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DISTRIBUTION OF SALINE SEEP IN MONTANA

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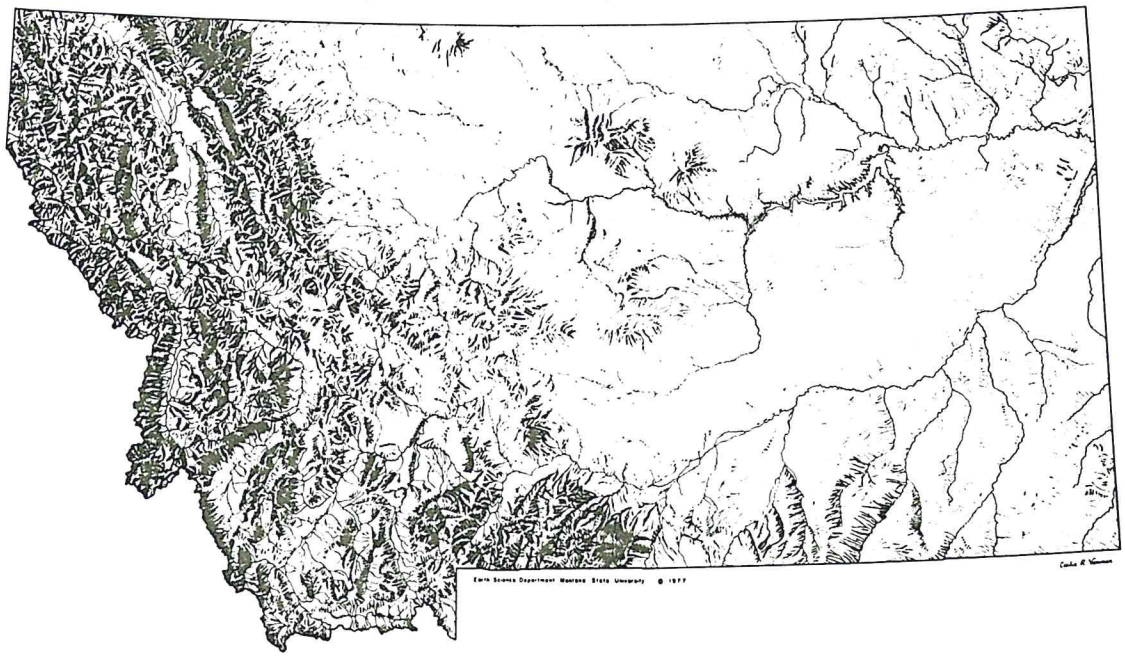

Physiographic map of Montana.

Hydrogeologic Map 7
(Text)

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Montana Bureau of Mines and Geology
A Department of
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Front cover: Courtesy Earth Science Department, Montana State University.

Introduction

One of the most serious conservation and water-quality problems in the Great Plains region of North America is the widespread occurrence and rapid growth of saline seeps. They are manifestations of (1) 20th-century dryland agriculture and the crop-fallow rotation system that was developed for moisture conservation, and (2) large-scale cereal-grain production such as is practiced in Montana. Saline seeps have been defined as *intermittent or continuous saline-water discharge at or near the soil surface, downslope from recharge areas, under dry-land conditions, that reduces or eliminates crop growth in the affected area because of increased soluble-salt concentration in the root zone.* Saline seep or dryland salinity can be differentiated from other saline soil conditions by its recent and local origin, water-saturated root-zone profile, shallow water table, and sensitivity to precipitation and cropping systems. Dryland salinity, hardly recognized prior to 1950, has now taken approximately 2 million acres out of crop production in the United States and Canada; over 200,000 of these acres are in Montana. Equally as serious as the loss of arable land is the local and potential regional deterioration of surface- and shallow ground-water resources which, in many areas, are the primary sources of potable water. Significant concentrations of trace metals, as well as high nitrate levels, have been found in many ground-water and surface-water samples in seep-prone areas. Numerous landslides and slope failures along coulees and drainageways across the plains region can be attributed directly to the saline-seep process.

Origin

Since 1969, the hydrogeology of 25 saline-seep research sites across Montana has been investigated by the Montana Bureau of Mines and Geology in co-operation with other local, state and federal agencies. Research results show that saline seeps are caused by a combination of cultural, climatic and hydrogeological conditions. The dominant factors causing the rapid growth of seep are as follows:

(1) Land-use practices that allow excess moisture to migrate downward through the soil profile beneath the root zone. The alternate crop-fallow (summer-fallow) farming system particularly aggravates the problem, in contrast to the natural system of native vegetation or sod where grasses and forbs use most of the precipitation, leaving little to percolate beneath the root zone.

(2) A climate in which about 50 percent of the annual precipitation occurs during the spring season (April, May and early June) before crops can effectively utilize stored moisture and before evaporation is significant.

(3) A soil, subsoil and substratum which contain significant quantities of water-soluble salts (predominantly sodium and magnesium sulfates) and an abundance of trace elements. These conditions are typical of semiarid regions underlain by geological formations deposited in a marine environment.

(4) A subsurface layer (normally shale or clay) beneath the soil profile, which effectively impedes the downward movement of water, thus forming a perched water table.

(5) The presence of numerous poorly drained areas on cultivated land (typical of glaciated terrain) which readily recharge the underlying perched ground water, thereby accelerating seep development downslope.

(6) The development of a local ground-water flow system whereby ground water migrates from upland recharge areas to nearby discharge areas, accumulating roughly 50 milligrams per liter (mg/L) of total dissolved solids (TDS) per foot of movement; these flow systems are usually less than 3,000 feet long. On fallow areas, an annual water-table rise of a few inches to ten feet can be expected.

The importance of any one of these factors may vary significantly from area to area, but the formation of saline seep follows the same general process throughout the region. A schematic diagram, **Figure 1,** illustrates this process. Seep formation begins when excess water percolates downward beneath the root zone picking up soluble salts. Water then accumulates over shallow, less-permeable layers such as shale or clay and forms a local ground-water flow system. The flow system moves saline water from the recharge to the discharge area or seep, where it evaporates, depositing the salts on the surface.

Any land-use practice that allows excess moisture to migrate downward through the soil profile beneath the root zone can contribute to the formation and growth of dryland salinity. A number of land-use practices have been identified as contributing to saline seep, but by far the most important one in the northern plains is the widespread use of the alternate crop-fallow (summer-fallow) farming system. (In Montana there are more than 12 million acres of farmland cultivated by this system.)

Most soils store only 4 to 8 inches of water in the root zone during a fallow period. Once recharged by

precipitation, any additional water entering the soil moves to the water table and may resurface downslope as a saline seep. Sandy soils, which have very limited holding capacity and allow water to infiltrate rapidly, can readily recharge the local ground-water flow system.

The overall soluble-salt load contained in the sediments of Cretaceous and Tertiary age is reflected in the concentration of TDS contained in the ground water at the discharge site. In general, concentrations of TDS range from 20,000 to 55,000 mg/L in the Colorado and Bearpaw shale; 10,000 to 25,000 mg/L in the Judith River, Claggett and Eagle formations; and 3,000 to 15,000 mg/L in the Fort Union Formation. **Figure 2** shows the general geographic distribution of these geologic units. The predominant soluble constituents in these formations are sodium, magnesium, sulfate and nitrate, along with unusually high concentrations of trace elements, particularly selenium. Increased salinity of several community water supplies has been attributed to saline seep, and nitrate poisoning of livestock from salinized farm reservoirs has been reported in a number of areas.

Growth

Hydrogeologic conditions conducive to the formation of saline seeps exist over more than 225,000 square miles in the Great Plains of North America where the dominant cropping system is the alternate crop-fallow farming system. Accurate estimates of seep development are difficult to obtain, particularly for the earlier days when the problem was much smaller and farmers were unaware of its existence. Estimates of seep-affected areas in Montana have risen from 80,000 acres in 1971, to 149,000 in 1974, to 170,000 in 1976, to over 200,000 acres in 1978.

On a regionwide basis, saline-seep acreage appears to be expanding at an average rate of about 10 percent a year. The rate varies substantially from year to year, depending upon variations in weather patterns such as changes in precipitation, but the general trend is toward a significant increase. In a typical span of several years, with average to above-average spring precipitation, expansion of seep areas by 20 to 200 percent is common. On the other hand, very little or no expansion may occur during periods when spring precipitation is below average for several years.

An example of saline-seep growth in a 4-square-mile area on the Highwood Bench, southeast of Fort Benton is shown in **Figure 3**. The information was obtained by using aerial photographs for the dates shown.

Control

Because climatic and geologic factors causing saline seep are natural and essentially unchangeable, the solution to the problem lies in making adjustments and changes in the cultural or land-use sector. The best solution to the problem of controlling seepage is to utilize precipitation before it moves below the root zone. Four effective control methods are (1) growing deep-rooted perennial crops, such as alfalfa, to dry out the soil profile; (2) switching to flexible, intensive, cropping systems in which precipitation is used more effectively than in conventional alternate crop-fallow systems; (3) draining selected upland fresh-water potholes (Class I and II wetlands); and (4) utilizing effective snow-management practices such as leaving stubble over the winter to provide a uniform snow cover and to help prevent blowing and drifting conditions.

In areas where two or more of these methods have been employed, an appreciable lowering of the water table has occurred, significantly reducing the size of salt-affected areas. For example, on one research site where these practices were applied during the last ten years, significant results include lowering the ground-water table an average of 8.2 feet; decreasing the salinity of ground water by approximately 25 percent; reducing the soil salinity in the seep area by 75 percent at depths up to 2 feet; and decreasing the salt-affected area from 30 acres to less than one acre.

It should be emphasized that cause and control of dryland salinity can vary significantly from farm to farm, and especially from area to area. Each farm needs to be evaluated carefully to determine all sources of excess water and to implement the appropriate control practices.

Saline-seep mapping

The accompanying map was compiled largely from a statewide saline-seep investigation program conducted from 1975 to 1978. Most of the information was obtained by detailed aerial reconnaissance flights, but much supplemental information was derived from ground-based examinations of seep-affected areas by many agencies.

The reconnaissance flights were generally made at an altitude of about 3,000 feet above the ground

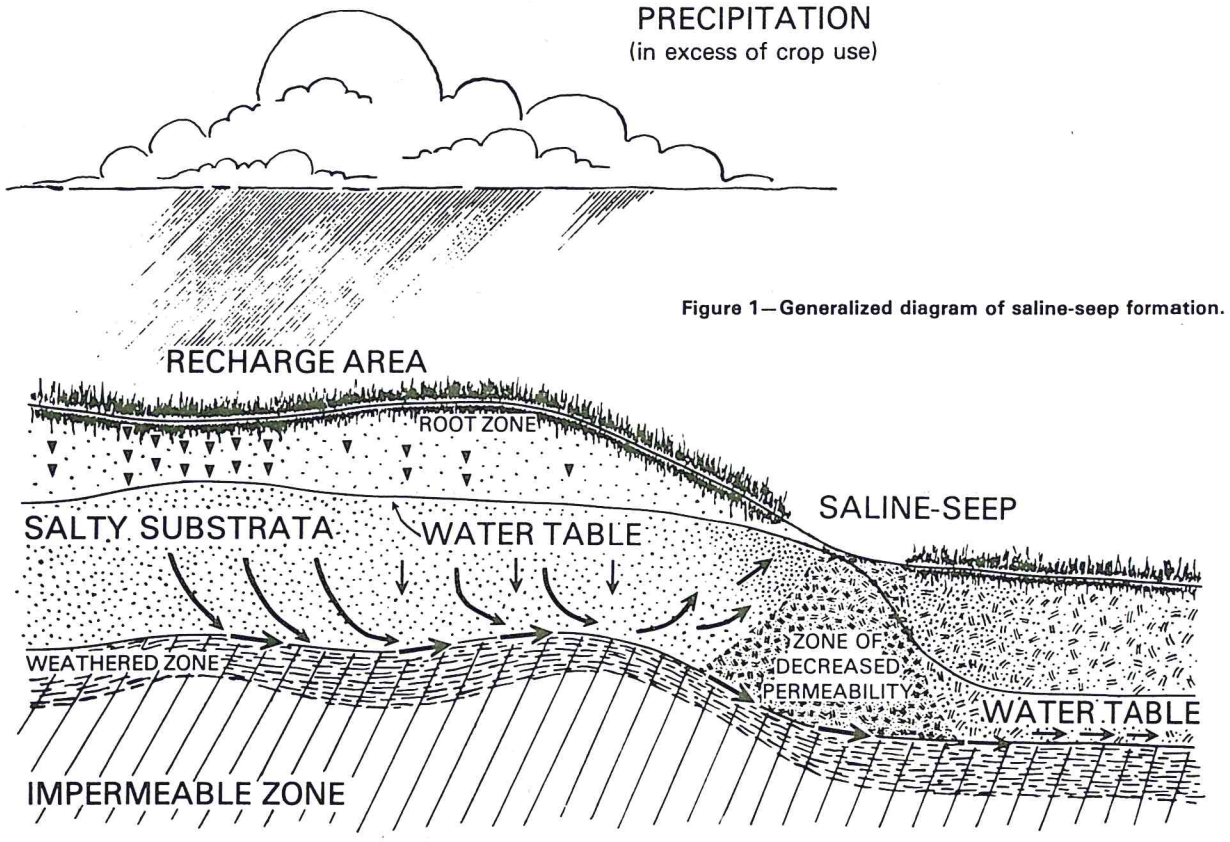

Figure 1—Generalized diagram of saline-seep formation.

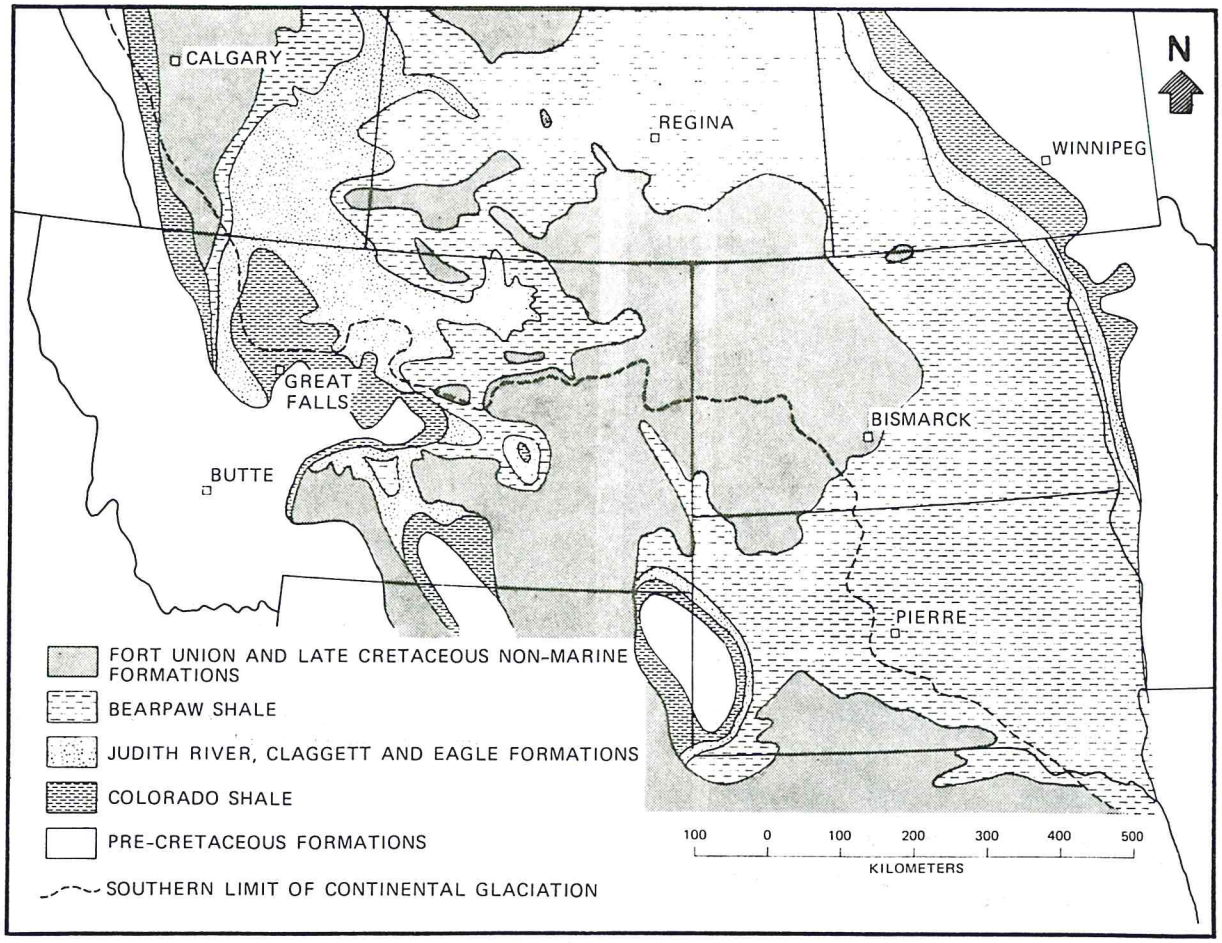

Figure 2—Generalized geology of the North American Great Plains.

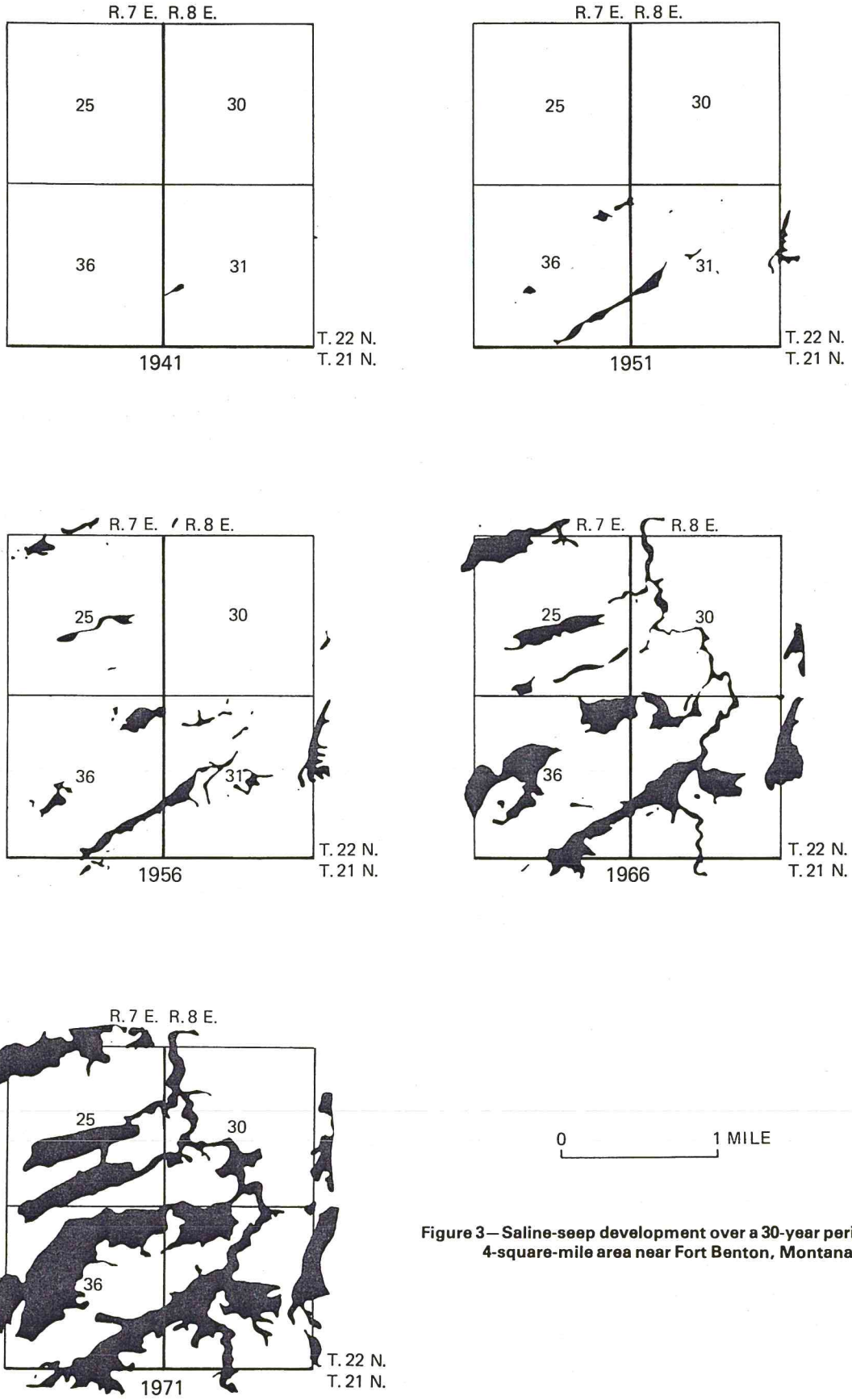

Figure 3—Saline-seep development over a 30-year period on a 4-square-mile area near Fort Benton, Montana.

surface. White salt crusts (the most recognizable element of a saline area at that altitude) were mapped on aerial photographs during flight. Supplementary photographs were taken in areas where salt crusts were especially numerous. Saline seeps that showed no white crusts could not be mapped during these flights. Conversely, white crusts resulting from irrigation salinity (such as along the Milk and Yellowstone rivers) and natural saline areas (such as in the southern parts of Blaine, Phillips and Valley counties) were mapped. When the reconnaissance flights were completed, the information on the aerial photographs was transferred to topographic maps at a scale of 1 inch equals 4 miles.

Saline seeps that had been identified in the Great Falls-Cut Bank-Shelby area by the Triangle Conservation District were also plotted on the maps, and seeps in the Rapelje area of northern Stillwater County that had been identified from ground and aerial investigations were also added. Other information came from special county projects. The topographic maps were then reduced photographically to about 1 inch equals 16 miles to produce the accompanying map.

Although the accompanying map is necessarily incomplete because of the method of compilation and because of the rapid growth and development of saline seep itself, it shows how widespread saline areas are throughout the Montana plains. The inclusion of native saline areas on the map shows that saline-seep development would almost surely occur in those places if the rangeland were converted to cropland.

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