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WATER QUALITY IN PLEASANT VALLEY, UTAH

by

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Final Report

WG-281

HYDROLOGY AND HYDRAULICS SERIES

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Utah Water Research Laboratory
Utah State University
Logan, Utah 84322

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ABSTRACT

Pollution of shallow groundwater due to wastewater disposal in Pleasant Valley, Utah, was investigated from October 1979 through August 1980. Water samples were collected from 23 wells and 5 stream sampling sites. Water quality analyses revealed pollution at several sites. Groundwater pollution caused by man's activities in the area was observed in Bolotas and Scofield Campsite subdivisions.

Severe shallow groundwater pollution measured in wells which were located in south and north profiles of the town of Scofield, Utah, could have originated from the municipal waste disposal practice in the town. Natural phenomena, however, such as pyrite oxidation, could possibly have been the cause of the depletion of dissolved oxygen in the groundwater near Scofield.

In the town of Scofield the shallow water table, less than 1.22 m (4 ft) below ground throughout the whole study period, could limit septic tank use in the study area.

The seasonally variable nitrate and phosphate concentration in the surface stream reached its maximum value in May (i.e. 1.12 mg/l NO_3-N and 3.37 mg/l total phosphorus) when the stream flow reached a maximum flow of 9.06 m^3/s (370 cfs). These increases in nitrate and phosphorus content in the stream, resulting from spring thawing, could increase the nutrient level in the Scofield Reservoir.

Natural phenomena produced a high concentration of mercury, averaging 2.55 μg/l during the study period. It is possible that the water in Scofield Reservoir might have a similar level of mercury. The maximum contamination level of mercury accepted by the State of Utah and U. S. EPA for drinking water is 2.0 μg/l. Therefore, potential health problems may exist for the people who depend on the Scofield Reservoir for their source of drinking water.

Fluoride concentration ranged from 0.06 mg/l to 0.42 mg/l. Natural processes are responsible for fluoride in the water.

ACKNOWLEDGMENTS

This investigation of shallow groundwater contamination in Pleasant Valley, Utah, has been funded by the State of Utah through the Groundwater Resources Research Program of the Utah Water Research Laboratory of Utah State University and by the Southeastern Utah Association of Governments with the assistance of the U.S. Environmental Protection Agency.

Special thanks are given to Richard Walker of the Southeastern Utah Association of Governments. Appreciation is given to the many persons in city and county governments, state agencies and corporations and to the many private citizens and landowners who gave their cooperation and suggestions in the study.

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Calvin G. Clyde
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INTRODUCTION

Pleasant Valley, Utah (Figure 1), nestled in the Wasatch Plateau northwest of the Book Cliffs, comprises the eastern part of the Scofield Reservoir Basin. Coal mining has been an important industry in the area for many years, but there had been a decline in mining activity until the recent nationwide energy crisis caused renewed interest in and development of the coal resources in Scofield basin. The area is also used for some grazing of cattle and sheep. After the construction of Scofield Dam in the 1940s, recreation uses for hunting, fishing, camping, and summer home construction have greatly expanded. Now a continued growth in population and human activities in Pleasant Valley is expected due to the attractive recreational, summer home, and mining opportunities in this basin. Effective management of the water and land resources requires an assessment of water quality in the basin. While past studies have provided the needed data on surface water quality and quantity, additional information on groundwater quality is needed.

This investigation focuses mainly on shallow groundwater contamination due to domestic and agricultural wastes which are currently disposed of in septic systems and pit privies, or spread on the land surface. Possible contamination of deeper groundwater by coal mining activities was not studied except as it may affect the shallow groundwater and surface waters through the natural flow system.

The goal of the project water sampling was to obtain information about all the water of the study area including streams, shallow groundwater, deep groundwater flowing naturally to the surface, and the reservoir water. Information describing the water quality constituents, the variations in water quality at different places in the basin, and variations of water quality in time in the basin provides a basis for determining how these patterns are being changed by development and what threats the changes pose for the future. One would expect the first indications of pollution to occur in the shallow groundwater in the vicinity of concentrated human activities. Descriptions of these activities were gathered for the purposes of correlating pollution sources and integrating groundwater quality considerations into overall land use planning.

PROJECT OBJECTIVES

The overall objectives of the Pleasant Valley project were to:

1. Review shallow groundwater data from all available sources and collect the existing information about groundwater quality in Pleasant Valley.

2. Establish a network of groundwater and surface water sampling points in Pleasant Valley.

3. Determine the characteristics of shallow soil and groundwater aquifers in the area.

4. Determine the pattern of groundwater movement through Pleasant Valley.

5. Investigate the seasonal variations of shallow groundwater quality at selected observation wells.

6. Collect information concerning the waste disposal practices and seasonal variation of population in Pleasant Valley.

7. Make a preliminary investigation of the effects of the various residential and recreational areas on the groundwater quality.

By performing all these objectives, the water quality in the Pleasant Valley could be determined. Furthermore, the impact of human activities on the water quality in the study area could be assessed.

DESCRIPTION OF THE STUDY AREA

Geography

Pleasant Valley is located in the Colorado River Drainage Basin in Eastern Utah (Figure 1 and Figure 2). The westernmost headwaters of the Price River drain the northern sector of the Wasatch Plateau and flows into Scofield Reservoir which is an irrigation storage reservoir in Pleasant Valley. Scofield Reservoir has a usable capacity of 81,140,000 m^3 (65,780 acre feet) between elevations 2312 m (7,586 ft) (bottom of outlet works) and 2322 m (7,617.5 ft) (crest of spillway). Dead storage is 9,868,000 m^3 (8,000 acre-feet) below elevation 2312 m (7,586 ft). Drainage area is approximately 401 km^2 (155 mi^2).

Geology

The Wasatch Plateau is formed by Tertiary and Cretaceous strata, mostly limestone, sandstone, and shale, that differ greatly in resistance to erosion. One of the Cretaceous strata, the Blackhawk formation, which is in the middle of the Mesaverde group, contains the minable coal beds of the Wasatch Plateau. The processes of erosion have cut into the formations to form stream channels and valleys and have exposed the coal beds at many locations. Unconsolidated alluvium has accumulated as stream channel and valley fill deposits made up of mixtures of clay, silt, sand, gravel, and boulders. These unconsolidated Quarternary deposits contain the shallow groundwater studied in this report. A more detailed description of the Geology and Stratigraphy of the Wasatch Plateau near Scofield is given in Appendix N.

Hydrology and Climatology

Precipitation and Evapotranspiration

Average annual precipitation ranges between 410-640 mm (16-25 in) in the valley and reaches 1020 mm (40 in) on the peaks of the Wasatch Plateau nearby (Mundorff 1972).

A greater amount of precipitation falls during the October-April period than during the May-September period. In the winter, precipitation falls in the form of rain or snow while precipitation in the summer is characterized by thunderstorm activity, resulting from the flow of warm air masses from the Gulf of Mexico (Mundorff 1972).

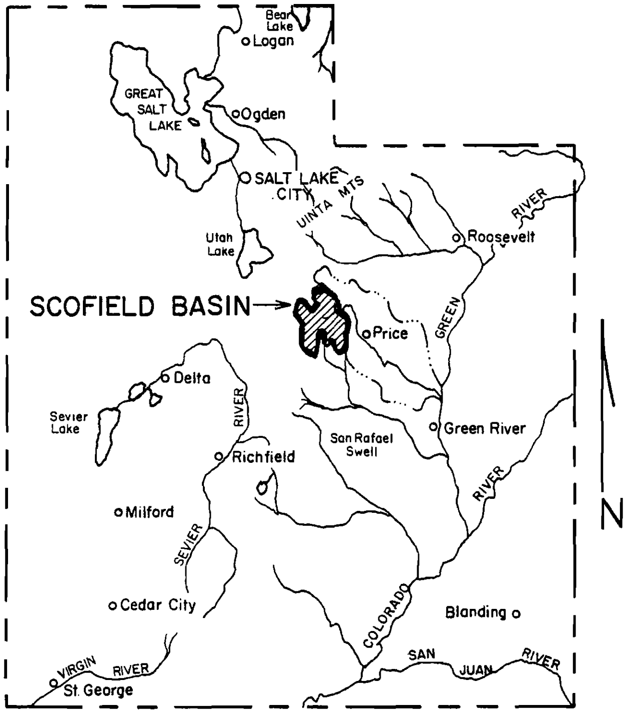


Figure 1. Location of Pleasant Valley in the State of Utah.

Average annual potential evapotranspiration is 460-530 mm (18-21 in) for the valley and less than 457 mm (18 in) for the higher elevations according to the Thornthwaite formula (Thornthwaite 1957).

Runoff

The mean annual runoff amounts to 100-300 mm (4-12 in) in the valley and exceeds 304 mm (12 in) on the plateau (Mundorff 1972). Fish Creek in 1974 (Figure 3) demonstrated the typical tremendous increase in flow during spring runoff and the relatively low baseflow during the other months. Scofield Reservoir Dam is used for the timely release of irrigation water during the growing season as depicted in Figure 4.

The United States Geological Survey (USGS) Gaging Stations in the study area are listed in Table 1 and are shown on the map of Figure 5.

Growing season

In an average summer there are 60 frost-free days in the valley and 20 days in the high mountain areas.

Vegetation

Forests include aspen, alpine fir, Douglas fir, and blue spruce. Vegetation on the rangelands is comprised of lathyrus, poa, penstemon, balsamroot, bromegrass, carex, vicia, agropyron, and sagebrush. Willows are found along the streams (personal communication, USFS, Manti-LaSal National Forest 1980).

Land Use

Coal mining is the primary economic activity in Pleasant Valley and is expanding in the southern end of the basin where over 5.5 x 10^9 kg (6.1 x 10^6 tons) will be mined annually by the Coastal States Energy Company. Livestock is also important with approximately 4,000-5,000 head of cattle and 15,000 sheep grazing during the period June-September (personal communication with private ranchers). The livestock grazed on both private land and federal lands on the Manti-LaSal National Forest. The sheep allotments are shown in Table 2.

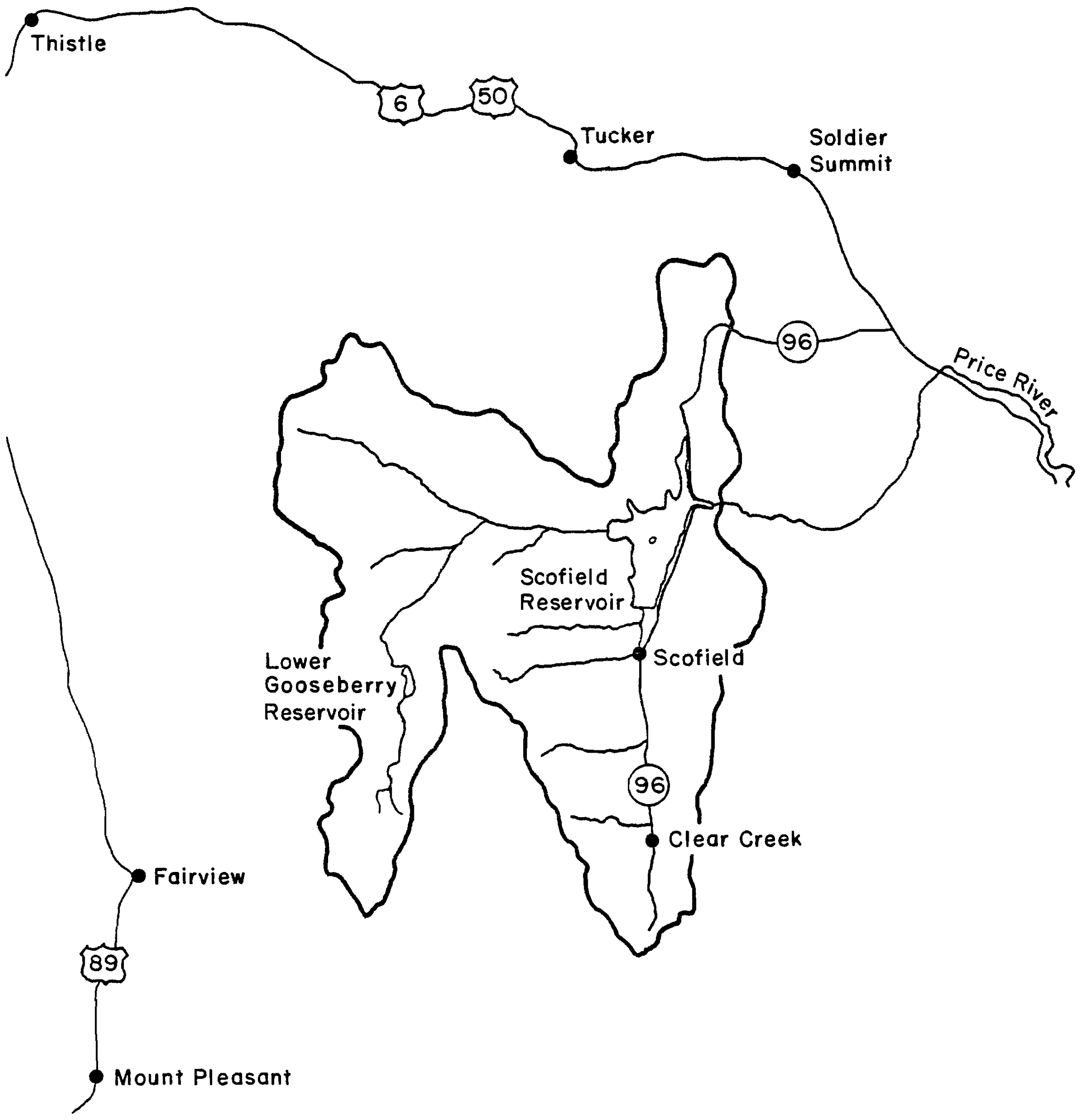


Figure 2. Location of Scofield Reservoir near Soldier Summit, Utah.

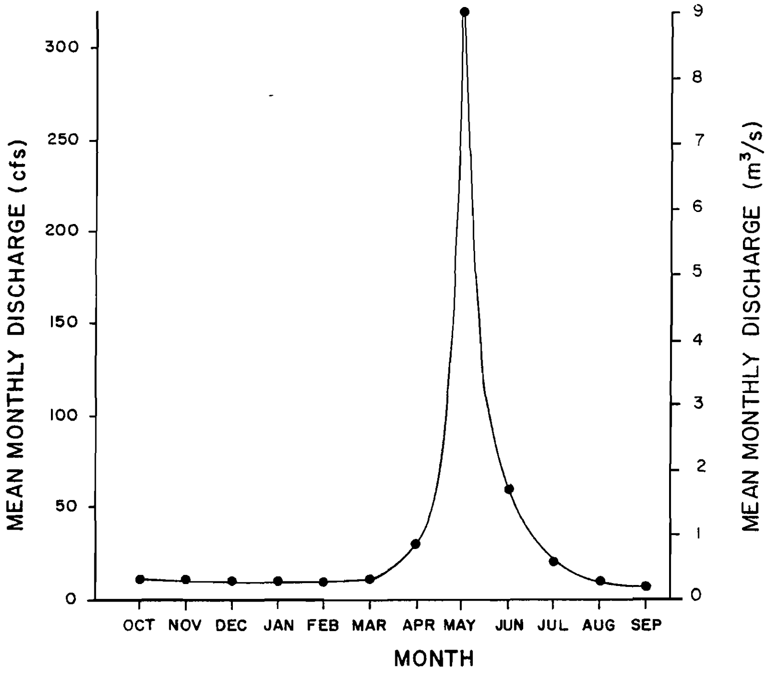


Figure 3. Hydrograph of Fish Creek above Scofield Reservoir, USGS Gaging Station 09310500 (Water Resources Data for Utah 1969).

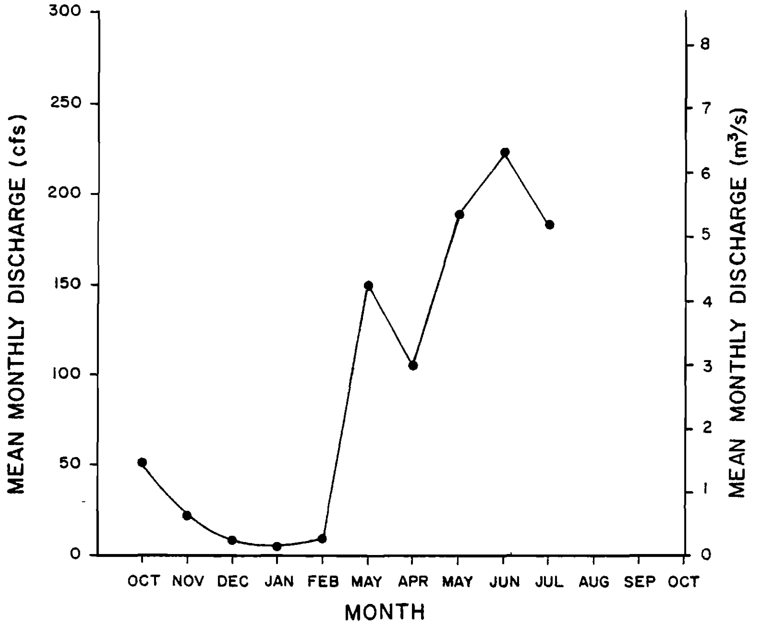
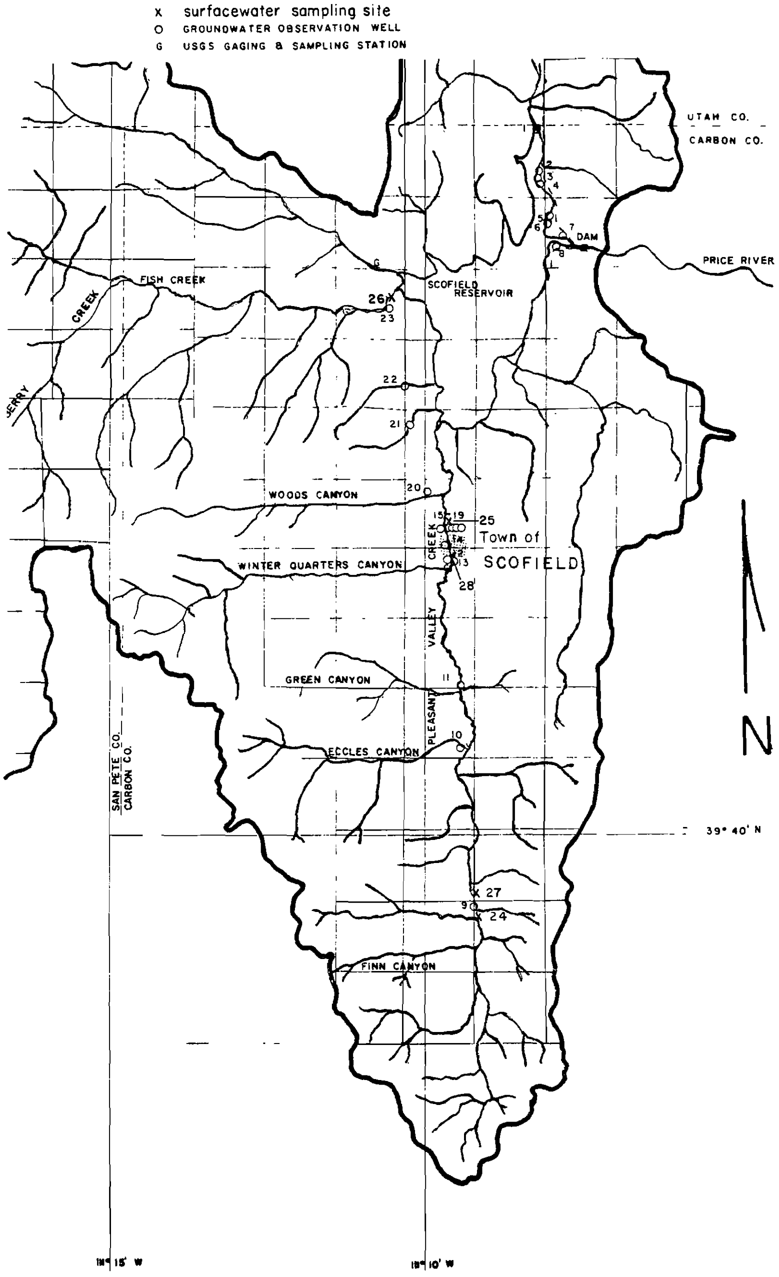


Figure 4. Hydrograph of Price River 800 feet downstream from Scofield Reservoir Dam, USGS Gaging Station 9-3115 (Water Resources Data for Utah 1969).

Table 1. USGS gaging stations in Pleasant Valley.

Number	Station	Near	County	Drainage Area
09310500	Fish Creek	Scofield	Carbon	168 km^2 (65 mi^2)
09311000	Scofield Reservoir	Scofield	Carbon	401 km^2 (155 mi^2)
09311500	Price River	244 m (800 ft)	downstream of the dam	



Note: Pleasant Valley Creek is also known as Mud Creek.

Figure 5. Location of water sampling sites.

Table 2. Sheep allotments on the Manti-LaSal National Forest in the Pleasant Valley, Utah.

Allotment Name	Allotment	Dates
Bob Wright	1,013	July 1 to Sept. 30
Yellow Brush Flat and Trough Spring Ridge	1,849	July 1 to Sept. 30
Mon Peak	601	July 1 to Sept. 30
Coal Ridge	377	July 6 to Sept. 25
Burnout	678	July 1 to Sept. 25
Eccles	1,000	July 1 to Sept. 30
Bean Ridge	1,000	July 1 to Sept. 30
French Creek	1,156	July 1 to Sept. 30
Granger Ridge	1,156	July 1 to Sept. 30
Winter Quarters	848	July 1 to Sept. 30
Bennion	656	July 1 to Sept. 30
W. Bear	663	July 1 to Sept. 30
W. Fish Creek	897	July 1 to Sept. 30
E. Fish Creek	991	July 1 to Sept. 30
C Canyon	900	July 1 to Sept. 30
Silver Creek	936	July 1 to Sept. 30
Cabin Hollow	1,050	July 1 to Sept. 30
E. Gooseberry	269	July 1 to Oct 30
Mansion	727	July 1 to Oct. 30
Johnson Ridge	684	July 1 to Sept. 30
Pondtown	1,417	July 1 to Sept. 30
E. Bear Ridge	1,200	June 11 to Sept. 30

(Personal communication: USFS: Manti-LaSal National Forest 1980)

Recreation is characterized by boating and fishing in the summer, hunting in the fall, snowmobiling and cross-country skiing during the winter.

Population

The population of the town of Scofield and of the summer home develoments varies widely between the summer and winter seasons. Scofield boasts a year-round residency of 35, which increases to 150 during the summer months. The average family size is 3.18 people per household. The summer home developments are vacated during the winter and early spring, with the peak population occurring between Memorial Day and Labor Day (Southeastern Utah Association of Governments 1980). Bolotas subdivision and the County Street subdivision at the north end of the lake and Perry's boat camp just south of the outlet provide space for housing, camping, and other facilities mostly for summertime recreational use. A few residents stay all year. Some additional year-round homes are located in the settlement at Clear Creek and other scattered locations.

A State Park, which hosted 125,000 visitors during the summer of 1979, is located south of the county subdivision on the shoreline of the reservoir. Facilities include two trailers used as living quarters for the state rangers, parking area, a water supply obtained from a nearby 42 m (140 ft) well, a boat ramp, restrooms and a fish-cleaning station.

METHODS AND PROCEDURES

Selection of Sampling Sites

Several factors were considered during the selection of sampling sites: 1) likely locations for detection of contaminants; 2) wide areal coverage of the lower inhabited parts of the basin; 3) accessibility; 4) owners' permission; and 5) economics. Points where contaminants were likely to be detected were 1) down-gradient from tile or leach fields (particularly in areas where houses are clustered); 2) in valley alluvium downstream of possible pollution sources; and 3) in valley alluvium at the mouth of canyons where grazing occurred. Wide areal coverage provided a general sampling of groundwater contamination in the basin. Accessibility was a practical consideration in the drilling of wells and the collection of samples. Owners' permission dictated the location of several wells. Economics (well drilling costs and analytical costs) was a factor in determining the number of wells to be drilled.

Description of Individual Sampling Sites

Figures 5, 6, and 7 and Tables 3 and D-2 (Appendix D) show the well locations. Well #1, which is a flowing well, was the sole sampling station on the north end of the Scofield Reservoir, Utah. Wells #2, 3, and 4 are located in the Bolotas subdivision on the east shore of the Scofield Reservoir. Wells #5 and 6 are in the Scofield Reservoir Campsite subdivision. This subdivision and the Bolotas subdivision were characterized by clusters of the few score cottages. Contamination of the shallow groundwater and the reservoir by domestic waste from septic tank leach fields and pit privies might occur due to a high groundwater table (1.22 m from the ground surface) and the short distance between the shoreline and the cottages (less than 200 m). Well #7 is located down-gradient of the state park septic tank leach field which treats wastes produced from tourists and sportsmen during the spring, summer, and fall.

Well #8 is in Perry's Boat Camp. The owner designated a well location approximately one hundred meters southwest of the pit privies, which was not a good location to detect the pollutants from pit privies.

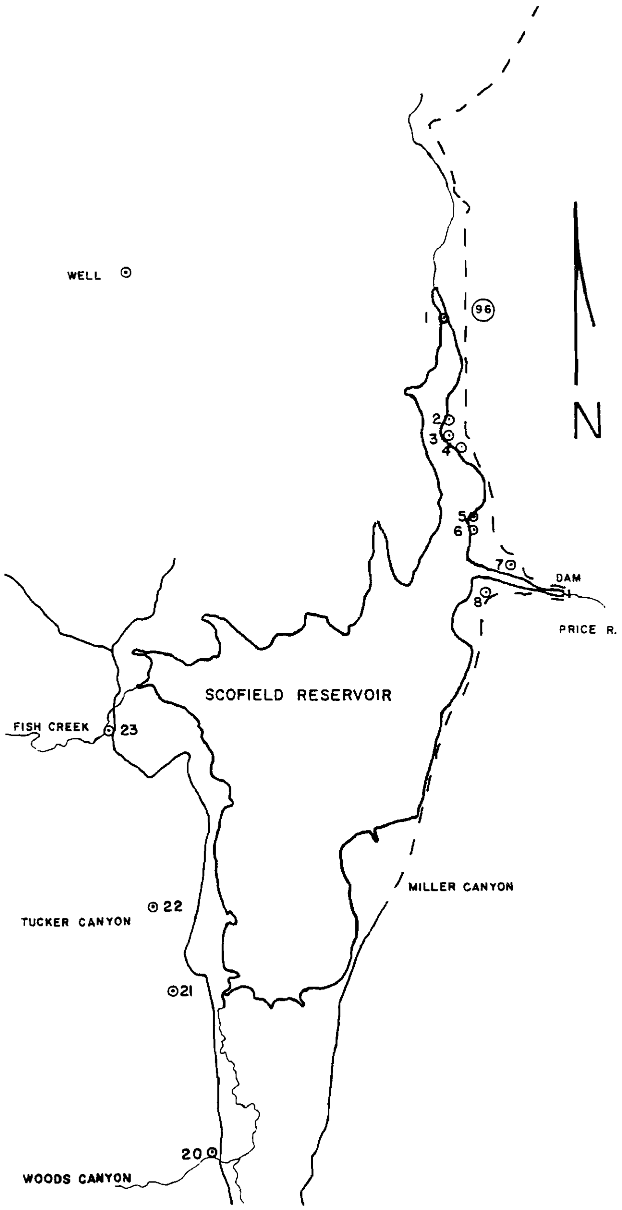


Figure 6. Location of groundwater observation wells adjacent to the Scofield Reservoir.

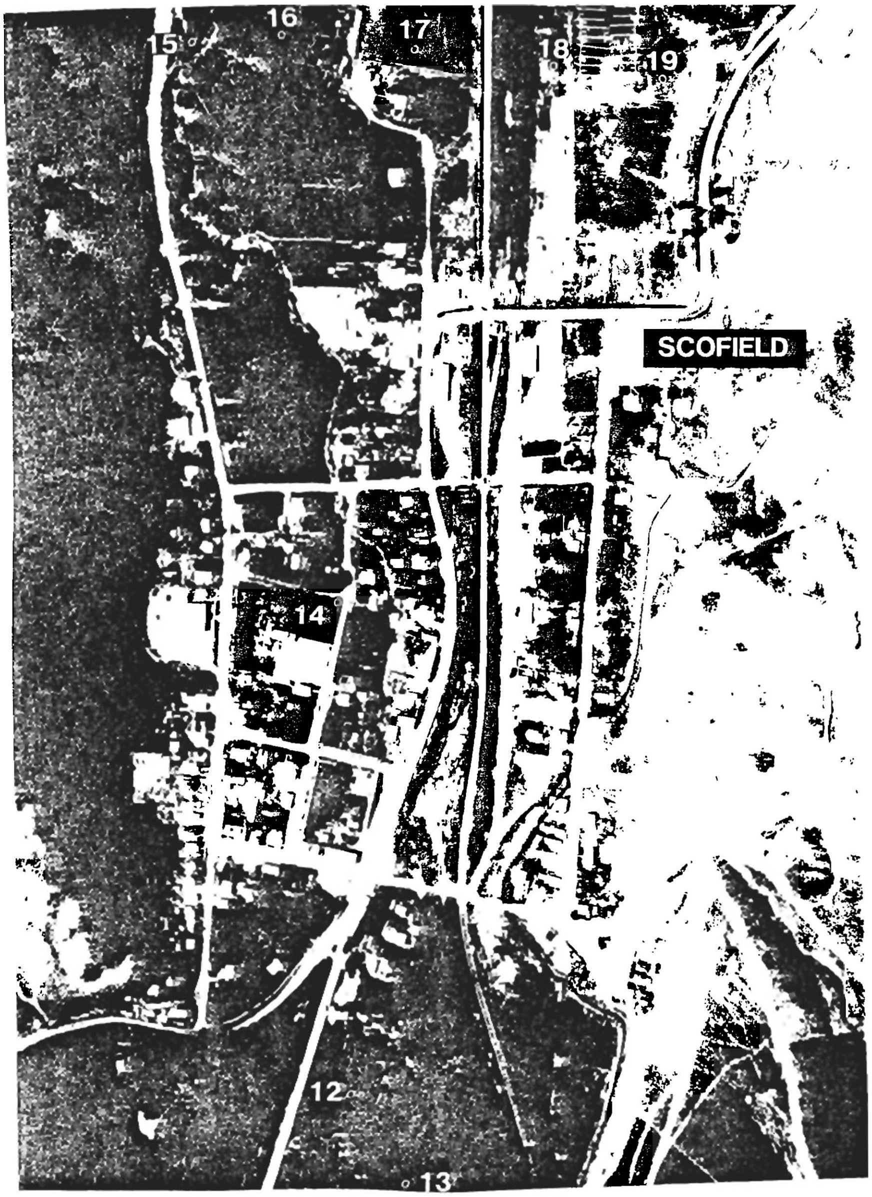


Figure 7. Town of Scofield and location of groundwater observation wells.

Well #9 is located in the Mud Creek alluvium, downstream of the town of Clear Creek and approximately 10 meters (33 feet) from the streambed. Although the exact location of the town communal tile leach field was unknown, the well was estimated to be downstream of the field. There are two surface water sampling sites near well #9 (Figure 5), wells #24 and 27 located south and north, respectively, of Clear Creek town.

Well #10 was drilled by a private firm under contract with Coastal States Energy Company. It is at the base of Eccles Canyon which was used mostly by hunters and picnickers prior to the beginning of coal company operations.

Well #11 was drilled in the Mud Creek alluvium at a distance of approximately 150 meters (490 feet) from the Valley Camp Coal Company leach field.

One cluster of four wells is located south of Scofield. Well #12 is located south of the town and west of Mud Creek in a pasture. Well #13 is nearby but east of Mud Creek. In addition, two uncased, un-numbered piezometers or observation wells were drilled only for the measurement of water table. Their location and the observations made in them are given in Table D-1 (Appendix D). Wells #12 and 13 were selected to define the groundwater quality upstream from the town of Scofield. The north group of wells (#15 to 19) was established to assess the

Table 3. Location of sampling sites.

Site	Location	Drilled Depth		Latitude	Longitude
		(m)	(ft)		
Well #1 (Flowing)	North Lake Location	6.10	20'	39° 48.75'	111° 8.25'
Well #2	Bolotas Subdivision, Orr	5.67	18'6"	39° 48.17'	111° 8.21'
Well #3	Bolotas Subdivision, Pappas	6.40	21'	39° 48.09'	111° 8.22'
Well #4	Bolotas Subdivision, Joufflas	6.10	20'	39° 48.03'	111° 8.12'
Well #5	County St. Subdiv., First Ave.	5.18	17'	39° 47.65'	111° 8.00'
Well #6	County St. Subdiv., 4th Ave.	5.49	18'	39° 47.58'	111° 8.03'
Well #7	State Park	5.33	17'6"	39° 47.43'	111° 7.82'
Well #8	Perry's Boat Camp	4.20	13'9½"	39° 47.25'	111° 7.96'
Well #9	Clear Creek	3.05	10'	39° 39.12'	111° 9.18'
Well #10	Eccles Canyon	8.33	27'4"	39° 41.08'	111° 9.45'
Well #11	Valley Camp Coal Co.	5.18	17'	39° 41.82'	111° 9.50'
Well #12	South Profile #1, Hallsten	2.59	8'6"	39° 43.30'	111° 9.70'
Well #13	South Profile #2, Tucker	2.89	9'6"	39° 43.28'	111° 9.60'
Well #14	Scofield Town	4.27	14'	39° 43.54'	111° 9.66'
Well #15	North Profile #1	3.35	11'	39° 43.84'	111° 9.71'
Well #16	North Profile #2	3.50	11'6	39° 43.83'	111° 9.65'
Well #17	North Profile #3	3.05	10'	39° 43.82'	111° 9.59'
Well #18	North Profile #4	2.74	9'	39° 43.81'	111° 9.53'
Well #19	North Profile #5	3.35	11'	39° 43.80'	111° 9.47'
Well #20	Woods Canyon	3.00	9'10"	39° 44.23	111° 9.90'
Well #21	Section 29 Canyon	5.03	16'6"	39° 45.11	111° 10.17'
Well #22	Mountain Home Subdivision	6.27	20'7"	39° 45.57'	111° 10.29'
Well #23	Fish Creek	4.42	14'6"	39° 46.53'	111° 10.56'
Surface Sample #24	South Edge of Clear Creek Town			39° 38.46'	111° 9.20'
Surface Sample #25	North Edge of Scofield			39° 43.66'	111° 9.64'
Surface Sample #26	Fish Creek			39° 46.65'	111° 10.54'
Surface Sample #27	North Edge of Clear Creek Town			39° 39.21'	111° 9.23'
Surface Sample #28	South Edge of Scofield			39° 43.36'	111° 9.40'

groundwater underflow and groundwater quality downstream of the town. The comparison of data from the wells north and south of the town was expected to provide information on the impact of the town of Scofield on groundwater quality. Surface sampling site #28 is in the Mud Creek near well #12.

Well #14 is located in the town of Scofield approximately 50 meters (160 feet) from Mud Creek. This well site was selected in an attempt to assess groundwater quality in a residential area. Surface water sampling site #25 was in the Mud Creek near well #15.

Well #20 is located at the mouth of Woods Canyon, 20 meters (66 feet) west of the road. The depth of this well was limited to 3 meters (10 feet) by an impassable boulder. Sulfur springs and seeps were found 75 meters (250 feet) up-gradient of well #20. Cattle and sheep graze in this canyon from June to September.

The location of well #21 was established at the mouth of a small canyon between Tucker Canyon and Woods Canyon. This well site was chosen to evaluate the groundwater quality of an undeveloped basin which was subject to occasional livestock grazing. Seeps are situated 60 meters (200 feet) northwest of the well.

Well #22 is located near the entrance to Mountain Home Subdivision in the valley alluvium of Tucker Canyon.

Well #23 is at the mouth of Fish Creek Canyon, 3 meters (10 feet) west of the road. The only human activity in the area was fishing. One surface sampling site, #26, was in Fish Creek near well #23. Wells #20 to 23 are located at the mouths of canyons in valley alluvium to monitor diffuse sources of pollution to the reservoir.

As indicated above, many wells were located to monitor point-source pollution, i.e., pollution originating from a well-defined source such as an individual septic tank system or a group of systems. Other sampling sites, such as surface water, were intended to monitor diffuse sources of pollution contributed from nature, town, livestock, and mines.

Drilling, Casing, and Developing the Observation Wells

A hydraulic auger was used to drill the first 3 meters (10 ft) of the 50 mm (2 in) diameter well. Soil samples were collected, labeled, and logged. A 50 mm (2 in) diameter steel pipe was used as a temporary well casing. Well logs are in Appendix D.

Beyond the 3-meter depth attainable by the auger, a manually operated jet-drill (Figure 8) was employed to reach up to 6.4 m (21 ft). The drill consisted of a bit, a 38 mm (1.5 in) pipe, and a handlebar. The bit at the end of the pipe consisted of three triangular-shaped cutting edges to cut and grind the soil as the pipe was manually rotated and forced downward. As new sections of pipe were added to the temporary casing, the handlebar was momentarily attached to the 50 mm (2 in) pipe for grinding and widening of the well.

A three hp Briggs and Stratton pump injected drilling mud into the well via the 38 mm (1.5 in) diameter pipe being used as a drill shaft. Manual drilling continued to a depth of up to 6.4 m (21 ft) or until a boulder blocked further progress.

Near the well, a small settling pit and circulation pit were dug and coated with bentonite clay (Figure 8). Under pressure from the pump through the cutting pipe, mud flowed from the well carrying sand, clay, and bits of gravel into the settling pit from which samples were collected and recorded. Then, the mud flowed into the circulation pond where the suction line of the pump was located.

After the well was drilled, the mud and fine particles in the well were removed by 30 minutes to 1 hour of intermittent surging.

PVC pipe (25 mm (1 in) inside diameter) was cut to fit from the bottom of the hole to the ground surface. Slots were cut with a hacksaw perpendicular to the center line of the line at 75 to 100 mm (3 to 4 in) intervals, alternating on each side of the pipe. A 25 mm (1 in) outside diameter metal pipe was slid up and down inside the PVC pipe to clean out shavings. Pipe lengths longer than 3.6 m (12 feet) long were temporarily strengthened by a steel pipe before insertion to provide additional protection against bending. With the PVC pipe in place, the 50 mm (2 in) temporary steel pipe casing was removed (Figure 9).

A 50 mm (2 in) diameter surface pipe, 0.3 m to 0.45 m (12 in to 18 in) long, was cut and threaded on the top end. A cap, greased to prevent rusting and freezing, was screwed onto the surface pipe. This unit was then placed over the PVC pipe and cemented to a depth of 0.3 m (1 foot) (Figure 9). The cement plug around the top of the casing had a diameter of 150 to 250 mm (6 to 10 in). The cementation was intended to stabilize the surface pipe and prevent contamination by surface drainage into the well.

All wells were pumped (developed) to eliminate fines and sands in order to provide fairly clean water samples and establish transport of water from the aquifer. Wells were pumped until the effluent was fairly clean. Continued surging, however, usually

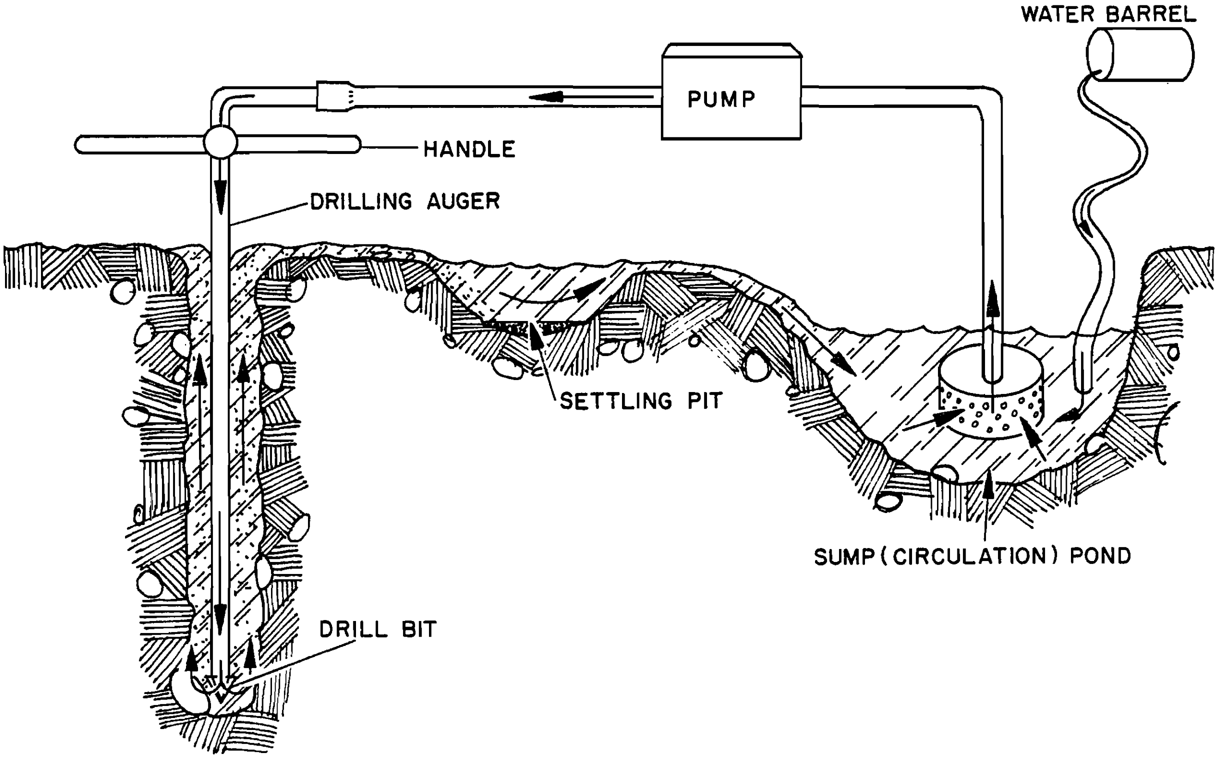


Figure 8. The jet drill.

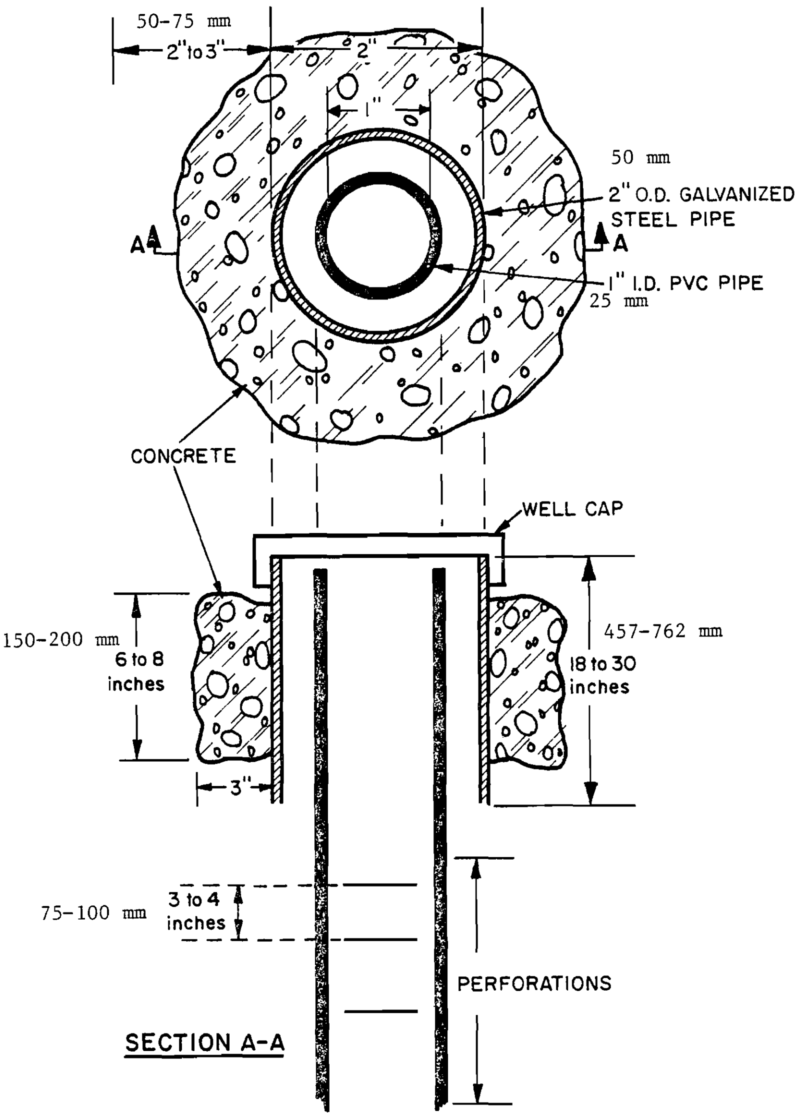


Figure 9. Plan and section views of well and casing.

resulted in additional turbidity for a short time.

A maximum pumping rate of 15 ℓ/min (4 gpm) was realized with the 12.9 mm (0.5 in) diameter suction pipe. Higher pumping rates could be attained on some wells using a larger suction hose.

Location maps were drawn in order to facilitate location of the wells by other parties and under snow cover. Prominent landmarks were selected for distance and bearing measurements. Near the wells used to establish profiles north and south of Scofield, two piezometers each were installed near a well to form an equilateral triangle with the well in order to determine the direction of the hydraulic gradient of the groundwater under the valley floor. Locations of and data from the piezometers are given in Table D-1 (Appendix D).

Grain Size Analyses of Cuttings from Selected Observation Wells

A grain-size determination of cuttings from selected observation wells (#1, 3, 6, 7, 9, 11, 13, 14, 16, and 23) was performed to aid in the estimation of aquifer characteristics. The wells selected for grain size study were chosen to give some insight into the variation in the sediments in the shallow groundwater aquifer(s) throughout the study area.

The gravel to fine sand size fractions (coarser than 0.062 mm) were determined by wet sieve analysis. The silt and clay size fraction (< 0.062 mm) was calculated from the excess after sieving, except in the case of selected samples from wells #3, 7, and 14 which were determined by sedimentation cylinder techniques. The sample (15-20 grams) was placed in a 100 ml beaker and mixed with deionized water and a clay mineral dispersant (sodium hexametophosphate). To insure dispersion of the clay minerals, the sample was subjected to ultrasonic disaggregation using a Bronwell Biosonic III disaggregator. Size fractions were then determined from observations of settling time and amount.

Grain-size distributions of the samples are shown in Appendix E.

X-Ray Mineralogy

Samples of cuttings from 22 of the study wells in the Scofield area were analyzed for mineral composition by x-ray diffraction techniques. The analyses were performed so that estimates of the effects of the soil and sediment on groundwater passing through them could be made. These effects would be either chemical--in terms of materials easily dissolved by groundwater, such as gypsum or calcite, or as exchangeable constitutents easily removed and exchanged from clay minerals, or biological--for example, the adsorption of organic chemicals on clay mineral surfaces.

Sediments containing large quantities of clay minerals, especially the mineral montmorillonite, would be likely to produce the greatest effects on groundwater quality. Montmorillonite is a clay mineral with a very high cation-exchange-capacity. Thus it is possible that groundwater passing through a montmorillonite-rich sediment could completely alter its chemical makeup, exchanging one ion for another, Na^+ for Ca^{+2} for example, because of the influence of the clay mineral. Such a clay-rich sediment would also tend to remove organic contaminants from the groundwater very rapidly by adsorption of the contaminants onto the clay mineral surfaces.

Sediments in which the dominant clay mineral is kaolinite or illite would have a much lower cation-exchange-capacity, and consequently would probably not exert as large an influence in the chemistry of the groundwater. Such clay minerals also have a small amount of surface area and lower charge with which to adsorb organic contaminants.

In order to determine the mineral composition, approximately 25 grams of each sample were placed in a 50 ml beaker and covered with about 40 ml of distilled water and 5 ml of a saturated solution of sodium hexametaphosphate. This solution acts as a dispersant, breaking up and dispersing clay mineral particles. A Biosonic III ultrasonic source was then used to disaggregate and disperse the sample.

Dispersed samples were allowed to settle for 10-15 minutes. A small amount of the dispersed sample was then withdrawn from the upper 3 cm of the beaker using an eyedropper. The time interval of 10-15 minutes allowed the sediment coarser than about 16 microns to settle below the withdrawal depth. The sample was transferred to a small, clean glass plate and allowed to dry. During the drying process the clay minerals became oriented, with their platy structure oriented parallel with the surface of the glass plate. This orientation is necessary for identification of the different clay minerals in which the major structural difference is in the basal spacing.

Samples were analyzed on a Siemens Krystalloflex IV x-ray machine, with a copper tube and a nickel filter, producing copper K_α radiation. Samples were scanned from 2° to 35° 2 θ, covering all major peaks of the clay minerals, and also those of quartz, calcite, dolomite, and feldspars as well. After the first scan, samples showing peaks suggesting the presence of montmorillonite were placed in a desiccator containing ethylene glycol. The desiccator was then heated to 65°C for one hour. This process enables ethylene glycol vapor to enter the montmorillonite crystal structure and expand it. Glycolated samples were then analyzed a second time on the x-ray for the presence of montmorillonite. In some cases an expandable component appeared to be present in the sample. However, the component was too poorly crystalline to produce a good diffraction maximum. In such cases the analysis was shown as "expandable," but without actually applying the mineral name "montmorillonite."

Results of the x-ray analyses are shown in Appendix F and are discussed later.

Hydraulic Conductivity (Permeability), K, in Selected Wells

The permeability of the alluvial material was determined by slug tests of selected wells. The procedures outlined in Bouwer (1978, p. 114-115) were followed as described below.

The undisturbed static water level was determined. A bailer of known capacity was lowered into the well and quickly removed (within five seconds). The water level in the well was then measured at various times after removal of the bailer. The equations shown below as given by Bouwer (1978) were used to calculate K. The distance y_o (drawdown the instant after the bailer was removed) was estimated from the known volume of water removed from the casing.

$$K = \frac{r_c^2 \ln (R_e/r_w)}{2 L_e} \; \frac{1}{t} \ln \frac{y_o}{y_t} \quad . \quad . \quad . \quad . \qquad (1)$$

$$\ln (R_e/r_w) = \frac{1}{\dfrac{1.1}{\ln (L_w/r_w)} + \dfrac{A+B \ln (H-L_w)/r_w}{(L_e/r_w)}} \quad . \qquad (2)$$

in which

R_e = Effective radius of well (cm)

r_w = Radial distance from center of well to undisturbed aquifer material (cm)

L_e = Perforated length of well (cm)

y_o = Drawdown at time zero (cm)

y_t = Drawdown at time t (cm)

t = Time since y_o (cm)

A,B, = Dimensionless parameters from experience, see Bouwer (1978)

H = Aquifer thickness (cm)

K = Permeability (cm/sec)

Results of slug tests in selected wells are reported in Appendix G.

Shallow Seismic Surveys

To determine the depth to bedrock where groundwater underflow estimates were wanted, shallow seismic refraction surveys were made at the sites shown in Figure 10 with a Nimbus Instruments Model ES-125 signal enhancement seismograph. With the geophone at a fixed location, the striker plate and hammer were moved from point to point along the straight line traverse. At each point the striker plate was hit with many hammer blows until the arrival time signal could be clearly read on the display. The distance from geophone to striker plate and the in Appendix H. Distance and arrival time were then plotted as in Figures H-1 through H-3 and straight lines fitted to the data. The shape of the first arrival time plots are those of the classic three layer problems. Once the locations of the breaks in the data plots are known, the depths to each layer can be calculated using the equations

$$d_1 = \frac{X_1}{2} \sqrt{\frac{V_2 - V_1}{V_2 + V_1}} \quad . \; . \; . \; . \; . \; . \; . \qquad (3)$$

and

$$d_2 = 0.8\, d_1 + \frac{X_2}{2} \sqrt{\frac{V_3 - V_2}{V_3 + V_2}} \quad . \; . \; . \; . \qquad (4)$$

where V_1, V_2, and V_3 are the velocities of sound waves in the first three layers as shown in Figure H-1 (m/sec), Appendix H; d_1 and d_2 are depths to the first and second interfaces (m); X_1 and X_2 are the distances from the initial point to the first and second breaks in the plotted data (m). Because the velocity of sound changes at the water table and again at bedrock, generally d_1 is the depth through dry alluvial material to the water table and d_2 is the depth through dry and wet alluvial material to bedrock.

Groundwater Movement

From the estimated depths to the water table and to bedrock at the north profile near Scofield an approximate cross-section of the valley fill was prepared as in Figure J-1 (Appendix J). The saturated area can then be determined. From the water table elvations further upstream, the slope of the water table along the valley can be determined. Then since the hydraulic conductivity is known from the slug tests described earlier, an estimate of the groundwater underflow passing the town of Scofield is given by Darcy's law.

$$Q = K\, i\, A \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \qquad (5)$$

in which Q is the flow rate (m^3/sec), K is the hydraulic conductivity (m/sec), i is the slope of the water table (dimensionless), A is the saturated area of the valley fill (m^2).

Results of this calculation are given in a later section and in Appendix J.

Water Sampling Procedures

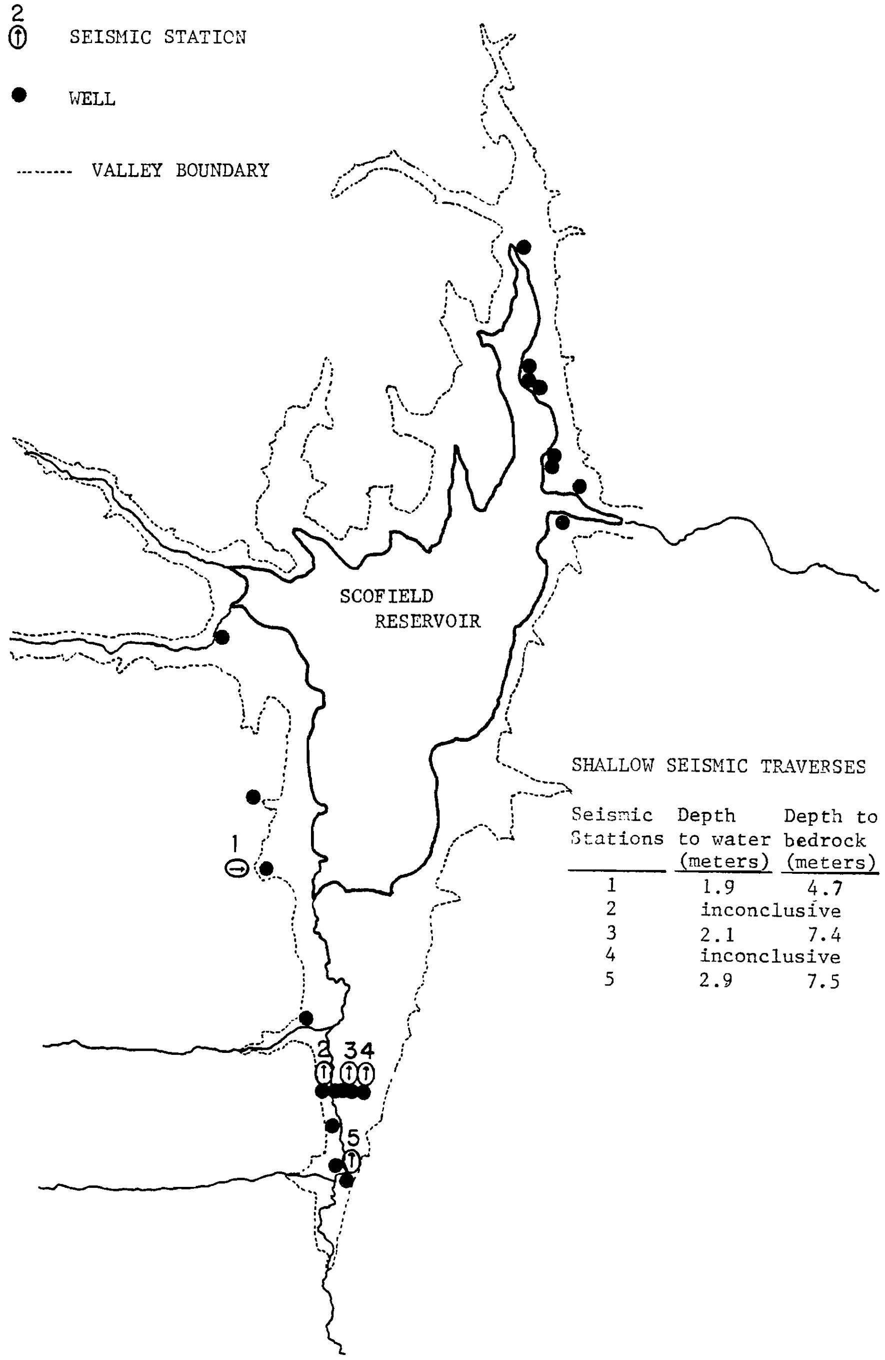
Taking a set of samples requires organization of equipment, instruments, and schedules. The necessary equipment and instruments are listed in Table L-1, Appendix L. Most water samples were collected from the study area in October and November 1979, and February, April, May, June, July, and August 1980. A few samples were taken in September 1979 and December 1979.

When those taking the samples arrived at the site, the previously prepared maps were used to locate the wells or surface sampling sites. Often wood stakes, large rocks, ribbons, or a nearby structure facilitated the search. These were particularly helpful when snow covered the sites.

After a well was located, precautions were taken to minimize the possibility of well contamination. Excess soil, snow, and vegetation were brushed away from the well.

Upon removal of the well cap and a cursory well inspection, the static water level was measured and recorded. The cap was replaced and the electrodes (for pH and D.O. tests) were rinsed with sterile distilled water.

The preparation for pumping began with the convenient arrangement of the 12-volt car battery and the peristaltic pump. The pumps used were made by Instrumentation Specialties Company, Model 1580; and Cole-Parmer Instruments Company, Portable Masterflex, 7573-60. The electrical leads were attached to the proper terminals and the appropriate suction tube was unwrapped and placed in the chamber of the pump. The well cap was again removed and the suction end of the tube was lowered down the well, while the pressure end of the



SHALLOW SEISMIC TRAVERSES

Seismic Stations	Depth to water (meters)	Depth to bedrock (meters)
1	1.9	4.7
2	inconclusive	
3	2.1	7.4
4	inconclusive	
5	2.9	7.5

Figure 10. Shallow seismic traverses.

tubing was placed in the 3.8 liter (1 gallon) jug. Aluminum foil was used to cover the well in order to avoid well contamination during pumping. Pumping proceeded for 10 minutes before any samples were taken so that water was drawn into the well from the aquifer. During the pumping, adjustment of the length of the suction tube in the well was required when air was pumped or when turbidity became excessive due to contact between the hose and the well bottom.

Field measurements included air and water temperature, dissolved oxygen, and pH. Water samples taken in October and November 1979, and February 1980 were collected in a plastic 3.8 liter (1 gallon) jug, a plastic 200 ml bottle for heavy metals, a sterile 150 ml glass bottle for coliforms, and a plastic bag for coliforms. The water sample contained in the plastic bag was used as a back-up sample in case of loss of coliform samples due to bottle breakage. During the April to

August 1980 sampling periods, two 3.8 liter containers were used for several wells to provide enough water for seeded BOD analyses on a number of the samples.

Inasmuch as the elapsed time between sampling and analyzing was nearly 32 hours for some samples, a delayed-incubation MF method (EPA 1978) was used in May. 10 ml and 100 ml samples for the total coliform microorganisms were filtered through a 0.45 μ pore size membrane filter, using a filtering flask (of ground glass) connected to a pump which provides a vacuum and draws water through the filter. The filter was placed in a petri dish with the holding medium. The holding medium served to keep coliform alive in the filter paper, but did not allow the bacteria to grow. The holding medium was prepared one day in advance of the sampling date and inspected for contamination before leaving the lab. The usual glass-bottle samples were taken for the purpose of comparison between the Membrane Filter Method and the Delayed-Incubation Membrane Filter Method. Comparable results were obtained (see Appendix E). Tweezers were sanitized by rinsing in 70 percent ethyl alcohol and flaming. The funnel and filter were sanitized by immersion in 70 percent ethyl alcohol for a least 20 minutes, followed by rinsing with well water and sterile peptone water. Autoclaved 0.1 percent peptone water with pH of 7.0 ± 0.1 was used.

Labels on all containers indicated the site number and appropriate analyses to be conducted. Field book entries were then checked for completeness with regard to place, time, date, and pertinent observations. Sample bottles were placed in a large container (cooler) for the purpose of maintaining the sample at a temperature just above the freezing point. During the winter, a number of the samples (particularly the coliform samples) froze during transport from the field well sites to the pickup truck. Freezing of a water sample will drastically increase the rate of coliform kill. Fecal coliform is very sensitive to freezing conditions. Therefore, frozen samples were not analyzed for bacteria contamination. In more moderate temperatures, the samples were packed with snow or ice in a cooler to maintain samples at a temperature just above the freezing point.

Nitrate- and nitrite-nitrogen was preserved in the field by adding concentrated sulfuric acid to the sample (APHA et al. 1976). In addition heavy metals were preserved by acidifying the sample. Five (5) ml concentrated nitric acid per liter of sample was added at the time of sampling (APHA et al. 1976).

Upon completion of sampling, the equipment and hose were removed from the well site. The well cap was greased, if necessary, and replaced. Based on the samples taken the first two months and in order to improve the reliability of the data, modifications were planned for the continuing analyses on the project. Particulates in turbid samples can mask coliform colonies on the filter after incubation or heavy metals may kill bacteria by toxicity. The toxicity problem was handled by the addition of a chelating agent which suspends heavy metals (EPA 1978).

As shown in Appendix A, concentrations of zinc exceed the threshold requiring the chelating agent for many wells.

Water Quality Analysis and Methods Employed

Water samples were analyzed for various combinations of physical, chemical, and biological water quality parameters (Table 4). Water quality analysis data in Appendix A give the results of each test.

Among the various water quality parameters, only certain analyses were common to all wells and all samples throughout the entire study period. These parameters included temperature, pH, coliform bacteria, ammonia-N, nitrite-N, nitrate-N, orthophosphate, total phosphorus, BOD_5, and specific conductivity. This partial water quality analysis was performed on water samples obtained from wells #1, 8, 10, 18, 20, and 22 throughout the entire study period. Water collected from the remaining sampling sites was tested for all the parameters of Table 4. Complete analyses were conducted on certain well water only once (wells #11, 12, 14, 15, 17, 19, and 21)

The availability of trailers equipped with laboratory facilities enabled more field measurements to be made during the July and August 1980 sampling period. In addition to pH, temperature, and DO, parameters measured in the field mobile laboratory were BOD_5, orthophosphate, ammonia-nitrogen, coliform bacteria, and fecal streptococci.

Temperature was measured with mercury thermometers which had been calibrated with a standard certified thermometer. pH was measured with a portable battery operated pH meter. The pH meter was calibrated immediately prior to use in the field, using pH buffers 4.0, 7.0, and 9.0. Dissolved oxygen was measured by DO meters in the beginning of the study. Due to freezing of electrodes and apparent malfunction, the DO meter was replaced by Hach Kits during November 1979, February and April 1980 sampling. During the May through August 1980 sampling periods, the Winkler method azide modification (APHA et al. 1976) was used.

Bacteriological tests of water samples included total coliform and fecal coliform until the June 1980 sampling period. Fecal streptococci (APHA et al. 1976) were measured in July and August 1980. Here, a 0.45 μ filter was used to filter a 10 ml and 100 ml water sample. After incubation, the number of colonies that developed was counted.

Table 4. Water quality parameters and procedures for analyses performed.

Biochemical Oxygen Demand (BOD_5)	Standard Methods	APHA et al. 1976
Total Coliform	Standard Methods (Membrane)	APHA et al. 1976
Fecal Coliform	Standard Methods (Membrane)	APHA et al. 1976
Fecal STreptococci	Standard Methods (Membrane)	APHA et al. 1976
MBAS	Standard Methods (Surfactants)	APHA et al. 1976
Fluoride	Standard Methods	APHA et al. 1976
Total Dissolved Solids	Standard Methods	APHA et al. 1976
Total Phosphorus	EPA Methods	EPA 1976
Orthophosphorus	Strickland & Parsons (Murphy-Riley Technique)	Strickland & Parsons 1968
Ammonia	Solorzano (Indophenol)	Solorzano 1969
Nitrite	Strickland & Parsons (Diasotization Method)	Strickland & Parsons 1968
Nitrate	Strickland & Parsons (Cadmium-Reduction Method)	Strickland & Parsons 1968
Heavy Metals (i.e. Cd, Mo, Mn, Cu, Co)	Standard Methods (Atomic Absorption Spectrophotometry)	
Calcium	Standard Methods	APHA et al. 1976
Magnesium	Standard Methods	APHA et al. 1976
Potassium	Standard Methods (Atomic Absorption Spectrophotometry)	APHA et al. 1976
Sodium	Standard Methods (Atomic Absorption Spectrophotometry)	APHA et al. 1976
Boron	Standard Methods (Atomic Absorption Spectrometry)	APHA et al. 1976
Chloride	Standard Methods	APHA et al. 1976
Alkalinity	Standard Methods	APHA et al. 1976
Temperature	Standard Methods	APHA et al. 1976
Conductivity	Standard Methods	APHA et al. 1976
Sulfate	Standard Methods	APHA et al. 1976
Dissolved Oxygen	Standard Methods	APHA et al. 1976
pH	Standard Methods	APHA et al. 1976

WASTEWATER DISPOSAL PRACTICE IN THE STUDY AREA

To ascertain the waste disposal practices in the study area, a questionnaire (Appendix K) was circulated to residents or home owners of the area during May 1980. After the responses to the questionnaire were received and evaluated, personal contacts were made with as many of the remaining residents of the study area as possible during July 1980.

The total number of responses to the questionnaire was 126 out of 292, or 43.1 percent (Table 5). The higher percentage returns of responses came from Bolotas (58.6 percent), Scofield Campsite (50.9 percent), and Mountain Home (55.5 percent). The lowest number of questionnaire returns came from the town of Scofield (17.1 percent).

Waste disposal systems being employed in the study area included septic tank with leach field system, cesspools, pit privy, holding tank, and a combination of these systems. In general, the stricter the regulation of waste disposal systems, the better the system. Residences in newly developing subdivisions such as Mountain Home and Aspen View have septic tank systems installed. Each septic tank system was inspected by the county health office. In contrast, wastewater produced in other subdivisions in the study areas is not treated solely by septic tank systems. The distribution of waste disposal systems for each subdivision is summarized in Table 6. The data shown in this table have been computed based upon the survey results. However, as shown in Table 5, the response was not complete.

Table 5. Responses to the questionnaire.[a]

Subdivision	Number of Residences	Number of Responses	Percent of Responses
Bolotas	99	58	58.6
Scofield Campsite	55	28	50.9
Mountain Retreat	12	3	25.0
Mountain Home	29	19	55.5
Aspenview	21	5	23.8
Scofield Town	76	13	17.1
Total	292	126	43.1

[a] Includes responses by personal contact.

The septic tank with leach field system was the most popular waste disposal system in the study area (65.5 percent of the total number of residences use this system). There were at least two different septic tank systems in the study area. One was a true septic tank, and the other was a cesspool with leach field which was called a septic tank by the resident or owner of the area.

The septic tank systems in the study areas consisted of a single compartment and a leach field (Figure 11). The average size of compartments was 3.4 m^3 (900 gal), and ranged from 1.9 m^3 (500 gal) to 3.8 m^3 (1000 gal). The major building materials used in the construction of septic tanks were concrete and steel; sometimes masonry had been used. Trenches were common adsorption systems in the study area. The distribution pipe size in the adsorption field averaged 10 cm (4 in) in diameter, varying from 3.8 cm (1.5 in) to 15.2 cm (6 in). Clay, steel, and PVC pipes were used. The underlying soil was different in each subdivision. In general, the soil profile consisted of silt, sand, fine gravel, and coarse gravel from the top

Table 6. Type of waste disposal systems in the study area (expressed in percentage).

Subdivision	Septic Tank	Holding Tank	Pit Privy	Septic Tank Plus Pit Privy	Holding Tank Plus Pit Privy
Bolotas	60.4	24.6	11.0	2.7	1.3
Scofield Campsite	33.0	11.0	33.0	20.0	3.0
Mountain Retreat	75.0	--	--	25.0	--
Mountain Home	100.0	--	--	--	--
Aspen View	100.0	--	--	--	--
Scofield Town	71.0	7.0	14.0	7.0	--
Total	65.5	12.4	13.6	7.5	1.0

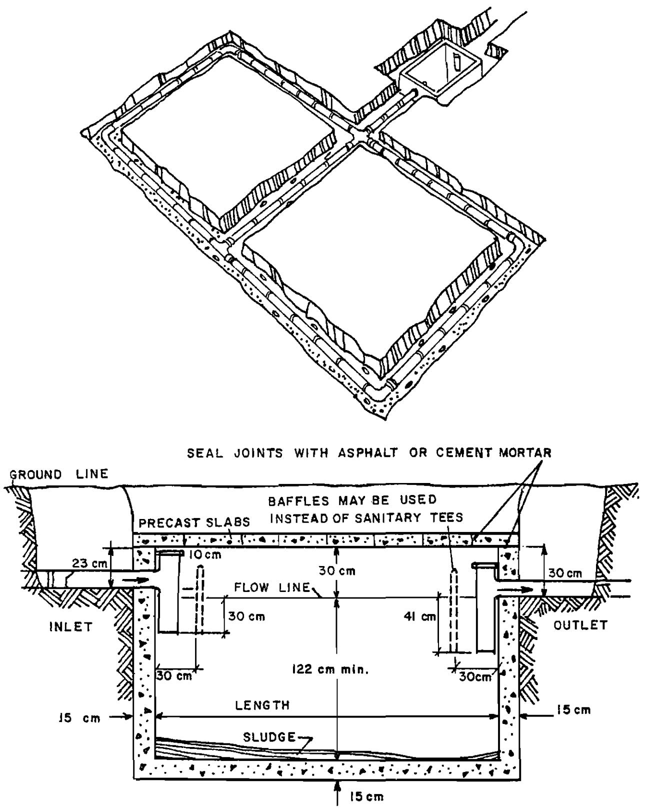


Figure 11. Typical septic tank: absorption field (trenches) on top and longitudinal section of concrete septic tank at the bottom (Clark, Viessman, and Hammer 1977, p. 615, 617).

to the bottom. The well log data are presented in Appendix D. The leach field area (possibly determined by the percolation test) may vary significantly between each subdivision. Mountain Home septic tank systems were installed according to guidelines reported in The USPHS Septic Tank Manual (1957). The percolation test reported data which indicated that percolation rates varied from 5.9 min/cm (15 min/in) to 2 min/cm (5 min/in). The depth of the groundwater table, if any, was also measured.

Seepage pits have been widely used in the Mountain Home subdivision instead of the leach field by drain pipes. The general dimension of the seepage pit used was 2.13 m (7 ft) or 2.43 m (8 ft) wide by 9.14 m (30 ft) long and 0.61 m (2 ft) or 0.91 m (3 ft) deep (Figure 12). A seepage pit is a covered excavation with an open joint lining through which effluent from the septic tank compartment may seep or leach into the surrounding soil. Drain fields or trench systems use tiled, porous drains embedded in gravel which distribute effluent into the surrounding soil. However, information obtained from the field survey and questionnaire revealed the existence of unsuitable waste disposal systems in other subdivisions.

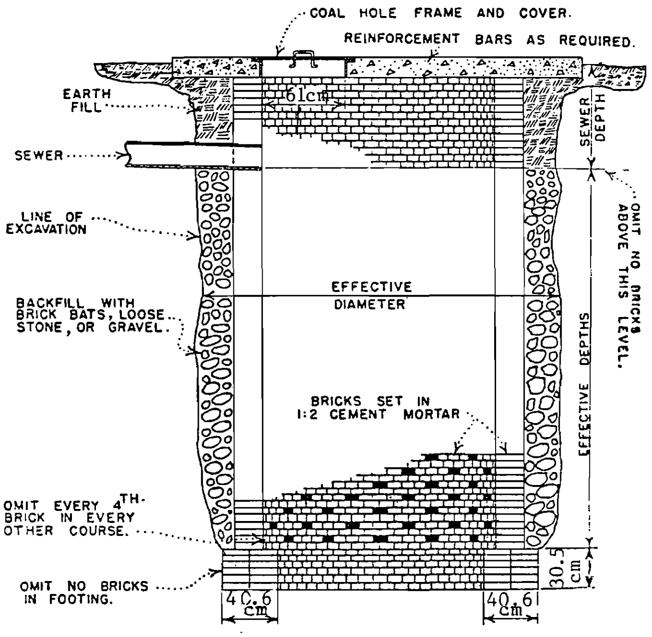


Figure 12. Sectional view of seepage pit (Hopkins and Schulze 1958).

The fundamental design criteria concerning the applicability of septic tank systems in the study area is related to the groundwater table elevation. The Manual of Septic Tank Practice (1957) states, "the maximum elevation of the groundwater table should be at least 1.22 m (4 ft) below the ground surface." However, in certain locations, the current groundwater table elevation was so shallow (less than 1.16 m) that the guidelines set by USPHS could not have been met. The groundwater table elevation in well #14, located in the town of Scofield (Figure 13), varied from 0.6 m (1.96 ft) to 1.16 m (3.81 ft) during the period from October 1979 to August 1980. The groundwater elevation beneath Bolotas and Scofield Campsite subdivisions, which border Scofield Reservoir, fluctuated from 0.52 m (1.7 ft) to 4.17 m (13.62 ft) during the study period. The septic tank effluent may discharge into the reservoir, because the septic tanks are located close to the reservoir shore. Most of the septic tanks are within 100 m (328 ft) of the reservoir shore. The nearest residence was along the shore.

The fluctuation of the groundwater table is summarized in Table 7. Well 14 maintained a water table elevation always less than 1.2 m (4 ft) from the ground surface throughout the entire study period. Groundwater depth from the surface of wells #3, 5, and 14 are shown in Figure 13.

Wells #3, 5, and 14 represent the groundwater fluctuations underneath Bolotas, Scofield Campsite, and the town of Scofield, respectively.

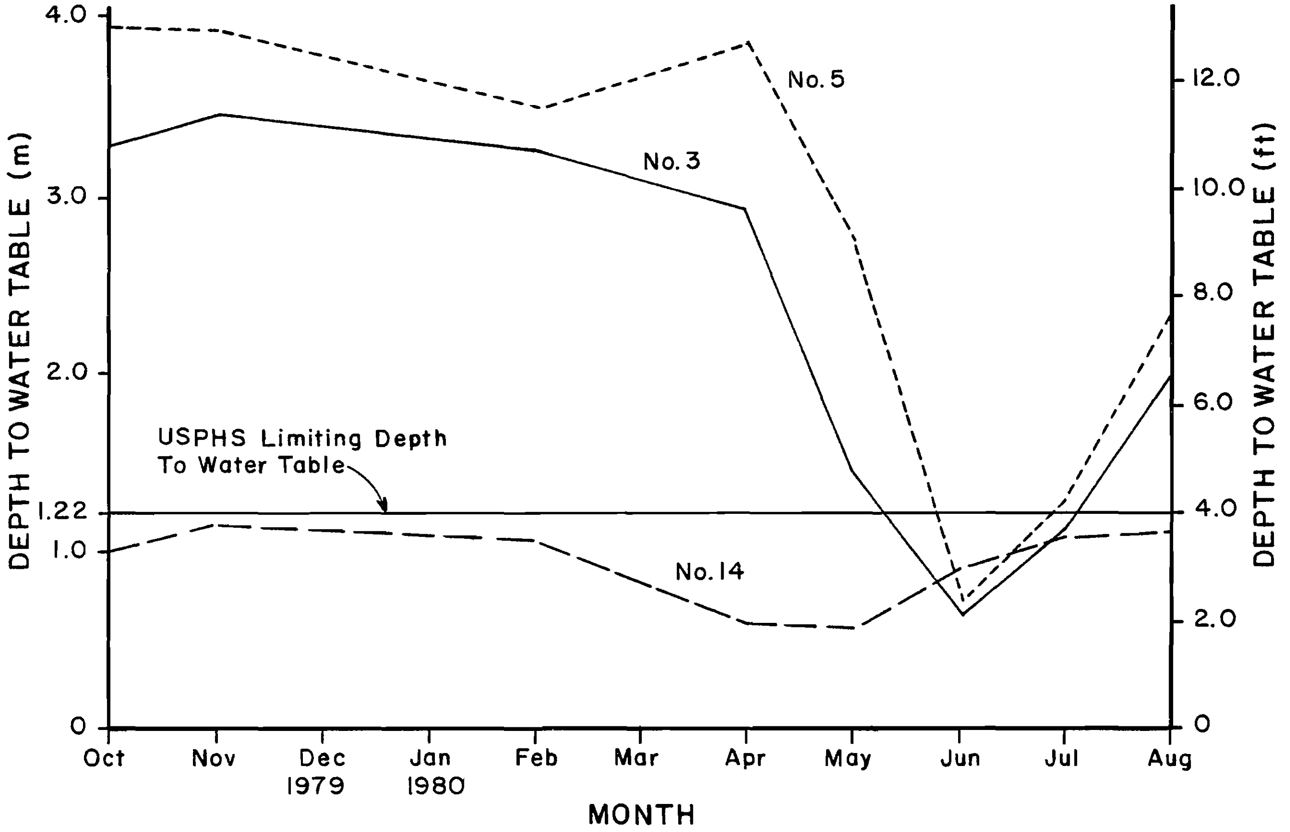


Figure 13. Depth of water table in wells #3, 5, and 14.

Table 7. Depth to water table (measured from the ground surface) in meters.

Well #	Oct	Nov	Feb	Apr	May	Jun	Jul	Aug
2	3.26	3.4	3.13	2.99	1.34	0.48	1.06	1.93
3	3.28	3.47	3.26	2.93	1.47	0.64	1.11	1.99
4	4.03	4.15	--	3.7	2.37	1. 8	1.98	2.69
5	3.96	3.95	3.5	3.86	2.76	0.74	1.29	2.38
6	3.86	3.81	3.4	3.77	2.69	0.66	1.21	2.31
7	3.86	3.89	3.2	2.27	2.1	1.54	2.13	2.9
8	Dry	Dry	--	--	2.0	1.11	1.82	2.9
9	1.05	1.29	0.61	0.38	0.5	0.53	0.6	0.69
10	2.13	2.20	1.86	1.13	1.29	1.65	1.85	--
11	2.2	2.18	--	1.13	1.15	1.42	2.05	2.31
12	0.81	0.95	0.83	0.44	0.59	0.67	0.6	0.75
13	1.06	1.15	1.06	--	0.45	1.4	1.78	1.92
14	1.01	1.16	1.08	0.62	0.59	0.9	1.09	1.13
15	1.21	1.22	1.21	--	0.78	0.95	1.67	1.55
16	0.56	1.22	1.58	0.55	0.66	1.31	1.82	2.06
17	--	2.41	2.86	2.31	1.49	2.21	2.84	Dry
18	1.51	2.24	--	1.77	1.67	2.0	2.56	Dry
19	2.43	3.05	--	2.95	2.18	2.74	3.22	Dry
20	Dry	Dry	--	Dry	1.16	0.05	0.25	1.33
21	1.02	1.11	--	1.53	1.66	0.33	0.81	0.96
22	--	--	--	5.5	flowing	flowing	0.17	3.84
23	--	--	--	1.81	--	flooded	0.6	1.52

Maintenance of septic tank systems was neglected by most homeowners. Out of 126 responses, no one indicated that their septic tank had ever been pumped out since installation. Some tanks are relatively new ones (less than two years old), and others much older. Accumulated solids in a septic tank should be pumped out every few years as needed. Failure to clean out the accumulated mass may lead to the failure of the system. There was only one individual, however, who reported a system malfunction which produced terrible odors. The septic tank system was installed ten years ago and should have been pumped clean some years ago. This odor problem usually can be solved by pumping the sludge from the septic tank regularly.

A large number of individuals stated they had introduced chemical or biological conditioner into the septic tank. Generally, they put yeast or lime into the septic tank at the end of fall when they stopped using the cabin and cottage. This procedure may help to reduce the odor problems temporarily, but is not a permanent solution to the problem. The Manual of Septic Tank Practice (USPHS 1957) also states that such activities are ineffective.

Cesspools, which some owners mistakenly regard as septic tanks, also are found in the study area. Septic tank percent utilization data listed in Table 7 includes cesspools in the septic tank category. It was uncertain from the questionnaires how many homeowners regarded cesspools as septic tanks. The information obtained from the owner of one cottage revealed its cesspool size is 6.1 m (20 ft) by 6.1 m (20 ft) with 1.83 m (6 ft) depth. The cesspool has rocks and gravel on its bottom layer. This kind of waste disposal in the study area is not desirable because it gives inadequate treatment to the wastes especially with the high water table elevation and the short distance from the reservoir. Cesspools may also be relatively abundant in the Bolotas and Scofield Campsite subdivisions.

The pit privy is the next most popular (approximately 14 percent of total wastewater treatment systems were pit privies) waste disposal system in the study area. Scofield Campsite has 9 pit privies out of 28 wastewater treatment systems (33 percent). The general size of the pit privy is about 0.91 m (3 ft) by 1.22 m (4 ft), and 1.83 m (6 ft) or 2.13 m (7 ft) deep. New pits are dug approximately every five years, depending on the situation. Since it was not feasible to connect the kitchen sink waste to the pit privy, several people in this area had a holding tank, septic tank, or cesspool to treat these waste flows. Scofield Campsite subdivision is unique in its high percentage of septic tank plus pit privy combination systems. Obviously, the pit privy system is a problem in the study area due to the high groundwater table (less than 1.16 meters from the surface in some areas).

Holding tanks pose a large pollution problem in the study area; especially in Bolotas and Scofield Campsite subdivisions. Each holding tank consists of a 0.19 m^3 (50 gal) drum embedded in the ground, which receives all wastes. The typical holding tank is mostly used by the owner of the residence during the recreational season. The recreation, including fishing and water skiing, is mostly active in summer season -- from June through August. But the capacity of the holding tanks is too small. Furthermore, according to the survey result, in most cases, the holding tanks are never pumped out. The overflow waste, if any, enters the soil-water matrix without any prior treatment which is practically the same as dumping the raw waste into the ground. Very few, if any, people have the very large holding tanks (37.85 m^3 [10,000 gal]) which would be large enough for total contamination of the wastes for pumping out and hauling away.

In conclusion, the high groundwater table (less than 1.22 m from the surface) restricts the usefulness of septic tank systems in some locations within the study area. The use of holding tanks is a potential problem, especially in the Bolotas and Scofield Campsite subdivisions. The pit privy is a potential source of pollution, and the cesspool may also pose problems. The negligence of residents in the study area to maintain their systems also accelerates the problem of contamination from waste disposal practices.

ORGANIC WASTE PRODUCTION IN THE STUDY AREA

The waste disposal activity survey (questionnaire plus personal communication) was used to estimate the total mass of organic matter, nitrogen, and phosphorus produced by the inhabitants of the study area. Most residents of Scofield were reluctant to provide information for the survey. Hence, data gathered earlier by the Southeastern Utah Association of Governments was obtained to augment data obtained from the field survey.

The method of data processing follows simple arithmetic calculation. Since there are great fluctuations of population between seasons, the 12 months were divided into four seasons. To estimate the total amount of waste mass production during an entire year, regardless of the population fluctuation, person-days data were computed. The person-days simply mean the number of days a person stays in the study area in a year. If he/she is a permanent resident, it is 365 person-days. If he/she is the owner of a cabin and visits the cabin during weekends (two days in a weekend) in summer season (seven times), then the person-days are 14.

To simplify the computation, each month was assumed to consist of 30 days. Spring season included March, April, and May; summer was June, July, and August; fall was September, October, and November; and winter included December, January, and February. The computation for Bolotas subdivision is listed in Appendix M to illustrate the method employed. The unit organic, nutrient, and hydraulic loading data (Table 8) employed in this study come from Bennett et al. (1975). Since most of the sites do not have garbage disposals, the unit loading data used did not reflect garbage disposal use.

Table 8. Unit loading values (Bennett et al. 1975).

Pollutant	With Garbage Disposal (g/capita-day)	Without Garbage Disposal (g/capita-day)
BOD_5	50.0	38.0
N	6.7	5.9
PO_4	3.8	3.7
Flow	168 ℓ (44.4 gal)	165 ℓ (43.6 gal)

1 lb = 454 g.

The estimated person-days, BOD_5, total nitrogen, and total phosphorus mass loading values are listed in Table 9. The total person-days (68,554) produce 2605 kg (5743 lb) BOD_5, 404.4 kg (891.5 lb) total nitrogen, and 253.6 kg (559.1 lb) total phosphorus annually. The summer season from June through August produces 47 percent of the total waste (i.e. 1235 kg (2723 lb) BOD_5, 191.7 kg (422.6 lb) total nitrogen, and 120.2 kg (265.0 lb) total phosphorus). In winter, from December to February, only 11 percent was produced, and the remaining mass was discharged during spring and fall.

Table 9. Use (person-days) and organic load for the study area

Item	Number of Days	Person-Days	BOD_5 kg	Organic Load* Total-N kg	Total-P kg
SPRING					
Weekday	65	8262	314.0	48.7	30.6
Weekend	22	3523	134.0	20.8	13.0
Holiday	3	1405	53.2	8.3	5.2
Subtotal	90	13190	501.2	77.8	48.8
SUMMER					
Weekday	62	9936	377.6	58.6	36.8
Weekend	22	16444	624.9	97.0	60.8
Holiday	6	6124	232.7	36.1	22.6
Subtotal	90	32504	1235.2	191.7	120.2
FALL					
Weekday	76	9576	363.9	56.5	35.4
Weekend	8	2475	94.0	14.6	9.2
Holiday	3	1926	73.2	11.4	7.1
Hunting day	3	1156	43.9	6.8	4.3
Subtotal	90	15133	575.0	89.3	56.0
WINTER	90	7727	293.6	45.6	28.6
TOTAL	360	68554	2605.0	404.4	253.6

*Note: Organic load value has been obtained from Bennett et al. (1975) Individual Home Wastewater Characterization and Treatment. Colorado State University, Fort Collins, Environmental Resource Center. July 1975. NTIS: PB-245 259.

BOD_5 = 38 g/capita-day
Total Nitrogen = 5.9 g/capita-day
Total Phosphorus = 3.7 g/capita-day
1 lb = 454 g.

The simple daily average of the data listed in Table 9 gives a clear picture of the seasonal variation of persons/day with its associated loading values. Table 10 lists the computed average value by season.

Figure 14 presents a histogram of the annual variation of BOD_5 and person-days per day.

The waste loading for each subdivision is shown in Table 11. The town of Scofield was the biggest waste producer (64 percent of total waste loading) in the study area. The estimated total flow in the study area was about 11,400 m^3 (3 million gal) per year. Using this hydraulic flow value, the resulting concentration of BOD_5, total nitrogen, and phosphorus in the wastewater becomes 230 mg/l, 35.7 mg/l, and 22.4 mg/l, respectively.

It is expected for the future that more people will live in the town of Scofield and its vicinity because of increasing coal mining activities in the region. Also, more people near the study area will come to Scofield Reservoir for recreation because of higher gasoline costs. This may be partly balanced by a decrease in recreational use from further away. However, it is highly likely that more wastes will be produced in the future.

Table 10. Seasonal variation of waste load.

Season	Persons-days Days	BOD_5 kg/day	Total-N kg/day	Total-P kg/day
Spring	146.5	5.57	0.86	0.54
Summer	361.1	13.72	2.13	1.34
Fall	168.1	6.4	0.99	0.62
Winter	85.8	3.26	0.50	0.32
Average	190.4	7.24	1.12	0.70

1 lb. = 0.454 kg.

Table 11. Waste loading data by subdivisions.

Subdivision	Person-Days Per Year	BOD_5 kg/yr	Total-N kg/yr	Total-P kg/yr	Percentage %
Bolotas	9291	352.3	54.7	34.3	13.5
Scofield Campsite	5886	223.7	34.7	21.8	8.6
Mountain Retreat	1392	52.9	8.2	5.1	2.0
Mountain Home	4934	168.5	26.2	16.4	7.2
Aspen View	3621	137.5	21.3	13.4	5.3
Scofield Town	43500	1670.1	259.3	162.6	63.4
Total	68554	2605.0	404.4	253.6	100.0

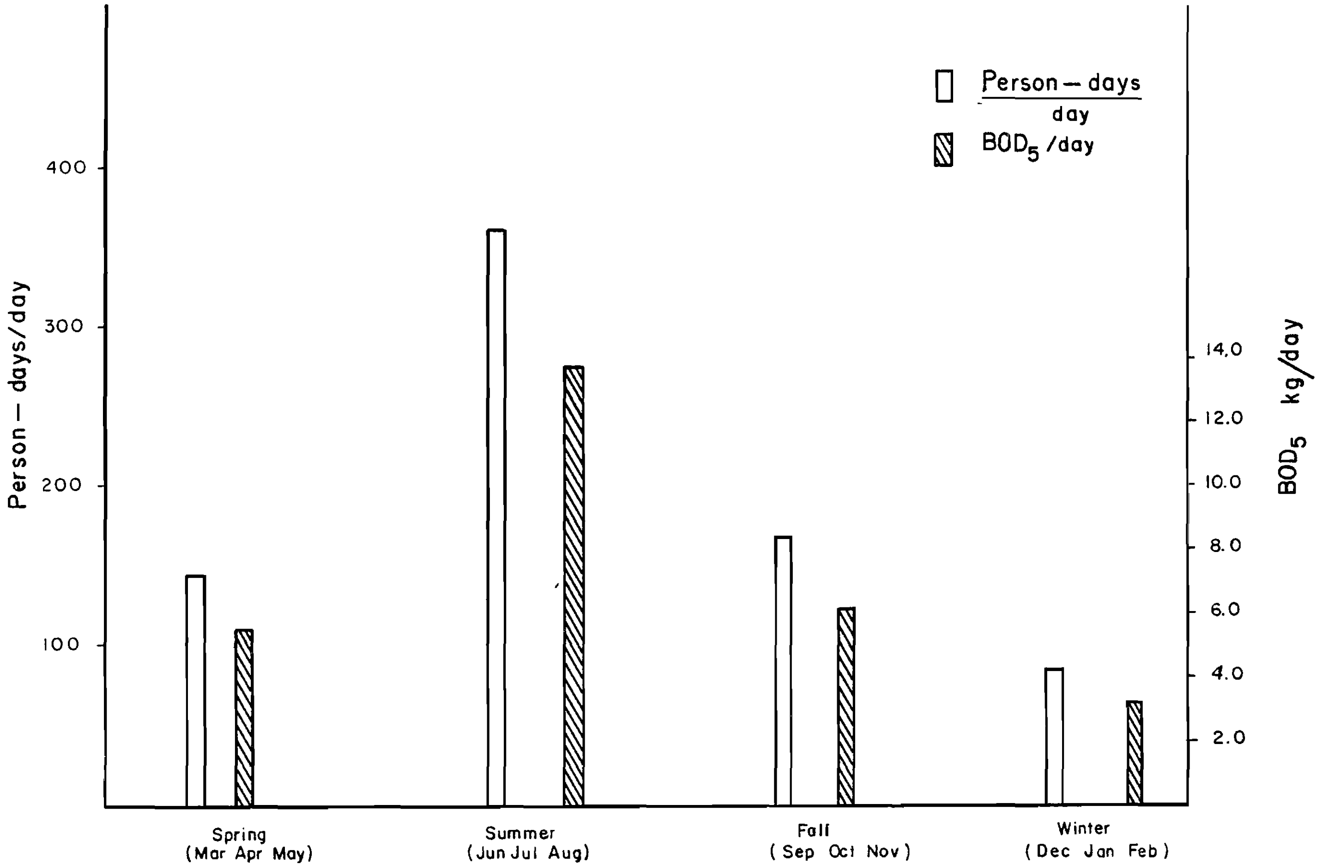


Figure 14. Histogram of the annual variation of BOD_5 and person/day.

RESULTS AND DISCUSSION

The results of the study are discussed under two broad areas--the groundwater hydrology and the water quality.

Groundwater Hydrology

Movement of Groundwater

From the measured water levels in the observation wells, water table elevations at a few locations were known. From this sparse data the typical slope of the water table is known at a few locations. Figure I-1 in Appendix I shows the water table elevations and contours near the lake in July 1980.

Grain Size Analyses of Cuttings from Selected Observation Wells

Samples taken from the cuttings recovered during construction of the observation wells were analyzed. Particle size distributions are shown in Figures E-1 through E-10, Appendix E. Textural classification shows that most of the 26 samples were sandy loam or loam. One sample was classified as sand and three were loamy sands. The average particle sizes (D_{50}) ranged from 0.05 mm to 0.70 mm.

X-Ray Mineralogy of Cuttings from Selected Observation Wells

Results of the x-ray analyses of cuttings from selected wells are listed in Table F-1, Appendix F. Clay minerals are listed first, in order of their relative abundances; then nonclay minerals are listed in order of their abundances. No attempt was made to perform quantitative analyses between clay and nonclay minerals, and just because the clay minerals are listed first does not mean they are more abundant than the nonclay minerals.

It can be seen from Table F-1 that the dominant clay mineral in the samples from the Scofield area is kaolinite, with illite being the second most abundant clay mineral. This clay mineralogy suggests that the clays would have a relatively small effect on changes in the chemistry of the groundwater, mainly because these two clays have very low cation-exchange-capacities.

A poorly-crystalline expandable material appears in many of the samples. It has been shown that poorly crystalline and amorphous materials in soils can have a high cation-exchange-capacity. Scofield sediments containing such material thus might be more effective in removing organic contaminants from groundwater than sediments which do not contain this poorly-crystalline material.

Slug Tests in Selected Observation Wells

To determine the approximate permeability of the aquifer materials near selected wells, slug tests were performed at wells #12, 14, 20 and 21. Permeabilities of 0.0026 cm/sec, 0.0019, 0.0006 and 0.0019 cm/sec were estimated from the field tests. Data and calculations for the four wells are shown in Appendix G.

Shallow Seismic Surveys

Locations and results of the shallow seismic surveys are shown on Figure 10. Depths to the water table are consistent with depths measured in the observation wells. The depth to bedrock gives an estimate of the depth of the aquifer at the sites. Data and typical computations are in Appendix H.

Groundwater Underflow Past Scofield

From the valley fill cross-section of Figure J-1, Appendix J, an estimate of groundwater underflow past Scofield was made. A flow of 34.4 l/min (9.1 gpm) or 18,500 m^3/year (15 acre feet per year) flows down Pleasant Valley under Scofield. Thus the underflow is quite small under Mud Creek. A similar situation is believed to occur at Fish Creek. Ungaged direct shallow groundwater inflow around the lake is also believed to be small due to the shallow soils of low permeability near the lake. Deeper groundwater inflow was not studied and may be more significant than the shallow groundwater due to bedrock springs under the lake. The USGS is currently investigating the deeper groundwater flow.

Groundwater Quality

A network of groundwater and surface water sampling points was established in Pleasant Valley, Utah. Observation wells were constructed at selected points in Clear Creek, Scofield, and the valley between Clear Creek and Scofield, Mountain Home Subdivision, and major lakeside developments, and the areas where major tributaries empty into Scofield Reservoir. A total of 28 sampling sites was used during the study (23 wells and 5 surface water sampling sites (Figures 5, 6, and 7 and Table 3). The shallow groundwater quality was investigated at selected observation wells by periodic water sampling and analysis. Sampling was carried out in October and November of 1979, and February, April, May, June, July, and August of 1980. Water quality constituents were examined with the objective of determining pollution hazards from man's activities.

Being limited to only one year, this study does not provide sufficient data to fully assess the composition of the groundwater quality in the basin. The data collected in this study may be viewed as baseline data and as an indicator of potential pollution hazards.

Water quality parameters analyzed in the study are presented in the following sections. A complete listing of all the water quality data for all 28 sampling sites is presented in Appendix A. Each parameter is discussed; however, the discussion emphasizes several important parameters which indicate degradation of groundwater quality. These parameters are nitrate-nitrogen, iron and manganese, dissolved oxygen, and total phosphorus.

Water Quality Parameters Not Indicating Potential Pollution

Temperature

The temperature of groundwater ranged from 2°C to 12°C (Appendix A). Temperature of water drawn from wells 7, 13, 16, and 21 is shown in Table 12 and Figure 15. Water temperatures in wells 7, 13, 16, and 21 are indicative of water temperatures in surrounding wells. Wells #7, 13, 16, and 21 are located in the state park south of Scofield town, north profile of Scofield town, and near Tucker and Woods Canyon, respectively (Figures 5, 6, 7, and Table 3).

The variation of temperature was fairly mild. The arithmetic mean temperature of the groundwater in the study area was 7.4°C throughout the entire study period and the standard deviation was 2.2°C (n = 145). The highest groundwater temperature occurred in July and August 1980 (averaging 9.3°C) and the lowest in February 1980 (averaging 3.2°C) Since no samples were collected in December, January, or March, the lowest temperature may have actually occurred in one of these missing months.

pH

The pH value of the groundwater ranged from 6.0 to 7.7 (Figure 16). Generally, the pH remained approximately 7.0. The stream water pH in all surface water sampling sites was somewhat alkaline. The average pH was 8.2 (Appendix A). The pH in several wells during the study period is shown in Table 13 and Figure 16. Wintertime field pH measurements are recognized to be less accurate because of the difficulty of calibrating the probes and because of the effect of temperature on the measurement. There are two peaks in the graph which occurred in February 1980 and July 1980 (Figure 16). The variation, however, is in general less than 1 pH unit.

Specific Conductance

The specific conductance values of the groundwater in the study area varied from 216 to 1309 μmhos/cm at 25°C (Appendix A). The specific conductance values in wells #4, 5, 9, 13, and 16 (Figure 17 and Table 14) exhibited wide variations among wells. Table 14 and Figure 17 present the specific conductivity values in wells #4, 5, 9, 13 and 16. Wells #4 and 5 were located in Bolotas subdivision and Scofield Campsite subdivision, respectively. Both subdivisions are situated nearly at the east edge of the Scofield Reservoir. Furthermore both subdivisions are characterized by the high density of cottages and cabins. However, the difference in specific conductance of well water at the two subdivisions was significant. Well #9 was located in the town of Clear Creek. Table 15 summarizes the statistical parameters of specific conductivity values in wells #4, 5, 8, 13, and 16.

The lowest CV (coefficient of variability) occurred in well #5, which means that the specific conductance values were fairly constant during the entire study period. Values in the other wells fluctuated significantly, ranging four or five times largest than well #5. Figure 17 also shows the general trend of fluctuation of the specific conductance value. The highest values were observed in well #16, averaging 1040 μmhos/cm at 25°C. Specific conductance levels measured on all water samples were below the upper consumer-acceptance limits

Table 12. Temperature of groundwater (^{o}C).

Well #	Oct	Nov 1979	Feb 1980	Apr	May	June	July	Aug
7	10	9	2	6	6.5	7	11	9
13	10	4	3.5	5.5	8	8	10	11
16	8	4.5	3	4	4.5	8	9	8.5
21	10	4	-	-	7	9.5	12	11.5

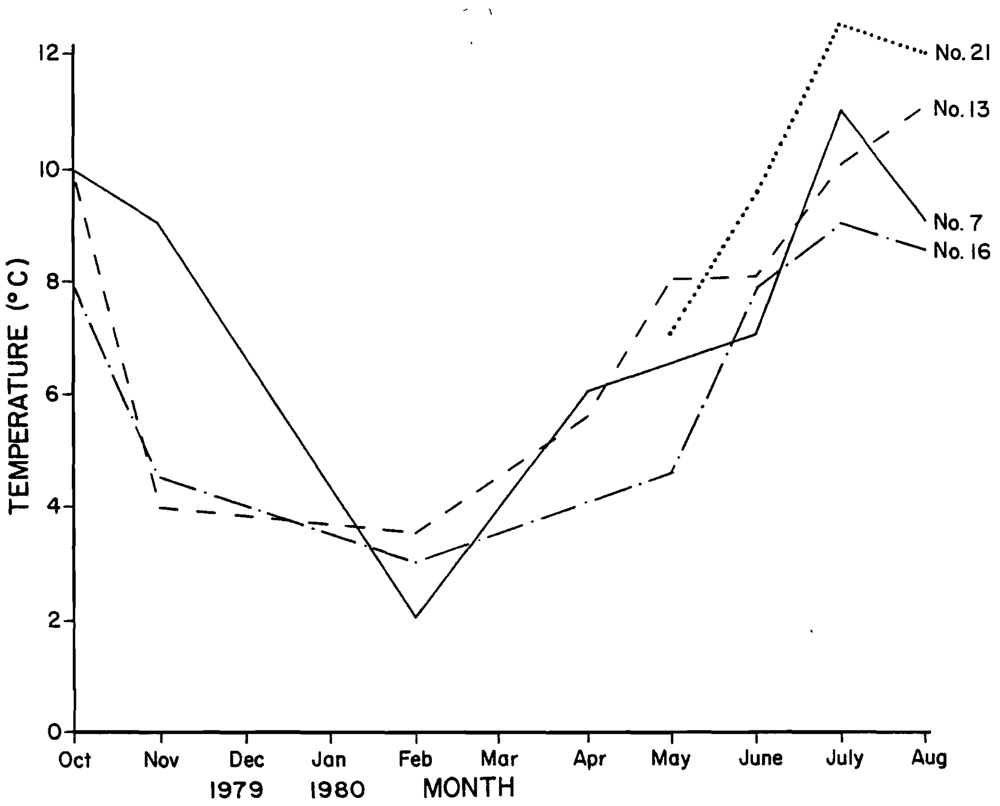


Figure 15. Groundwater temperatures in wells #7, 13, 16, and 21.

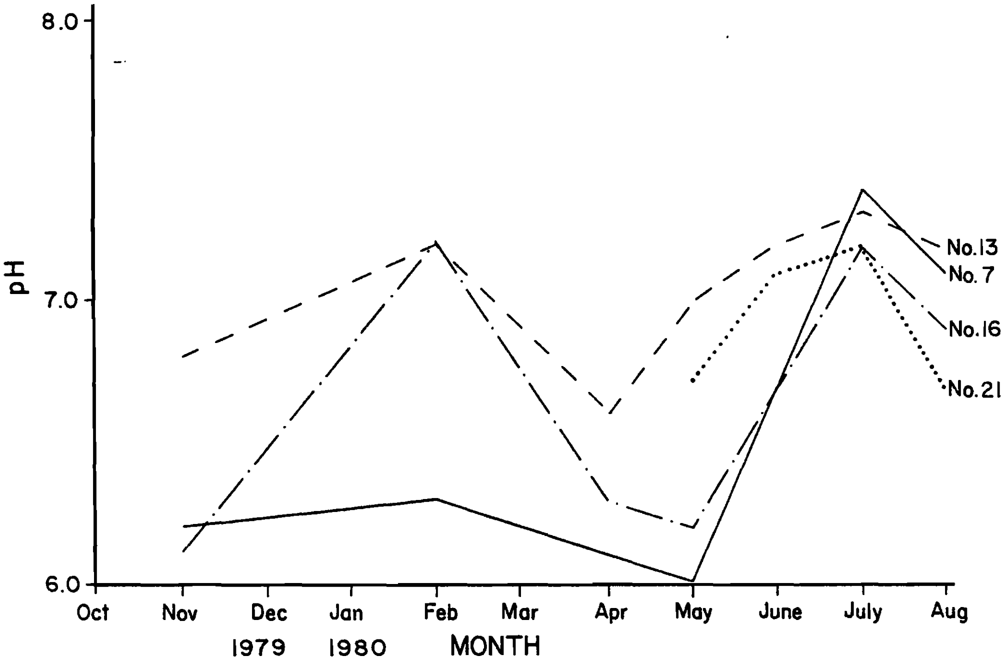


Figure 16. pH of groundwater in wells #7, 13, 16, and 21.

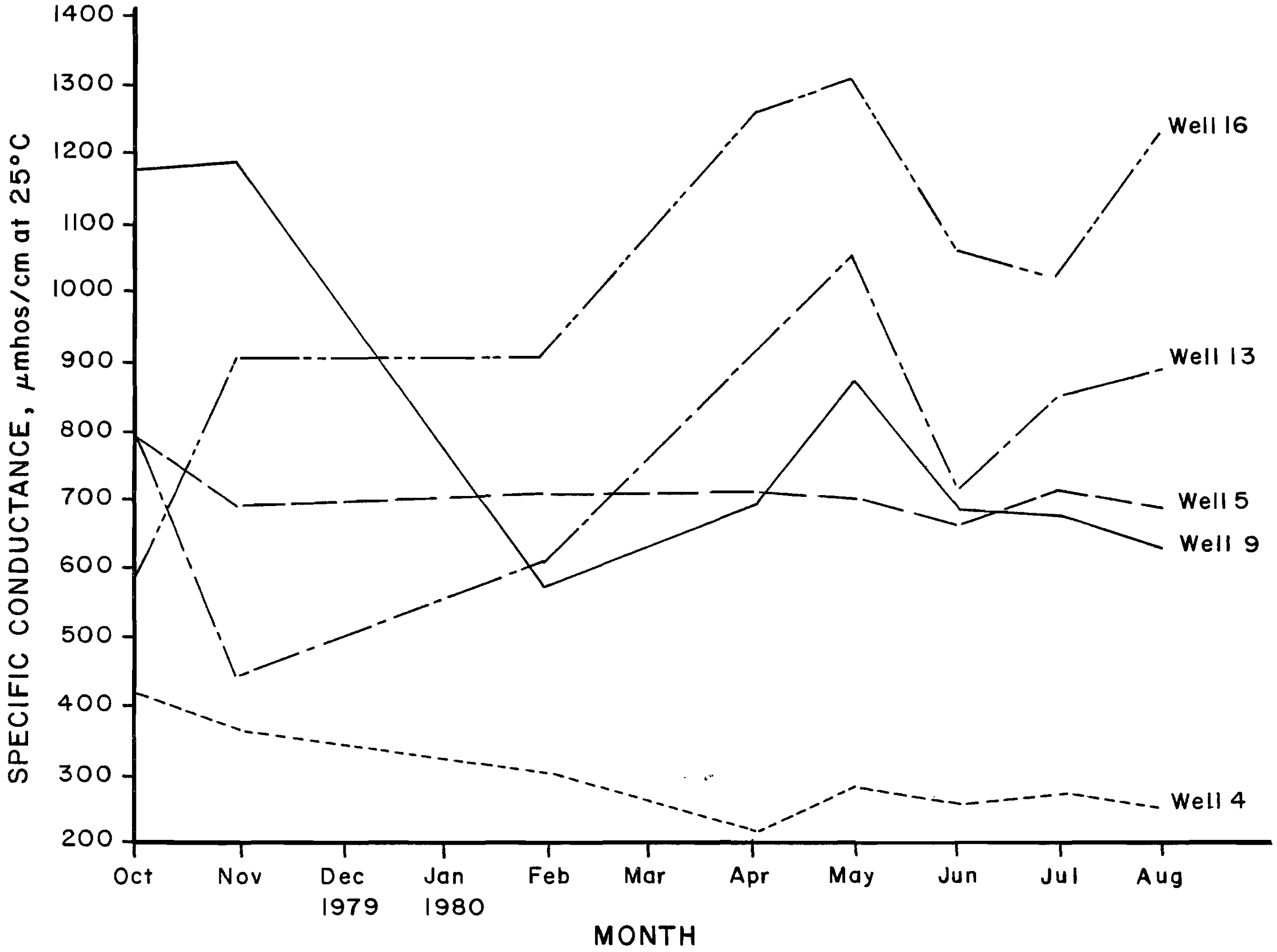


Figure 17. Specific conductance values in wells #4, 5, 9, 13, and 16.

Table 13. pH of groundwater.

Well #	Oct	Nov 1979	Feb 1980	Apr	May	June	July	Aug
7	-*	6.2	6.3	6.1	6.0	6.7	7.4	7.1
13	-*	6.8	7.2	6.6	7.0	7.2	7.3	7.2
16	-*	6.1	7.2	6.3	6.2	6.7	7.2	6.9
21	-*	-*	-*		6.7	7.1	7.2	6.7

Table 14. Specific conductance of groundwater (µmhos/cm at 25°C).

Well #	Oct	Nov 1979	Feb 1980	Apr	May	June	July	Aug
4	417	368	306	216	280	260	175	257
5	793	692	698	715	704	663	710	682
9	1174	1186	560	687	875	681	676	627
13	806	439	594	904	1055	716	851	891
16	584	900	895	1259	1309	1059	1022	1228

Table 15. Statistical parameters of specific conductance of groundwater.

Well #	$\overline{X}$	S	C.V.	N
4	297	65.3	22	8
5	707	38.4	5.4	8
9	807	244	30	8
13	782	194	25	8
16	1040	248	24	8

$\overline{X}$ = mean value of specific conductance values, µmhos/cm at 25°C

S = standard deviation of specific conductance values, µmhos/cm at 25°C

CV = coefficient of variability, S/$\overline{X}$, %

N = number of data

(1600 µmhos/cm) specified by the State of California (Appendix B). The State of Utah and the U.S. Environmental Protection Agency fail to specify a maximum value for specific conductance. Figure 18 indicates the number of well water samples which exceeded the California recommended consumer-acceptance limit of 800 µmhos/cm (State of California 1972). The specific conductance measures the ion content in the water; the higher the specific conductance, the more ions in the water. The fact that there are more ions in the water is due to more dissolved solids in the water. Hence, the specific conductance measurement indicates the changes in dissolved solids in a groundwater. The increase in total dissolved solids in the groundwater may be caused by both natural and/or artificial means.

Specific conductance values in five surface sampling sites ranged from 238 to 592 µmhos/cm at 25°C (Appendix A). These values are similar to values obtained from groundwater in the Bolotas subdivision.

Total Dissolved Solids

Total dissolved solids (TDS) contents were measured in some wells which were suspected of being polluted. The wells chosen were wells #2, 3, 4, 5, 6, 7, 8, 9, 11, 12, 13, 14, 15, 16, 17, 19, 21, and 23 (Figures 5, 6, and 7 and Table 3). Only water from wells #4, 5, 6, 7, 9, 11, 13, and 16 was analyzed for TDS throughout the entire study period. The remaining wells were analyzed intermittently. Water regularly sampled from the eight wells contained total

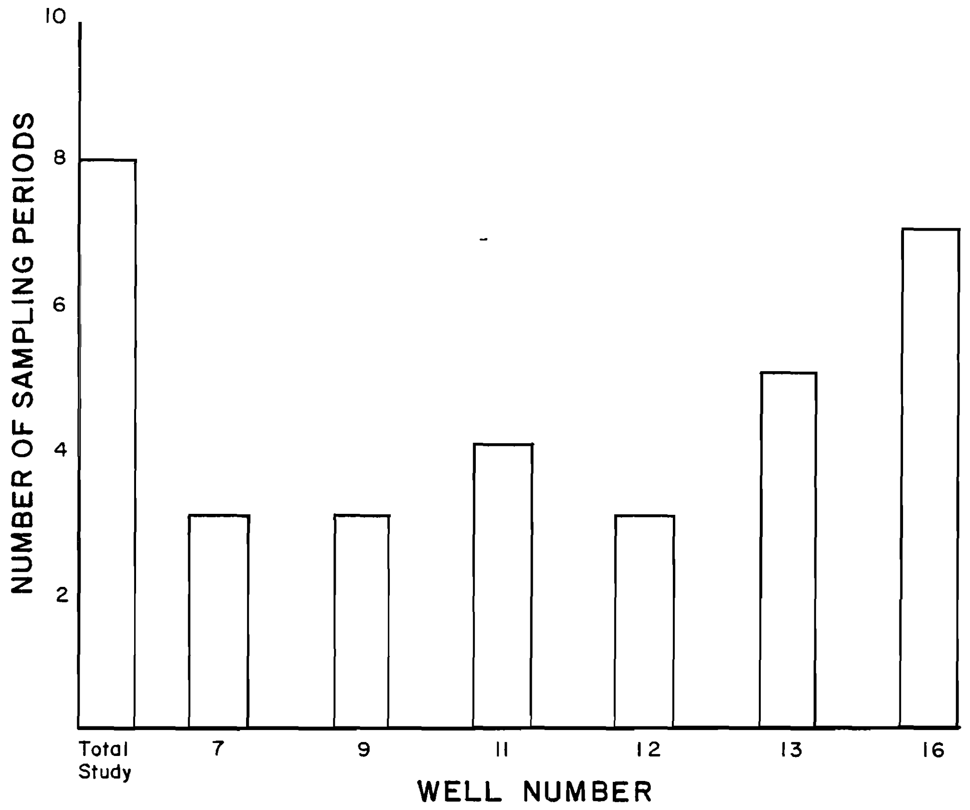


Figure 18. Number of water samples out of eight which exceeded the California (1972) recommended consumer acceptance limit for specific conductance (800 µmhos/cm).

dissolved solids content which ranged from 105 mg/l to 893 mg/l. The lowest TDS values were in well #4, and the highest in well #16. The annual patterns of TDS values for the eight wells are shown graphically in Figure 19 and are listed in Table 16. TDS levels of all water samples extracted from well #16 violated the U. S. Environmental Protection Agency (EPA) drinking water standard for TDS (500 mg/l). However, the State of Utah maximum contaminent level for TDS (1000 to 2000 mg/l) was not exceeded by any groundwater sample. Furthermore the TDS data obtained from wells #11 and 13 indicated that spring snowmelt may increase the TDS concentrations in these wells during the spring and summer (Table 16). Generally, the TDS peak occurred in May 1980, in most wells. This seasonal trend is the same as that of specific conductance in those wells. Figure 20 is a plot of the total dissolved solids (TDS) contained in water from 21 sampling sites for the entire study period versus the specific conductance value for the same sample. The following linear equation was employed to correlate TDS to specific conductance (Hem 1970).

$$S = KX \qquad (6)$$

in which

S = total dissolved solids, mg/l

X = specific conductance values, µmhos/cm

K = conversion coefficient

In determining the K value, specific conductance values and total dissolved solids content of water from 21 sampling sites were used. The remaining 7 sites did not have total dissolved solids measurements. The coefficient K of each sampling site is shown

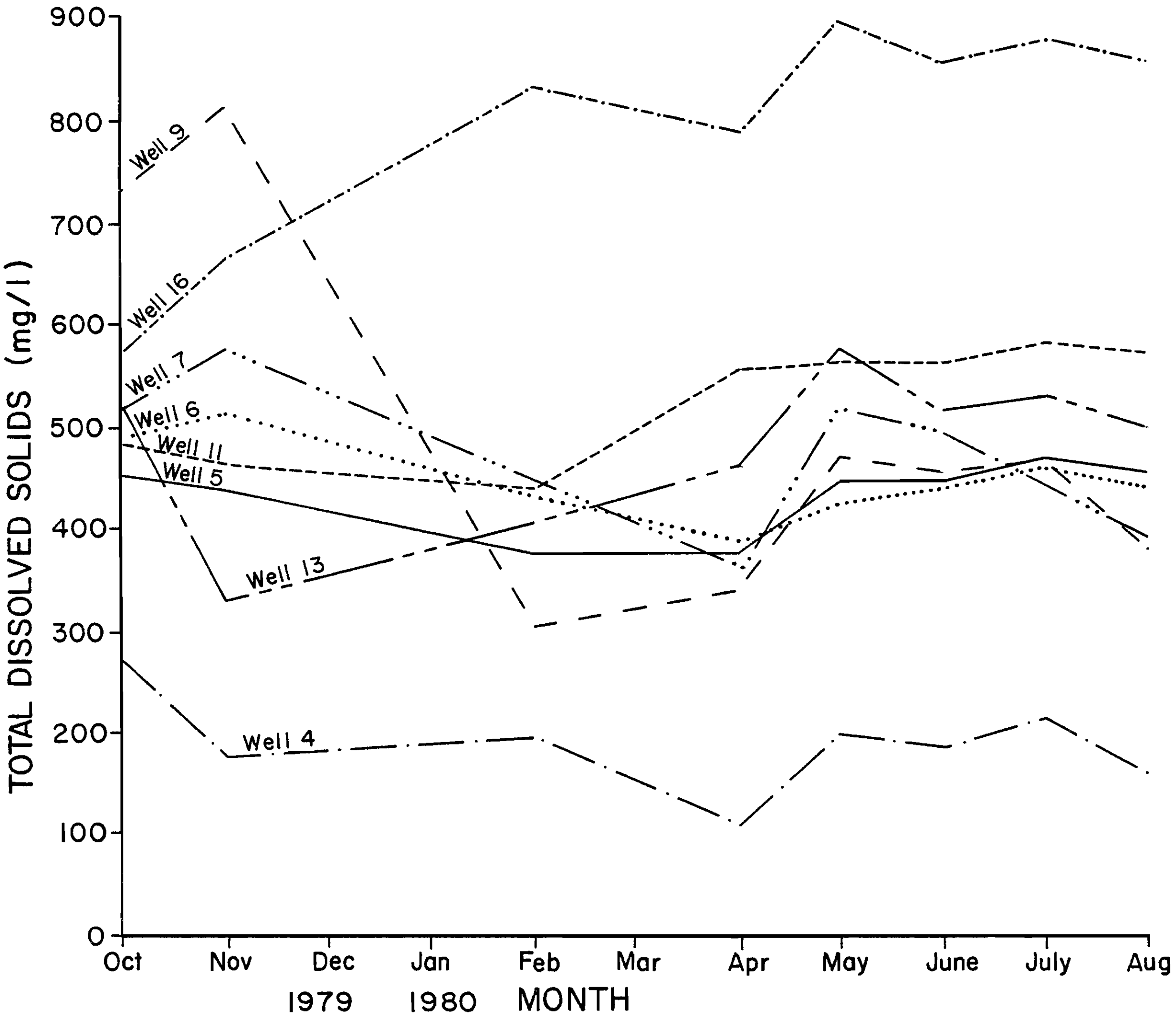


Figure 19. TDS values in wells #4, 5, 6, 7, 9, 11, 13, and 16.

Table 16. Total dissolved solids of groundwater (mg/l).

Well #	Oct	Nov 1979	Feb 1980	Apr	May	June	July	Aug
4	272	176	191	105	194	185	207	158
5	450	435	372	371	443	441	463	449
6	486	508*	428	384	419	434	461	434
7	508*	572*	458	355	516*	494	--	387
9	725*	810*	302	337	466	451	454	382
11	480	461	--	434	550*	558*	574*	566*
13	525*	325	400	459	572*	510*	523*	494
16	566*	658*	829*	786*	893*	854*	875*	852*

*TDS value exceeds EPA Secondary Maximum Contaminant Level of 500 mg/l TDS.

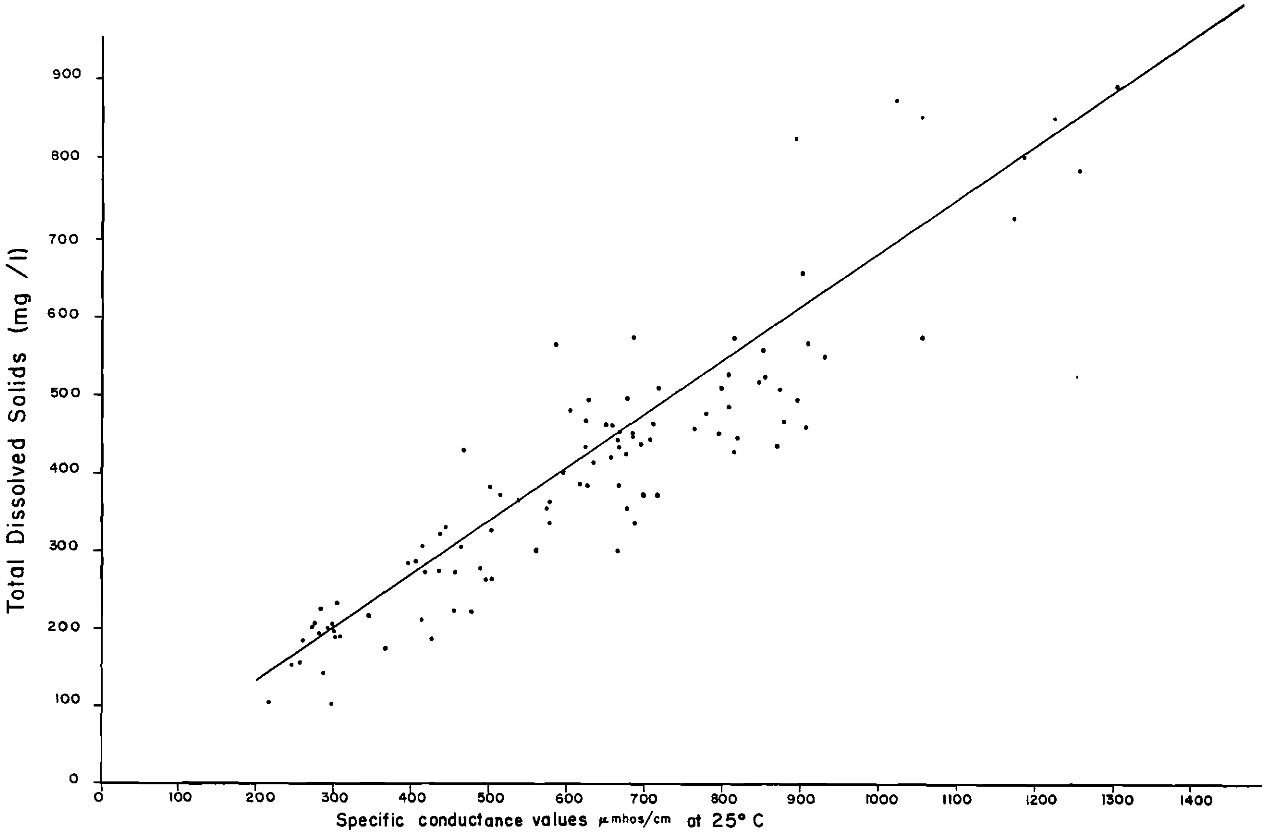


Figure 20. TDS vs specific conductance of water samples.

in Table 17. The value of K ranged from 0.5239 to 0.7821. The weighted mean was 0.6411. The standard deviation was 0.0612 and the coefficient of variability was 9.55 percent. Normally the coefficient K is between 0.55 and 0.95 (Hem 1970); the value obtained in this study is within this range. Hence, the relationships between the specific conductance values and total dissolved solids contents in the water in the study area could be expressed as,

$$S = 0.6411X \quad . \ . \ . \ . \ . \ . \ . \ . \ . \quad (7)$$

in which

S = total dissolved solids content (mg/l)

X = specific conductance values (μmhos/cm at 25°C)

Equation 7 predicts a TDS value with a 9.55 percent deviation from the expected value or mean. The resulting linear regression equation showing the relationship between specific conductance and total dissolved

Table 17. Coefficient K in each sampling site.

Sampling sites No.	No. of data used	Coefficient K
2	5	0.6247
3	5	0.6820
4	8	0.6266
5	8	0.6066
6	8	0.6391
7	7	0.6344
9	8	0.6010
11	7	0.6745
12	2	0.6725
13	8	0.6247
14	3	0.6881
15	1	0.6291
16	8	0.7821
17	2	0.6316
19	4	0.6224
21	2	0.6750
23	2	0.6852
24	1	0.5272
25	4	0.7224
27	5	0.5239
28	5	0.5493

solids is shown in Figure 20. The highest value of coefficient K occurred in the water drawn from well #16 (.7821). The highest value of K generally is associated with waters high in sulfate (Hem 1970). The sulfate content in well #16 was highest among all the sampling sites, ranging from 123 mg/l to 207 mg/l with the mean value of 178 mg/l (standard deviation 33.8 mg/l).

Biochemical Oxygen Demand

The five day biochemical oxygen demand (BOD_5) measurement was made throughout the entire study period for every sampling site. The maximum BOD_5 level measured was 3 mg/l BOD_5 which is within the accepted error of the test. Therefore, the numerical BOD_5 values are meaningless. Because of the low BOD_5 level observed in the study area, this parameter is not discussed further.

Sodium

High sodium in the groundwater may indicate wastewater pollution. The typical sodium concentration found in most of the wells ranged from 4 mg/l to 18 mg/l, as Na. Wells #5 and 9 have sodium ion levels ranging from 28 mg/l to 59 mg/l and 21 mg/l to 79 mg/l, respectively. The higher sodium value in well #5 is especially meaningful, because there are several wells (2, 3, 4, and 6) in the same area which have the same geological conditions. Since wells #2, 3, 4, and 6 have the typical sodium values (4 to 18 mg Na/l); the abrupt deviation from the typical sodium value in well #5 is puzzling. Table 18 lists the sodium values in wells #4, 5, and 6. On the average, water from well #5 had four to five times more sodium. Wells #4, 5, and 6 were adjacent to each other on the east shore of the Scofield Reservoir. The area is characterized by a dense population of cottages and cabins. Hence, the source of high sodium value in well #5 is unknown.

There were no sampling wells in close proximity to well #9 to determine whether the higher sodium value contained in water from well #9 was derived from waste disposal activities or from natural phenomena. Higher chloride values in well #9, however, may indicate specific geological characteristics were the source of sodium. Unless there were wells nearby which could correcty give background levels of sodium, the high sodium observation from one well would not reliably indicate a degradation in the water quality of the aquifer. In surface water sampling sites, the sodium concentration was less than 10 mg/l and the majority fell below 5 mg/l.

Chloride

The chloride ion was analyzed in wells #2, 3, 4, 5, 6, 7, 9, 11, 13, 14, 15, 16, 17, 19, 21, 23 and surface water sampling sites #25, 29, and 28. These sampling sites were chosen to get baseline data and to monitor actual chloride levels. Secondary maximum contaminant level of chloride in drinking water as specified by EPA (1975) is 250 mg/l. Chloride concentration measured in water samples collected throughout the study area ranged from 1 mg/l to 166 mg/l. The majority of the values (amounting to over 60 percent of all analyzed values) were in the range of 6 mg/l to 30 mg/l in well samples. Water obtained from well #9 contained chloride ion levels which fluctuated from 29 mg/l to 166 mg/l during the study period (Figure 21). Consistently higher than normal chloride values were found in water collected from well #7 (55 mg/l to 90 mg/l Cl^-). The most drastic changes in percentage chloride concentration (fluctuating between 100 percent and 1100 percent) occurred in wells #13 and #16 (Figure 21). Higher chlorlde ion in certain wells may have been related to

Table 18. Sodium concentrations of groundwater (mg/l).

Well #	Oct	Nov 1979	Feb 1980	Apr	May	June	July	Aug
4	9	10	9	11	9	7		
5	28	45	48	56	51	57		
6	12	14	10	12	12	11		

solubilization of chloride from surrounding geological formations. In addition, waste water contains significant chloride ion. Medium strength (wastewater whose BOD_5 is about 200 mg/l) domestic wastewater contains 50 mg/l Cl^- (Metcalf and Eddy 1979). Chloride ion from the waste water may be leached and transported to the aquifer. In surface water sampling sites, chloride content was less than 16 mg/l as Cl^-. Most of them (over 80 percent) were less than 6 mg/l as Cl^-.

Potassium

The potassium values in the study area were fairly constant. Potassium in water samples ranged from 1 mg/l to 10 mg/l. The majority of potassium levels measured (43 values out of 68 analyses) fell between 2 mg/l and 6 mg/l. Similar potassium values throughout the whole study area suggest that the water from the 23 wells may have traveled through similar geological formations. The surface water samples contained always less than 6 mg/l.

Boron

The boron concentration measured in the groundwater ranged from less than 0.1 mg/l to 1.45 mg/l. The majority of boron values ranged from 0.1 mg/l to 0.8 mg/l. The highest value, 1.45 mg/l, occurred in well #9; no other well water samples exceeded 1 mg/l. Therefore, boron was not degrading the groundwater quality in the study area. Surface water samples contained less that 0.1 mg/l of boron, except for the April 1980 sample taken from #27 which had 0.4 mg/l of boron.

Sulfate

Sulfate concentrations ranged from 7 mg/l to 207 mg/l. The values ranged between 18 mg/l to 60 mg/l. Exceptionally high sulfate concentrations (123 mg/l to 207 mg/l) consistently occurred in well #16. The interrelationships among ferrous ion, low dissolved oxygen, and sulfate ion in well #16 indicate the possible oxidation of pyrite (FeS_2) (Bailey 1978). The average level of

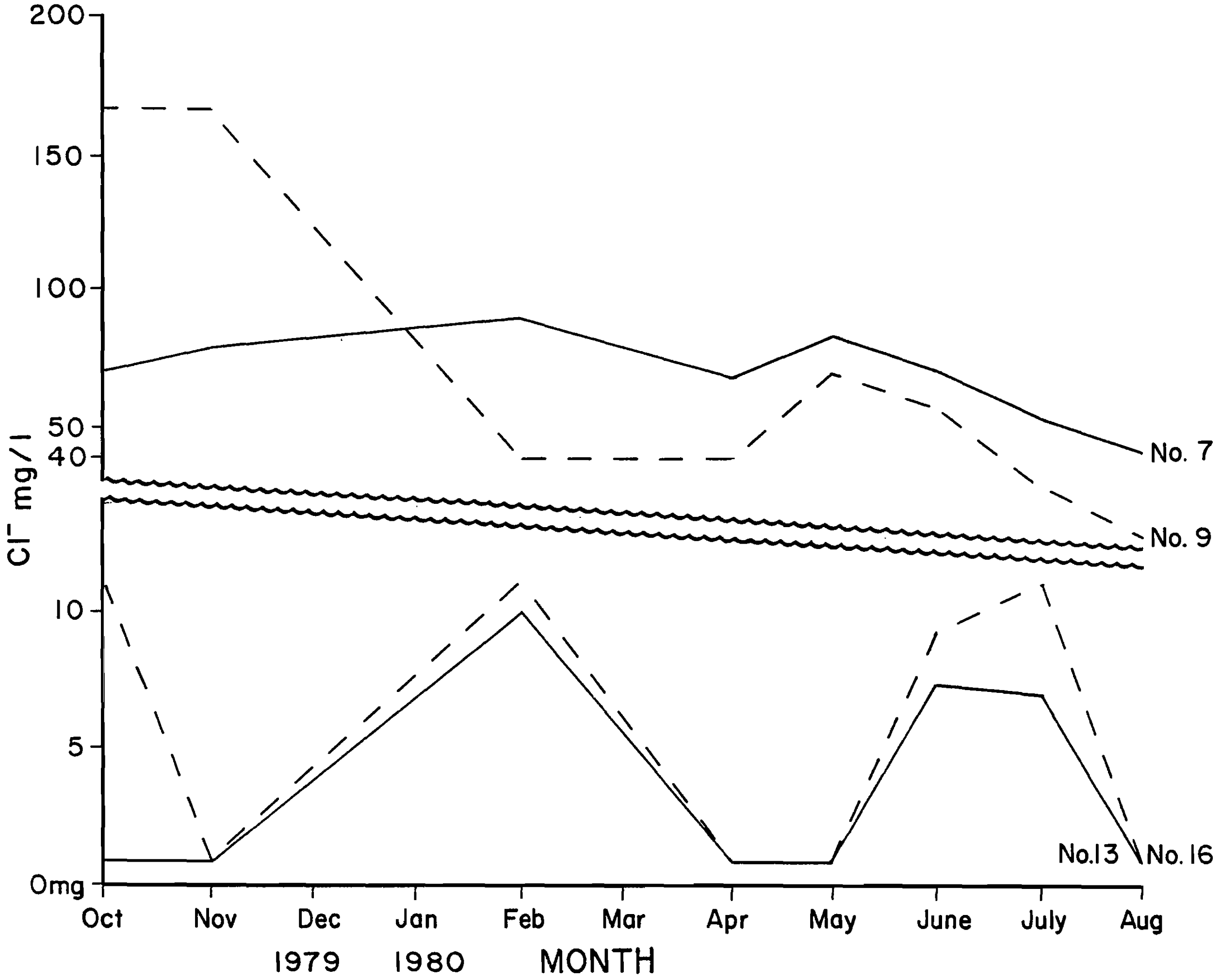


Figure 21. Chloride ion concentrations in wells #7, 9, 13, and 16 (mg/l).

ferrous ion and dissolved oxygen in well #16 was 16 mg/l, and 1.0 mg/l, respectively. The same phenomenon may apply to wells #9, 12, and 13 which have higher iron content, lower DO, and relatively high concentrations of sulfate. In addition, sulfate ion can originate from the dissolving of limestone formations. Sulfate values in surface water sampling sites were less than 55 mg/l as SO_4^{-2}. Most sulfate values were less than 30 mg/l.

Hardness

The hardness concentrations which, in most cases, mainly consist of calcium and magnesium ions ranged from 103 mg/l to 511 mg/l as $CaCO_3$. Total hardness was relatively constant throughout the entire study period and study area. In general the water in the study area was hard (150 mg/l to 300 mg/l as $CaCO_3$) and/or very hard water (more than 300 mg/l as $CaCO_3$) based upon the common classification (Sawyer and McCarty 1978). The major reason for this hard water is the geological formation of the study area, which is predominantly limestone, sandstone, and shale.

The topsoil of the area is thick (minimum thickness = 1 meter or 3 feet) and is primarily composed of silty sandy soil. In many wells the topsoil is rich in organic substances. The soil color is dark and rich in nutrients. This provides a good environment for microorganisms degradation of organic debris in the topsoil. Carbon dioxide produced by the microbial decomposition of organic matter is dissolved in water as carbonic acid in most of the natural soils (Sawyer and McCarty 1978). The carbonic acid goes into the deeper layer of the ground to dissolve the limestone layer resulting in calcium and magnesium. Sulfate and chloride ions which may be associated with the limestone could be liberated into the groundwater. Water from well #9 contained high levels of calcium (205 mg/l as $CaCO_3$), magnesium (80 mg/l as $CaCO_3$), chloride (72 mg/l as Cl^-), and sulfate (45 mg/l as SO_4). In addition, high calcium, magnesium, chloride, and sulfate levels were measured in wells #7, 13, and 16. However, there are possibilities of sulfate increase due to the oxidation of pyrite (FeS_2), and also the formation of ferrous ion (Fe^{++}) by the pyrite oxidation. The surface water in the study area was classified as hard water whose values fell between 150 mg/l and 300 mg/l as $CaCO_3$. This could be the result of natural phenomena.

Alkalinity

Alkalinity is a measure of the capacity of water to neutralize acids. It originates mainly from the salts of weak acids, predominantly bicarbonates in most natural waters. In the study area, most of the alkalinity measured was due to bicarbonate (HCO_3). Alkalinity in the water samples ranged from 83 mg/l to 519 mg/l as $CaCO_3$. All wells except wells #5, 12, 13, and 16 contained water with alkalinity levels less than 300 mg/l as $CaCO_3$. Most water samples had an alkalinity of about 200 mg/l as $CaCO_3$. Water from wells #5, 11, 12, 13, and 16 had alkalinity concentrations greater than 300 mg/l. The average values of alkalinity in wells #5, 11, 12, 13, and 16 were 370 mg/l, 344 mg/l, 359 mg/l, 419 mg/l, and 458 mg/l as $CaCO_3$, respectively. Carbon dioxide (CO_2) in the soil produced by bacterial action produces the alkalinity in groundwater. Whenever there is enough calcium or magnesium carbonate in the soil, the CO_2 reacts with these to produce bicarbonate salt (Sawyer and McCarty 1978). Based upon this fact, the high concentration of bicarbonate or alkalinity suggests the active microbial action. It could be aerobic and/or anaerobic. As long as the heterotrophic organisms are involved, the end product is carbon dioxide. The chemical reaction when the CO_2 reacts with carbonate minerals will be

$$CO_2 + CaCO_3 + H_2O \rightarrow Ca(HCO_3)_2 . \quad . \quad . \quad . \qquad (8)$$

When there is not enough calcium and magnesium carbonate in the soil, the carbon dioxide produced may remain in the soil-water matrix without having a chance to react with the carbonate minerals such as calcium carbonate. Hence, it is not uncommon to encounter groundwaters with 30 to 50 mg/l of carbon dioxide (CO_2) (Sawyer and McCarty 1978). The chemical reaction in equation ( ) does not take place under these geological conditions. The alkalinity levels in surface water ranged from 135 mg/l to 248 mg/l as $CaCO_3$. This level of alkalinity is similar to that of most groundwater in the study area.

Surfactants

The surfactant concentrations measured as Methyl Blue Active Substances (MBAS) never exceeded 100 µg/l or 0.1 mg/l throughout the entire study. The majority of water samples contained less than 30 µg/l MBAS. The USPHS (1962) set 0.5 mg/l as the drinking water standard. Therefore, surfactants are not a problem.

Bacteriological Test

Coliform bacteria

Bacteriological examination of the well samples failed to show detectable coliform groups present in each well. Occasionally there appeared a total coliform bacteria count (10 in 100 ml) in a certain well (such as #7) at the state park. This may indicate organic waste pollution, especially from septic tank leachate in the case of well #7 which was located below the septic tanks leach field. Total coliform and/or fecal coliform were detected four times in well #7 from the total of eight water samples collected during the study. The presence of coliform groups in well #7 may be due to the occasional malfunction of septic tank systems in the state park. Considering the overall water quality data in well #7, however, it was not possible to conclude the well was polluted (Appendix A). Except for the coliform test, no other water quality indicators showed pollution. This may be interpreted that the waste produced by the septic tank system near well #7 was sufficiently treated to reduce organic and nutrient matter. There were very few coliform bacteria detected in other wells (Appendix A).

Fecal Streptococci

The fecal streptococci test was conducted on the water samples obtained in July and August 1980. The fecal coliform to fecal streptococci (FC/FS) ratio was determined on these waters. Almost every well contained fecal streptococci with the exception of water from wells #6, 7, and 17. Since most well water did not have fecal coliform, this ratio can only be applicable to surface water samples. As shown in Figure 5, four surface water samples (#24, 25, 27, and 28) out of five were obtained from Mud Creek. Mud Creek passes through the community of Clear Creek, a mining company, a cattle grazing field, the town of Scofield and finally enters Scofield Reservoir. One surface sample came from Fish Creek (sampling site #26). The FC/FS ratios were between 1.0 and 0.3 (Table 19); and therefore, the major sources of coliform organisms in Mud Creek and Fish Creek may have originated from warm blooded animals (i.e. cattle, sheep, etc.). The low FC/FS ratio does not mean that there were not human coliform groups; it indicates that the major sources of these bacteria came from cattle or other warm blooded animals. This is reasonable because people in the study area discharge their waste into the soil mantle by septic tank and leach field system.

Water Quality Parameters Indicating Potential Pollution

Several important water quality parameters in the study area indicated degradation of the groundwater. They included nitrate-nitrogen, total phosphorus, iron and manganese, mercury and fluoride. Because of their significance in terms of water quality interpretation, separate discussions are presented for groundwater and surface water.

1. Surface water

Total Phosphorus. Total phosphorus which may accelerate the eutrophication of a body of water may be a problem in the study area. Total phosphorus concentrations in surface streams in the study area ranged from 22 µg/l to 3370 µg/l. In May 1980 the total phosphorus levels ranged from 185 µg/l to 3370 µg/l with an average value of 1177 µg/l. Water in Fish Creek, which was not affected by human wastewater disposal contained 185 µg/l in May 1980 and 136 µg/l in April 1980. Water samples collected during other months had less than 60 µg/l. Table 20 lists total phosphorus values in surface streams. High levels of total phosphorus occurred during the period of maximum flow in the stream. The hydrograph of Fish Creek (USGS 1974) is shown in Figure 3. In May the flow reached a peak of approximately 9.2 m^3/sec (325 cfs). During the remaining months flow was less than 0.57 m^3/sec (20 cfs). Since Fish Creek and Mud Creek drain similar watersheds, the hydrograph in Mud Creek may be similar to that of Fish Creek. Hence, it may be assumed to be the same pattern in Mud Creek which passes through the town of Scofield. Therefore, the mass loading of total phosphorus during May may stimulate the eutrophication process in Scofield reservoir.

Table 19. FC/FS ratio in surface streams.

Sample Site	FC/FS
South edge of Clear Creek town #24	1.0
North edge of Clear Creek town #27	1.0
South edge of Scofield town #28	0.3
North edge of Scofield town #25	0.3
Fish Creek #26	0.75

Nitrite. The nitrite-nitrogen concentration in stream water was generally less than 10 µg/l. The highest nitrite-nitrogen (18 µg/l) value was measured in Mud Creek in February 1980. Cold water temperatures may have inhibited nitrite oxidation to nitrate.

Nitrate. The nitrate-nitrogen concentration in stream water ranged from less than 0.04 mg/l to 1.12 mg/l. The peak nitrate-nitrogen concentration occurred in May (0.46 mg NO_3-N/l to 1.12 mg NO_3-N/l). The nitrate concentrations are listed in Table 21.

Human waste disposal activities did not occur in the Fish Creek drainage area. Nitrate-nitrogen concentration in Fish Creek was therefore, lower than that in Mud Creek which was subjected to wastewater produced by human activities. Fish Creek may represent the natural, unpolluted stream in the study area. The occurrence of peak nitrate-nitrogen concentration in May coincided with the peak in stream flow as previously discussed (Figure 3). Hence the increase in stream flow resulting from snow melting may carry significant organic debris from overland flow and instream scouring processes. This organic material may contain nitrogen compounds which are biologically converted to ammonia. Nitrification of ammonia to nitrate can occur if proper environmental conditions exist. This situation may have occurred in Fish Creek. The difference between Fish Creek and Mud Creek was that humans were active in Mud Creek. Livestock feeding near Mud Creek could introduce high levels of

Table 20. Total phosphorus concentration in surface streams (μg/l).

Sampling site	Oct 1979	Apr 1980	May	June	July	Aug
South edge of Clear Creek town #24	85	-	241	93	64	13
North edge of Clear Creek town #27	20	136	421	119	36	31
South edge of Scofield town #28	-	177	3370	220	22	42
North edge of Scofield town #25	185	84	1670	320	72	20
Fish Creek #26	15	136	185	36	62	12

Table 21. Nitrate-nitrogen concentration in surface streams (mg/l).

Sampling site	Oct 1979	Apr 1980	May	June	July	Aug
South edge of Clear Creek town #24	0.11	-	1.12	0.31	<0.04	<0.04
North edge of Clear Creek town #27	-	0.39	1.03	0.32	<0.04	0.60
South edge of Scofield town #28	-	0.57	0.94	0.28	0.05	<0.04
North edge of Scofield town #25	0.14	0.78	0.81	0.31	<0.04	<0.04
Fish Creek #26	0.13	0.34	0.46	0.20	<0.04	<0.04

organic nitrogen in that watershed. The majority of organic nitrogen is probably stored in the soil strata and in benthic regions of streams during cold winter months. The abrupt increase in flow may sweep those stored substances into the stream, resulting in a high nitrate concentration in the sample. Nonetheless, nitrate-nitrogen levels observed in surface waters pose no danger to water users.

Iron and Manganese. Iron and manganese levels in surface streams were generally less than 40 μg/l, and 2 μg/l, respectively. On occasion, there were very high concentrations of iron (2106 μg/l) and manganese (468 μg/l). Table 22 shows iron and manganese concentrations in surface streams. The EPA primary drinking water limit (EPA 1975) is 300 μg/l, and 50 μg/l for iron and manganese, respectively. Consequently both the level of iron and manganese violated the EPA limit during April 1980. However, the level of iron and manganese was not a problem during the remainder of the study period.

Trace inorganics. Trace inorganics were analyzed in water samples collected from several surface water sampling sites. Table 23 presents the measured concentrations of trace inorganic chemicals in surface water in the study area. Most of the trace inorganics monitored pose no serious public health hazards. However, in May 1980, water samples collected from #27 contained 11 μg/l cadmium (Cd) which exceed the EPA maximum contaminant Limit (MCL). In addition, the water sample collected from wells #25 and 28 in May and April contained selenium (Se) levels which violated the EPA selenium MCL. Nonetheless, the low concentrations Cd (> 3 μg/l) and Se (> 2 μg/l) observed throughout most of the study period indicates that these chemicals present no serious problem to public health.

High concentration of mercury in surface streams poses a potential health threat to the community. The level of mercury in surface water ranged from 0.5 μg/l to 4 μg/l. Table 24 shows the mercury content in several surface streams. High concentrations of mercury during April and May 1980 worsened the mercury problem because of high stream flow (9.2 m^3/s or 325 cfs) (Figure 3). The EPA interim primary drinking water limit for mercury (2.0 μg/l) had been violated in surface streams. The high level of mercury during spring thaw in surface streams coincided with the high level of mercury measured in the groundwater.

Whereas, mercury poses a potential public health hazard, low fluoride levels measured in surface streams were not adequate to prevent dental caries. The concentration of fluoride in surface water ranged from 0.08 to 0.42 mg/l. Table 25 lists the fluoride concentrations in sampling sites #25, 27, and 28.

Table 22. Iron and manganese concentrations in surface streams (μg/1).

Sampling Site		Oct 1979	Apr 1980	May	June	July	Aug
North edge of Clear Creek Town #27	(Fe)	--	445	--	73	<11	
	(Mn)	--	72	--	15	10	
South edge of Scofield Town #28	(Fe)	--	106	--	39	17	
	(Mn)	--	131	<4	19	<6	
North edge of Scofield Town #25	(Fe)	20	2,106	20	21	17	
	(Mn)	41	468	5	19	15	

Table 23. Measured and EPA maximum contaminant levels (MCL's) of trace inorganic chemicals.

	Trace Inorganics										
	Arsenic	Barium	Cadmium	Chromium	Copper	Lead	Selenium	Silver	Zinc	Mercury	Fluoride
Measured Concentration	> 1 μg/ℓ[*]	3 μg/ℓ - 83 μg/ℓ	> 3 μg/ℓ May: Well 29 11 μg/ℓ	> 11 μg/ℓ	> 7 μg/ℓ[*]	> 3 μg/ℓ	> 2 μg/ℓ May: Well 25 19 μg/ℓ April: Well 28 15 μg/ℓ	> 8 μg/ℓ	1 μg/ℓ - 87 μg/ℓ	0.5 μg/ℓ - 4 μg/ℓ	0.09 mg/ℓ - 0.42 mg/ℓ
EPA Drinking Water MCL	50 μg/ℓ	1 μg/ℓ	10 μg/ℓ	50 μg/ℓ	1 μg/ℓ	50 μg/ℓ	10 μg/ℓ	50 μg/ℓ	5 μg/ℓ	2 μg/ℓ	1.4 mg/ℓ -[†] 2.4 mg/ℓ

[*] Below detection limits

[†] Acceptable fluoride concentration is a function of ambient temperature

Table 24. Mercury concentration in surface streams (μg/1).

Sampling Site	Oct 1979	Apr 1980	May	June	July	Aug
North edge of Clear Creek Town #27	--	3.0	--	2.4	--	--
South edge of Scofield Town #28	--	3.0	--	1.6	--	--
North edge of Scofield Town #25	<0.5	4.0	3.0	3.1		

Table 25. Fluoride concentrations in surface streams (mg/l).

Sampling Site	Oct 1979	Apr 1980	May	June	July	Aug
North edge of Clear Creek Town #27	--	0.38	0.25	0.17	0.09	0.13
South edge of Scofield Town #28	--	0.26	0.24	0.20	0.42	0.28
North edge of Scofield Town #25	0.10	0.36	0.24	0.18	0.18	0.26

2. Groundwater

Total Phosphorus. The total phosphorus concentration in the wells ranged from less than 10 μg/l to 9000 μg/l, with the peak values occurring in May 1980. The total phosphorus concentration in wells #4, 5, 6, 16, and 20 is shown in Figure 22 and Table 26. Wells #6 and 20 were chosen to show their relatively constant level of phosphorus concentration while wells #4, 5, and 16 show large fluctuations. Wells #4 and 5 were located in Bolotas and Scofield Campsite subdivision, respectively, which are characterized by a dense population of cottages and cabins. Well #16 was located in the north profile of Scofield town. With the exception of wells #6 and 20, all the wells that had high concentration of total phosphorus were located in residential or recreational areas. Well #6 was located in the Scofield Campsite subdivision. Water from well #6 had relatively constant total phosphorus throughout the whole study period (122 μg/l to 175 μg/l) with the peak value in May 1980. The area surrounding well #20, which was located in the foothills of the mountains, did not have any residential and/or recreational lots. A herd of cattle grazed on the land occasionally during the summer. Most of the time they grazed in the other fields across the road which are adjacent to the reservoir and not at this well site. The increase in total phosphorus concentration may originate from wastewater disposal by man. The drastic fluctuation of phosphorus concentration during the study period may be linked with the exchange reaction between phosphorus and the soil matrix.

Nitrogen. Ammonia and nitrite are precursors of nitrate in the nitrification process. The ammonia-nitrogen concentration was less than 90 μg/l in well water which contained sufficient dissolved oxygen. Wells #13 and 16 which have very little dissolved oxygen (0.1 μg/l) had ammonia-nitrogen concentrations ranging from 10 μg/l to 311 μg/l, with the average value of 155 μg/l. The ammonia levels were very low and should not produce any adverse effect on the aquatic life in Scofield Reservoir.

The nitrite is an intermediate product of nitrification from ammonia to nitrate. The nitrite-nitrogen concentration in the groundwater ranged from 1 μg/l to 1200 μg/l with majority of the values less than 10 μg/l. The relatively high nitrite concentration occurred during the cold weather, especially February 1980. In February, concentration ranged from 60 μg/l to 1200 μg/l in wells #2, 4, 5, 6, and 7. These wells were located in Bolotas and Scofield Campsite subdivision plus Scofield Reservoir State Park. The high nitrite concentration suggests the retardation of nitrification due to probably the lower temperature of the groundwater. Ammonia present in these shallow groundwater wells was probably derived from degradation of organic nitrogen compounds present in wastewater.

The relatively high concentration of nitrate-nitrogen was a common occurrence in two subdivisions, Bolotas and Scofield Campsite (wells #2, 3, 4, 5, and 6). Except for well #6, nitrate levels were less than 10 mg/l NO_3-N (Figure 23 and Table 27) which is the EPA drinking water standard (EPA

Table 26. Total phosphorus concentration of groundwater (μg/l).

Well #	Oct	Nov 1979	Feb 1980	Apr	May	June	July	Aug
4	106	272	237	379	9000	812	370	749
5	597	1864	978	242	3685	338	277	3432
6	122	129	156	152	175	145	135	116
16	310	<10	885	88	199	91	421	324
20	-	-	-	-	292	152	131	106

1975). The nitrate-nitrogen concentration in wells #2, 3, 4, and 5 ranged from 0.93 mg/l to 7.37 mg/l as NO_3-N, with an exception in well #2 reading 13.40 mg/l in July 1980. Well #6 had nitrate-nitrogen concentration exceeding the EPA limit (7.84 mg/l NO_3-N to 14.30 mg/l NO_3-N). The nitrate-nitrogen level in well #6 exceeded the EPA limit four times out of eight samplings. Only one case had violated EPA limit in well #2 in July 1980.

In contrast to these high nitrate concentrations, water from well #20 contained low nitrate-nitrogen concentration (0.04 mg/l NO_3-N to 0.59 mg/l NO_3-N). Water in well

Table 27. Nitrate-nitrogen concentrations of groundwater (mg/l as NO_3-N).

Well #	Oct	Nov 1979	Feb 1980	Apr	May	Jun	Jul	Aug
1	0.38	0.31[a]	-	0.33	0.48	0.53	0.50	0.44
2	3.68	4.0	3.47	2.64	2.71	2.31	13.40	5.84
3	1.84	2.4	3.37	3.14	3.23	3.50	3.39	4.29
4	1.12	0.93	1.42	4.84	7.37	3.44	2.03	4.24
5	2.78	2.86	3.41	3.49	4.78	4.48	4.98	6.89
6	11.03	8.64	12.24	7.84	10.13	9.95	9.00	14.30
20	-	-	-	-	0.39	0.59	0.11	0.04

[a]Data for December sample

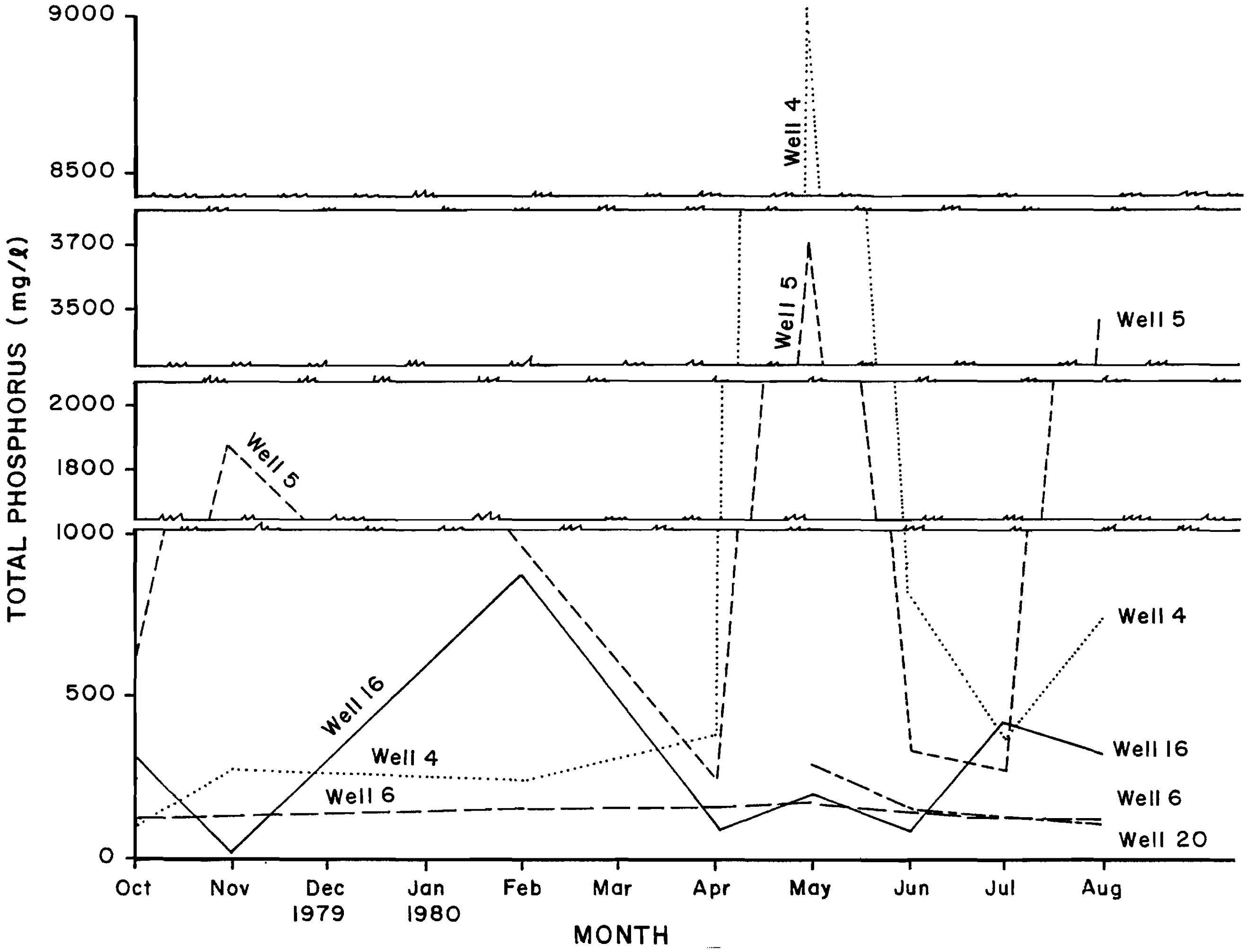


Figure 22. Total phosphorus concentration in wells #4, 5, 6, 16, and 20.

#20 had a high dissolved oxygen content. The aforementioned wells had ample dissolved oxygen except well #1 which is an artesian well (Table 28).

Dissolved oxygen was not a limiting factor for the possible nitrification process in the soil (Table 28). In the vicinity of well #20 is a steep hill covered with dwarf trees and bushes. There is not much waste disposal activity in the area. A few herds of cattle grazed the land near well #20 during the summer months. Well #20, hence, could provide a background level of nitrate-nitrogen in the study area (Figure 23) with its nitrate concentration less than 0.6 mg/l NO_3-N throughout the study period.

Another possible background level of nitrate concentration in the groundwater may be water taken from well #1 which penetrated an artesian aquifer. Its nitrate-nitrogen concentration ranged from 0.31 mg/l to 0.53 mg/l and was fairly constant throughout the study period (Figure 23).

High nitrate concentrations were measured in wells #2, 3, 4, 5, and 6. Comparing the levels of nitrate in these wells to the background level in wells #1 and 20 suggests pollution, possibly from wastewater disposal activities. The Bolotas and Scofield Campsite subdivision where wells #2, 3, 4, 5, and 6 were located were quite crowded with cottages and cabins. Surrounding these wells are the reservoir and hills which highway 96 passes through. No agricultural activities are in this area. Since nitrate-nitrogen is formed from organic nitrogen sources by the nitrification process, the nitrate-nitrogen in these wells could be the result of organic pollution from the cottages and cabins in these areas and also possibly due to the decay of dwarf plants.

The nitrate-nitrogen concentration and dissolved oxygen content in wells #17, 18, and 19 which were located in the same profile with well #16 (Figures 5 and 7) have relatively high nitrate content together with a slightly aerobic condition. Table 29 sum-

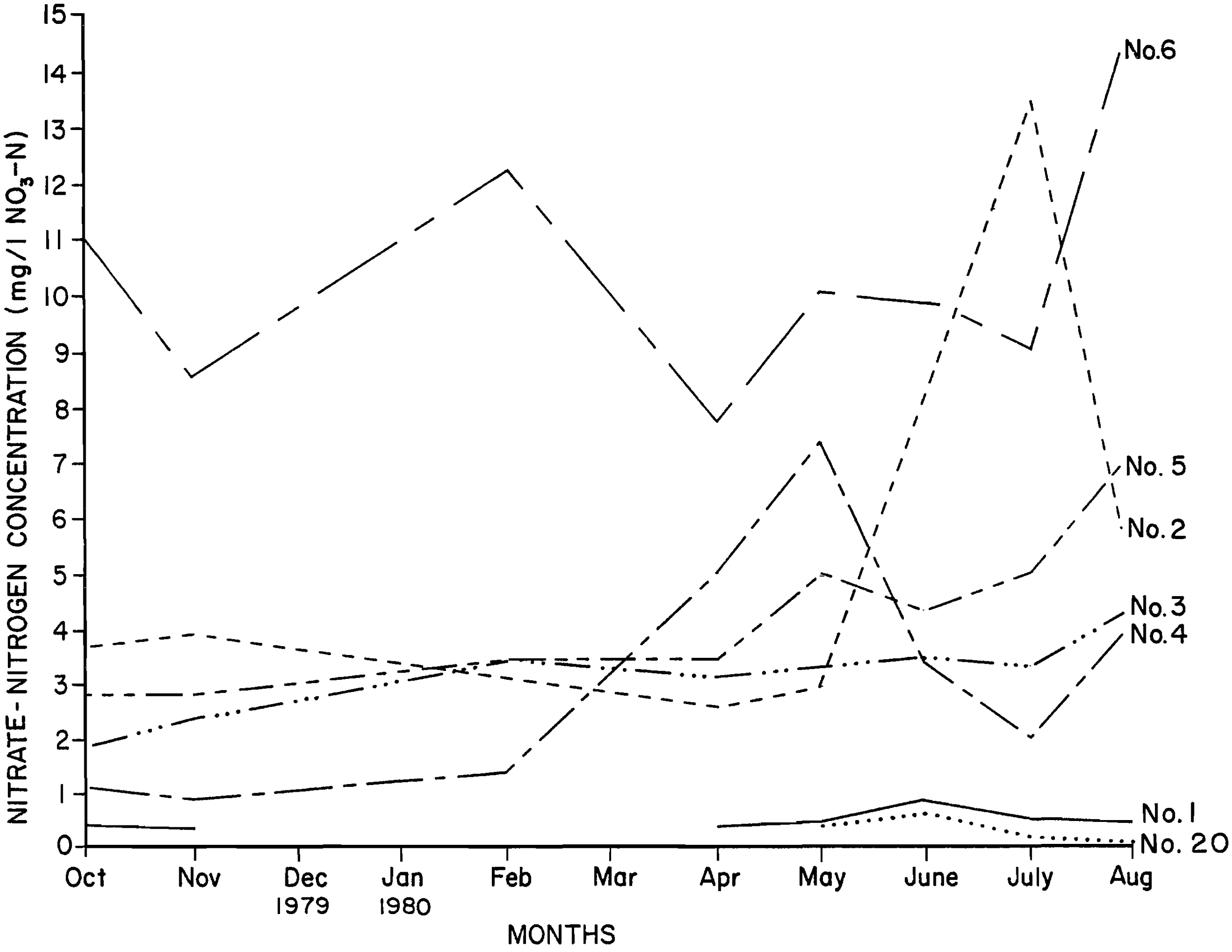


Figure 23. Monthly variation in NO_3^- concentration.

Table 28. Dissolved oxygen level of groundwater.

Well #	Oct	Nov 1979	Feb 1980	Apr	May	Jun	Jul	Aug
1	-	1.0[a]	-	1.0	1.5	-	2.0	2.2
2	7.1	5.0	6.0	8.0	8.4	-	7.1	6.5
3	7.8	7.0	8.0	8.5	9.0	-	9.0	6.8
4	6.8	7.0	7.0	7.0	7.8	-	6.3	7.0
5	6.7	4.0	4.0	7.0	8.1	-	6.7	5.8
6	8.3	8.0	6.7	6.5	8.6	-	9.6	5.8
20	-	-	-	-	9.2	-	7.3	3.9

[a]Data for December sample

Table 29. DO and nitrate nitrogen content of groundwater (mg/l).

Well #	Parameter	Oct	Nov	Apr	May	Jul
16	DO	2.0	2.8	4.0	0.0	0.0
	NO_3-N	0.1	0.04	0.15	0.06	0.18
17	DO	1.7	4.0	4.0	8.6	7.2
	NO_3-N	0.16	0.61	1.54	2.91	2.47
18	DO	1.9	4.0	5.0	9.3	-
	NO_3-N	4.71	5.0	0.54	2.57	-
19	DO	3.5	6.5	3.0	8.2	6.4
	NO_3-N	1.54	1.5	1.89	3.95	1.70

marizes DO and nitrate-nitrogen in these wells for October and November 1979, April, May, and July 1980. The generally high nitrate concentrations in wells #17, 18, and 19 (located at the north profile of Scofield town) compared to background nitrate-nitrogen level in wells #1 and 20 suggest active nitrification of ammonia within the soil water matrix as wastewater migrates to the aquifer.

Low nitrate concentration was accompanied by low dissolved oxygen content in wells #13 and 16. Low nitrate concentration alone does not necessarily mean lower organic pollution in the groundwater. If it is accompanied by higher ammonia (NH_3) concentration together with zero dissolved oxygen, the groundwater may be contaminated by the pollutants. However, neither high ammonia levels nor BOD levels were measured in wells #13 and 16. Therefore, organic pollution in these wells is doubtful.

Aerobic degradation of organic matter in the soil mantle followed by nitrification of ammonia to nitrate could produce localized anoxic conditions. Under relatively anoxic conditions, nitrate leached from the soil mantle may be lost from the soil-water matrix by the action of bacteria that use nitrate as terminal electron receptors. The process of nitrate reduction is termed denitrification. If nitrification occurred in the upper soil profile, subsequent denitrification of nitrate to nitrogen gas can explain the lack of nitrate in the groundwater. Sometimes oxygen depletion can come from natural oxidation of minerals in the aquifer.

Iron. Pyrite (FeS_2) is common in coal mining areas. When pyrite is exposed to oxygen and water, it is oxidized to ferrous and sulfate ion. The probable reaction is as follows (Bailey et al. 1978):

$$FeS_2(s) + \frac{7}{2} O_2 + H_2O \rightleftharpoons Fe^{++} + 2SO_4^{--} + 2H^{+} \quad . \quad . \qquad (9)$$

This leads to a highly acidic water. Further ferrous (Fe^{++}) ion could be oxidized to ferric (Fe^{+++}) ion. Iron bacteria, if they are present, accelerate this reaction,

$$Fe^{++}\ (aq) + \frac{1}{4} O_2 + H^{+} \rightleftharpoons Fe^{+++} + \frac{1}{2} H_2O \quad . \quad . \quad . \qquad (10)$$

Stoichiometrically, 3.75 moles of oxygen could be consumed per mole of pyrite, or one gram oxygen is consumed for one gram pyrite oxidation. If the ferric ion conversion from the ferrous ion is too slow, then 3.5 moles O_2 would be required per mole of pyrite or 0.94 gram O_2 would be consumed per gram pyrite oxidation. The thorough examination of well log samples taken from wells #13 and 16 showed no pyrite. However, there is still the possibility of pyrite existence upstream of the well, and below the well log and/or in the bedrock. However, water from well #16 contained high iron concentrations reaching almost 28 mg/l.

The presence of ferrous (Fe^{++}) and/or manganese ion (Mn^{++}) in groundwater may indicate anaerobic conditions due to organic pollution (Stumm and Morgan 1970). Biological oxidation of organic matter penetrating into the soil-groundwater matrix may consume dissolved oxygen in water. Since the solubility of oxygen is low, the dissolved oxygen content in the water may soon be depleted when there are oxidizing substances in soil-groundwater matrix. The anaerobic condition is manifested by low or negative redox potential (pE) and zero dissolved oxygen content. Under these conditions, Fe and Mn become dissolved as Fe^{++} and Mn^{++}. Equilibrium chemistry of iron shows the relationship between ferrous (Fe^{++}) ion and ferric ion (Fe^{+++}). The solubilization of $FeO(OH)(s)$ can be expressed stoichiometrically as:

$$FeO(OH)(s) + 3H_3O^+ \rightleftharpoons Fe^{+++}(aq) + 5H_2O, \ K = 10^4 \quad . \ . \ . \ . \ . \ . \ . \ . \ . \ (11)$$

$Fe^{+++}(aq)$ represents the ferric complexes in solution and,

$$Fe^{+++}(aq) + e \rightleftharpoons Fe^{++}(aq), \ K = 10^{12.53}$$

Combining these two reactions (1 and 2),

$$FeO(OH)(s) + 3H_3O^+ + e \rightleftharpoons Fe^{++}(aq) + 5H_2O, \ K = 10^{16.53} \quad . \ . \ . \ . \ . \ . \ . \ . \ . \ (12)$$

The equilibrium constant (K) for the reaction is mathematically defined as,

$$K = \frac{[Fe^{++}]}{[H_3O^+]^3 \ [e]} \quad . \ . \ . \ . \ . \ . \ . \ . \ (13)$$

in which

$[Fe^{++}]$ = molar concentration of ferrous ion

$[e]$ = molar concentration of electrons

$[H_3O^+]^3$ = molar concentration of hydrogen ion

Since the redox potential can be defined as,

$$pE = -\log[e] \quad . \ . \ . \ . \ . \ . \ . \ . \ . \ (14)$$

The molar concentration of ferrous ion can be determined from the following expression.

$$\log[Fe^{++}] = \log K - 3pH - pE \quad . \ . \ . \ . \ (15)$$

The ferric ion (Fe^{+++}) makes salts which are virtually insoluble under neutral pH conditions. Actually, the ferric salts are dissolved only at or below pH 4.0. Ferrous ion (Fe^{++}), however, does not form complexes significantly at pH less than 10, and is soluble near neutral pH conditions (Bailey et al. 1978).

The air saturated water has pE value of 12.5. At a neutral pH, ferrous ion (Fe^{++}) concentration may be $10^{-16.5}$, which is negligible However, at anaerobic condition, which means lower pE, Fe^{++} concentration becomes significant. Therefore, Fe^{++} appears primarily under anaerobic conditions (Bailey et al. 1978).

Iron exists on the ground mainly as insoluble ferric oxide and ferrous sulfide (pyrite, FeS_2). The latter ion specie (FeS_2) is especially abundant in coal areas such as the study area of Scofield. Acid-mine drainage may result from pyrite oxidation, which yields high SO_4^{-2} and lower pH in the water.

Manganese exists in the ground mainly as manganese oxide (MnO_2), which is insoluble in natural water. The basic chemistry of this compound resembles that of iron.

In summary, Fe^{++} and Mn^{++} exist in groundwater only under reducing (anaerobic) circumstances. Well #16 contained high concentrations of iron (annual average iron concentration was 13.6 mg/l). In addition, well #13 contained water which had a high iron content (maximum 10.2 mg/l), lower nitrate-nitrogen content (less than 0.1 mg/l), and low dissolved oxygen content (less than 1.8 mg/l). A possible source of pollution in well #13 might be from cattle grazing just above this well, but the true source is not known. The general relationship among dissolved oxygen content, nitrate-nitrogen content and ferrous plus manganese content in wells #13 and 16 is shown in Figures 24 and 25. The lower dissolved oxygen was accompanied by lower nitrate-nitrogen concentration and high concentration of iron and manganese.

<u>Dissolved Oxygen.</u> The dissolved oxygen in the wells of the Bolotas and Scofield Campsite subdivisions (#2, 3, 4, 5, and 6) ranged from 4.0 mg/l to 9.6 mg/l (Table 28). These levels are generally high, and the occurrence of lower BOD_5 could be interpreted as a result of vigorous oxidation. It is evident that organic substances get into the ground through various wastewater disposal practices such as septic tanks, cesspools, pit privies, and even dumping the waste into the ground.

The BOD_5 level (less than 3.0 mg/l) is far below the detection range and could be explained by the microbial oxidation of these organic substances. The organic substances penetrated into the ground are degraded to stable inert materials which do not exert an oxygen demand.

<u>Trace Inorganics.</u> Trace inorganics have been analyzed in most of the wells. Water samples were analyzed for arsenic (As), barium (Ba), cadmium (Cd), chromium (Cr), copper (Cu), mercury (Hg), lead (Pb), selenium (Se), silver (Ag), zinc (Zn), iron (Fe), and manganese (Mn). In addition, fluoride (F) was analyzed. The discussion here will exclude iron and manganese since they were measured in high concentrations and therefore were important parameters in this study. The purpose of trace inorganics analysis was to find any abnormal concentration of these substances which might be formed naturally. There was no industrial waste disposal except a small amount of coal mining wastes. EPA interim primary drinking water standards (EPA 1975) are presented on Table 30 for these trace elements.

Arsenic concentrations were always less than 1 μg/l in all the wells except for one instance in well #13 in April 1980 when the sample contained 2 μg/l arsenic. This level of arsenic concentration is less than the

Table 30. EPA interim primary drinking water standards (1975-1976).

Metals	μg/l	Nonmetals	μg/l
Barium (Ba)	1000	Arsenic (As)	50
Cadmium (Cd)	10	Selenium (Se)	10
Chromium (Cr)	50	Fluoride (F)	1400-2400[a]
Lead (Pb)	50		
Mercury (Hg)	2		
Silver (Ag)	50		
Copper (Cu)	1000[b]		

[a] Depends upon the ambient air temperature.

[b] No regulation in EPA standards. Adopted from USPHS 1962 standards.

5 μg/l reported by Sawyer and McCarty (1978) as typical for most natural water systems. Furthermore, the current arsenic level is far below the standard (50 μg/l) and hence no health problem is likely from arsenic in the wells of the study area.

Barium levels ranged from 3 μg/l to 160 μg/l. The majority of the values fall between 25 μg/l and 60 μg/l. Even the highest concentration is far below the standard (Table 31).

Cadmium concentrations were always less than 3 μg/l, which is near the detection limit and less than a third of the drinking water standard of 10 μg/l.

Only in one sample did chromium concentrations exceed 11 μg/l. In well #9, however, 96 μg/l chromium was measured in May 1980 which violated the EPA standard (50 μg/l). Since well #9 is the only exception, chromium in the water most likely is not a health problem.

Copper regulations were dropped from EPA interim primary drinking water standard in 1975. Formerly USPHS (1962) set 1 1000 μg/l limit. A copper concentration in the water from well #9 was 33 μg/l in May 1980. All the other wells showed less than 7 μg/l throughout the study period.

In some samples from every well, mercury exceeded the EPA limit. Mercury concentrations ranged from 0.2 μg/l to 6 μg/l and the average mercury concentration of all well water samples throughout the entire study period was 2.52 μg/l. The number of data used in this average was 65, their standard deviation was 1.65, and the coefficient of variability was 65.4 percent. The majority

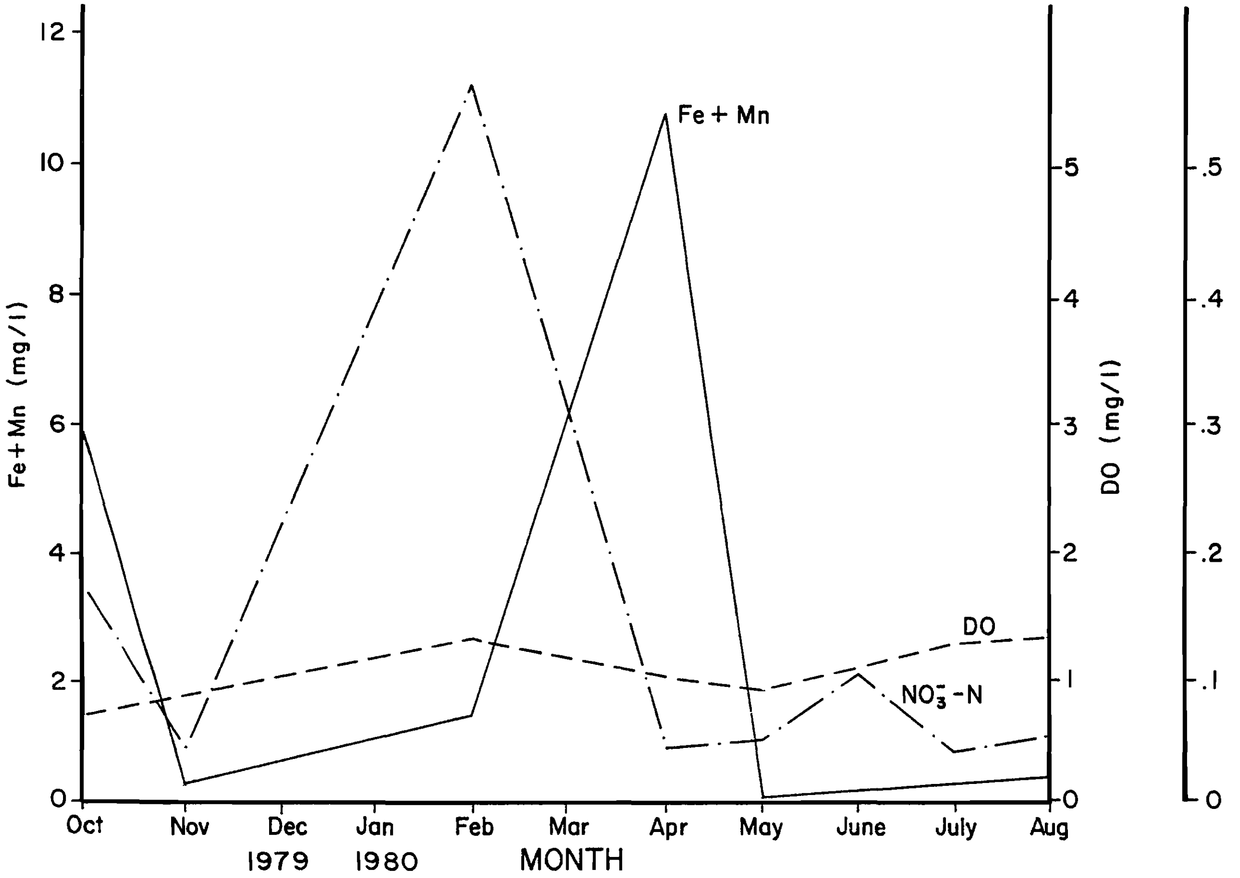


Figure 24. Relationship among NO_3-N, DO, and Fe^{2+} and Mn^{2+} in well #13.

of water samples have mercury concentrations between 1 μg/l and 4 μg/l some of which are listed in Table 31. Consistently higher values occurred during April and May 1980 when the average mercury levels exceeded 3 μg/l for the whole area. In certain wells, the highest value occurred during February (#6 and 7). A seasonal fluctuation in the mercury concentration seemed to occur, however, no special variation was observed. Further, there was no significant difference between groundwater and surface water. Hence the relatively high mercury concentration may be a common characteristic of water in the study area. The high mercury level poses serious health hazards if the water is used for potable water. Furthermore, mercury could be accumulated in fish through the food chain in what is called biomagnification. The high mercury level in the study area may thus become a problem to the people who over a long period of time drink the water or eat the fish taken from the basin. For this reason drinking water should be taken only from those sources which have concentrations below the standard.

Lead is also a toxic element. The concentration of lead in the water samples varied from less than 1 μg/l to 13 μg/l. The highest value was measured in water collected from well #11 in June 1980. The majority of the values were less than 3 or 4 μg/l, and most were less than 1 μg/l. Consequently, lead concentration in the water is not a problem in Pleasant Valley.

Selenium levels were normally less than 3 μg/l and the majority were less than 1 μg/l. However, a few exceptions exceeding the 10 μg/l standard were observed during April and May 1980. Then wells #4 and 16 had 11 μg/l, well #13 had 44 μg/l, surface site #25 had 19 μg/l and surface site #28 had 15 μg/l selenium. The peak selenium concentration in the groundwater and surface water occurred at about the same time.

Silver concentrations ranged from less than 1 μg/l to 11 μg/l, which was far below the EPA limit (50 μg/l). This is the same both in groundwater and in surface water.

Zinc is not very toxic to humans. The 5.0 mg/l limit set by the USPHS in 1962 was based on a taste problem, not a toxicity problem. It has since been dropped from the EPA regulations. The zinc values ranged

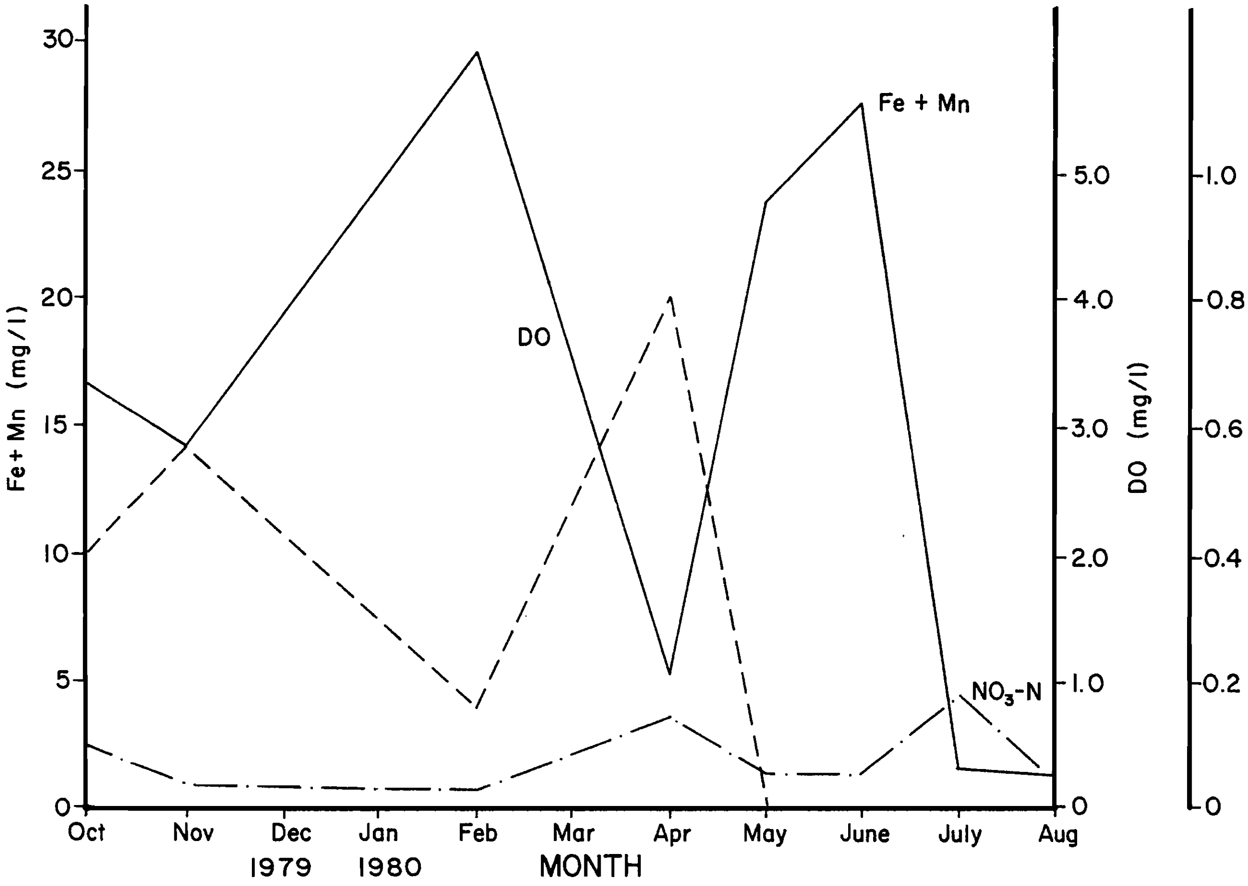


Figure 25. Relationship among NO_3-N, DO, and Fe^{2+} and Mn^{2+} in well #16.

Table 31. Typical mercury (Hg) concentrations in some sampling sites (µg/l).

Sampling Site	Oct	Nov	Feb	Apr	May	June	July	Aug
#2	-	-	-	4	3	0.8		
#3	-	-	-	4	3	3.9		
#4	0.5	1	3	5	3	3.6		
#5	0.5	1	0.7	5	t	2		
#6	0.5	0.2	6	4	3	2.7		
#7	0.5	0.6	6	5	4	2		
#9	0.5	-	1.9	5	-	1.5		
#11	0.5	-	-	5	3	2.6		
#13	0.5	-	1.6	2	3	2		
#14	5	-	1.3	-	-	-		
#15	-	-	5	-	3	-		
#16	0.5	-	1.8	3	1	1.5		
#17	2	-	-	4	-	-		
#19	-	-	-	4	2	2.2		
#25	0.5	-	-	4	3	3.1		
#27	-	-	-	3	-	2.4		
#28	-	-	-	3	-	1.6		

from 1 µg/l to 1020 µg/l with most of the values between 60 µg/l and 80 µg/l. Zinc in the water is not a health problem to the community.

Fluoride concentrations ranged from 70 µg/l to 640 µg/l. These values are generally lower than the EPA Interior Drinking Water Standard of 1490 µg/l to 2400 µg/l. Hence permanent residents may develop a dental caries problem if the typical groundwater from these wells were to be used for drinking water.

A review of trace inorganics revealed only one element, mercury, as an important threat to public health. The mercury level averaging 2.5 µg/l and sometimes reaching 6.0 µg/l poses a threat to public health and a potential pollutional threat to fishing in Scofield Reservoir because it exceeds an EPA limit of 2.0 µg/l. The similarity between groundwater and surface water concentrations in mercury and other trace inorganics suggests a natural geological source, not one from the waste disposal activities.

SUMMARY AND CONCLUSIONS

Pollution of shallow groundwater due to wastewater disposal in Pleasant Valley, Utah, was investigated from October 1979 through August 1980. The study included the assessment of the groundwater hydrology and surface and groundwater quality in the study area. Water samples were obtained at monthly or longer intervals from 28 sampling sites. Most wells were sampled eight times in the year. Water table levels were measured throughout the study period. A comprehensive questionnaire concerning waste disposal practices was sent to all property owners of Pleasant Valley. The results from the questionnaire identified the various types of waste disposal practices and the seasonal variation in individuals residing in the study area. Based on the population data obtained from the questionaire an estimate of the organic waste production was made. The following specific conclusions were obtained from the results of the study:

Hydrology

Water levels were recorded in all wells during the study period. Water table elevations fluctuated on an annual cycle reaching a maximum in the spring (May) and a minimum in the fall (November). The range of changes in elevations varied from 0.30 m (1.0 ft) to 5.6 m (18.4 ft). The highest elevation of the groundwater was 0.31 m (1.02 ft) above the ground in flowing well #1 in May and its lowest elevation was 5.84 m (19.2 ft) below the ground surface in September in well #22.

Pollution in the shallow groundwater moves slowly towards the lake. Slug tests in observation wells showed hydraulic conductivities between 0.0006 cm/sec on the west side hill above the lake to 0.0026 cm/sec in the valley fill near Scofield. Using a mean conductivity of 0.002 cm/sec for the valley fill and assuming a porosity of 0.30, the velocity of travel of pollution through the valley fill is 0.007 cm/sec or 6 m/day. This is in the range to be expected in fine sands or loam soils.

Underflow past Scofield was estimated to be about 9 gpm or 0.0006 m^3/sec. Therefore, ungaged underflow to the lake due to shallow groundwater is very small. Ungaged underflow to the lake from bedrock springs rising in the lake was not investigated and should be studied in the future.

X-ray mineralogy of cuttings from typical observation wells suggests that the clays present would have a relatively small effect on changes in the chemistry of the shallow groundwater. Furthermore, the sediments would be moderately effective in removing organic contaminants from the groundwater.

Wastewater Disposal Practice

After 126 responses out of 292 questionnaires had been analyzed, it was found that 65.5 percent of the structures in the study area have septic tanks, 13.6 percent have privies, 12.4 percent have holding tanks, 7.5 percent have septic tanks plus pit privies, and 10 percent have holding tanks plus pit privies.

There are two types of septic tanks in the study area; one is a typical septic tank consisting of a single compartment together with a leach field, and the other is a cesspool. The applicability of subsurface waste disposal practices, including septic tanks, cesspools, and pit privies is questionable because the groundwater is so shallow.

The maintenance of these systems in the study area is generally not up to acceptable standards.

Organic Waste Production

The total person-days in the study area is 70,000 person-days per year, excluding people in state park and other campsites. The resulting annual production of BOD_5, Total-N, and phosphorus is calculated at 2605 kg, 404.4 kg, and 253.6 kg, respectively. Summer seasons produce more than 50 percent of the total wastes. The town of Scofield produces 64 percent of the total waste production in the study area.

Water Quality

Water quality analyses were conducted on water samples obtained from 5 surface water sites and 23 shallow groundwater wells during the period of October 1979 to August 1980. The results indicate domestic waste disposal practices in the town of Scofield, Bolotas Subdivision, and Scofield Campsite Subdivision may be degrading the quality of the shallow groundwater. The water quality data failed to show any surface or groundwater pollution in the remaining portions of the study area. Specific conclusions obtained from the study are:

1. Temperature of groundwater ranged from 2°C to 12°C during the study period. The arithmetic mean groundwater temperature was 7.4°C.

2. The pH of the groundwater ranged from 6.0 to 7.7. Surface water had an average pH of 8.2.

3. Groundwater specific conductivity values varied from 216 to 1309 µmhos/cm at 25°C. The range of specific conductivity in surface water was 238 to 592µmhos/cm at 25°C. These levels of specific conductance are below the upper consumer-acceptance limits (1600 µmhos/cm) specified by the State of California.

4. The total dissolved solids (TDS) concentrations in eight groundwater wells ranged from 105 mg/l to 893 mg/l. These TDS levels are below the maximum contaminant levels specified by the State of Utah (2000 mg/l).

5. The five day biochemical oxygen demand measured in all samples during the study period was below 3 mg/l. Therefore, organic pollution of groundwater and surface water was not measured.

6. Cation and anion concentrations (i.e. sodium, chloride, potassium, boron, sulfate) monitored in surface and shallow groundwater samples remained relatively constant throughout the study period. High values of sulfate occurred in water obtained from well #16 (123 mg/l to 207 mg/l). The interrelationships among ferrous ion, low dissolved oxygen and sulfate ion in well #16 indicate the possible oxidation of pyrite.

7. The water in the study area was generally hard (150 mg/l to 300 mg/l as $CaCO_3$). The limestone geological formations in the study area are the major source of calcium and magnesium in the water.

8. Bacteriological examination of well water samples did not show the presence of detectable coliform groups. On occasion a total coliform bacteria count of 10/100 ml was measured in well #7 at the state park adjacent to Scofield Reservoir.

9. The ratios of fecal coliform to fecal streptococci in surface water samples were between 1.0 and 0.3. The major source of coliform organisms in Mud Creek and Fish Creek was from warm blooded animals (i.e. cattle, sheep, etc.).

10. Alkalinity in all water samples ranged from 83 mg/l to 419 mg/l as $CaCO_3$. The average values of alkalinity contained in wells #5, 12, 13, and 16 were 370 mg/l, 344 mg/l, 359 mg/l, 419 mg/l, and 458 mg/l as $CaCO_3$, respectively. The remaining surface and groundwater sampling sites contained water with alkalinity less than 300 mg/l as $CaCO_3$.

11. Surfactant concentrations measured in water throughout the study area were less than the USPHS drinking water standard of 0.5 mg/l and, therefore, do not pose any problem.

12. Total phosphorus in surface streams ranged from 22 µg/l to 3,370 µg/l. Peak total phosphorus levels were measured in May 1980 (185 µg/l to 3,370 µg/l). The average total phosphorus concentration in May 1980 was 1,177 µg/l. In addition, periods of maximum flow occur in May. Therefore, maximum mass loading of total phosphorus occurs in May. The total phosphorus loading to the surface water is from natural sources and not human waste disposal practices.

13. Total phosphorus levels in well water ranged from less than 10 µg/l to 9000 µg/l. The peak total phosphorus concentration occurred in May 1980. Water in wells #4 and 5 contained the highest levels of total phosphorus. The arithmetic annual mean total phosphorus values were 1491 µg/l and 1427 µg/l for water obtained from wells #4 and 5, respectively. The annual average background levels of total phosphorus was approximately 170 µg/l (well #20). These wells were located in Bolotas and Scofield Scofield Campsite Subdivisions. Total annual arithmetic average total phosphorus levels in water obtained from well #16 was 291 µg/l. Well #16 is located on Northern Profile of the town of Scofield. Therefore, phosphorus contamination of groundwater may be caused by domestic waste disposal practices.

14. Ammonia-nitrogen levels in surface water were less than 180 µg/l and, therefore, presents no problem to human or aquatic life. Similarly, nitrite-nitrogen and nitrate-nitrogen levels in surface waters were less than 18 µg/l and 1.12 mg/l, respectively and present no public health threat.

15. Ammonia-nitrogen levels in groundwater samples were less than 155 µg/l and should not produce any adverse effects to aquatic life. The majority of nitrite-nitrogen concentrations in groundwater were less than 10 µg/l. One sampling period (February) produced a nitrite-nitrogen level of 1200 µg/l in well #6. Bolotas and Scofield Campsite Subdivision (wells #2, 3, 4, 5, and 6) had shallow groundwater with high concentrations of nitrate-nitrogen (0.93 mg/l to 14.30 mg/l). Water sampled from well #6 had nitrate-nitrogen levels of 10 mg/l or greater 5 out of 8 sampling periods. The EPA drinking water standard is 10 mg NO_3-N/l. Nitrate-nitrogen data indicate a potentially hazardous condition existing resulting from wastewater disposal practices.

16. Generally, surface water iron and manganese concentrations were less than 50 µg/l and 2 µg/l, respectively. The EPA secondary drinking water standard is 300 µg iron/l and 50 µg manganese/l. In April 1980, both the standard for iron and manganese were violated (2106 µg iron/l and 468 µg manganese/l at site #25). Iron and manganese in surface water do not create a drinking water problem.

17. Wells #16 and #13 contained water with annual average iron concentration of 13.6 mg/l and 2.2 mg/l, respectively, which will violate EPA secondary drinking water standards.

18. The majority of trace inorganics (i.e. Cd, Se, Cr, Cu, Pb, Ag, Zn, and F) in surface and groundwater were far below the maximum contaminant levels (MCL's) proposed by EPA. Mercury levels in surface water, however, may pose a potential public health threat. The level of mercury in surface water varied from 0.5 µg/l to 4 µg/l. One data point at sampling site #25 in October 1979 and one data point at sampling site site #28 in June 1980 did not exceed the EPA drinking water MCL for mercury of 2.0 µg/l.

19. Groundwater mercury concentrations in all wells exceed the EPA MCL of 2.0 µg/l. Mercury levels ranged from 0.2 µg/l to 6 µg/l, with an arithmetic average concentration of 2.52 µg/l. The majority of groundwater samples had mercury concentrations between 1 µg/l and 4 µg/l. Surface and groundwater samples collected in April and May 1980 contained mercury levels exceeding 3 g/l.

Pollution of shallow groundwater by leachates from septic tank drain fields can pose a serious public health hazard if water is used for human consumption. Table 32 indicates that well #6, located in the Scofield Reservoir Campsite subdivision had the highest frequency of nitrate levels that exceeded the Federal and State of Utah drinking water MCL (10 mg/l Nitrate-nitrogen). Furthermore, 50 percent of the water samples obtained from well #7 located down-gradient of the state park septic tank drain field contained water which exceeded the State of Utah MCL. Therefore, septic tank systems located in close proximity to Scofield reservoir may be potential sources of shallow groundwater pollution.

Shallow groundwater in Pleasant Valley is polluted with a natural source of mercury (Table 32). Mercury levels greater than 2 µg/l may pose a serious public health problem if the water is used for human consumption. Furthermore, bioaccummulation of mercury in fish in Scofield Reservoir may threaten anglers.

Data obtained in this study indicate that areas utilizing septic tank systems for waste treatment must be designed with regard to seasonal variation of groundwater levels and potential groundwater inundation of leach fields. Furthermore, the proper design and construction of a septic tank system is required. In Scofield Reserviur Campsite subdivision only a third of the people who responded to the waste disposal questionnaire had septic tank systems; this was the lowest percentage of any subdivision surveyed.

Table 32. Violation of MCL (Maximum Contaminant Level) of Primary Drinking Water Standards for State of Utah during the study period (Oct. 1979 to Aug. 1980).

	Parameters		
Sampling Site #	Coliform Bacteria (/100 ml)	Nitrate-Nitrogen (as N) mg/l	Mercury (mg/l)
MCL	1	10	0.002
2	1/8*	1/8	2/3
3	-	-	3/3
4	1/8	-	4/6
5	1/8	-	3/3
6	1/8	4/6	4/6
7	4/8	-	4/7
9	-	-	1/4
11	-	-	3/4
12	1/8	-	-
13	2/8	-	3/5
14	1/6	-	1/2
15	1/7	-	2/2
16	1/8	-	1/5
17	-	-	2/2
19	-	-	3/3
24	4/5	-	-
25	6/6	-	3/4
26	6/6	-	-
27	6/6	-	2/2
28	4/4	-	1/2

*Numerator represents the number of samples exceeding or equal to MCL, the denominator represents the number of samples analyzed during the study period.

Recommendation for Research

1. Periodic harvesting of fish in Scofield Reservoir to measure mercury levels in tissue.

2. Research needs to be conducted delineating the complete chemical, biological and physical properties of Scofield Reservoir. Algal activity should be measured. Bioassays should be conducted to detect nutrient limitations of algae. In addition, mercury accumulation in phytoplankton should be measured.

3. Selected septic tank drainage areas in subdivisions in Pleasant Valley should be isolated and a more comprehensive shallow and deep groundwater investigation needs to be conducted. Sufficient wells need to be drilled to adequately describe the hydrology and quality of the groundwater.

4. An indepth investigation concerning the movement and time of transport of the groundwater needs to be conducted.

Table A-3. Well #3.

	October	November	February	April	May	June	July	August
Date	10-23-79	11-27-79	2-24-80	4-20-80	5-20-80	6-22-80	7-23-80	8-21-80
Time	12:00	13:00	11:30	8:30	11:00	11:40	17:15	
Temp								
Air (°C)	--	--	--	--	--	24	22	23
Water (°C)	9.5	8	--	5	6	7.5	7.5	8
Depth to Water Table (ft)	-10.79	-11.40	-10.70	-9.63	-4.83	-2.12	-3.66	-6.53
(m)	-3.29	-3.47	-3.27	-2.94	-1.47	-0.65	-1.12	-1.99
Snow Depth (inches)	--	--	36.5	--	--			
DO (mg/l)	7.8	7	8	8.5	9.0	--	9.0	6.8
pH (Field)		--	6.2	--	7.0	6.9	7.7	6.6
Coliform								
Total/100 ml	<1	<1	<1	<1	<1	<1	<1	<1
Fecal/100 ml	<1	<1	<1	<1	<1	<1	<1	<1
Fecal streptococci/100 ml							1	<1
Nitrogen								
NH_3-N (μg/l)	87	15	33	11	36	18	44	50
NO_3-N (mg/l)	1.84	2.4	3.37	3.14	3.23	3.50	3.39	4.29
NO_2-N (μg/l)	5	44	10	5	20	5	10	6
Phoshpate								
Ortho (μg/l)	136	114	98	225	110	108	100	150
Total (μg/l)	857	1136	542	225	1385	110	<800	178
BOD (mg/l)				<1	<1	<2	1.2	<1
TDS (mg/l)				143	196	227	234	205
Specific Conductivity (μmhos/cm at 25°C)	421	417	286	288	300	283	303	299
Cations								
Na (mg/l)				13	11	9		
Mg as $CaCO_3$ (mg/l)				7	76	15	28	22
K (mg/l)				4	2	1		
Ca as $CaCO_3$ (mg/l)				64	114	133	108	106
Anions								
Cl (mg/l)				7	8	6	8	51
SO_4 (mg/l)				21	18	19	21	13
B (mg/l)					<0.1	0.11	0.14	0.22
Total Hardness as $CaCO_3$ (mg/l)				71	190	148	136	128
Total Alkalinity as $CaCO_3$ (mg/l)				126	113	112	131	114
pH (Lab)				7.82	8.08	7.89	7.80	8.15
Surfactant as MBAS (μg/l)	--	--	--	<100	<25	<25	<25	<25
Trace Inorganic								
As (μg/l)				<1	<1	<1		
Ba (μg/l)				<50	62	<3		
Cd (μg/l)				<3	<2	<2		
Cr (μg/l)				<10	<11	<11		
Cu (μg/l)				<7	<7	<7	<5	
Fe (μg/l)				467	<11	24	<11	142
Hg (μg/l)				4	3	3.9		
Mn (μg/l)				9	<5	<4	<6	<7
Pb (μg/l)				<1	<1	<1	<1	
Se (μg/l)				<1	4	<1	<1	
Ag (μg/l)				<3	<6	<3		
Zn (μg/l)				27	54	68		
F (mg/l)				0.18	0.26	0.18	0.12	0.17

APPENDIX A

WATER SAMPLE DATA AND ANALYSES

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Table A-4. Well #4.

	October	November	February	April	May	June	July	August
Date	10-23-79	11-27-79	2-24-80	4-20-80	5-20-80	6-22-80	7-22-80	8-21-80
Time	--	14:30	12:30	9:00	12:10	12:20	19:30	
Temp								
Air (°C)	--	--	--	--	23	25	25	24
Water (°C)	9.5	7	--	3	6.5	8.5	9.5	8
Depth to Water Table (ft)	-13.25	-13.62	--	-12.14	-7.79	-5.29	-6.50	-8.85
(m)	-4.04	-4.15	--	-3.70	-2.37	-1.61	-1.98	-2.69
Snow Depth (inches)	--	--	--	--	--			
DO (mg/l)	6.8	7	7	7	7.8	--	6.3	7.0
pH (Field)		--	6.6	--	7.1	6.6	7.3	6.7
Coliform								
Total/100 ml	1	<1	~20	<1	<1	<1	<1	<1
Fecal/100 ml	<1	<1	<1	6	<1	<1	<1	<1
Fecal Streptococci/100 ml							2	25
Nitrogen								
NH_3-N (μg/l)	11	23	14	54	29	39	116	41
NO_3-N (mg/l)	1.12	0.93	1.42	4.84	7.37	3.44	2.03	4.24
NO_2-N (μg/l)	4	3	60	10	25	10	6	6
Phosphate								
Ortho (μg/l)	106	132	123	77	95	109	260	60
Total (μg/l)	106	272	237	379	9000	812	370	749
BOD (mg/l)	1.05	<1	<1	1	2	<2	1	<1
TDS (mg/l)	272	176	191	105	194	185	207	158
Specific Conductivity (μmhos/cm at 25°C)	417	368	306	216	280	260	275	257
Cations								
Na (mg/l)	9	10	9	11	9	7		
Mg as $CaCO_3$ (mg/l)	38	27	111	22	8	26	16	26
K (mg/l)	<3			5	3	2		
Ca as $CaCO_3$ (mg/l)	122	106	222	44	127	89	91	87
Anions								
Cl (mg/l)	5	4	6	6	7	4	4	4
SO_4 (mg/l)	21	14	14	11	9	7.7	7	8
B (mg/l)	0.1		0.20		0.49	0.77	<0.1	<0.1
Total Hardness as $CaCO_3$ (mg/l)		133	333	66	135	115	107	113
Total Alkalinity as $CaCO_3$ (mg/l)	148	114	139	86	93	103	130	111
pH (Lab)	8.22	7.9	8.22	7.92	8.19	7.11	8.25	7.68
Surfactant as MBAS (μg/l)	<30	--		<100	<25	<25	<25	<25
Trace Inorganics								
As (μg/l)	<1	<1		<1	<1	<1		
Ba (μg/l)	63	26		<50	39	7		
Cd (μg/l)	<3	<3		<3	<2	<2	<2	
Cr (μg/l)	<8	<7		<10	<11	<11	<11	
Cu (μg/l)	<7	<9		<7	<7	<7	<5	
Fe (μg/l)	<1	44	32	403	101	139	81	69
Hg (μg/l)	<0.5	1	3	5	3	3.6		
Mn (μg/l)	<6	<7	<5	18	<5	<4	5	<7
Pb (μg/l)	<1			4	<1	<1	2	
Se (μg/l)	<1	<1		12	<1	<1	<1	
Ag (μg/l)	11	<5		<3	<6	4	<3	
Zn (μg/l)	2	4	4	40	56	59		
F (mg/l)	0.15			0.12	0.20	0.25	0.13	0.29

Table A-5. Well #5.

	October	November	February	April	May	June	July	August
Date	10-23-79	11-27-79	2-24-80	4-20-80	5-20-80	6-22-80	7-22-80	8-21-80
Time	--	15:30	13:15	11:00	11:45	13:35	20:20	
Air (^oC)	--	--	--	--	25	26	18.5	23
Water (^oC)	9.5	4	--	6	5	8	7	7.5
Depth to Water Table (ft)	-13.00	-12.96	-11.48	-12.67	-9.06	-2.44	-4.25	-7.83
(m)	-3.96	-3.95	-3.50	-3.86	-2.76	-0.74	-1.30	-2.38
Snow Depth (inches)	--	--	15.5	--	--	--	--	
DO (mg/l)	6.7	4	4	7	8.1	--	6.7	5.8
pH (Field)		--	6.3	--	6.0	7.3	7.55	7.2
Coliform								
Total/100 ml	10	<1	<1	<1	<1	<1	<1	<1
Fecal/100 ml	<1	<1	<1	<1	<1	<1	<1	<1
Fecal Streptococci/100 ml							<1	4
Nitrogen								
NH_3-N (μg/l)	93	26	76	35	27	57	66	45
NO_3-N (mg/l)	2.78	2.86	3.41	3.49	4.78	4.48	4.98	6.89
NO_2-N (μg/l)	56	24	106	10	15	15	22	9
Phosphate								
Ortho (μg/l)	116	89	89	87	83	106	33	1500
Total (μg/l)	597	1864	978	242	3685	338	277	3432
BOD (mg/l)	1.15	<1	<1	<1	<1	<2	<1	<1
TDS (mg/l)	450	435	372	371	443	441	463	449
Specific Conductivity (μmhos/cm at 25^oC)	793	692	698	715	704	663	710	682
Cations								
Na (mg/l)	28	45	48	56	51	57		
Mg as $CaCO_3$ (mg/l)				30	107	113	81	84
K (mg/l)	<3			4	2	1		
Ca as $CaCO_3$ (mg/l)				73	163	167	168	174
Anions								
Cl (mg/l)	12	12	14	11	17	14	12	9
SO_4 (mg/l)	84	44	74	77	68	65	79	82
B (mg/l)	0.39		0.42		0.87	0.46	0.36	0.49
Total Hardness as $CaCO_3$ (mg/l)				103	270	280	249	258
Total Alkalinity as $CaCO_3$ (mg/l)				318	314	359	362	498
pH (Lab)	--	--	--	7.86	8.36	7.79	8.00	8.15
Surfactant as MBAS (μg/l)	<30	--	--	<100	<25	<25	<25	<25
Trace Inorganics								
As (μg/l)	<1	<1		<1	<1	<1		
Ba (μg/l)	122	29		143	46	79		
Cd (μg/l)	<3	<3		<3	<2	<2	<2	
Cr (μg/l)	<8	<7		<10	<11	<11	<11	
Cu (μg/l)	<7	<9		<7	<7	<7	<5	
Fe (μg/l)	18	44	88	674	42	12	<11	<12
Hg (μg/l)	<0.5	1	0.7	5	4	2		
Mn (μg/l)	<6	799	73	72	<5	<4	16	173
Pb (μg/l)	<1			<1	<1	<1	4	
Se (μg/l)	<1	<1		3	<1	<1	3	
Ag (μg/l)	10	<5		<3	<6	<3	<3	
Zn (μg/l)	<1	12	16	28	64	53		
F (mg/l)	0.33			0.53	0.53	0.64	0.63	0.58

Table A-6. Well #6.

	October	December	February	April	May	June	July	August
Date	10-23-79	12-11-79	2-24-80	4-20-80	5-20-80	6-22-80	7-22-80	8-21-80
Time	16:00	9:30	14:30	12:00	11:00	14:35	21:10	
Temp								
Air (°C)	--	-10	--	--	25	28	15	21
Water (°C)	9.25	8	--	6	6	9	8.5	8
Depth to Water Table (ft)	-12.67	-12.57	-11.17	-12.37	-8.83	-2.17	-4.00	-7.60
(m)	-3.86	-3.82	-3.41	-3.78	-2.70	-0.66	-1.22	-2.31
Snow Depth (inches)	--	--	--	--	--	--		
DO (mg/l)	8.3	8	6.7	6.5	8.6	--	9.6	5.8
pH (Field)		6.3	--	--	6.1	7.0	7.6	6.9
Coliform								
Total/100 ml	TNTC	<1	<1	<1	<1	<1	<1	<1
Fecal/100 ml	TNTC	<1	<1	<1	<1	<1	<1	<1
Fecal Streptococci/100 ml							<1	<1
Nitrogen								
NH_3-N (µg/l)	16	9	10	<10	62	16	77	26
NO_3-N (mg/l)	11.03	8.64	12.24	7.84	10.13	9.95	9.00	14.30
NO_2-N (µg/l)	6	2	1200	5	15	5	4	4
Phosphate								
Ortho (µg/l)	122	123	126	138	173	143	133	115
Total (µg/l)	122	129	156	152	175	145	135	116
BOD (mg/l)	0.75	<1	1	<1	2	<2	1.5	<1
TDS (mg/l)	486	508	428	384	419	434	461	434
Specific Conductivity (µmhos/cm at 25°C)	806	796	713	665	654	622	658	663
Cations								
Na (mg/l)	12	14	10	12	12	11		
Mg as $CaCO_3$ (mg/l)	51	50	51	--	36	24	26	51
K (mg/l)	<3			4	2	1		
Ca as $CaCO_3$ (mg/l)	281	280	303	--	306	322	299	287
Anions								
Cl (mg/l)	30	30	30	26	23	21	21	12
SO_4 (mg/l)	60	35	41	44	39	33	46	50
B (mg/l)	0.09		0.17		<0.1	0.48	0.16	0.1
Total Hardness as $CaCO_3$ (mg/l)	332	330	354	--	342	346	325	338
Total Alkalinity as $CaCO_3$ (mg/l)	237	257	240	227	221	258	263	234
pH (Lab)	8.47	8.26	8.08	7.89	8.49	7.64	8.03	7.84
Surfactant as MBAS (µg/l)	<30	<100		<100	<25	<25	<25	<25
Trace Inorganics								
As (µg/l)	<1	<1		<1	<1	<1		
Ba (µg/l)	57	35		<50	18	<3		
Cd (µg/l)	<3	<3		<3	<2	<2	<2	
Cr (µg/l)	<8			<10	<11	<11	<11	
Cu (µg/l)	<7			<7	<7	<7	<5	
Fe (µg/l)	11	<19	31	<12	<11	<11	<11	19
Hg (µg/l)	<0.5	<0.2	6	4	3	2.7		
Mn (µg/l)	<6	<7	<5	<5	<5	<4	<4	<7
Pb (µg/l)	1			<1	<1	<1	<1	
Se (µg/l)	<1			<1	<1	<1	<1	
Ag (µg/l)	10			3	<6	<3	<3	
Zn (µg/l)	4	19	7	22	49	57		
F (mg/l)	0.14			0.22	0.23	0.20	0.23	0.24

Table A-7. Well #7.

	October	December	February	April	May	June	July	August
Date	10-25-79	12-11-79	2-24-80	4-20-80	5-20-80	6-22-80	7-22-80	8-21-80
Time	18:30	10:50	8:00	13:00	10:10	9:00	17:00	
Temp								
Air (°C)	--	-5	-9.4	--	25	21	28	25
Water (°C)	10	9	2	6	6.5	7	11	9
Depth to Water Table (ft)	-12.08	-12.79	-10.50	-7.45	-6.91	-5.08	-7.00	-9.54
(m)	-3.68	-3.90	-3.20	-2.27	-2.11	-1.55	-2.13	-2.90
Snow Depth (inches)	--	--	28.75	--	--	--	--	--
DO (mg/l)	2.5	4	2	7	3.1	--	2.7	4.5
pH (Field)	--	6.2	6.3	6.1	6.0	6.7	7.4	7.1
Coliform								
Total/100 ml	23	<1	∿10	<1	2-9	3	<1	<1
Fecal/100 ml	<1	<1	∿8	<1	<1	<1	<1	<1
Fecal Streptococci/100 ml							<1	<1
Nitrogen								
NH_3-N (μg/l)	21	25	19	<10	19	16	48	34
NO_3-N (mg/l)	0.55	3.00	1.66	0.30	1.81	2.30	2.90	5.94
NO_2-N (μg/l)	3	5	100	4	4	2	4	6
Phosphate								
Ortho (μg/l)	197	214	219	295	226	257	247	184
Total (μg/l)	235	257	620	503	243	368	385	200
BOD (mg/l)	<1	<1	<1	<1	<1	<2	2.0	<1
TDS (mg/l)	508	572	458	355	516	494	--	387
Specific Conductivity (μmhos/cm at 25°C)	870	812	761	676	843	629	652	616
Cations								
Na (mg/l)	12	15	10	18	14	14		
Mg as $CaCO_3$ (mg/l)	55	89	71	85	56	68	40	25
K (mg/l)	3			5	2	3		
Ca as $CaCO_3$ (mg/l)	265	260	283	116	286	278	259	247
Anions								
Cl (mg/l)	72	82	90	69	83	71	55	42
SO_4 (mg/l)	44	31	36	25	28	26	29	29
B (mg/l)	<0.05		0.17		<0.1	0.25	0.11	0.18
Total Hardness as $CaCO_3$ (mg/l)	320	349	354	201	342	346	299	272
Total Alkalinity as $CaCO_3$ (mg/l)	206	216	211	220	207	213	235	206
pH (Lab)	8.39	8.2	8.22	7.57	8.23	7.07	8.50	7.75
Surfactant as MBAS (μg/l)	30	--		<100	<25	<25	--	<25
Trace Inorganics								
As (μg/l)	<1	<1		<1	<1	<1		
Ba (μg/l)	54	61		<50	22	<3		
Cd (μg/l)	<3	<3		<3	<2	<2	<2	
Cr (μg/l)	<8			<10	<11	<11	<11	
Cu (μg/l)	<7			<7	<7	<7	<5	
Fe (μg/l)	<1	229	27	323	<11	20	92	16
Hg (μg/l)	<0.5	0.6	6	5	4	2	1	
Mn (μg/l)	12	36	<5	13	<5	<4	46	<7
Pb (μg/l)	<1			<1	<1	2	1	
Se (μg/l)	<1			<1	<1	<1	<1	
Ag (μg/l)	6			<3	<6	<3	<3	
Zn (μg/l)	27	52	38	25	63	25		
F (mg/l)	0.07		0.21		0.16	0.15	0.15	0.05

Table A-8. Well #8.

	October	November	February	April	May	June	July	August
Date	10-25-79	11-26-79	--	4-20-80	5-21-80	6-22-80	7-23-80	8-22-80
Time	17:30	17:30	--	17:30	8:15	15:10	17:40	
Temp								
Air (°C)	--	--	--	--	--	24	22	20
Water (°C)	--	--	--		6	9	9	8.5
Depth to Water Table (ft)	Dry	Dry	--	--	-6.58	-3.67	-6.00	-9.54
(m)					-2.01	-1.12	-1.83	-2.90
Snow Depth (inches)	--	--	--	--	--	--	--	
DO (mg/l)	--	--	--		9.0	--	7.4	6.2
pH (Field)	--	--	--		7.4	7.3	7.7	7.0
Coliform								
Total/100 ml	--	--	--	--	<1	<1	<1	<1
Fecal/100 ml	--	--	--	--	<1	<1	<1	<1
Fecal streptococci/100 ml							3	<1
Nitrogen								
NH_3-N (μg/l)					18	36	44	37
NO_3^--N (mg/l)					2.06	1.69	0.64	0.52
NO_2^--N (μg/l)					11	2	2	7
Phosphate								
Ortho (μg/l)					78	101	133	50
Total (μg/l)					1874	101	372	378
BOD (mg/l)					<1	<2	<1	--
TDS (mg/l)								
Specific Conductivity (μmhos/cm at 25°C)					539	451	497	533
Cations								
Na (mg/l)								
Mg as $CaCO_3$ (mg/l)								
K (mg/l)								
Ca as $CaCO_3$ (mg/l)								
Anions								
Cl (mg/l)							15	16
SO_4(mg/l)								
B mg/l)								
Total Hardness as $CaCO_3$ (mg/l)								
Total Alkalinity as $CaCO_3$ (mg/l)								
pH (Lab)						7.55	7.77	7.71
Surfactant as MBAS (μg/l)								
Trace Inorganics								
As (μg/l)								
Ba (μg/l)								
Cd (μg/l)								
Cr (μg/l)								
Cu (μg/l)								
Fe (μg/l)								
Hg (μg/l)								
Mn (μg/l)								
Pb (μg/l)								
Se (μg/l)								
Ag (μg/l)								
Zn (μg/l)								
F (mg/l)								

Table A-9. Well #9.

	October	November	February	April	May	June	July	August
Date	10-25-79	11-25-79	2-24-80	4-20-80	5-21-80	6-22-80	7-24-80	8-23-80
Time	8:30	9:30	--	6:30	15:00	--	13:15	
Temp								
Air (°C)	--	--	1	0	--	24	21.5	15
Water (°C)	$8\frac{3}{4}$	5	2.5	--	6	9	9	10
Depth to Water Table (ft)	-3.46	-4.25	-2.03	-1.25	-1.67	-1.76	-2.00	-2.27
(m)	-1.06	-1.30	-0.62	-0.38	-0.51	-0.54	-0.60	-0.69
Snow Depth (inches)	--	--	50		--	--	--	
DO (mg/l)	2.3	--	2.8	4	1.7	--	7.2	3.1
pH (Field)	--	6.5	6.9	6.1	7.0	7.5	7.3	7.2
Coliform								
Total/100 ml	<1	<1	<1	<1	<1	<1	<1	<1
Fecal/100 ml	<1	<1	<1	<1	<1	<1	<1	<1
Fecal Streptococci							1	2
Nitrogen								
NH_3-N (μg/l)	32	25	28	68	15	23	<10	31
NO_3-N (mg/l)	1.65	0.75	0.91	0.29	0.11	0.40	<0.04	0.04
NO_2-N (μg/l)	17	12	8	13	6	5	3	5
Phosphate								
Ortho (μg/l)	75	67	48	55	43	12	<10	50
Total (μg/l)	495	234	1078	267	90	92	55	108
BOD (mg/l)	<1	1	<1	<1	<1	<2	<1	--
TDS (mg/l)	725	810	302	337	466	451	454	382
Specific Conductivity (μmhos/cm at 25°C)	1174	1186	560	687	875	681	676	627
Cations								
Na (mg/l)	52	79	21	25	43	39		
Mg as $CaCO_3$ (mg/l)	115	99	48	89	78	69	74	71
K (mg/l)	4			7	5	5		
Ca as $CaCO_3$ (mg/l)	277	343	202	70	237	244	243	242
Anions								
Cl (mg/l)	166	165	40	39	70	58	29	11
SO_4 (mg/l)	72	41	34	42	40	44	43	42
B (mg/l)	1.452		0.49		0.63	0.77	0.39	
Total Hardness as $CaCO_3$ (mg/l)	392	442	250	159	315	313	317	313
Total Alkalinity as $CaCO_3$ (mg/l)	292	312	308	259	258	243	313	294
pH (Lab)	8.22	8.2	8.28	8.22	7.80	7.63	7.91	7.58
Surfactant as MBAS (μg/l)	<30	<100		<100	<25	--	<25	<25
Trace Inorganics								
As (μg/l)	<1			<1	<1	<1		
Ba (μg/l)	71			140	74	8		
Cd (μg/l)	<3			<3	<2	<2		
Cr (μg/l)	<8			<10	96	<11		
Cu (μg/l)	<7			<7	33	<7	<5	
Fe (μg/l)	135	<19	97	584		31	<11	<12
Hg (μg/l)	<0.5		1.9	5		1.5		
Mn (μg/l)	1482	1607	710	855	807	769	804	755
Pb (μg/l)	<1			<1	<1	<1	<1	
Se (μg/l)	<1			<1	<1	<1	<1	
Ag (μg/l)	5			<3	3	<3		
Zn (μg/l)	180	271	113	107	101	1020		
F (mg/l)	0.12			0.46	0.25	0.48	0.42	0.48

Table A-10. Well #10.

	October	November	February	April	May	June	July	August
Date	10-25-79	11-25-79	2-24-80	4-20-80	5-21-80	6-22-80	7-22-80	Well Buried in parking lot
Time	10:00	11:00	10:00	8:20	16:35	--	12:20	
Temp								
Air (°C)	--	--	2	11	24	22	21	
Water (°C)	8	6	5	4.5	6	5.5	7	
Depth to Water Table (ft)	-7.02	-6.64	-6.13	-3.72	-4.25	-5.43	-6.08	
(m)	-2.13	-2.20	-1.86	-1.13	-1.29	-1.65	-1.85	
Snow Depth (inches)	--	--	58	35	--			
DO (mg/l)	2.2	--	1.5	2	0.8	--	2.8	
pH (Field)	--	6.7	7.2	6.3	7.1	7.2	7.6	
Coliform								
Total/100 ml	<1	<1	<1	<1	<1	<1	<1	
Fecal/100 ml	<1	<1	<1	<1	<1	<1	<1	
Fecal Streptococci/100 ml							1	
Nitrogen								
NH_3-N (µg/l)	18	36	23	41	19	23	72	
NO_3-N (mg/l)	0.13	0.06	0.99	0.07	0.18	0.27	0.05	
NO_2-N (µg/l)	3	1	20	2	5	3	4	
Phosphate								
Ortho (µg/l)	<10	<10	<10	<10	10	<10	24	
Total (µg/l)	48	37	103	48	15	81	33	
BOD (mg/l)				<1	<1	<2	1.0	
TDS (mg/l)								
Specific Conductivity (µmhos/cm at 25°C)	608	578	523	539	532	492	555	
Cations								
Na (mg/l)								
Mg as $CaCO_3$ (mg/l)								
K (mg/l)								
Ca as $CaCO_3$ (mg/l)								
Anions								
Cl (mg/l)							5	
SO_4 (mg/l)								
B (mg/l)								
Total Hardness as $CaCO_3$ (mg/l)								
Total Alkalinity as $CaCO_3$ (mg/l)								
pH (Lab)				7.77		7.30	7.40	
Surfactant as MBAS (µg/l)								
Trace Inorganics								
As (µg/l)								
Ba (µg/l)								
Cd (µg/l)								
Cr (µg/l)								
Cu (µg/l)								
Fe (µg/l)								
Hg (µg/l)								
Mn (µg/l)								
Pb (µg/l)								
Se (µg/l)								
Ag (µg/l)								
Zn (µg/l)								
F (mg/l)								

Table A-11. Well #11.

	October	November	April	May	June	July	August
Date	10-25-79	11-25-79	4-20-80	5-20-80	6-22-80	7-24-80	8-23-80
Time	11:00	8:00	10:15	16:40	-	14:10	-
Temp							
Air (°C)	--	--	17	--	26	25	18
Water (°C)	10.5	5.5	6	7	6.5	9	9
Depth to Water Table (ft)	-7.25	-7.18	-3.73	-3.97	-4.68	-6.75	-7.60
(m)	-2.21	-2.19	-1.14	-1.21	-1.43	-2.06	-2.32
Snow Depth (inches)	--	--	0	--	--	--	--
DO (mg/l)	2.7	1.0	2.5	3.3	--	7.3	3.2
pH (Field)	--	6.7	6.6	6.9	7.0	7.3	6.7
Coliform							
Total/100 ml	<1	<1	<1	<1	<1	1	<1
Fecal/100 ml	<1	<1	<1	<1	<1	<1	<1
Fecal streptococci/100 ml						4	1
Nitrogen							
NH_3-N (μg/l)	15	15	<10	15	<10	16	20
NO_3-N (mg/l)	0.05	0.04	3.34	5.82	4.49	0.53	0.45
NO_2-N (μg/l)	6	1	2	25	8	2	5
Phosphate							
Ortho (μg/l)	117	152	101	132	114	67	50
Total (μg/l)	148	152	101	135	115	112	67
BOD (mg/l)	0.60	1	1	1	<2	<1	--
TDS (mg/l)	480	461	434	550	558	574	566
Specific Conductivity (μmhos/cm at 25°C)	602	648	869	929	850	682	908
Cations							
Na (mg/l)	7	7	11	10	9		
Mg as $CaCO_3$ (mg/l)			108	138	144	125	149
K (mg/l)	<3		6	3	3		
Ca as $CaCO_3$ (mg/l)			46	306	389	347	343
Anions							
Cl (mg/l)	4	<1	2	2	19	23	<1
SO_4 (mg/l)	85	74	65	72	71	78	80
B (mg/l)	0.535			<0.1	0.39	0.2	0.31
Total Hardness as $CaCO_3$ (mg/l)			154	444	533	472	492
Total Alkalinity as $CaCO_3$ (mg/l)			361	345	198	420	394
pH (Lab)			8.30	8.44	7.38	8.07	7.35
Surfactant as MBAS (μg/l)	<30		<100	<25	<25		<25
Trace Inorganics							
As (μg/l)	<1		<1	<1	<1		
Ba (μg/l)	39		<50	20	<3		
Cd (μg/l)	<3		<3	<2	<2		
Cr (μg/l)	<8		<10	<11	<11		
Cu (μg/l)	<7		<7	<7	<7	<5	
Fe (μg/l)	<1	<19	<12	<11	<11	<11	15
Hg (μg/l)	<0.5		5	3	2.6		
Mn (μg/l)	<6	20	<5	<5	<4	<6	<7
Pb (μg/l)	1		<1	<1	13	<1	
Se (μg/l)	<1		<1	<1	<1	<1	
Ag (μg/l)	2		3	<6	3		
Zn (μg/l)	15	20	16	48	46		
F (mg/l)	0.16		0.38	0.32	0.38	0.41	0.44

Table A-12. Well #12.

	October	November	February	April	May	June	July	August
Date	10-25-79	11-25-79	2-24-80	4-20-80	5-20-80	6-22-80	7-22-80	8-23-80
Time	12:00	12:30	--	11:40	14:10	--	13:35	
Temp								
Air (^{o}C)	--	--	4	17	--	26.5	25	20.5
Water (^{o}C)	10	4	3	4.5	7	6	10	10
Depth to Water Table (ft)	-2.67	-3.12	-2.73	-1.45	-1.95	-2.21	-2.00	-2.48
(m)	-0.82	-0.96	-0.84	-0.45	-0.60	-0.68	-0.61	-0.76
Snow Depth (inches)	--	--	35	0	--	--	--	--
DO (mg/l)	2.2	--	1	1.5	3.2	--	3.7	1.7
pH (Field)	--	6.7	7.3	6.3	6.9	7.2	7.5	6.6
Coliform								
Total/100 ml	<1	<1	<1	40	<1	<1	1	<1
Fecal/100 ml	<1	<1	<1	<1	<1	<1	--	<1
Fecal Strepotococci/100 ml							1	3
Nitrogen								
NH_3-N (μg/l)	35	34	36	42	43	200	68	30
NO_3-N (mg/l)	0.13	<0.04	1.05	0.13	0.06	0.08	0.06	0.04
NO_2-N (μg/l)	12	1	3	10	4	<2	4	6
Phosphate								
Ortho (μg/l)	3	<1	<10	<5	<10	<10	39	35
Total (μg/l)	220	39	136	11	<10	56	39	37
BOD (mg/l)				1	1	<2	1.5	--
TDS (mg/l)						495	485	477
Specific Conductivity (μmhos/cm at 25^{o}C)	873	645	577	794	894	677	--	777
Cations								
Na (mg/l)						13		
Mg as $CaCO_3$ (mg/l)						90		87
K (mg/l)						10		
Ca as $CaCO_3$ (mg/l)						300		298
Anions								
Cl (mg/l)						29.9	30	5
SO_4 (mg/l)						53.3	--	75
B (mg/l)						0.39	--	0.82
Total Hardness as $CaCO_3$ (mg/l)						390		385
Total Alkalinity as $CaCO_3$ (mg/l)						413	355	300
pH (Lab)				7.67	7.17	7.03	8.31	7.35
Surfactant as MBAS (μg/l)						<25	--	<25
Trace Inorganics								
As (μg/l)						<1		
Ba (μg/l)						4		
Cd (μg/l)						<2	<2	
Cr (μg/l)						<11	<11	
Cu (μg/l)						<7	<5	
Fe (μg/l)						1120	323	<12
Hg (μg/l)						1.4		
Mn (μg/l)						206	211	187
Pb (μg/l)						<1	<1	
Se (μg/l)						2	<1	
Ag (μg/l)						<3	<3	
Zn (μg/l)						50		
F (mg/l)						0.18	0.12	0.23

Table A-13. Well #13.

	October	November	February	April	May	June	July	August
Date	10-25-79	11-25-79	2-24-80	4-20-80	5-20-80	6-22-80	7-24-80	8-23-80
Time	14:00	13:00	13:25	12:00	15:05	--	12:30	
Temp								
Air (°C)	--	--	-4	--	17	26	24	20.5
Water (°C)	10	4	3.5	5.5	8	8	10	11
Depth to Water Table (ft)	-3.48	-3.79	-3.48	--	-1.50	-4.61	-5.87	-6.30
(m)	-1.06	-1.15	-1.06	--	-0.46	-1.41	-1.79	-1.92
Snow Depth (inches)	--	--	29		--	--	--	
DO (mg/l)	1.8	--	1.3	1.0	0.9	--	1.1	1.3
pH (Field)	--	6.8	7.2	6.6	7.0	7.2	7.3	7.2
Coliform								
Total/100 ml	<1	<1	∿10	<1	<1	7	<1	<1
Fecal/100 ml	<1	<1	<1	<1	<1	<1	<1	<1
Fecal Streptococci/100 ml							3	3
Nitrogen								
NH_3-N (μg/l)	169	53	32	113	10	47	136	113
NO_3-N (mg/l)	0.07	<0.04	0.56	0.04	0.05	0.10	<0.04	0.04
NO_2-N (μg/l)	8	1	5	1	4	2	3	6
Phosphate								
Ortho (μg/l)	24	36	<10	<5	24	<10	33	40
Total (μg/l)	210	128	243	494	25	115	130	73
BOD (mg/l)	0.70	1	<1	2	<1	<2	1	--
TDS (mg/l)	526	325	400	459	572	510	523	494
Specific Conductivity (μmhos/cm at 25°C)	806	439	594	904	1055	716	851	891
Cations								
Na (mg/l)	8	8	8	9	9	6		
Mg as $CaCO_3$ (mg/l)	386	157	91	120	195	155	149	149
K (mg/l)	<3			5	3	2		
Ca as $CaCO_3$ (mg/l)	98	212	222	31	164	356	318	328
Anions								
Cl (mg/l)	<1	1	10	<1	<1	7.4	7	<1
SO_4 (mg/l)	72	58	57	48	48	44	43	51
B (mg/l)	<0.05		0.20		<0.1	0.45	0.91	0.34
Total Hardness as $CaCO_3$ (mg/l)	484	369	312	151	359	511	467	477
Total Alkalinity as $CaCO_3$ (mg/l)	443	445	294	504	371	402	415	429
pH (Lab)	8.28	8.3	8.09	7.55	8.19	7.47	7.63	7.24
Surfactant as MBAS (μg/l)	<30	--		<100		27		<25
Trace Inorganics								
As (μg/l)	<1			2	<1	<1		
Ba (μg/l)	113			160	39	24		
Cd (μg/l)	<3			<3	<2	<2		
Cr (μg/l)	<8			<10	<11	<11		
Cu (μg/l)	<7			<7	<7	<7	<5	
Fe (μg/l)	5579	200	1215	10,200	<11	88	<11	<12
Hg (μg/l)	<0.5		1.6	2	3	2		
Mn (μg/l)	278	86	201	543	83	113	232	253
Pb (μg/l)	<1			<1	<1	1	<1	
Se (μg/l)	<1			6	44	<1	<1	
Ag (μg/l)	7			<3	<6	<3		
Zn (μg/l)	33	5	13	360	178	123		
F (mg/l)	0.11			0.26	0.32	0.25	0.27	0.27

Table A-14. Well #14.

	October	November	February	April	May	June	July	August
Date	10-24-79	11-26-79	2-24-80	4-20-80	5-21-80	6-22-80	7-22-80	8-23-80
Time	17:45	7:50	8:40	13:00	20:30	--	15:00	
Temp								
Air (°C)	--	--	-18.5	19		22	21	20.5
Water (°C)	9	6	3	--	8	7	9	9.5
Depth to Water Table (ft)	-3.33	-3.81	-3.57	-0.20	-1.96	-2.98	-3.58	-3.73
(m)	-0.99	-1.16	-1.09	-0.06	-0.60	-0.92	-1.09	-1.14
Snow Depth (inches)	--	--	39	8	--	--	--	
DO (mg/l)	1.3	1	1.8		--	--	1.0	2.2
pH (Field)	--	7.5	7.8	--	7.2	7.2	7.6	7.2
Colifrom								
Total/100 ml	5	<1	<1	--		<1	<1	<1
Fecal/100 ml	<1	<1	<1			<1	<1	<1
Fecal Streptococci/100 ml							1	<1
Nitrogen								
NH_3-N (μg/l)	66	40	23	--	51	25	47	20
NO_3-N (mg/l)	2.48	3.3	2.43		4.79	8.17	1.62	1.81
NO_2-N (μg/l)	44	29	12	--	205	32	3	5
Phosphate								
Ortho (μg/l)	11	18	<10	--	<10	10	13	90
Total (μg/l)	11	19	30	--	733	37	17	271
BOD (mg/l)	0.70	<1	<1	--	1	<2	<1	--
TDS (mg/l)	468	384	444	--				
Specific Conductivity (μmhos/cm at 25°C)	621	500	818	--	693	668	707	673
Cations								
Na (mg/l)	10	10	8					
Mg as $CaCO_3$ (mg/l)								
K (mg/l)	4							
Ca as $CaCO_3$ (mg/l)								
Anions								
Cl (mg/l)	9	13	21	--			14	9
SO_4 (mg/l)	77	60	53					
B (mg/l)	0.501		0.29					
Total Hardness as $CaCO_3$ (mg/l)								
Total Alkalinity as $CaCO_3$ (mg/l)								
pH (Lab)						7.20	7.21	7.80
Surfactant as MBAS (μg/l)	<30	<100						
Trace Inorganics								
As (μg/l)	<1							
Ba (μg/l)	63							
Cd (μg/l)	<3							
Cr (μg/l)	<8							
Cu (μg/l)	<7							
Fe (μg/l)	82	<19	81	--				
Hg (μg/l)	5		1.3					
Mn (μg/l)	108	88	101					
Pb (μg/l)	<1							
Se (μg/l)	<1							
Ag (μg/l)	4							
Zn (μg/l)	24	12	8					
F (mg/l)	0.08					0.31		

Table A-15. Well #15.

	October	November	February	May	June	July	August
Date	10-24-79	11-25-79	2-24-80	5-20-80	6-22-80	7-22-80	8-22-80
Time	15:15	16:30	15:45	17:25	17:35	15:40	
Temp							
Air (°C)	--	--	3	23	25	23	21.5
Water (°C)	10	3.8	3.3	5.5	10	11	10.5
Depth to Water Table (ft)	-4.00	-4.02	-3.98	-2.56	-3.12	-5.50	-5.31
(m)	-1.22	-1.23	-1.21	-0.78	-0.95	-1.68	-1.62
Snow Depth (inches)	--	--	47	--	--	--	--
DO (mg/l)	--	--	1.3	1.3	--	6.7	2.8
pH (Field)	--	7.9	7.6	6.2	6.9	7.6	7.8
Coliform							
Total/100 ml	6	<1	<1	<1	<1	<1	<1
Fecal/100 ml	<1	<1	<1	<1	<1	<1	<1
Fecal streptococci/100 ml						1	45
Nitrogen							
NH_3-N (µg/l)	25	18	12	15	81	36	25
NO_3-N (mg/l)	0.08	<0.04	0.54	0.48	0.95	<0.04	<0.04
NO_2-N (µg/l)	5	1	3	15	16	3	4
Phosphate							
Ortho (µg/l)	32	41	10	23	32	87	25
Total (µg/l)	133	246	247	328	146	141	215
BOD (mg/l)				1	<2	<1	--
TDS (mg/l)				363			
Specific Conductivity (µmhos/cm at 25°C)	549	604	520	577	629	667	569
Cations							
Na (mg/l)	6	5		7			
Mg as $CaCO_3$ (mg/l)		101	91	76			
K (mg/l)				3			
Ca as $CaCO_3$ (mg/l)		206	222	245			
Anions							
Cl (mg/l)		5.4	8	6		8	5
SO_4 (mg/l)				39			
B (mg/l)				<0.1			
Total Hardness as $CaCO_3$ (mg/l)		307	312	321			
Total Alkalinity as $CaCO_3$ (mg/l)		273		258			
pH (Lab)			7.74	8.45	7.23	7.53	7.64
Surfactant as MBAS (µg/l)							
Trace Inorganics							
As (µg/l)				<1			
Ba (µg/l)	41	39		16			
Cd (µg/l)				<2			
Cr (µg/l)				<11			
Cu (µg/l)				<7			
Fe (µg/l)	<19	<19	193	<11			
Hg (µg/l)			5	3			
Mn (µg/l)	142	102		83			
Pb (µg/l)				<1			
Se (µg/l)				1			
Ag (µg/l)				9			
Zn (µg/l)	23	<d.l.		58			
F (mg/l)				0.31			

Table A-16. Well #16.

	October	November	February	April	May	June	July	August
Date	10-24-79	11-26-79	2-24-80	4-20-80	5-20-80	6-22-80	7-24-80	8-22-80
Time	13:30	9:30	15:45	17:30	16:30	16:10	11:40	
Temp								
Air (°C)	--	--	2	17	25	19	26	24.5
Water (°C)	8	4.5	3.0	4	4.5	8	9	8.5
Depth to Water Table (ft)	-1.85	-4.02	-5.20	-1.83	-2.17	-4.33	-6.00	-6.78
(m)	-0.57	-1.23	-1.59	-0.56	-0.66	-1.32	-1.83	-2.07
Snow Depth (inches)	--	--	42	30	--	--	--	
DO (mg/l)	2.0	2.8	0.8	4	0	0	0	0
pH (Field)	--	6.1	7.2	6.3	6.2	6.7	7.2	6.9
Coliform								
Total/100 ml	4	<1	<1	<1	<1	<1	<1	<1
Fecal/100 ml	<1	<1	<1	<1	<1	<1	<1	<1
Fecal Streptococci/100 ml							1	<1
Nitrogen								
NH_3-N (μg/l)	310	311	307	72	222	193	236	164
NO_3-N (mg/l)	0.10	<0.04	0.03	0.15	0.06	0.06	0.18	0.04
NO_2-N (μg/l)	2	2	2	3	6	<2	3	4
Phosphate								
Ortho (μg/l)	3	1	<10	9	<10	<10	<10	<10
Total (μg/l)	310	10	885	88	199	91	421	324
BOD (mg/l)	1.05	<1	<1	<1	1	<2	2.0	--
TDS (mg/l)	566	658	829	786	893	854	875	852
Specific Conductivity (μmhos/cm at 25°C)	584	900	895	1259	1309	1059	1022	1228
Cations								
Na (mg/l)	9	8	5	11	8	7		
Mg as $CaCO_3$ (mg/l)			142	160	169	331	242	121
K (mg/l)	<3			6	3	4		
Ca as $CaCO_3$ (mg/l)			525		303	444	1050	576
Anions								
Cl (mg/l)	11	<1	11	<1	1	9.3	11	<1
SO_4 (mg/l)	123	128	201	181	191	193	207	205
B (mg/l)	0.637		0.40		<0.1	0.46	0.15	0.16
Total Hardness as $CaCO_3$ (mg/l)			666	186	472	775	1292	697
Total Alkalinity as $CaCO_3$ (mg/l)			519	342	439	483	500	465
pH (Lab)	--	--	8.09	7.43	8.43	7.58	7.44	7.33
Surfactant as MBAS (μg/l)	<30			<100	<25			<25
Trace Inorganics								
As (μg/l)	<1			<1	<1	<1		
Ba (μg/l)	64			<50	39	10		
Cd (μg/l)	<3			<3	<2	<2		
Cr (μg/l)	<8			<10	<11	<11		
Cu (μg/l)	<7			<7	<7	<7	<5	
Fe (μg/l)	15,265	12,834	27,900	4,780	22,200	25,800	371	<12
Hg (μg/l)	<0.5		1.8	3	1	1.5		
Mn (μg/l)	1615	1184	<1632	450	1650	1800	1290	1322
Pb (μg/l)	1			<1	<1	2	<1	
Se (μg/l)	<1			11	1	<1	<1	
Ag (μg/l)	8			4	7	3		
Zn (μg/l)	95	36	8	41	153	51		
F (mg/l)	0.07			0.30	0.33	0.31	0.44	0.29

Table A-17. Well #17.

	October	November	February	April	May	June	July	August
Date	10-24-79	11-26-79	2-24-80	4-20-80	5-20-80	6-22-80	7-24-80	Dry
Time	12:00	11:00	18:00	16:35	15:50	16:50	11:00	
Temp								
Air (°C)	--	--	--	14	22	19	22.5	
Water (°C)	12	6	--	6	6	8	10	
Depth to Water Table (ft)	--	-7.91	-9.41	-7.62	-4.90	-7.25	-9.33	
(m)	--	-2.41	-2.87	-2.31	-1.48	-2.21	-2.84	
Snow Depth (inches)	--	--	36	12	--	--	--	
DO (mg/l)	1.7	4	--	4	8.6	--	7.2	
pH (Field)	--	6.7	--	6.2	6.1	--	7.6	
Coliform								
Total/100 ml	<1	<1	--	<1	<1	<1	<1	
Fecal/100 ml	<1	<1		<1	<1	<1	<1	
Fecal Streptococci/100 ml							<1	
Nitrogen								
NH_3-N (µg/l)	31	15		<10	13	11	28	
NO_3-N (mg/l)	0.16	0.61		1.54	2.91	3.16	1.47	
NO_2-N (µg/l)	2	1		2	8	<2	2	
Phosphate								
Ortho (µg/l)	79	58		141	69	72	67	
Total (µg/l)	109	62		149	135	76	83	
BOD (mg/l)	1.20	<1		1	1	<2	<1	
TDS (mg/l)	338	365						
Specific Conductivity (µmhos/cm at 25°C)	578	538		598	614	671	785	
Cations								
Na (mg/l)	7	7		9				
Mg as $CaCO_3$ (mg/l)	76	10						
K (mg/l)	<3			6				
Ca as $CaCO_3$ (mg/l)	196	204						
Anions								
Cl (mg/l)	2	6		--			51	
SO_4 (mg/l)	53	44						
B (mg/l)	0.264							
Total Hardness as $CaCO_3$ (mg/l)			666	186				
Total Alkalinity as $CaCO_3$ (mg/l)	238	243						
pH (Lab)	8.26	8.64		7.52	7.26	7.25	7.69	
Surfactant as MBAS (µg/l)	<30	--		--				
Trace Metals								
As (µg/l)	<1			<1				
Ba (µg/l)	51			<50				
Cd (µg/l)	<3			<3				
Cr (µg/l)	<8			<10				
Cu (µg/l)	<7			<7				
Fe (µg/l)	24	<19		<12				
Hg (µg/l)	2			4				
Mn (µg/l)	11	20		<5				
Pb (µg/l)	<1			<1				
Se (µg/l)	<1			<1				
Ag (µg/l)	3			<3				
Zn (µg/l)	188	7		34				
F (mg/l)	0.10							

Table A-18. Well #18.

	October	November	April	May	June	July	August
Date	10-25-79	11-26-79	4-20-80	5-20-80	6-22-80	7-24-80	
Time	15:30	16:00	16:00	14:30	-	16:00	
							Dry
Temp							
Air (°C)	--	--	17	25	22.5	23.5	
Water (°C)	10	5	5	6	8	-	
Depth to Water Table (ft)	-4.98	-7.37	-5.84	-5.50	-6.55	-8.41	
(m)	-1.52	-2.25	-1.78	-1.68	-2.00	-2.57	
Snow Depth (inches)	--	--	8		--		
DO (mg/l)	1.9	4	5	9.3	--		
pH (Field)	--	--	6.3	6.1	7.4		
Coliform							
Total/100 ml	<1	<1	--	<1	<1		
Fecal/100 ml	<1	<1		<1	<1		
Fecal streptococci/100 ml							
Nitrogen							
NH_3-N (μg/l)	10	21	42	14	17		
NO_3-N (mg/l)	4.71	5.0	0.54	2.57	0.87		
NO_2-N (μg/l)	8	5	2	8	<2		
Phosphate							
Ortho (μg/l)	64	59	68	132	58		
Total (μg/l)	99	59	373	195	131		
BOD (mg/l)			1	<1	<2		
TDS (mg/l)							
Specific Conductivity (μmhos/cm at 25°C)	828	658	760	857	727		
Cations							
Na (mg/l)							
Mg as $CaCO_3$ (mg/l)							
K (mg/l)							
Ca as $CaCO_3$ (mg/l)							
Anions							
Cl (mg/l)							
SO_4 (mg/l)							
B (mg/l)							
Total Hardness as $CaCO_3$ (mg/l)							
Total Alkalinity as $CaCO_3$ (mg/l)							
pH (Lab)			7.53	7.28	7.28		
Surfactant as MBAS (μg/l)		<100					
Trace Inorganics							
As (μg/l)							
Ba (μg/l)							
Cd (μg/l)							
Cr (μg/l)							
Cu (μg/l)							
Fe (μg/l)							
Hg (μg/l)							
Mn (μg/l)							
Pb (μg/l)							
Se (μg/l)							
Ag (μg/l)							
Zn (μg/l)							
F (mg/l)							

Table A-19. Well #19.

	September	October	November	April	May	June	July	August	Sept.
Date	9-26-79	10-24-79	11-26-79	4-20-80	5-20-80	6-22-80	7-24-80		
Time	--	10:30	14:30	15:30	13:25	--	16:37		
								Dry	
Temp									
Air (°C)				15	28	24	26.5		
Water (°C)	--	10	5	5	6	7	--		
Depth to Water Table (ft)	-6.33	-8.00	-10.02	-9.68	-7.17	-9.00	-10.58	--	-6.33
(m)	-1.93	-2.43	-3.05	-2.95	-2.18	-2.74	-3.22	--	-1.93
Snow Depth (inches)	--	--	--	--	6	--	--		
DO (mg/l)	--	3.5	6.5	3	8.2	--	6.4		
pH (Field)	--	--	7.8	6.4	6.0	7.5	7.4		
Coliform									
Total/100 ml	--	<1	<1	<1	<1	<1	<1		
Fecal/100 ml	--	<1	<1	<1	<1	<1	<1		
Fecal streptococci/100 ml							1		
Nitrogen									
NH_3-N (μg/l)	--	23	12	<10	<10	53	36		
NO_3-N (mg/l)	--	1.54	1.5	1.89	3.95	3.15	1.70		
NO_2-N (μg/l)	--	3	2	2	12	2	<2		
Phosphate									
Ortho (μg/l)	--	118	105	100	106	98	100		
Total (μg/l)	--	196	113	150	110	100	421		
BOD (mg/l)				1	1	<2	1.5		
TDS (mg/l)				300	424	309	414		
Specific Conductivity (μmhos/cm at 25°C)	--	618	618	664	673	411	631		
Cations									
Na (mg/l)				11	10	8			
Mg as $CaCO_3$ (mg/l)				86	102	91	106		
K (mg/l)				6	3	5			
Ca as $CaCO_3$ (mg/l)				68	227	189	290		
Anions									
Cl (mg/l)				18	24	20	30		
SO_4 (mg/l)				41	43	33	40		
B (mg/l)					<0.1	0.525	0.2		
Total Hardness as $CaCO_3$ (mg/l)				154	329	280	396		
Total Alkalinity as $CaCO_3$ (mg/l)				278	260	198	290		
pH (Lab)				7.99	8.52	7.62	7.83		
Surfactant as MBAS (μg/l)				<100	<37	--			
Trace Inorganics									
As (μg/l)				<1	<1	<1			
Ba (μg/l)				<50	40	4			
Cd (μg/l)				<3	<2	<2			
Cr (μg/l)				<10	<11	<11			
Cu (μg/l)				<7	<7	<7	<5		
Fe (μg/l)				160	<11	<11	<11		
Hg (μg/l)				4	2	2.2			
Mn (μg/l)				17	<5	42	<6		
Pb (μg/l)				<1	<1	<1	<1		
Se (μg/l)				<1	7	<1	<1		
Ag (μg/l)				<3	<6	<3			
Zn (μg/l)				30	62	64			
F (mg/l)				0.21	0.18	0.12	0.39		

Table A-20. Well #20.

	September	October	December	April	May	June	July	August
Date	9-21-79	10-16-79	12-11-79	4-19-80	5-21-80	6-22-80	7-23-80	8-22-80
Time	--	--	12:10	15:15	11:50	18:40	20:50	
Temp								
Air(^oC)	--	--	--	--	--	24	16	20.5
Water (^oC)	--	--	--	--	6	9	10	10
Depth to Water Table (ft)	-8.50	Dry	Dry	Dry	-3.83	-0.17	-0.88	-4.38
(m)	-2.59				-1.17	-0.06	-0.27	-1.33
Snow Depth (inches)	--	--	--	--	--	--	--	
DO (mg/l)	--	--	--	--	9.2	--	7.3	3.9
pH (Field)	--	--	--	--	7.3	7.0	7.5	7.2
Coliform								
Total/100 ml	--	--	--	--	<1	1	<1	<1
Fecal/100 ml	--				<1	--	<1	<1
Fecal Streptococci/100 ml							<1	2
Nitrogen								
NH_3-N (μg/l)	--				15	84	--	25
NO_3-N (mg/l)					0.39	0.59	0.11	0.04
NO_2-N (μg/l)					7	<2	2	·5
Phosphate								
Ortho (μg/l)					115	125	100	90
Total (μg/l)					292	152	131	106
BOD (mg/l)					<1	<2	1.5	--
TDS (mg/l)								
Specific Conductivity (μmhos/cm at 25^{o}C)					585	464	472	499
Cations								
Na (mg/l)								
Mg as $CaCO_3$ (mg/l)								
K (mg/l)								
Ca as $CaCO_3$ (mg/l)								
Anions								
Cl (mg/l)							9	7
SO_4 (mg/l)								
B (mg/l)								
Total Hardness as $CaCO_3$ (mg/l)								
Total Alkalinity as $CaCO_3$ (mg/l)								
pH (Lab)						7.41	7.58	7.67
Surfactant as MBAS (μg/l)								
Trace Inorganics								
As (μg/l)								
Ba (μg/l)								
Cd (μg/l)								
Cr (μg/l)								
Cu (μg/l)								
Fe (μg/l)								
Hg (μg/l)								
Mn (μg/l)								
Pb (μg/l)								
Se (μg/l)								
Ag (μg/l)								
Zn (μg/l)								
F (mg/l)								

Table A-21. Well #21.

	September	October	November	April	May	June	July	August
Date	9-21-79	10-24-79	11-25-79	4-19-80	5-21-80	6-22-80	7-23-80	8-22-80
Time	8:30	16:30	15:15	15:45	10:00	--	18:35	
Temp								
Air (°C)	--	--	--	--	--	21.5	20	21
Water (°C)	--	10	4	00	7	9.5	12	11.5
Depth to Water Table (ft)	-4.33	-3.37	-3.66	-5.02	-5.46	-1.11	-2.67	-3.15
(m)	-1.32	-1.02	-1.11	-1.53	-1.66	-0.34	-0.84	-0.96
Snow Depth (inches)	--	--	--	--	--	--	--	--
DO (mg/l)	--	2	--	--	--	--	0.5	2.4
pH (Field)	--	--	7	--	6.7	7.1	7.2	6.7
Coliform								
Total/100 ml	--	1	<1	--	<1	<1	<1	<1
Fecal/100 ml	--	<1	<1	--	<1	<1	<1	<1
Fecal Streptococci/100 ml							1	12
Nitrogen								
NH_3-N (μg/l)	--	97	14		31	18	40	10
NO_3-N (mg/l)	--	0.11	0.05		0.07	0.08	<0.04	0.04
NO_2-N (μg/l)	--	2	1		6	2	3	5
Phosphate								
Ortho (μg/l)	--	58	58		57	82	67	75
Total (μg/l)	--	559	152		1181	108	175	195
BOD (mg/l)	--	1.40	<1		<1	<2	1	--
TDS (mg/l)		354	373					
Specific Conductivity (μmhos/cm at 25°C)		571	511		469	589	607	633
Cations								
Na (mg/l)		9	10					
Mg as $CaCO_3$ (mg/l)								
K (mg/l)		<3						
Ca as $CaCO_3$ (mg/l)								
Anions								
Cl (mg/l)		7	23				22	3
SO_4 (mg/l)		26	25					
B (mg/l)		<0.05						
Total Hardness as $CaCO_3$ (mg/l)								
Total Alkalinity as $CaCO_3$ (mg/l)								
pH (Lab)						7.13	7.33	7.50
Surfactant as MBAS (μg/l)		<30						
Trace Inorganics								
As (μg/l)		<1						
Ba (μg/l)		31						
Cd (μg/l)		<3						
Cr (μg/l)		<8						
Cu (μg/l)		<7						
Fe (μg/l)		13	<19					
Hg (μg/l)		<0.5						
Mn (μg/l)		19	37					
Pb (μg/l)		1						
Se (μg/l)		<1						
Ag (μg/l)		2						
Zn (μg/l)		12	9					
F (mg/l)		0.15						

Table A-22. Well #22

	Sept.	Sept.	Sept.	December	April	May	June	July	August
Date	9-19-79	9-20-79	9-21-79	12-11-79	4-19-80	5-20-80	6-22-80	7-23-80	8-22-80
Time	18:45	11:00	8:00	12:30	16:00	18:00	--	19:15	
Temp									
Air (^oC)	--	--	--	--	--	--	23	17	22.5
Water (^oC)	--	--	--	--	--	--	7.5	11	11.5
Depth to Water Table (ft)	-15.25	-19.17	-17.30	-18.17	-12.04	Flowing	Flowing	-0.58	-12.63
(m)	-4.65	-5.84	-5.27	-5.54	-5.50			-0.18	-3.85
Snow Depth (inches)									
DO (mg/l)	--	--	--	--	--	9.2	--	7.8	5.5
pH (Field)	--	--	--	--	--	--	7.1	7.6	7.3
Coliform									
Total/100 ml						<1	<1	<1	<1
Fecal/100 ml						<1	<1	<1	<1
Fecal streptococci/100 ml								<1	1
Nitrogen									
NH_3-N (µg/l)				210		83	24	36	203
NO_3-N (mg/l)				0.63		2.02	0.61	0.07	0.22
NO_2-N (µg/l)				8		4	3	3	7
Phosphate									
Ortho (µg/l)				118		109	17	133	305
Total (µg/l)				1434		1722	93	<94	801
BOD (mg/l)						1	<2	2.0	--
TDS (mg/l)									
Specific Conductivity (µmhos/cm at 25^oC)						425	425	543	549
Cations									
Na (mg/l)				243					
Mg as $CaCO_3$ (mg/l)									
K (mg/l)									
Ca as $CaCO_3$ (mg/l)									
Anions									
Cl (mg/l)								11	10
SO_4 (mg/l)									
B (mg/l)									
Total Hardness as $CaCO_3$ (mg/l)									
Total Alkalinity as $CaCO_3$ (mg/l)									
pH (Lab)						7.35	7.33	7.75	7.83
Surfactant as MBAS (µg/l)									
Trace Inorganics									
As (µg/l)				25					
Ba (µg/l)				379					
Cd (µg/l)				<3					
Cr (µg/l)									
Cu (µg/l)									
Fe (µg/l)				<19					
Hg (µg/l)									
Mn (µg/l)				167					
Pb (µg/l)									
Se (µg/l)									
Ag (µg/l)									
Zn (µg/l)				118					
F (mg/l)									

Table A-23. Well #23.

	October	November	April	April	May	June	July	August
Date	10-23-79	11-25-79	4-19-80	4-20-80	5-21-80	6-22-80	7-23-80	8-22-80
Time	18:00	14:00	18:15	16:00	18:15	--	20:12	
Temp								
Air (°C)	--	--	--	--	22	--	21	24
Water (°C)	8.5	6.0	--	--	5	--	7	8
Depth to Water Table (ft)			-5.96	-5.60		--	-2.00	-5.00
(m)			-1.82	-1.71		--	-0.61	-1.52
Snow Depth (inches)						--	--	
DO (mg/l)	1.6				0.7	--	<0.1	1.7
pH (Field)		6.1			6.5		7.55	7.6
Coliform								
Total/100 ml	<1	<1			<1	--	<1	<1
Fecal/100 ml	<1	<1			<1	--	<1	<1
Fecal Streptococci/100 ml							2	<1
Nitrogen								
NH_3-N (μg/l)	98	68			72		140	91
NO_3-N (mg/l)	0.17	<0.04			0.14		<0.04	<0.04
NO_2-N (μg/l)	2	1			13		4	7
Phosphate								
Ortho (μg/l)	6	<1			<10		<10	30
Total (μg/l)	30	26			12		43	30
BOD (mg/l)	0.80	<1			<1		3.5	--
TDS (mg/l)	327	285						
Specific Conductivity (μmhos/cm at 25°C)	504	395			472		446	494
Cations								
Na (mg/l)	5	4						
Mg as $CaCO_3$ (mg/l)	80	288						
K (mg/l)	<3							
Ca as $CaCO_3$ (mg/l)	200	184						
Anions								
Cl (mg/l)	<1	3					4	2
SO_4 (mg/l)	17	13						
B (mg/l)	0.535							
Total Hardness as $CaCO_3$ (mg/l)		472						
Total Alkalinity as $CaCO_3$ (mg/l)	244	227						
pH (Lab)	8.36	8.3			7.36		7.98	7.78
Surfactant as MBAS (μg/l)	<30							
Trace Inorganics								
As (μg/l)	<1							
Ba (μg/l)	83							
Cd (μg/l)	<3							
Cr (μg/l)	<8							
Cu (μg/l)	<7							
Fe (μg/l)	22	1140						
Hg (μg/l)	<0.5							
Mn (μg/l)	249	182						
Pb (μg/l)	1							
Se (μg/l)	<1							
Ag (μg/l)	6							
Zn (μg/l)	18	27						
F (mg/l)	0.12							

Table A-24. Surface sample #24.

	October	May	June	July	August
Date	10-25-79	5-21-80	6-22-80	7-22-80	8-23-80
Time	8:00	12:45		11:40	
Temp					
Air (°C)	1	19.5	22.5	24	15
Water (°C)	-0.25	4	3.5	13	9
Depth to Water Table (ft)					
(m)					
Snow Depth (inches)					
DO (mg/l)		9.6	--	9.3	7.5
pH (Field)		8.2	7.8	8.5	8.1
Coliform					
Total/100 ml	43	<1	23	23	30
Fecal/100 ml	15	1	<1	20	30
Fecal streptococci/100 ml				17	TNTC
Nitrogen					
NH_3-N (µg/l)	5	35	19	64	30
NO_3-N (mg/l)	0.11	1.12	0.31	<0.04	<0.04
NO_2-N (µg/l)	8	6	3	3	6
Phosphate					
Ortho (µg/l)	23	55	17	13	10
Total (µg/l)	85	241	93	64	13
BOD (mg/l)	1.40	1	<2	1.0	--
TDS (mg/l)	262				
Specific Conductivity (µmhos/cm at 25°C)	497	315	238	468	563
Cations					
Na (mg/l)	5				
Mg as $CaCO_3$ (mg/l)	77				
K (mg/l)	<3				
Ca as $CaCO_3$ (mg/l)	167				
Anions					
Cl (mg/l)	1			6	1
SO_4 (mg/l)	22				
B (mg/l)	0.060				
Total Hardness as $CaCO_3$ (mg/l)					
Total Alkalinity as $CaCO_3$ (mg/l)	228				
pH (Lab)	8.45		8.24	8.44	7.74
Surfactant as MBAS (µg/l)	<30				
Trace Inorganics					
As (µg/l)	<1				
Ba (µg/l)	26				
Cd (µg/l)	<3				
Cr (µg/l)	<8				
Cu (µg/l)	<7				
Fe (µg/l)	54				
Hg (µg/l)	<0.5				
Mn (µg/l)	<6				
Pb (µg/l)	1				
Se (µg/l)	<1				
Ag (µg/l)	0				
Zn (µg/l)	<1				
F (mg/l)	0.06				

Table A-25. Surface sample #25.

	October	April	May	June	July	August
Date	10-23-79	4-20-80	5-20-80	6-22-80	7-22-80	8-22-80
Time	18:30	17:00	19:10	17:35	16:00	--
Temp						
Air (°C)	--	--	--	25	23	21.5
Water (°C)	10.5	5.5	6	16	18	17
Depth to Water Table (ft)						
(m)						
Snow Depth						
DO (mg/l)	8.3	7.5	6.9	--	7.5	8.0
pH (Field)	--	6.7	7.8	8.1	8.3	8.2
Coliform						
Total/100 ml	TNTC	10	~30	~190	TNTC	900
Fecal/100 ml	TNTC	<1	180	~100	TNTC	130
Fecal streptocci/100 ml					TNTC	440
Nitrogen						
NH_3-N (μg/l)	180	<10	36	33	47	170
NO_3-N (mg/l)	0.14	0.78	0.81	0.31	<0.04	<0.04
NO_2-N (μg/l)	5	7	8	4	3	6
Phosphate						
Ortho (μg/l)	21	29	35	25	40	<10
Total (μg/l)	185	84	1670	320	72	20
BOD (mg/l)	1.25	<1	2	<2	1.5	--
TDS (mg/l)	404	429	--	201	305	279
Specific Conductivity (μmhos/cm at 25°C)	--	465	336	273	462	489
Cations						
Na (mg/l)	7	10	6	1		
Mg as $CaCO_3$ (mg/l)	105	56	29	37	66	91
K (mg/l)	<3	6	2	2		
Ca as $CaCO_3$ (mg/l)	167	81	159	133	178	170
Anions						
Cl (mg/l)	10	16	6	1.5	5	5
SO_4 (mg/l)	53	35	26	18.8	31	39
B (mg/l)			<0.1	0.11	<0.1	<0.1
Total Hardness as $CaCO_3$ (mg/l)		137	188	170	244	261
Total Alkalinity as $CaCO_3$ (mg/l)	248	205	155	135	241	225
pH (Lab)	8.44	8.21	8.36	8.30	8.47	8.24
Surfactant as MBAS (μg/l)	<30	<100	<25	<100	<25	<25
Trace Inorganics						
As (μg/l)	<1	<1	<1	<1		
Ba (μg/l)	70	<50	57	<3		
Cd (μg/l)	<3	<3	<2	<2	<2	
Cr (μg/l)	<8	<10	<11	<11	<11	
Cu (μg/l)	<7	<7	<7	<7	<5	
Fe (μg/l)	20	2,106	20	21	17	<12
Hg (μg/l)	0.5	4	3	3.1		
Mn (μg/l)	41	468	5	19	15	<7
Pb (μg/l)	1	<1	<1	2	<1	
Se (μg/l)	<1	<1	19	<1	<1	
Ag (μg/l)	5	<3	<6	<3	<3	
Zn (μg/l)	<1	26	49	30		
F (mg/l)	0.10	0.36	0.24	0.18	0.18	0.26

Table A-26. Surface sample #26.

	October	April	May	June	July	August
Date	10-23-79	4-20-80	5-20-80	2-22-80	7-23-80	8-22-80
Time	17:30	16:00	18:30	--	20:10	
Temp						
Air (°C)		--	22	23	21	24
Water (°C)	5	0	5	17	20	16.5
Depth to Water Table (ft)						
(m)						
Snow Depth (inches)						
DO (mg/l)	9.6	10	8.0	--	8.0	7.8
pH (Field)	9.2	--	6.8	8.4	8.4	8.1
Coliform						
Total/100 ml	115	90	30	10	30	10
Fecal/100 ml	106	<1	43	4	25	30
Fecal streptococci/100 ml					TNTC	40
Nitrogen						
NH_3-N (µg/l)	49	<10	69	60	--	28
NO_3-N (mg/l)	0.13	0.34	0.46	0.20	<0.04	<0.04
NO_2-N (µg/l)	3	4	6	3	3	5
Phosphate						
Ortho (µg/l)	15	29	185	<10	33	10
Total (µg/l)	15	136	185	36	62	12
BOD (mg/l)	0.90	2	1	<2	2.2	--
TDS (mg/l)	241					
Specific Conductivity (µmhos/cm at 25°C)	--	285	334	323	343	323
Cations						
Na (mg/l)	5					
Mg as $CaCO_3$ (mg/l)	54					
K (mg/l)	<3					
Ca as $CaCO_3$ (mg/l)	122					
Anions						
Cl (mg/l)	1				3	3
SO_4 (mg/l)	15					
B (mg/l)	<0.05					
Total Hardness as $CaCO_3$ (mg/l)						
Total Alkalinity as $CaCO_3$ (mg/l)						
pH (Lab)		8.16	8.54	8.49	8.61	8.31
Surfactant as MBAS (µg/l)	<30					
Trace Inorganics						
As (µg/l)	<1					
Ba (µg/l)	60					
Cd (µg/l)	<3					
Cr (µg/l)	<8					
Cu (µg/l)	<7					
Fe (µg/l)	8					
Hg (µg/l)	<0.5					
Mn (µg/l)	21					
Pb (µg/l)	<1					
Se (µg/l)	<1					
Ag (µg/l)	8					
Zn (µg/l)	<1					
F (mg/l)	0.08					

Table A-27. Surface sample #27.

	February	April	May	June	July	August
Date	2-24-80	4-20-80	5-20-80	6-22-80	7-22-80	8-23-80
Time	12:00	6:30			12:00	
Temp						
Air (°C)	1	0	--	24	24	18.5
Water (°C)	6	3	4.5	5	13	9
Depth to Water Table (ft)						
(m)						
Snow Depth (inches)						
DO (mg/l)	3.5	4.5	9.4	--	9.2	8.3
pH (Field)	6.9	7.1	8.0	8.1	8.5	8.1
Coliform						
Total/100 ml	14	130	70	12	30	40
Fecal/100 ml	<1	34	~30	<1	28	30
Fecal streptococci/100 ml					28	30
Nitrogen						
NH_3-N (μg/l)	41	51	19	23	50	20
NO_3-N (mg/l)	0.55	0.39	1.03	0.32	<0.04	0.60
NO_2-N (μg/l)	18	3	6	2	5	6
Phosphate						
Ortho (μg/l)	17	42	44	29	17	30
Total (μg/l)	20	136	421	119	36	31
BOD (mg/l)	<1	1	1	<2	<1	--
TDS (mg/l)	--	224	104	154	217	213
Specific Conductivity (μmhos/cm at 25°C)	592	454	299	243	345	413
Cations						
Na (mg/l)	4	7	1	2		
Mg as $CaCO_3$ (mg/l)		32	24	70	41	62
K (mg/l)		5	2	1		
Ca as $CaCO_3$ (mg/l)		68	135	100	142	166
Anions						
Cl (mg/l)		5	3	1.5	3	3
SO_4 (mg/l)	55	37	14	15.5	18	17
B (mg/l)	0.19		0.4	<0.1	<0.1	<0.1
Total Hardness as $CaCO_3$ (mg/l)		100	159	170	183	228
Total Alkalinity as $CaCO_3$ (mg/l)		226	150	141	184	207
pH (Lab)		8.15	8.27	8.17	8.54	8.42
Surfactant as MBAS (μg/l)		<100	57	30	<25	<25
Trace Inorganics						
As (μg/l)		<1	<1	<1		
Ba (μg/l)		<50	28	<3		
Cd (μg/l)		<3	11	<2	<2	
Cr (μg/l)		<10	<11	<11	<11	
Cu (μg/l)		<7	<7	<7	<5	16
Fe (μg/l)		445		73	<11	
Hg (μg/l)		3		2.4		
Mn (μg/l)		72	10	15	10	<7
Pb (μg/l)	<1	<1	<1	3	<1	
Se (μg/l)		<1	<1	<1	<1	
Ag (μg/l)		<3	<3	<3	<3	
Zn (μg/l)		20	73	22		
F (mg/l)		0.38	0.25	0.17	0.09	0.13

Table A-28. Surface sample #28.

	April	May	June	July	August
Date	4-20-80	5-20-80	6-22-80	7-22-80	8-23-80
Time	12:00	19:30		14:05	
Temp					
Air (^{o}C)	16	--	26	25	20.5
Water (^{o}C)	8	9	10	11	13
Depth to Water Table (ft)					
(m)					
Snow Depth (inches)					
DO (mg/l)	9	--	--	8.8	8.3
pH (Field)	7.6	--	8.1	8.4	8.1
Coliform					
Total/100 ml	210	--	~106	TNTC	830
Fecal/100 ml	<1	~110	~200	TNTC	55
Fecal streptococci/100 ml				TNTC	180
Nitrogen					
NH_3-N (µg/l)	62	61	23	44	30
NO_3-N (mg/l)	0.57	0.94	0.28	0.05	<0.04
NO_2-N (µg/l)	7	8	3	2	6
Phosphate					
Ortho (µg/l)	100	33	18	20	32
Total (µg/l)	177	3370	220	22	42
BOD (mg/l)	<1	4	<2	<1	--
TDS (mg/l)	222	141	200	191	265
Specific Conductivity (µmhos/cm at 25^{o}C)	478	318	293	303	504
Cations					
Na (mg/l)	-9	1	2		
Mg as $CaCO_3$ (mg/l)	60	41	59	48	93
K (mg/l)	5	2	2		
Ca as $CaCO_3$ (mg/l)	50	172	133	121	182
Anions					
Cl (mg/l)	15	5	1.5	3	5
SO_4 (mg/l)	36	23	19.9	12	40
B (mg/l)		<0.1	0.1	<0.1	0.1
Total Hardness as $CaCO_3$ (mg/l)	110	213	192	169	275
Total Alkalinity as $CaCO_3$ (mg/l)	218	146	135	186	234
pH (Lab)	8.30	8.39	8.28	8.36	8.26
Surfactant as MBAS (µg/l)	<100	48	<25	--	<25
Trace Inorganics					
As (µg/l)	<1	<1	<1		
Ba (µg/l)	<50	36	<3		
Cd (µg/l)	<3	<2	<2		
Cr (µg/l)	<10	<11	<11		
Cu (µg/l)	<7	<7	<7	<5	
Fe (µg/l)	106		39	17	13
Hg (µg/l)	3		1.6		
Mn (µg/l)	131	<4	19	<6	<7
Pb (µg/l)	<1	<1	2	<1	
Se (µg/l)	15	<1	2	<1	
Ag (µg/l)	<3	<3	<3		
Zn (µg/l)	24	87	20		
F (mg/l)	0.26	0.24	0.20	0.42	0.28

APPENDIX B

DRINKING WATER CRITERIA

Appendix B

Water Quality Parameters

Water quality parameters. In the design of this groundwater study, financial restrictions necessitated that a limited set of tests be performed on the water samples. The selected tests are considered essential in assessing the impact of septic tanks and livestock on groundwater and reservoir water quality. In order to demonstrate the limited scope of this study, Tables B-1 - B-7 are presented which enumerate known water pollutants, their effects on man, and current drinking water criteria. Long-term effects of many pollutants are unknown. The criteria have been based on limited data, practical considerations of treatment systems, and economic factors.

> Generally, the aspects of water quality about which most regulations are concerned can be divided into five categories: inorganic chemicals, organic chemicals, radioactive materials, physical parameters, and microbiological parameters. Table B-4 summarizes the quality levels specified for inorganic chemicals by five different agencies, the World Health Organization (WHO) (International Standards for Drinking Water 1971), the EPA (National Interim Primary Drinking Water Regulations 1975), the American Waterworks Association (Quality Goals for Potable Water 1968), the USPHS (Public Health Service Drinking Water Standards 1962), and the State of California (California Department of Health, Laws and Regulations Relating to Domestic Water Supplies' Quality and Monitoring 1972). The WHO standards are shown because they represent an internationally recognized standard of fairly recent vintage. The EPA Interim Primary Drinking Water Regulations are included because they are the most recently developed and because they are of direct concern to most US water purveyors. The California regulatons are included as being representative of well-developed state regulations. The AWWA goals and the purpose of general comparison.

Inorganic chemicals. The inorganic chemicals of concern in these regulations consist of a number of metals, some anions of established health significance, and a few other compounds mostly associated with health effects. Most of these materials are summarized in Table B-2 along with the forms they generally take in the aqueous environment and the effects with which they generally are associated. Among the most toxic compounds, arsenic, selenium, and lead probably are encountered most often. The presence of lead is associated generally with aggressive waters and lead plumbing. As a consequence, excessive concentrations of lead often may be reduced through corrosion-control techniques. Although the presence of arsenic or selenium is associated sometimes with man-made sources, they also occur at high levels in some natural waters. If necessary, arsenic may be reduced by conventional methods of treatment. (Tate and Trussell 1977, p. 486)

Nitrate is appearing with increasing frequency in groundwater, principally because of agricultural and municipal discharges. Although work has been done on the development of inexpensive methods of nitrate removal, no completely satisfactory method is yet available. (Tate and Trussell 1977, p. 486)

Organic chemicals. Table B-3 summarizes the quality levels specified for organic chemicals by the same five agencies. These consist of a number of pesticides and herbicides as well as some general indicators of total organic and detergen content. Many of the specific compounds are also shown in Table B-4 along with their stoichiometric formula, their structure, and comments on their associated health effects. A great deal of research presently is being conducted on organics in water supplies, and indications are that some additional requirements may be

Table B-1. Drinking water criteria for inorganic chemicals (mg/l) (Tate and Trussell 1977, p. 487).

Constituent	World Health Organization (1971)			EPA Interim Primary Regulation (1975-1976) Maximum Contaminant[a] Levels		AWWA Goal (1962)	USPHS (1962)		California (1972)				Utah (1979)	
									Consumer-Acceptance Limits			Limiting Concentration		(Maximum Contaminant Level)
	Highest Desirable	Maximum Permissible	Upper Limit	Primary	Secondary[a]		Recommended	Mandatory	Recommended	Upper	Short-term		Primary	Secondary
Alkalinity	-	-	-	-	-	b	-	-	-	-	-	-	-	-
Aluminum	-	-	-	-	-	0.05	-	-	-	-	-	-	-	-
Arsenic	-	-	0.05	0.05	-	-	0.01	0.05	-	-	-	0.10	0.05	-
Barium	-	-	-	1.0	-	-	-	1.0	-	-	-	1.0	1.0	-
Cadmium	-	-	0.01	0.01	-	-	-	0.01	-	-	-	0.01	0.01	-
Calcium	75	200	-	-	-	-	-	-	-	-	-	-	-	-
Chloride	200	600	-	-	250	-	250	-	250	500	800	-	-	250
Chromium (total)	-	-	-	0.05	-	-	-	-	-	-	-	0.05	0.05	-
Chromium (VI)	-	-	-	-	-	-	-	0.05	-	-	-	-	-	-
Copper	0.05	1.5	-	-	1	0.2	1.0	-	-	-	1.0[c]	-	-	1.0
Cyanide	-	-	0.05	-	-	-	0.01	0.2	-	-	-	0.2	-	-
Fluoride	d	d	-	e	-	-	d	d	-	-	-	d	-	-
Hardness[f]	100	500	-	-	-	80-100	-	-	-	-	-	-	-	-
Hydrogen sulfide	-	-	-	-	0.05	-	-	-	-	-	-	-	-	-
Iron	0.1	1.0	-	-	0.3	0.05	0.3	-	-	-	0.3[c]	-	-	0.3
Lead	-	-	0.1	0.05	-	-	-	0.05	-	-	-	0.05	0.05	-
Magnesium	30	150	-	-	-	-	-	-	-	-	-	-	-	-
Manganese	0.05	0.5	-	-	0.05	0.01	0.05	-	-	-	0.05[c]	-	-	0.05
Mercury	-	-	0.001	0.002	-	-	-	-	-	-	-	0.005	0.002	-
Nitrate (as N)	-	-	10	10	-	-	10	-	-	-	-	10	10	-
Selenium	-	-	0.01	0.01	-	-	-	0.01	-	-	-	0.01	0.01	-
Silver	-	-	-	0.05	-	-	-	0.05	-	-	-	-	0.05	-
Specific conductance	-	-	-	-	-	-	-	-	800	1600	2400	-	-	-
Sulfate	200	400	-	-	250	-	250	-	250	500	600	-	500	-
TDS	500	1500	-	-	500	200	500	-	500	1000	1500	-	2000[g]	-
Zinc	5	15	-	-	5	1.0	5	-	-	-	5.0[c]	-	-	5

[a] Under consideration.

[b] See original goals.

[c] General consumer-acceptance limit, not strictly short-term.

[d] The acceptable fluoride concentration varies as a function of ambient temperature from 0.6 to 1.7 mg/l.

[e] The acceptable fluoride concentration is described as a function of ambient temperature. Values range from 1.4 to 2.4 mg/l.

[f] As $CaCO_3$.

[g] If TDS is greater than 1000 mg/l, the supplier shall show to the Committee that no better water is available. The Committee shall not allow the use of an inferior source of water if a better source of water (i.e., lower TDS) is available.

established soon. Environmental surveys recently have been completed for aldrin, chlordane, DDT, dieldrin, heptachlor, and heptachlor epoxide. (Tate and Trussell 1977, p. 486)

...and regulations for some of these are under consideration. Also likely are monitoring requirements and a maximum contaminant level (MCL) for the trihalomethanes and possibly for some overall measure of total organic carbon, such as nonpurgeable total organic carbon (NPTOC). Other standards well may result from a study by the Natl. Academy of Sci., soon to be completed. (Tate and Trussell 1977, p. 486)

Physical parameters. Table B-5 summarizes the levels specified by the same agencies for the three remaining quality parameters; radioactive materials, physical parameters, and microbiological parameters. Table B-6 summarizes these parameters and some of their most important effects. (Tate and Trussell 1977, p. 486)

Table B-7 lists the nature, sources, results, and control of some major types of pollutants.

Table B-2. Significance of inorganic parameters (Tate and Trussell 1977, p. 488).

Constituent	Chemical Symbol	Forms in Aqueous Environment*	Effects
Arsenic	As	$HAsO_4^-$, $H_2AsO_4^-$, $HAsO_2$, $(CH_4)_2\ AsO(OH)$, $(CH_3)AsO(OH)_2$	Has been linked with skin cancer and black foot disease; recognized carcinogen
Barium	Ba	Ba^{++}, $Ba^{*}SO_4$, $BaCO_3{}^{*}$	Muscle stimulant, toxic to heart, blood vessels, and nervous system
Cadmium	Cd	Cd^{++}, humic acid complex, $CdCO_3^{*}$	Causes nausea and vomiting, accumulates in the liver and kidney; recognized carcinogen
Chloride	Cl	Cl^-	Imparts taste at concentrations above 400 mg/l, no known health effects
Chromium	Cr	$HCrO_4^-$, $HCr_2O_7^-$, Cr^{+++}	Nausea, ulcers after long-term exposure; trivalent form harmless
Copper	Cu	Cu^+, Cu^{++}, $Cu(OH)^+$, $Cu(NH_3)_x^{++}$	Disagreeable taste above 1 mg/l; therefore, ingestion unlikely
Cyanide	CN	HCN	Toxic gas released at pH's below 6; high concentrations affect nervous system
Fluoride	F	F^-	About 1.0 mg/l reduces decay in teeth, especially in children; above about 4.0 mg/l causes mottled teeth; greater than 15-20 mg/l may cause fluorosis
Iron	Fe	Fe^{++}, $Fe(OH)^+$	High levels impart an unattractive appearance and taste; no health effects
Lead	Pb	Pb^{++}, $Pb(OH)^+$, $(CH_3)_4\ Pb$	Accumulates in bones; constipation, loss of appetite, anemia, abdominal pain, paralysis
Manganese	Mn	Mn^{++}, MnO_3^-, $MnO_4^=$, MnO_4	Disagreeable taste, discolors laundry; not considered health hazard in water because of unpleasant taste and other dietary sources
Mercury	Hg	$HgCl_2{}^{*}$, CH_3Hg^+, $Hg(NH_3)_x^{++}$	Highly toxic to man; gingivities, stomatitis, tremors, chest pains, coughing
Nitrate	NO_3	NO_3^-	High levels have been associated with methemoglobinemia and diarrhea; above 100 mg/l interferes with coliform test
Selenium	Se	$HSeO_3^-$, $SeO_4^=$, $(CH_3)_2Se$, $(CH_3)_2Se_2$	Widely believed to have symptoms similar to arsenic poisoning; has been associated with increased dental carries
Silver	Ag	$AgCl^{*}$	Fatal at very high concentrations, at low concentrations causes a darkening of skin
Sulfate	SO_4	$SO_4^=$	At high concentrations, has laxative effect on new users; no permanent effects
Total dissolved solids	TDS	Minerals, etc.	Very high levels have cathartic reaction and do not quench thirst
Zinc	Zn	Zn^{++}, $Zn(OH)^+$, $Zn(Cl)_x^y$	Astringent taste above 5 mg/l; higher concentrations give milky appearance and form a greasy film upon boiling; very high concentrations associated with nausea and fainting

*Describes species in aqueous solution. Many of the heavy metals are primarily present as precipitates or suspended material.

Table B-3. Drinking water criteria for organic chemicals (mg/l) (Tate and Trussell 1977, p. 489).

Constituent	World Health Organization (1971)			EPA Interim Primary Regulation (1975-1976) Maximum Contaminant Levels		AWWA Goal (1968)	USPHS (1962)		California (1972) Limiting Concentrations	Utah (1979) Maximum Contaminant Levels
	Highest Desirable	Maximum Permissible	Upper Limit	Primary	Secondary[a]		Recommended	Mandatory		
Carbon-alcohol extract	-	-	-	-	-	0.10	-	-	3.0	-
Carbon-chloroform extract	-	-	-	-	-	0.04	0.2	-	0.7	-
Foaming agents (MBAS)	0.2	1.0	-	-	0.5	0.2	0.5	-	0.5	0.5
Aldrin	-	-	-	a	-	-	-	-	0.017	-
Chlordane	-	-	-	a	-	-	-	-	0.003	-
DDT	-	-	-	a	-	-	-	-	0.042	-
Dieldrin	-	-	-	a	-	-	-	-	0.017	-
Endrin	-	-	-	0.0002	-	-	-	-	0.001	0.0002
Heptachlor	-	-	-	a	-	-	-	-	0.018	-
Heptachlor epoxide	-	-	-	a	-	-	-	-	0.018	-
Lindane	-	-	-	0.004	-	-	-	-	0.056	0.004
Methoxychlor	-	-	-	0.1	-	-	-	-	1.0	0.1
Organophosphates and carbamates	-	-	-	-	-	-	-	-	0.1	-
Toxaphene	-	-	-	0.005	-	-	-	-	0.005	0.005
2, 4-D	-	-	-	0.1	-	-	-	-	-	0.1
2, 4, 5-TP (silvex)	-	-	-	0.01	-	-	-	-	-	0.01
Total herbicide	-	-	-	-	-	-	-	-	0.1	-
Chloroform	-	-	-	b	-	-	-	-	-	-
Phenols	0.001	0.002	-	-	-	-	0.001	-	-	-
Mineral oil	0.01	0.30	-	-	-	-	-	-	-	-

[a] Regulations are under consideration.

[b] Regulations being seriously considered.

Table B-4. Significance of organic parameters (Tate and Trussell 1977, p. 490).

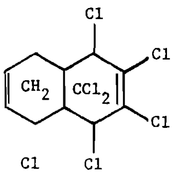
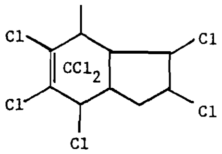
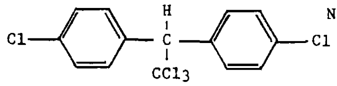
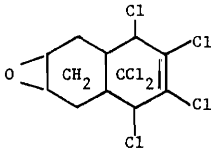
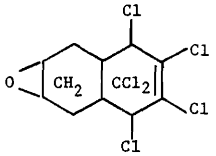
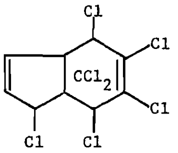
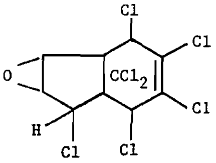
Constituent	Stoichiometric Formula	Structure	Effects
Carbon-alcohol extract			May produce taste and odors; provides gross indication of exposure to organics
Carbon-chloroform extract			May produce taste and odors; provides gross indication of exposure to organics
Foaming agent (MBAS)			Causes foaming
Aldrin	$C_{12}H_6Cl_6$		Neurotoxin; suspect carcinogen
Chlordane	$C_{10}H_6Cl_8$		Suspect carcinogen
DDT	$C_{14}H_9Cl_5$		Neurotoxin; causes unsteadiness, dizziness, paraesthesis, vomiting, convulsions
Dieldrin	$C_{12}H_4OCl_6$		Neurotoxin; suspect carcinogen
Endrin	$C_{12}HOCl_6$		Neurotoxin; suspect carcinogen
Heptachlor	$C_{10}H_5Cl_7$		Neurotoxin; suspect carcinogen
Heptachlor Epoxide	$C_{10}H_3OCl_7$		Neurotoxin

Table B-4. Continued.

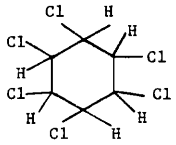
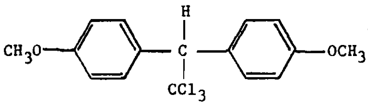
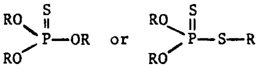
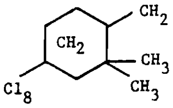
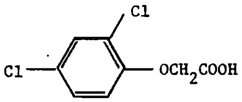
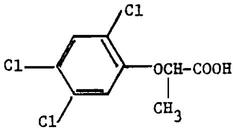
Constituent	Stoichiometric Formula	Structure	Effects
Lindane	$C_6H_6Cl_6$		Suspect carcinogen
Methoxychlor	$C_{16}H_{15}Cl_3O_2$		Fatal at high doses
Organophosphates			Parasympathetic stimulation, convulsions, respiratory failure, death
Carbamates		H_2N-COOR	Lachrymation, salivation, myosis, convulsions, death
Toxaphene	$C_{10}H_{10}Cl_8$		Neurotoxin
Herbicide; 2, 4-D	$C_8H_6Cl_2O_3$		Nonpoisonous; may produce unpleasant taste in water
Silvex	$C_9H_7O_3Cl_3$		Can cause unpleasant, oily taste in exposed fish

Table B-5. Physical, radiological, and microbiological parameters for drinking water (Tate and Trussell 1977, p. 492).

Constituent	World Health Organization (1971)			EPA Interim Primary Regulation (1975-1976) Maximum Contaminant Levels		AWWA Goal (1968)	USPHS (1962)		California (1972)		Utah (1979)	
	Highest Desirable	Maximum Permissible	Upper Limit	Primary	Secondary[a]		Recommended	Mandatory	Consumer Acceptance Limits	Limiting Concentration	Primary	Secondary
Physical												
Color-Acu	5	50	-	-	15	3	15	-	15	-	-	15
Corrosivity	-	-	-	-	b	c	-	-	-	-	-	b
Odor-TON	d	d	-	-	3	none	3	-	3	-	-	3
pH	7.0-8.5	6.5-9.2	-	-	6.5-8.5	-	-	-	-	-	-	6.5-8.5
Suspended solids--mg/l	-	-	-	-	-	0.1	-	-	-	-	-	-
Taste	d	d	-	-	-	d	d	-	-	-	-	-
Turbidity--tu	5	25	-	1[e]	-	0.1	5	-	-	0.5[f]	1.0	-
Radiological[g]												
Gross Alpha--pc/l	3	10	-	15	-	-	-	-	-	-	1.5	-
Gross Beta--pc/l	30	100	-	-	-	100	-	1000	-	1000	4	-
Radium 226--pc/l	3	-	-	5[h]	-	-	-	3	-	3	5	-
Strontium 90--pc/l	30	-	-	8	-	-	-	10	-	10	8	-
Tritium				20000							20000	-
Microbiological												
Coliform[g]--organisms/100 ml	1	-	-	1	-	none	-	1	-	1	1	-
Plankton count--organisms/ml	-	-	-	-	-	none	-	-	-	-	-	-
Virus[g]--pfu/l	-	1	-	-	-	-	-	-	-	-	-	-

[a] Under

[b] Noncorrosive.

[c] See original goals.

[d] Not objectionable.

[e] Maximum contaminant level is average of 1 tu but may be increased to 5 tu under special circumstance.

[f] For water exposed to significant sewage hazards.

[g] Here the standards have been simplified to allow a straight-forward presentation. The original documents should be referred to.

[h] Radium--226 and -228.

Table B-6. Significance of other parameters (Tate and Trussell 1977, p. 492).

Parameters	Effects
Physical parameters	
Color	Aesthetically displeasing; may dull clothes or stain food and fixtures; colored compounds may be precursors to organohalides
Odor	Undesirable for drinking; may add odor to fish or shellfish; some odor-causing compounds may be precursors to organohalides
Turbidity	Aesthetically displeasing; may interfere with disinfection and the maintenance of chlorine residual
Specific conductance	Related to TDS; very high levels have cathartic reaction and do not quench thirst
Radionuclides	
Gross beta	Somatic and genetic damage
Radium-226	Somatic and genetic damage
Strontium-90	Somatic and genetic damage
Gross alpha	Somatic and genetic damage
Biological factors	
Coliform bacteria	Serves as indicator organism to determine adequacy of disinfection; most are believed to be nonpathogenic

Table B-7. The nature, sources, results and controls of some major types of pollutants (Jones 1979).

Pollutant (Type)	Nature of Pollutant	Common Sources	Overpollution Results in:	How Measured, Controlled, Etc.
1 Sewage and other oxygen-demanding wastes	Putrescible organics; normally reduced by aerobic bacteria (which require water-dissolved oxygen).	Domestic sewage; food-processing industries.	Excessive depletion of oxygen in water damages fish life; complete oxygen removal causes anaerobic bacterial action on pollutants resulting in bad colours, offensive odours.	Measurable in terms of biochemical oxygen demand (BOD); i.e., amount of water-dissolved oxygen used in aerobic bacterial decomposition of the waste. Sometimes expressed in terms of pollution equivalent (PE); includes oxygen demand by industrial waste as well as municipal sewage. Based on average oxygen need of 0.17 lb per person to stabilize daily sewage and related wastes.
2 Infectious agents	Disease-causing organisms (bacteria, viruses).	Human and animal wastes, certain industries (e.g. tanning, slaughtering).	Need for stringent purification treatment to obtain potable supplies; losses to fishing industry (especially shellfish); curtailed recreational uses of streams, lakes, etc.	Most commonly controlled with chlorine; all bacterial and viral contamination probably impossible to remove in most cases, but concentrations are greatly reduced.
3 Plant nutrients	Principally nitrogen and phosphorus compounds.	Municipal sewage; industrial wastes; farms (chemical fertilizers).	Excessive growth of aquatic plant life leading to secondary oxygen-demanding pollution, offensive odours, bad taste.	Serious problem; not removed by ordinary sewage treatment methods.
4 Organic chemicals	Detergents, pesticides, many industrial by-products.	Domestic and industrial sewage; farms (pesticides, etc.).	Threat to fish and other wildlife; possible long-term ingestion hazards to human beings.	Very often not removed by usual sewage or water purification treatments.
5 Minerals and inorganic chemicals	Common salt; acids; metallic salts; cyanides; etc.	Mining; industrial processes; natural deposits (e.g., salt).	Interference with manufacturing processes; obvious or insidious toxic effects on humans and wildlife; bad odours and tastes; corrosion of equipment (industrial, navigational power plants).	Difficult to detect and measure; removal often costly.
6 Sediments	Primarily soils and minerals; also some industrial by-products.	Land erosion by storms, flood waters, etc.; pulpmill and other plant effluents.	Obstruction or filling of streams, lakes, reservoirs, navigational channels; increases cost of water purification; interferes with manufacturing processes; causes equipment corrosion; reduces fish life.	Controlled by use of soil conservation and flood control methods; also by improvement of industrial technology.
7 Radioactive materials		Mining operations; refining of uranium and thorium; power reactors; medical and research centres.	Health hazards to all animal life; small amounts may be concentrated by aquatic life and sediments to increase long-term hazards.	Detectable by automatic stream monitoring; controlled by proper storage of wastes. Future disposal problems will become critical. Normal water treatment methods are ineffective for removal.
8 Heat	Heated water returned to streams and lakes.	Steam-electric power plants; steel mills; refineries; other industrial cooling units.	Reduction of water-contained oxygen, resulting in slower or incomplete pollutant decomposition and damage to aquatic life.	Minimized by recirculation and reuse of industrial cooling waters; choice of proper plant location; use of spray ponds, cooling towers, etc.

APPENDIX C

TOTAL COLIFORMS BY MEMBRANE FILTER TECHNIQUE

Table C-1. Determination of total coliforms-membrane filter technique.

Sample	Vol. (ml)	Holding[b] Media Count (ml)	Media[c] Count	#/100 ml
Date: 5/20 - 5/21/80				
1	10	0	0	<1
	100	0	0	<1
2	10	0	0	<1
	100	0	0	<1
3	10	0	0	<1
	100	-	Conf.	<1
4	10	0	0	<1
	100	Conf.[a]	Conf.	<1
5	10	0	0	<1
	100	Conf.	Conf.	<1
6	10	0	0	<1
	100	0	0	<1
7	10	0	0	<1
	100	2[a]	Not very sheenish conf.	Possibly 2-9
11	10	0	0	<1
	100	0	0	<1
12	10	0	0	<1
	100	0	0	<1
13	10	0	0	<1
	100	0	0	<1
15	10	0	0	<1
	100	0	0	<1
16	10	0	0	<1
	100	0	0	<1
17	10	0	0	<1
	100	0	0	<1
18	10	0	0	<1
	100	Conf.	Conf.	<1
19	10	0	0	<1
	100	0	0	<1
22	10	0	0	<1
	100	-	Conf.	<1
23	10	0	0	<1
	100	0	0	<1
25	10	-	∿3 Motile	∿30
	100	-	Conf.	-
26	10	2	3	30
	100	41	30	30
Date: 6/23/80				
1	10	0	0	<1
	100	-	0	<1
2	10	0	-	1
	100	0	0,1	1
3	10	0	0	<1
	100	0	0	<1
4	10	0	0	<1
	100	0	0	<1
5	10	0	0	<1
	100	0	0	<1
6	10	0	0	<1
	50	0	0	<1
7	10	0	-	3
	100	2	2,4	3
8	10	0	-	<1
	75	0	0,0	<1
9	10	0	-	<1
	100	0	0	<1
10	10	0	-	<1
	100	0	0	<1
11	10	0	-	<1
	100	0	0	<1
Date: 6/23/80 (Continued)				
12	10	0	-	<1
	100	0	0	<1
13	10	1	1	7
	100	5	-	7
14	10	0	-	<1
	100	0	0	<1
15	10	0	-	<1
	100	0	0,0	<1
16	10	0	-	<1
	45	0	0,0	<1
17	10	0	-	<1
	90	0	0,0	<1
18	10	0	-	<1
	100	0	0	<1
19	10	0	-	<1
	100	0	0	<1
20	10		-	1
	100		1	1
21	10	0	-	<1
	100	0	0	<1
22	10	0	-	<1
	100	0	0	<1
24	10	4	-	23
	100	∿20	23	23
26	10	4	-	10
	100	∿48	10	10
27	10	2	-	12
	100	4 (Conf.)	12	12
28	10	65	-	∿106
	100	8 (Conf.)	∿106	∿106

[a] CONF: CONFLUENT indicates that the media was smeared or that an exact count of colonies was impossible.

[b] Holding medium.

[c] Samples were transported in sterile bottles. A time lapse of 20-26 hrs. occurred between sampling and analysis.

APPENDIX D

OBSERVATION WELL LOCATIONS AND LOGS

Table D-1. Piezometer information.

Site: East Piezometer Near Well #13
Location: South Profile

Date	10-25-79	11-25-79	2-24-80	4-20-80	5-20-80
Time	14:00	13:00	13:25	12:00	15:05
SWL	-2'10½"	-3'6 3/4"	-2'11 3/4"	Submerged	-1'5½"
Snow Depth	--	--	3'4"	1'7"	

Site: South Piezometer Near Well #13
Location: South Profile

Date	10-25-79	11-25-79	2-24-80	4-20-80	5-20-80
Time	14:00	13:00	13:25	12:00	15:05
SWL	-3'1 3/4"	-3'4"	-2'7 3/8"	-1 1/8"	-7 3/4"

Site: North Piezometer Near Well #17
Location: North Profile

Date	--	11-26-79	2-24-80	4-20-80	5-20-80
Time	--	11:00	18:00	16:35	15:50
SWL	--	-7'6"	Dry	-7'2 7/8"	-4' 10 5/8"
Snow Depth	--	--	3'2"	2'	--

Site: West Piezometer Near Well #17
Location: North Profile

Date	9-25-79	11-26-79	2-24-80	4-20-80	5-20-80
Time	--	11:00	18:00	16:35	15:50
SWL	-2'10"	-7'11 1/8"	-8'5 1/8"	-7'7 3/4"	-4'11"
Snow Depth	--	--	33"	24"	--

SWL = Static Water Level

Table D-2. Other well locations--Pleasant Valley study area.

CLAIM NUMBER	NAME	LOCATION	DEPTH/STATIC
x-678	Albert S. Veltri	NW¼NW¼ Sec. 3, T12S, R7E	
x-1581	Ernest Salerno	W½NW¼ Sec. 3, T12S, R7E	
x-430	Theresa A. Phelps	SW¼SW¼ Sec. 3, T12S, R7E	
x-1245	Glyn Matthews	SW¼SW¼ Sec. 3, T12S, R7E	120'/45
827	Boyd Bunnell	SW¼SW¼ Sec. 3, T12S, R7E	
x-660	James D. Bertelsen	SW¼SW¼ Sec. 3, T12S, R7E	
x-709	Clede Andreini	NE¼SE¼ Sec. 4, T12S, R7E	
x-1166, 1350	Carl R. Hatch	NE¼SE¼ Sec. 4, T12S, R7E	100'/60
290, x-175	Francis & Rudy Scartezina	NE¼SE¼ Sec. 4, T12S, R7E	85'
x-397	Robert S. Mallard	SW¼SW¼ Sec. 4, T12S, R7E	
x-336	Frank Marrelli	SE¼SE¼ Sec. 4, T12S, R7E	
284	Chris Jouflas	SE¼SE¼ Sec. 4, T12S, R7E	
112	Carbon County	SW¼NE¼ Sec. 9, T12S, R7E	
193	Carbon County	SW¼NE¼ Sec. 10, T12S, R7E	
285	James J. Diamanti	SW¼NW¼ Sec. 10, T12S, R7E	
206	Paul Mancina	SW¼SW¼ Sec. 10, T12S, R7E	
223	Paul Sutton	NW¼NW¼ Sec. 15, T12S, R7E	
x-1483	G. Pete Frandsen	N½NE¼ Sec. 30, T12S, R7E	
3401	Waino Burton	SW¼SE¼ Sec. 32, T12S, R7E	
3402	Waino Burton	SW¼SE¼ Sec. 32, T12S, R7E	
x-164	Louis Gorishek	SW¼SE¼ Sec. 32, T12S, R7E	
x-452	Robert Radakovich	NW¼SW¼ Sec. 5, T13S, R7E	
x-772	Valley Camp Coal Company	SE¼SE¼ Sec. 8, T13S, R7E	210'/75
200, 3460	Mountain Fuel Supply Co. and Utah Natural Gas Company	SW¼SE¼ Sec. 8, T13S, R7E	
x-1560	Coastal States Energy Company	SE¼SW¼ Sec. 13, T13S, R6E SE¼SE¼ Sec. 13, T13S, R6E SW¼SW¼ Sec. 17, T13S, R7E	
x-1114	Coastal States Energy Company	S½SW¼ Sec. 13, T13S, R6E NE¼NE¼ Sec. 23, T13S, R6E SE¼NW¼ Sec. 24, T13S, R6E	
x-1058	Price River Water Users Assn.	NW¼NW¼ Sec. 30, T13S, R7E	

Well #1 North Lake Location

Sample Number	Depth	Description
1	0' - 8½'	Dark, fine quartz sandy, silt and clay rich in organics. Drilled with soils auger.
2	8½' - 11½'	Dark, fine quartz sandy, silt and clay rich in organics. Drilled with jet rig from 8½' to base of bore hole.
3	11½' - 14'	Grayish brown coarse iron stained quartz sand to fine silt and clay.
4	14' - 17½'	Grayish medium quartz sand with some silt and clay.
5	17½' - 19'	Medium gravely, grayish quartz sand - gravel is rounded sandstone fragments.
6	19' - 20'	Coarse rounded sandstone gravel with gray quartz sandstone.

Well is located in an area of silting of the lake.

Cased to 20' with 1" PVC, perforated from 12' - 20' with 1½" galvanized surface casing cemented in place.

Well #2 ORR PROPERTY

Sample Number	Depth	Description
1	0 - 3'	Brown, sandy soil with some rounded pebbles up to ½" in diameter.
2	3' - 5'	Brown, sandy soil with some rounded pebbles up to ½" in diameter.
3	5' - 8½'	Brownish gray fine quartz sand with some fine gravel.
4	8½' - 9'	Brownish gray fine quartz sand with coarse pebbles 1" in diameter.
5	9' - 10½'	Tannish brown medium quartz sand and silt - drilled to 10½' with soils auger.
6	10½' - 14'	Tan medium quartz sand and silt - drilled to 18½' with jet rig.
7	14' - 18½'	Tan coarse quartz sand to fine silt.

Cased to 18½' with 1" PVC, perforated from 8' to 18½', with 1½" galvanized surface casing cemented in place.

Well #3 PAPPAS WELL

Sample Number	Depth	Description
1	0 - 4'	Light tan fine silty sand with pebbles up to 1½" in diameter.
2	4' - 10½'	Light tan fine silty sand with pebbles up to 1½" in diameter - drilled with soils auger.
3	10½' - 14'	Coarse to fine light tan sand with some sandstone rock fragments - drilled with jet rig.
4	14' - 14½'	Sandy clay layer - clay is light in color and firm.
5	14½' - 16½'	Coarse to fine light tan sand.
6	16½' - 21'	Medium gravel with tan sand rock fragments from several different sandstones.

Cased to 20' with 1" PVC, perforated from 13' to 20' with 1½" galvanized surface casing cement in place.

Well #4 JOUFFLAS WELL

Sample Number	Depth	Description
1	0 - 2'	Tannish brown silty soil.
2	2' - 3'	Badly weathered sandstone boulder.
3	3' - 4'	Tannish brown medium quartz silty sand.
4	4' - 10'	Tannish brown medium quartz silty sand with clay - drilled with soils auger.
5	10' - 15'	Tannish brown fine quartz silty sand with streaks of clay - drilled to depth with jet rig.
6	15' - 20'	Tannish brown fine quartz silty sand with some layers of medium to coarse sand.

Cased to 20' with 1' PVC, perforated from 7' to 20', with 1½" galvanized surface casing cemented in place.

Well #5 First Avenue Well

Sample Number	Depth	Description
1	0 - 11'	Tannish fine silty sand.
2	11' - 13'	Tannish medium to fine silty sand - contains some clay.
3	13' - 15'	Tannish medium to fine sand with medium to fine gravel - gravel is sandstone fragments - very angular.
4	15' - 17'	Medium to coarse sand with medium gravel - gravel is sandstone fragments.

Cased with 1" PVC to a depth of 16' with perforations from 9' to 16'. Surface cased with 1½" galvanized pipe 1½' long cemented in place.

Well #6 4th Avenue Well

Sample Number	Depth	Description
1	0 - 10'	Light tan fine sand to coarse silt - drilled with soils auger.
2	10' - 11'	Light tannish white silty clay.
3	10' - 18'	Light tan medium to fine gravel with sand and firm clay.
	18'	Coarse gravel - lost circulation.

Lost circulation at 18' in coarse gravel, unable to continue drilling.

Cased with 1' PVC to 17' with 65 perforations from 10' - 17', surface cased with 1½" galvanized pipe 1½' long.

Well #7 STATE PARK WELL

Sample Number	Depth	Description
1	0 - 9'	Yellowish tan silty quartz sand with some highly weathered pebbles turning to clay - drilled with soils auger.
2	9' - 14'	Same as above - drilled with jet rig.
3	14' - 15'	Tannish coarse to fine sand with large angular sandstone fragments with clumps of gray clay.
4	15' - 17½'	Tan gravely coarse to fine sand with clumps of gray clay.

Cased with 1" PVC to 17½', performated from 10½' to 17½', surface cased with 1½" galvanized pipe 2½' long.

Well #8 PERRY'S BOAT CAMP

Sample Number	Depth	Description
1	0 - 8'	Rust brown, very fine silt and clay.
2	8' - 11'	Yellowish brown fine sand with some silt.
	11' - 11½'	Thin hard layer - no cuttings to suggest coarse material.
	11½' - 12½'	Firm grayish white clay.

Lost circulation several times.

Cased to 12½' with 1" PVC, perforated from 4' to 12½', with 1½" galvanized surface casing 2½' long cemented in place.

Table F-1. Continued.

Well #19. North Profile #5

2'	Kaolinite, illite, expandable; quartz, feldspar
5'	Kaolinite, expandable, illite; quartz, feldspar
6'	Kaolinite, expandable, illite; quartz
9½'	Kaolinite, expandable, illite; quartz, calcite, feldspar

Well #20. Woods Canyon

1'	Kaolinite, illite; quartz, feldspar
6'	Kaolinite, illite, expandable; quartz, feldspar
8'	Kaolinite, illite, expandable; quartz, feldspar
9½'	Kaolinite, illite, expandable; quartz, calcite, feldspar

Well #21. Section 29 Canyon

2'	Kaolinite, expandable, illite; quartz
7'	Kaolinite, expandable, illite; quartz, feldspar
8½'	Kaolinite, expandable, illite; quartz, feldspar
10'	Kaolinite, expandable, illite; quartz
14'	Kaolinite, expandable, illite; quartz, feldspar
15'	Kaolinite, expandable, illite; quartz, feldspar

Well #22. Mountain Home

1'	Kaolinite, illite; quartz, feldspar
5'	Kaolinite, illite; quartz, feldspar
9'	Kaolinite, illite; quartz, feldspar
10'	Kaolinite, montmorillonite, illite; quartz, feldspar
12½'	Kaolinite, montmorillonite, illite; quartz, feldspar
17'	Kaolinite, expandable, illite; quartz, feldspar
19½'	Kaolinite, expandable, illite; quartz, feldspar
20½'	Kaolinite, expandable, illite; quartz, feldspar

Well #23. Fish Creek

2'	Kaolinite, montmorillonite, illite; quartz, calcite, feldspar
6'	Kaolinite, montmorillonite, illite; quartz, calcite
8'	Kaolinite, montmorillonite, illite; quartz, calcite

APPENDIX G

SLUG TESTS IN SELECTED OBSERVATION WELLS

Well #12

Slug Test Data

SWL = 70.49 cm

Well Depth = 272.73 cm

Perforated = 121.92 cm to bottom

Depth to Bedrock = 762.00 cm

Estimated y_0 = 30.5 cm

Time t sec.	Drawdown y_t cm.
0	30.5
10	7.8

r_c = 1.27 cm L_w = 202.24 cm   H = 691.51 cm   A = 3.5

r_w = 1.91 cm L_e = 121.92 cm L_e/r_w = 63.8   B = .60

$$\ln\frac{R_e}{r_w} = \frac{1}{\dfrac{1.1}{\ln(202.24\text{ cm}/1.91\text{ cm})} + \dfrac{3.5 + .6\ln(691.51\text{ cm} - 202.24\text{ cm})/1.91\text{ cm}}{63.8}}$$

$$= 2.916$$

$$K = \frac{(1.27\text{ cm})^2\,(2.916)}{2\,(121.92\text{ cm})}\ \frac{1}{10\text{ sec}}\ \ln\frac{30.5\text{ cm}}{7.8\text{ cm}}$$

$$= .0026\text{ cm/sec}$$

Well #14

Slug Test Data

SWL = 113.35 cm

Well Depth = 444.50 cm

Perforated = 121.92 cm

Depth to Bedrock = 762.00 cm

Estimated y_0 = 30.5 cm

Time t sec.	Drawdown y_t cm.
0	30.5
10	3.6

r_c = 1.27 cm L_w = 331.15 cm   H = 648.65   A = 5.5

r_w = 1.91 cm L_e = 322.58 cm L_e/r_w = 168.9   B = 1.0

$$\ln\frac{R_e}{r_w} = \frac{1}{\dfrac{1}{\ln(331.15\text{ cm}/1.91\text{ cm})} + \dfrac{5.5 + 1\ln(648.65\text{ cm} - 331.15\text{ cm})/1.91\text{ cm}}{168.9}}$$

$$= 3.62$$

$$K = \frac{(1.27\text{ cm})^2\,(3.62)}{2\,(322.58\text{ cm})}\ \frac{1}{10}\ \ln\frac{30.5\text{ cm}}{3.6\text{ cm}}$$

$$= .0019\text{ cm/sec}$$

Well #20

Slug Test Data

SWL = 177.8 cm

Well Depth = 307.6 cm

Perforated = 137.2 cm to bottom

Depth to Bedrock = 307.6 cm

Estimated y_o = 30.5 cm

Time t sec.	Drawdown y_t cm.
0	30.5
35	7.9

r_c = 1.27 cm L_w = 129.8 cm H = 129.8 cm C = 3.8

r_w = 1.91 cm L_e = 170.4 cm L_e/r_w = 89.2 cm

$$\ln \frac{R_e}{r_w} = \frac{1}{\frac{1.1}{\ln (129.8 \text{ cm}/1.91 \text{ cm})} + \frac{3.8}{(170.4 \text{ cm}/1.91 \text{ cm})}}$$

$$= 3.30$$

$$K = \frac{(1.27 \text{ cm})^2 (3.30)}{2 (170.4 \text{ cm})} \quad \frac{1}{35 \text{ sec}} \quad \ln \frac{30.5 \text{ cm}}{7.9 \text{ cm}}$$

$$= .0006 \text{ cm/sec}$$

Well #21

Slug Test Data

SWL = 102.55

Well Depth = 503.55

Perforated = 182.88

Depth to Bedrock = 762.00

Estimated y_o = 30.5 cm

Time t sec.	Drawdown y_t cm.
0	30.5
10	4.0

r_c = 1.27 cm L_w = 401.00 H = 659.45 A = 5.5

r_w = 1.91 cm L_e = 320.67 L_e/r_w = 167.89 B = 1.0

$$\ln \frac{R_e}{r_w} = \frac{1}{\frac{1.1}{\ln (401.00 \text{ cm}/1.91 \text{ cm})} + \frac{5.5 + 1.0 \ln \quad (659.45 = 401.00)/1.91 \text{ cm}}{167.89}}$$

$$= 3.74$$

$$K = \frac{(1.27 \text{ cm})^2 (3.74)}{2 (320.67 \text{ cm})} \quad \frac{1}{10} \quad \ln \frac{30.5 \text{ cm}}{4.0}$$

$$= .0019 \text{ cm/sec}$$

APPENDIX H

SHALLOW SEISMIC SURVEYS

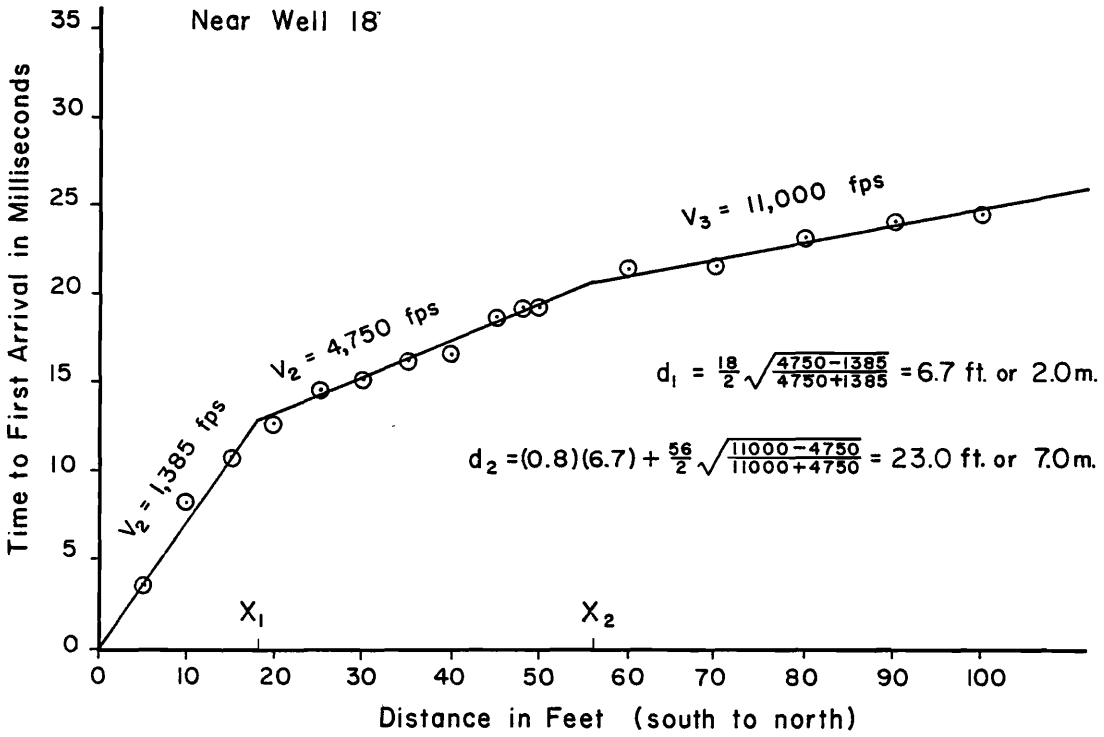


Figure H-1. Seismic traverse near well #18.

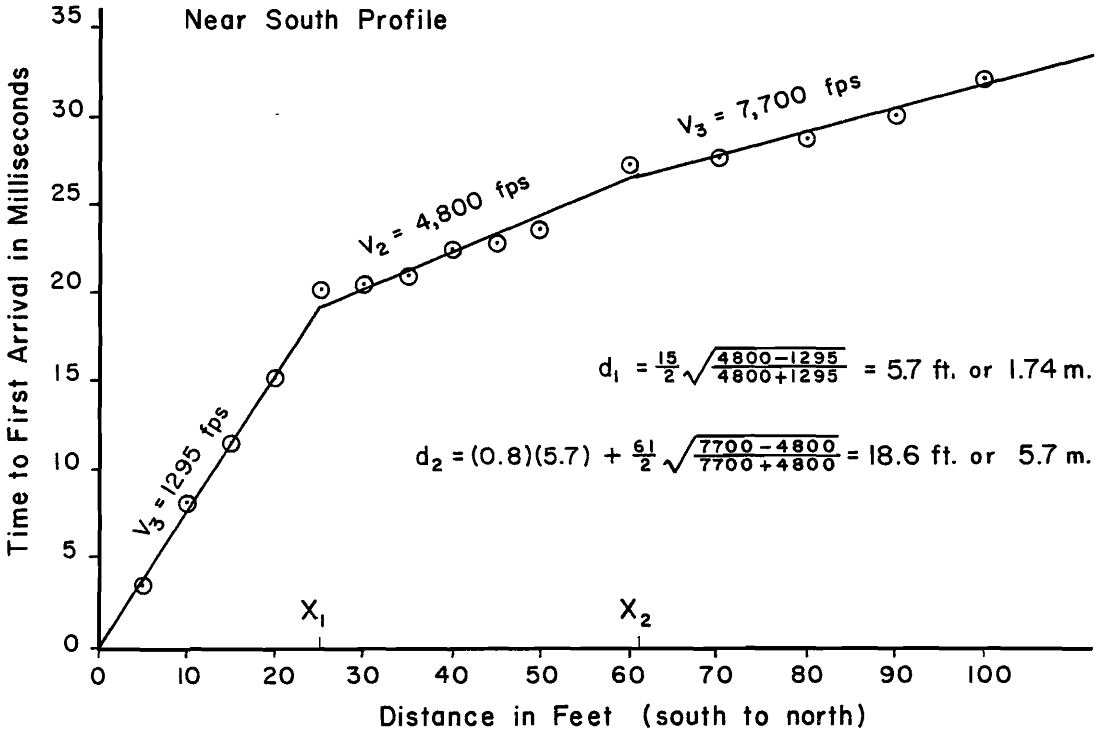


Figure H-2. Seismic traverse near south profile in center of valley.

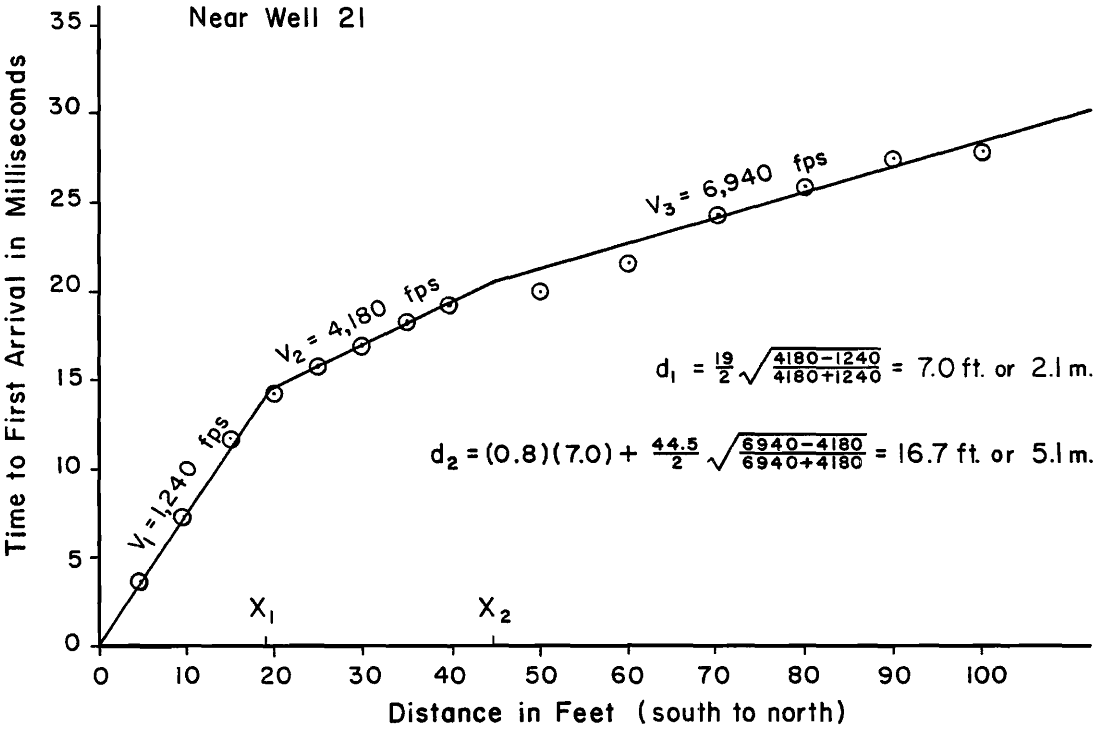


Figure H-3. Seismic traverse near well #21.

APPENDIX I

WATER TABLE ELEVATIONS IN OBSERVATION WELLS

Table I-a. Water levels in observation wells.

Well Number	Ground Surface (ft)	Water Table (feet above sea level)								Remarks
		October	November	February	April	May	June	July	August	
1	7619.15	7620.65	7620.69 (Dec)	-	7620.75	7622.07				Flowing well
2	7620.31	7609.61	7609.13	7610.04	7610.50	7615.90	7618.73	7616.81	7613.98	
3	7620.86	7610.07	7609.47	7610.15	7611.23	7616.03	7618.73	7617.19	7614.34	
4	7623.80	7610.55	7610.17	-	7611.65	7616.00	7618.51	7617.30	7614.96	
5	7621.16	7608.16	7608.20	7609.68	7608.49	7612.10	7618.72	7616.91	7613.35	
6	7620.89	7608.22	7608.37	7609.72	7608.51	7612.05	7618.72	7616.89	7613.32	
7	7623.99	7611.90	7611.19	7613.49	7616.53	7617.07	7618.90	7616.99	7614.47	
8	7622.37	Dry	Dry	-	-	7615.79	7618.70	7616.37	7612.86	
9	8263.31	8259.85	8259.06	8261.28	8262.06	8261.64	8261.55	8261.34	8261.04	
10	Unknown	* 6.99	7.22	6.10	3.71	4.23	5.41	6.07	-	Well was buried in a parking lot in July 1980
11	7838.28	7831.03	7831.10	-	7834.54	7834.30	7833.60	7831.53	7830.68	
12	7703.82	7701.16	7700.70	7701.08	7702.37	7701.87	7701.61	7701.82	7701.35	
13	7705.81	7702.31	7702.02	7702.31	-	7704.31	7701.18	7699.93	7699.51	
13-East piez.	7705.58	7702.70	7702.01	7702.60	-	7704.12	7700.84	7699.49	-	
13-South piez.	7706.37	7703.22	7703.04	7703.75	7705.25	7705.72	7701.94	7700.73	-	
14	7685.55	7682.30	7681.75	7681.97	7685.35	7683.60	7682.55	7681.97	7681.83	
15	7666.82	7662.82	7662.80	7662.84	-	7664.26	7663.70	7661.32	7661.52	
16	7665.90	7664.05	7661.88	7660.69	7664.07	7663.73	7661.57	7659.90	7659.12	
17	7665.56	-	7657.65	7656.15	7657.94	7660.69	7658.31	7656.23	Dry	
17-North piez.	7664.09	-	7656.59	Dry	7656.84	7659.21	7657.13	7655.59	Dry	
17-West piez.	7665.71	-	7657.78	7657.28	7658.06	7660.79	7658.40	7657.38	Dry	
18	7664.85	7659.88	7657.48	-	7659.02	7659.35	7658.31	7656.44	Dry	
19	7667.53	7659.53	7657.51	-	7657.85	7660.37	7658.53	7656.95	Dry	(7661.20 in Sept)
20	7672.98	7664.48 (Sept)	Dry	-	Dry	7669.15	7672.81	7672.10	7668.61	
21	7654.31	7650.94	7650.66	-	7649.29	7648.85	7653.20	7651.54	7651.14	
22	7781.61	7764.33 (Sept)	7799.79 (Dec)	-	7763.57	Flowing	Flowing	7781.02	7768.98	
23	7618.38	-	-	-	7612.40	-	Flooded	7616.38	7613.38	

*For well #10, the depth to the water table is given

Table I-b. Water levels in observation wells.

Well Number	Ground Surface (ft)	Water Table (meters above sea level) October	November	February	April	May	June	July	August	Remarks
1	2322.32	2322.78	2322.79 (Dec)	-	2322.81	2323.21				Flowing well
2	2322.67	2319.41	2319.26	2319.54	2319.68	2321.33	2322.19	2321.61	2320.74	
3	2322.84	2319.55	2319.37	2319.57	2319.90	2321.37	2322.19	2321.72	2320.85	
4	2323.73	2319.69	2319.58	-	2320.03	2321.36	2322.12	2321.75	2321.04	
5	2322.93	2318.97	2318.98	2319.43	2319.07	2320.17	2322.19	2321.63	2320.55	
6	2322.85	2318.99	2319.03	2319.44	2319.07	2320.15	2322.19	2321.63	2320.54	
7	2323.79	2320.11	2319.89	2320.59	2321.52	2321.68	2322.24	2321.66	2320.89	
8	2323.30	Dry	Dry	-	-	2321.29	2322.18	2321.47	2320.40	
9	2518.66	2317.60	2517.36	2518.04	2518.28	2518.15	2518.12	2518.06	2517.97	Well was buried in a parking lot in July 1980
10	Unknown	* 2.13	2.20	1.86	1.13	1.29	1.65	1.85	-	
11	2389.11	2386.90	2386.92	-	2387.97	2387.90	2387.68	2387.05	2386.79	
12	2348.13	2347.31	2347.17	2347.29	2347.68	2347.53	2347.45	2347.52	2347.37	
13	2348.73	2347.67	2347.58	2347.67	-	2348.27	2347.32	2346.94	2346.81	
13-East piez.	2348.66	2347.78	2347.57	2347.75	-	2348.22	2347.22	2346.81	-	
13-South piez.	2348.90	2347.94	2347.89	2348.10	2348.56	2348.71	2347.55	2347.18	-	
14	2342.56	2341.57	2341.40	2341.47	2342.50	2341.96	2341.64	2341.47	2341.42	
15	2336.85	2335.63	2335.62	2335.64	-	2336.07	2335.90	2335.17	2335.23	
16	2336.57	2336.00	2335.34	2334.98	2336.01	2335.91	2335.25	2334.74	2334.50	
17	2336.46	-	2334.05	2333.59	2334.14	2334.98	2334.25	2333.62	Dry	
17-North piez.	2336.01	-	2333.73	Dry	2333.80	2334.53	2333.89	2333.42	Dry	
17-West piez.	2336.51	-	2334.09	2333.94	2334.18	2335.01	2334.28	2333.97	Dry	
18	2336.25	2334.73	2334.00	-	2334.47	2334.57	2334.25	2333.68	Dry	
19	2337.06	2334.63	2334.01	-	2334.11	2334.88	2334.32	2333.84	Dry	(2335.13 in Sept)
20	2338.73	2336.14 (Sept)	Dry	-	Dry	2337.56	2338.67	2338.46	2337.40	
21	2333.03	2332.01	2331.92	-	2331.50	2331.37	2332.69	2332.19	2332.07	
22	2371.84	2366.57 (Sept)	2377.38 (Dec)	-	2366.34	Flowing	Flowing	2371.66	2367.99	
23	2322.08	-	-	-	2320.26	-	Flooded	2321.47	2320.56	

*For well #10, the depth to the water table is given

Figure I-1. Water levels in wells 2-8, July 1980, and inferred groundwater contours.

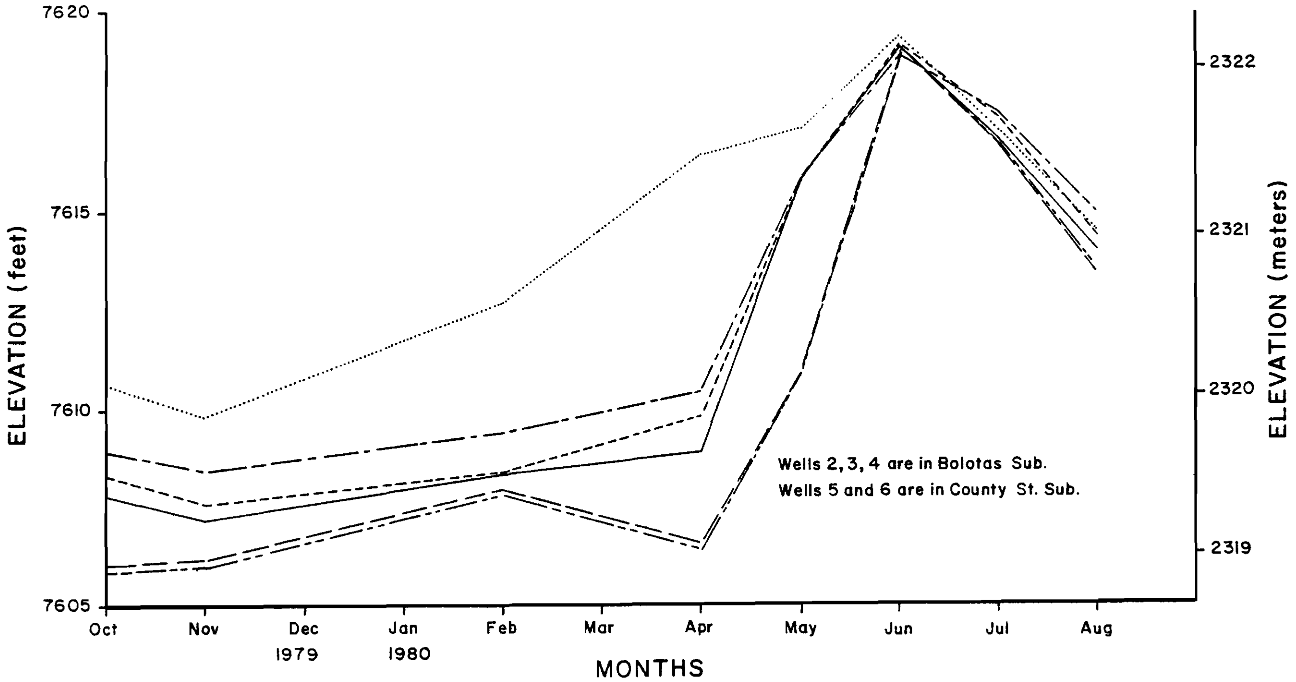


Figure I-2. Water level in wells 2, 3, 4, 5, and 6.

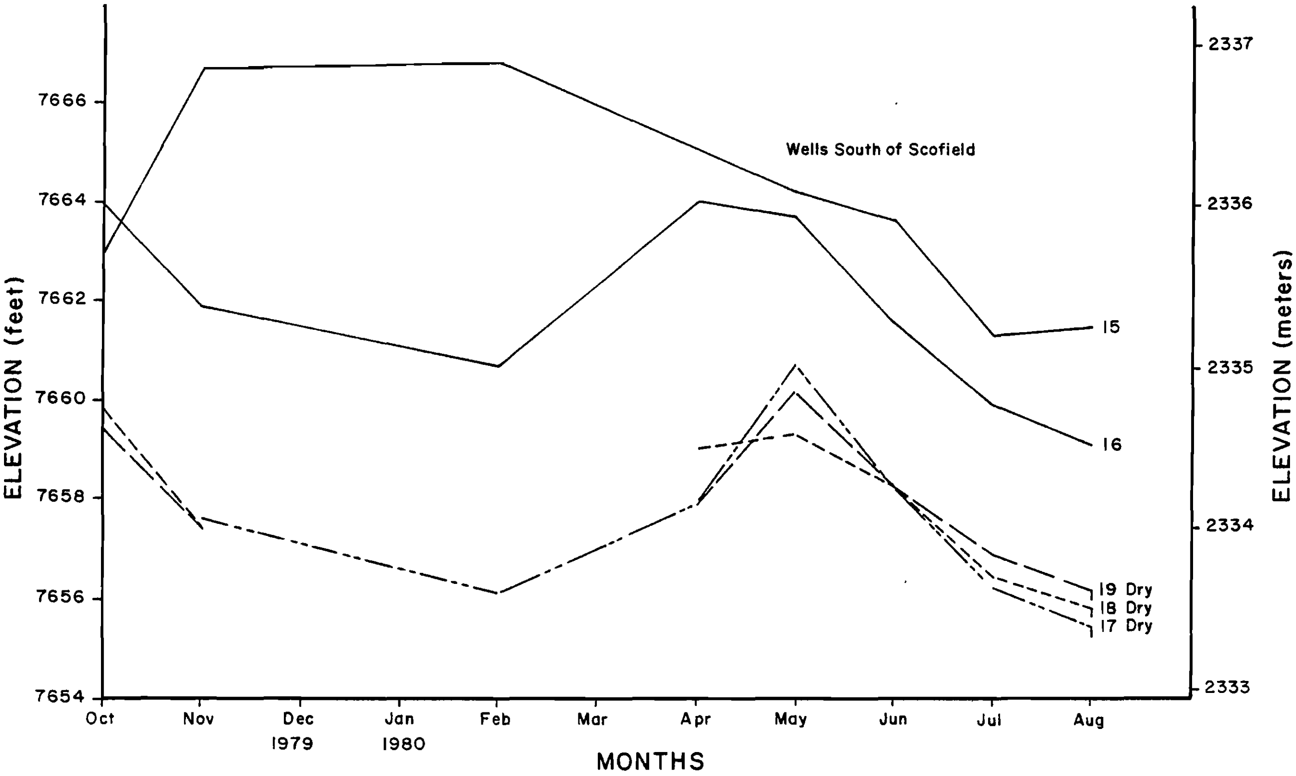


Figure I-3. Water levels in wells 15, 16, 17, 18, and 19.

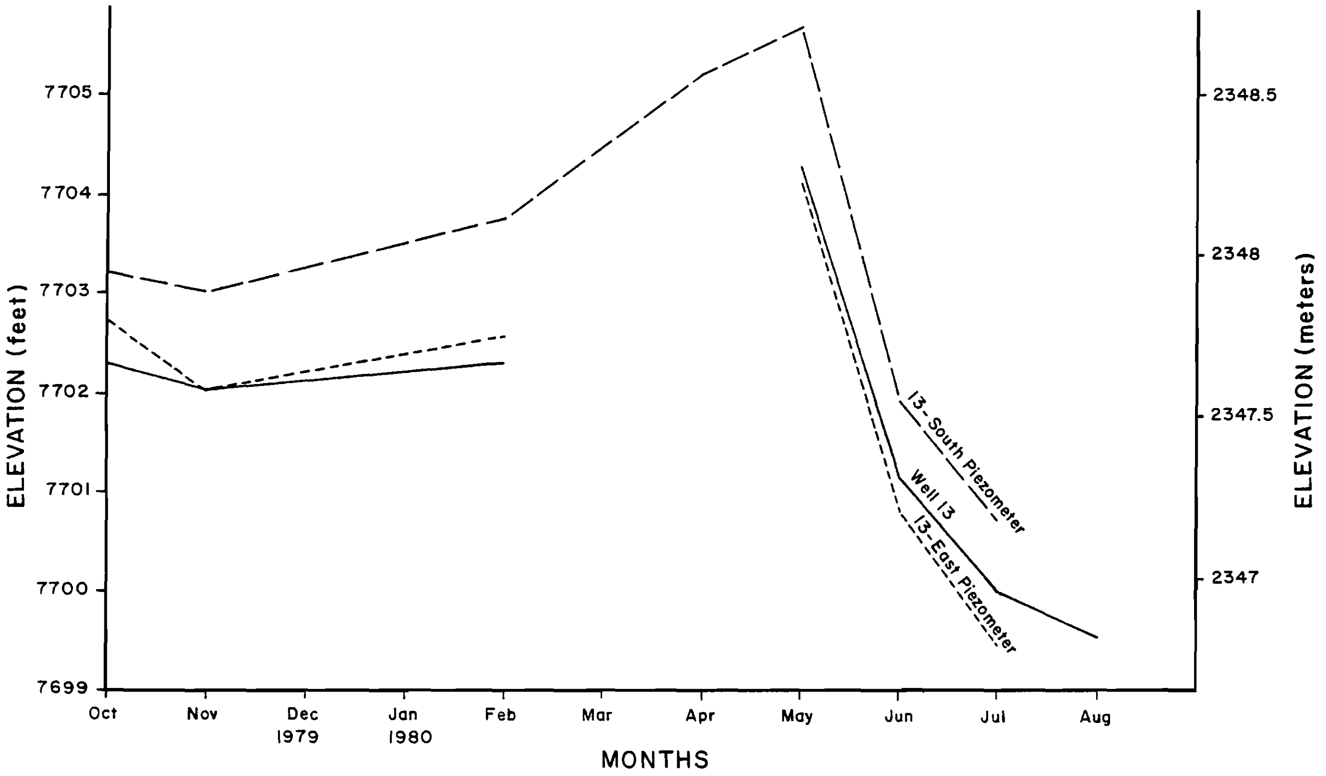


Figure I-4. Water level in well 13 and nearby piezometers.

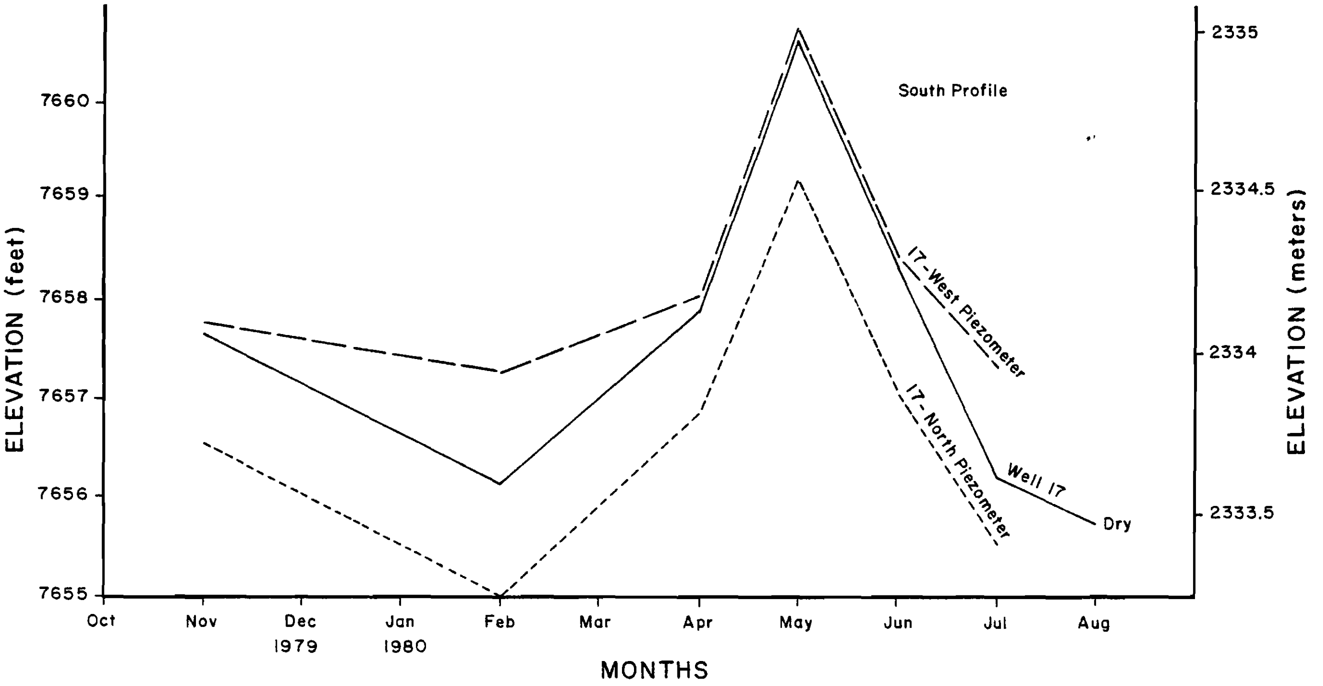


Figure I-5. Water level in well 17 and nearby piezometers.

APPENDIX J

ESTIMATE OF GROUNDWATER UNDERFLOW PAST SCOFIELD

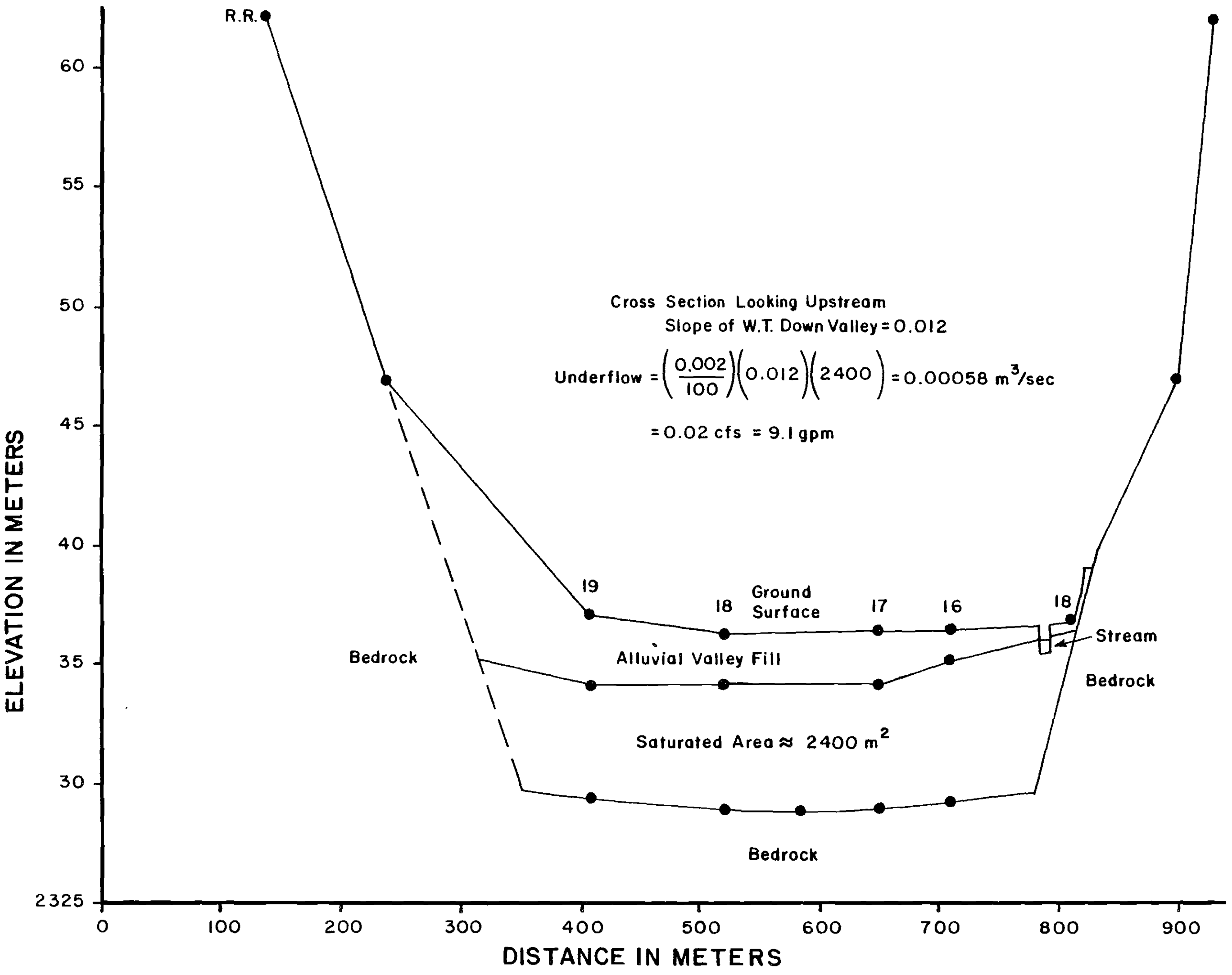


Figure J-1. Estimation of groundwater underflow past Scofield.

APPENDIX K

WASTE DISPOSAL QUESTIONNAIRE

UTAH STATE UNIVERSITY · LOGAN, UTAH 84322
UTAH WATER RESEARCH LABORATORY
UMC 82

COLLEGE OF ENGINEERING

The Utah Water Research Laboratory is conducting a study of the shallow groundwater near Scofield, Utah for the Southeastern Utah Association of Governments. The enclosed questionnaire concerning your septic system is part of the study designed to evaluate the quality of shallow groundwater in Pleasant Valley. The questionnaire is being sent to all persons in the area who use such a system in order to determine the amounts of waste which are being added to shallow groundwater in the vicinity.

The natural system (soil, air, water, and micro-organisms in the soil) is capable of decomposing wastes into basic harmless elements. It is important to avoid overloading the natural system. Otherwise, the result may be poorer drinking water, unpleasant odors and accelerated growth of plants in the reservoir.

Your cooperation in providing information about your property will help keep your environment clean and safe. Please respond to the questions the best you can and feel free to add any comments and suggestions which could assist the study.

Questionnaire on Septic Tank and Pit Privy Systems

Name the kind of structures on your property.

____

If none, is your property used for camping and picnics? Yes ___ No ___

Is a mobile home parked there? Yes ____ No ____

If wastewater is flushed into (CIRCLE)	then please complete parts
Septic Tank	I, II, III, VI, VII
Pit Privy	II, IV, VI, VII
Holding Tanks	II, V, VI, VII
Stream	II, VI, VII

If you raise livestock in the Scofield Reservoir Basin, please complete the Livestock page.

The results will be reported in general terms without referring to individuals or specific properties.

Thank you for your help on this project which is of great importance to you as a land owner.

Sincerely,

Calvin G. Clyde

Calvin G. Clyde
Professor of Civil Engineering
Project Leader

PART 1. Description of Septic Tank System
CIRCLE:

A. Box Tank Length ______ Width ______ Height ______
Cylinder Length ______ Diameter ______

Material used in construction: Circle: Steel Concrete Masonry

B. Drain Field

Drain field pipe size ______ diameter Steel Clay PVC
Size of inlet pipe to tank ______ diameter Steel Clay PVC

Please make (on the reverse side) a sketch of the lay-out of your system, including at least the house, septic tank, and drainfield. Also include if possible the property lines, neighboring houses, wells in the vicinity, roads, streams, etc.

C. Soil type surrounding the tank and drainfield

Circle the types of bedding materials surrounding your tank

silt clay sand gravel rock

It consists mostly of ____________.

If there is gravel or rock in the bedding material, circle the sizes of materials (diameter)

a. less than ¼"
b. ¼" - ½"
c. ½" - 1"
d. 1" - 3"
e. 3" - 6"
f. 6" - 12"

The most common size range is a b c d e f.

The thickness of the layer of bedding material between the bottom of the drain field pipe(s) and the existing soil is

0" 3" 6" 9" 12" 15" 18" 21" 24" more _____"

The thickness of the bedding material on the sides of the drain field pipe(s) is

0" 3" 6" 9" 12" 15" 18" 21" 24" more _____"

The soil beneath the bedding material is composed of (Circle)

silt clay sand gravel rock

It consists mostly of __________.

Size of Rocks or Gravel (CIRCLE)

a. less than ¼"
b. ¼" - ½"
c. ½" - 1"
d. 1" - 3"
e. 3" - 6"
f. 6" - 12"

The most common size range is a b c d e f

Sketch of Septic Tank System

PART II. Load on the System.

Is there a garbage disposal in your kitchen sink? ___ Is it used? ____

Besides normal toilet, sink and shower wastes, what else is flushed down the system?
(CIRCLE):

Cooking oil   Auto oil   acids   chemicals   disposable diapers

What brands of soaps, detergents and drain flushes are used?

How much water is used during

Spring __________ gal.   Fall __________ gal.
Summer __________ gal.   Winter __________ gal.

For stablization of wastes, are any chemicals, such as lime, added to your waste system?

Name them: ____

Are clothes laundered at home? (CIRCLE):   Yes

No

PART III. History of Construction, Use and Performance of the Septic Tank System.

A. Who installed the septic tank and pipes? ______________________

His address is ____

B. When was it installed? ______________________________________

		Day	Month	Year
C. Given the dates when the tank was emptied		______	______	______
	serviced	______	______	______
D. Give the dates when the tank has been full		______	______	______
	plugged	______	______	______
Give the dates when the drain field pipes have been plugged?		______	______	______
When were they serviced?		______	______	______

E. How often does the system back into the residence? ______________

F. How often does the sewage visibly seep out of the ground? ________

G. Have you noticed any other problems?

H. Are there any places in your vicinity or in the community where sewage seeps out of the ground?

				When
I. Do you plan to install another tank?	(CIRCLE)	Yes	No	__________
Do you plan to extend leach lines?		Yes	No	__________
Rebuild?		Yes	No	__________

PART IV. Pit Privy Description and Use

A. Size of Pit Depth ______ Width ______ Length ______

B. Make a sketch of the location of the pit and nearby buildings, streams, gullies, wells, roads, etc.

C. The soil dug from the pit is composed of (CIRCLE):

silt clay sand gravel rock

It consists mostly of __________.

D. How often is a new pit dug? ____________________

When will the next new pit be dug? ____________________

Has the pit ever filled up with liquid and overflowed? ____________

When? ____________________

PART V. Holding Tanks

Are wastes discharged into a holding tank? ____________________

Is the tank (a) Part of a mobile home? ____________________

(b) Buried in the yard? ____________________

How is the tank emptied? ____________________

How often is the tank emptied? ____________________

Where is the waste material disposed of? ____________________

____

PART VI. Amount of Use of the Waste System

A. The number of people using your system regularly

		Dates	
Spring	______	From ______	To ______
Summer	______	______	______
Fall	______	______	______
Winter	______	______	______
All Year	______		

B. The maximum number of people using your system during a one-week period ________. DATES: ____________________

C. My system is used (Check)

	Spring	Summer	Fall	Winter
Daily	______	______	____	______
Weekends	______	______	____	______
Unused	______	______	____	______

If used occassionally, estimate the total number of days of use in each season

______ ______ ____ ______

D. Are other residences tied to your system? ______

How many? ______

E. What animals do you take care of?

Dogs Cats other ____________________

How many?

APPENDIX N

GEOLOGY AND STRATIGRAPHY OF THE WASATCH PLATEAU COAL FIELD

Geology

The Wasatch Plateau comprises Tertiary and Cretaceous strata, predominantly limestone, sandstone, and shale that differ in resistance to erosion; the limestones and sandstones form cliffs, and the shales form slopes. The consolidated rocks of the [Wasatch Plateau] coal field [see Figures N-1 to N-4] ... range in age from Late Cretaceous to Paleocene. [See Table N-1.] (Davis and Doelling 1977, p. 3.)

Stratigraphy

Masuk Shale

The Masuk Shale is the uppermost member of the Mancos Shale. It consists of light gray to blue gray sandy marine shale of Santonian age. The Masuk ranges in thickness from 91 m to 396 m (300 to 1,300 feet) and forms the slope at the base of the Wasatch Plateau beneath the Star Point Sandstone. (Davis and Doelling 1977, p. 3.)

Star Point Sandstone

The oldest formation, Campanian in age (Upper Cretaceous), exposed in and around Pleasant Valley is the Star Point Sandstone. The Star Point is considerably thicker here than in other parts of the [Wasatch Plateau coal] field; on the west side of Pleasant Valley between Clear Creek and Scofield at least 304 m (1,000 ft) of sandstone have been measured beneath the horizon of the Hiawatha coal bed.... The thickness tapers to 61 m (200 ft) in the eastern part of the coal field. (Doelling 1972, p. 217.)

As the lowermost of three formations composing the Mesaverde Group of the Wasatch Plateau, the Star Point consists of several tan, massive, cliff-forming sandstones separated by one or several shale tongues of the underlying Masuk Shale. (Davis and Doelling 1977, p. 3.)

The Mancos Shale is not exposed at the surface beneath the sandstone. The yellow-gray sandstone beds are mostly massive but occasionally broken by shale partings or partings of shaley sandstone. The amount of shale in the unit is also considerably less than to the east. (Doelling 1972, p. 217.)

Blackhawk Formation

The Blackhawk Formation, the middle member of the Mesaverde Group, contains the minable coal beds of the Wasatch Plateau. All the thick and important coal beds are in the lower half of the formation. The Blackhawk is Campanian in age, and the type section is near the Blacknawk mine at Hiawatha (sec. 3, T. 16 S., R. 8 E.).

The unit consists of light to medium gray sandstone, light gray to black shale, light to medium gray siltstone, and coal. The sandstones are mostly fine grained and weather to shades of tan, yellow brown, yellow gray, and occasionally white. They form ledges and cliffs. The shales and siltstones underlie covered slopes. Many of the siltstones and darker shales are carbonaceous, containing leaf imprints of sequoias, ferns, and willows.

Price River Formation

Castlegate Sandstone Member. The Price River Formation is the uppermost member of the Mesaverde Group, and the Castlegate Sandstone is the lowermost unit of the Price River. The Castlegate is Campanian in age, and the type section is in Price River Canyon about 3.2 km (2 mi) above the old town of Castlegate.

Along the eastern front of the plateau and within the canyons, the unit forms the uppermost cliff of the escarpment. Ranging in thickness from 45 to 152 m (150 to 500 ft), it consists of fluvial sandstones, conglomerates, and a few thin beds of gray sandy shale. The sandstones, chiefly medium to coarse grained and massive, weather to shades of light gray, tan, white, and yellow brown. The cliff, however, generally has a light gray hue. The conglomerates, light gray in most places, contain pebbles of white quartzite and gray limestone in a coarse sandy matrix.

Upper Price River Member. The upper Price River Member forms a steep receding slope above the Castlegate Sandstone cliff. The strata are predominantly fluvial sandstones, but there are a few thin interbedded pebble conglomerates and gray shales. The sandstones are gray, grayish tan, tan, and brown; most are medium to coarse grained, but some are fine grained.

North Horn Formation

The North Horn generally forms slopes and, in places, produces a hummocky terrain. Mostly it consists of shales, but it has

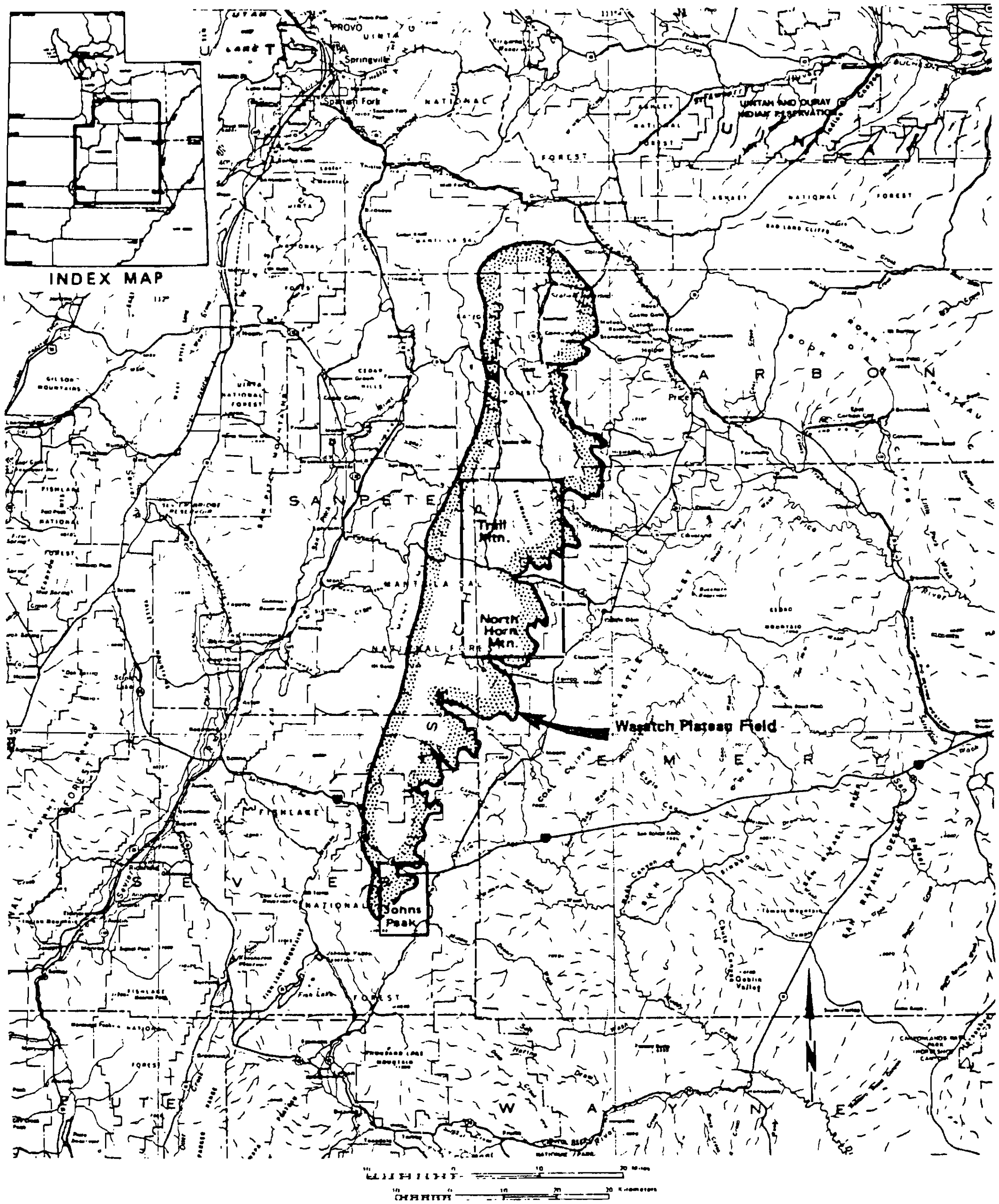


Figure N-1. Location map of Wasatch Plateau and adjacent areas in central Utah (Davis and Doelling 1977, p. 2).

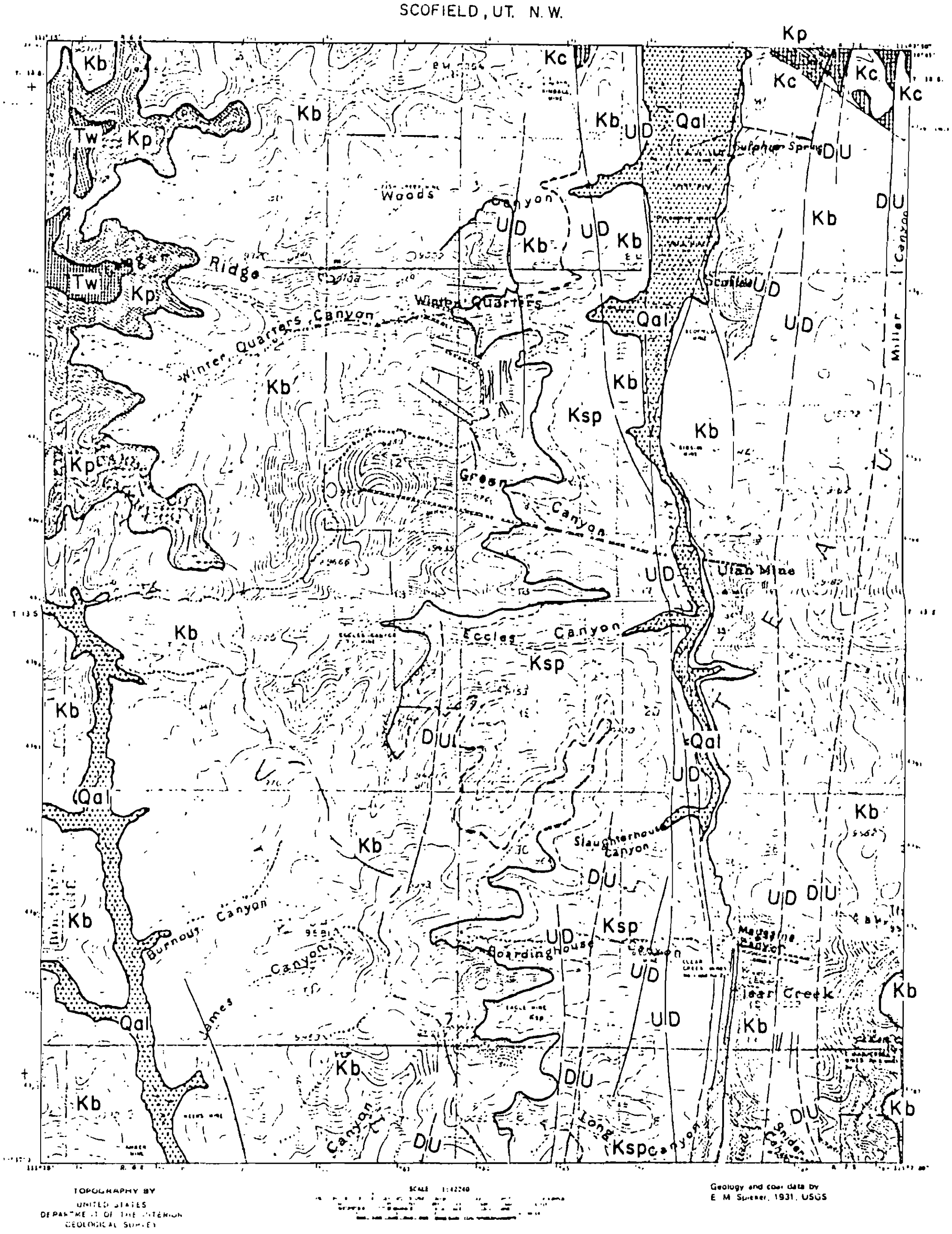


Figure N-2. Coal fields and geology, Scofield NW quadrangle. (Explanation on Figures N-3 and N-4)

QUATERNARY

Qal Alluvium
Stratified clay, silt, sand, gravel and some unsorted flood deposits.

Ql Landslide Deposits
Mixed rubble and blocks of material slumped from formations at higher elevations.

Qg Gravel Deposits
Partly consolidated poorly sorted and stratified deposits of rock fragments of local origin, pediments or terrace, up to 75 feet thick.

TERTIARY

Tv Volcanic Flows
Bullion Canyon Series, volcanic flows.

Tg Green River Formation
Chiefly greenish lacustrine shale and siltstone.

Tc Colton Formation
Varicolored shale with sandstone and limestone lenses, thickest to the north. 300-1,500 feet.

Tf Flagstaff Formation
Dark yellow-gray to cream limestone, evenly bedded with minor amounts of sandstone, shale and volcanic ash, ledge former. 200-1,500 feet.

TERTIARY
CRETACEOUS

Tw North Horn Formation
Variegated shales with subordinate sandstone, conglomerate and freshwater limestone, thickens to north, slope former. 500-2,500 feet.

Kp Price River Formation
Gray to white gritty sandstone interbedded with subordinate shale and conglomerate, ledge and slope former. 200-1,000 feet.

Kc Castlegate Sandstone
White to gray, coarse-grained often conglomeratic sandstone, cliff former, weathers to shades of brown. 150-500 feet.

·Unconformity·

Kb Blackhawk Formation
Yellow to gray, fine- to medium-grained sandstone, interbedded with subordinate gray and carbonaceous shale, several thick coal *seams. 600-1,500 feet.*

Ksp Star Point Sandstone
Yellow-gray massive cliff-forming sandstone, often in several tongues separated by Masuk Shale, thickens westward. 90-1,000 feet.

Km Masuk Shale
Yellow to blue-gray sandy shale, slope former, thick in north and central plateau area thins southward. 300-1,300 feet.

Ke Emery Sandstone
Yellow-gray friable sandstone tongue or tongues, cliff former, may contain coal *(?) in south part of plateau if mapping is correct, thickens to west and south.* Coal *may be present in subsurface to west. 50-800 feet.*

Kbg Blue Gate Shale
Pale blue-gray, nodular and irregularly bedded marine mudstone and siltstone with several arenaceous beds, weathers into low rolling hills and badlands, thickens northerly. 1,500-2,800 feet.

Kf Ferron Sandstone
Alternating yellow-gray sandstone, sandy shale and gray shale with important coal *beds of Emery coal field, resistant cliff former, thickens to the south. 50-950 feet.*

Kt Tununk Shale
Blue-gray to black sandy marine slope forming mudstone. 400-650 feet.

Figure N-3. Key to Figure N-2 (Doelling 1972, p. 137).

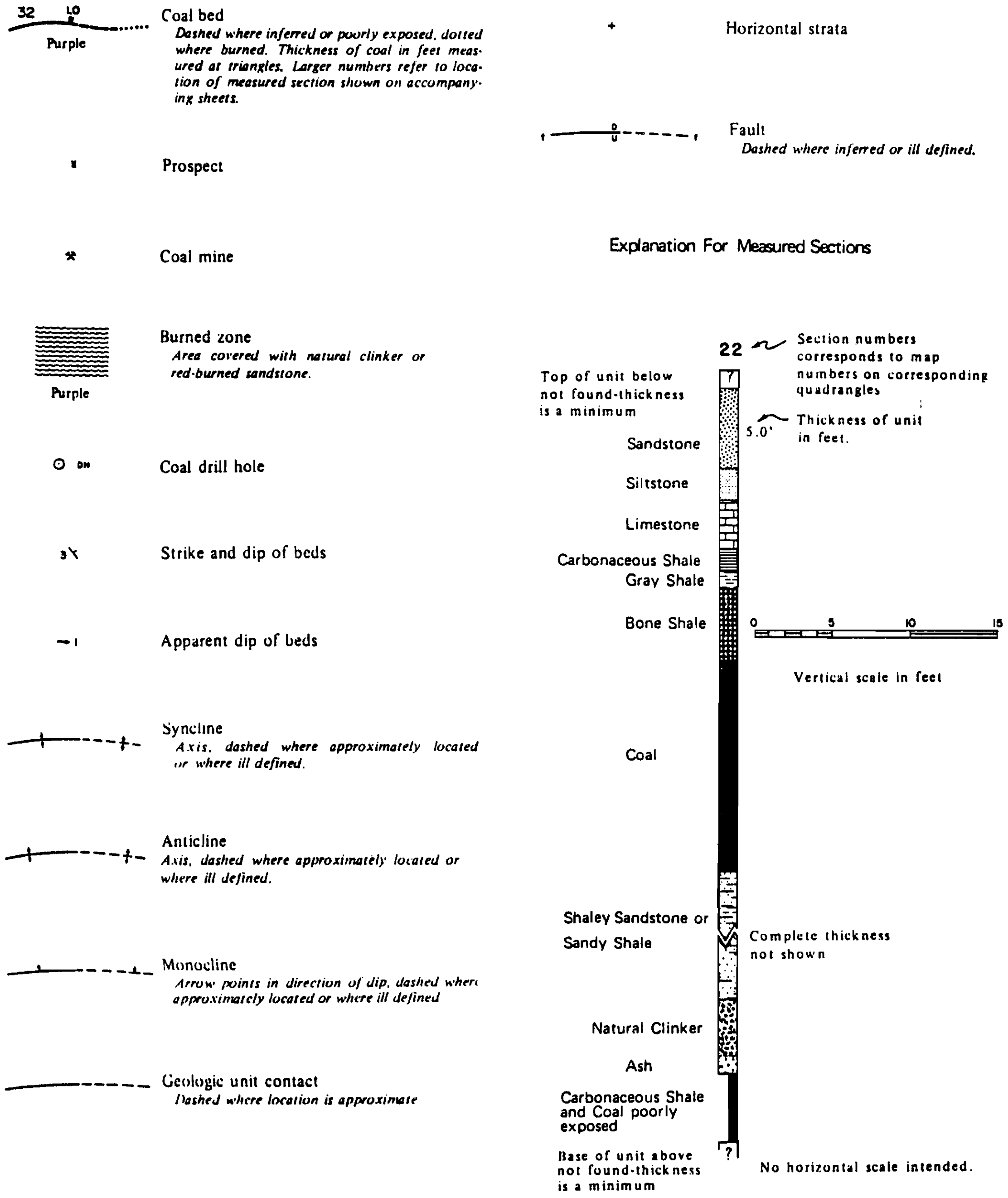


Figure N-4. Key to Figure N-2 (Doelling 1972, p. 137).

Table N-1. Generalized section of rocks in the Wasatch Plateau coal field.

System	Group	Formation		Description
Tertiary	Wasatch	Flagstaff Limestone		Light gray to cream limestone; thin and even bedded; dense; fossiliferous; ledge- and cliff-forming.
		North Horn Formation		Mostly red-, brown-, and salmon-colored shales; varying thicknesses of sandstone, fresh-water limestone and conglomerate; slope-forming.
Cretaceous	Mesaverde	Price River Fm.	Upper Price River Member	Mostly tan and gray, medium- to coarse-grained sandstone; some gray shale and conglomeratic sandstone; ledge- and slope-forming.
			Castlegate Sandstone Member	Light gray, yellowish brown, and white, medium- to coarse-grained sandstone and conglomeratic sandstone; cliff-forming.
		Disconformity		
		Blackhawk Formation		Light to medium gray sandstones; gray to black shales; gray siltstones; important coal beds in lower half; sandstones weather tan, brown, yellowish brown; ledge- and slope-forming.
		Star Point Sandstone		Tan, light gray, and white massive sandstones separated by one or more shale tongues; cliff-forming.
	Mancos Shale	Masuk Shale		Light gray to blue gray sandy marine shale; thins to west and south; slope forming.

subordinate amounts of sandstone and thin beds of white and light gray freshwater limestone. Distant views of the formation show it distinctly pink or salmon colored. Late Cretaceous fossils have been found in the lower part of the unit, and Tertiary fossils have been identified from the upper part.

Flagstaff Limestone

The Flagstaff was the original middle member of the Wasatch Formation, but it now has formational status. The unit forms a white cliff around the highest summits and ridges of the plateau and consists of white and light gray, thin-bedded lacustrine limestone with some thin beds of gray shale and dense white volcanic ash. The Flagstaff is Paleocene in age.

Quarternary Deposits

Unconsolidated consist of alluvium (stream channel and valley fill deposits), regolith, glacial drift, moraines, and colluvium (including talus) on slopes and at the base of slopes and cliffs. These deposits consist of mixed proportions of clay, silt, sand, and gravel with boulders.

Structure

Tectonically, the Wasatch Plateau is in a transition zone between the relatively stable Colorado Plateau on the east side and the relatively complex and unstable Basin and Range province on the west side. On the west side the strata of the plateau dip into a complexly faulted monocline, whereas on the east side, gentle dips prevail and faults are less numerous [Figure N-5].

The Pleasant Valley fault zone is a north-trending graben with an average width of about 6.4 km (4 mi). The bounding faults have the greatests displacements, up to 457 m (1,500 ft), but many splinter faults within the zone have much less. This fault zone extends from the north end of Pleasant Valley southward across Huntington Creek and dies out in the cliffs just north of Cottonwood Creek between Grimes Wash and Danish Bench. (Davis and Doelling 1977, p. 4-9.)

The importance of faults has been well illustrated by Taff (1906, p. 343):

> The principal fault of the Pleasant Valley group is the westernmost one. It follows the west side of the valley in an almost due south course, crossing the foothills and spurs near the stream and passing through the west sides of Scofield and Clear Creek. North of Scofield it lies in a swampy valley and is not traceable. Whether there is a series of fractures or a single fault is not determinable .... Near the head of the valley opposite Clear Creek the throw is nearly 304 m (1,000 ft)...

Two elongate faults parallel the ridge on the east side of Pleasant Valley. Their displacement is unknown; several paralleling subsidiary faults possibly occur between them.

The strata enclose a north-south trending anticline with an ill-defined axis and an east side faulted by the Pleasant Valley zone. East of Pleasant Valley the beds are nearly horizontal dipping less than 2 degrees. To the west the beds dip 3 to 4 degrees northwesterly down the gentle limb of the anticline.

Unconformities

The upper Cretaceous formations in the Wasatch Plateau reveal a remarkable succession of mixed and intertonguing marine and continental sediments. Up to the end of the deposition of the Blackhawk strata, these sediments are mainly fine grained, thus indicating relatively long intervals of quiet and uniform conditions. The erosion and flood of the coarse clastics of the Castlegate Sandjstone produced an erosional disconformity at the top of the Blackhawk Formation. These coarse continental sediments indicate crustal disturbance to the west and probably the first phase of the Laramide orogeny. The model of deposition of the Price River Formation produced many intraformational disconformities and local unconformities. (Davis and Doelling 1977, p. 9-10.)

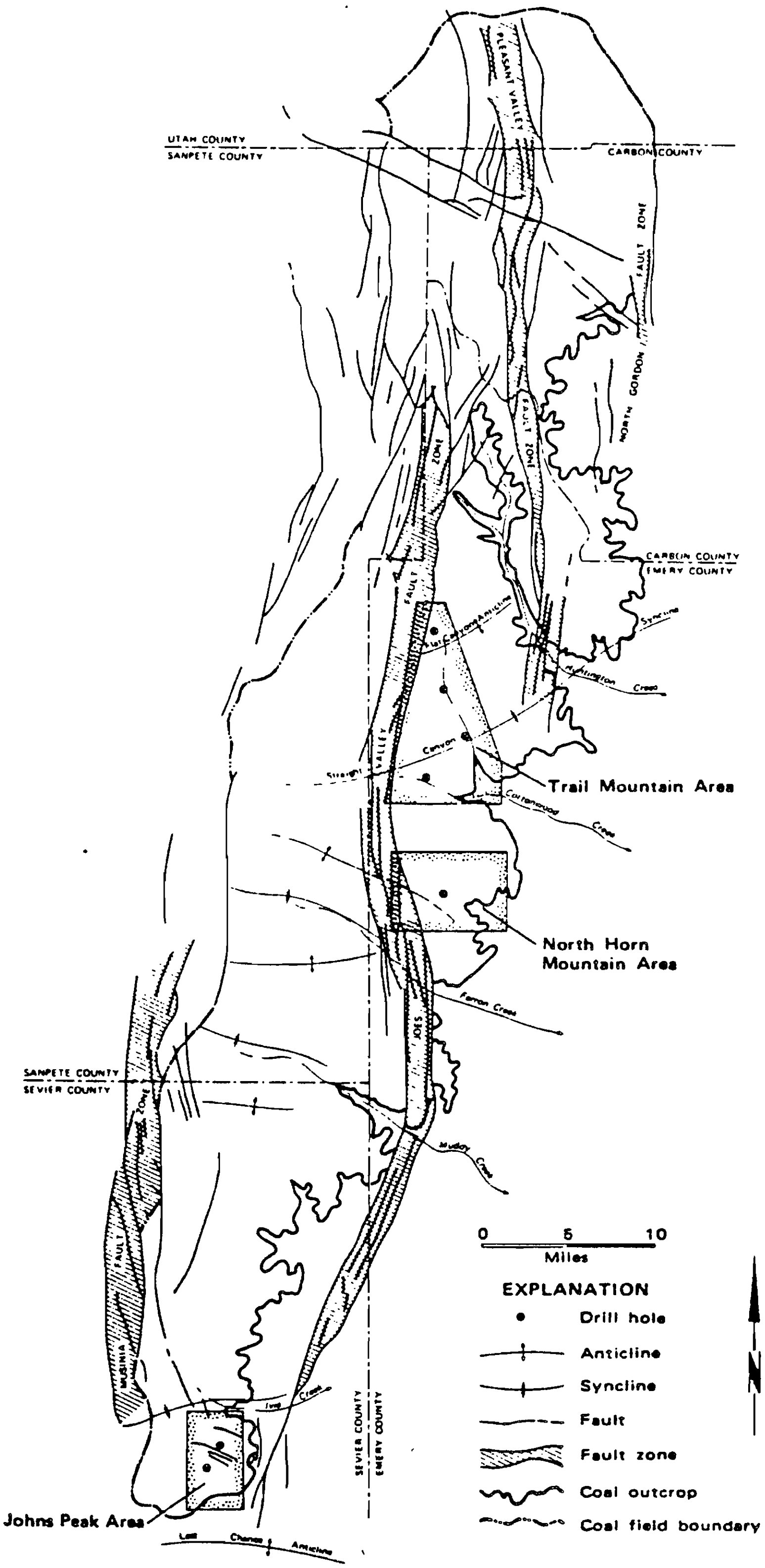


Figure N-5. Principal structural features of the Wasatch Plateau coal field (Davis and Doelling 1977, p. 8).