side of road, NW corner of slough

Recorded by: TT Date hole Started: 11/07/88 Date hole Completed: 11/07/88 Driller: F. Schmidt Drilling Company MBMG

Total well depth (ft) 13 Well diameter: 6" Solid Stem Casing diameter(s) and length (s): 2" PVC

Type of casing(s): Weight or gage of casing: Method-perforated or screened:

Interval-perforated or screened: SI = 8-13' #40 slot screen

Has well been test pumped?: No Were material samples taken?: No Was a water sample taken?: Yes

Remarks: Gravel pack 3-13', bentonite seal to surface

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	2	Pebbly clay loam, dark brownish-grey, organic rich, very hard, salt crystals in fractures (topsoil)
2	5	Pebbly clay loam, dark brownish-grey, salt crystals larger, more numerous (oxidized till)
5	13	Loam, yellowish-brown, slightly cohesive, interbedded with sand and clay lenses, prominent salt crystals (oxidized till)

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Sheridan Location: T. 37N R. 57E Sec. 05 Tract: DCDA01 Hole name or Number 151B

Hole location: Grassed waterway at west end of slough, west of road

Recorded by: TI Date hole Started: 11/07/88 Date hole Completed: 11/07/88 Driller: F. Schmidt Drilling Company MBMG

Total well depth (ft) 18 Well diameter: 6" Solid Stem Casing diameter(s) and length (s): 2" PVC

Type of casing(s): ______ Weight or gage of casing: ______ Method-perforated or screened: ______

Interval-perforated or screened: SI = 13-18' #20 slot screen

Has well been test pumped?: No Were material samples taken?: No Was a water sample taken?: Yes

Remarks: Gravel pack 3-18', bentonite seal to surface

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	2	Pebbly loam, olive-brown, cohesive, hard, salt crystals (oxidized till)
2	11	Pebbly loam, dark olive-brown, salt crystals (transition till)
11	16	Pebbly loam, medium brownish=gray, cohesive, hard (transition till)
16	18	Pebbly loam, dark gray, cohesive, hard, dry (unoxidized till)

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Sheridan Location: T. 37N R. 57E Sec. 12 Tract: BABB01 Hole name or Number 167A

Hole location: Along fence west of pad, 190' south of road

Recorded by: TT Date hole Started: 11/08/88 Date hole Completed: 11/08/88 Driller: F. Schmidt Drilling Company MBMG

Total well depth (ft) 9 Well diameter: 7" hollow stem Casing diameter(s) and length (s): 2" PVC

Type of casing(s): Weight or gage of casing: Method-perforated or screened:

Interval-perforated or screened: SI = 3-6' #40 slot screen plus 2-1/2' drop pipe

Has well been test pumped?: No Were material samples taken?: No Was a water sample taken?: Yes

Remarks: Plugged hole with cuttings 12-38', bentonite 9-12', installed well, gravel pack 3-9' bentonite seal to surface

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	2	Silt loam, dark brown, loose (slopewash)
2	6	Pebbly loam, light olive-brown, gravel layer 4-6' (oxidized till)
6	15	Pebbly loam, dark olive-brown, cohesive, hard (transition till)
15	38	Pebbly silt loam, dark bluish-gray, cohesive, hard (unoxidized till)

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Sheridan Location: T. 37N R. 57E Sec. 12 Tract: BBAA01 Hole name or Number 167B

Hole location: In road ditch on east side of slough 200' E of white pumphouse

Recorded by: TT Date hole Started: 11/08/88 Date hole Completed: 11/08/88 Driller: F. Schmidt Drilling Company MBMG

Total well depth (ft) 13 Well diameter: 7" hollow stem Casing diameter(s) and length (s): 2" PVC

Type of casing(s): Weight or gage of casing: Method-perforated or screened:

Interval-perforated or screened: SI = 8-13" #20 Slot screen

Has well been test pumped?: No Were material samples taken?: No Was a water sample taken?: Yes

Remarks: Gravel packed 3-10', bentonite seal to surface, hole collapsed around bottom 3' of casing

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	9	Sand and gravel, yellowish-brown, loose, dry (outwash)
9	11	Coarse sand, yellowish-brown, wet, noncohesive (outwash)
11	13	Pebbly clay loam, dark bluish-gray (unoxidized till)

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Sheridan Location: T. 38N R. 58E Sec. 06 Tract: CBCC01 Hole name or Number 167F

Hole location: East of trail 1/4 mile north of section line- border channel

Recorded by: JR Date hole Started: 05/31/89 Date hole Completed: 05/31/89 Driller: F. Schmidt Drilling Company MBMG

Total well depth (ft) 17' Well diameter: 7" hollow stem Casing diameter(s) and length (s): 2" PVC

Type of casing(s): Weight or gage of casing: Method-perforated or screened:

Interval-perforated or screened: 12-17 #20 slot screen

Has well been test pumped?: No Were material samples taken?: No Was a water sample taken?: Yes

Remarks: Natural pack ground screen, bentonite seal to surface, 4-1/2 ft drop pipe below surface

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	1	Sandy loam, grayish-brown (topsoil)
1	3	Fine to medium sand, reddish-brown, poorly sorted, gravelly, thin layers of silty clay (outwash)
3	17	Sand and gravel, reddish-brown, medium sand to medium gravel, coarsens downward (outwash)
17	23	Pebbly clay loam, bluish-gray (unoxidized till)

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Sheridan Location: T. 37N R. 57E Sec. 12 Tract: CBCC01 Hole name or Number 167G

Hole location: East side of county road

Recorded by: JR Date hole Started: 05/31/89 Date hole Completed: 05/31/89 Driller: F. Schmidt Drilling Company MBMG

Total well depth (ft) 33 Well diameter: ___ Casing diameter(s) and length (s): None

Type of casing(s): ___ Weight or gage of casing: ___ Method-perforated or screened: ___

Interval-perforated or screened: No well

Has well been test pumped?: No Were material samples taken?: No Was a water sample taken?: No

Remarks: Backfilled with cuttings and bentonite

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	3	Loam, brownish-gray sandy (slopewash)
3	10	Sand and gravel, reddish-brown, grain size from very fine sand to coarse gravel, poorly sorted (outwash)
10	21	Fine to medium sand, reddish-brown, gravelly, interbedded with thin (1-2 ft) layers of gravel (outwash)
21	24	Pebbly clay loam, blue-gray (unoxidized till)
24	33	Sand and gravel, grayish-brown, interbedded with blue-gray till (more till than gravel) dry part of channel (outwash/unoxidized till)

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Sheridan Location: T. 37N R. 57E Sec. 12 Tract: BBDB01 Hole name or Number 167K

Hole location: On refuge land 50 yards SE of lone cottonwood tree

Recorded by: JR Date hole Started: 06/01/89 Date hole Completed: 06/01/89 Driller: F. Schmidt Drilling Company MBMG

Total well depth (ft) 8 Well diameter: 7-1/2" Casing diameter(s) and length (s): 2" PVC

Type of casing(s): Weight or gage of casing: Method-perforated or screened:

Interval-perforated or screened: 3-8 #20 slot screen

Has well been test pumped?: No Were material samples taken?: No Was a water sample taken?: Yes

Remarks: Set gravel pack from 3-8', bentonite seal 0-3'

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	1	Silt, dark brown, clayey
1	6	Sand and gravel, orangish-brown, silty, poorly sorted (outwash)
6	8	Pebbly clay loam, brownish-gray and bluish-gray, moderately cohesive (transition till)

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Sheridan Location: T. 37N R. 57E Sec. 12 Tract: BACB01 Hole name or Number 1671

Hole location: In east surface channel

Recorded by: JR Date hole Started: 06/01/89 Date hole Completed: 06/01/89 Driller: F. Schmidt Drilling Company MBMG

Total well depth (ft) 8 Well diameter: 7-1/2" Casing diameter(s) and length (s): No well

Type of casing(s): Weight or gage of casing: Method-perforated or screened:

Interval-perforated or screened:

Has well been test pumped?: No Were material samples taken?: No Was a water sample taken?: No

Remarks: Backfilled with bentonite and cuttings

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	3	Silt, dark brownish-gray, silty (alluvium-colluvium)
3	4	Sand and gravel, orangish-brown, rusty, silty, poorly sorted (outwash)
4	6	Pebbly clay loam, yellowish-brown, moderately cohesive (oxidized till)
6	8	Pebbly clay loam, olive-brown, soft, silty (unoxidized till)

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Sheridan Location: T. 37N R. 57E Sec. 12 Tract: BBDA01 Hole name or Number 167J

Hole location: On ridge between 167H and 167I

Recorded by: JR Date hole Started: 06/01/89 Date hole Completed: 06/01/89 Driller: F. Schmidt Drilling Company MBMG

Total well depth (ft) 13 Well diameter: 7-1/2" Casing diameter(s) and length (s): No well

Type of casing(s): Weight or gage of casing: Method-perforated or screened:

Interval-perforated or screened: None

Has well been test pumped?: No Were material samples taken?: No Was a water sample taken?: No

Remarks: Dry -- border channel aquifer is a myth; backfilled with bentonite and cuttings

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	1	Sandy loam, dark grayish-brown (topsoil)
1	3	Very fine sand, very pale brown, silty, gravelly, poorly sorted (outwash)
3	10	Sand and gravel, reddish-brown, silty, poorly sorted, hard drilling, dry (outwash)
10	13	Pebbly clay loam, olive-brown, moderately cohesive, easy drilling (oxidized till)

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Sheridan Location: T. 37N R. 57E Sec. 12 Tract: BBAD01 Hole name or Number 167K

Hole location: South of white pump house about 510 feet

Recorded by: JR Date hole Started: 06/01/89 Date hole Completed: 06/01/89 Driller: F. Schmidt Drilling Company MBMG

Total well depth (ft) 16 Well diameter: 7-1/2" Casing diameter(s) and length (s): 2" PVC

Type of casing(s): Weight or gage of casing: Method-perforated or screened:

Interval-perforated or screened: 6.5-11.5 #10 slot screen

Has well been test pumped?: No Were material samples taken?: No Was a water sample taken?: Yes

Remarks: Gravel pack to top of screen, cuttings to 3', bentonite seal 0-3'

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	6	Silt, grayish-brown, clayey, pebbly, moderately cohesive (alluvium/colluvium)
6	13	Sand and gravel, reddish-brown, silty, very poorly sorted, rocks at 11 and 12 (outwash)
13	16	Pebbly clay loam, dark bluish-gray, moderately cohesive (unoxidized till)

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Sheridan Location: T. 37N R. 57E Sec. 12 Tract: BBAA03 Hole name or Number 167L

Hole location: 250' south of white pump house

Recorded by: JR Date hole Started: 06/01/89 Date hole Completed: 06/01/89 Driller: F. Schmidt Drilling Company MBMG

Total well depth (ft) 13 Well diameter: 7-1/2" Casing diameter(s) and length (s): 2" PVC 10' 2' out of ground

Type of casing(s): Weight or gage of casing: Method-perforated or screened:

Interval-perforated or screened: 8-13' #10 slot screen

Has well been test pumped?: No Were material samples taken?: No Was a water sample taken?: Yes

Remarks: natural pack, backfilled with cuttings, bentonite seal 0-3'

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	1	Sandy loam, dark brownish-grey (topsoil)
1	3	Sand, pale brown, poorly sorted, silty (outwash)
3	12	Sand and gravel, reddish-brown, moderately well sorted (outwash)
12	13	Pebbly clay loam, olive-brown, moderately cohesive (transition till)

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Sheridan Location: T. 37N R. 57E Sec. 12 Tract: BBAC01 Hole name or Number 167M

Hole location: 200' north of 167H (near dead trees)

Recorded by: JF Date hole Started: 06/01/89 Date hole Completed: 06/01/89 Driller: F. Schmidt Drilling Company MBMG

Total well depth (ft) 13 Well diameter: 7-1/2" Casing diameter(s) and length (s): 2" X 7'

Type of casing(s): Weight or gage of casing: Method-perforated or screened:

Interval-perforated or screened: 5-10 #10 slot screen

Has well been test pumped?: No Were material samples taken?: No Was a water sample taken?: Yes

Remarks: Installed well, total length 15', 3' tailpipe, 5' screen SI = 5-10

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	1	Silty clay loam, dark grayish-brown (topsoil)
1	6	Silt, grayish-brown, clayey, soft (alluvium/colluvium)
6	10	Sand and gravel, reddish-brown, poorly sorted, silty (outwash)
10	13	Pebbly clay loam, olive-brown, moderately cohesive, sticky (transition till)

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Sheridan Location: T. 37N R. 58E Sec. 06 Tract: CAAC01 Hole name or Number 222A

Hole location: 30' south of fire break, 150' east of site

Recorded by: TT Date hole Started: 11/08/88 Date hole Completed: 11/08/88 Driller: F. Schmidt Drilling Company MBMG

Total well depth (ft) 43 Well diameter: 6" Solid Stem Casing diameter(s) and length (s): 2" PVC

Type of casing(s): Weight or gage of casing: Method-perforated or screened:

Interval-perforated or screened: SI = 38 - 43' #20 slot screen

Has well been test pumped?: No Were material samples taken?: No Was a water sample taken?: Yes

Remarks: Gravel pack 13-43', cuttings 3-13', bentonite seal to surface

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	2	Sandy loam, light brown (slopewash)
2	23	Pebbly silt loam, dark olive-brown, abundant large salt crystals (transition till)
23	43	Pebbly clay loam, dark bluish-gray (unoxidized till)

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Sheridan Location: T. 37N R. 58E Sec. 06 Tract: CADA01 Hole name or Number 222E

Hole location: 300' east of site in dry slough near dead tree

Recorded by: TT Date hole Started: 11/08/88 Date hole Completed: 11/08/88 Driller: F. Schmidt Drilling Company MBMG

Total well depth (ft) 48 Well diameter: 6" Solid Stem Casing diameter(s) and length (s): 2" PVC

Type of casing(s): Weight or gage of casing: Method-perforated or screened:

Interval-perforated or screened: SI = 43-48' #20 slot screen

Has well been test pumped?: No Were material samples taken?: No Was a water sample taken?: Yes

Remarks: Gravel pack 20-48', bentonite seal 16-20', cuttings 3-16', bentonite seal to surface

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	4	Silt loam, dark brown, semi-cohesive (slopewash)
4	15	Pebbly clay loam, light olive-brown, salt crystals in fractures (oxidized till)
15	20	Pebbly clay loam, dark olive-brown, (transition till)
20	48	Pebbly clay loam, dark bluish-gray (unoxidized till)

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Sheridan Location: T. 37N R. 58E Sec. 06 Tract: DBCX01 Hole name or Number 222D

Hole location: Yard of Richard Westgard's Farmhouse

Recorded by: CC Date hole Started: 10/16/88 Date hole Completed: 10/16/88 Driller: Curtis Carlson Drilling Company Carlson Drillg

Total well depth (ft) 82 Well diameter: 8" Casing diameter(s) and length (s): 8"

Type of casing(s): Weight or gage of casing: Method-perforated or screened:

Interval-perforated or screened: 71-81 WL = 11'

Has well been test pumped?: Yes Were material samples taken?: No Was a water sample taken?: Yes

Remarks: Pumped at 12 gpm for 2 hrs with 20' drawdown

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	3	Clay, yellow (lake deposits)
3	12	Gravel (outwash)
12	17	Clay, yellow (lake deposits)
17	52	Till
52	54	Gravel (wet) (outwash)
54	72	Till
72	77	Coal, loose (Fort Union Formation)
77	79	Fine sand
79	81	Coal
81	82	Clay, blue

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Sheridan Location: T. 34N R. 58E Sec. 14 Tract: BDAC01 Hole name or Number 252A

Hole location: Three towers from end of pivot, at north edge of well pad

Recorded by: JR Date hole Started: 11/03/88 Date hole Completed: 11/03/88 Driller: F. Schmidt Drilling Company MBMG

Total well depth (ft) 32 Well diameter: 7" hollow stem Casing diameter(s) and length (s): 2" PVC

Type of casing(s): Weight or gage of casing: Method-perforated or screened:

Interval-perforated or screened: SI = 27-32' #20 slot screen

Has well been test pumped?: No Were material samples taken?: No Was a water sample taken?: Yes

Remarks: Natural pack, bentonite seal to surface

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	1	Gravelly sand loam, gray-brown (topsoil)
1	24	Sand and gravel, reddish-brown, loose, dry, moderately well-sorted (outwash)
24	32	Medium to coarse sand, grayish-brown, a few silty stringers (outwash)

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Sheridan Location: T. 34N R. 58E Sec. 14 Tract: BDBD01 Hole name or Number 252E

Hole location: Just outside 4th tower from end of pivot, irrigated alfalfa field

Recorded by: TT Date hole Started: 11/03/88 Date hole Completed: 11/03/88 Driller: F. Schmidt Drilling Company MBMG

Total well depth (ft) 32 Well diameter: 7" hollow stem Casing diameter(s) and length (s): 2" PVC

Type of casing(s): Weight or gage of casing: Method-perforated or screened:

Interval-perforated or screened: 27-32' #20 slot screen

Has well been test pumped?: No Were material samples taken?: No Was a water sample taken?: Yes

Remarks: Natural pack, bentonite seal to surface

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	1	Gravelly sand loam, gray-brown, loose (topsoil)
1	24	Sand and gravel, reddish-brown, loose, dry, clean, moderately well-sorted (outwash)
24	32	Medium to coarse sand, brownish-gray (outwash)

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Sheridan Location: T. 34N R. 58E Sec. 14 Tract: DBBD01 Hole name or Number 253A

Hole location: NW of well site, north edge of trenched reserve pit

Recorded by: JR Date hole Started: 11/02/88 Date hole Completed: 11/02/88 Driller: F. Schmidt Drilling Company MBMG

Total well depth (ft) 32 Well diameter: 7" hollow stem Casing diameter(s) and length (s): 2" PVC

Type of casing(s): ______ Weight or gage of casing: ______ Method-perforated or screened: ______

Interval-perforated or screened: SI=26-31' #20 slot screen

Has well been test pumped?: No Were material samples taken?: No Was a water sample taken?: Yes

Remarks: Natural pack, bentonite seal to surface

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	5	Silty fine sand, grayish-brown (eolian)
5	23	Sand and gravel, reddish-brown, loose, dry (outwash)
23	33	Medium to coarse sand, gray (outwash)

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Sheridan Location: T. 34N R. 58E Sec. 14 Tract: DBBD02 Hole name or Number 253B

Hole location: 75' SW of 253A in trenched reserve pit

Recorded by: JR Date hole Started: 11/02/88 Date hole Completed: 11/02/88 Driller: F. Schmidt Drilling Company MBMG

Total well depth (ft) 30 Well diameter: 7" hollow stem Casing diameter(s) and length (s): 2" PVC

Type of casing(s): Weight or gage of casing: Method-perforated or screened:

Interval-perforated or screened: SI = 25-30' #20 slot screen

Has well been test pumped?: No Were material samples taken?: No Was a water sample taken?: Yes

Remarks: Natural pack 16-30', bentonite seal 12-16', natural pack 3-12, bentonite seal to surface

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	4	Silty fine sand, grayish-brown (eolian)
4	6	Medium sand, reddish-brown (outwash)
6	13	Silty medium to coarse sand, grayish brown, wet (outwash)
		All of above material disturbed -- probably in spiderleg trench of reserve pit
13	22	Medium to coarse sand, reddish-brown, loose, dry (outwash)
22	30	Medium to coarse sand, grayish-brown (outwash)

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Sheridan Location: T. 34N R. 58E Sec. 14 Tract: DBCA01 Hole name or Number 253C

Hole location: 150' south of 253B on edge of irrigated grain field

Recorded by: JR Date hole Started: 11/02/88 Date hole Completed: 11/02/88 Driller: F. Schmidt Drilling Company MBMG

Total well depth (ft) 32 Well diameter: 7" hollow stem Casing diameter(s) and length (s): 2" PVC

Type of casing(s): Weight or gage of casing: Method-perforated or screened:

Interval-perforated or screened: SI = 27-32' #20 Slot screen

Has well been test pumped?: No Were material samples taken?: No Was a water sample taken?: Yes

Remarks: Natural pack, bentonite seal to surface

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	3	Silty fine to medium sand, grayish-brown (eolian)
3	17	Medium to very coarse sand, reddish-brown, loose, dry (outwash)
17	25	Very fine to medium sand, yellowish-brown, loose, dry (outwash)
25	30	Fine to coarse sand, grayish-brown (outwash)
30	32	Silty fine sand and lignite, very dark brownish-gray (outwash)

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Sheridan Location: T. 35N R. 58E Sec. 09 Tract: CDCD01 Hole name or Number 258A

Hole location: In depression just NE of site, about 75' from fence corner

Recorded by: JR Date hole Started: 11/04/88 Date hole Completed: 11/04/88 Driller: F. Schmidt Drilling Company MBMG

Total well depth (ft) 32 Well diameter: 6" Solid Stem Casing diameter(s) and length (s): 2" PVC

Type of casing(s): Weight or gage of casing: Method-perforated or screened:

Interval-perforated or screened: SI = 27-32' #10 slot screen

Has well been test pumped?: No Were material samples taken?: No Was a water sample taken?: Yes

Remarks: Gravel pack 20-32', cuttings 10-20', bentonite seal to surface

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	3	Clay loam, very dark brown (topsoil)
3	19	Pebbly clay loam, light olive-brown (oxidized till)
19	27	Pebbly clay loam, dark olive-brown, (transition till)
27	31	Pebbly clay loam, dark olive-brown and dark bluish-gray mixed (transition till)
31	33	Pebbly clay loam, dark bluish-gray (unoxidized till)

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Sheridan Location: T. 35N R. 58E Sec. 09 Tract: CDCA01 Hole name or Number 258E

Hole location: 400' north of site in swale just above small slough

Recorded by: JR Date hole Started: 11/04/88 Date hole Completed: 11/04/88 Driller: F. Schmidt Drilling Company MBMG

Total well depth (ft) 28 Well diameter: 6" Solid Stem Casing diameter(s) and length (s): 2" PVC

Type of casing(s): ______ Weight or gage of casing: ______ Method-perforated or screened: ______

Interval-perforated or screened: SI = 23-28' #10 slot screen

Has well been test pumped?: No Were material samples taken?: No Was a water sample taken?: Yes

Remarks: Gravel pack 14-28', cuttings 10-14', bentonite seal to surface

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	1	Loam, dark brown (topsoil)
1	4	Loam, black, saturated with tar (waste oil)
4	8	Silty pebbly loam, gray, soft, oil smell, moist (wasted drilling mud)
8	22	Pebbly clay loam, light olive-brown (oxidized till)
22	26	Pebbly clay loam, dark olive-brown (transition till)
26	28	Pebbly clay loam, dark bluish-gray (unoxidized till)

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Sheridan Location: T. 36N R. 58E Sec. 32 Tract: DDAB01 Hole name or Number 262A

Hole location: Tip of grassy/rocky area below earth dam SW of site

Recorded by: JF Date hole Started: 11/05/88 Date hole Completed: 11/05/88 Driller: F. Schmidt Drilling Company MBMG

Total well depth (ft) 33 Well diameter: 6" Solid Stem Casing diameter(s) and length (s): 2" PVC

Type of casing(s): Weight or gage of casing: Method-perforated or screened:

Interval-perforated or screened: 28-33 #10 slot screen

Has well been test pumped?: No Were material samples taken?: No Was a water sample taken?: Yes

Remarks: Gravel pack 13-33', cuttings 5-13', bentonite seal to surface

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	3	Clayey silt, laminated, dark brown (lake deposits)
3	10	Silty clay, laminated, grayish-brown (lake deposits)
10	20	Pebbly clay loam, light olive-brown (oxidized till)
20	24	Pebbly clay loam, dark olive-brown (transition till)
24	28	Silty clay, dark bluish-gray (lake deposits)
28	32	Silty clay, cobalt blue, soft, sticky, cuttings appear vuggy (lake deposits)
32	33	Pebbly clay loam, dark olive-brown, mottled with light olive-brown (transition till)

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Sheridan Location: T. 36N R. 58E Sec. 32 Tract: DDDB01 Hole name or Number 262B

Hole location: In waterway just south of rockpile, 400' south of 262A

Recorded by: JR Date hole Started: 11/05/88 Date hole Completed: 11/05/88 Driller: F. Schmidt Drilling Company MBMG

Total well depth (ft) 43 Well diameter: 6" Solid Stem Casing diameter(s) and length (s): No well installed

Type of casing(s): ______ Weight or gage of casing: ______ Method-perforated or screened: ______

Interval-perforated or screened: No well

Has well been test pumped?: No Were material samples taken?: No Was a water sample taken?: No

Remarks: Dry hole

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	3	Clayey silty loam, dark grayish-brown (topsoil)
3	15	Pebbly clay loam, light olive-brown (oxidized till)
15	21	Pebbly clay loam, dark olive-brown, gravelly 15-18' (transition till)
21	23	Sandy clayey silt, light brownish-gray (lake deposits)
23	32	Pebbly clay loam, dark olive-brown, and light olive-brown, mixed (transition till)
32	38	Silty clay, cobalt blue, massive to finely bedded, noncohesive (lake deposits)
38	41	Clayey sandy silt, light brownish-yellow, noncohesive, dry (lake deposits)
41	43	Pebbly clay loam, dark olive-brown (unoxidized till)

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Sheridan Location: T. 36N R. 58E Sec. 28 Tract: AADA02 Hole name or Number 264A

Hole location: 100' south of tank battery in pasture

Recorded by: JR Date hole Started: 11/05/88 Date hole Completed: 11/05/88 Driller: F. Schmidt Drilling Company MBMG

Total well depth (ft) 23 Well diameter: 7" hollow stem Casing diameter(s) and length (s): 2" PVC

Type of casing(s): Weight or gage of casing: Method-perforated or screened:

Interval-perforated or screened: SI = 18-23' #20 slot screen

Has well been test pumped?: No Were material samples taken?: No Was a water sample taken?: Yes

Remarks: Gravel pack 10-18' slumped in 18-23', bentonite seal to surface

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	3	Silty clay, dark brown (topsoil)
3	5	Sand and gravel, yellowish-brown (outwash)
5	8	Pebbly clay loam, light olive-brown, (oxidized till)
8	10	Silty very fine sand, yellowish-brown (outwash)
10	12	Very fine sand, light gray (outwash)
12	16	Very fine sandy silt, yellowish-brown, laminated (lake deposits)
16	21	Silty fine to medium sand, grayish-brown (outwash)
21	23	Silty clay, bluish-gray, massive to laminated (lake deposits)

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Sheridan Location: T. 36N R. 58E Sec. 28 Tract: AADD01 Hole name or Number 264B

Hole location: In barren gully due south of 264A

Recorded by: JR Date hole Started: 11/05/88 Date hole Completed: 11/05/88 Driller: F. Schmidt Drilling Company MBMG

Total well depth (ft) 8 Well diameter: 7" hollow stem Casing diameter(s) and length (s): 2" PVC

Type of casing(s): Weight or gage of casing: Method-perforated or screened:

Interval-perforated or screened: SI = 3-8' #20 slot screen

Has well been test pumped?: No Were material samples taken?: No Was a water sample taken?: Yes

Remarks: Natural pack, bentonite seal to surface

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	1	Sand and gravel, black, organics and oil residue (slopewash/oil field waste)
1	6	Silty sand and gravel, gray, poorly sorted (outwash)
6	8	Pebbly clay loam, dark olive-brown (transition till)

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Sheridan Location: T. 36N R. 58E Sec. 28 Tract: AADD02 Hole name or Number 264C

Hole location: North edge of gully, 150' east of 264B, near fenceline

Recorded by: JR Date hole Started: 11/05/88 Date hole Completed: 11/05/88 Driller: F. Schmidt Drilling Company MBMG

Total well depth (ft) 18 Well diameter: 7" hollow stem Casing diameter(s) and length (s): No well installed

Type of casing(s): Weight or gage of casing: Method-perforated or screened:

Interval-perforated or screened: No well

Has well been test pumped?: No Were material samples taken?: No Was a water sample taken?: No

Remarks: Dry hole, backfilled with bentonite and cuttings

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	1	Sandy silty clay, black (topsoil)
1	14	Pebbly clay loam, light olive-brown (oxidized till)
14	18	Pebbly clay loam, dark olive-brown (transition till)

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Sheridan Location: T. 36N R. 58E Sec. 27 Tract: BCBC01 Hole name or Number 264D

Hole location: 40' upstream of old road grade on east side of road

Recorded by: JF Date hole Started: 11/05/88 Date hole Completed: 11/05/88 Driller: F. Schmidt Drilling Company MBMG

Total well depth (ft) 13 Well diameter: 7" hollow stem Casing diameter(s) and length (s): 2" PVC

Type of casing(s): ______ Weight or gage of casing: ______ Method-perforated or screened: ______

Interval-perforated or screened: SI = 8-13' #40 slot screen

Has well been test pumped?: No Were material samples taken?: No Was a water sample taken?: Yes

Remarks: Gravel pack 5-13', bentonite seal to surface

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	3	Clayey pebbly silt, very dark brown (topsoil)
3	5	Pebbly clay loam, light olive-brown (oxidized till)
5	10	Coarse gravel (outwash)
10	13	Pebbly clay loam, dark bluish-gray (unoxidized till)

MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Sheridan Location: T. 36N R. 58E Sec. 27 Tract: BCBD01 Hole name or Number 2640

Hole location: Coulee SE of abandoned roadway -- 50' north of fence

Recorded by: JR Date hole Started: 06/02/89 Date hole Completed: 06/02/89 Driller: F. Schmidt Drilling Company MBMG

Total well depth (ft) 23 Well diameter: 7-1/2" Casing diameter(s) and length (s): 2" PVC

Type of casing(s): Weight or gage of casing: Method-perforated or screened:

Interval-perforated or screened: 15-20' #10 slot screen

Has well been test pumped?: No Were material samples taken?: No Was a water sample taken?: Yes

Remarks: Installed 2" well, natural pack, set surface bentonite seal, set 2-1/2 feet drop pipe below screen

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	1	Pebbly clay loam, dark olive-brown, (topsoil)
1	20	Sand and gravel, yellowish-brown, silty, very poorly sorted (outwash)
20	23	Pebbly clay loam, dark grayish-brown (transition till)

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Sheridan Location: T. 36N R. 58E Sec. 27 Tract: DAAD01 Hole name or Number 264R

Hole location: West side of county road

Recorded by: JR Date hole Started: 06/04/89 Date hole Completed: 06/04/89 Driller: F. Schmidt Drilling Company MBMG

Total well depth (ft) 22 Well diameter: 7-1/2" Casing diameter(s) and length (s): 2" PVC

Type of casing(s): ______ Weight or gage of casing: ______ Method-perforated or screened: ______

Interval-perforated or screened: W 15-20' #10 slot screen 2' drop pipe

Has well been test pumped?: ______ Were material samples taken?: ______ Was a water sample taken?: ______

Remarks: Installed 2" well, natural pack, bentonite seal to surface, set 2 feet drop pipe below screen

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	1	Sandy loam, very dark brown (topsoil)
1	3	Silt, yellowish-brown, clayey, sandy (slopewash)
3	8	Sand and gravel, yellowish-brown, silty, poorly sorted, wet @ 6' (outwash)
8	19	Sand and gravel, brownish-gray, silty, very poorly sorted (outwash)
19	22	Pebbly clay loam, dark bluish-gray, moderately cohesive, massive (unoxidized till)

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Sheridan Location: T. 36N R. 58E Sec. 27 Tract: CX01 Hole name or Number 2649

Hole location: Take road to oil well in SW1/4 sec. 27 follow trail east and south -- east of Ducout

Recorded by: JR Date hole Started: 06/04/89 Date hole Completed: 06/04/89 Driller: F. Schmidt Drilling Company MBMG

Total well depth (ft) 18 Well diameter: 7-1/2" Casing diameter(s) and length (s): 11'

Type of casing(s): Weight or gage of casing: Method-perforated or screened:

Interval-perforated or screened: 8-13 #10 slot screen

Has well been test pumped?: No Were material samples taken?: No Was a water sample taken?: Yes

Remarks: Installed 2" well, natural pack, bentonite seal to surface, set 4 ft drop pipe below screen

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	1	Sandy loam, brownish-gray (topsoil)
1	7	Sand and gravel, yellowish-brown, silty, poorly sorted, wet @ 3' (outwash)
7	14	Sand and gravel, brownish-gray, silty, very poorly sorted (outwash)
14	18	Dark bluish-gray, moderately cohesive, massive, sticky (lake deposits)

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Sheridan Location: T. 36N R. 58E Sec. 27 Tract: DBCC01 Hole name or Number 264T

Hole location: 1/4 mile east of 264S

Recorded by: JR Date hole Started: 06/04/89 Date hole Completed: 06/04/89 Driller: F. Schmidt Drilling Company MBMG

Total well depth (ft) 23 Well diameter: 7-1/2" Casing diameter(s) and length (s): 2" PVC

Type of casing(s): Weight or gage of casing: Method-perforated or screened:

Interval-perforated or screened: 15-20' #10 slot screen

Has well been test pumped?: No Were material samples taken?: No Was a water sample taken?: Yes

Remarks: Installed 2" well, natural pack, surface bentonite seal, pipe came up when pulling augers out moved up 4' and redrilled, set 2 ft drop below screen

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	3	Silt, gray, clayey, sandy, pebbly, (slopewash/slough deposits)
3	6	Sand and gravel, yellowish-brown, silty, clayey, very poorly sorted (wet) (outwash)
6	18	Sand and gravel, olive-gray, silty, slightly clayey, very poorly sorted (outwash)
18	19	Clay, gray, silty, sandy (drilling change) (lake deposits)
19	23	Sand and gravel, gray, silty, slightly clayey, very poorly sorted (outwash)
23	27	Clay, bluish-gray, slightly silty, cohesive, massive, sticky (lake deposits)

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Sheridan Location: T. 35N R. 58E Sec. 30 Tract: ABAB01 Hole name or Number 266A

Hole location: Across road from Peterson battery pit

Recorded by: JR Date hole Started: 11/03/88 Date hole Completed: 11/03/88 Driller: F. Schmidt Drilling Company MBMG

Total well depth (ft) 38 Well diameter: 7" hollow stem Casing diameter(s) and length (s): No well installed

Type of casing(s): ______ Weight or gage of casing: ______ Method-perforated or screened: ______

Interval-perforated or screened: No well

Has well been test pumped?: No Were material samples taken?: No Was a water sample taken?: No

Remarks: Dry hole

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	1	Pebbly loam, grayish-brown (topsoil)
1	6	Pebbly clay loam, dark olive-brown, (transition till)
6	11	Silty clay, yellowish-green and brownish-gray (Fort Union Formation)
11	13	Sandy silty, yellow, with clay lenses
13	25	Silty very fine sand, yellow, well sorted
25	30	Silty clay, yellow, with gray silty clay laminations
30	38	Silty clay, laminated, multi-colored

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Sheridan Location: T. 37N R. 57E Sec. 11 Tract: DCAC01 Hole name or Number 286A

Hole location: East side of oil well pad near slough, 35' W of fenceline

Recorded by: TT Date hole Started: 11/08/88 Date hole Completed: 11/08/88 Driller: F. Schmidt Drilling Company MBMG

Total well depth (ft) 13 Well diameter: 7" hollow stem Casing diameter(s) and length (s): 2" PVC

Type of casing(s): Weight or gage of casing: Method-perforated or screened:

Interval-perforated or screened: SI =8-13' #20 slot screen

Has well been test pumped?: No Were material samples taken?: No Was a water sample taken?: Yes

Remarks: Set gravel pack 3-13', bentonite seal to surface

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	2	Silty loam, medium grayish-brown, loose, dry (topsoil)
2	4	Silty loam, reddish-brown, loose, dry (slopewash)
4	5	Pebbly sand, yellowish-brown (outwash)
5	7	Pebbly clay loam, dark olive-brown (transition till)
7	13	Coarse sand and gravel, yellowish-brown (outwash)

APPENDIX D

QUANTAB CHLORIDE TITRATORS

Quantab chloride titrators are measuring devices for chloride in aqueous solutions. General and technical information are summarized in the following section.

QUANTAB® CHLORIDE TITRATORS

INFORMATION SUMMARY

GENERAL

INTRODUCTION: QUANTAB Chloride Titrators are convenient measuring devices for salt (chloride) in aqueous solutions or dilute aqueous extractions of solids. QUANTAB Titrators are self-acting and provide objective results which are easy to read and interpret.

PRODUCT IDENTIFICATION	APPROXIMATE TITRATION RANGE
QUANTAB Chloride Titrator No. 1175	.01% to 0.08% NaCl 60 to 480 ppm. Cl⁻
QUANTAB Chloride Titrator No. 1176	.05% to 0.8% NaCl⁻ 300 to 4,900 ppm. Cl⁻ (With dilution/extraction procedure up to 8.0% Cl or 49,000 ppm. Cl⁻

PREPARATION OF TEST SOLUTIONS

Good results with QUANTAB Chloride Titrators may be achieved by following these instructions carefully.

For Aqueous Samples

Measure directly by using the appropriate QUANTAB Chloride Titrator and carefully following the section headed "DIRECTIONS." Aqueous samples containing more salt than the QUANTAB upper limit can be measured with QUANTAB Chloride Titrators by diluting the sample to be tested before performing the measurement. To obtain the correct value of salt content before dilution, multiply the result on QUANTAB calibration table by the dilution factor.

For Solid or Semi-Solid Samples, Use Dilution/Extraction Procedure Below

1. Mix or grind a representative portion of solid or semi-solid product, thus dividing the product into small particles to insure extraction of salt.
2. Weigh 10 grams of finely-divided product and place in a suitable container.
3. Add 90 ml. boiling water. Stir mixture vigorously for 30 seconds, then wait one minute and stir another 30 seconds to obtain a good extraction of salt from the sample. (Dilution factor is 10 in this example.)
4. Fold filter paper circle in half twice; open into cone-shaped cup and place cup into extraction solution to collect a few drops of filtrate solution inside cup before performing test.

DIRECTIONS

1. Place *lower* end of QUANTAB in the solution to be tested. (Immersion of entire QUANTAB will pre-trigger completion signal.)
2. Allow test solution to saturate column. This is accomplished two minutes after the yellow test completion signal across the top of the column begins to turn dark blue.
3. Results may be read up to 5 minutes after signal color change occurs.

INTERPRETATION OF DATA

1. Record QUANTAB reading to the nearest one-half division on the numbered scale at the tip of the white color change.
2. Convert QUANTAB reading to percent salt or ppm. chloride (mg chloride per liter) using the calibration table.
3. If sample has been diluted, multiply result on calibration table by dilution factor to obtain salt content of sample.
4. Strip excess fluid out open end to make test result permanent.

TECHNICAL

CHEMISTRY: QUANTAB Chloride Titrators consist of a thin, chemically inert plastic strip. Laminated within the strip is a column impregnated with silver dichromate. When QUANTAB is placed in aqueous solutions, fluid will rise in the column by capillary action. The reaction of silver dichromate with chloride (salt) produces a white color change in the capillary column. When the capillary column is completely saturated, a moisture-sensitive signal across the top of the column turns dark blue.

The length of the white color change in the *capillary* column is proportional to chloride concentration.

SPECIFICITY: Bromides, Iodides, Sulfates, strong acids and strong bases can react with QUANTAB Chloride Titrators, however, they are not present in most samples to be tested in sufficient amounts to affect test results. Nitrite and nitrate have no effect on the test.

Chloride concentrations between about 40 mg/L to about 500 mg/L can be measured using low range 1175 titrators. Chloride concentrations between about 400 mg/L and 5000 mg/L can be measured using high range 1176 titrators. Chloride concentrations were measured up to 150,000 mg/L by diluting the original solution using high range titrators.

APPENDIX E-1

Stepwise Regression Prediction of Contamination Index Based Exclusively on Available Physical Data

Dependent Variable: CI
Independent Variables: YEAR, LOG, SWL

R-squared = 0.2927 F-ratio = 1.79323

Independent Variable	Coefficients
CONSTANT	13.147562
YEAR (year site was drilled)	-0.006442
LOG (log of soil permeability)	-.091397
SWL (static water level)	.000558

Regression Results

Observation Number	Observed Values	Fitted Values
1	.585	.477
2	.591	.53
3	.351	.359
4	.417	.359
5	.080	.363
6	.454	.358
7	.571	.461
8	.595	.540
9	.385	.373
10	.111	.466
11	.216	.233
12	.337	.236
13	.568	.478
14	.525	.481
15	.543	.338
16	.188	.271
17	.240	.432

Equation to predict CI:

$$CI = 13.1475 + (-0.006442 * YEAR) + (-0.091397 * LOG) + (0.000558 * SWL)$$

APPENDIX E-2

Stepwise Regression Prediction of Contamination Index Based on Available Data and Preliminary Field Data

Dependent Variable: CI
Independent Variable: EM, LOG, YEAR, PRELIMCI

R-squared = .558 F-ratio = 3.788

Independent Variable	Coefficients
CONSTANT	-6.93566
PRELIMCI	0.23948
LOG	-0.09490
EM	0.03842
YEAR	0.003652

Regression Results

Observation Number	Observed Values	Fitted Values
1	.585	.394
2	.591	.730
3	.351	.415
4	.417	.369
5	.080	.232
6	.454	.353
7	.571	.383
8	.595	.487
9	.385	.395
10	.111	.310
11	.216	.229
12	.337	.234
13	.568	.567
14	.525	.513
15	.543	.495
16	.188	.269
17	.240	.381

Equation to predict CI:

$$CI = -6.93566 + (0.23948 * PRELIMCI) + (-0.09490 * LOG) + (0.03842 * EM) + (0.003652 * YEAR)$$