SURVEY OF POTENTIAL WATER QUALITY EFFECTS CAUSED BY SUBSURFACE DRAINAGE OF SALINE SEEP AREAS

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ACKNOWLEDGMENTS

I would like to thank all those who made this thesis a possibility, for without them I could never have completed this work. I would like to thank Guido Bugni, my thesis advisor and director, for his patience, support, interest, and guidance. Also thanks to Dr. James J. Manion and Les Pederson and Dr. John Christenson, my readers, for their helpful suggestions and assistance. Special acknowledgment to Les Pederson and Peter Gorman of the State Water Quality Bureau, who with technical assistance contributed equipment, references, and their time, which made this study possible. I would also like to thank Loren Bahls of the Water Quality Bureau for his work and data on the Periphyton analysis. A deep appreciation to my family for their love, prayers, encouragement, and confidence in me. To all those people not acknowledged but complementary to the production of this work, my special thanks.

ABSTRACT

A study on the water quality of saline seep drainage was taken over a six-month period, ranging from June 1978 to November 1978. Intermittent analyses were made along the drainage route from the tile drains to its termination in Benton Lake, a closed basin. Tests were conducted for Na^{+}, Ca^{++}, K^{+}, Mg^{++}, Cl^{-}, SO_4^{--}, total N, pH, and specific electrical conductance. Conditions were studied for human and stock consumption safety.

Results showed water quality of the drains to be unacceptable for irrigation or stock and human consumption. Drainage was effective for hydrological control and reduction of seep, yet the water quality did not significantly improve even after extended time periods following drain installation.

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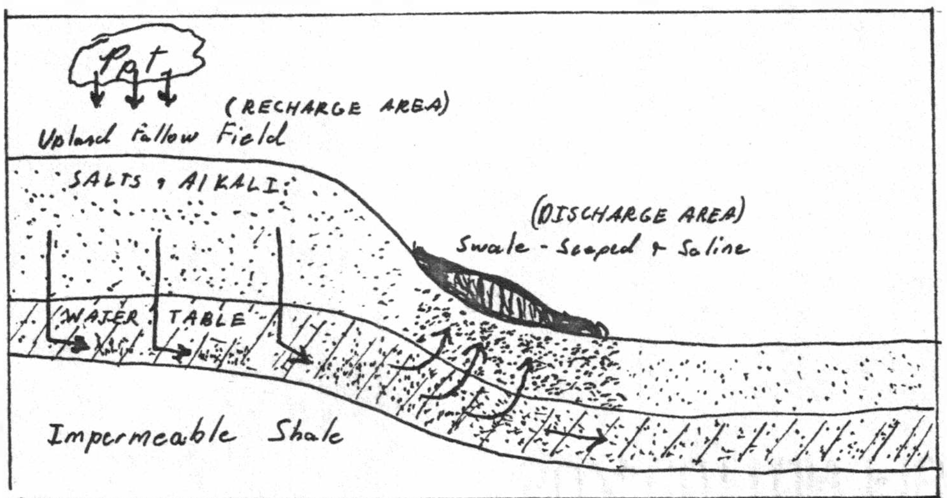
INTRODUCTION

Saline seep is a growing ecological and economic problem especially for the Northern Great Plains. Saline seeps are a major problem for causing lost productivity in dryland farming. Dryland saline seeps are recently developed saline soils, in nonirrigated areas, that are wet some or all of the time, often with white crusts, and where crop or grass production is reduced or eliminated (1).

Natural seeps or salt licks have always been present on the Great Plains and were described by Lewis and Clark in their journals. Natural seep areas differ from saline seep in that they have occurred over long geologic time and remain a relatively constant size. Saline seep is a recent phenomenon which started in the late 1940s and is increasing at about 10 per cent a year (1). One Montana survey has shown the problem to have grown from 53,250 acres in 1959 to 156,000 acres in 1975 (14). The problem arose with the introduction of summerfallow farming in the 1930s. Summerfallow, which allows for moisture to increase in the soil for next year's crop, can cause excessive soil moisture accumulation which may lead to a perched water table and the formation of alkaline deposits in the surface soil.

Formation of saline seep depends on the geology, climate, and agricultural practices of an area. Saline seep occurs in agricultural areas where the soils are derived from marine shale parent material which is heavily laden with salts. Excess moisture percolates below the root zone and collects above an impermeable layer forming a perched water table that contains dissolved salts, minerals, and nutrients in the soil. The water then flows downslope along a gravitation gradient to the discharge area where the water surfaces, and through evapotranspiration deposits the soluble salts collected from the soil (Fig. 1).

Fig. 1 -- Diagramatic Sketch of Saline Seep



The most successful approach for the control of saline seep has been through continuous recropping of the recharge area with deep-rooted perennials which can absorb the excess soil moisture in the soil, preventing the movement of water downslope to the seep area (1, 3, 4, 6, 9).

Other methods have been applied where the surface water is drained or removed through ditches and canals, preventing the percolation of excess moisture below the root zone.

Subsurface drainage to intercept saline water has been used in a few areas of the Western United States and Canada, but because of the questionable quality of the discharging water and potential water quality degradation to surface waters, it must be carefully considered before being applied as a long-term solution.

In June of 1978, a contract was made with the State Water Quality Bureau to do a study of an area 6 miles north of Vaughn, Montana, which is severely impacted with saline seep. This area was chosen because of an extensive drainage system that was installed by Julius Summerfeldt to improve part of his land that was affected by saline seep. This drain discharges continually into an open ditch which leads to Lake Creek and ultimately flows toward the Benton Lake National Wildlife Refuge (BLNWR). This whole area is a closed basin and an addition of saline water to Benton Lake could cause possible degradation. There are also several coulees which drain saline water into the lake intermittently and there is more interest in installing drains in the area. This study hopes to assess the quality and quantity of water discharge from a subsurface drainage system and note its impact on any surface waters.

The unique situation that the drainage is into a closed basin, the extended periods of time since drain installation, and the cooperation of the farmer made this an ideal site for concentrated study.

History and Description of the Study Site

During 1918 and 1919 pioneers homesteaded the area which was divided into quarter sections. In 1923, the present farmer, Julius Summerfeldt, purchased the land. With the advent of the tractor in 1928, he began

Drain 3A (Fig. 3), constructed in 1975, is 800 feet of 6-inch perforated concrete pipe and drains the water on the south eastern edge of the seep; it also lies on the perched water table line. Drain 3B, constructed in the early fall of the same year, extends in an easterly direction from its outlet for 300 feet. These #3 drains are not significantly reducing the seep and future drains are planned. The outlet for these drains is a well dug 16 feet down through the impermeable clay layer and is released onto the underlying Black Colorado Marine Shale, the outflow of which is unknown.

The drainage ditch empties into Lake Creek, which leads to and supplies the BLNWR with water. Lake Creek, which has a very low flow during the summer (1-2 cubic feet per second), is at times augmented with water pumped from Muddy Creek near Power, Montana to maintain the water level of the Benton Lake ponds.

to break up the land for dryland farming. Alternate crop fallow farming for wheat and small grains was utilized as it became popular with Montana farmers. During the wet years of 1953 and 1954, seep first began to appear on the Summerfeldt location and grew steadily worse until measures were taken by the farmer, Julius Summerfeldt. In the early sixties (1961-1962), he unsuccessfully used an open drainage ditch to lower the groundwater level and had difficulties with slimping and erosion of the land. The following year the first 6-inch clay perforated tile was laid in a bed of gravel at the level of the water table 6-8 feet below the surface. The first drain (#1) was placed in the center of the seep, but little drainage occurred due to the impermeable nature of saline soils. Clay particles in the soil floculate when Ca^{++} and Mg^{++} ions are replaced by the Na^{+} ions of seep waters (13). In the following two years four spurs of similar construction were dug in a southeasterly direction, extending outside of the seep, and drained the waters from the more permeable soils. The interceptor drain, according to the farmer, was 1050 feet long with spurs 150-200 feet long and extending 15 feet beyond the visible seep (Fig.3).

Interceptor drain 2A (Fig. 3), constructed in 1965, is 5000 feet of 6-inch perforated clay tile placed on a gravel bed at the perched water table 6-8 feet below the surface of the glacial till. Drain 2B intercepts drain 2A 2000 feet from the outlet, constructed at the same time and of a similar make. Both drains 1 and 2 have a common discharge into the head of an open drain ditch which leads to Lake Creek and ultimately to the BLNWR.

Fig. 2 -- Map of Study Area

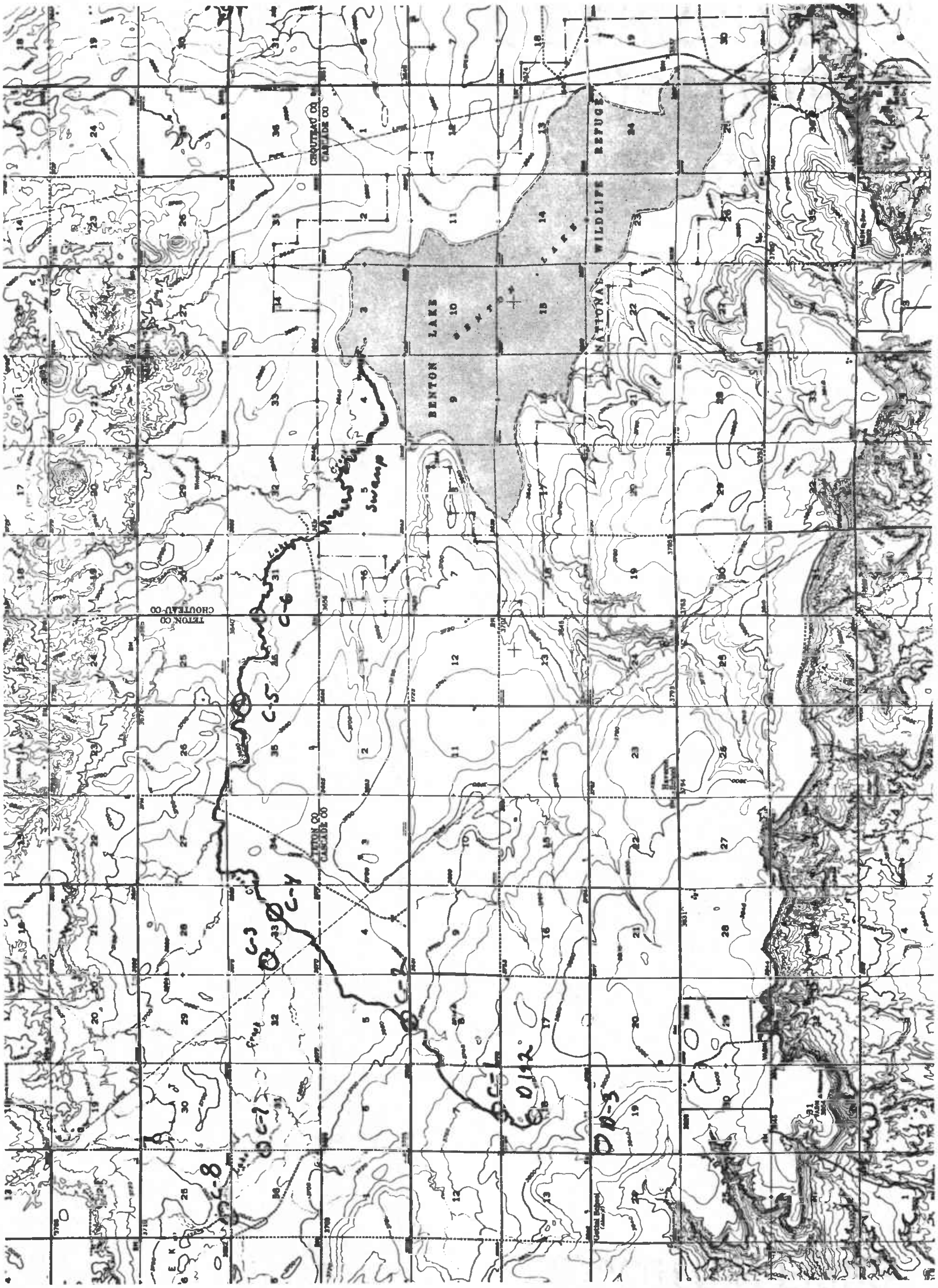
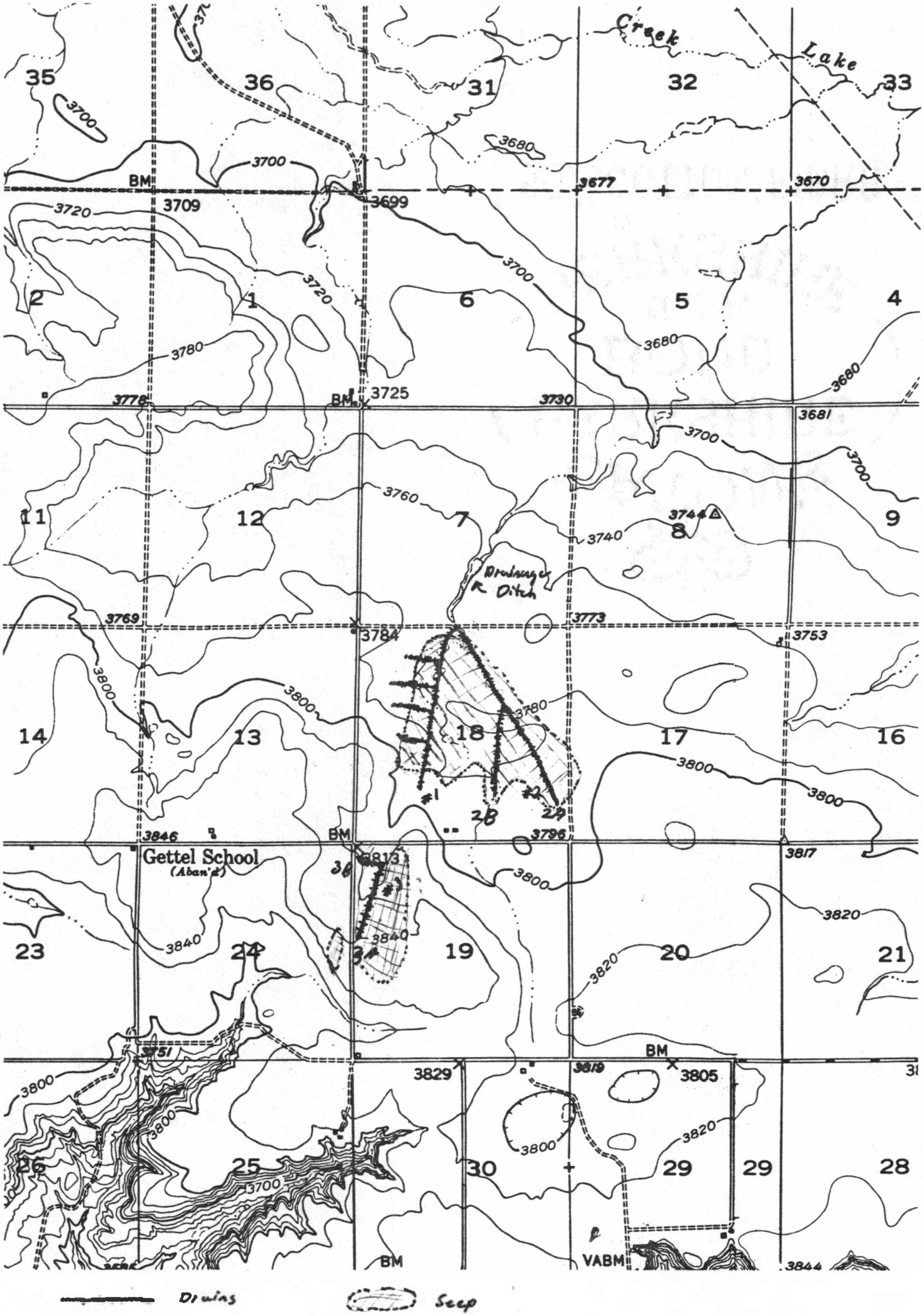


Fig. 3 -- Drainage Systems and Seep Diagram



PHYSICAL CHARACTERISTICS

Soils

Data from the National Cooperative Soil Survey was supplied by Dean Farnsworth of the Soil Conservation Bureau in Great Falls. From the studies on the soils of the area, it was found that the soils are of the fine montmorillonitic calcareous family of soils (Abor, Cargill, Dutton, Pylon, Poser, and Mckenzie series) weathered from the sedimentary deposits of clay, shale, and the interbedded sandstone and siltstone lenses. The result is a silty clay loam with a composition of clay ranging from 40-60 per cent and an underlying horizon of Black Colorado Marine Shale with interbedded sandstone and siltstone lenses. Surface drainage in the area is moderate to high runoff and has a slow permeability due to the clay-textured soils. Mean annual soil temperatures range from 40-45^{o}F.

Wells drilled by Marvin Miller in 1974 at the Gettel-Jones site (12), 2 miles north of the study site, show the surface soil to be a silty clay loam composed of clay 30-75 per cent, silt 25-35 per cent, and sand 0-25 per cent. Depth of the surface soil to the Black Marine Shale ranges from 15-23 feet, and averages about 18 feet.

Vegetation

Major native vegetation includes Western Wheatgrass, Blue Bunch Wheatgrass, Needle and Thread Grass, Prairie Junegrass, Blue Gram, and salt-tolerant species of Kochia and Foxtail Barley.

Agriculture in the area is predominantly small grain production using alternate crop fallow system. Principal crops include Winter Wheat and barley with some surplus crops of sunflower, mustard, and alfalfa.

Climate

Climate is cool, dry, and semi-arid with a mean annual precipitation of 12 inches, with 70 per cent of the moisture falling when the soil is not frozen. Precipitation for the 1978 year totaled 24.71 inches. Mean annual temperature is 44^{o}F.; mean January temperature is 10-26^{o}F.; mean July temperature is 67-72^{o}F. The 32^{o}F. growing season is 105-135 days.

METHODS AND PROCEDURES

The study of water quality ranged from the discharge points of the drains, along the drainage ditch, on to Lake Creek, and into the BLNWR. There were two sites at the drain discharges, designated as D-1&2, and D-3, for drains 1&2 and 3 respectively. Eight stations were set along the drainage ditch and Lake Creek, designated C-1 through C-8. One monitoring site designated L-1 was in Pond 2 of Benton Lake (Fig. 2).

Samples were analyzed for specific electrical conductivity (EC), pH, sodium absorption ratio (SAR), Na^{+}, Ca^{++}, Mg^{++}, Cl^{-}, K^{-}, SO_4^{++}, HCO_3^{+}, and total N. Three 1000 ml samples were taken with 5 ml of HgCl preserving the nitrates, 5 ml concentrated H_2SO_4 preserving the metals, and a sample taken for analysis of common parameters. Analyses were performed at the State Department of Health and Environmental Sciences Lab in Helena. Analytical procedures followed the American Public Health Association (1971, 1975) or the U. S. Environmental Protection Agency (1974).

The materials for this study were made available by the State Water Quality Bureau in Helena. This included all the materials necessary for the collection and preservation of samples and also included the field equipment for measuring conductivities and pH's.

Tests for electrical conductivity were conducted both by the state lab and the author, using standard commercial EC measuring equipment. The test is the reciprocal of resistance to a current flow through a water extract, expressed in mmhos/cm. It is a useful indicator of the total ionic concentration of solutes.

SAR values are basically a ratio of sodium to calcium and magnesium ions. These values predict reasonably well the degree to which water tends to enter cation exchange in soil. High values of SAR greater than 6 imply a hazard of sodium replacing calcium and magnesium in the soil; this results in damage to the soil structure. The exchange process results in a floculation of the soil and decreases the permeability and aeration (13, 15).

Surface soil descriptions were obtained from Dean Farnsworth, Soil Conservation Service, Great Falls. Underlying strata were characterized by Marvin Miller, Montana Bureau of Mines and Geology, from wells drilled 2 miles north of the study site. Precipitation data was obtained from Bob Pearson, manager of the BLNWR. Periphyton analyses were conducted by Loren Bahls, ecologist for the State Water Quality Bureau.

RESULTS AND DISCUSSION

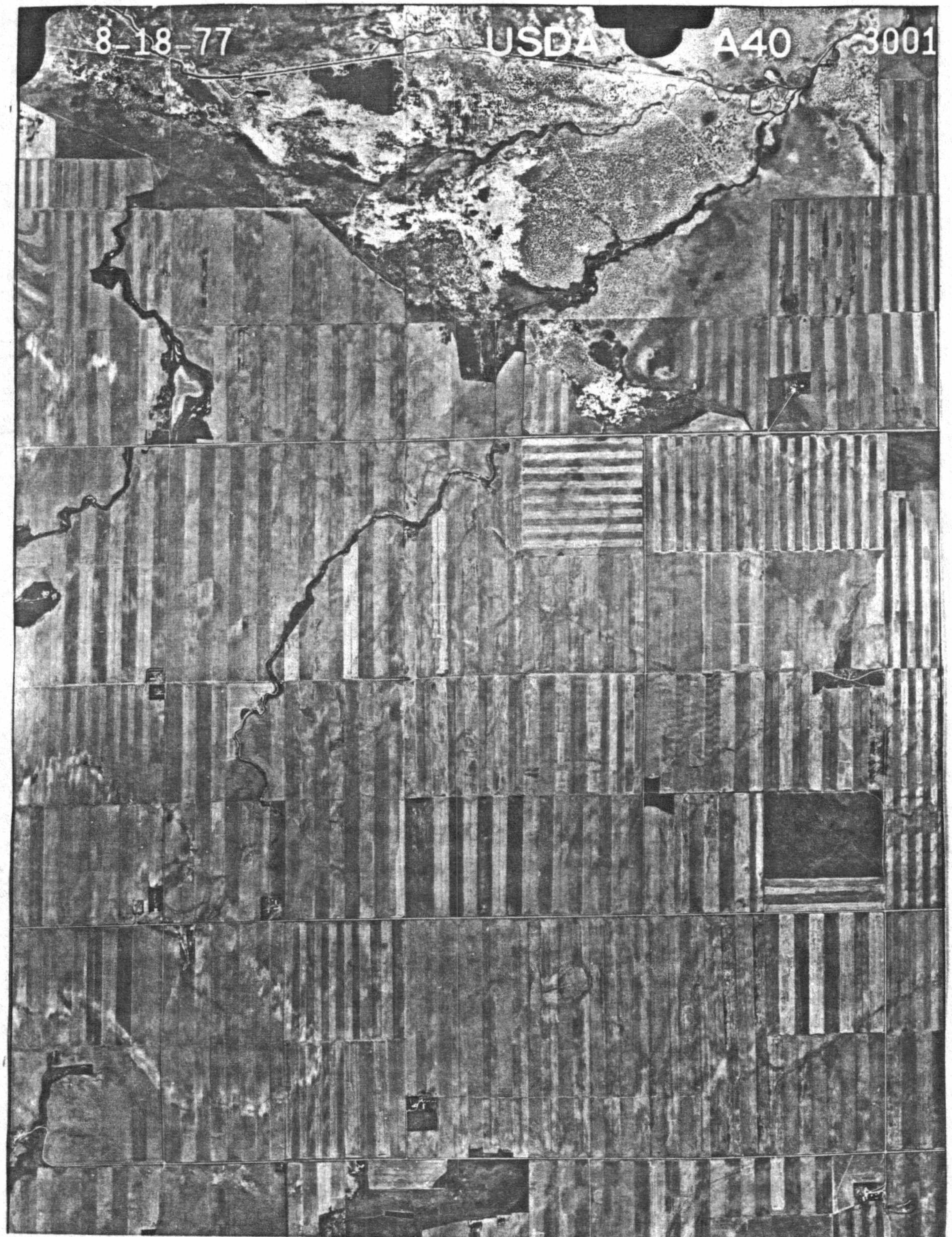
Discharge of drain 1, 2A&B, and 3A&B remained continuous throughout the dry summer months with rates varying according to precipitation and groundwater present. Flow rates of the drainage ditch were the same or slightly higher than the output of drains 1 and 2. According to Summerfeldt, drainage occurs year round with water continuously flowing in the drainage ditch. Other seeps also discharge into the drainage ditch at points below the study site.

Installation of the drains has reclaimed 80-90 acres of land taken by the seep and returned it to production of wheat and barley crops. A 1966 aerial photograph shows about 150 acres to be affected by saline seep (Fig. 3, sketch of seep superimposed on topographic map), whereas a 8-18-77 aerial photograph shows saline seep to have been reduced to 70 acres with success especially noted for the older drains 1 and 2 (Fig. 4).

As a result of lowering the perched water table in the discharge area, the surface profile has dried, allowing the excess salts in the soil to be leached back down by natural precipitation. On the study site, this effect of the drains was seen 3-4 years following drain installation. Salt content of the soils can be reduced below the level of the drains by the radial flow of water around subsurface drains (16).

Complete analysis of the water quality samples has been summarized in Table 1. Chemical analysis of the drain effluents shows that the water is completely unfit for human or stock consumption, and irrigation,

Fig. 4 -- 1977 Aerial Photograph of Study Site



Site	Date	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	HCO_3	Cl^{-}	Total N	SO_4^{-}	pH	EC	SAR	Flow Rate
D-1&2	*7-13-73	419	835	928	6	--	299	--	6500	4.17	8580	6	10 gpm
	5-78	400	380	718	438.5	--	861	1400	2016	7.1	1160	6.2	15 gpm
	7-78	478	--	1310	18	--	450	930	1400	--	11616	16.5	22 gpm
	8-78	--	--	--	--	--	--	625	--	4.14	10890	--	12 gpm
	9-78	--	--	--	--	--	--	--	--	--	10354	--	--
	10-78	--	--	--	--	--	--	--	--	4.24	10520	--	--
D-3	5-78	170	1200	736.4	181.8	--	435	640	6765	4.00	21600	4.4	40 gpm
	7-78	1260	381	5920	29	--	7980	1200	2450	--	15004	37.5	35 gpm
	8-78	--	--	--	--	--	--	2250	--	7.54	12130	--	--
	10-78	--	--	--	--	--	--	--	--	6.91	11454	--	--
C-1	7-78	532	622	1350	18	--	399	246	1230	--	13200	9.4	--
	10-78	--	--	--	--	--	--	--	--	4.25	10270	--	60 gpm
C-2	10-78	--	--	--	--	--	--	--	--	4.48	11493	--	--
C-5	10-78	--	--	--	--	--	--	--	--	4.81	10816	--	--
C-6	6-78	--	--	240.4	--	58.6	50	7.80	1520	7.41	2463	--	2 cubic ft/sec
	7-78	164	281	368	13	--	141	29	2450	--	4356	6.2	1 cubic ft/sec
	8-78	--	--	--	--	--	--	100	--	6.92	6190		1 cubic ft/sec
C-7	10-78	--	--	--	--	--	--	--	--	8.73	7780	--	10 gpm
C-8	10-78	--	--	--	--	--	--	--	--	7.86	5286	--	10 gpm
L-1	6-78	--	--	147.3	--	198.9	23.1	--	910	7.98	1388	--	--
	*7-17-74	42	40	32.6	2.7	258	5.2	--	115	8.12	1150	.9	--

All values reported as mg/l

* Montana Bureau of Mines and Geology, Marvin Miller

Table 1 -- Laboratory Analysis of Waters Along Drainage from Seep Site

and that this discharge is not sufficiently diluted by the low flow of Lake Creek during the dry summer months, making Lake Creek also unfit for stock consumption.

Magnesium, total nitrogen (NO_2 + NO_3), sulfate, sodium, and calcium concentrations exceed public drinking water standards and at times are unfit for stock levels set at 500, 110, 500, 2000, and 1000 mg/l respectively (7). Highest concentrations of mineral values obtained are summarized in Table 2 below.

Table 2 -- Concentration of Minerals and Nutrients Found in Seep Drainage Waters (all values reported as mg/l)

Site	Mg^{++}	Total N	SO_4^{++}	Na^+	Ca^{++}
D-3	200	2250	6765	5920	1260
D-1&2	835	1400	6500	5920	478
C-2	622	240	1730	1350	532
C-6	281	29	2450	563	164
L-1	40	--	910	326	42

Conductivity readings were obtained along the complete drainage flow from the seeps to Benton Lake. Readings are summarized in Table 3 and the sampling site locations are indicated on the map in Figure 2. Lake Creek at this time had a very low flow with ponding and some subsurface flow in places. This is a characteristic of many prairie streams; they have a high spring runoff and low summer flows. Because of this low flow, streams concentrate salts as demonstrated by samples collected above and below the drain on Lake Creek (8). The bottom of the creek remained extremely muddy, with dry rocks having white alkali deposits on them. Salt-tolerant species of Kochia and Foxtail Barley, lining the banks, indicated alkaline deposits all along the drainage of the creek. Much evidence of erosion and slumping of the drainage ditch was evident, with the farmer reporting the need to redig the ditch every few years, especially in the area of the drain output.

Table 3 -- Conductivity Values Along the Drainage

Site	Month	Readings (EC)*
D-3**	Sept.	11,788
	Oct.	11,454
D-1&2	Sept.	10,354
	Oct.	10,520
C-1	Oct.	10,270
C-2	Sept.	12,367
	Oct.	11,493
C-3	Sept.	13,629
C-4	Sept.	16,199
C-5	Sept.	9,110
	Oct.	10,816
C-6	Sept.	7,048
C-7	Oct.	7,780
C-8	Oct.	5,286
L-1		1, 757

* Electrical conductance (EC) recorded in mmhos per cm at 25^{o}C.

** Drains into well where outflow is unknown.

Table 4 shows the electrical conductivities recorded over the 6-month period for Drains 1&2, Drain 3, and Benton Lake.

Table 5 shows the rainfall the BLNWR received over the 1978 year.

Periphyton analyses were used as indicators for saline and nutrient conditions of Benton Lake, Lake Creek, and Drain #3. From the periphyton analysis, Bahls has concluded that the significant tributaries to Benton Lake, including the seeps, are contributing water that is higher in conductivity (salinity) but lower in nutrients than the lake itself. He also found that the nutrient situation of Lake Creek is much more similar to the seeps than to Benton Lake and that the salinity of Lake Creek falls between those of the seeps and Benton Lake (Appendix 3).

Low pH values were obtained from the seep drains having a range of 4.14-7.54, usually tending toward an acidic pH. Low pH values are probably due to a weathering of the pyrite in the shale and soil. Pyrite is oxidized to SO_4^{--} producing an acidic condition which in turn oxidizes the pyrite even further (12). The presence of buffers usually as $CaCO_3$ can minimize the effects of acid production and maintain the pH around 7.

The source of nitrate has not been identified, but three main sources are suspected: fertilizer N which has been applied over the past 15 years at 30 pounds/acre year, the release of NO_3 from the root zone during the fallow period, and the conversion of ammonium from the geological materials below the root zone. In areas that have been farmed over extended periods of time, nitrate has been shown to arise from the application of fertilizer and also from the converted ammonium in the minerals below the root zone (6).

Table 4 -- Electrical Conductance of Drains Over 6-month Time Period

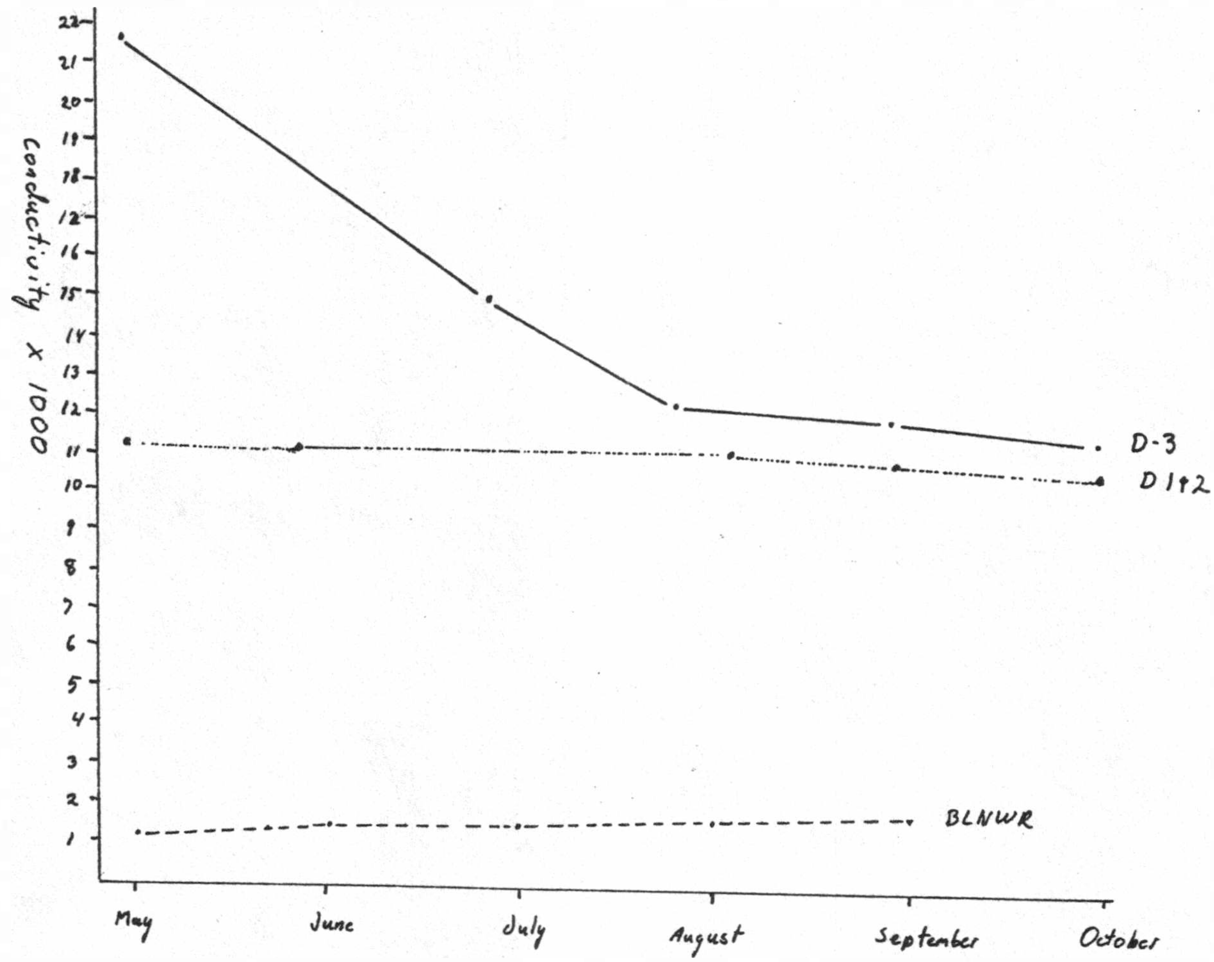
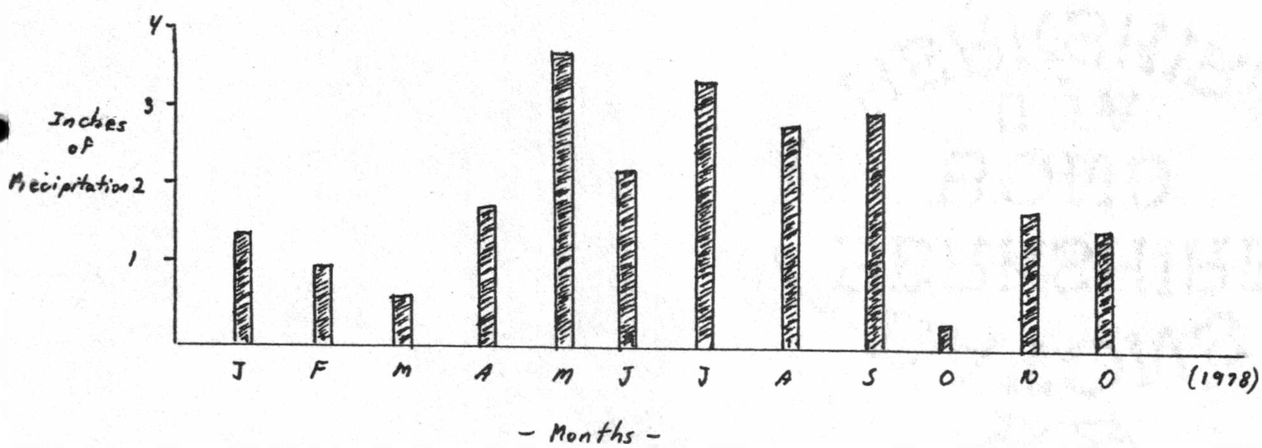


Table 5 -- Hydrograph of Rainfall During 1978 Year



One area of concern from saline seeps is the high level of nitrate in the water. Nitrate is converted to nitrite in the body and produces methemaglobinemia in the blood of animals and man. The condition of methemaglobinemia inhibits the ability of blood to carry oxygen and results in anoxia, a kind of suffocation (18).

Sulfates have deleterious effects on plants and livestock with diarrhetic effects to humans and livestock provided by the sulfates and sulfate salts (19).

CONCLUSIONS

Summerfeldt, using approximately 9850 feet of tile drain, has managed to reclaim 70 out of 150 acres affected by saline seep. Drains 1 and 2 are producing an average year-round flow of 25-35 gallons/ minute (17). From the samples collected, the water is known to contain high levels of total dissolved solids (TDS). The acidic pH, high nitrates and dissolved ions can have deleterious effects to plant and aquatic life and pose a potential hazard to livestock that range near the drainage ditch and Lake Creek. The total concentration of calcium, magnesium, sodium and potassium ions can prove injurious to plant life, since these salts reduce the osmotic activity of plants, preventing the absorption of nutrients from the soil. The salts may also affect the metabolism of plants and reduce the permeability of the soil, preventing adequate drainage or aeration (19).

Water level control can be obtained with the use of interceptor drains, but drainage is environmentally unacceptable because of the salts and nitrates in the water. Even after a 17-year period, drains 1 and 2 continue to discharge water of extremely poor quality.

Treating the symptoms of the problem of saline seep through subsurface drainage remains an ecological and economic liability and continues to be a detriment to the ground and surface water. The continuous discharge of salts and ions from the soils of the recharge and discharge area is decreased only slightly in concentration as the seep is eliminated or reduced in size. For drains 1 and 2, an 80 per cent decrease in seep size does not significantly reduce the harmful salt load when compared to the more recently installed drain #3.

Studies have shown that a more favorable alternative of continuous cropping attacks the problem where it begins by utilizing the water for crop use before the moisture can percolate below the root zone and become a salinized source of water pollution and seep formation.

Further long-term study, by the Montana Water Quality Bureau, will be done to assess the full impact of saline seep drainage systems on surrounding water sources.

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Appendix 1

A STUDY TO DETERMINE POSSIBLE WATER QUALITY EFFECTS OF DRAINING SALINE SEEP AREAS

W O R K   P L A N

Introduction:

During the last few years, there has been a growing interest in the installation of artificial drainage systems for the control and reclamation of saline seep. As the acreage affected by saline seeps continues to grow in Montana, quick, easy solutions to the problem are likely to be sought. While drainage in itself does not represent a long-term solution to the cause of saline seep, it has the potential for becoming increasingly widespread because it appears to many to be a "quicker, easier solution" than altering existing methods of crop production or changing land use. The disposal of the salinized water discharged by drains can present many problems, not the least of which is degradation of downstream water quality.

Purpose of the Study:

The purpose of this study will be to assess the quality of discharge waters from selected saline seep drainage projects and to generally determine the present impacts of drainage and make some predictions of potential impacts.

It is important to begin collecting data from various existing drainage projects in order to provide documented data and better inform landowners and agencies (such as the SCS) contemplating drainage of any possible consequences. Hopefully, knowledge gained in this study will be used to help formulate a statewide policy regarding saline seep drainage.

Scope of Study:

Saline seep drainage monitoring sites will be selected from locations in the Triangle Area of northcentral Montana. One ideal site has been located about 5 miles north of Vaughn. This drainage project produces a year-round discharge which eventually flows via Lake Creek into Benton Lake, a national wildlife refuge. The Water Quality Bureau may select additional suitable sites as they are identified.

For each site selected:

(1) Field conductivity measurements will be made of the discharge and receiving waters on at least a monthly basis through September 1978. The frequency of monitoring will be determined by the Water Quality Bureau. Samples of the discharge and receiving waters will be collected at the same frequency for analysis of nutrients and metals. The samples will be analyzed by the Water Quality Lab.

(2) An estimate of the discharge flow will be recorded when each sample is collected.

(3) Periphyton samples may be collected upon discretion of the Water Quality Bureau.

(4) Key indicator vegetation present on the seep area will be identified.

(5) Photographs (slides and prints) will be taken of the recharge, saline seep, and drain discharge areas.

(6) A general description of the area will be compiled, including soils, geology and topography information, approximate acreage of the recharge area, history of the land use and saline seep development, precipitation data, and date of drain installation.

A final report will be written and submitted to the Water Quality Bureau not later than November 1, 1978. The report will include a summary of the above information and will discuss in general terms:

(1) possible impairment of beneficial uses to downstream water users caused by degradation of receiving water quality;

(2) possible increase of erosion and sedimentation in coulles and natural drainages caused by the elimination of vegetation by saline water; and

(3) potential hazards to livestock or wildlife caused by saline water discharge into ponds or lakes.

Projected Budget:

Mileage @ .15/mile 5 field trips @ 350 miles/trip		$262.50
Meals $10/day x 20 man-days		200.00
Lodging $16/day x 10 days		160.00
Film & Processing		100.00
Miscellaneous (maps, photos, etc.)		50.00
	TOTAL	$772.50

Appendix II

Office Memorandum •

STA_ DEPARTMENT OF HEALTH AND ENVIRONMENTAL SCIENCES

TO : LES PEDERSON

DATE: MAY 9, 1978

FROM : LOREN BAHLS *Loren Bahls*

SUBJECT : SALINE SEEP PERIPHYTON ANALYSIS

I have completed a diatom proportional count on the May 4, 1978 periphyton sample from the saline seep in Cascade County located at T22N R02E Sec. 19BB. I understand that field conductivity of the seep measured 90,000 micromhos.

Diatoms were the only algae present in the sample. A random proportional count of 309 individuals produced the following taxa and relative abundances:

TAXA	NO.	% RELATIVE ABUNDANCE
Navicula cincta var. *rostrata*	140	45.3
Navicula tenelloides	140	45.3
Navicula salinarum	14	4.5
Navicula bulnheimii	9	2.9
Nitzschia frustulum	3	1.0
Unknown Taxon	3	1.0
	309	100.0

All of these diatoms, with the possible exception of the unkown taxon, are indicators of brackish to saline water or exposed habitats. The two co-dominants are frequently found in Montana waters affected by saline seep and over a broad range of total dissolved solids (Bahls, 1976). This is the first Montana record and possibly the first U.S. record for *Navicula bulnheimii*, a "salt water form" reported previously from Europe and Asia (Hustedt, 1966).

The Shannon-Weaver diversity index for this diatom association is 1.52. Only six taxa were identified during the proportional count. When similar numbers of individuals are counted in samples from unpolluted Montana waters, the Shannon-Weaver index falls between 3.00 and 4.00 and the number of taxa identified usually ranges from 25 to 40 (Bahls, In Press).

wa

Office Memorandum

STATE DEPARTMENT OF HEALTH
AND ENVIRONMENTAL SCIENCES

TO : Les Pederson

DATE: September 20, 1978

FROM : Loren Bahls *Loren Bahls*

SUBJECT : Results of Benton Lake Saline Seep Periphyton Analyses

I have completed analyses on the five periphyton samples collected June 2, 1978 from Benton Lake, Lake Creek, and three saline seeps feeding Benton Lake. Periphyton collections were made from natural substrates.

Table 1 gives the relative abundance of significant algae groups at the various stations. The one notable feature in this table is the abundance of the green alga Stigeoclonium in Benton Lake Pond III. Stigeoclonium is an indicator of polluted, nitrogen-rich water (Palmer, 1962).

Values for selected diatom association parameters are presented in Table 2. Ordinarily, unpolluted waters have diatom associations with 25 to 40 taxa (taxa counted) and diversity ($\bar{d}$) values of 3 to 4 when 300 to 400 frustules are counted (Bahls, In Press). None of the sites had more than 25 taxa counted and only one--the first saline seep--had a diversity greater than 3.

Equitability (e) generally drops below 0.50 under the influence of organic, oxygen-demanding waste (Weber, 1973). Equitability values for the three saline seeps were all above 0.50; values for Benton Lake Pond III and Lake Creek were both below 0.50.

The total percent relative abundance (PRA) of Achnanthes species is usually proportional to the dissolved oxygen content of water and the total PRA of Nitzschia species is considered a rough indicator of the amount of nitrogen enrichment (Cholnoky, 1968). The first saline seep was the only water with any Achnanthes. Benton Lake Pond III had the highest PRA Nitzschia value and, theoretically, the highest nitrogen content.

Among the major taxa listed in Table 2, several are salinity indicators (S). Of these, Navicula secreta var. apiculata, Nitzschia frustulum var. subsalina, and Synedra famelica are indicators of only moderate salinities; the remaining indicate significantly higher salinities (Bahls, 1976). These data indicate that Benton Lake and Lake Creek are not appreciably saline and that of the three saline seeps, the second and third are significantly more saline than the first.

(Continued)

Three of the major taxa in Table 2 are nutrient indicators (N). Navicula lamii "favors waters enriched with nitrogenous organic compounds" (Schoeman, 1973). Nitzschia dissipata and N. palea are indicators of eutrophic conditions (Lowe, 1974).

Environmental requirements of the remaining three major taxa in Table 2 are summarized by Lowe (1974). Achnanthes affinis is found over a wide range of salinities and has optimum growth in excess of pH 7. Cylindrotheca gracilis is typical of shallow pools rich in organic nitrogen and high in conductivity. Surirella ovata is a current-loving species preferring cool (0-24^{o}C) and alkaline (pH 7.5-8) water.

To summarize, the periphyton community of Benton Lake Pond III indicates a highly eutrophic situation. Of the three saline seeps, the first is significantly less saline than the other two and, judging by the diatom indicators, it has generally better water quality than Benton Lake Pond III, in spite of its higher salinity. Lake Creek has a salinity level falling between those of the seeps and Benton Lake, but probably closer to Benton Lake. On the other hand, the nutrient situation in Lake Creek is much more similar to the seeps than to Benton Lake.

From this, one might conclude that the significant tributaries to Benton Lake, including these three seeps, are contributing water that is higher in conductivity but lower in nutrients than the lake itself. The eutrophic status of the lake is apparently aggravated by its large waterfowl population. Observed nutrient and salinity relationships among these waters may vary appreciably from season to season.

Table 1. Estimated rank and relative abundance of diatoms and significant non-diatom algae, by volume

Station and Code	Rank	Relative Abundance
Benton Lake, Pond III (BL)	1. *Stigeoclonium* (G)	Very Abundant
	2. Diatoms (GB)	Abundant
Saline Seep to Benton Lake T22N R03E Sec.21A (SS1)	1. Diatoms (GB)	Abundant
	2. *Tribonema* (GB)	Abundant
	3. *Anabaena* (BG)	Common
Saline Seep to Benton Lake T22N R03E Sec.16C (SS2)	1. Diatoms (GB)	Very Abundant
	2. *Oscillatoria* (BG)	Common
Saline Seep to Benton Lake T22N R03E Sec. 17B (SS3)	1. Diatoms (GB)	Abundant
	2. *Oscillatoria* (BG)	Very Common
	3. *Anabaena* (BG)	Common
Lake Creek above Benton Lake T23N R03E Sec. 31BC (LC)	1. *Oscillatoria* (BG)	Abundant
	2. Diatoms (GB)	Abundant
	3. *Spirulina* (BG)	Rare

BG = blue-green algae GB = golden-brown algae G = green algae

Table 2. Values for selected diatom association parameters

Parameters	BL	SS1	SS2	SS3	LC
			Stations		
Frustules counted	321	341	320	329	324
Taxa counted	18	22	10	17	20
Total taxa	23	34	10	20	26
Species diversity ($\bar{d}$)	2.30	3.39	2.48	2.81	2.21
Equitability (e)	0.39	0.68	0.80	0.59	0.30
*PRA *Achnanthes* spp.	-	20.5	-	-	-
*PRA *Nitzschia* spp.	81.3	41.7	17.2	68.5	16.9
*PRA Major taxa					
Achnanthes affinis	-	19.9	-	-	-
Cylindrotheca gracilis	-	-	16.3	1.2	0.3
(S) *Navicula cincta* var. *rostrata*	t**	9.4	15.3	8.2	-
(N) *N. lamii*	10.9	2.9	-	-	0.6
(S) *N. salinarum*	-	0.6	13.8	6.4	-
(S) *N. secreta* var. *apiculata*	0.3	t**	-	2.4	47.8
(S) *N. tenelloides*	-	0.6	34.4	4.3	3.1
(S) *Nitzschia communis*	-	4.4	15.9	27.4	10.8
(N) *N. dissipata*	21.8	-	-	-	-
(S) *N. frustulum* var. *subsalina*	4.7	22.0	-	0.3	t**
(S) *N. longissima* var. *reversa*	-	-	-	35.0	-
(N) *N. palea*	50.5	1.2	1.3	4.9	4.0
Surirella ovata	0.9	-	-	-	27.8
(S) *Synedra famelica*	t**	11.4	-	1.8	-

S = salinity indicator
N = nutrient indicator

*PRA = Percent Relative Abundance; major taxa are those that contribute 10 PRA or more in one or more samples

t** = trace; found in scan but not during proportional count

GORMAN Apendix III

STATE HEALTH DEPT. . ..TER QUALITY BUREAU HELENA, MONTANA 59601

STATE	MONTANA	COUNTY	CASCADE
LAT.-LONG.	473955N 1113154W	SAMPLE LOCATION	22N 2E 18B
STATION CODE		ANALYSIS NUMBER	78W0678
DATE SAMPLED	05-04-78	DRAINAGE BASIN	041K -SUN RIVER
TIME SAMPLED		WATER FLOW RATE	5. GPM(M)
METHOD SAMPLED	GRAB	FLOW MEASUREMENT METHOD	BUCKET+ TIME
SAMPLE SOURCE		ALTITUDE OF LAND SURFACE	
WATER USE	UNUSED	TOTAL WELL DEPTH BELOW LS	
AQUIFER(S)		SWL ABOVE(+) OR BELOW LS	
SAMPLED BY	WQBH	SAMPLE DEPTH BELOW SURFACE	

SAMPLING SITE: SALINE SEEP DRAIN ON SUMMERFELT FARM COLBERT

	MG/L	MEQ/L		MG/L	MEQ/L
CALCIUM (CA)	400.0	19.960	BICARBONATE(HCO3)		
MAGNESIUM (MG)	380.0	31.260	CARBONATE (CO3)		
SODIUM (NA)	718.2	31.242	CHLORIDE (CL)	861.0	24.280
POTASSIUM (K)	438.5	11.226	SULFATE (SO4)	2016.0	41.973
			FLUORIDE (F)		
			PHOSPHATE(PO4 AS P)	< .01	
			NO3+NO2 (TOT AS N)	1400.00	99.960
	------	------		------	------
SUM CATIONS	1936.7	93.688	SUM ANIONS	4277.0	166.213

LABORATORY PH	7.10	TOT HARDNESS(MG/L-CACO3)	2563
FIELD WATER TEMPERATURE (C)		TOT ALKALINITY(MG/L-CACO3)	
SUM-DISS. IONS MEAS.(MG/L)		LABORATORY TURBIDITY (NTU)	
LAB-CONDUCTIVITY-UMHOS-25C	11160.0	SODIUM ADSORPTION RATIO	6.2

A D D I T I O N A L P A R A M E T E R S

PHOSPHOROUS,TOT (MG/L-P)	.028	SELENIUM,TR (MG/L AS SE)	.002
IRON,TR (MG/L AS FE)	.10	CNDUCTVY,FIELD MICROMHOS	9000.E+01
STRONTIUM, TR (MG/L-SR)	12.	LITHIUM ,TR (MG/L AS LI)	1.1
BORON, TOTAL (MG/L AS B)	0.40		

REMARKS: 206-SALINE SEEP

EXPLANATION: MG/L=MILLIGRAMS PER LITER MEQ/L=MILLIEQUIVILENTS PER LITER
ALL CONSTITUENTS DISSOLVED (DISS) EXCEPT AS NOTED. TOT=TOTAL SUSP=SUSPENDED
(M)= MEASURED(R)=REPORTED (E)=ESTIMATED M=METERS TR=TOTAL RECOVERABLE

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SAMPLE NO SITE 1 SAMPLER PCG HANDLING 3200 ANALYST ROB LAB WQBH
COMPLETED 06-19-78 COMPUTER RUN 07/12/78 DATA 0975/PROG 0876 FUND

STND DEV. ION BALANCE 9.99	CA	MG	NA	K	CL	SO4	HCO3	CO3	NO3
SEGMENT MPDES	21.3	33.4	33.3	12.0	36.6	63.4	0.0	0.0	0.0

CALC. MEQ/L= INSUFFICIENT DATA 78W0678

STATE HEALTH DEPT. WATER QUALITY BUREAU HELENA, MONTANA 59601

STATE	MONTANA	COUNTY	CASCADE
LAT.-LONG.	473955N 1113154W	SAMPLE LOCATION	22N 2E 18B
STATION CODE		ANALYSIS NUMBER	78WC679
DATE SAMPLED	05-04-78	DRAINAGE BASIN	041K -SUN RIVER
TIME SAMPLED		WATER FLOW RATE	40. GPM(M)
METHOD SAMPLED	GRAB	FLOW MEASUREMENT METHOD	BUCKET+ TIME
SAMPLE SOURCE		ALTITUDE OF LAND SURFACE	
WATER USE	UNUSED	TOTAL WELL DEPTH BELOW LS	
AQUIFER(S)		SWL ABOVE(+) OR BELOW LS	
SAMPLED BY	WQBH	SAMPLE DEPTH BELOW SURFACE	

SAMPLING SITE: TILE DRAIN FROM SUMMERFELT FARM

	MG/L	MEQ/L		MG/L	MEQ/L
CALCIUM (CA)	170.0	8.483	BICARBONATE(HCO3)		
MAGNESIUM (MG)	1200.0	98.717	CARBONATE (CO3)		
SODIUM (NA)	736.4	32.033	CHLORIDE (CL)	435.0	12.267
POTASSIUM (K)	181.8	4.654	SULFATE (SO4)	6765.0	140.847
			FLUORIDE (F)		
			PHOSPHATE(PO4 AS P)	0.111	0.011
			NO3+NO2 (TOT AS N)	640.00	45.696
SUM CATIONS	2288.2	143.887	SUM ANIONS	7840.1	198.821

LABORATORY PH	4.00	TOT HARDNESS(MG/L-CACO3)	5365
FIELD WATER TEMPERATURE (C)		TOT ALKALINITY(MG/L-CACO3)	
SUM-DISS. IONS MEAS.(MG/L)		LABORATORY TURBIDITY (NTU)	
LAB CONDUCTIVITY-UMHOS-25C	21600.0	SODIUM ADSORPTION RATIO	4.4

A D D I T I O N A L P A R A M E T E R S

PHOSPHOROUS,TOT (MG/L-P)	.111	SELENIUM,TR (MG/L AS SE)	< .002
IRON,TR (MG/L AS FE)	.36	CNDUCTVY,FIELD MICROMHOS	8000.E+01
STRONTIUM, TR (MG/L-SR)	2.8	LITHIUM ,TR (MG/L AS LI)	3.7
BORON, TOTAL (MG/L AS B)	0.30		

REMARKS: 208-SALINE SEEP

EXPLANATION: MG/L=MILLIGRAMS PER LITER MEQ/L=MILLIEQUIVILENTS PER LITER
ALL CONSTITUENTS DISSOLVED (DISS) EXCEPT AS NOTED. TOT=TOTAL SUSP=SUSPENDED
(M)= MEASURED(R)=REPORTED (E)=ESTIMATED M=METERS TR=TOTAL RECOVERABLE

SAMPLE NO SITE 2 SAMPLER PCG HANDLING 3200 ANALYST ROB LAB WQBH
COMPLETED 06-19-78 COMPUTER RUN 07/12/78 DATA 0975/PROG 0876 FUND

		CA	MG	NA	K	CL	SO4	HCO3	CO3	NO3
STND DEV. ION BALANCE	9.99									
SEGMENT	HPDES	5.9	68.6	22.3	3.2	8.0	92.0	0.0	0.0	0.0

CALC. MEQ/L= INSUFFICIENT DATA 78WC679

STATE HEALTH DEPT. WATER QUALITY BUREAU HELENA, MONTANA 59601

STATE	MONTANA	COUNTY	CASCADE
LAT.-LONG.	474220N 1112 5 9W	SAMPLE LOCATION	23N 2E 36
STATION CODE	SITE	ANALYSIS NUMBER	78W1378
DATE SAMPLED	07-19-78	DRAINAGE BASIN	041Q -TETON R.
TIME SAMPLED	0	WATER FLOW RATE	
METHOD SAMPLED		FLOW MEASUREMENT METHOD	NOT MEASURED
SAMPLE SOURCE	STREAM	ALTITUDE OF LAND SURFACE	
WATER USE		TOTAL WELL DEPTH BELOW LS	
AQUIFER(S)		SWL ABOVE(+) OR BELOW LS	
SAMPLED BY	WQBH	SAMPLE DEPTH BELOW SURFACE	

SAMPLING SITE: LAKE CR NEAR MOUTH

	MG/L	MEQ/L		MG/L	MEQ/L
CALCIUM (CA)	164.0	8.184	BICARBONATE(HCO3)		
MAGNESIUM (MG)	281.0	23.116	CARBONATE (CO3)		
SODIUM (NA)	568.0	24.708	CHLORIDE (CL)	141.0	3.976
POTASSIUM (K)	13.0	0.333	SULFATE (SO4)	2450.0	51.009
			FLUORIDE (F)		
			PHOSPHATE(PO4 AS P)	0.007	0.001
			NO3+NO2 (TOT AS N)	29.00	2.071
SUM CATIONS	1026.0	56.341	SUM ANIONS	2620.0	57.056

LABORATORY PH		TOT HARDNESS(MG/L-CACO3)	1566
FIELD WATER TEMPERATURE (C)		TOT ALKALINITY(MG/L-CACO3)	
SUM-DISS. IONS MEAS.(MG/L)		LABORATORY TURBIDITY (NTU)	
LAB CONDUCTIVITY-UMHOS-25C		SODIUM ADSORPTION RATIO	6.2

A D D I T I O N A L P A R A M E T E R S

PHOSPHOROUS,TOT (MG/L-P)	.034	SELENIUM,TR (MG/L AS SE)	< .005
IRON,TR (MG/L AS FE)	.09	STRONTIUM, TR (MG/L-SR)	.84
LITHIUM ,TR (MG/L AS LI)	.31	BORON, TOTAL (MG/L AS B)	.549

REMARKS: 208-SALINE SEEP COUNTY ROAD SITE NEAREST BENTON NWR

EXPLANATION: MG/L=MILLIGRAMS PER LITER MEQ/L=MILLIEQUIVILENTS PER LITER
ALL CONSTITUENTS DISSOLVED (DISS) EXCEPT AS NOTED. TOT=TOTAL SUSP=SUSPENDED
(M)= MEASURED(R)=REPORTED (E)=ESTIMATED M=METERS TR=TOTAL RECOVERABLE

SAMPLE NO 1 SAMPLER AV HANDLING 32 ANALYST JAH LAB WQBH
COMPLETED 01-11-79 COMPUTER RUN 01/18/79 DATA C975/PROG C876 FUND 6053

STND DEV. ION BALANCE 0.74	CA	MG	NA	K	CL	SO4	HCO3	CO3	NO3
SEGMENT MPDES	14.5	41.0	43.9	0.6	7.2	92.8	0.0	0.0	0.0

CALC. MEQ/L= INSUFFICIENT DATA 78W1378

STATE HEALTH DEPT. WATER QUALITY BUREAU HELENA, MONTANA 59601

STATE	MONTANA	COUNTY	CASCADE
LAT.-LONG.	474220N 11125 9W	SAMPLE LOCATION	23N 2E 36
STATION CODE	SITE	ANALYSIS NUMBER	78W1378
DATE SAMPLED	[redacted]	DRAINAGE BASIN	[redacted] -TETON R.
TIME SAMPLED	0	WATER FLOW RATE	
METHOD SAMPLED		FLOW MEASUREMENT METHOD	NOT MEASURED
SAMPLE SOURCE	STREAM	ALTITUDE OF LAND SURFACE	
WATER USE		TOTAL WELL DEPTH BELOW LS	
AQUIFER(S)		SWL ABOVE(+) OR BELOW LS	
SAMPLED BY	WQBH	SAMPLE DEPTH BELOW SURFACE	

SAMPLING SITE: [redacted]

	MG/L	MEQ/L		MG/L	MEQ/L
CALCIUM (CA)	164.0	8.184	BICARBONATE(HCO3)		
MAGNESIUM (MG)	281.0	23.116	CARBONATE (CO3)		
SODIUM (NA)	568.0	24.708	CHLORIDE (CL)	141.0	3.976
POTASSIUM (K)	13.0	0.333	SULFATE (SO4)	2450.0	51.009
			FLUORIDE (F)		
			PHOSPHATE(PO4 AS P)	0.007	0.001
			NO3+NO2 (TOT AS N)	29.00	2.071
SUM CATIONS	1026.0	56.341	SUM ANIONS	2620.0	57.056

LABORATORY PH		TOT HARDNESS(MG/L-CACO3)	1566
FIELD WATER TEMPERATURE (C)		TOT ALKALINITY(MG/L-CACO3)	
SUM-DISS. IONS MEAS.(MG/L)		LABORATORY TURBIDITY (NTU)	
LAB CONDUCTIVITY-UMHOS-25C		SODIUM ADSORPTION RATIO	6.2

A D D I T I O N A L P A R A M E T E R S

PHOSPHOROUS,TOT (MG/L-P)	.034	SELENIUM,TR (MG/L AS SE)	< .005
IRON,TR (MG/L AS FE)	.09	STRONTIUM, TR (MG/L-SR)	.84
LITHIUM ,TR (MG/L AS LI)	.31	BORON, TOTAL (MG/L AS B)	.549

REMARKS: 208-SALINE SEEP COUNTY ROAD SITE NEAREST BENTON NWR

EXPLANATION: MG/L=MILLIGRAMS PER LITER MEQ/L=MILLIEQUIVILENTS PER LITER
ALL CONSTITUENTS DISSOLVED (DISS) EXCEPT AS NOTED. TOT=TOTAL SUSP=SUSPENDED
(M)= MEASURED(R)=REPORTED (E)=ESTIMATED M=METERS TR=TOTAL RECOVERABLE

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SAMPLE NO 1 SAMPLER AV HANDLING 32 ANALYST JAH LAB WQBH
COMPLETED 01-11-79 COMPUTER RUN 01/18/79 DATA 0975/PROG 0876 FUND 6053

		CA	MG	NA	K	CL	SO4	HCO3	CO3	NO3
STND DEV. ION BALANCE	0.74									
SEGMENT	MPDES	14.5	41.0	43.9	0.6	7.2	92.8	0.0	0.0	0.0

CALC. MEQ/L= INSUFFICIENT DATA 78W1378