PESTICIDES IN SOILS AND GROUND WATER IN SELECTED IRRIGATED AGRICULTURAL AREAS NEAR HAVRE, RONAN, AND HUNTLEY, MONTANA

by David W. Clark

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 90-4023

Prepared in cooperation with the

MONTANA BUREAU OF MINES AND GEOLOGY

U.S. DEPARTMENT OF THE INTERIOR
March 3, 1849

Helena, Montana
1990

DEPARTMENT OF THE INTERIOR
MANUEL LUJAN, JR., Secretary

U.S. GEOLOGICAL SURVEY
Dallas L. Peck, Director

For additional information
write to:

District Chief
U.S. Geological Survey
428 Federal Building
301 South Park, Drawer 10076
Helena, MT 59626-0076

Copies of this report can
be purchased from:

U.S. Geological Survey
Books and Open-File Reports Section
Federal Center, Bldg. 810
Box 25425
Denver, CO 80225-0425

CONTENTS

ILLUSTRATIONS

TABLES

CONVERSION FACTORS

Multiply	By	To obtain
acre	0.4047	hectare
foot (ft)	0.3048	meter
foot per foot (ft/ft)	1.0	meter per meter
gallon per minute (gal/min)	0.06309	liter per second
inch (in.)	25.4	millimeter
mile (mi)	1.609	kilometer
pound (lb)	453.6	gram
pound per acre (lb/acre)	1.121	kilogram per hectare
pound per cubic foot (lb/ft^3)	16.02	kilogram per cubic meter
quart (qt)	0.9464	liter (L)

Temperature can be converted to degrees Celsius (°C) or degrees Fahrenheit (°F) by the following equations:

$$°C = 5/9\ (°F - 32)$$
$$°F = 9/5\ (°C) + 32$$

National Geodetic Vertical Datum of 1929 (NGVD of 1929)--A geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called "Sea Level Datum of 1929."

Other units that are abbreviated in this report are:

gram per cubic centimeter (g/cm^3)
gram per kilogram (g/kg)
microgram per kilogram (µg/kg)
microgram per liter (µg/L)
microsiemen per centimeter at 25 degrees Celsius (µS/cm)
milligram (mg)
milligram per liter (mg/L)

PESTICIDES IN SOILS AND GROUND WATER IN SELECTED IRRIGATED AGRICULTURAL AREAS NEAR HAVRE, RONAN, AND HUNTLEY, MONTANA

By David W. Clark

ABSTRACT

Three areas, chosen to represent a range of agricultural practices and applied pesticides, were studied to document whether agricultural pesticides are being transported into the soil and shallow ground water in irrigated areas of Montana. Analytical scans for triazine herbicides, organic-acid herbicides, and carbamate insecticides were performed on soil and shallow ground-water samples. The results indicate pesticide residue in both types of samples. All detectable concentrations of pesticides in ground water were less than health-advisory limits established by the U.S. Environmental Protection Agency.

At the Havre Agricultural Experiment Station, three coreholes and eight wells were used to collect data at two sites. All four soil samples and two of four water samples collected after application of pesticides contained detectable concentrations of atrazine or dicamba.

In an area where seed potatoes are grown near Ronan, eight wells were installed at two privately owned sites. Pesticides were not detected after an initial application of pesticides and irrigation water. After a second application of irrigation water, the site was re-sampled. Aldicarb metabolites were detected in four of five soil samples and in one of five water samples.

At the Huntley Agricultural Experiment Station, five wells were installed in a no-tillage corn field where atrazine was applied in 1987. Soil and water samples were collected in June and July 1988; pesticides were not detected in any samples.

Although pesticides were detected in several water samples, the wells sampled were completed in the shallowest available ground water. Most nearby domestic wells were several hundred feet deeper. The presence of residue of two pesticides in soil samples and three soluble pesticides in ground-water samples indicates that irrigated agricultural areas of Montana might be susceptible to the transport of soluble pesticides through permeable soils, to the shallow ground-water system.

INTRODUCTION

For the past several decades, pesticides (herbicides and insecticides) have been increasingly used throughout the United States. The use of these chemicals is well documented and regulated; however, some chemicals have been misused and misapplied. In addition, the multitude of climates, soil types, and other conditions that exist in the United States, and particularly in Montana, have not always been considered during the onsite testing and analysis of chemicals whose use is regulated. Because of the semiarid climate, the predominantly alkaline soils, the types of crops grown, and the types and quantities of pesticides applied, the potential for pesticide contamination in Montana may differ from areas of the Midwest where contamination has been documented.

The National Council on Agricultural Science and Technology (1985) ranked the lack of knowledge on the transport of herbicides and insecticides in the environment as one of the principal water-quality concerns in the country. Also, little is known about the processes and conditions that control the transport of pesticides in Montana. Therefore, the potential for ground-water-quality degradation is largely unknown.

Recent sampling by the Montana Department of Agriculture has documented the presence of several herbicides--including dicamba, MCPA, and picloram--in small concentrations in ground water in areas of north-central Montana. Most pesticides registered for use in Montana probably pose only a minor threat to ground-water quality when properly applied. However, even a small percentage of some pesticides in ground water used for drinking supply could be serious. Therefore, information is needed on whether present and future agricultural practices, including the use of newly developed pesticides, could cause ground-water-quality problems throughout large areas of Montana.

To provide additional information about applied agricultural pesticides in the environment, the U.S. Geological Survey conducted a study from January 1988 through September 1989, in cooperation with the Montana Bureau of Mines and Geology. The purpose of the study was to document whether pesticides are present in the soils and are being leached below the rooting zone to the shallow ground water in selected agricultural areas of Montana.

This report, which presents the results of that study, documents the occurrence and transport of pesticides in soils and ground water at three selected irrigated agricultural areas in Montana (fig. 1). Results from this study could be used to help define the potential for pesticide contamination in other parts of Montana, particularly where agricultural and geohydrologic conditions are similar to those in the selected study areas. Data were collected at five sites within the three areas--two sites at the Havre Agricultural Experiment Station, two privately owned sites near Ronan, and one site at the Huntley Agricultural Experiment Station. The sites were chosen to represent a range of crops, soil types, and quantity and type of pesticides applied. These sites also were chosen on

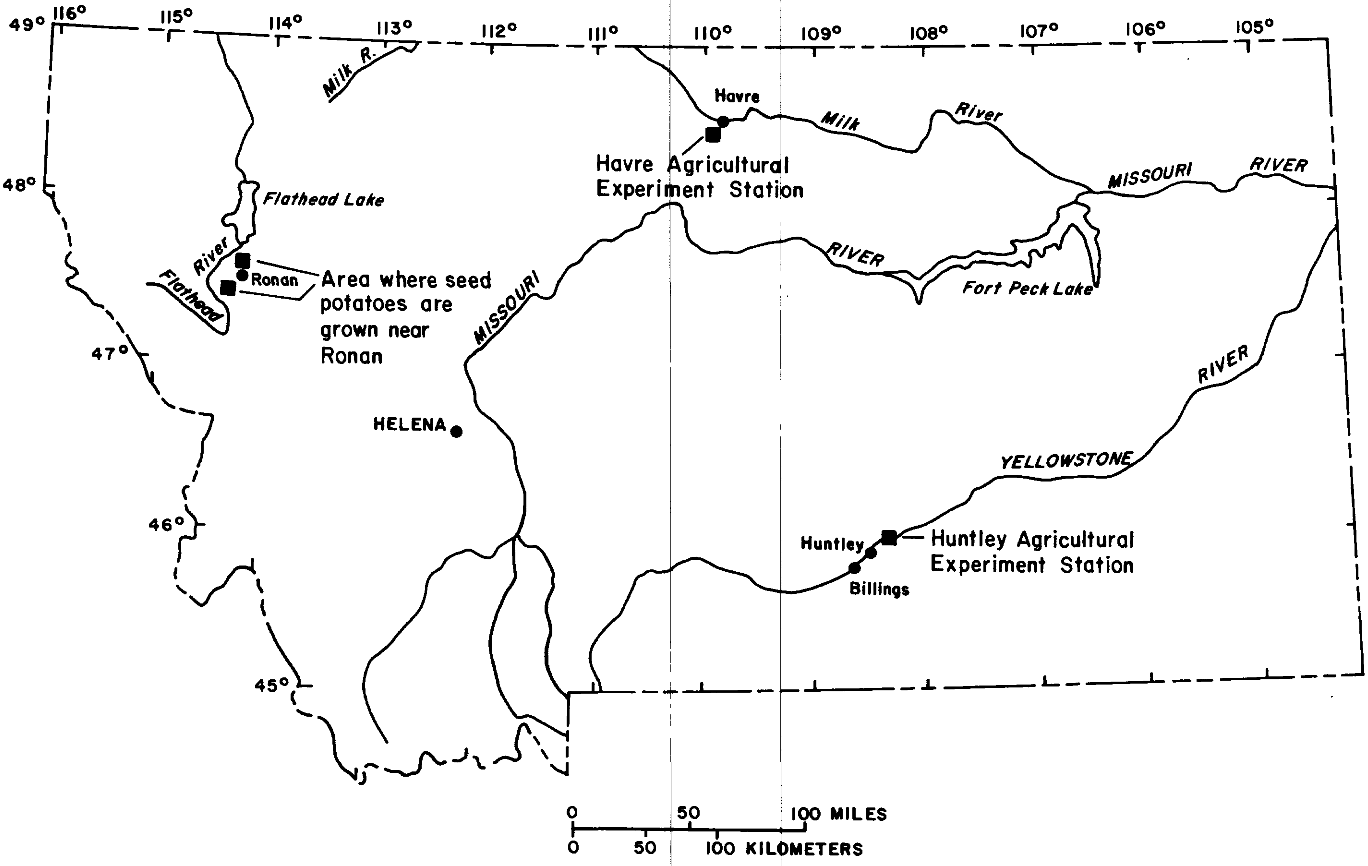

Figure 1.--Location of study areas.

the basis of knowledge of past agricultural practices in an area, depth to the shallow water table, and, because of drought conditions, potential for a site to be irrigated. An attempt was made to choose three different types of agricultural areas that were representative of irrigated agriculture in Montana.

METHODS OF DATA COLLECTION

Soil samples were collected from planted fields where pesticides had been directly applied. Samples were collected from sediments below the rooting zone of the particular crops and above the saturated zone. Samples were not collected within the rooting zone because any pesticides within this zone were assumed to be available for use by the plants. Pesticides below the rooting zone were assumed to be no longer available to the plants; instead, they could degrade, adsorb to soil particles, or be transported to the water table.

Soil samples were collected to a maximum depth of 6 ft below land surface using acetone-rinsed, stainless-steel push tubes, 1.5 in. in diameter and 14 in. long. Separate soil samples were collected from various depths in the same core hole when possible. Samples from a given depth were thoroughly mixed, screened through a 1/4-in. grid when sediments warranted, and placed in acetone-rinsed, wide-mouth glass jars with lids lined with aluminum foil. As soon as possible after collection the samples were put on ice and frozen until they could be analyzed for pesticides. Twenty-eight soil samples were analyzed for pesticide residue and 17 were analyzed for carbon content.

Observation wells (tables 1 and 2) for water-level measurements and water-quality sampling were installed at all study sites in holes drilled with a hollow-stem auger. Holes were augered at least several feet into the shallowest, coarse-grained, water-saturated sediments to ensure adequate water supply for sampling. Wells were completed with 2-in.-diameter, threaded, polyvinyl-chloride (PVC) pipe. The bottom section of pipe in each well was capped and had machine-slotted openings. Clean, coarse sand was poured around the open section of pipe, and a well packer was placed above the sand. The annular space above the packer was filled with bentonite to within several feet of the land surface; the annular space above the bentonite was grouted with a cement-bentonite mixture. Careful construction of the wells should have eliminated chemical contributions of water from sources other than natural ground-water flow, such as vertical movement along the well casing.

The number of observation wells installed at each study site depended on local hydrology, topography, soil conditions, and crop type. Each study site was small (70 acres or less) to permit quantification of local conditions. Observation wells generally were installed around the study sites to document the direction of ground-water flow and to ensure a sampling point at the downgradient side of a particular site. Some wells were used only to determine the altitude of the water table and lithologic changes of the aquifer, and were not sampled for the presence of pesticides.

The observation wells used for analysis were completed in the shallowest aquifer available in each study area. The average depth of these observation wells was about 20 ft, whereas wells presently used for domestic supplies near the study areas generally were as much as 300 ft deeper (Slagle, 1988, p. 78; oral communication with well owners). Wells completed in the shallow aquifers near some of the study sites have previously been used to supply water for domestic and irrigation use. A few of these shallow wells might still be in use.

Prior to water-quality sampling, all observation wells were cleaned and developed by bailing or, when possible, with a small centrifugal pump. Water samples for organic analysis were collected from the developed wells using a 1-in.-diameter, acetone-rinsed Teflon[1] bailer. Where possible, at least three well

---

[1] Use of trade names in this report is for descriptive purposes only and does not constitute endorsement by the U.S. Geological Survey.

volumes of water were removed from wells just prior to sampling. However, in less productive wells, well casings were dewatered by bailing several hours prior to sampling, and samples were collected after water levels had recovered to near-static levels. Water samples for pesticide analysis were put in acetone-rinsed, amber-colored glass bottles with Teflon-lined caps, and placed on ice until delivery to the laboratory. Thirty-three water samples were collected for pesticide analysis.

Analyses of specific conductance, pH, water temperature, alkalinity, and nitrate concentration (by colorimetric method) were completed onsite. An enzyme-based, onsite-screening test kit was used to check for the presence of triazine and 2,4-D herbicides. The timing for pesticide sampling was determined on the basis of the particular pesticide, when and how often the pesticide was applied, and when and how often irrigation water was applied. Water samples collected from at least two observation wells at each study site and from a total of 11 wells were analyzed for major inorganic constituents and trace metals.

Analyses to determine the presence of pesticides in soil cores and ground water were performed by the Analytical Laboratory of the Montana State University Agricultural Experiment Station. Analytical scans were made to determine pesticides of a particular chemical family and some metabolites of those pesticides. Samples were analyzed for only those families of pesticides that were known to have been applied at a particular site. The three families of pesticides analyzed were triazine herbicides, organic-acid (phenoxy) herbicides, and carbamate insecticides. The triazine-herbicide scan was for atrazine, cycloate, prometon, and simazine. The organic-acid-herbicide scan was for dicamba, MCPA, picloram, silvex, 2,4-D, and 2,4-DB. The carbamate-insecticide scan was for aldicarb and two metabolites (aldicarb sulfone and aldicarb sulfoxide), carbaryl, carbofuran and a metabolite (3 hydroxy-carbofuran), and methomyl. Cross reference lists of the common names and associated common trade names of the pesticides are given in table 3.

The analytical techniques used for most of the soil and water samples were based on the methods developed for use in the U.S. Environmental Protection Agency's National Pesticide Survey. Pesticide residues in soils were analyzed by gas or liquid chromatography by standard methods and methods modified by the Analytical Laboratory of the Montana State University Agricultural Experiment Station (Laszlo Torma, written commun., 1988). Triazine herbicides in water were analyzed by gas chromatography using Method 1 of the U.S. Environmental Protection Agency (1987b). Organic-acid herbicides in water were analyzed by gas chromatography using Method 3 of the U.S. Environmental Protection Agency (1987c) with electron capture or Hall detector. Carbamate insecticides in water were analyzed by direct aqueous, high-pressure liquid chromatography using Method 5 of the U.S Environmental Protection Agency (1987d).

Analyses of major inorganic chemical constituents and trace metals in water samples were performed by the Montana Bureau of Mines and Geology. Analysis of carbon content in soil samples was performed by the U.S. Geological Survey.

STUDY AREAS

Havre Agricultural Experiment Station

The Havre Agricultural Experiment Station is located about 7 mi southwest of Havre in north-central Montana (fig. 2). The mean annual precipitation in this study area is about 12 in. During the first 7 months of 1988, precipitation was about 50 percent of normal (National Oceanic and Atmospheric Administration, 1989). The mean annual temperature is about 42 °F. The monthly mean temperatures during May, June, and July 1988 were as much as 10 degrees higher than the normal monthly mean temperatures (National Oceanic and Atmospheric Administration, 1989). During the 1988 growing season, the study area was affected by extreme drought, which greatly affected agricultural practices.

The study area contained two sites. Both sites are located on a glacial-outwash plain within an area of extensive glacial till.

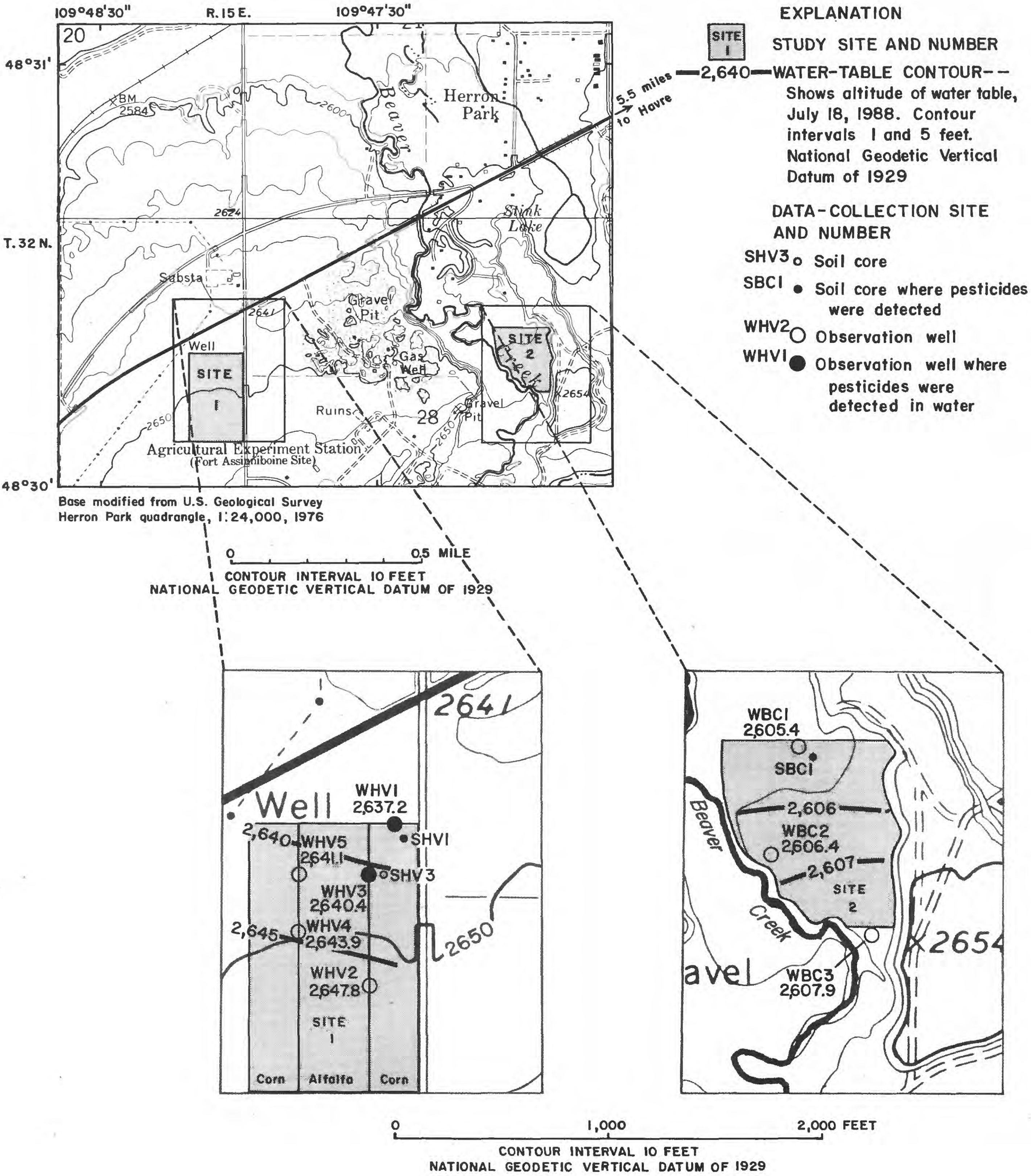

Figure 2.--Location of study sites and data-collection sites, and altitude of water table at the Havre Agricultural Experiment Station.

Site 1 is a 15-acre section of a larger field that slopes gently to the north (fig. 2). The predominant soil type is the Attewan loam, which is a thick, well-drained soil having moderate permeability that is generally underlain by gravelly loamy sand (G.L. Snell, U.S. Soil Conservation Service, written commun., 1988). The predominant soil upgradient from site 1 is the Evanston loam, which contains less coarse-grained sediments than does the Attewan loam.

Five observation wells were installed at site 1 for the study (table 1). The wells, 15 to 35 ft deep, were located at the edges of plots planted to corn. The lithology of the uppermost 10 ft of material penetrated by the wells was mostly sand and gravel with some cobbles (table 2). Underlying the coarse material at most locations was a sandy clay layer. Water levels in the wells were about 4 to 7 ft below the land surface (table 1).

Site 2 is about 10 acres of almost level bottomland adjoining Beaver Creek (fig. 2). The predominant soil type is the Havre loam, which is a dark sandy loam. This soil is well drained and has a moderate permeability.

Three observation wells were installed at site 2 near Beaver Creek. The wells were located at or near the north, south, and west edges of the field (fig. 2) and were about 15 ft deep. Sediments were predominantly sandy loam near the land surface, sand and silt at middepth, and sand and gravel near the bottom of the wells (table 2). Water levels were about 3 to 9 ft below the land surface.

Area Where Seed Potatoes Are Grown near Ronan

An area used to grow seed potatoes in northwestern Montana is centered near Ronan. Mean annual precipitation in the vicinity of Ronan is about 15 in. During the first 7 months of 1988, precipitation was about 80 percent of normal. The mean annual temperature is about 45 °F. The monthly mean temperatures for May, June, and July 1988 were several degrees higher than the normal monthly mean temperatures (National Oceanic and Atmospheric Administration, 1989).

Two sites were selected for study: Site 1 located about 2 mi north of Ronan (fig. 3), and site 2 located about 5 mi southwest of Ronan (fig. 4). The sites are underlain by valley-fill deposits that are located between terminal-moraine deposits to the north and south (Slagle, 1988, pl. 1). The valley fill is most likely a combination of fine-grained sediments deposited in glacial Lake Missoula, and coarse sand and gravel glacial-outwash deposits.

Site 1 is a 70-acre field that generally slopes toward the southeast (fig. 3). The predominant soil type in the northwestern part of the field is the Blanchard loamy fine sand, which has a small water-holding capacity, a moderate permeability, and a moderate organic-matter content. In the southeastern part of the field, the soil is the Grid silt loam, which has a large water-holding capacity, a small permeability, and a large organic-matter content (Carlos Rodriques, U.S. Soil Conservation Service, written commun., 1988).

Five observation wells with depths ranging from 15 to 30 ft were installed at site 1--four near the northwest corner and one at the southeast corner (fig. 3). Sediments were predominantly fine sand, tan silt, and a combination of the two, with sandy loam near the land surface (table 2). Water levels in the wells were about 7 to 17 ft below the land surface (table 1). The field was irrigated by sprinkler system, primarily using surface water, with ground water as an alternate supply.

Site 2 is a 45-acre field located between West Miller Coulee and Mud Creek (fig. 4). The terrain of the area is hilly and generally slopes south-southwest. The predominant soil type is the Talley fine sandy loam, which has a moderate water-holding capacity and permeability, and a large organic-matter content. The other major soil type is the Grid silt loam, which has a large water-holding capacity, a small permeability, and a large organic-matter content (Carlos Rodriques, written commun., 1988).

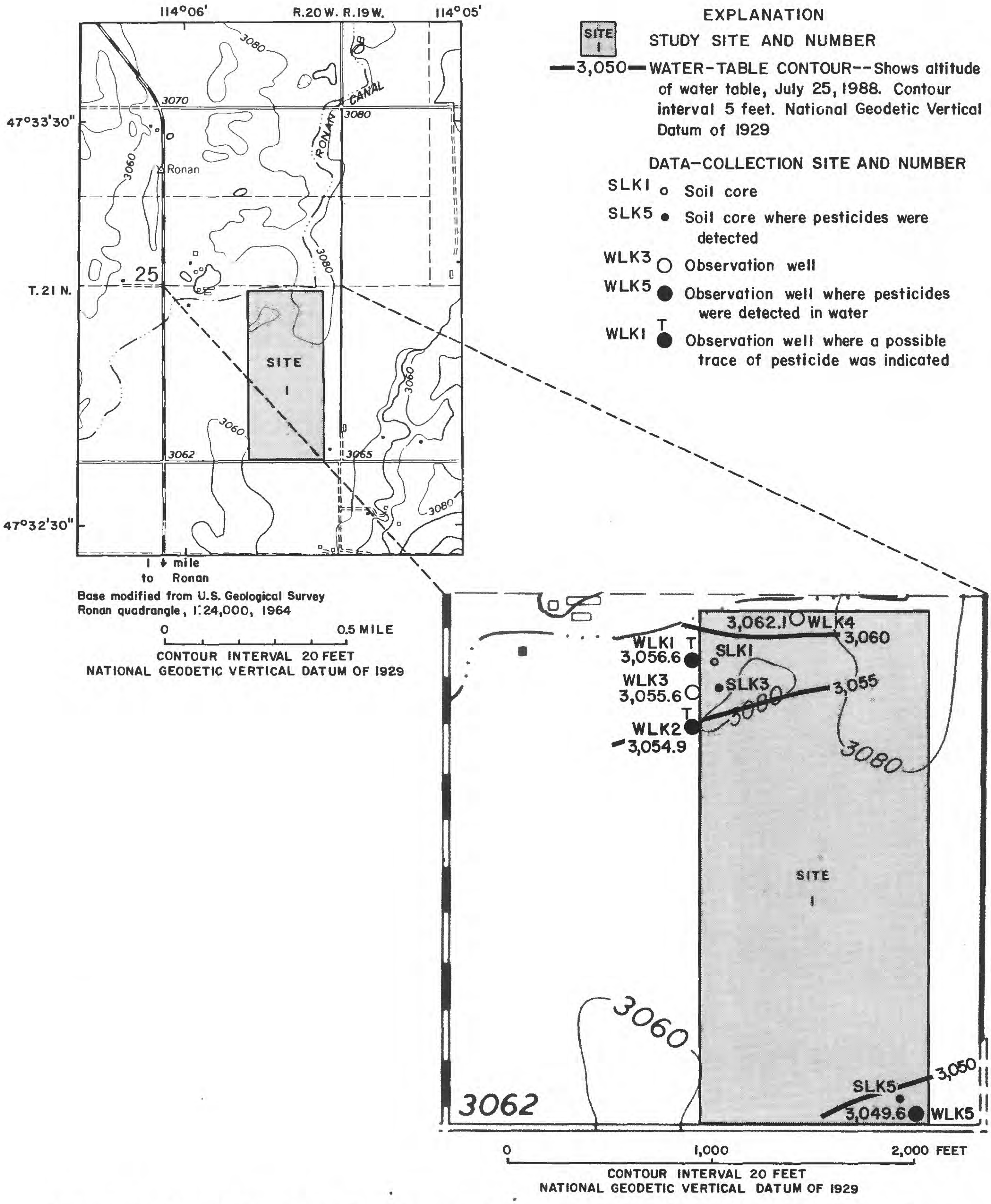

Figure 3.--Location of study site and data-collection sites, and altitude of water table in the area where seed potatoes are grown north of Ronan.

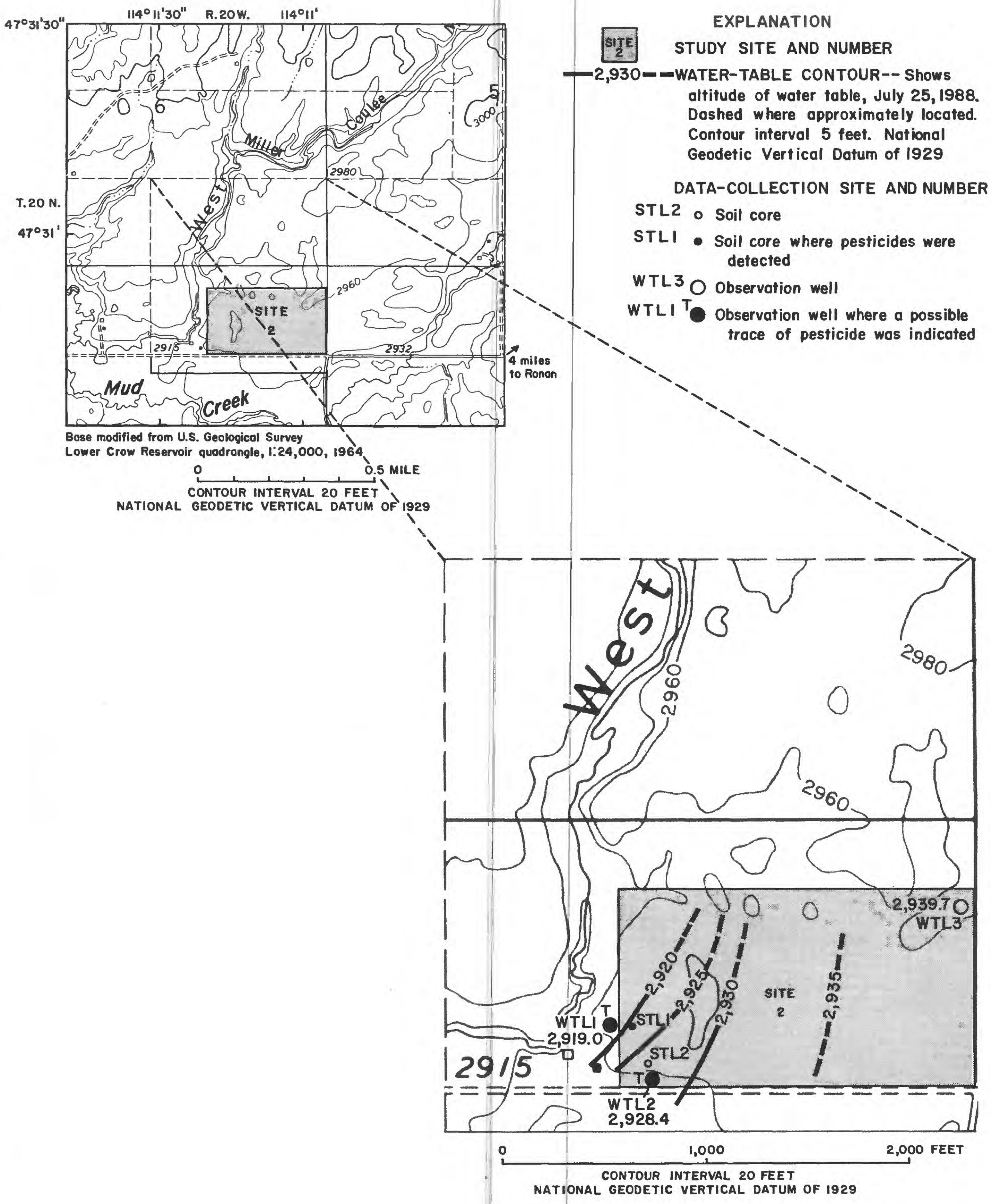

Figure 4.--Location of study site and data-collection sites, and altitude of water table in the area where seed potatoes are grown southwest of Ronan.

Three observation wells, from 20 to 25 ft deep, were installed at this site (fig. 4). Fine sand was the predominant sediment penetrated by all wells; however, some layers also contained silt and small gravel (table 2). Water levels generally were about 8 to 15 ft below the land surface (table 1).

Huntley Agricultural Experiment Station

The Huntley Agricultural Experiment Station is located about 15 mi northeast of Billings and about 3 mi northeast of Huntley (fig. 5). Mean annual precipitation at the station is about 13 in. During the first 7 months of 1988, precipitation was about 70 percent of normal. The mean annual temperature is about 45 °F. The monthly mean temperatures during May, June, and July 1988 were as much as 10 degrees higher than the normal monthly mean temperatures (National Oceanic and Atmospheric Administration, 1989). This site also was part of an area affected by drought during the 1988 growing season.

The study site is a 20-acre field, with a slope generally less than 1 percent, on the flood plain of the Yellowstone River. The predominant soil type is the well-drained Lohmiller silty clay, with a large available water capacity, a moderately small permeability, and a moderate organic-matter content (Meshnick and others, 1972, p. 103). The other predominant soils in the area are the Fort Collins and Thurlow clay loams. The shallow ground-water resources in the area have been described in a report by Hutchinson (1983). In 1982, water levels generally were less than 10 ft below land surface, and, during the irrigation season, generally were less than 5 ft below land surface.

Five observation wells, from 15 to 28 ft deep, were installed in the field--one at each corner and one in the middle (fig. 5). The predominant lithology of the upper 20 ft is a saturated sandy clay overlying a shallow sand and gravel aquifer (table 2). Water levels in the wells were about 2 to 8 ft below land surface (table 1).

PESTICIDES IN SOILS AND GROUND WATER

Havre Agricultural Experiment Station

The Havre Agricultural Experiment Station was chosen as a study area primarily because of the permeable soils of glacial origin, two plots of irrigated corn separated by a center strip of alfalfa, and use of the herbicides atrazine and dicamba. Atrazine is one of the most commonly detected pesticides in ground water (Cohen and others, 1986). Atrazine has a moderate solubility, with 33 to 70 mg of atrazine being able to be dissolved in 1 L of water; it also is appreciably adsorbed to inorganic soils, is moderately to extremely mobile in soils, and typically persists in soils for about 2 to 8 months (Farm Chemicals, 1988, p. C 205; U.S. Environmental Protection Agency, 1988a). Dicamba is extremely soluble, with 4,500 to 6,500 mg of dicamba being able to be dissolved in 1 L of water. Dicamba is also extremely mobile, is not appreciably adsorbed to most inorganic soils, and persists in the soil for 1 to 1.5 months (Farm Chemicals, 1988, p. C 205; U.S. Environmental Protection Agency, 1988b). Crops grown at the station were both irrigated and nonirrigated and included small grains, safflower, alfalfa, and corn. Commonly used pesticides in addition to atrazine and dicamba included MCPA, 2,4-D, carbaryl, and carbofuran.

Site 1

The observation wells at site 1 were cleaned and developed during the first week of June 1988. Water levels were measured and selected water-quality properties and constituents were analyzed onsite during June and July 1988. The ground-water flow direction was north-northeast (fig. 2), on the basis of water levels measured on July 18, 1988. The water-table gradient was about 0.01 ft/ft. Water in the shallow aquifer was predominantly a sodium sulfate type. Specific conductance measured onsite ranged from 2,100 to 20,000 µS/cm (table 1) and concentrations of nitrate measured onsite ranged from 2.0 to 10 mg/L. Properties and chemical constituents in water from selected wells are listed in table 4. Water from

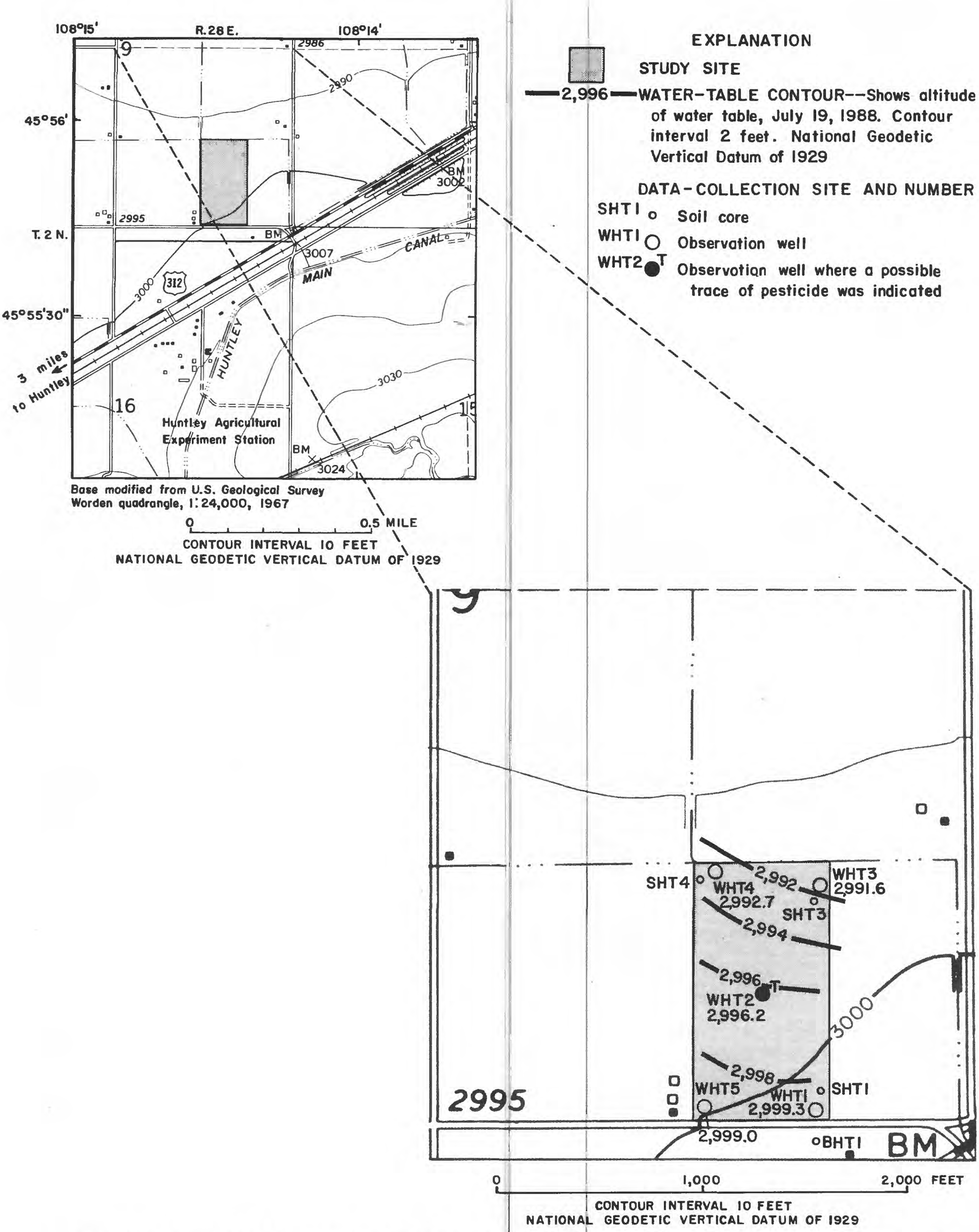

Figure 5.--Location of study site and data-collection sites, and altitude of water table at the Huntley Agricultural Experiment Station.

a 56-ft deep stock well, located several hundred feet north of the site, had an onsite specific conductance of 1,500 µS/cm and no measurable onsite nitrate concentration.

Corn for silage had been grown on the plots at site 1 for the preceding 5 years. The herbicides alachlor and atrazine had been applied to the ground planted to corn during the summer of 1987. Observation wells were installed prior to the application of any pesticides during the 1988 growing season.

One soil sample and one water sample were collected at site 1 on June 22 and 23, 1988, respectively, after the initial application of irrigation water and prior to the application of pesticides. Soil sample SHV3, a sandy loam, was collected about 30 ft east of observation well WHV3, from a depth of 1.5 to 3.5 ft. Large gravel at a depth of 3.5 ft prevented collecting a sample from a greater depth. The water level in the well was about 5.5 ft below land surface (table 1). The soil and water samples were analyzed for triazine and organic-acid herbicides; pesticides were not detected in either sample (tables 5, 6).

One soil sample and water samples from two observation wells were collected on July 18 and 19, 1988. Pesticides had been applied in the last week of June 1988 to one of the two plots planted to corn. The eastern corn plot (fig. 2) had a mixture of atrazine and dicamba applied to the eastern one-third of the plot and only dicamba applied to the western two-thirds. The western corn plot had no pesticides applied. Atrazine was applied at a rate of about 2.0 lb/acre of active ingredient, and dicamba was applied at a rate of about 0.25 lb/acre of active ingredient. Furrows on the plots were flooded twice between the application of pesticides and the sampling of the soil and ground water.

A concentration of 82 µg/kg of atrazine residue (table 5) was detected in soil sample SHV1 (sandy loam and gravel), which was a composite collected from a depth of 1 to 2.5 ft at a location about 30 ft southeast of observation well WHV1, within the plot where atrazine had been applied (fig. 2). Water samples were collected from observation wells WHV1 and WHV3 on July 19, when water levels were about 4 to 5 ft below land surface (table 1). Concentrations of 1 µg/L atrazine and 8 µg/L dicamba were detected in the water from well WHV1, and a concentration of 0.3 µg/L dicamba was detected in water from well WHV3 (table 6).

Site 2

The observation wells at site 2 were cleaned and developed during the first week of June 1988. Water levels were measured and selected water-quality properties and constituents were analyzed onsite during June and July 1988. The ground-water flow direction was north (fig. 2), on the basis of water levels measured July 18, 1988. The water-table gradient was about 0.003 ft/ft. Water in the shallow aquifer was predominantly a sodium bicarbonate type. Specific conductance measured onsite ranged from 800 to 1,020 µS/cm and concentrations of nitrate measured onsite ranged from 1.0 to 5.5 mg/L (table 1). Properties and chemical constituents in water from selected observation wells are listed in table 4.

Corn to be grown for silage was planted at site 2 for the first time in 1988. In prior years, the plot had been planted in grass or alfalfa, with little or no pesticide applications.

Soil samples from one location and water samples from two observation wells were collected on July 18 and 19, 1988. Insufficient soil moisture necessitated the application of irrigation water to the plot in early June to germinate the corn seed. A mixture of atrazine and dicamba was applied to the foot-tall corn on June 24, 1988, followed by furrow irrigation. Atrazine was applied at the rate of about 2.0 lb/acre of active ingredient, and dicamba was applied at a rate of about 0.25 lb/acre of active ingredient. Soil samples were collected from three sections of a 6-ft-deep soil core located about 30 ft south of observation well WBC1 (fig. 2). Atrazine residue was detected in all three soil samples, with the concentrations decreasing with depth (table 5). The concentration of the atrazine residue in sample SBC1-2, from a depth of 0.8 to 2.0 ft, was 52 µg/kg. The concentration in sample SBC1-4, from a depth of 2.0 to 4.0 ft, was 49 µg/kg. The concentration from the deepest sample, SBC1-6, from a depth of 4.0 to 6.0 ft, was 26 µg/kg. Neither atrazine nor diacamba was detected in the water samples collected from observation wells WBC1 or WBC2 about 2 weeks after pesticide application (table 6). No other pesticides were detected in the water samples. Water levels at the time of sampling were about 7 to 9 ft below the land surface (table 1).

Area Where Seed Potatoes Are Grown near Ronan

The area planted to seed potatoes was chosen for study primarily because of the use of the insecticide aldicarb. Aldicarb is a systemic pesticide that generally is applied to the potato-field furrow during planting to control a variety of insects, including the Colorado potato beetle and nematodes. Studies have indicated that the use of aldicarb in areas with sandy soil and shallow water-table conditions can create the potential for ground-water contamination. Aldicarb contamination of ground water in the eastern part of Long Island, N.Y., planted to potatoes led to the discontinuation of the sale of the pesticide in that area in 1980 (Wartenberg, 1988, p. 186). Aldicarb also has been detected in ground water in 10 additional States, with 3 detections exceeding health-advisory levels (Parsons and Witt, 1988).

Aldicarb is readily soluble, with about 6,000 mg of aldicarb being able to be dissolved in 1 L of water; aldicarb is mobile in sandy loam soils and is moderately persistent in soil (Farm Chemicals, 1988; U.S. Environmental Protection Agency, 1987a). The degree of solubility of this systemic insecticide allows rapid uptake by target plants. Soil studies have indicated that after introduction to the soil column, aldicarb is rapidly oxidized to its metabolite, aldicarb sulfoxide, which is then slowly oxidized to nontoxic products and a small quantity of the metabolite, aldicarb sulfone (Rothschild and others, 1982).

Seed potatoes must be disease free to attain certification; therefore, a genral practice is to use a field no more than 2 consecutive years for seed-potato cultivation. This practice also decreases the chance of the accumulation of pesticide residue in the soils and ground water. Site 1 had been used for growing seed potatoes several times in the past, including 1987 when aldicarb was applied. Site 2 had been planted with alfalfa for at least the previous 10 years.

Site 1

The observation wells at site 1 were cleaned and developed during the second week of June 1988. Water levels were measured and selected water-quality properties and constituents were measured during June and July 1988. The ground-water flow direction in the shallow aquifer was south-southeast (fig. 3), on the basis of water levels measured on July 25, 1988. The water-table gradient ranged from about 0.02 ft/ft at the north end of the plot to about 0.002 ft/ft toward the south end. The water from observation wells WLK1 and WLK2 was a calcium bicarbonate type, whereas the water from observation well WLK5 was a magnesium bicarbonate type. Specific-conductance values measured onsite ranged from 440 to 650 µS/cm, and nitrate concentrations measured onsite ranged from 2.0 to 12 mg/L (table 1). Properties and chemical concentrations in water from selected wells are listed in table 4.

Observation wells had been installed during the last week in May along the edges of the potato field. Wells were located in the northwestern part of the field (fig. 3) primarily because of the presence of deep sandy loam soil and a potentially shallow water table. Well WLK5 was located downgradient in the field to monitor the quality of ground water as it flowed from the study plot. The potato crop was planted and aldicarb was applied to the soil during the last week in May. Aldicarb was mixed into the soil at the time of planting at a rate of about 2.5 lb/acre of active ingredient. About 5 in. of rain fell in the area during May and June; therefore, sprinkler irrigation was not begun until mid-July. Irrigation water was applied at a maximum rate of about 1 in. per application to permit sufficient moisture for plant growth yet minimize the movement of aldicarb through the soil profile.

Three soil and three water samples were collected at site 1 on July 11 and 12, 1988, prior to application of irrigation water. Two soil samples were collected from a location about 50 ft east of observation well WLK1 on the slope of a sandy swale. Sample SLK1-2 was a sandy loam from a depth of 1.0 to 2.5 ft, and sample SLK1-3 was sand and clay from 2.5 to 3.5 ft, ending at a light-colored hardpan layer. A third soil sample, SLK5, was collected from an area about 50 ft northwest of observation well WLK5 (fig. 3), and was a composite of sandy loam collected from a depth of 1.0 to 3.0 ft. A light-colored hardpan at a depth of 3.0 ft prevented sampling at greater depths. No carbamate insecticide residue was detected in any of these soil samples (table 7). Water samples collected from wells WLK1, WLK3, and WLK5 contained no detectable concentrations of any carbamate insecticide (table 8).

Soil samples from two locations and water samples from three observation wells also were collected on July 25 and 26, 1988. The plot planted to potatoes had been irrigated twice after July 11 and 12, 1988, and was being irrigated when the samples were collected. The increased irrigation was due primarily to hot, dry weather conditions. Two soil samples were collected from a core hole located 50 ft east of observation well WLK3. Sample SLK3-2 was an almost dry sandy loam soil at a depth of 0.8 to 2.5 ft below the rooting zone, and sample SLK3-5 was a slightly moist sand and silty sand at a depth of 2.5 to 5.0 ft from the same core. Sample SLK5 was collected northwest of observation well WLK5 from a depth of 0.8 to 1.8 ft, which was the depth that the soil became too hard for coring. The upper 0.8 ft was moist from recent irrigation, whereas the sampled part of the core was almost dry. Residues of aldicarb sulfone and aldicarb sulfoxide were detected at concentrations of 70 µg/kg in subsample SLK3-2. Sample SLK5 had a detectable concentration of aldicarb sulfone residue of 90 µg/kg and a detectable concentration of aldicarb sulfoxide of 40 µg/kg (table 7). Water samples were collected from observation wells WLK1, WLK2, and WLK5. Aldicarb sulfoxide was detected at a concentration of 3 µg/L in water collected from observation well WLK5. In addition, a possible trace of aldicarb sulfoxide in water from observation wells WLK1 and WLK2 was indicated by liquid chromatography at a concentration less than the 2-µg/L detection limit of the analytical method (table 8).

Site 2

The observation wells at site 2 were cleaned and developed during the second week of June 1988. Water levels and selected water-quality properties and constituents were measured during June and July 1988. The ground-water flow direction at this site was west-northwest (fig. 4), on the basis of water levels measured on July 25, 1988. The water-table gradient was about 0.01 ft/ft. Water from observation well WTL1 was a calcium magnesium bicarbonate type, whereas water from observation well WTL2 was a sodium calcium bicarbonate type. Specific-conductance values measured onsite ranged from 600 to 970 µS/cm (table 1), and nitrate concentrations measured onsite ranged from 1.5 to 6.5 mg/L. Properties and chemical constituents in water from selected wells are listed in table 4.

At site 2, part of the applied aldicarb was mixed into the soil at the time of planting in late May at a rate of about 1.2 lb/acre of active ingredient. The remaining aldicarb was applied in early July at a rate of about 1.5 lb/acre of active ingredient as a sidedressing after the plants had emerged. The second application was delayed to decrease potential leaching of aldicarb and to increase plant utilization of aldicarb. The field was first irrigated during early July after the second application of aldicarb. Irrigation water was applied at a minimal rate, less than 1 in. per sprinkler application, to decrease the potential of leaching aldicarb to the water table.

Two soil samples and two water samples were collected at site 2 on July 12, 1988, which was 3 days after the second application of irrigation water. Two soil samples were collected from a core hole located 30 ft north of observation well WTL2. Sample STL2-2 was a sandy loam from a depth of 1.0 to 2.5 ft, and sample STL2-3 was sand from a depth of 2.5 to 3.5 ft. No carbamate insecticide residue was detected in either of these soil samples (table 7). Water samples from observation wells WTL1 and WTL2 did not contain detectable concentrations of any carbamate insecticide (table 8).

Two soil samples and water samples from two observation wells also were collected on July 25, 1988. The plot planted to potatoes had been irrigated 3 days previously and was being irrigated when the samples were collected. The increased irrigation activity was due to hot, dry weather conditions. Two soil samples were collected from a core hole located 50 ft east of observation well WTL1. Sample STL1-2 was a dark sandy loam at a depth below the rooting zone of 0.7 to 2.0 ft, and sample STL1-3 was a dark sandy loam and gravel at a depth of 2.0 to 3.0 ft from the same core. Residue of aldicarb sulfone was detected at a concentration of 20 µg/kg in sample STL1-2. Sample STL1-3 had a detectable concentration of aldicarb sulfone residue of 40 µg/kg and a detectable concentration of aldicarb sulfoxide of 30 µg/kg (table 7). Water samples were collected from observation wells WTL1 and WTL2. A possible trace of aldicarb sulfoxide in water from both wells was indicated by liquid chromatography at a concentration less than the 2-µg/L detection limit of the analytical method (table 8).

Huntley Agricultural Experiment Station

The Huntley Agricultural Experiment Station was chosen as a study area primarily because of the no-tillage conservation practices at the study site. This site also permitted study of potential ground-water contamination beneath an irrigated corn field in soils of the flood plain of the Yellowstone River where atrazine had previously been applied.

Observation wells WHT1 to WHT5 at the Huntley Agricultural Experiment Station were cleaned and developed during the first week of June 1988. Water levels were measured and selected water-quality properties and constituents were measured during June and July 1988. Ground-water flow was north-northeast (fig. 5), on the basis of water levels measured July 19, 1988. The water-table gradient was about 0.01 ft/ft. Water in the shallow aquifer was a sodium sulfate type, with these ions contributing nearly 90 percent of the total dissolved ions (milliequivalents per liter). Specific-conductance values measured onsite ranged from 1,000 to 4,400 µS/cm, and concentrations of nitrate measured onsite ranged from 1.0 to 3.0 mg/L (table 1). Properties and chemical constituents in water from selected wells are listed in table 4.

The study site had been planted in corn for silage for several years prior to 1988. The field was not plowed after the 1987 growing season. Atrazine had been applied at a rate of about 4 lb/acre of active ingredient during 1987. Barley planted in 1988 around the edge of the plot planted to corn was damaged by atrazine residue remaining in the soil from previous applications. No atrazine was applied at the study site during 1988, owing to minimal weed growth. MCPA was applied at a minimal rate around the edges of the field during the growing season. The field directly upgradient (south) from the site was planted in barley in 1988 and MCPA was applied. In 1987, the upgradient field was planted in corn, barley, and sugar beets, and atrazine, cyanizine, cycloate, and MCPA were applied.

Four soil and four water samples were collected at the Huntley site on June 23 and 24, 1988, about 1 week after the field had been furrow irrigated for 3 consecutive days and several weeks after the border treatment with MCPA. Soil samples were collected in or near the corn field on June 23, 1988. Soil samples SHT1, SHT3, and SHT4 were collected in the outer planted rows of the field (fig. 5) from below the rooting zone in soils that still retained considerable moisture from irrigation water. The samples were a sandy clay from a depth of about 1.0 to 2.5 ft. Soils were saturated at an approximate depth of 2.5 ft. Sample BHT1 was collected from the upgradient field planted to barley about 100 ft south of observation well WHT1. The soil was a sandy clay from a depth of about 1.0 to 2.5 ft. No residue of either triazine or organic-acid herbicides was detected in any of the soil samples (table 5). Water samples were collected from observation wells WHT1, WHT2, WHT3, and WHT4 on June 24, 1988, and were analyzed for triazine and organic-acid herbicides. Analysis for 2,4-D was not completed, owing to laboratory complications. Water levels in the wells at the time of sampling were shallow, generally about 2 to 5 ft below land surface. No pesticides were detected in these water samples (table 6).

Water samples from four observation wells also were collected on July 20, 1988. An organic-acid scan was run on the samples from observation wells WHT1, WHT2, WHT3, and WHT5, and the sample from observation well WHT2 was also analyzed for triazine. No organic-acid herbicides were detected in the water samples. A possible trace of atrazine was indicated in the water from observation well WHT2 by gas chromatography at a concentration less than the 0.1-µg/L detection limit of the analytical method (table 6).

TRANSPORT OF PESTICIDES

Analysis of soil and water samples documents the presence of pesticide residue in both the soil and the shallow ground water. Thus, irrigated agricultural areas of Montana might be susceptible to the transport of soluble pesticides through permeable soils to the shallow ground-water system. The transport of pesticides through unsaturated soil and into shallow ground water depends on several factors, including the solubility of the pesticide and its mobility, persistence, and adsorptivity within the soil. The latter factors may vary considerably for a given pesticide, depending on the texture, mineralogy, moisture, and organic-matter content of the soil. These soil characteristics are largely responsible for the detection or nondetection of selected pesticides in the soil and ground water.

Atrazine was detected in both soil and shallow ground water 2 weeks after it was applied with dicamba at the Havre Agricultural Experiment Station study sites. Although some atrazine was transported through the soil profile and entered the ground water, a substantial quantity remained in the soil.

Dicamba was detected in the shallow ground water about 2 weeks after it was applied to the study area near Havre, yet it was not detected in the soil samples. The study area was flood irrigated twice between dicamba application and sampling. Because of its extreme solubility and mobility, dicamba is not readily adsorbed to most inorganic soils, and generally does not persist in the soils for more than a few weeks. Therefore, the portion of the applied dicamba not utilized in the rooting zone can be assumed to have been transported through at least the part of the soil profile that was sampled and possibly to have entered the ground water.

In the area planted in seed potatoes near Ronan, aldicarb was detected in both soil samples and ground water collected about 9 weeks after application, yet aldicarb was not detected in samples collected about 7 weeks after application. The aldicarb sulfoxide detected in water from observation well WLK5 (table 8) was most likely transported to the shallow ground-water table from an area upgradient of the well, perhaps where the water table was shallow and the soil sediments coarse. A probable reason that aldicarb metabolites were detected only in the later samples is that the additional water from precipitation and irrigation was enough to transport at least some of the metabolites from the rooting zone deeper into the soil and possibly to the shallow ground-water table.

Herbicide applications made during previous years or during the 1988 growing season did not result in detectable residues in soil and water samples collected from the no-tillage corn field at the Huntley Agricultural Experiment Station. Although barley planted around the corn field in 1988 was apparently damaged by residue of atrazine applied in 1987, atrazine was not detected in soil samples and only a possible trace was indicated in one water sample at a concentration less than the detection limit.

This study indicates the presence of three soluble pesticides in the shallow ground water. Health advisories for concentrations of these pesticides in drinking water have been issued by the U.S. Environmental Protection Agency. The health-advisory limits, assuming an adult drinks 2 L of water a day, and the maximum concentrations detected during this study are compared as follows:

	Micrograms per liter	
	Health advisory	Maximum concentration detected
Atrazine[1]	3	1
Dicamba[2]	200	8
Aldicarb sulfoxide[3]	10	3

[1] U.S. Environmental Protection Agency (1988a).
[2] U.S. Environmental Protection Agency (1988b).
[3] U.S. Environmental Protection Agency (1987a).

The maximum concentrations of pesticides detected in ground water were all less than the health-advisory limits. Also, no water from the observation wells is used for domestic supplies.

Pesticide residues detected in soil samples have no recommended or advisory levels to which they can be compared. Residues in soils below the rooting zone are adsorbed to soil particles, degrade either chemically or biologically, or potentially leach farther down the soil profile and eventually reach the water table. If the application rate of a pesticide is known, the approximate percentage that remains in the soil profile can be determined from the concentration of the pesticide residue and bulk density of the soil.

The percentage of the applied atrazine that was detected as residue in soil samples was estimated for four sites. The percentage for site 1 near Havre was calculated from an atrazine application rate of 2.0 lb/acre, an assumed bulk density of 1.5 g/cm^3, (93.6 lb/ft^3), and the concentration of residue in sample SHV1. One acre of soil 1 ft thick with a bulk density of 1.5 g/cm^3 would weigh about 4.08 x 10^6 lb. Using the concentration of 82 µg/km for the sample from SHV1, the quantity of atrazine residue in a 1-acre plot that is 1.5-ft thick would be about 0.5 lb. This quantity of atrazine residue is equal to about 25 percent of the 2.0 lb/acre of active ingredient that was applied.

The percentage of atrazine detection in soil at site 2 near Havre was calculated from the application rate of 2.0 lb/acre, a bulk density of 1.5 g/cm^3, and the total atrazine residue concentration from the three composite samples collected near observation well WBC1 (table 5). Calculations indicate that the atrazine residue was about 0.25 lb/acre for the section from 0.8 to 2.0 ft (SBC1-2), 0.40 lb/acre from 2.0 to 4.0 ft (SBC1-4), and 0.20 lb/acre from 4.0 to 6.0 ft (SBC1-6). The total atrazine residue in the soil profile from 0.8 to 6.0 ft, therefore, is estimated to be about 0.85 lb/acre or about 40 percent of the active ingredient applied.

The percentage of applied aldicarb detected as residue in soil at site 1 near Ronan was calculated from an application rate of 2.5 lb/acre, a bulk density of 1.5 g/cm^3, and the total residual concentration of aldicarb and its metabolites in the 1-ft-thick sample SLK5 (130 µg/kg, table 7). The total pesticide residue in a 1-acre plot would be about 0.5 lb, or 20 percent of the total quantity applied. If the 1.7-ft thick sample SLK3-2 containing a total residual concentration of 140 µg/kg (table 7) is used in the calculation, the residue would be 1.0 lb, or 40 percent of the total quantity applied.

The percentage of applied aldicarb residue remaining in soil at site 2 near Ronan was estimated from 0.1 lb of residue for the 1.3-ft thick sample from STL1-2, 0.3 lb per a 1-ft thick sample from STL1-3, and a bulk density of 1.5 g/cm^3. The total of 0.4 lb/acre of pesticide residue is about 15 percent of the 2.7 lb/acre of applied aldicarb.

The percentage of applied pesticide present in shallow ground water also can be estimated. Observation well WLK5 at site 1 near Ronan can be used as an example. The concentration of aldicarb sulfoxide in a water sample collected on July 25, 1988, was 3 µg/L; the applied rate of aldicarb was about 2.5 lb/acre; the thickness of the water-bearing zone was assumed to be 15 ft on the basis of the lithology at observation well WLK5; and an effective porosity of 20 percent was assumed for the silty sand zone. On the basis of these values, the aldicarb detected in the shallow ground water at the time of sampling was an estimated 1 percent of the aldicarb applied.

Data in this report could be used as a basis for future study of the potential for agricultural pesticides to enter domestic water supplies. The scope of this study included only limited sampling of pesticides in soil and ground water below the rooting zone during one growing season. Therefore, the data base established during this study was not adequate to determine the eventual fate of pesticides detected within the soil profile and in the shallow ground-water system. Additional samples of the soil and ground water would have enabled more detailed quantification of the transport of pesticides in the soils and water of the study sites. Because some of the applied pesticides are at least moderately persistent, samples need to be collected at regular intervals for a period of time at least equal to the length of persistence of the pesticides in soil.

SUMMARY

This study was undertaken to document whether agricultural pesticides are being transported from the rooting zone of crops and are present in the soils and shallow ground water beneath irrigated agricultural areas of Montana. Three areas were chosen to represent a range of crops, soils, agricultural practices, and application of pesticides.

Analytical scans were conducted on soil and water samples for three types of pesticides--triazine herbicides, organic-acid (phenoxy) herbicides, and carbamate insecticides. Each scan was capable of detecting concentrations of at least four chemically similar pesticides.

At the Havre Agricultural Experiment Station, eight observation wells were installed at two sites. The station is located on a glacial-outwash plain. The soils are typically sandy and contain some gravel or sandy loam. The herbicides atrazine and dicamba were applied to fields of corn grown for silage during late June 1988. Soil and ground-water samples were collected prior to application of the herbicides and about 2 weeks after application. No concentrations of pesticides from applications during previous years were detected. All four soil samples collected after application of pesticides contained detectable concentrations of atrazine ranging from 26 to 82 µg/kg. Water samples collected from two of four wells after the application of pesticides contained 0.3 and 8 µg/L dicamba and water from one well contained 1 µg/L atrazine.

In an area where seed potatoes are grown near Ronan, eight observation wells were installed at two privately owned sites. The study sites are underlain by valley-fill deposits consisting of fine sand with some gravel overlying layers of silt. The sites were chosen because of the use of the insecticide aldicarb. Soil and ground-water samples were collected 7 and 9 weeks after application of the aldicarb. No insecticides were detected in the first set of samples. Irrigation water was applied between the first and second sampling. In the second sampling, aldicarb metabolites were detected in four of five soil samples ranging from 20 to 90 µg/kg and one of five water samples containing 3 µg/L.

At the Huntley Agricultural Experiment Station, five wells were installed in a no-tillage corn field. The site is on the flood plain of the Yellowstone River, where the predominant soil type is silty clay. Atrazine had been applied to the site in 1987, and the field was not tilled after the growing season. Atrazine was not applied in 1988 because of sparse weed growth. Soil and water samples were collected in June and July 1988; pesticides were not detected in any samples.

The results of the study indicate the presence of two types of soluble pesticides in soil samples and three types of soluble pesticides from samples of shallow ground water. The concentrations of pesticides in water detected during this study were all less than the health advisories for drinking water issued by the U.S. Environmental Protection Agency.

At sites where pesticides were detected, the percentage of the applied pesticide that remained in a soil profile at the time of sampling was estimated from the residue concentration in the soil samples, the rate of application of the pesticide, and an assumed bulk density of the soil. The estimated percentages ranged from about 15 to 40 percent of the total quantity of pesticide applied at a given site. The percentage of applied pesticide in the shallow ground water at one site was estimated on the basis of the pesticide concentration and the thickness and effective porosity of the shallow aquifer. The percentage was 1 percent of the pesticide applied. The presence of pesticide residues indicated that irrigated agricultural areas of Montana might be susceptible to the transport of soluble pesticides through permeable soils to the shallow ground-water system.

REFERENCES CITED

Cohen, S.Z., Eiden, C. and Lorber, M.N., 1986, Monitoring ground water for pesticides: Washington, D.C., American Chemical Society Symposium Series 315, p. 170-196.

Farm Chemicals, 1988, Farm Chemicals Handbook 88: Willoughby, Ohio, Meister Publishing Co., 258 p.

Hutchinson, R.D., 1983, Changes in the shallow ground-water resources of the Yellowstone River valley near Billings, Montana, August 1968-78: Montana Bureau of Mines and Geology Hydrogeologic Map 6, scale 1:48,000, 6 sheets.

Meshnick, J.C., Miller, F.T., Smith, J.H., Gray, L., and Bourne, W.C., 1972, Soil survey of Yellowstone County, Montana: Washington, D.C., U.S. Soil Conservation Service, 133 p.

National Council on Agricultural Science and Technology, 1985, Pesticides in agriculture and ground water quality: Washington, D.C., p. 38-62.

National Oceanic and Atmospheric Administration, 1989, Climatological data, annual summary, Montana, 1988: Asheville, N.C., National Environmental Satellite, Data and Information Service, v. 91, no. 13, 44 p.

Parsons, D.W., and Witt, J.M., 1988, Pesticides in ground water in the United States of America: Corvallis, Oregon State University Extension Service, 18 p.

Rothschild, E.R., Manser, R.J., and Anderson, M.P., 1982, Investigation of aldicarb in ground water in selected areas of the Central Sand Plain of Wisconsin: Ground Water, v. 20, no. 4, p. 437-445.

Slagle, S.E., 1988, Geohydrology of the Flathead Indian Reservation, northwestern Montana: U.S. Geological Survey Water-Resources Investigations Report 88-4142, 152 p.

U.S. Environmental Protection Agency, 1987a, Health advisory for aldicarb (sulfoxide and sulfone): Washington, D.C., Office of Drinking Water, March, 17 p.

______1987b, National pesticide survey, Method 1. Determination of nitrogen- and phosphorus-containing pesticides in ground water by gas chromatography with a nitrogen-phosphorus detector: Washington, D.C., Office of Drinking Water, October, 49 p.

______1987c, National pesticide survey, Method 3. Determination of chlorinated acids in ground water by gas chromatography with an electron capture detector: Washington, D.C., Office of Drinking Water, October, 42 p.

______1987d, National pesticide survey, Method 5. Measurement of N-methylcarbamoyloximes and N-methylcarbamates in ground water by direct aqueous injection HPLC with post column derivatization: Washington, D.C., Office of Drinking Water, October, 32 p.

______1988a, Health advisory for atrazine: Washington, D.C., Office of Drinking Water, August, 21 p.

______1988b, Health advisory for dicamba: Washington, D.C., Office of Drinking Water, August, 17 p.

Wartenberg, Daniel, 1988, Groundwater contamination by Temik aldicarb pesticide--The first 8 months: Water Resources Research, v. 24, no. 2, p. 185-194.

SUPPLEMENTAL INFORMATION

Table 1.--*Records of observation wells*

[Abbreviations: ft, feet; gal/min, gallons per minute; °C, degrees Celsius; µS/cm, microsiemens per centimeter at 25 °C; mg/L, milligrams per liter; ND, not detected. Symbols: <, less than; --, no data]

Observation well No.	Site identification No.	Altitude of measuring point (ft)	Height of measuring point above land surface (ft)	Depth of well (ft below land surface)	Depth to water below measuring point (ft)	Date water level measured	Well discharge (gal/min)	Date discharge measured	Onsite water temperature (°C)	Onsite specific conductance (µS/cm)	Onsite pH (units)	Onsite nitrate (mg/L as N)	Date water-quality data measured
Havre Agricultural Experiment Station--Site 1													
WHV1	32N15E29ADDA01	2,642.0	0	15	6.30	06-07-88	<1	06-06-88	13	3,650	7.8	9.0	07-18-88
					6.58	06-22-88							
					4.80	07-18-88							
WHV2	32N15E29ADDD01	2,653.2	1	24	6.20	06-07-88	<1	06-06-88	10	10,000	7.1	--	06-08-88
					7.03	06-22-88							
					5.44	07-18-88							
WHV3	32N15E29ADDA02	2,645.2	.5	17	5.50	06-07-88	4	06-06-88	10	2,100	7.6	2.0	06-08-88
					6.00	06-22-88			--	2,150	7.6	--	06-23-88
					4.80	07-18-88			13	2,450	7.9	6.5	07-18-88
WHV4	32N15E29ADDC01	2,648.6	.5	21	4.71	06-07-88	<1	06-06-88	--	20,000	7.2	10	06-08-88
					5.39	06-22-88			--	--	7.5	--	06-23-88
					4.68	07-18-88							
WHV5	32N15E29ADDB01	2,645.7	1	35	5.50	06-07-88	<1	06-06-88	10	7,500	7.0	--	06-08-88
					6.88	06-22-88							
					4.59	07-18-88							
Havre Agricultural Experiment Station--Site 2													
WBC1	32N15E28ACAA01	2,612.6	.5	15	6.07	06-07-88	10	06-07-88	11	1,000	7.1	1.0	06-07-88
					6.30	06-22-88			13	1,020	7.8	5.5	07-18-88
					7.20	07-18-88							
WBC2	32N15E28ACDA01	2,615.7	.5	15	8.00	06-07-88	4	06-07-88	13	800	7.9	4.0	07-18-88
					9.00	06-22-88							
					9.33	07-18-88							
WBC3	32N15E28ADCD01	2,617.3	2	16	7.86	06-07-88	5	06-07-88	--	--	--	--	--
					5.01	06-22-88							
					9.38	07-18-88							

Table 1.--*Records of observation wells*--Continued

Observation well No.	Site identification No.	Altitude of measuring point (ft)	Height of measuring point above land surface (ft)	Depth of well (ft below land surface)	Depth to water below measuring point (ft)	Date water level measured	Well discharge (gal/min)	Date discharge measured	Onsite water temperature (°C)	Onsite specific conductance (µS/cm)	Onsite pH (units)	Onsite nitrate (mg/L as N)	Date water-quality data measured
Area where seed potatoes are grown near Ronan--Site 1													
WLK1	21N20W25DBAD01	3,064.8	1	15	9.00	06-14-88	<1	06-14-88	11	450	7.1	7.0	06-15-88
					8.29	07-12-88			--	450	--	5.0	07-12-88
					8.16	07-25-88			13	440	7.7	6.5	07-25-88
WLK2	21N20W25DBAD02	3,071.6	0	25	17.00	06-14-88	2	06-14-88	11	500	7.4	12	06-15-88
					16.46	07-12-88			12	480	7.8	10	07-25-88
					16.71	07-25-88							
WLK3	21N20W25DBAD03	3,066.5	.5	15	11.33	06-14-88	<1	06-14-88	--	650	--	6.0	06-15-88
					10.79	07-12-88							
					10.86	07-25-88							
WLK4	21N20W25DBAA01	3,074.2	0	25	15.67	06-14-88	<1	06-14-88	--	--	--	--	--
					12.87	07-12-88							
					12.07	07-25-88							
WLK5	21N20W25DDDC01	3,067.8	1	30	17.95	06-14-88	1	06-14-88	11	520	7.2	2.0	06-15-88
					16.05	07-12-88			--	490	--	2.5	07-12-88
					18.15	07-25-88			13	620	7.9	10	07-25-88
Area where seed potatoes are grown near Ronan--Site 2													
WTL1	20N20W07ABDC01	2,934.7	1	25	15.85	06-14-88	<1	06-15-88	12	720	7.4	1.5	06-15-88
					16.13	07-12-88			--	600	--	6.5	07-12-88
					15.70	07-25-88			13	620	8.0	--	07-25-88
WTL2	20N20W07ABDD01	2,936.9	0	20	9.13	06-14-88	2	06-15-88	12	880	7.1	3.0	06-15-88
					8.90	07-12-88			--	850	--	3.5	07-12-88
					8.48	07-25-88			14	970	7.8	3.0	07-25-88
WTL3	20N20W07AAAD01	2,955.0	1	25	15.39	06-14-88	3	06-15-88	12	680	--	--	06-15-88
					15.33	07-25-88							
Huntley Agricultural Experiment Station													
WHT1	02N28E09DDCD01	3,003.2	2	28	6.32	06-02-88	10	06-03-88	10	3,500	--	--	06-03-88
					3.98	06-23-88			12	2,800	8.2	1.0	07-19-88
					3.91	07-19-88							
WHT2	02N28E09DDBD01	2,998.7	0	20	5.17	06-02-88	.2	06-03-88	10	4,000	8.2	2.0	06-03-88
					2.55	06-23-88			11	4,100	7.8	3.0	06-23-88
					2.50	07-19-88			13	4,400	8.1	3.0	07-19-88
WHT3	02N28E09DDBA01	3,000.0	3	24	10.59	06-02-88	2	06-03-88	--	--	--	--	--
					8.50	06-23-88							
					8.40	07-19-88							
WHT4	02N28E09DDBB01	2,995.0	.5	15	3.35	06-02-88	1	06-03-88	11	1,000	6.9	ND	06-23-88
					2.87	06-23-88							
					2.28	07-19-88							
WHT5	02N28E09DDCC01	3,001.5	.5	19	5.70	06-02-88	2	06-03-88	11	4,000	--	3.0	06-03-88
					2.39	06-23-88			--	1,150	7.0	--	06-23-88
					2.50	07-19-88							

Table 2.--*Lithologic logs of observation wells*

[Thickness is in feet. Bottom of depth interval is in feet below land surface. Abbreviation: in., inches]

Lithology	Thickness	Bottom of depth interval
Havre Agricultural Experiment Station--Site 1		
Well WHV1; drilled May 17, 1988		
Topsoil	2	2
Gravel, as much as 2 in. in diameter; and sandy silt	5	7
Sand, fine, and gravel, as much as 2 in. in diameter	2	9
Sand, wet	3	12
Clay; contains some sand and gravel, yellowish-brown	3	15
Well WHV2; drilled May 17, 1988		
Topsoil	2	2
Gravel, pea size to 2 in. in diameter; dry	2	4
Gravel and sand; contains some silt; dry	2	6
Sand; dry	2	8
Sand; contains some gravel; moist	1	9
Clay, sandy, yellowish-brown; moist	15	24
Well WHV3; drilled May 17, 1988		
Topsoil	2	2
Clay, sandy, brownish-gray	1	3
Gravel, as much as 6 in. in diameter	3	6
Sand; contains some gravel; dry	3	9
Sand; contains some gravel; wet	3	12
Clay, sand, and gravel	1	13
Sand and gravel	4	17
Well WHV4; drilled May 17, 1988		
Topsoil and gravel	2	2
Sand and gravel; dry	4	6
Clay, sandy, brown	15	21
Well WHV5; drilled May 17, 1988		
Topsoil, loam	2	2
Sand; contains some gravel	2	4
Gravel and cobbles	1	5
Sand; contains some gravel; moist	2	7
Clay, sandy, brown; moist; no water	24	31
Clay, sandy, grayish-brown	4	35

Table 2.--*Lithologic logs of observation wells*--Continued

Lithology	Thick-ness	Bottom of depth interval
Havre Agricultural Experiment Station--Site 2		
Well WBC1; drilled May 18, 1988		
Topsoil, loam	2	2
Silt and sand	2	4
Sand, silty; moist	2	6
Sand and silt loam, dark-brown; saturated	4	10
Sand; contains some coarse sand; wet	3	13
Sand and gravel, bluish-gray	2	15
Well WBC2; drilled May 18, 1988		
Topsoil, loam	2	2
Sand and loam; moist	5	7
Sand; wet	6	13
Gravel and sand; wet	2	15
Well WBC3; drilled May 18, 1988		
Topsoil, loam, sandy	1	1
Silt and fine sand; moist	3	4
Sand, fine; contains some silt, hard; dry	2	6
Clay, sandy; dry	2	8
Sand and clay; water	4	12
Gravel and sand	4	16
Area where seed potatoes are grown near Ronan--Site 1		
Well WLK1; drilled May 23, 1988		
Fill	1	1
Loam, sandy, dark-brown	3	4
Sand, fine, light-brown; wet	4	8
Sand, fine, and silt, tan	7	15
Well WLK2; drilled May 23, 1988		
Loam, fine, sandy, brown	6	6
Sand, fine, light-brown	2	8
Silt; contains some fine sand, light-tan	4	12
Silt; contains some sand, light-tan; wet	4	16
Silt and fine sand; wet	9	25
Well WLK3; drilled May 23, 1988		
Loam, dark-brown	6	6
Silt; contains some fine sand, tan; wet	5	11
Sand and silt, tan; wet	4	15

Table 2.--*Lithologic logs of observation wells*--Continued

Lithology	Thick-ness	Bottom of depth interval
Area where seed potatoes are grown near Ronan--Site 1--Continued		
Well WLK4; drilled May 23, 1988		
Loam, sandy, brown	5	5
Sand, fine, light-brown	8	13
Sand and silt	1	14
Silt; contains some fine sand, tan; wet	6	20
Sand, fine, and silt; wet	5	25
Well WLK5; drilled May 23, 1988		
Topsoil, loam, sandy	2	2
Sand, fine, and silt, tan	3	5
Silt; contains some fine sand, tan	4	9
Sand, fine, and silt	4	13
Silt and fine sand; moist	5	18
Silt and fine sand; wet	5	23
Silt; contains some sand, tan	7	30
Area where seed potatoes are grown near Ronan--Site 2		
Well WTL1; drilled May 24, 1988		
Topsoil, loam, sandy	1	1
Sand and gravel, as much as 2 in. in diameter	8	9
Sand; contains some small gravel	4	13
Silt, sand, and small gravel; wet	4	17
Silt and fine sand; wet	8	25
Well WTL2; drilled May 24, 1988		
Topsoil, loam, sandy, dark-brown	1	1
Sand, brown	3	4
Sand and gravel, as much as 4 in. in diameter	6	10
Sand and gravel, pea size	8	18
Silt and sand, contains some pea gravel; wet	2	20
Well WTL3; drilled May 24, 1988		
Topsoil, loam, sandy	1	1
Sand, fine	12	13
Sand, fine; contains some silt	3	16
Sand, fine, and silt; wet	1	17
Sand, fine to medium	8	25

Table 2.--*Lithologic logs of observation wells*--Continued

Lithology	Thickness	Bottom of depth interval
<u>Huntley Agricultural Experiment Station</u>		
<u>Well WHT1</u>; drilled May 4, 1988		
Topsoil	2	2
Clay, sandy	2	4
Silt, sandy; dry	2	6
Silt, sandy, brown; wet	6	12
Clay, sandy; dense	3	15
Sand and clay; wet	9	24
Gravel; contains some clay and fine sand	4	28
<u>Well WHT2</u>; drilled May 5, 1988		
Topsoil	2	2
Soil and sandy loam	2	4
Clay and silt, sandy, brown	16	20
<u>Well WHT3</u>; drilled May 5, 1988		
Topsoil	2	2
Sand; dry	4	6
Clay, sandy, brown	6	12
Clay, sandy; wet	8	20
Clay, sandy, and gravel	4	24
<u>Well WHT4</u>; drilled May 6, 1988		
Topsoil	2	2
Sand and clay; dry	3	5
Clay and silt, sandy, brown; wet	7	12
Sand and clay	3	15
Gravel, sand, and clay	4	19
<u>Well WHT5</u>; drilled May 6, 1988		
Topsoil	2	2
Sand; dry	2	4
Clay, sandy	2	6
Clay, sandy; wet	13	19

Table 3.--*Cross references of pesticide names*

Common name	Common trade name(s)[1]
Triazine herbicides	
Atrazine	AAtrex
Cycloate	Ro-Neet
Prometon	Pramitol
Simazine	Several names
Organic-acid herbicides	
Dicamba	Banvel
MCPA	Several names
Picloram	Tordon
Silvex	Kuron, Silvi-Rhap, Weed-B-Gon
2,4-D	Several names
2,4-DB	Butoxone, Butyrac
Carbamate insecticides	
Aldicarb	Temik
Carbaryl	Sevin
Carbofuran	Furadan
Methomyl	Lannate, Methomex, Nudrin

---

[1] Use of trade names in this report is for descriptive purpose only and does not constitute endorsement by the U.S. Geological Survey.

Table 4.--*Properties of and chemical constituents in water from selected observation wells*

[Analyses by Montana Bureau of Mines and Geology. Constituents are dissolved and concentrations are reported in milligrams per liter unless otherwise noted. Abbreviations: µS/cm, microsiemens per centimeter at 25 °C; °C, degree Celsius; $CaCO_3$, calcium carbonate; µg/L, micrograms per liter. Symbols: <, less than; --, no data]

Observation well No.	Site identification No.	Sample date	Onsite specific conductance (µS/cm)	Onsite pH (units)	Onsite water temperature (°C)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Onsite alkalinity, as $CaCO_3$
Havre Agricultural Experiment Station--Site 1											
WHV1	32N15E29ADDA01	07-18-88	3,650	7.8	13	140	160	530	11	780	660
WHV3	32N15E29ADDA02	07-18-88	2,450	7.9	13	40	98	400	8.0	690	560
Havre Agricultural Experiment Station--Site 2											
WBC1	32N15E28ACAA01	07-18-88	1,020	7.8	13	55	26	160	6.5	540	440
WBC2	32N15E28ACDA01	07-18-88	800	7.9	13	49	27	93	7.0	430	360
Area where seed potatoes are grown near Ronan--Site 1											
WLK1	21N20W25DBAD01	07-25-88	440	7.7	13	63	17	6.6	1.4	230	190
WLK2	21N20W25DBAD02	07-25-88	480	7.8	12	77	16	3.6	2.0	250	210
WLK5	21N20W25DDDC01	07-25-88	620	7.9	13	57	40	15	5.6	410	340
Area where seed potatoes are grown near Ronan--Site 2											
WTL1	20N20W07ABDC01	07-25-88	620	8.0	13	51	26	25	10	410	330
WTL2	20N20W07ABDD01	07-25-88	970	7.8	14	81	24	110	6.2	620	540
Huntley Agricultural Experiment Station											
WHT1	02N28E09DDCD01	07-19-88	2,800	8.2	12	23	19	610	3.0	320	270
WHT2	02N28E09DDBD01	07-19-88	4,400	8.1	13	63	38	1,000	3.3	360	300

Observation well No.	Sulfate (SO_4)	Chloride (Cl)	Fluoride (Fl)	Silica (SiO_2)	Dissolved solids, calculated	Onsite nitrate, as N	Nitrate, as N	Phosphorus (P)	Aluminum (Al) (µg/L)	Boron (B) (µg/L)	Cadmium (Cd) (µg/L)
Havre Agricultural Experiment Station--Site 1											
WHV1	1,400	30	0.3	22	2,660	9.0	10	<0.1	<30	370	<2
WHV3	730	25	.5	24	1,680	6.5	7.5	<.1	<30	320	<2
Havre Agricultural Experiment Station--Site 2											
WBC1	110	5.8	.4	18	646	5.5	5.0	<.1	<30	510	<2
WBC2	60	6.0	.4	18	475	4.0	4.0	.1	<30	360	6
Area where seed potatoes are grown near Ronan--Site 1											
WLK1	11	10	.1	21	249	6.5	6.4	<.1	<30	80	<2
WLK2	11	6.5	.3	26	278	10	11	<.1	<30	70	<2
WLK5	6.4	2.9	.5	22	354	1.0	1.1	<.1	<30	40	<2
Area where seed potatoes are grown near Ronan--Site 2											
WTL1	55	12	.3	17	399	--	1.0	<.1	<30	80	<2
WTL2	13	7.7	.4	26	574	3.0	3.3	<.1	<30	70	<2

Table 4.--*Properties of and chemical constituents in water from selected observation wells*--Continued

Observation well No.	Chromium (Cr) (µg/L)	Copper (Cu) (µg/L)	Iron (Fe) (µg/L)	Lithium (Li) (µg/L)	Manganese (Mn) (µg/L)	Molybdenum (Mo) (µg/L)	Strontium (Sr) (µg/L)	Titanium (Ti) (µg/L)	Zinc (Zn) (µg/L)	
				Huntley Agricultural Experiment Station						
WHT1	1,100	10	.9	34	2,000	1.0	.4	.1	<30	730	2
WHT2	2,100	17	1.3	23	3,440	3.0	2.1	.2	<30	1,300	3
				Havre Agricultural Experiment Station--Site 1						
WHV1	<2	<2	<2	220	27	<20	2,100	5	3	
WHV3	<2	<2	11	140	<1	<20	930	2	<3	
				Havre Agricultural Experiment Station--Site 2						
WBC1	<2	<2	10	<2	16	<20	520	4	<3	
WBC2	<2	<2	2	<2	<1	<20	480	8	3	
				Area where seed potatoes are grown near Ronan--Site 1						
WLK1	2	2	19	2	4	<20	56	4	<3	
WLK2	<2	2	5	2	6	<20	62	5	<3	
WLK5	<2	<2	<2	3	2	<20	150	3	<3	
				Area where seed potatoes are grown near Ronan--Site 2						
WTL1	<2	<2	10	<2	90	<20	140	4	<3	
WTL2	<2	<2	<2	<2	<1	<20	160	1	<3	
				Huntley Agricultural Experiment Station						
WHT1	<2	<2	42	59	2	36	400	3	3	
WHT2	<2	<2	68	76	13	33	1,100	8	<3	

Table 5.--*Residue concentrations of triazine and organic-acid herbicides, percent moisture, and carbon content in soil cores*

[Analyses of herbicides and moisture by Montana State University Agricultural Experiment Station; analyses of carbon content by U.S. Geological Survey. Abbreviations: ft, feet; µg/kg, micrograms per kilogram; g/kg, grams per kilogram. Symbols: <, less than--number following < is method detection limit; --, no data]

Soil core No.	Site identification No.	Sample date	Sample depth (ft below land surface)	Triazine herbicides			
				Atrazine (µg/kg)	Cycloate (µg/kg)	Prometon (µg/kg)	Simazine (µg/kg)
Havre Agricultural Experiment Station--Site 1							
SHV1	32N15E29ADDA01	07-18-88	1.0-2.5	82	<1	<0.1	<0.1
SHV3	32N15E29ADDA02	06-22-88	1.5-3.5	<.1	<1	<.1	<.1
Havre Agricultural Experiment Station--Site 2							
SBC1-2	32N15E28ACAA01	07-18-88	.8-2.0	52	<1	<.1	<.1
SBC1-4	32N15E28ACAA01	07-18-88	2.0-4.0	49	<1	<.1	<.1
SBC1-6	32N15E28ACAA01	07-18-88	4.0-6.0	26	<1	<.1	<.1
Huntley Agricultural Experiment Station							
BHT1	02N28E09DDCD02	06-23-88	1.0-2.5	<.1	<1	<.1	<.1
SHT1	02N28E09DDCD01	06-23-88	1.0-2.5	<.1	<1	<.1	<.1
SHT3	02N28E09DDBA01	06-23-88	1.0-2.5	<.1	<1	<.1	<.1
SHT4	02N28E09DDBB01	06-23-88	1.0-2.5	<.1	<1	<.1	<.1

Soil core No.	Organic-acid herbicides						Moisture (percent)	Carbon content		
	Dicamba, as acid equivalent (µg/kg)	MCPA, as acid equivalent (µg/kg)	Picloram, as acid equivalent (µg/kg)	Silvex, as acid equivalent (µg/kg)	2,4-D, as acid equivalent (µg/kg)	2,4-DB, as acid equivalent (µg/kg)		Carbon, total (g/kg)	Carbon, inorganic (g/kg)	Organic matter (percent)
Havre Agricultural Experiment Station--Site 1										
SHV1	<5	<10	<5	<5	<10	<10	12	11.0	5.2	0.6
SHV3	<5	<10	<5	<5	<10	<10	16	17.1	9.6	.8
Havre Agricultural Experiment Station--Site 2										
SBC1-2	<5	<10	<5	<5	<10	<10	10	10.0	3.9	.6
SBC1-4	<5	<10	<5	<5	<10	<10	8.7	4.9	1.9	.3
SBC1-6	<5	<10	<5	<5	<10	<10	19	8.9	5.5	.3
Huntley Agricultural Experiment Station										
BHT1	<5	<10	<5	<5	<10	<10	22	--	--	--
SHT1	<5	<10	<5	<5	<10	<10	22	--	--	--
SHT3	<5	<10	<5	<5	<10	<10	20	9.5	4.6	.5
SHT4	<5	<10	<5	<5	<10	<10	22	8.1	3.9	.4

Table 6.--*Concentrations of triazine and organic-acid herbicides in ground water*

[Analyses by Montana State University Agricultural Experiment Station. Abbreviation: µg/L, micrograms per liter. Symbols: <, less than--number following < is method detection limit; --, no data; *, possible trace indicated at concentration less than detection limit]

Observation well No.	Sample date	Triazine herbicides			
		Atrazine (µg/L)	Cycloate (µg/L)	Prometon (µg/L)	Simazine (µg/L)
Havre Agricultural Experiment Station--Site 1					
WHV1	07-19-88	1	<1	<0.1	<0.1
WHV3	06-23-88	<.1	<1	<.1	<.1
	07-19-88	<.1	<1	<.1	<.1
Havre Agricultural Experiment Station--Site 2					
WBC1	07-19-88	<.1	<1	<.1	<.1
WBC2	07-19-88	<.1	<1	<.1	<.1
Huntley Agricultural Experiment Station					
WHT1	06-24-88	<.1	<1	<.1	<.1
	07-20-88	--	--	--	--
WHT2	06-24-88	<.1	<1	<.1	<.1
	07-20-88	<.1*	<1	<.1	<.1
WHT3	06-24-88	<.1	<1	<.1	<.1
	07-20-88	--	--	--	--
WHT4	06-24-88	<.1	<1	<.1	<.1
WHT5	07-20-88	--	--	--	--

Table 6.--*Concentrations of triazine and organic-acid herbicides in ground water*--Continued

	Organic-acid herbicides					
Observation well No.	Dicamba, as acid equivalent (µg/L)	MCPA, as acid equivalent (µg/L)	Picloram, as acid equivalent (µg/L)	Silvex, as acid equivalent (µg/L)	2,4-D, as acid equivalent (µg/L)	2,4-DB, as acid equivalent (µg/L)
Havre Agricultural Experiment Station--Site 1						
WHV1	8	<2	<0.2	<0.1	<0.3	<0.5
WHV3	<.1	<2	<.2	<.1	--	<.5
	.3	<2	<.2	<.1	<.3	<.5
Havre Agricultural Experiment Station--Site 2						
WBC1	<.1	<2	<.2	<.1	<.3	<.5
WBC2	<.1	<2	<.2	<.1	<.3	<.5
Huntley Agricultural Experiment Station						
WHT1	<.1	<2	<.2	<.1	--	<.5
	<.1	<2	<.2	<.1	<.3	<.5
WHT2	<.1	<2	<.2	<.1	--	<.5
	<.1	<2	<.2	<.1	<.3	<.5
WHT3	<.1	<2	<.2	<.1	--	<.5
	<.1	<2	<.2	<.1	<.3	<.5
WHT4	--	--	--	--	--	--
WHT5	<.1	<2	<.2	<.1	<.3	<.5

Table 7.--*Residue concentrations of carbamate insecticides, percent moisture, and carbon content in soil cores*

[Analyses of insecticides by Montana State University Agricultural Experiment Station; analyses of carbon content by U.S. Geological Survey. Abbreviations: ft, feet; µg/kg, micrograms per kilogram; g/kg, grams per kilogram. Symbol: <, less than--number following < is method detection limit]

				Carbamate insecticides			
Soil core No.	Site identification No.	Sample date	Sample depth (ft below land surface)	Aldicarb (µg/kg)	Aldicarb sulfone (µg/kg)	Aldicarb sulfoxide (µg/kg)	Carbaryl (µg/kg)
		<u>Area where seed potatoes are grown near Ronan--Site 1</u>					
SLK1-2	21N20W25DBAB01	07-12-88	1.0-2.5	<10	<10	<10	<10
SLK1-3	21N20W25DBAB01	07-12-88	2.5-3.5	<10	<10	<10	<10
SLK3-2	21N20W25DBAA03	07-26-88	.8-2.5	<10	70	70	<10
SLK3-5	21N20W25DBAA03	07-26-88	2.5-5.0	<10	<10	<10	<10
SLK5	21N20W25DDDC01	07-11-88	1.0-3.0	<10	<10	<10	<10
		07-26-88	.8-1.8	<10	90	40	<10
		<u>Area where seed potatoes are grown near Ronan--Site 2</u>					
STL1-2	20N20W07ABDC01	07-25-88	.7-2.0	<10	20	<10	<10
STL1-3	20N20W07ABDC01	07-25-88	2.0-3.0	<10	40	30	<10
STL2-2	20N20W07ABDD01	07-12-88	1.0-2.5	<10	<10	<10	<10
STL2-3	20N20W07ABDD01	07-12-88	2.5-3.5	<10	<10	<10	<10

Table 7.--*Residue concentrations of carbamate insecticides, percent moisture, and carbon content in soil cores*--Continued

Soil core No.	Carbamate insecticides			Moisture (percent)	Carbon content		
	Carbofuran (µg/kg)	3 Hydroxycarbofuran (µg/kg)	Methomyl (µg/kg)		Carbon, total (g/kg)	Carbon, inorganic (g/kg)	Organic matter (percent)
			Area where seed potatoes are grown near Ronan--Site 1				
SLK1-2	<10	<10	<10	9.0	4.5	0.1	0.4
SLK1-3	<10	<10	<10	14	2.8	.0	.3
SLK3-2	<10	<10	<10	7.9	5.0	.0	.5
SLK3-5	<10	<10	<10	13	1.2	.0	.1
SLK5	<10	<10	<10	13	7.8	.0	.8
	<10	<10	<10	9.9	15.6	.3	1.5
			Area where seed potatoes are grown near Ronan--Site 2				
STL1-2	<10	<10	<10	7.8	6.1	.1	.6
STL1-3	<10	<10	<10	8.2	2.8	.0	.3
STL2-2	<10	<10	<10	13	6.8	.1	.7
STL2-3	<10	<10	<10	7.4	2.0	.1	.2

Table 8.--*Concentrations of carbamate insecticides in ground water*

[Analyses by Montana State University Agricultural Experiment Station. Abbreviation: µg/L, micrograms per liter. Symbols: <, less than--number following < is method detection limit; *, possible trace indicated at concentration less than detection limit]

Observation well No.	Sample date	Aldicarb (µg/L)	Aldicarb sulfone (µg/L)	Aldicarb sulfoxide (µg/L)	Carbaryl (µg/L)	Carbofuran (µg/L)	3 Hydroxycarbofuran (µg/L)	Methomyl (µg/L)
			<u>Area where seed potatoes are grown near Ronan--Site 1</u>					
WLK1	07-12-88	<1	<2	<2	<2	<1.5	<2	<0.5
	07-25-88	<1	<2	<2*	<2	<1.5	<2	<.5
WLK2	07-25-88	<1	<2	<2*	<2	<1.5	<2	<.5
WLK3	07-12-88	<1	<2	<2	<2	<1.5	<2	<.5
WLK5	07-12-88	<1	<2	<2	<2	<1.5	<2	<.5
	07-25-88	<1	<2	3	<2	<1.5	<2	<.5
			<u>Area where seed potatoes are grown near Ronan--Site 2</u>					
WTL1	07-12-88	<1	<2	<2	<2	<1.5	<2	<.5
	07-25-88	<1	<2	<2*	<2	<1.5	<2	<.5
WTL2	07-12-88	<1	<2	<2	<2	<1.5	<2	<.5
	07-25-88	<1	<2	<2*	<2	<1.5	<2	<.5

☆ US GOVERNMENT PRINTING OFFICE: 1990-792-904/35003