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Ground water nitrate
contamination in
Deer Park,
Washington

GROUND WATER NITRATE
CONTAMINATION
IN
DEER PARK, WASHINGTON

FINAL REPORT

GROUND WATER NITRATE CONTAMINATION IN DEER PARK, WASHINGTON
(Final Report)

Prepared For

Washington State Department of Ecology

Prepared By

ENVIRONMENTAL HEALTH DIVISION

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Funding Made Available Through
A Grant Under Section 205(j)
of the Federal Clean Water Act.

ACKNOWLEDGMENTS

It should be recognized that these persons and organizations provided constructive information in the completion of this study and were very helpful to staff during the year:

Steve Templeton - Deer Park Public Works

Chuck Arnold - Northwest Egg Sales

Bill & Nancy Hopkins

John Wagner

and

The Residents of Deer Park Area

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INTRODUCTION

Authority

Under the provisions of Section 205(j) of the Federal Clean Water Act, Spokane County Health District (SCHD), by petition to Washington State Department of Ecology (WDOE), established the 205(j) Grant Agreement approved January 2, 1986, through the Assistant Attorney General under grant provision number G0086058. The purpose of this Grant Agreement is to provide funding for a comprehensive ground water study to assess nitrate occurrence in area ground water in the City of Deer Park, Washington and adjacent areas. (Refer to Appendix A for Grant Proposal Agreement)

Problem Statement

In an approximate 10 sq. Km area 32 Km north of Spokane, Washington, within Spokane County, nitrate contamination has been identified in what initially appeared to be a primary use, unconfined aquifer serving both the potable water needs for a rural population of about 500 persons using private wells and 2500 persons of Deer Park who obtain water from five public wells. (See Figure #1 and #1A for map of area.)

In early 1985, a resident in a semirural area 2 Km east of Deer Park contacted Spokane County Health District to discuss the results of a water sample analysis taken from his private well. A physician had earlier suggested that a water sample be taken due to chronic health problems for which the family doctor could find no apparent cause.

Among the inorganic chemicals checked in the water, nitrate stood out significantly by exceeding the Environmental Protection Agency Health Advisory Standard of 10 milligrams per liter.

Following additional samples taken from the same well to confirm what appeared to be an excessive amount of nitrate in the ground water, it was determined that a random sampling of other private wells within a 2 Km radius of the property needed to be undertaken. The results from nine wells revealed two wells less than 10 mg/l, one well at 10.7 mg/l, and the remaining six wells ranging from 23 to 82 mg/l.

For the last several years, the nitrate as nitrogen (NO_3 as N) concentrations in four of the Deer Park city wells has been increasing with one well intermittently exceeding the 10 mg/l drinking water standard.

The land uses in the area of highest nitrate concentrations are characterized by 5-to 10-acre residential tracts interspersed among small farms where animal keeping and growing of hay and grain crops are the typical activities. Within 2 Km of the highest nitrate-displaying private well (115 mg/l), is a commercial egg production facility consisting of 200,000 chickens.

Interviews with property owners and long-time residents of the Deer Park area, combined with a review of SCHD files and records, suggested a number of potential nitrate contamination sources, including manure utilization and disposal practices of the small farms and egg production facility, residential and commercial sewage systems, fertilizer usage and tillage decay.

In order to effectively investigate a cause-and-effect relationship between the sources of contamination and the primary-use aquifer, the SCHD successfully petitioned the Washington State Department of Ecology for a water quality management grant.

Current Status

To date, the owners and consumers of 21 private water wells have been advised to discontinue use of the water for drinking and cooking purposes. Nitrate levels in excess of 150 mg/l NO_3-N have been identified at three private wells. Levels in excess of the standard (10 mg/l NO_3-N) have been identified at 23 ground water sources. All but two are private wells primarily located in an area 4 Km east of the City of Deer Park, Washington. (See Figure #2)

The results of water sampling has demonstrated a combined annual average nitrate level for 1986 at 8.0 mg/l NO_3-N, which does not exceed the 10 mg/l NO_3-N; however, the EPA Health Advisory Standard still warrants Health District concern because of successive increases in past years.

Goal

It was the intention of the Spokane County Health District to:

- Determine the extent of ground water nitrate contamination.
- Identify the possible sources and contributing factors.
- Provide recommendations to assist the Washington State Department of Ecology (WDOE) in fulfilling their obligations under RCW 90.48.260.

Objectives

- Conduct hydrogeologic assessments of study area.
- Monitor nitrate levels in public supply and private water wells for one year.
- Inventory land use and surface activities historical and present.
- Analyze data and generate causal hypotheses to explain nitrate contamination.

- Test hypotheses to confirm cause-and-effect relationships.
- Formulate recommendations for corrective actions based on findings.

Nitrates

What is it?

How can it affect me?

Who determines a safe level?

Properties

Nitrate as the nitrate ion (NO_3^-) is the physiochemically stable form of combined nitrogen in oxygenated aqueous systems. Nitrate salts are soluble in water, and in dilute aqueous solutions, are chemically nonreactive. However, nitrite as the nitrite ion (NO_2^-) is an intermediate and relatively unstable oxidation state of combined nitrogen. Nitrite is an oxidizing agent and its occurrence is reported to exist as 10% of nitrate as nitrogen (NO_3 as N).

Occurrence (References extracted from Randall Anderson thesis, 1986. See Appendix B)

Nitrate and nitrite are naturally occurring inorganic ions which make up part of the nitrogen cycle. Nitrogen is a gaseous element making up 79% of the earth's atmosphere. It is relatively inert to chemical reaction and has not ordinarily occurred in abundance in minerals or water.

Growth of all organisms require nitrogen. Photosynthetic organisms require nitrogen either as ammonium (NH_4^+) or nitrate (NO_3^-). However, certain soil bacterias and nitrogen-fixing legumes can utilize nitrogen directly from the atmosphere.

Sources of nitrogen compounds found in the soil consist of decomposing plant and animal tissue, animal and human urine and feces, nitrate fertilizers, and lightning (see Mechanisms of Nitrate Formation, Figure #3 and #3A). Wastes containing organic nitrogen enter the soil and are decomposed first to ammonium compounds which is subsequently oxidized to nitrite and nitrate.

Because nitrite (NO_2^-) is easily oxidized to form nitrate, nitrate predominates in ground and surface waters. The oxidation (nitrification of organic nitrogen) can be depicted as: NH_4^+ -- NO_2^- -- NO_3^-). Nitrate then is taken up by plants during their growth and converted back to organic form.

The process of oxidation or nitrification by soil bacteria (Nitrobacter) to form nitrates takes place in an aerobic (oxygen present) environment, where the bacteria derive energy from elemental oxygen (Viet and Hageman, 1971).

The formation of nitrates in an aerobic environment becomes more rapid at temperatures above 60°F (16°C), (Smith, 1969).

Infiltration of Nitrate

Most soils in nature possess a net negative charge which provides the capacity to attract and hold (absorb) positive charged compounds (cations); specifically, the ammonium compound (NH_4^+).

Nitrates are negatively charged (anions) and are not readily absorbed by the soil. Therefore, it is found that nitrates are mobile in soils, especially porous sediments (Smith, 1969). The movement of contamination plumes containing nitrates can travel great distances from their sources. In one study of returning wastes to the land, Bouwer, 1968, noted that nitrates may travel through fine loamy sand at a rate of three to four (3 - 4) feet per day (1 - 1.2 m/day).

Removal of Nitrate

Nitrogen compounds can be removed from waste water moving through the soil by various processes. Among the most effective are volatilization of ammonia and denitrification (Bouwer, 1968).

Ammonia is easily volatilized and can be detected by the pungent odor associated with concentrated animal wastes. Under anaerobic (oxygen absent) conditions, some bacteria can utilize nitrate, along with organic carbon compounds as a source of energy. The end product of this reaction is chiefly nitrogen gas (N_2) and some gaseous oxides of nitrogen which can escape to the atmosphere. The process of denitrification requires organic carbon, nitrate, nitrate reducing bacteria (Pseudemona and Micrococus), absence of oxygen, and favorable temperatures (Stevenson and Wager, 1971). Smith, 1969, has shown the denitrification process as: -- Nitrate NO_3^- -- NO_2^- -- NO -- N2O -- N_2 from his study on fertilizers and water pollution. In addition to the previous discussion of nitrate occurrence and chemical properties, the quantity of NO_3^- in ground water varies dependant on several factors including soil porosity, aquifer classification (confined, semi-confined, unconfined), flow and volume characteristics (hydraulic gradient), rainfall, irrigation practices, source proximity, quantity, and utilization of NO_3 containing compounds on the ground surface.

Nitrate and Its Effect on Human Physiology

Nitrate is absorbed by active transport from the upper small intestine, and nitrite is absorbed by diffusion across the gastric mucosa and also through the wall of the intestinal tract (U.S. EPA, 1985).

Absorption following ingestion is essentially complete. Both $13NO_3^-$ and $13NO_2^-$ were completely absorbed from the gastrointestinal tract within ten (10) minutes after intratracheal administration of 10 to 100 mg/kg in mice (Parks, et al., 1981). Rapid homogeneous distribution of nitrate was observed in rats 45 to 60 minutes after dosing (Witler, et al., 1979).

Nitrate secretion in saliva by humans was reported by Spregelhalder, et al., 1976, after ingestion of vegetables and vegetable juices.

It is assumed that ingestion of nitrate results in complete absorption and total distribution throughout the body.

Metabolism

No evidence of mammalian ability to metabolize nitrate into other compounds was found. However, the bacteria found in human saliva and stomachs can reduce nitrate to nitrite (U.S. EPA, 1985).

Nitrite

Nitrite reacts with hemoglobin in the erythrocytes, oxidizing the iron of hemoglobin to the ferric state. Ferric hemoglobin is called Methemoglobin and is unable to transport oxygen (Parks, et al., 1981).

No evidence was found for bioaccumulation of nitrates or nitrites in any tissue storage depot (U.S. EPA, 1985).

Nitrate is excreted readily through the kidneys. A measurable amount of nitrate could not be detected in the feces of humans that ingested 10 grams of ammonium nitrate (Keith, et al., 1930). Nitrate is also eliminated in human milk (Donahoe, 1949) and cow's milk (Davison, et al., 1964).

Health Effects

The toxicity of nitrate in humans is due to its conversion to nitrite. This reaction takes place in saliva of humans of all ages and in the gastric fluid of infants during the first three (3) months of life (U.S. EPA, 1985). About 25% of the nitrate absorbed is secreted in saliva, and oral bacteria reduces an average of 20% of this nitrate to nitrite, which is then swallowed.

The toxicity of nitrite takes two forms which vary greatly among different species:

1. A vasodilatory effect resulting in cardiovascular collapse; and
2. Oxidation of hemoglobin to methemoglobin resulting in asphyxia (U.S. EPA, 1985).

Normal methemoglobin levels in humans is shown to be between 1 + 2%; a level greater than 3% is defined as methemoglobinemia. However, there is a consistent elevation in pregnant women from the 14th week through delivery normally.

Health Advisories (H.A.)

(Reprint office of Drinking Water U.S. EPA. One-day HA)

No suitable studies for observation of a one-day HA were located. The ten-day should be protective of one-day exposures.

Ten-Day Health Advisory

Crown, et al., 1981, conducted an epidemiologic study of 102 children aged one (1) to eight (8) years at approximately 10 kg and up in Washington County, Illinois. Of the study subjects, 64 were consuming water with high nitrate levels (22 to 111 mg/l nitrate - nitrogen), and 38 were consuming water with low nitrate levels (less than 10 mg/l nitrate - nitrogen).

Ingestion of water containing 22 to 111 mg/l nitrate - nitrogen did not result in abnormal mean methemoglobin levels and was not related to increased methemoglobin levels in comparison to controls.

In the entire study group of 102 children, only five (5) had methemoglobin levels greater than 2%.

For a 70 kg adult and all age groups other than the 4 kg infant, the No Adverse Effect Level (NOAEL) value is 111 mg/l nitrate - nitrogen. (Crann, et al., 1981).

The ten-day nitrite HA for a 70 kg adult and all other age groups other than the 4 kg infant can be calculated from the NOAEL for nitrate, assuming 10% conversion of nitrate to nitrite as follows:

(111 mg/l nitrate - nitrogen)·(.10) = 11 mg/l nitrite - nitrogen

Where: 111 mg/l = NOAEL in 10 kg children (Crann, et al., 1981)
.10 = Assumed 10% conversion of nitrate to nitrite by 10 kg child.

H.A. For a 4 kg infant:

Walton, 1951, published a survey by the American Public Health Association which found more than 278 cases of cyanosis in infants that were definitely associated with consumption of nitrate contaminated water ranging from 15 - 100 mg/l by the infant or the nursing mother. No cases associated with water containing 10 mg/l or less of nitrite - nitrogen were found.

The ten-day nitrate HA for a 4 kg (9 lb.) infant is therefore 10 mg/l nitrate - nitrogen; the NOAEL for methemoglobinemia observed by Walton, 1951.

Current

Other studies support this HA. The ten-day nitrite HA for the 4 kg infant can be calculated from the NOAEL for nitrate as follows:

$$(10 \text{ mg/l nitrate - nitrogen})\cdot(.10) = 1 \text{ mg/l nitrite - nitrogen}$$

Where: 10 mg/l = NOAEL for nitrate - nitrogen in infants (Walton, 1951)
.10 = Conversion (uncertainty factor)

Long-term Health Advisory

No data adequate to calculate a longer term HA were located.

Lifetime HA

It is determined that the ten-day HA for the 4 kg infant (10 mg/l nitrate - nitrogen) will offer protection against the formation of methemoglobin induced by the ingestion of either nitrate or nitrite in all age groups.

(Reference U.S. E.P.A. Office of Drinking Water)

NITRATE STUDY PROCESS

Objective #1 - Determine Hydrogeology

In order to provide groundwater nitrate data, a thorough characterization of the hydrogeology within the affected area was fundamental to the project.

Spokane County Health District collaborated with Eastern Washington University (EWU) for the hydrogeology work.

Dr. John Buchanan, Assistant Professor of the EWU Geology Department, supervised the work conducted by Randall Anderson whose Masters Thesis centered on his research and investigation of the Deer Park area hydrogeology (see Appendix B - Randall Anderson, 1986).

Following several discussions between Spokane County Health District and Dr. Buchanan, a listing of tasks was developed in order to encompass all information that needed to be obtained.

These are listed as follows:

- Inspect surficial geology, topography, and well spacing in the field to provide a summarized map.
- Gather and scrutinize existing hydrogeologic data on the study area including well logs and all available data and reports from:

  United States Geological Survey
  United States Department of Agriculture
  Soils Conservation Service
  Environmental Protection Agency
  Washington State Department of Ecology
  Department of Social & Health Services
  Spokane County Health District
  Private well drillers
  Consulting firms and local field observations to provide a comprehensive compilation and analysis of available information on the study area.

- Synthesize and quantify all pertinent data from above sources to ascertain subsurface geology and stratigraphy.
- Provide hydrogeologic summary using maps of potentiometric surfaces, cross sections/fence diagrams of subsurface relationships based on well log information report on relationships of variations in water quality to ground water flow directions, and orientation of lithofacies (well logs).

Objective #2 - Water Monitoring

SCHD developed a specific methodology in order to best assess the Deer Park area ground water. After consulting with Dr. Buchanan and Randall Anderson, and evaluating information made available by local residents, SCHD concluded that wells which showed the highest NO_3 concentrations would be given first priority. Also, those wells in the area having well log information would be of most benefit to the study. Deer Park municipal wells were included due to elevated nitrate concentrations also being found in these sources. Deer Park city wells appeared to be using the same primary source unconfined sand aquifer as the rural residents to the east of Deer Park. Wells outside the City of Deer Park and adjacent to the study area, were monitored to evaluate and approximate nitrate background levels. A 12-month period of monitoring was necessary to compile pertinent data for area nitrate assessment.

Initial tasks performed were to:

1) Acquire well logs for the Deer Park area from the Washington Department of Ecology.

2) Develop a data base information form.

3) Distribute these information forms to the Deer Park area rural residents to obtain land use information and secure permission to conduct water sample collection.

A schedule was developed to conduct sample collection at six (6) week intervals to provide an annual assessment of seasonal variations in ground water nitrate levels. It was determined that to best measure ground water nitrate levels sample collection would be performed under the following operational procedure:

Equipment:
Sterile 100ml glass bottles
Ice chest with coolant block
Grease pencil

Sample Collection Process:
Announce arrival to land owner or secure permission to obtain sample during their absence.

Identify Well Location.

Identify tap closest and most convenient to well.

Run water for approximately five (5) minutes to flush line before drawing sample.

Fill bottle up to the top-producing meniscus head; seal bottle preventing any trapped air bubbles.

Store sample in ice chest until lab delivery.

Upon delivery to SCHD lab each sampling day, store samples refrigerated at 2°C. until analysis can be performed.

HISTORY OF LAND USE IN THE DEER PARK AREA

The community of Deer Park is located 32 Km north of the City of Spokane. Initially settled around 1870 by pioneers and then homesteaders, the area evolved into a lumber and farming community. Large lumber operations, such as the Deer Park Pine Industries, Inc., harvested trees generating high annual board feet yields. As land was being cleared, the area's abundance of rich soils and accessible water became available for extensive agricultural usage. Arcadia Orchard Co. (est. 1909), utilized an estimated 20,000 acres of land in developing the largest orchard cooperative of its time in Eastern Washington.

The construction of an elaborate irrigation project that extended from Deer Lake and Loon Lake in Stevens County intersected most of the farm land north and east of the City of Deer Park. During mid century, the orchards gradually disappeared. The irrigation project was discontinued by the Department of Natural Resources (DNR) who imposed restrictions on water usage from Deer Lake and Loon Lake. The Deer Park area later evolved into large volume production of poultry, eggs, dairy products, livestock, and alfalfa. Presently, subdivisions and housing additions have reduced many of the high volume agricultural land uses with a resulting increase in population density.

Within the City of Deer Park, residential housing development and associated support businesses have been the principle land use for the past 40 years. Public water and sewer utilities were established along with on-site sewage systems. A sewage lagoon irrigation project is in use 3.6 Km east in conjunction with secondary wastewater treatment methods. Recent residential development has taken place to the north and east sides of Deer Park.

The city has a central business district intersected by a rail line and Dragoon/Spring creeks to the north. An additional commercial area is developing to the southwest.

There are no significant industrial activities; however, grange supplies, repair shops, farm implements, and rail depot collectively comprise a small industrial area in the center of the city.

Overall, the Deer Park area remains predominantly agricultural in nature. The utilization of inorganic fertilizers, the generation of animal waste products, and essentially the presence of man's activities in relation to the land have placed many demands and stresses upon its natural resources. The potential exists for a degrative impact on the area's groundwater quality.

LAND USE IN RELATION TO POTENTIAL NITRATE SOURCES

SCHD undertook a preliminary task of screening potential sources of nitrate contamination. Conducting individual well site investigations and utilizing previous investigations from local and contracted agencies, these nitrate sources in the Deer Park area are recognized.

Excerpt from "Comprehensive Water System Plan for the City of Deer Park, Washington; CH_2 M Hill; February, 1986":

1. Liquid NH_3 Spill - It is reported that on May 7, 1985, a spill of liquid "aqua" ammonia occurred at the Inland Farmers Cooperative Facility in Deer Park. A total of 6,900 gallons of the product spilled from a broken pipe and flowed to an irrigation pond just southwest of the facility. From May 7, 1985, through May 29, 1985, approximately 5,000 gallons per day of product and water were pumped from the pond. Water samples from the pond were analyzed and showed initial concentrations of 174 mg/l NH_3-N that dropped to about 50 mg/l within a month. The pond was reported to be dry by July 22, 1985.

2. Solid NO_3 Spills - Solid ammonium nitrate (NH_4NO_3) spills are reported to occur infrequently at a railroad siding located approximately 200 feet west of well DP-2. Spills apparently occur during offloading of railroad cars at the siding. The material is reported to be used in the manufacture of explosives at a plant site northeast of Deer Park.

3. Leaky Sewer - City of Deer Park personnel have identified two areas of the City where the sanitary sewers may be leaking. The quantity of liquids escaping through these leaks is unknown. In 1980, raw sewage influent to the wastewater treatment facility contained 28 mg/l NH_3-N and 1.60 mg/l NO_3-N (WDOE, 1981).

4. Septic Tanks/Drainfields - City of Deer Park personnel are aware of two areas in the City that are unsewered. The north area is scheduled for hook-ups to the sanitary sewer in the near future. Drainfields are a known source contributing to nitrate contamination in other parts of the country. Ammonia and nitrate concentrations in drainfield effluent should be similar to sanitary sewer effluent.

5. Landfarmed Poultry Manure - It is reported that poultry manure was injected on agriculture lands east of the City of Deer Park in the mid 1970's. The manure was injected as a slurry for the purpose of adding nutrients to the soil which was a common practice at the time. The extent of the manure injection (as shown on Figure #4) has been estimated by previous landowners. Parts of this area is now being developed as the Arcadia Heights subdivision.

It is also reported that complaints of offensive odors by residents of Deer Park eventually stopped the injections at these locations. However, no records of the injection or complaints could be located by personnel at the Spokane County Air Pollution Control Administration.

The source of the poultry manure may have been an egg ranch located about 3 Km east of Deer Park. Poultry wastes are known to contain high concentrations of ammonia (NH_3).

Other activities in the Deer Park region that could result in excess nitrate formation are manure stock piles and feed lots; increased natural decay of plant matter exposed from increased tillage; and application of mineral fertilizers to lawns, gardens, and agricultural lands. The effects of these activities would tend to be regional.

Two other potential nitrate sources were identified but do not fall within or even close to the capture/recharge zone of the high NO_3 wells. An explosives manufacturing plant site and the Deer Park wastewater spray irrigation facility (both located near the Deer Park Airport) were initially identified as possible sources. Existing groundwater elevations, however, indicate a southeasterly flow direction from the Deer Park Airport. A west, southwest flow direction (a highly unlikely condition) would be required for leachate from either of these sources to impact the municipal wells. Further, the 1985 report by Hartz and Esvelt concluded that there is little likelihood of nitrate contamination resulting from wastewater spray irrigation. This conclusion is apparently supported by monitoring well water sampling and testing.

Screening Potential Nitrate Sources

While evaluating the potential nitrate sources several "tools" were used to screen out or eliminate certain potential sources as a major source of the contamination. For example, the liquid ammonia (NH_3) spill was immediately discounted primarily because the nitrate problem existed prior to the spill. However, maximum summer pumping rates for wells DP-2 and DP-3 may be able to capture the ammonia and any ammonia converted to nitrate. Fortunately, well DP-3 was not pumped at peak rates during the summer of 1985. Periodic sampling of wells DP-2 and DP-3 during late summer of 1985 failed to detect any ammonia. This suggests that the ammonia spill was not captured at these reduced pumping rates.

The solid ammonium nitrate (NH_4NO_3) spill(s) cannot be discounted by timing but can be generally discounted by location and groundwater flow direction. If this railroad siding was a primary source location, nitrate concentrations should be higher in well DP-2 than in well DP-3. The opposite condition exists (i.e., concentrations in well DP-3 are higher). In addition, it appears that well DP-3 has served as a blocking well in the past by capturing more contaminated water. Until the summer of 1985, the nitrate concentration in well DP-2 had been less than 7 mg/l. Immediately after the pumping rate in well DP-3 was substantially reduced (July, 1985), the nitrate concentrations in well DP-2 reached 10.5 mg/l in October, 1985. These observations suggest that the source location is probably northeast of well DP-3.

The water quality data have revealed additional meaningful trends. It was observed that both nitrate and chloride concentrations in well DP-3 increased dramatically from early June, 1985, through early July, 1985. Chloride concentrations increased from approximately 3 mg/l to 20 mg/l and nitrate concentrations increased from 8 mg/l to 12.8 mg/l. The only logical explanation for such an increase was that the pumping rates had been increased to meet higher summer demands. Two major observations can be made. First, a strong correlation exists between high nitrate concentration and high chloride concentration. Second, both higher nitrate and chloride concentrations correlate with higher pumping rates. These two observations indicate that at higher pumping rates well DP-3 captures a plume of groundwater containing higher concentrations of nitrate and much higher concentrations of chloride. Other studies conducted to identify nitrate contamination sources have revealed a correlation between chloride and nitrate exists when the nitrate source is either human or animal waste (Jones, 1973). It would be logical to conclude that at least the increase in nitrate concentrations from 8 mg/l to 13 mg/l in well DP-3 could be attributed to an animal or human waste with suspect sources being septic tank effluent, sewer effluent, and poultry wastes.

Natural nitrate produced by decaying vegetation cannot be ruled out as a contributing source to the nitrate contamination. Grasslands in semiarid climates favor naturally high nitrogen content in soils. Kreitler and Jones (1975) determined that nitrate contamination in groundwaters of Runnels County, Texas is the result of humus oxidation in semiarid grassland soils and the subsequent leaching of nitrate to the saturated zone. Both the increased oxidation and leaching may be a result of cultivating and terracing of dry land areas to conserve both soil and soil moisture.

This study in Texas and other nitrate contamination studies conducted for Long Island, New York have relied upon nitrate isotope ratios to distinguish nitrate from animal waste sources from natural nitrate sources. The technique relies upon the $^{15}N/^{14}N$ ratio in soil or groundwater nitrate. The analytical costs associated with the technique and proving the validity of the technique for the Deer Park area are very expensive and beyond the scope of this work. Furthermore, the nitrate-chloride correlations indicate that at least part of the nitrate problem is attributable to animal or human wastes. Hence, it is not necessary at this time to quantify the percentage of nitrate being contributed from natural sources. It is unfortunate that the isotope technique cannot discriminate between animal and human waste derived nitrate. This distinction would enable either the poultry manure or septic tank/sewer wastes to be isolated as a major source of nitrates in well DP-3.

All the previous discussions regarding nitrate sources lead to the conclusion that it is not possible to determine a single source. It seems very likely that the problem is the result of animal or human waste derived nitrate contributing to a high regional background. The regional background, potentially caused by both natural and mineral fertilizer sources, may have increased from levels of less than 2 mg/l (in 1975) to levels of 5 mg/l or greater today. These background levels are probably compounded by the addition of animal or human waste derived nitrate. The end results are nitrate levels of 8 mg/l to 13 mg/l that are observed in the City's wells completed in the shallow glaciofluvial aquifer.

Potential Sources of Future Groundwater Contamination

The nitrate contamination should serve as a focus upon the vulnerability of this shallow, unconsolidated sediments sand and gravel aquifer to contamination from other possibly more harmful substances. Any hazardous or toxic substance dumped or spilled upon the ground, buried, or leaked into the ground in Deer Park, has the potential to contaminate groundwater.

The EPA has identified types of businesses that handle hazardous materials which have the potential to contaminate groundwater supplies. The City of Deer Park is not a major industrial area but does contain auto body shops, dry cleaners, and gasoline stations. These types of facilities appear on the EPA list and have contaminated groundwater primarily through discharge to septic systems.

Potential contamination sources in Deer Park are shown on Figure #4. The above mentioned facilities in Deer Park are included although sanitary sewers are available to each facility. Additional potential sources shown include an abandoned landfill on the west side of the City and storm drainage ditches near the railroad right of way. These ditches are believed to be connected to drywells. Although the ditches are not a direct source, they are extremely vulnerable to spills due to their location adjacent to a major thoroughfare and the railroad right of way.

INDIVIDUAL WELL SITE SURVEY

Sixty (60) individual well sites; five (5) at Northwest Egg, and fifty-five (55) at private homes, were assessed for site characteristics in order to identify possible nitrate sources unique to each residence.

A well mapping form was developed which was used to record site specific data providing a synopsis of the site for nitrate contamination potential. Data included:

- Name and parcel number;
- Topography, emphasizing the direction of slope and drainage;
- Livestock and cover crops;
- Remarks section--overall impression describing site usage (i.e., residential, farm, or commercial);
- Well characteristics--description of well type and well seal;
- Static water level; and
- Site adjacency to potential nitrate sources.

An overview pictorial sketch of the site was drawn centering the well location and illustrating measured distances from septic tanks and drainfields, feed lots, and structures; and surface actions, direction, and degree of slope.

Overall findings concluded that the majority of the sites consisted of normal residential usage. Most on-site sewage systems were over 100 feet from the well. Nineteen (19) sites have livestock. Five (5) sampling sites are at the N.W. Egg, a commercial agricultural activity. Eight (8) sites utilize commercial fertilizer annually. One (1) site stores fertilizer for commercial sale. One (1) site, Oriard Manufacturing, stores solid ammonium nitrate (NH_4NO_3). A "Yes" notation for cover crops describes active farming including annual tillage, fertilizing, and harvest. A "No" notation describes residences which do not perform the above annual activity.

Five (5) wells are reported to be older than 35 years. Five (5) wells do not conform to Minimum Standards for Construction and Maintenance of Water Wells, Chapter 174-160 WAC.

A breakdown of the aforementioned sites is given with categories of location, livestock, cover crops, present well condition, and nitrate level (see following). All sites prior to the present uses were utilized in some agricultural capacity (i.e., crops, pasture, or abandoned farm site).

BREAKDOWN OF WELL SITES WITH POTENTIAL NITRATE SOURCES

Section 18 - Township 28 - Range 43

Site	Livestock	Cover Crop	Well Conditions	Avg. mg/l Nitrate Level
E-1	Yes	Yes	No - Does Not Meet 173-160 WAC	8.7

Section 03 - Township 28 - Range 42

Site	Livestock	Cover Crop	Well Conditions	Avg. mg/l Nitrate Level
L-1	No	No	Over 35 yrs. (0-35)	(3.3)
P-1	No	No	(0-35) Does Not Meet 173-160 WAC	20.0
K-2	No	No	(0-35)	7.2

Section 05 - Township 28 - Range 43

Site	Livestock	Cover Crop	Well Conditions	Avg. mg/l Nitrate Level
G-1	Yes	Yes	Yes - Meets 173-160 WAC	1.0
G-2	Yes	Yes	Yes - Meets 173-160 WAC	3.0
M-1	No	No	No - Does Not Meet 173-160 WAC	7.5

Section 06 - Township 28 - Range 43

Site	Livestock	Cover Crop	Well Conditions	Avg. mg/l Nitrate Level
K-1	Yes	Yes	Yes - Meets 173-160 WAC	31.0
K-2	Yes	Yes	Yes - Meets 173-160 WAC	26.0
K-3	Yes	Yes	Yes - Meets 173-160 WAC	41.4
K-4	Yes	Yes	Yes - Meets 173-160 WAC	11.4
K-5	Yes	Yes	Yes - Meets 173-160 WAC	1.2
L-1	Yes	Yes	No - Does Not Meet 173-160 WAC	28.8

Section 07 - Township 28 - Range 43

Site	Livestock	Cover Crop	Well Conditions	Avg. mg/l Nitrate Level
A-1	No	Yes	(0-35) Does Not Meet 173-160 WAC	60.7
H-1	Yes	No	Yes - Meets 173-160 WAC	1.2
H-2	Yes	No	Yes - Meets 173-160 WAC	11.5

Section 08 - Township 28 - Range 43

Site	Livestock	Cover Crop	Well Conditions	Avg. mg/l Nitrate Level
D-1(A)	Yes	Yes	Yes - Meets 173-160 WAC	26.5
D-1(B)	Yes	Yes	Yes - Meets 173-160 WAC	1.3
M-1	Yes	Yes	Yes - Meets 173-160 WAC	12.2
M-2	Yes	Yes	Yes - Meets 173-160 WAC	1.1

Section 10 - Township 28 - Range 42

Site	Livestock	Cover Crop	Well Conditions	Avg. mg/l Nitrate Level
H-1	Yes	Yes	Yes - Meets 173-160 WAC	2.4
H-2	Yes	Yes	Yes - Meets 173-160 WAC	1.4
J-1	Yes	Yes	Yes - Meets 173-160 WAC	1.0

Section 12 - Township 28 - Range 42

Site	Livestock	Cover Crop	Well Conditions	Avg. mg/l Nitrate Level
A-2	Yes	No	Yes - Meets 173-160 WAC	104.0
C-1	Yes	Yes	Yes - Meets 173-160 WAC	1.0
H-2	Yes	No	Yes - Meets 173-160 WAC	1.5
G-2	Yes	No	Yes - Meets 173-160 WAC	9.9

Section 13 - Township 28 - Range 42

Site	Livestock	Cover Crop	Well Conditions	Avg. mg/l Nitrate Level
K-1	Yes	Yes	Yes - Meets 173-160 WAC	4.0
R-1	Yes	Yes	Yes - Meets 173-160 WAC	4.5

Section 35 - Township 29 - Range 42

Site	Livestock	Cover Crop	Well Conditions	Avg. mg/l Nitrate Level
C-1	No	Yes	Yes - Meets 173-160 WAC	7.6
E-1	Yes	Yes	Yes - Meets 173-160 WAC	11.3

CONCLUSION

As evidenced from the data of this investigation, the Deer Park study area consists of two separate primary groundwater aquifer systems. The (unconsolidated sediments) aquifer system has shown to be the most vulnerable as nitrate concentrations are elevated in comparison to those found in the lower (basalt) aquifer system.

The upper aquifer consists of (glaciofluvial/glaciolacustrine) (unconsolidated) sediments, wherein water flows freely. The lower (basalt) aquifer is more confined, and somewhat protected by the overhead rock layer(s).

Analysis of well log data, with specific attention to depth, soil profile, and well construction, was used to determine which aquifer system is supplying each individual well site within the survey area. Speculation arose early in the investigation regarding the potential for the shallow aquifer to intermix with the deep aquifer system. This inspection was based on unexpected elevated nitrate concentrations found in some of the wells utilizing the lower (deep) aquifer. However, it was determined that inadequate or improper sealing around the well casings allowed the upper aquifer to intermix with the lower aquifer. With respect to the overall contamination in the study area, the seepage of water to the lower aquifer from the upper shallow aquifer was of a minor consequence.

The following is an estimation of the well site aquifer source, based on drillers well logs.

-40 private and 4 public wells within the study area obtain water from the unconsolidated sediment aquifer.

-45 private and 1 public wells within the study area obtain water from the deeper basalt aquifer.

The water samples obtained from well sources drawing from the unconsolidated aquifer have shown nitrate concentrations ranging from 1 mg/l to 250 mg/l with a mean average of 20.12 mg/l. The well depth vary from surface to 160' below surface elevation.

Water samples obtained from wells tapping the lower basalt aquifer have shown nitrate concentrations ranging from 1 mg/l to 19.5 mg/l with a mean average of 2.5 mg/l. The wells vary in depth from 81' to 347' from surface elevation. A typical well depth into the deep aquifer is 175'.

As indicated, the unconsolidated aquifer is more readily subjected to nitrate contamination due to the relatively unrestricted transmitting ability of the sandy gravelly soils. Conversely, the basalt and granite rock layers beneath the shallow aquifer restrict the movement of nitrate-rich groundwater into the deeper aquifer.

In the investigation, certain unconsolidated water source areas had higher nitrate concentration than others. The amount of the contamination depends upon the "exposure" of a particular water source to a nitrate contamination source combined with the concentration and continued availability of the source.

The City of Deer Park public wells positioned in the unconsolidated aquifer system displayed nitrate concentrations of 8 mg/l to 13 mg/l. The subterranean basalt ridge east of the City limits the groundwater flow contribution from the unconsolidated aquifer system. Therefore, the groundwater flows supplying the unconsolidated public wells are originating primarily from the area north of the City. The nitrate sources within the municipality are varied, and may include a previously recorded ammonia "spill", known cross-connection probabilities in the public water distribution system, use of mineral fertilizers, leaking sewer piping, and on-site sewage disposal systems. (Ref. conclusions section of CH_2M Hill report for City of Deer Park.)

The unconsolidated aquifer wells at the commercial poultry facility located near Mill Road and Deer Park/Milan Road were showing nitrate concentrations ranging from 1 mg/l to 57 mg/l during the study period. These wells appeared to be properly constructed; and it was not readily apparent that activity on the surrounding ground surface was being transmitted directly to the groundwater by channeling the well casings. Varied land surface activities, however, have occurred around the wells with the most prominent (in recent years) being the utilization and land spreading of poultry manure.

Repeated, multiple applications of animal manure placed on or incorporated into the surface soils exceeding the nitrogen utilizing capability by a growing crop or vegetative groundcover, can allow excess organic nitrogen to be mineralized, forming nitrate which can be transmitted easily to groundwater through climatic precipitation and/or irrigation events.

Several private wells that draw water from the unconsolidated aquifer are located within a groundwater flow zone which originates northeast from a geologic basalt plume at Section 6, Township 28, Range 43, and splits in a southeast and southwest flow pattern. Surface topography of this area consists of two rather major drainage ravines directionally corresponding to subsurface geology; and is considered to be the generalized hydraulic gradient. This area, inclusive of the northeast 1/4 of the northeast 1/4 of Section 12, Township 28, Range 42 near the intersection of Cedar Road and Antler Road, and also inclusive of the southeast 1/4 of the northeast 1/4 of Section 7, Township 28, Range 43 and the northeast 1/4 of the southeast 1/4 of Section 7, Township 28, Range 43 adjacent to Division Road, displays well site nitrate concentrations ranging from 15 mg/l to 250 mg/l.

Multiple nitrate sources can be identified, including organic and inorganic fertilization practices, on-site sewage systems, animal raising and feedlots, and vegetative decomposition. The high nitrate concentration, however, found in several shallow groundwater wells exceeds a typical elevated background nitrate concentration of 5-15 mg/l identified for the study area.

The commercial poultry facility established over 40 years ago in Section 6, Township 28, Range 43 on Cedar Road has utilized various on-site manure handling, storage and utilization practices...including land spreading. The poultry facility located upgradient to the groundwater flow pattern of the shallow wells showing the highest nitrate contamination is a potential contributor to the overall amount of contamination found during the study period.

RECOMMENDATIONS

1. The City of Deer Park, having contracted with a private engineering firm, has been advised to undertake several remedial measures for the reduction and control of additional nitrate contamination. These recommended measures include:

    a. Sewer service control through the repair/replacement of leaking sewers and eliminating on-site sewage disposal systems by connecting sewage generators to the public sewer system.

    b. If necessary, remove any/all nitrogen enriched soils from the area of a previous fertilizer spill.

    c. Develop an alternative groundwater source outside the contaminated area.

    d. Utilize one public well as a "blocking well". This measure would be a hydraulic control method of reducing nitrate concentrations to the remaining public well sources.

2. Recommendations for rural properties with high nitrate concentrations:

    a. Installation and use of small distillers. These systems, depending on type and size, have been capable of reducing nitrate concentrations to below 10 mg/l. There is a relatively high initial cost for installation; and continued on-going maintenance is necessary. Several identified well sources within the study area have already been so equipped as of this date.

    b. Purchase of "bottled water" may be a short-term remedy, but would not be economically feasible over a long extended period of time. The cost and inconvenience would be objected to by impacted individuals.

    c. Existing shallow wells utilizing the unconsolidated sediments aquifer may be deepened by drilling through the underlying basalt layer(s)...thus drawing water from the basalt aquifer. This would be a feasible method only if proper measures to seal the well casings are utilized during the drilling operation. This method of obtaining an alternative water source is probably the most cost-effective long term solution to the contamination problem. The well deepening procedure and construction techniques would need to be closely supervised by qualified engineers.

    d. A single public well drilled into the deeper aquifer, to serve a clustering of semi-rural residential properties, may be feasible, but also may have some drawbacks. The initial cost of installation of the well and distribution lines may be cost prohibitive. Control of the drilling process would be easier for one well rather than several...as explained in "c" above. Another consideration of importance would be the operation and maintenance of a public well. This cost would have to be borne by all served properties through a homeowners utility maintenance agreement. Our experience has shown that these arrangements have not proven to be very effective; however, operation by a public utility would make this alternative more feasible.

e. City of Deer Park municipal water could be extended to the area. This may be feasible initially to only those properties on Antler Road west of Cedar Road. Therefore, not all high nitrate private well owners would be served. Moreover, the extension of municipal utility services to semi-rural areas can affect land uses...thus, altering the life style of an area.

This groundwater investigation has concluded that an unconsolidated sediments aquifer system has been contaminated from various ground surface nitrate sources. These sediments above the aquifer readily transmit land surface nitrate sources to the aquifer. The amount of nitrate contamination found in any one water source is dependent on well construction, depth of penetration into the unconsolidated sediments aquifer, and availability and concentration of the nitrate source.

In this investigation, multiple nitrate sources have contributed to the contamination. Those most significant in the rural area east of Deer Park relate to fertilization practices, crop residues, and animal manure management and utilization activities.

The proper deepening of existing water sources into a deeper aquifer is an appropriate measure to restore potable water to the affected properties.

The controlled storage and utilization of crop residues and animal manures through Soil Conservation Service "Farm Plans" under the authority of a local solid waste management regulation will reduce the potential for nitrate contamination from these sources.

The contamination present in the unconsolidated sediments aquifer will persist for some time; however, the affected geographic area involved in this investigation can be readily identified. With property deeds notification procedures, all undeveloped properties can develop deep aquifer groundwater sources with reduced nitrate concentrations to the 1.0 - 2.0 mg/l background level typical of the lower basalt aquifer during the period of this investigation.

ILLUSTRATIONS

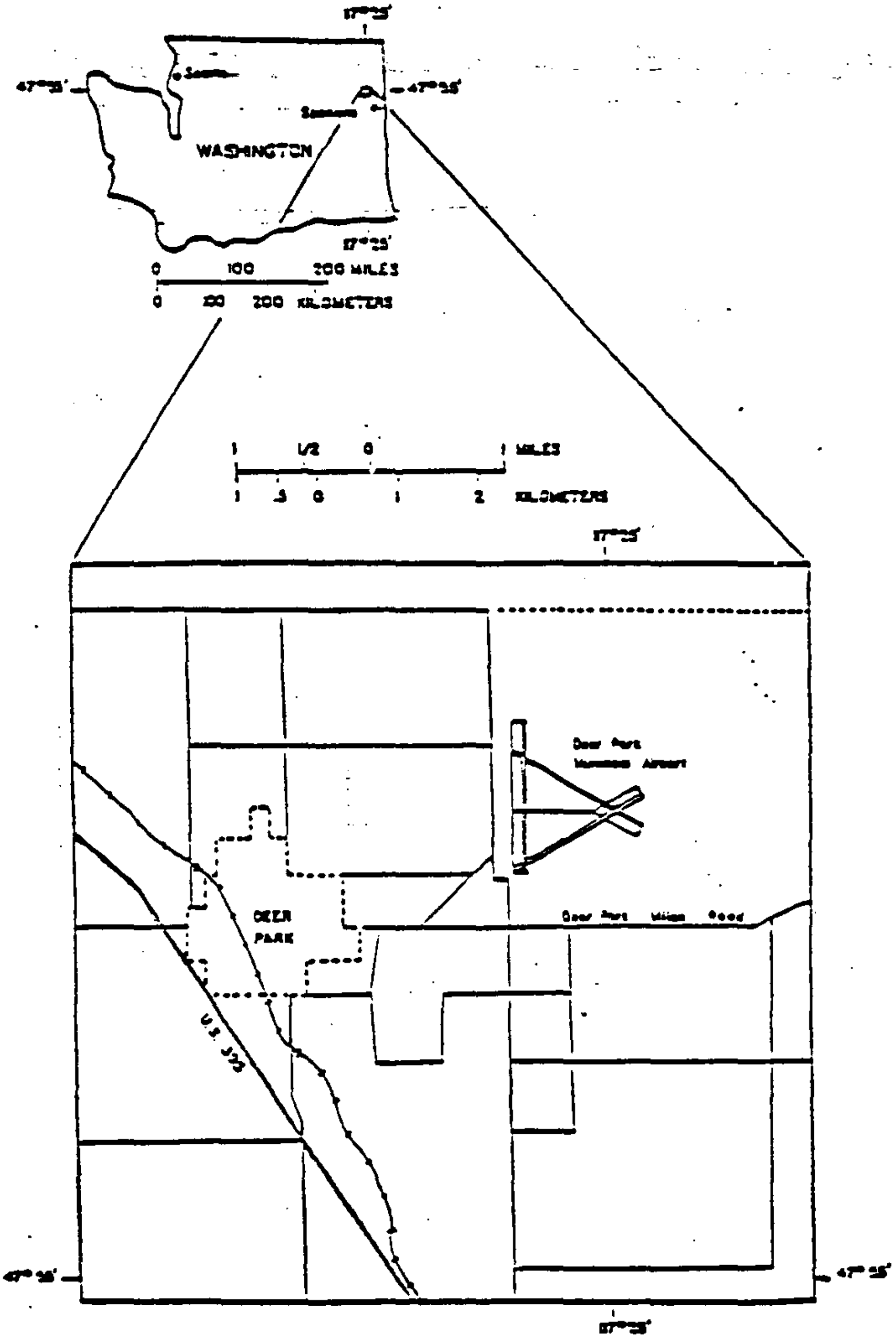
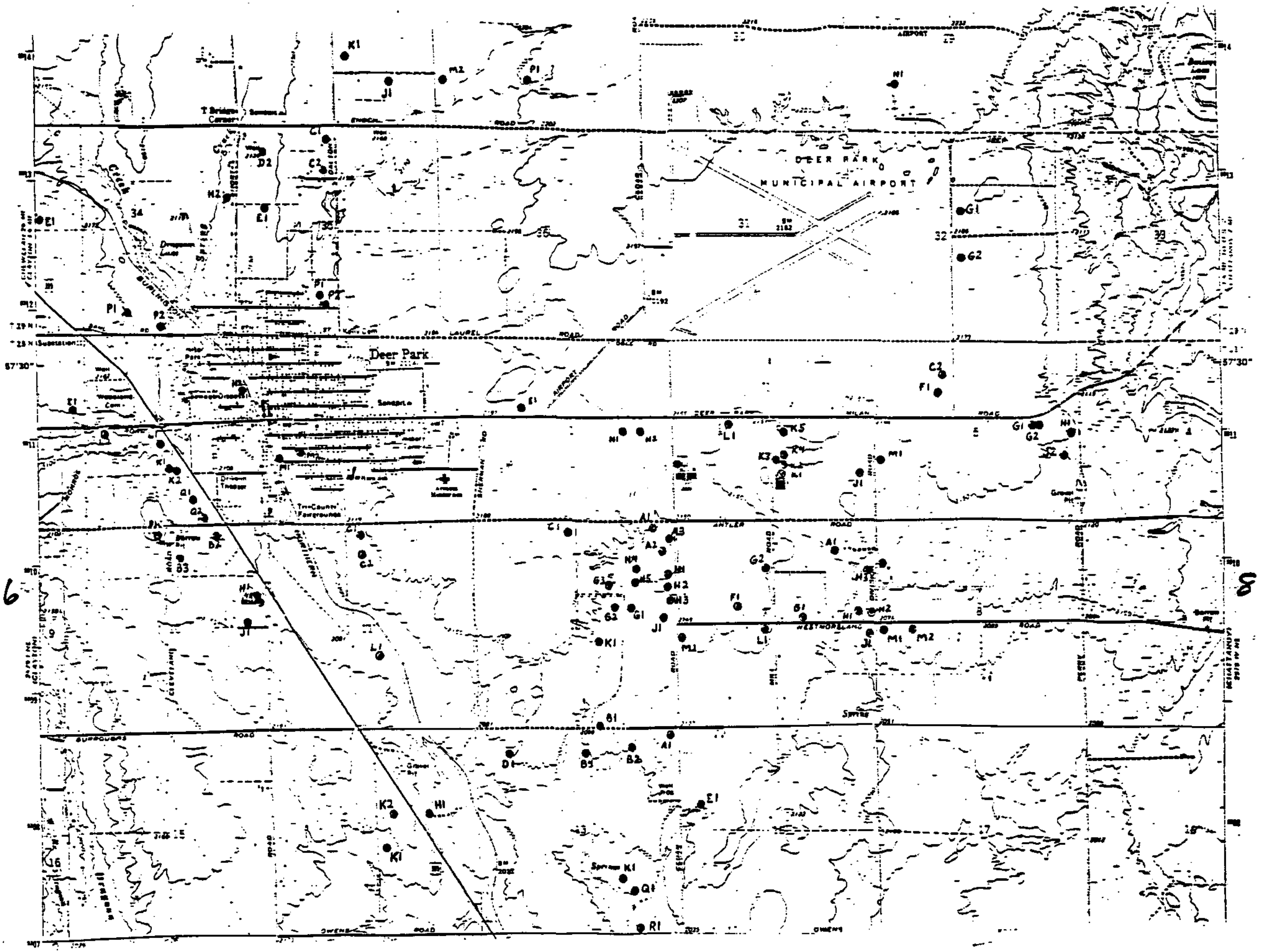


Figure 1 Location of study area.



DEER PARK MUNICIPAL AIRPORT
Deer Park
LAUREL ROAD
DEER PARK MILAN ROAD
ANTLER ROAD
WESTMORELAND ROAD
BURROUGHS ROAD
OWENS ROAD
AIRPORT
Tri-County Fairgrounds
Drive-in Theater
Spring
Gravel Pit
57'30"
T 29 N
T 28 N
6
8

FIGURE 1A

LEGEND:

▲ AVERAGES IN EXCESS OF HEALTH ADVISORY 10 mg./liter Nitrate as Nitrogen (NO_3-N)

■ AVERAGES BETWEEN 5 to 10 mg./liter NO_3-N)

● AVERAGES BETWEEN 2 to 4.9 mg./liter NO_3-N

+ AVERAGES BELOW 2 mg./liter NO_3-N

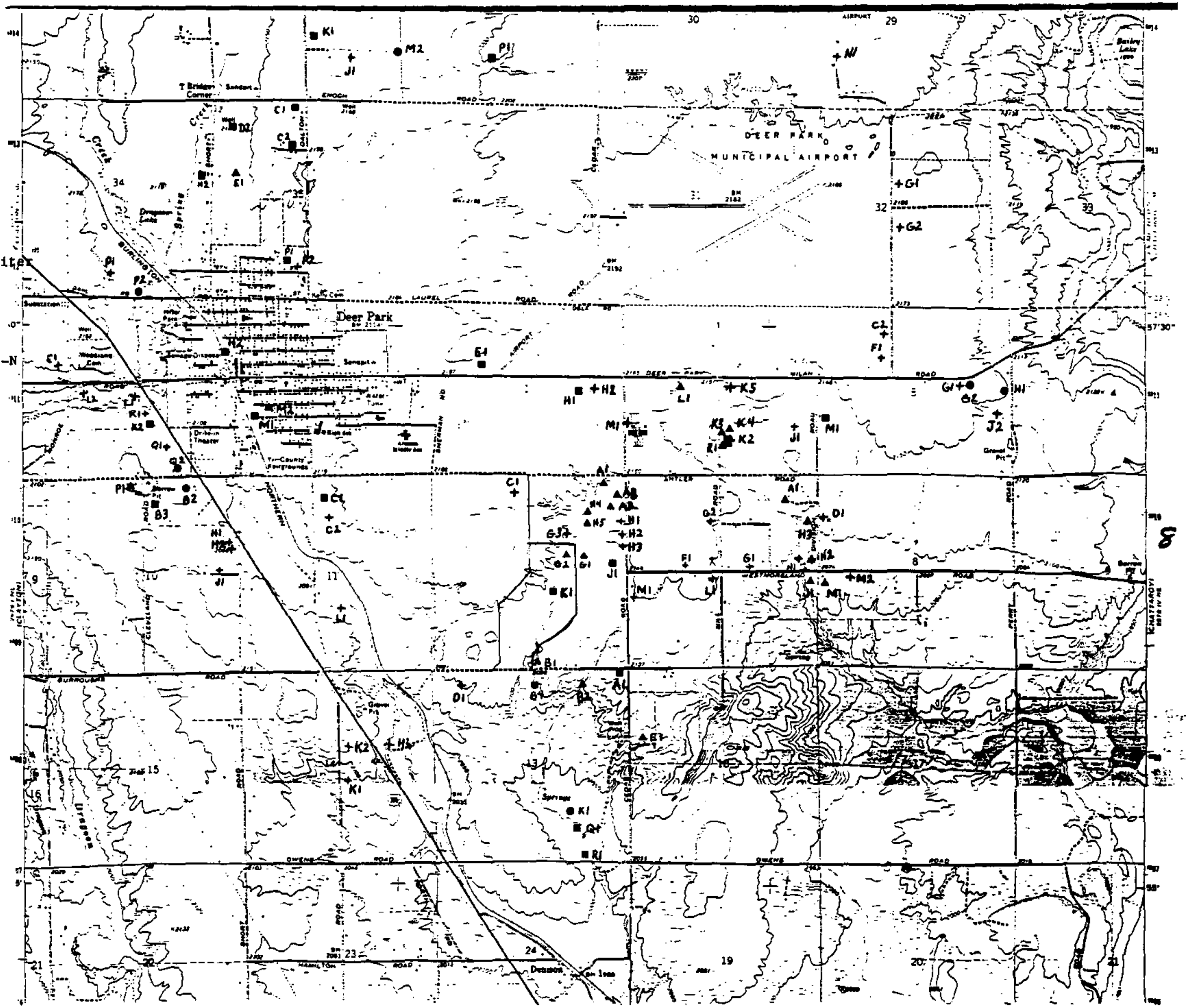
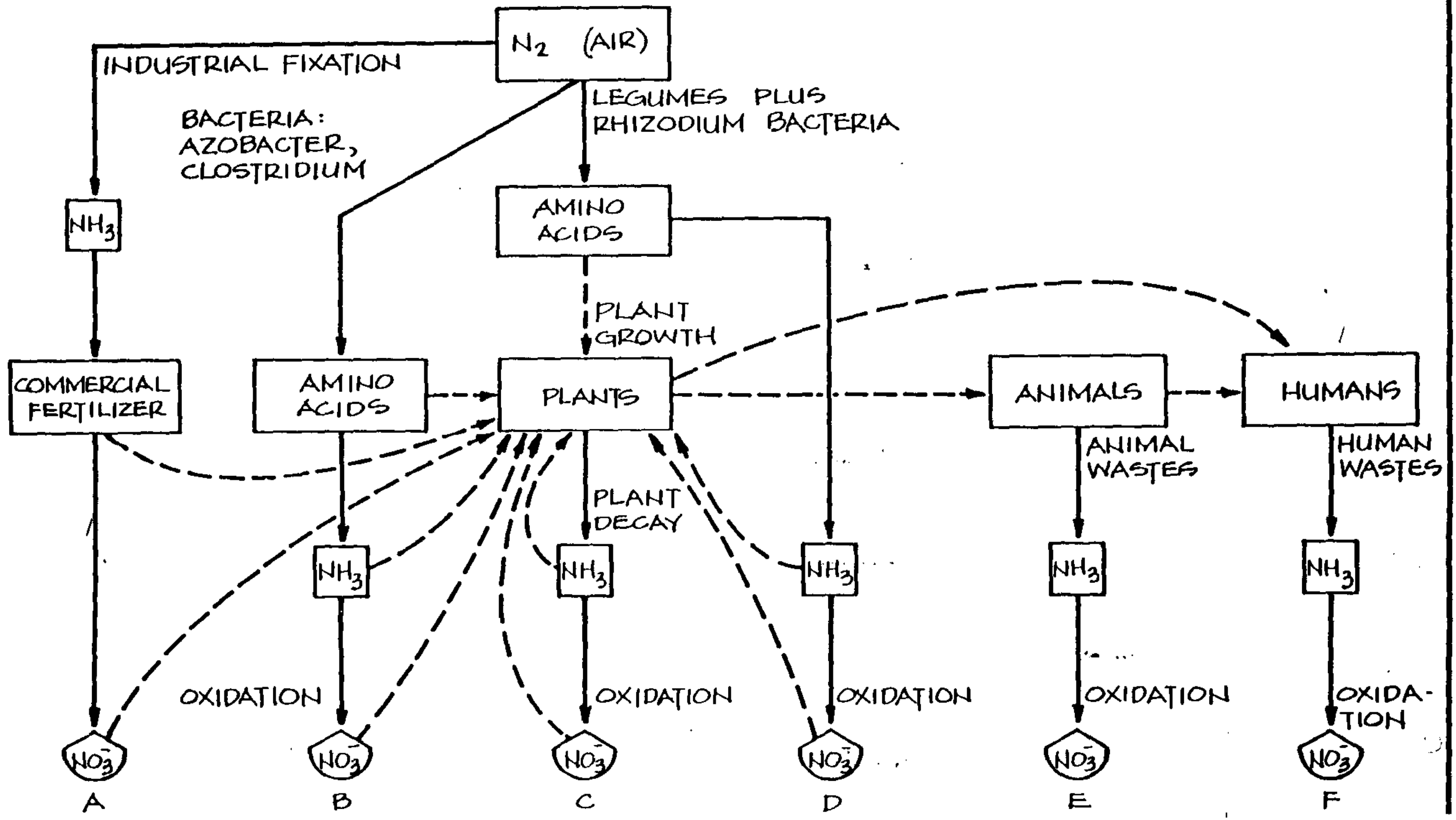


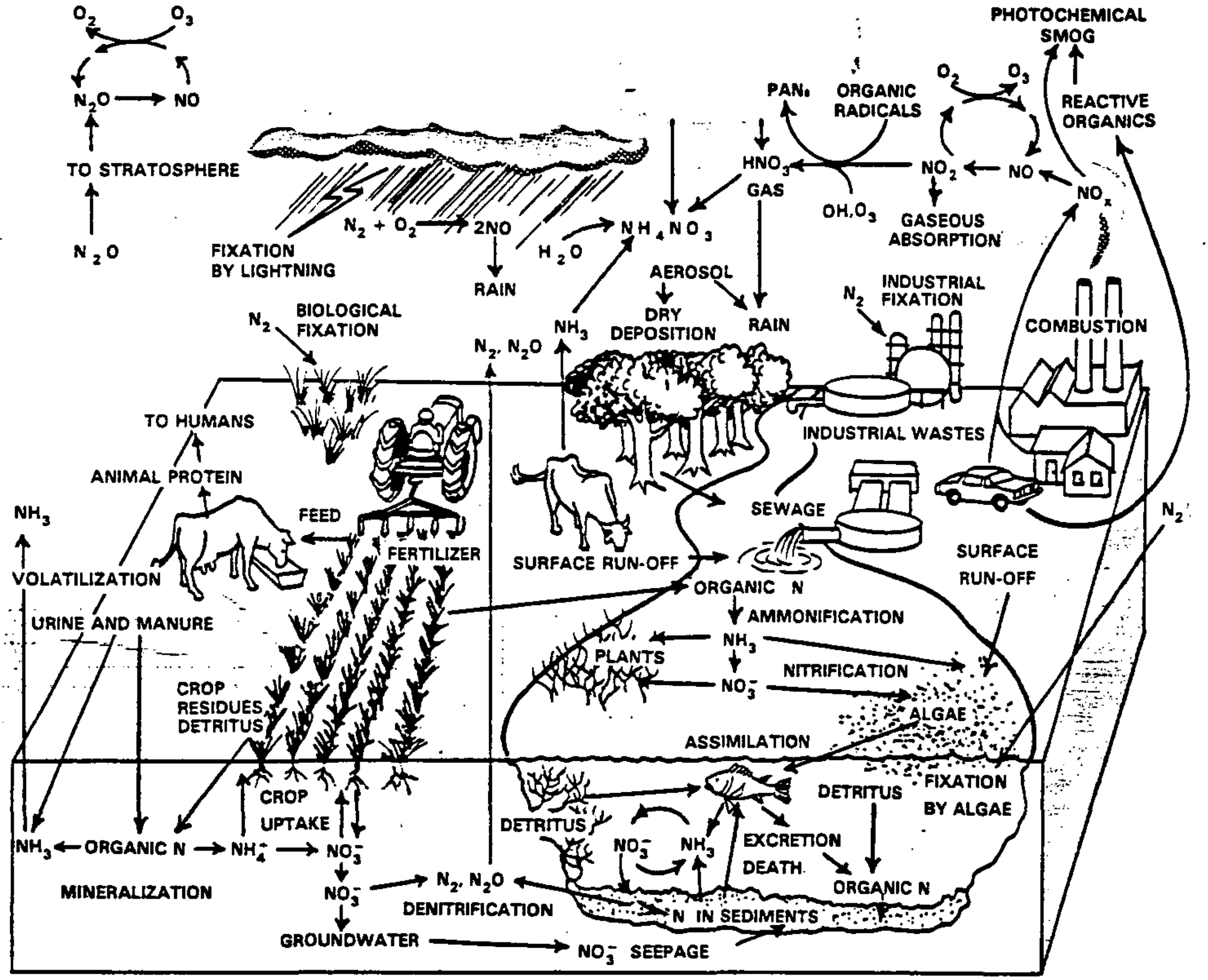
FIGURE 2

8



MECHANISMS OF NITRATE FORMATION
(U.S. ENVIRONMENTAL PROTECTION AGENCY, 1979)

Figure 3

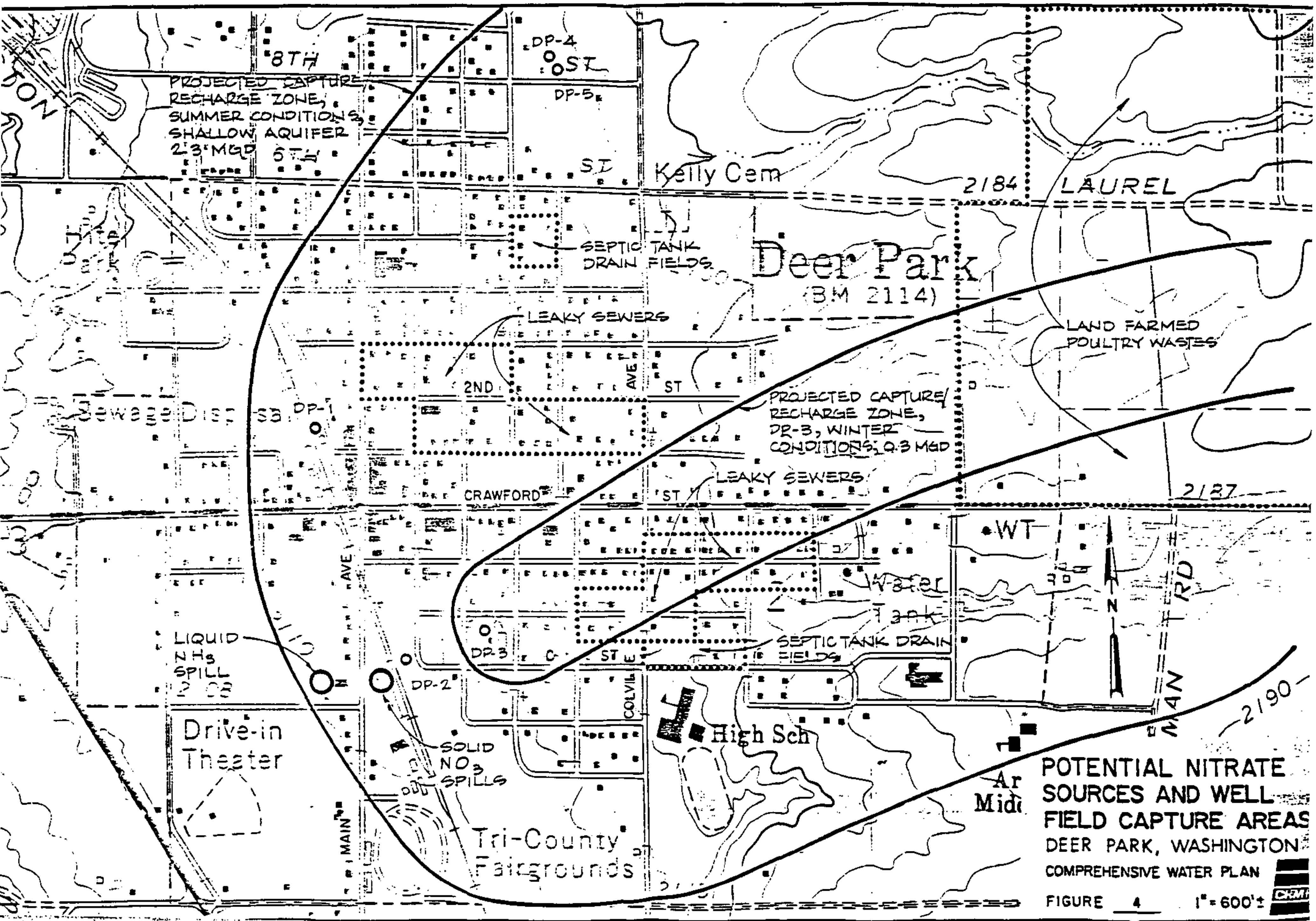


The nitrogen cycle and anthropic activities that affect nitrogen fluxes.

SOURCE: Adapted from National Research Council, *Nitrates: An Environmental Assessment* (Washington, D.C.: National Academy Press, 1978).

JIM TOOMEY/TOOS AND ASSOCIATES

Figure 3A



POTENTIAL NITRATE SOURCES AND WELL FIELD CAPTURE AREAS

DEER PARK, WASHINGTON

COMPREHENSIVE WATER PLAN

FIGURE 4 1" = 600'±

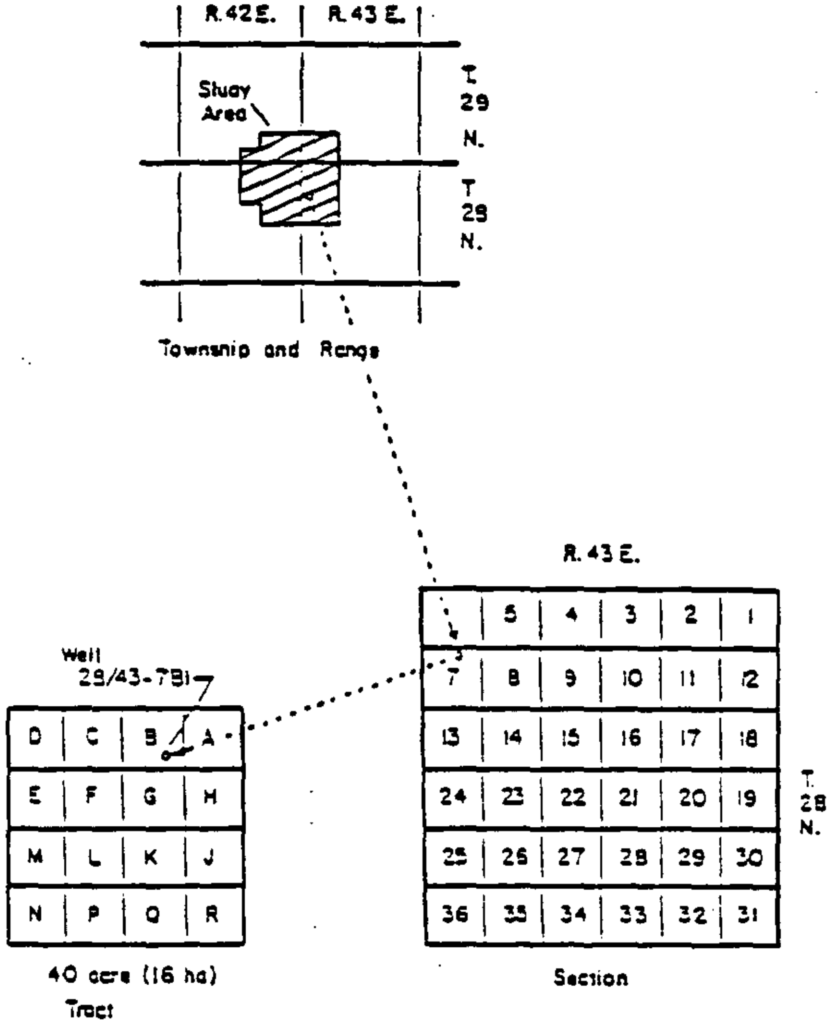


Figure 5 Well number system. A system of numbers and letters is used to designate the locations of wells (After Cline, 1969).

APPENDICES

Appendix A - 205j Grant Agreement

Appendix B - Randall Anderson Thesis

Appendix C - Nitrate in Drinking Waters

Appendix D - Chloride in Drinking Water, Wastewaters, and Brines

Appendix E - Tabulation of Groundwater Nitrate Data, 1986

205j Grant Agreement
Between
State of Washington Department of Ecology
and
Spokane County Health District

THIS is a binding agreement entered into by and between the State of Washington, Department of Ecology, hereinafter referred to as the "DEPARTMENT," and Spokane County Health District, hereinafter referred to as the "GRANTEE."

GRANTEE'S legal address and telephone number:

Spokane County Health District
West 1101 College Avenue
Spokane, WA 99201

THE PURPOSE of this agreement is to provide funds to the GRANTEE from the DEPARTMENT to conduct a geohydraulic study of the Deer Park area for the purposes of identifying sources of nitrate to the town's drinking water aquifer pursuant to RCW 90.48.260, and to aid in fulfilling the DEPARTMENT'S obligations under said chapter.

IT IS THEREFORE MUTUALLY AGREED THAT:

A. DEPARTMENT'S PERFORMANCE

The DEPARTMENT has found that the GRANTEE satisfies the applicable provisions of RCW 90.48.260 and the requirements of the DEPARTMENT. Having determined the proposed project is eligible for funds from the DEPARTMENT, the DEPARTMENT hereby offers a grant not to exceed the dollar amount specified in Appendix A (Scope of Work) to the GRANTEE subject to the GRANTEE's agreement to carry out its terms and conditions. This agreement is to aid in the financing of the project described in the attached Appendix A. No additional payment shall be made under this agreement except by written amendment.

B. PAYMENT OF GRANT FUNDS TO GRANTEE

1. Administrative costs of the GRANTEE and indirect costs are allowable as specified in Appendix A. The force account method will be allowed to the extent provided for in Appendix A.

2. Payment for major project elements described in Appendix A will be disallowed when the GRANTEE's request for reimbursement exceeds that element's total eligible cost by more than 5 percent without prior written approval.

   The DEPARTMENT will not provide reimbursement in excess of the DEPARTMENT's share of the total eligible project cost.

3. Requests for payment of eligible funds will be submitted by the GRANTEE on state voucher request forms provided by the DEPARTMENT. Each voucher shall be submitted to the DEPARTMENT along with information which documents the work performed, activities undertaken, and the progress of the project. The voucher request form and supportive documents must itemize all allowable costs by major elements as described in Appendix A. A general guideline for completion of the voucher request form and supportive documents is included in this agreement as Appendix B. Vouchers and supportive documents shall be submitted to:

Department of Ecology
Mail Stop PV-11
Olympia, WA 98504
Attention: Carol L. Fleskes

4. Payment requests will be submitted at least quarterly and not more often than monthly on a reimbursable basis.

5. All payments are conditioned upon submission to the DEPARTMENT of the above-mentioned itemized state voucher request form, certified by the GRANTEE. All payments will be for delivery of materials and/or services performed within the effective dates of this agreement unless a written modification is obtained.

6. The DEPARTMENT shall reimburse the GRANTEE for one hundred percent (100%) of the total eligible project cost set forth in Appendix A except for the amount withheld as security for GRANTEE'S performance as specified in Section B.7.

7. Ten percent (10%) of each reimbursement payment shall be withheld by the DEPARTMENT as security for GRANTEE's performance. Monies withheld by the DEPARTMENT as security under the provisions of this paragraph will be paid to the GRANTEE when the project(s) described in Appendix A have been completed, or portions thereof approved according to this agreement.

8. When voucher requests are approved by the DEPARTMENT, payments will be made to the mutually agreed upon designee.

9. The GRANTEE shall submit final request(s) for compensation within thirty (30) days after satisfactory completion of the project specified in Appendix A.

10. All payments to the GRANTEE shall be subject to final audit by the DEPARTMENT and any unauthorized expenditure(s) shall be refunded to the DEPARTMENT by the GRANTEE.

11. If mileage and per diem are paid, it shall not exceed the amount allowed state employees.

C. EFFECTIVE DATE AND TIME FOR PERFORMANCE

The effective date of this grant agreement shall be the date this agreement document is signed by the Assistant Director of the Office of Water Quality of the DEPARTMENT. Any work performed prior to the effective date of this agreement without prior written authorization will be at the sole expense and risk of the GRANTEE.

The project described in Appendix A must be completed on or before December 31, 1986.

This agreement shall expire no later than February 28, 1987.

In the event the GRANTEE fails to commence work on the project funded herein within four (4) months after the effective date of this agreement, or by any date mutually agreed upon in writing for commencement of work, the DEPARTMENT reserves the right to terminate this agreement.

D. KICKBACKS

The GRANTEE is prohibited from inducing by any means any person employed in the construction, completion, or repair of public work to give up any part of the compensation to which he/she is otherwise entitled by Department of Labor Regulations.

E. ACQUISITION PROJECTS

The following provisions shall apply if the project covered by this agreement includes funds for the acquisition of land or facilities:

1. Prior to disbursement of funds provided for in this agreement, the GRANTEE shall establish that the cost of land and/or facilities is fair and reasonable.

2. The GRANTEE shall provide satisfactory evidence of title or ability to acquire title for each parcel prior to disbursement of funds provided by this agreement. Such evidence may include title insurance policies, Torrens certificates, or abstracts, and attorney's opinions establishing that the land is free from any impediment, lien, or claim which would impair the uses contemplated by this agreement.

F. BIDDING

The GRANTEE shall not advertise for bids for construction until receipt of written approval from the Contract/Project Officer. Contracts for construction and purchase of equipment shall be awarded through a process of competitive bidding, if required by State law. No contract shall be awarded until approved in writing by the DEPARTMENT. The GRANTEE shall retain copies of all bids and contracts awarded for inspection and use by the DEPARTMENT.

G. CONVERSIONS

The GRANTEE shall not at any time convert any equipment, property, or facility acquired or developed pursuant to this agreement to uses other than those for which State assistance was originally approved without prior written approval of the DEPARTMENT. Such approval may be conditioned upon payment to the DEPARTMENT of that proportion of the proceeds of the sale, lease, or other conversion, or encumbrance which monies granted pursuant to this agreement bore to the original acquisition, purchase, or construction cost.

H. TERMINATION

1. For Cause: The obligation of the DEPARTMENT to the GRANTEE is contingent upon satisfactory performance by the GRANTEE of all of its obligations under this agreement. In the event the GRANTEE unjustifiably fails to perform any obligation required of it by this agreement, the DEPARTMENT may refuse to pay any further funds thereunder and/or terminate this agreement by giving written notice of termination. A notice shall be given at least five (5) days prior to the effective date of termination. In that event, all finished or unfinished documents, data studies, surveys, drawings, maps, models, photographs, and reports or other materials prepared by the GRANTEE under this agreement, at the option of the DEPARTMENT, shall become its property, and the GRANTEE shall be entitled to receive just and equitable compensation for any satisfactory work completed on such documents and other materials.

   Notwithstanding the above, the GRANTEE shall not be relieved of liability to the DEPARTMENT for damages sustained by the DEPARTMENT because of any breach of agreement by the GRANTEE. The DEPARTMENT may withhold payments for the purpose of setoff until such time as the exact amount of damages due the DEPARTMENT from the GRANTEE is determined.

2. Insufficient Funds: The obligation of the DEPARTMENT to make payments is contingent upon the availability of such funds through legislative appropriation, State allotment, and the sale of bonds authorized by RCW 90.48.260. When this agreement crosses over state fiscal years, the obligation of the DEPARTMENT is contingent upon the allotment of funds during the next fiscal year.

I. RECOVERY OF PAYMENTS TO GRANTEE

The right of the GRANTEE to retain monies paid to it as reimbursement payments is contingent upon satisfactory completion of the project described in Appendix A. In the event that the GRANTEE fails to perform any obligation required of it by this agreement, and does not complete the project described in Appendix A, the GRANTEE shall pay interest on the amount of outstanding funds disbursed. In addition, the GRANTEE shall pay interest on the amount of outstanding funds dispersed computed at 12 percent per annum. Interest shall accrue from the time the DEPARTMENT demands repayment of funds. Any property acquired under this agreement, at the option of the DEPARTMENT, may become the DEPARTMENT's property and the GRANTEE's liability to repay monies shall be reduced by an amount reflecting the fair value of any such property.

J. COMPLIANCE WITH APPLICABLE LAWS, AND REGULATIONS

1. The GRANTEE shall comply fully with all applicable Federal, State and local laws, orders, regulations and permits, such as, but not limited to, compliance with State Environmental Policy Act and Shoreline Management Act, approval of engineering reports and facility plans prior to commencing design, and approval of plans and specifications prior to advertising for bid. The GRANTEE shall secure the necessary permits required by authorities having jurisdiction over the project, provide assurance that all permits have been secured, and make copies available to the DEPARTMENT if requested.

2. Discrimination, Labor, and Job Safety - The GRANTEE shall fully comply with all applicable Federal, State, and local laws, and regulations related to discrimination, labor, and job safety. Further, the GRANTEE shall affirmatively support the State Minority and Women Owned Businesses policies.

3. Industrial Insurance - The GRANTEE certifies full compliance with all State industrial insurance laws where applicable. If the GRANTEE fails to comply with such laws, the DEPARTMENT shall have the right to immediately terminate this agreement for cause as provided in Section H.1., herein.

K. INDEMNIFICATION

1. The DEPARTMENT shall in no way be held responsible for payment of salaries, consultant's fees, and other overhead costs related to the project described herein, except as provided in Appendix B.

2. To the extent the Constitution and Laws of the State of Washington permit, the GRANTEE shall indemnify and hold harmless the DEPARTMENT from any claim of liability arising out of the project described in this agreement, or from operation of the facilities or equipment obtained.

L. CONTRACT/PROJECT OFFICER

1. The extent and character of all work and services to be performed by the GRANTEE shall be subject to the review and approval of the DEPARTMENT through the Contract/Project Officer to whom the GRANTEE shall report and be responsible. In the event that there shall be any dispute with regard to the extent and character of the work to be done, the determination of the Contract/Project Officer as to the extent and character of the work to be done shall govern. The GRANTEE shall have the right to appeal as provided for below.

2. For the purpose of this agreement, the Contract/Project Officer shall be Carol L. Fleskes unless otherwise changed in writing by the Assistant Director of the Office of Water Quality.

M. DISPUTES

Except as otherwise provided in this agreement, any dispute concerning a question of fact arising under this agreement which is not disposed of in writing shall be decided by the Contract/Project Officer, who shall provide a written statement of decision to the GRANTEE. The decision of the Contract/Project Officer shall be final and conclusive unless, within thirty (30) days from the date of receipt of such statement, the GRANTEE mails or otherwise furnishes to the Contract/Project Officer a written appeal addressed to the Director of the DEPARTMENT. In connection with appeal of any proceeding under this clause, the GRANTEE shall be afforded an opportunity to be heard and to offer evidence in support of this appeal. The decision of the Director, or duly authorized representative for the determination of such appeals, shall be final and conclusive. Appeals from the Director's determination shall be brought in the Superior Court of Thurston County. Review of the decision of the Director will not be sought under Chapter 43.21B RCW. Pending final decision of a dispute hereunder, the GRANTEE shall proceed diligently with the performance of the agreement and in accordance with the decision rendered.

N. AUDITS AND INSPECTIONS

1. The GRANTEE shall maintain complete program and financial records relating to the construction or purchases of equipment financed in part by this agreement. Engineering documentation and field inspection reports of all construction work accomplished with this agreement shall be maintained by the GRANTEE. Such records shall clearly indicate total receipts and expenditures by fund source and object classification. All records shall be available to the DEPARTMENT for such use as the DEPARTMENT sees fit.

2. Engineering documentation of construction, and all financial records prepared by the GRANTEE shall be open for audit or inspection by the DEPARTMENT or by any duly authorized audit representative for a period of at least three years after the final grant payment or any dispute hereunder; and in the event any such audits determine discrepancies in the financial records adjustments and/or clarification shall be made accordingly.

3. All work performed under this agreement and any equipment purchased, shall be made available to the DEPARTMENT and to any authorized State, Federal, or local representative for inspection at any time during the course of this agreement and for at least three years thereafter, or following any dispute thereunder.

4. The GRANTEE shall keep all records in a manner which will provide an audit trail to the expenditures for which State support is provided, and all records shall be kept in a common file so as to facilitate audits and inspections.

O. MISCELLANEOUS PROVISIONS

1. Copyrights and Patents: When the GRANTEE creates any copyrightable material(s), or invents any patentable property, the GRANTEE may copyright or patent the same, but the DEPARTMENT retains a royalty-free, nonexclusive, and irrevocable license to reproduce, publish, recover, or otherwise use the material(s) or property and to authorize others to use the same for Federal, State, or local governmental purposes.

2. Tangible Property Rights: The DEPARTMENT's current edition of "Financial Guidelines for Grants Management," Ch. 4, shall control the utilization and disposition of all real and personal property purchased wholly or in part with funds furnished by the DEPARTMENT in the absence of State/Federal statute(s), regulation(s), or policy(s) to the contrary.

3. Conflict of Interest: No officer, member, agent, or employee of either party to this agreement who exercises any function or responsibility in the review, approval, or carrying out of this agreement, shall participate in any decision which affects his/her personal interest or the interest of any corporation, partnership or association in which he/she is, directly or indirectly interested; nor shall he/she have any personal or pecuniary interest, direct or indirect, in this agreement or the proceeds thereof.

4. Assignments: No right or claim of the GRANTEE arising under this agreement shall be transferred or assigned by the GRANTEE.

5. Waiver: Waiver of any GRANTEE default is not a waiver of any subsequent default. Waiver of a breach of any provision of this agreement is not a waiver of any subsequent breach and will not be construed as a modification of the terms of this agreement unless stated as such in writing by the authorized representative of the DEPARTMENT.

6. Subgrantee Compliance: The GRANTEE is responsible for ensuring that all subgrantees, contractors, etc., comply with the terms of this agreement.

P. ALL WRITINGS CONTAINED HEREIN

This agreement, appendices, exhibits, and the DEPARTMENT's current edition of "Financial Guidelines for Grants Management" and the appropriate Program Guidelines, contain the entire understanding between the parties, and there are no other understandings or representations set forth or incorporated by reference herein. No subsequent modification(s) or amendment(s) of this agreement shall be of any force or effect unless in writing, signed by authorized representatives of the GRANTEE and DEPARTMENT and made a part of this agreement; EXCEPT, that in relation ~~to~~; 1) increases or decreases in the grant amount as set forth in Appendix A, Grant Amount Adjustments; 2) change of Contract/Project Officer as set forth in Section L; and 3) in relation to project completion and agreement date extensions as set forth in Section C, the DEPARTMENT may modify or amend this agreement without the signature of the GRANTEE.

STATE OF WASHINGTON
DEPARTMENT OF ECOLOGY

Carol Jolly 2-24-86
CAROL JOLLY DATE
ASSISTANT DIRECTOR
DEPARTMENT OF ECOLOGY

GRANTEE

Mary [illegible]
SPOKANE COUNTY HEALTH DISTRICT DATE

Approved as to form this 2 day
of January, 1986.

Gary J. Manning
ASSISTANT ATTORNEY GENERAL

Grant No. G0086058

Accounting Data ____________

APPENDIX A

GOAL: To evaluate baseline geohydraulic information relative to the Deer Park drinking water aquifer for the purpose of defining the causes of nitrate contamination to the aquifer; to involve the public in the process through public meetings; to inform involved agencies of problems and preliminary findings; and to evaluate means to make potable water available to property owners with contaminated wells.

SCOPE OF WORK:

Objectives	Task/Procedure	Outputs
I. Determine a perimeter/boundary of the aquifer flowing in the direction of the high nitrate contaminated wells.	1) Obtain property location information from County Assessor's maps.	1) Develop a summary map showing relative positions of wells and surficial geology.
	2) Inspect surficial geology, topography, and well spacing.	
II. Within the defined aquifer flow boundary, characterize and identify land uses, depth and well locations, and determine potential nitrate contamination sources.	1) Use County Assessor's maps with the surficial geology boundaries identified.	1) Consolidate and overlay information on same summary map as begun for Objective I.
	2) Interview property owners and note well construction location, relative to contamination sources and conduct well depth measurements.	
III. Determine which ground water aquifers are being utilized by various wells, and sample existing wells to characterize source and effects of nitrate contamination in each of the aquifers.	1) Gather and scrutinize existing hydrogeologic data from USGS, USDA, EPA, Ecology, consulting engineers, well drillers, and property owners. information.	1) Develop maps of potentiometric surface, cross-sections fence diagrams of surface relationships based on well log (lithofacies)
	2) Sample selected wells for concentration of nitrates, chlorides, and coliform bacteria.	2) Utilizing maps and water sample data, develop a report on the relationship of areal variations in water quality to ground water flow direction and orientation of
	3) Ascertain subsurface geology and stratigraphy and delineate extent and number of aquifers including: depth to basalt, net sand, gravel in wells, water	

Objectives	Task/Procedure	Outputs
	table elevations in aquifers, transmissivity, hydraulic conductivity, and chemical data.	lithofacies. Report to include preliminary conclusions on cause and effect relationships based on first year's sampling and geological data without test wells.
IV. Review and evaluate alternatives for potable water supply.	1) Review all data and reports to determine most feasible water source for property owners whose wells are contaminated.	Evaluation of the following Alternative Water Source Measures: 1) Deepen existing well. 2) Drill new well into contamination free aquifer. 3) Mix or dilute contaminated water with a noncontaminated source. 4) Connect to a neighboring contamination-free water source. 5) Chemically treat or filter water to remove contamination.
V. Convey information to all appropriate local, state, and federal agencies.	1) Send copy of final report to DSHS, Ecology, USGS, and EPA	1) Agencies will record and incorporate information into their maps, files, and records.
VI. Public notification.	1) Public meetings preceded by written notice in local newspaper.	1) Describe the objectives and procedures of the work plan prior to launching any of the on-site field investigations and water sampling activities. 2) After completing the first year of information gathering, share preliminary results with public at a meeting. 3) Convene a final public meeting to discuss alternatives for corrective action.

BUDGET BY TASK

Objective	Task	Total Cost
I.	Determine Aquifer Boundary	$ 344.00
II.	Identify land uses and characterize aquifer for source identification	11,820.00
III.	Determine well use and ground water quality	27,389.17
IV.	Evaluate alternative sources for potable water	3,849.40
V.	Information dissemination	8,646.43
VI.	Public participation	443.25
		$52,492.25

BUDGET BY OBJECT

	JFM	AMJ	JAS	OND	TOTAL
Salary	$10,803.91	$8,294.00	$4,110.82	$6,725.30	$29,934.03
Benefits	2,782.18	2,154.68	1,108.84	1,762.49	7,808.19
Services (Contract)	1,737.10	1,511.36	1,590.00	2,129.00	6,967.46
Indirect	850.74	647.33	396.19	520.20	2,414.46
Travel	451.84	336.48	232.07	745.06	1,765.45
Supplies	999.49	909.66	840.00	853.51	3,602.66
					$52,492.25

Total Ecology 205(j) Cost - $52,492

GRANT AMOUNT ADJUSTMENT

The Contract Officer, as provided for in Section P, may increase or decrease the amount of this grant by an amount not to exceed ten percent (10%) of the total grant amount shown in this Appendix A. Notification of said adjustment shall be in writing to the GRANTEE and signed by the Contract Officer. Any expense incurred in excess of the grant amount prior to an increase authorized in writing by the Contract Officer shall not be eligible for reimbursement.

The aggregate amount of grant increases made by the Contract Officer under this clause may not exceed ten percent (10%) of the grant amount shown in Appendix A. Any necessary increases in excess of this ten percent (10%) limit must be executed by an authorized amendment to this agreement, as set forth in Section P.

SCHEDULE

Objective/Task	J F M	A M J	J A S	O N D
I. Boundary Definition	————	————		
II. Aquifer Characterization	————	————		
III. Ground Water Quality	————[1]	————[1]	————[1]	————[1]
IV. Alternative Water Supply			————	————
V. Information Dissemination				——[2]
VI. Public Participation	*[3]			*[4]

[1] Quarterly Reports
[2] Final Project Report
[3] First Public Meeting
[4] Final Public Meeting

Appendix B

GUIDELINE:
SUBMISSION OF A19-1 VOUCHER AND SUPPORTIVE DOCUMENTS

The purpose of this appendix is to assist the CONTRACTOR/GRANTEE in determining allowable items of cost. If the CONTRACTOR/GRANTEE fails to name an item of cost in the request for payment, this does not imply it is either allowable or unallowable; rather, determination of allowability shall be based upon the treatment of similar or related items of cost.

1. Factors Allowing Cost

In order to be allowable, costs must:

a. Be necessary and reasonable and not be a general expense,
b. Not be prohibited by any laws or regulations,
c. Conform to any cost limitations or exclusions,
d. Be consistent with state and federal (when applicable) policies, regulations and procedures,
e. Be given consistent treatment through uniform accounting principles,
f. Not be allocated to or included as a cost of any other state/federally financed program, past, or present,
g. Be net of all allowable credits.

2. Certification

To assure expenditures are proper, vouchers requesting payment must be certified by the CONTRACTOR/GRANTEE. Form A19-1 has a certification provision which must be signed by the CONTRACTOR/GRANTEE or its authorized representative before payment will be allowed.

3. Credits

The applicable portion of any income, rebate, allowance, and other credit relating to any allowable cost, received by or accruing to the CONTRACTOR/GRANTEE, must be credited to the DEPARTMENT, either as a cost reduction, or by cash refund, as appropriate.

4. Unforeseen/Emergency Expenditures

A contingency line item providing a specified amount for reimbursements for unforeseen expenditures may be made only with the prior written approval of the DEPARTMENT.

5. Allowable Expenditures

No request for payment will be honored for those expenditures incurred before the commencement date of the agreement, or after termination of such agreement, unless otherwise agreed upon in writing.

6. Contract Provisions Controlling

Where any discrepancies between the specific provisions of the agreement and the applicable cost principles arise, the agreement provisions shall apply.

7. Deviation From Major Project Elements

Payment for major project elements described in Appendix "A" will be disallowed when the GRANTEE'S request for reimbursement exceeds that element's total eligible cost without prior written approval.

The DEPARTMENT will not provide reimbursement in excess of the DEPARTMENT'S share of the total eligible project cost.

8. Phone Number

The CONTRACTOR/GRANTEE must include his business phone number along with the documents requesting payment to expedite processing should questions arise.

9. Instructions - Form A19-1

Specific instructions for filling out the A19-1 voucher and supportive documents are found in "Financial Guidelines for Grants Management," Chapter 6, published by the Washington State Department of Ecology (WDOE). A copy of this text is available from the DEPARTMENT and is furnished with the Pre-Application package.

10. Cost Object Breakdown

The documents supporting each request for payment must have a brief concise breakdown of each cost object under the agreement, along with a brief explanation for the charges.

11. Allowable Costs

Generally, whether costs are allowable depends upon cost principles applicable to the particular project agreement. However, certain costs are commonly allowed. These include:

advertising
compensation for personal services
depreciation and use allowances
employee fringe benefits
employee morale, health and welfare
maintenance and repair
materials and supplies
taxes
training and education
transportation
travel related directly to this Referendum 39 grant

Employee benefits in the form of regular compensation paid to employees during periods of authorized absences from the job, such as for annual leave, sick leave, court leave, military leave, and the like, if they are: (1) provided pursuant to an approved leave system, and (2) the cost thereof is equitably allocated to all related activities, including grant programs.

Employee benefits in the form of employers' contribution or expenses for social security, employees' life and health insurance plans, unemployment insurance coverage, workmen's compensation insurance, pension plans, severance pay, and the like, provided such benefits are granted under approved plans and are distributed equitably to grant programs and to other activities.

Where any questions involving allowability of costs arise, the DEPARTMENT contracts officer should be consulted; otherwise, certain costs may be disallowed.

12. Payroll and Distribution of Time

Amounts charged for personal service, regardless of whether treated as direct or indirect costs, will be based on payrolls documented and approved in accordance with the generally accepted practice of the state or local agency. Payrolls must be supported by time and attendance or equivalent records for individual employees. Salaries and wages of employees chargeable to more than one cost objective must be supported by appropriate time distribution records. The method used should produce an equitable distribution of time and effort. Such time records must be certified by the project director. Such certified records are the only allowable source document for charging and reporting personnel expenditures.

13. Costs Allowable With Prior Written Approval

Certain costs require prior written approval of the DEPARTMENT. Costs requiring prior approval include indirect costs, some direct costs such as equipment, insurance and indemnification, and preagreement costs. Again, reference to cost principles and consultation with DEPARTMENT officials should eliminate any questions and possible rejection of incurred costs.

14. Unallowable Costs

Certain Costs are commonly disallowed. These unallowable costs include:

bad debts
contingencies
contributions and donations
entertainment
fines and penalties
interest and other financial costs
underrecovery of costs under grant agreements
See Section XI, D.3., "Financial Guidelines For Grants Management"

Once again, whether a cost is unallowable depends upon the applicable cost principles to the agreement. Failure to clarify any question whether a cost is unallowable or allowable may result in its disallowance by the DEPARTMENT.

APPENDIX B

HYDROGEOLOGIC STUDY OF THE DEER PARK, WASHINGTON AQUIFER SYSTEM

A Thesis
Presented to
Eastern Washington University
Cheney, Washington

In Partial Fulfillment of the Requirements
For the Degree
Master of Science
in
Geology

By
Randall Anderson
Fall, 1986

THESIS OF RANDALL ANDERSON APPROVED BY

John P. Buchanan 21 NOVEMBER 1986
Chairman, Graduate Study Committee Date

Eugene Kiver 11/21/86
Member, Graduate Study Committee Date

John E. Douglas 11/21/86
Member, Graduate Study Committee Date

Theophil M. Otto 11-21-86
Librarian Date

ABSTRACT

The Deer Park, Washington aquifer system consists of two aquifers: a relatively shallow unconfined aquifer in glaciolacustrine and glaciofluvial sediments and a deeper semiconfined basalt aquifer. Domestic and municipal water wells of Deer Park constructed in the unconsolidated sediments have exceeded the United States Public Health Service (1962) recommended drinking water standard of 10 milligrams per liter for nitrate-nitrogen. Nitrate-nitrogen concentrations greater than 10 mg/l pose a health threat to humans, especially infants. Infants fed formula made from high-nitrate water may develop cyanosis or methemoglobinemia, which can lead to death.

Infiltration of nitrate-rich groundwater into the surficial unconfined glacial-sediment aquifer produces varying levels of contamination. The levels range from less than 1.0 mg/l to greater than 100 mg/l. Nitrate concentrations plotted on a map appear to indicate a random distribution of values. However, within the study area there are two areas of concern which include the city of Deer Park and Section 6, T.28 N., R.43 E.W.M. Sources of nitrates may include septic tanks, barnyards and feedlots, farm fertilizers and animal and municipal wastes.

Shallow wells tapping the unconsolidated surficial sediment aquifer near nitrate sources are most susceptible to nitrate contamination. Nitrate-rich water may reach the water table via abandoned or poorly constructed wells and by percolation through the zone of aeration. Deeper wells penetrating the basalt aquifer that effectively case off the unconsolidated sediments are less likely to become contaminated.

Prevention of contamination of the aquifer near a water well includes 1) suitable location, that is, away from present and future nitrate sources, 2) substantial depth, which may mean deepening existing wells and casing past nitrate-rich groundwater, 3) maintaining a surface seal so that contaminated water does not communicate to the water table, and 4) proper well construction and maintenance.

ACKNOWLEDGEMENTS

I would like to thank the Spokane County Health Department, Environmental Division for arranging financial assistance for this thesis. In particular I want to acknowledge John Jordan, Mike LaScuola, Daryl Way and Dennis Kroll for their stimulating conversations concerning the problem of nitrate contamination. I would like to thank my wife Susan for her help and patience with my thesis. I would like to thank Dr. John Douglas for being on my thesis committee. I would like to thank Dr. Eugene Kiver for his assistance with my thesis and a special thanks to Dr. John Buchanan for his expertise and good humor.

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INTRODUCTION

The Spokane County Health District, Environmental Health Division, has determined that the aquifer, which is the source of drinking water for an estimated 3,000 persons in an approximately 20 square mile (52 square kilometer) area inclusive of and adjacent to the city of Deer Park, Washington, is affected by nitrate contamination. Some private wells around Deer Park and one of the city's public water supply wells have exceeded the allowable nitrate-nitrogen (NO_3-N) level set by the Environmental Protection Agency and the United States Public Health Drinking Water Standards (1962).

Many authors, including Goldberg (1970), have presented a catalog of some sources of nitrogen in water supplies resulting from agriculture, animal and human wastes, atmosphere, feedlots, geology, industrial wastes, lake sediments, pond waters, rural and urban wastes and storm water. Several potential sources of nitrate contamination in the Deer Park area include storage and distribution of poultry wastes (from a nearby egg farm), Deer Park's sewage disposal plant, septic tanks, storage facilities of blasting compounds in abandoned missile silos (northeast of Deer Park's airport), the use of chemical fertilizers, and barnyard wastes. Because of local, state and federal concern about the effects of degradation of groundwater quality, the Spokane County Health District, Environmental Health Division, in conjunction with the city of Deer Park and the Washington Department of Ecology, requested funds for water quality management planning under section 205(j) of the Federal Clean Water Act. A concept paper was formulated by Kroll and Hicks (1985) of the Spokane County Health Department, Environmental Health Division, outlining a comprehensive groundwater study of the Deer Park area. Eastern Washington University, through Professor John Buchanan, was sub-contracted to perform the hydrogeological and geologic investigation of the Deer Park area.

OBJECTIVES AND APPROACH

The objectives of the study were to determine the geology and hydrogeology of the study area and to describe the concentrations of dissolved substances in the aquifer. The approach used to meet these objectives include: 1) assembling and interpreting data collected by previous authors, 2) mapping the surface and subsurface geology, 3) summarizing aquifer characteristics within the study area, including groundwater table elevations, porosity, permeability, groundwater recharge and discharge zones, transmissivity and aquifer storage, 4) determining the lateral and vertical extent and flow direction of the contaminated zones, and 5) identifying the potential source(s) of nitrate contamination.

PREVIOUS INVESTIGATION

Surficial geology of north-central Spokane county has been mapped by Cline (1969) and Griggs (1973). Kiver (Personal communication, 1979) has aerially interpreted the surficial geology on the 7.5 minute Deer Park quadrangle (unpublished map).

Water quality data of the Deer Park area has been conducted by Cline (1969). Van Denbaugh and Santos (1965) analyzed groundwater samples from northeastern Washington.

Hydrogeologic studies of the Deer Park area have been conducted by Cline (1969) and Tanaka (D.O.E. memorandum, 1980). Other studies not pertaining to the Deer Park area, but within the general region, include those by Luzier and Burt (1974), Tanaka and others (1974), Drost and Seitz (1978), and Olson (1979).

REGIONAL SETTING

In Spokane county, the study area including the community of Deer Park is located approximately 15 miles (25

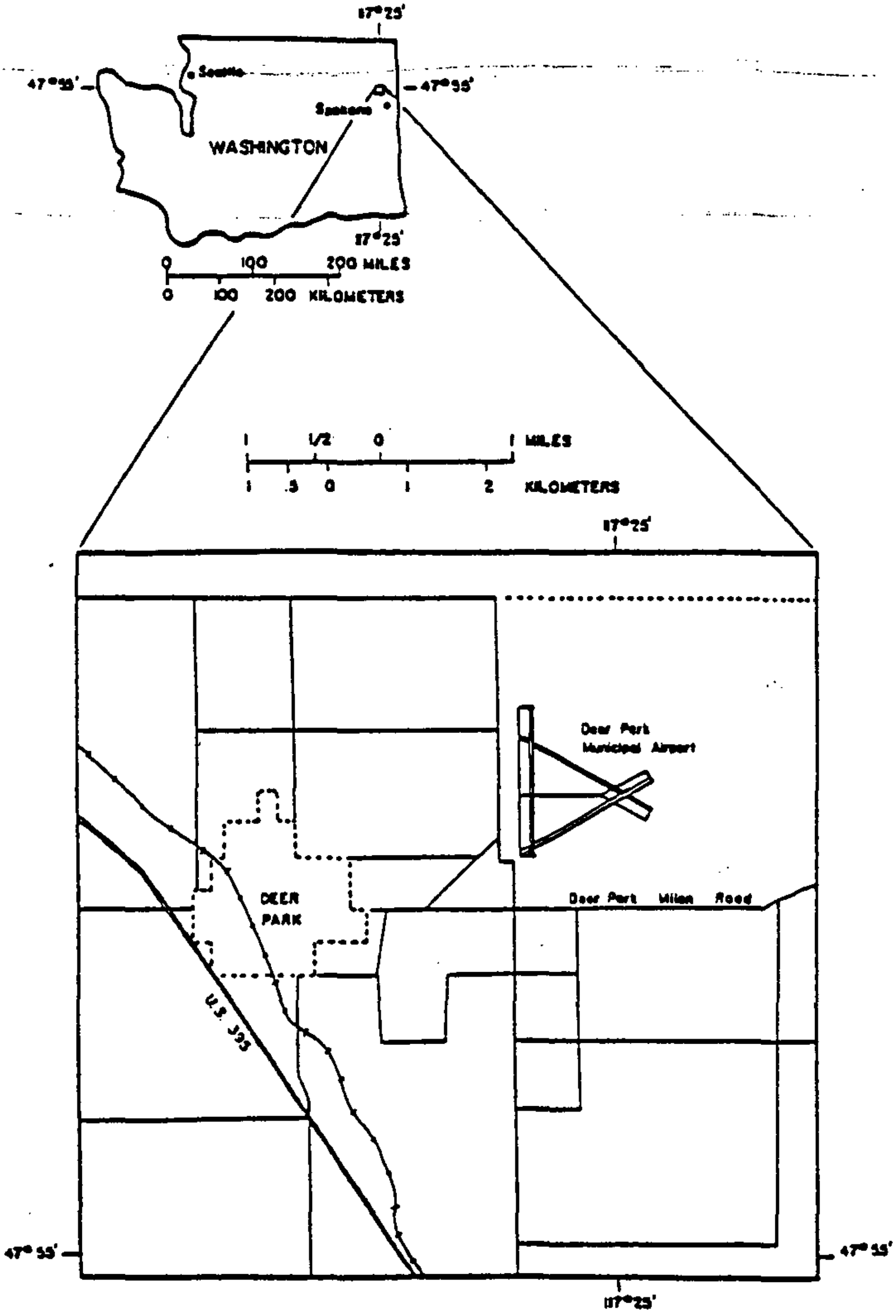


Figure 1. Location of study area.

kilometers) via Highway 395 north of Spokane, Washington (Figure 1). The semi-rural area is situated on a small broad plain between Deer Park and Milan.

Topography and Drainage

Regionally, Deer Park is on a 2200 foot (670 meter) plateau forming part of the foothills of the Selkirk Mountains, which attain an elevation of 5900 feet (1798 m) at Mount Spokane, and extend northward into Canada. The Deer Park plain extends into the Chewelah Valley to the north and the Spokane Valley to the south.

The study area covers an area of approximately 20 square miles (52 square km). Changes in elevation are not great, with the lowest altitude about 2000 feet (619 m) and the highest altitude approximately 2200 feet (670 m). Major drainages include the Little Spokane River and Dragoon Creek. The Little Spokane River forms the eastern drainage and flows south at an average discharge, measured at the Dartford gauging station, of 286 cfs (cubic feet per second) (8.0 cubic meters per second) (U.S. Geological Survey Water-Water Supply Paper 2133, 1977). Dragoon Creek and the Spring Creek tributary flow through the western corner of the city of Deer Park. Periodic measurements of flow in Dragoon Creek show that the mean discharge is 26 cfs (0.7 cms) (Water Resources Data for Washington, 1977). It appears that Dragoon Creek (Figure 2)

EXPLANATION

Water Well Location

N1 ○	From water well report
J1 △	From Cline (1969)
A—A'	Cross section location

Figure 2. Explanation for map showing locations for water wells and cross-sections.

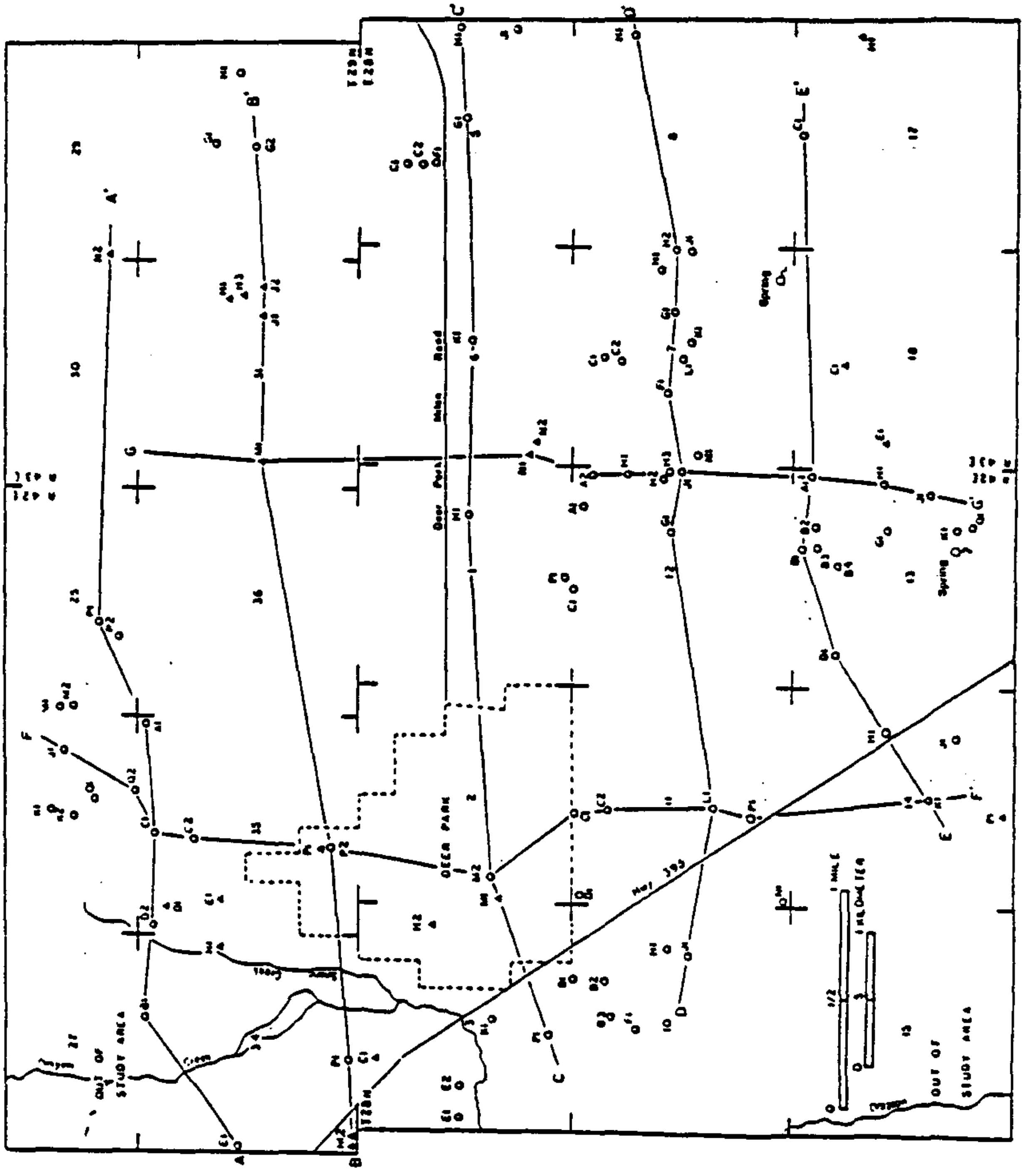


Figure 2a. Map showing locations for water wells and cross-sections.

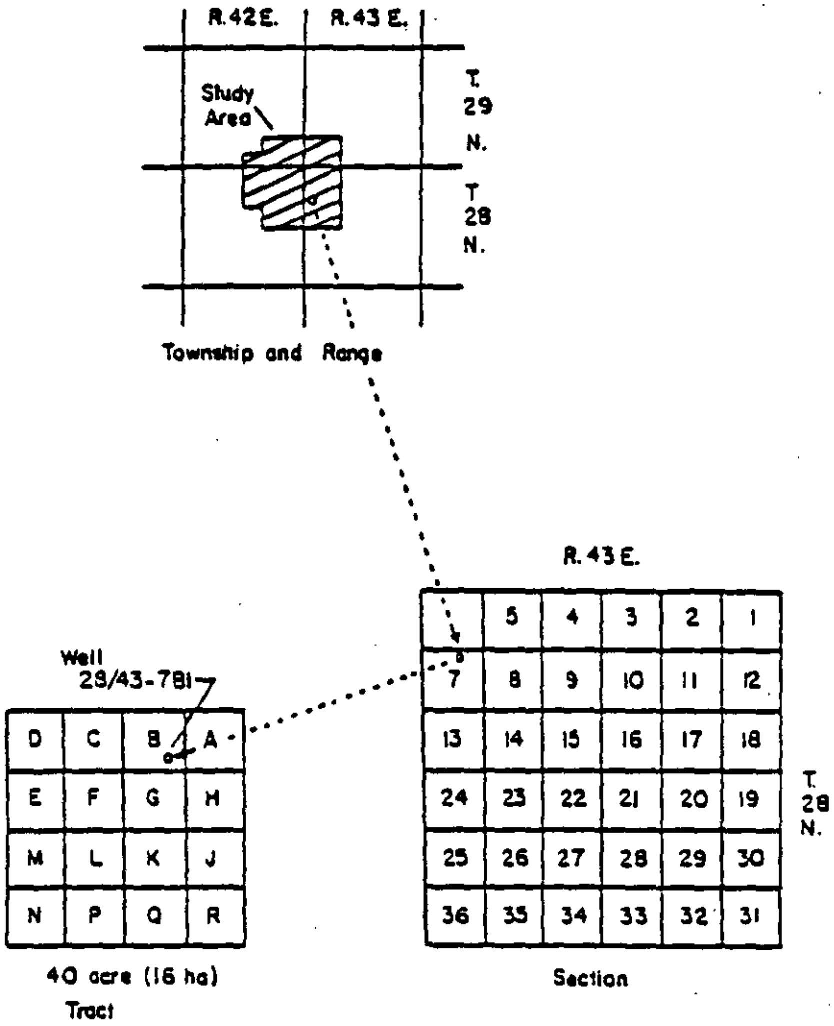


Figure 3. Well number system. A system of numbers and letters is used to designate the locations of wells (After Cline, 1969).

changed its flow direction, because it diverges to the west immediately south of Deer Park before resuming its southerly meandering course. Dragoon Creek and the Little Spokane River then flow into the Spokane River, which flows westerly to the Columbia River. Several intermittent streams traverse the study area. Two springs at about the 2050 foot (624 m) elevation are located in the southern portion of the study area. The elevation of the springs corresponds to the elevation of basalt contacts.

Water Well Locations

Figure 2 is a map of water well site location and locations for geologic cross-sections (Plates 1-7). A system of numbers and letters is used to designate the location of wells (Cline, 1969). Using the example shown in Figure 3, well 28/43-7B1 is located in Section 7, Township 28 North, Range 43 East of the Willamette baseline and meridian. The capital letter indicates the 40-acre (16 hectare) tract within that section. The last number indicates the order in which the wells are inventoried in each 40-acre (16 ha) tract.

GEOLOGIC SETTING

Geology of the cross-sections shown in Figure 4 and Plates 1-7 is based on water well logs completed by the well driller and submitted to the Department of Ecology. The geology is a literal lithologic description and not rock-stratigraphic units as defined in the "Code of Stratigraphic Nomenclature" (1983). No attempt was made to interpret genetically the rock units represented in cross-sections through the study area.

Pre-Tertiary Intrusive

The oldest rock unit in the study area is a pre-Tertiary granitic rock considered to be part of the Loon Lake batholith (Figure 4). Millar and Clark (1975) describe a quartz monzonite, which has similar characteristics to the intrusive that outcrops in Section 7, T.28N., R.43E. of the study area. The pluton, according to Millar and Clark (1975), extends into the Clayton quadrangle and may crop out as far as 20 miles (32 km) to the southwest, which is just north of the study area. Within the study area, the intrusive appears as a weathered leucrocratic muscovite quartz monzonite.

Latah Formation

The Latah Formation is considered to be Miocene in age (Cline, 1969). As described by Pardee and Bryan (1925), the Latah Formation is a series of beds consisting mostly of clay and shale of fresh water origin, containing abundant Middle or Lower Miocene flora. The authors state that these

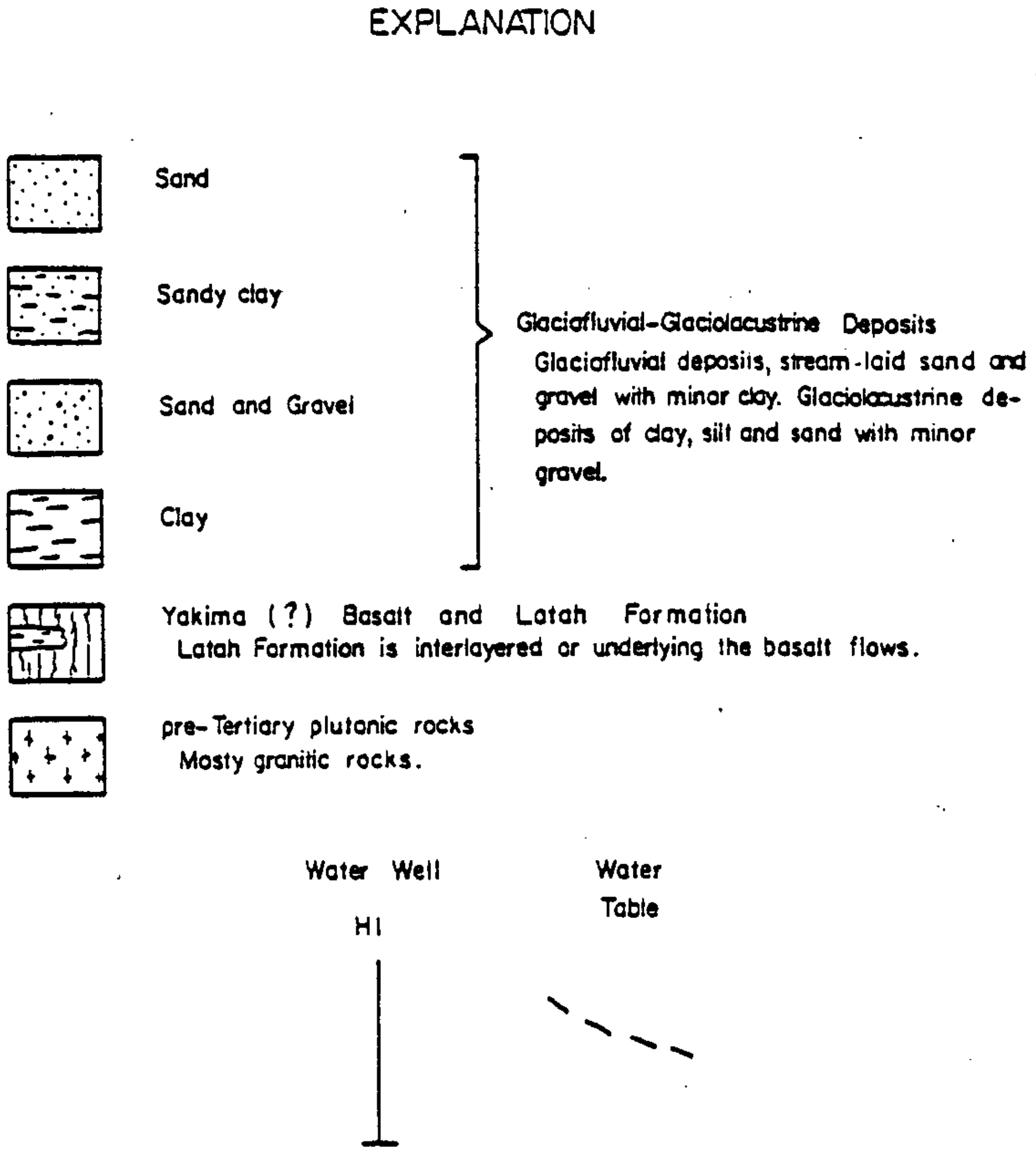


Figure 4. Explanation and description for Figure 4a and Plates 1-7. See Figure 2 for location of cross-sections. Vertical exaggeration for plates is 25 times. Geologic description after Cline (1969).

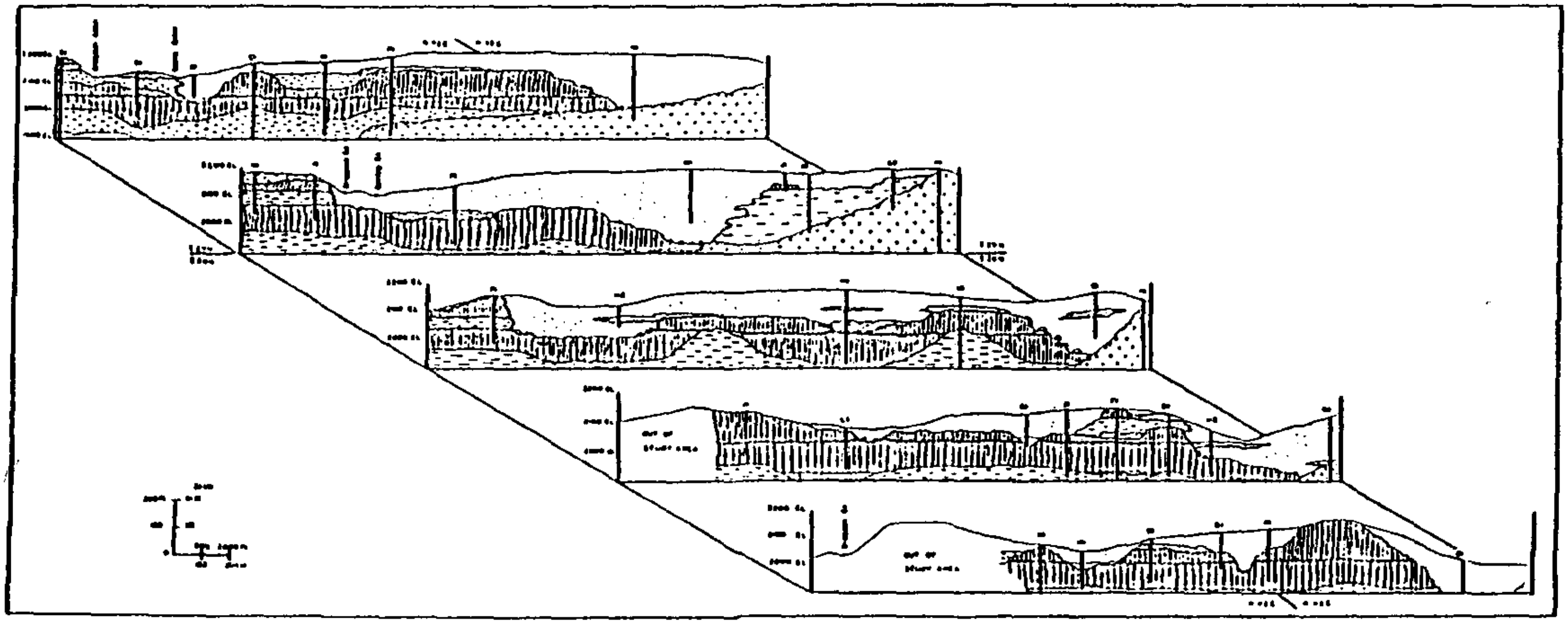


Figure 4a. Composite of east-west cross-sections through study area. Vertical exaggeration is 10 times. Cross-sections from bottom to top are Plates 1 to 5. Elevations are in feet above sea level.

beds rest upon an erosional surface developed on granite and metamorphic rocks of unknown age. The following authors have also described the Latah Formation as interformational units of the Columbia River Basalt flows: Kirkham and Johnson (1929), Glover (1941), Mackin (1961), Mackin and Cary (1965), Cline (1969), Griggs (1973), and Olson (1979).

Pardee and Bryan (1925) describe the colors of the formation as ranging from yellowish-gray to lead-gray or bluish-gray and indicate that the fossil-bearing beds consist mostly of clay and shale with minor sandy layers. Cline (1969) states that no Latah outcrops in the Deer Park area, but approximately one mile (1.6 km) to the east of the study area on Westmoreland Road, the Latah Formation was noted at the 1969 foot (600 m) elevation. In well number 29/42-34E1 (Figure 2), a piece of coalified wood was collected by the owner from below a basalt flow at a depth of 285 feet (86.8 m). Cline (1969) notes that plant remains are common in the Latah Formation and that pieces of wood have been found during well drilling. Thickness of the Latah Formation in the Deer Park area is highly variable and probably does not exceed a few hundred feet (meters) (Cline, 1969). As seen in the cross-sections (Plates 1-7), Latah clays range from absent to approximately 120 feet (0-36.5 m) in thickness.

A deep excelsior weathering period was occurring in the study area during the Miocene epoch (Lehrman, personal communication, 1979). The Selkirk Mountains and other eastern Washington ranges were probably the highest obstacles in the way of any advancing weather fronts from the west and consequently deep soil profiles may have existed on many of the plains west of these mountains (Anderson, memorandum to Dawn Mining Company, 1980). No attempt has been made to differentiate residual clays from Latah clays in the cross-sections of the study area. Glover (1941) showed that some clay deposits were doubtlessly forming before the invading basalts had a chance to block pre-existing stream valleys that contemporaneously formed Latah deposits (Figure 5). Huntting (1966) notes that some of the clays found in Spokane county were derived from pre-Tertiary igneous rocks.

Yakima (?) Basalt

Within the study area, basalt flows outcrop predominantly in the southern portion (Figure 6). Cline (1969) defines the basalt flows as the Yakima (?) Basalt of the Columbia River Group. G.O. Smith coined the name "Yakima Basalt" for the basaltic flows of equivalent age in Washington (Baldwin, 1950).

The Columbia River Basalt was extruded upon an erosional surface of varying ages and with varying degrees of relief (see, for example, Plate 1). Baldwin (1950) states that the thickness ranges from that of a

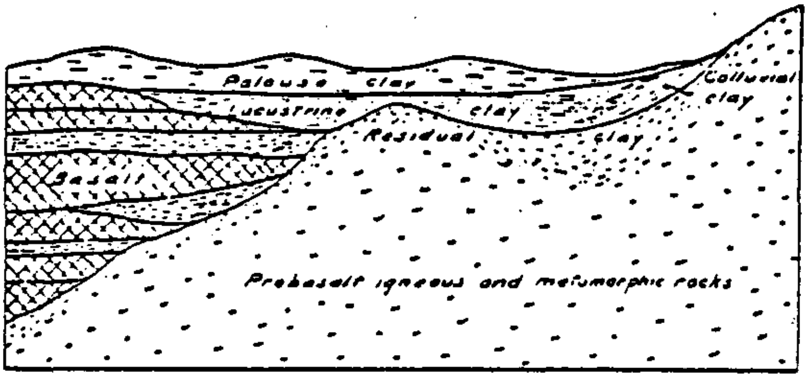


Figure 5. Section to illustrate the relationship between pre-Tertiary granitic rocks, basalt flows and interflow lacustrine (Latah) clays. (Taken from Glover, 1941, p. 231).

EXPLANATION

Quaternary	Qgl	**Glaciolacustrine Deposits** Deposits consist of silt, sand and some clay, with a little gravel. Usually stratified. In places covered by thin remnants of flood deposits. (After Griggs, 1973).
Tertiary	Tcl	**Yakima (?) Basalt** Flows of dense, dark basalt belonging to the upper part of the Columbia River Group. Included but not shown separately are interlayered beds of the Latah Formation. The Latah Fm is composed of siltstone, claystone and minor conglomerate. (After Griggs, 1973).
pre-Tertiary	pTg	**Granitic rocks** Plutons to batholithic complexes of predominately quartz monzonite and granodioritic composition. (After Griggs, 1973).

Contact ———— - - - - - -

Contacts, approximately located. Dashed where inferred.

Figure 6. Explanation for map showing surface geology of study area.

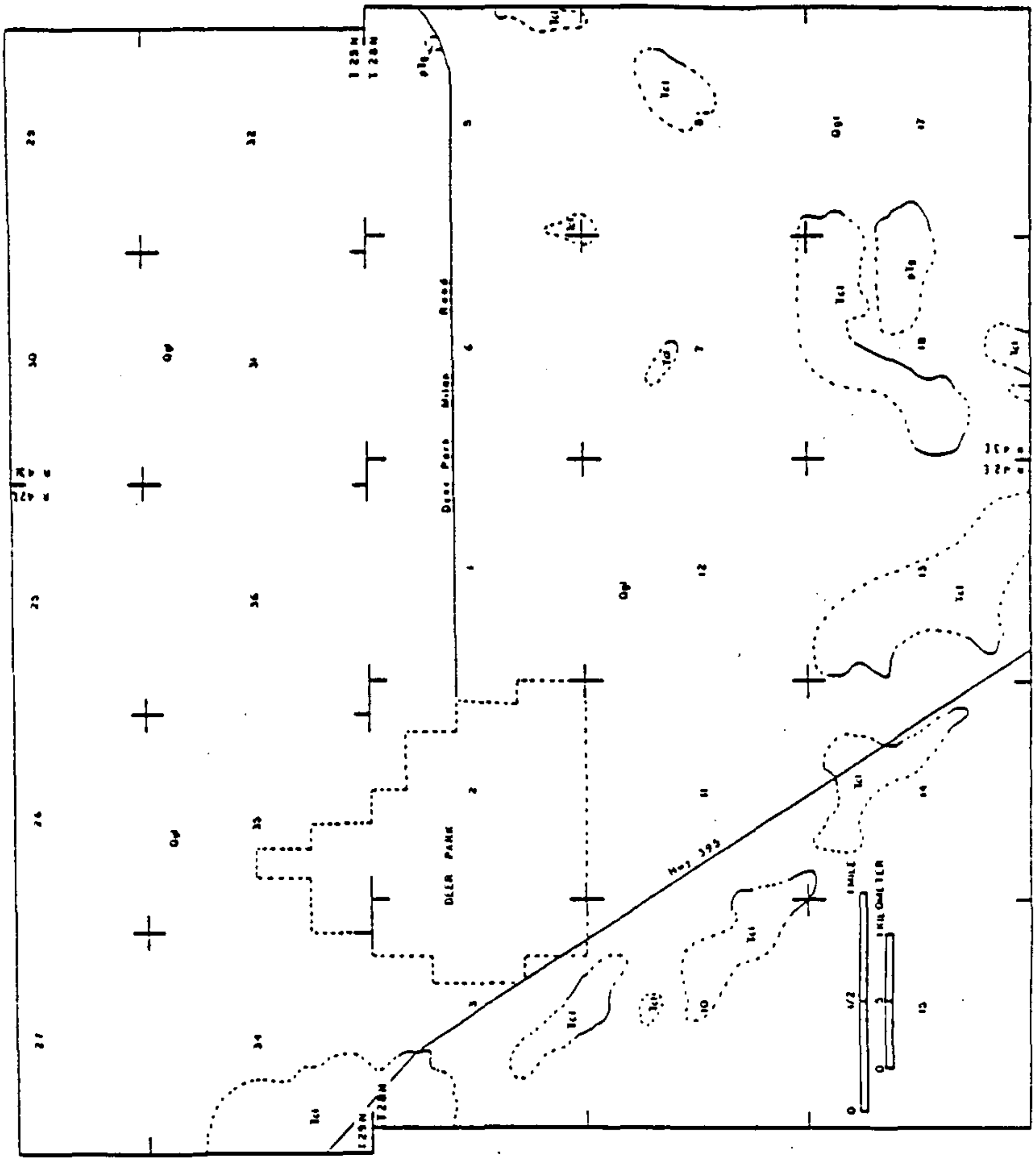


Figure 6a. Map showing surface geology of study area.

few hundred feet (meters) along the margin of the basalt field to more than a mile (1.6 km) in thickness near the center of extrusion and/or points of greatest subsidence. In the study area, Cline (1969) and Griggs (1973) note the thickness of the basalt flows as ranging from 50 to 350 feet (15 to 106 m).

Basalt exposed in the study area is considered the upper part of the Columbia River Basalt Group, which is known as the upper Yakima Basalt Formation (Cline, 1969). The basalt underlies much of the unconsolidated deposits of the Channeled Scabland to the south (Bretz, 1959). Several authors, including Griggs (1973), consider these basalts to be Miocene to Pliocene in age. The basalt is fine-grained, gray to black on fresh surfaces and yellow- to reddish-brown on oxidized surfaces. A well-developed flow was not observed in the study area, but where exposed, the basalt is extensively jointed. No colonnades were noted. Vesicular flow tops were described in well logs, but were not seen in outcrop.

The basalt flows in the Deer Park area seem to have advanced from a southerly direction, which is in accord with Mackin and Cary's (1965) work on the origin of Cascade landscapes. In the southern portion of the study area (Plates 1, 2, and 3), three flows may exist, whereas to the north, only two flows are present (Plates 4 and 5). The flows seem to terminate in the northeastern part of the

EXPLANATION

Generalized contours (in feet above sea level) of the basalt flows. Contour interval 20 feet. To obtain metric equivalent multiply value by 0.3048 meter. Contours are dashed where inferred.

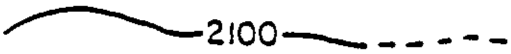


Figure 7. Explanation for structure contour map representing connected points of equal altitude of the upper surface of the basalt flows. Points of altitude were determined from well logs.

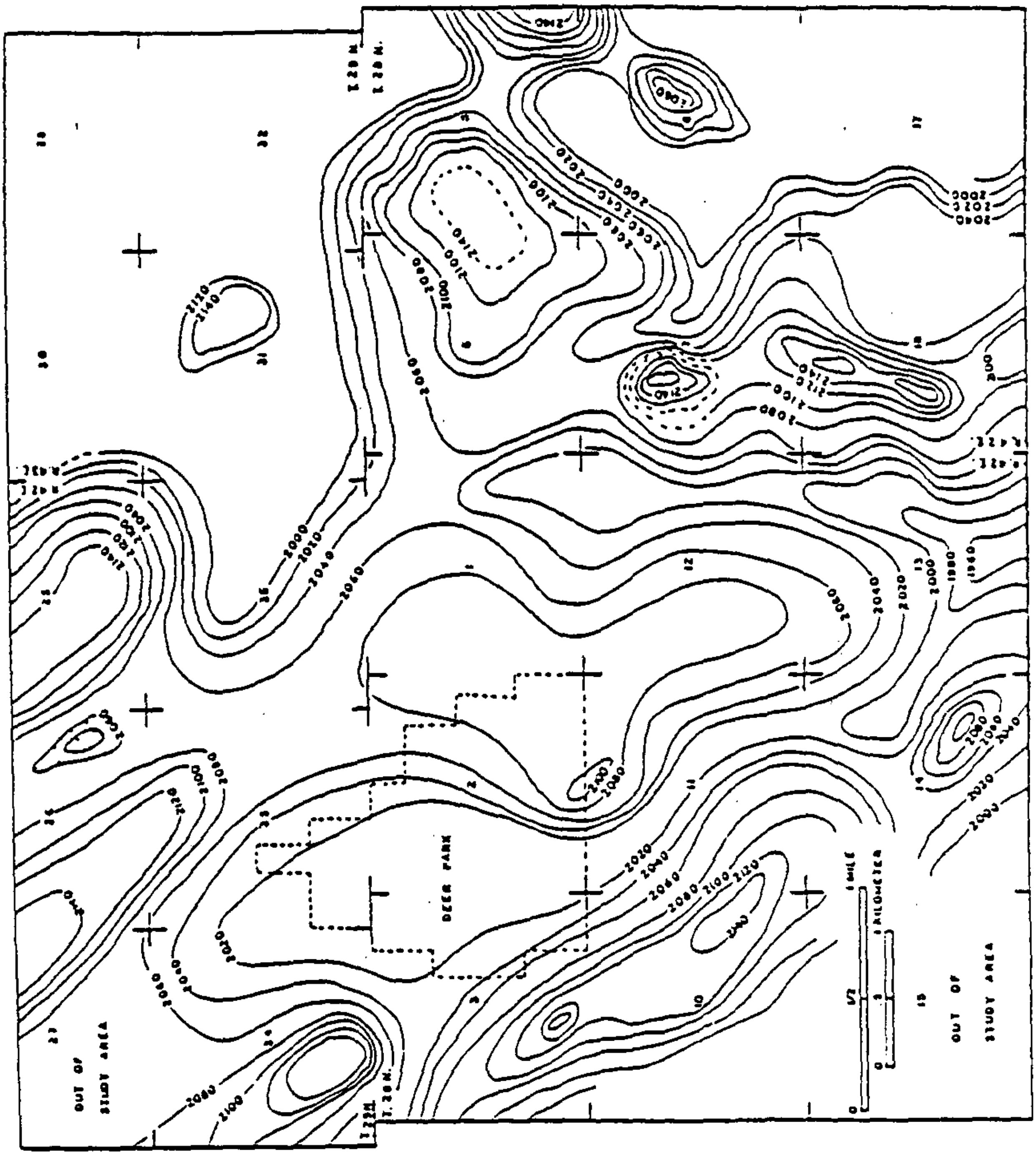


Figure 7a. Structure contour map of the upper surface of the basalt flows in the study area.

study area (Figure 7). Elevations of flow contacts tend to remain fairly consistent and are at approximately 1920 to 1940 feet (585 to 591 m), 2040 to 2060 feet (621 to 627 m), and 2100 to 2120 feet (640 to 646 m) above sea level. Near the eastern portion of the study area, part of the upper flow is seen to be isolated from the rest of the flows. Assuming that the basalt flowed northward as essentially horizontal outpourings, then the pre-existing drainages would be sites of thickest accumulations. Thicker units should then occupy former stream drainages and/or depressions upon pre-Tertiary basement rock (Plates 6 and 7). Millar and Clark (1975) worked around the Chewelah and Loon Lake area and noted that individual basalt flows and flow thicknesses could not be discerned, but were confined to elevations below 2500 feet (762 m). The highest elevation of the basalt in the study area is approximately 2160 feet (658 m) above sea level. The upper flow(s) are incised by what seem to be former stream channels and thus represent an irregular surface on which latter unconsolidated sediments were deposited (Plates 1-7).

Unconsolidated Sediments

Most of the surficial material within the study area is composed of glaciofluvial and glaciolacustrine deposits of Pleistocene age. No attempt was made to differentiate the glaciofluvial and glaciolacustrine deposits on the geologic map (Figure 6). According to Cline (1969) and Griggs (1973), the glaciolacustrine deposits consist mostly of silt, sand and clay, while the interbeds of glaciofluvial deposits are mostly coarser-grained sands. The glaciofluvial and glaciolacustrine deposits overlie the basalts and pre-Tertiary igneous rocks. These unconsolidated sediments have probably been reworked by the flood waters of the Spokane Flood (Bretz, 1959). The glaciolacustrine deposits possibly resulted from a large lake (Glacial Lake Spokane) that formed by the damming of the Spokane River at Long Lake by a glacial lobe (Cline, 1969) or by damming of the Columbia River near Grand Coulee forming a high level glacial Lake Columbia (Kiver and Stradling, 1982). Thicknesses of the deposits range as high as 200 feet (61 m). From the tailings pond dug by Dawn Mining Company at Ford, Washington, the clay layers dip from two to four degrees in a southwesterly direction (Anderson, Geology of Uranium Tailings Pond, Dawn Mining Company, 1981). Attitudes of the clay layers in the study area are assumed to be similar, implying that the direction of flow of the drainages were to the south-southwest.

Holocene Deposits

Dune deposits and alluvium of Holocene age are described by Cline (1969) and Griggs (1973). The dune deposits consist of reworked and wind-blown glaciolacustrine and glaciofluvial sand (Griggs, 1973). According to Cline (1969), the dune areas are elongated in a northeast-southwest direction. Griggs (1973) has noted that the alluvium consists of silt, sand and gravel along stream valleys, with silt and peat being deposited in ponds and lakes. The alluvium occurs mostly along the drainageways and was not extensive enough to present on the geologic map (Figure 6).

HYDROGEOLOGY

Climate

The climate in the study area ranges from mid-latitude arid to semi-arid. The annual precipitation ranges from 15 to 20 inches (38 to 50 centimeters) at the Spokane International Airport (Figure 8), about 20 miles (32 kilometers) south of the study area. Critchfield (1966) states that a major factor influencing the arid and semi-arid climates of middle latitudes is their location in the continents, that is, their distance from the windward coasts. Most precipitation in the study area occurs as snow during the winter months and is lowest during July and August. Reports from the records at Spokane International Airport show that snow accumulation in the area was 55.1 inches (139 cm) in 1984 and 66.4 inches (168 cm) in 1985. Average frost penetration, according

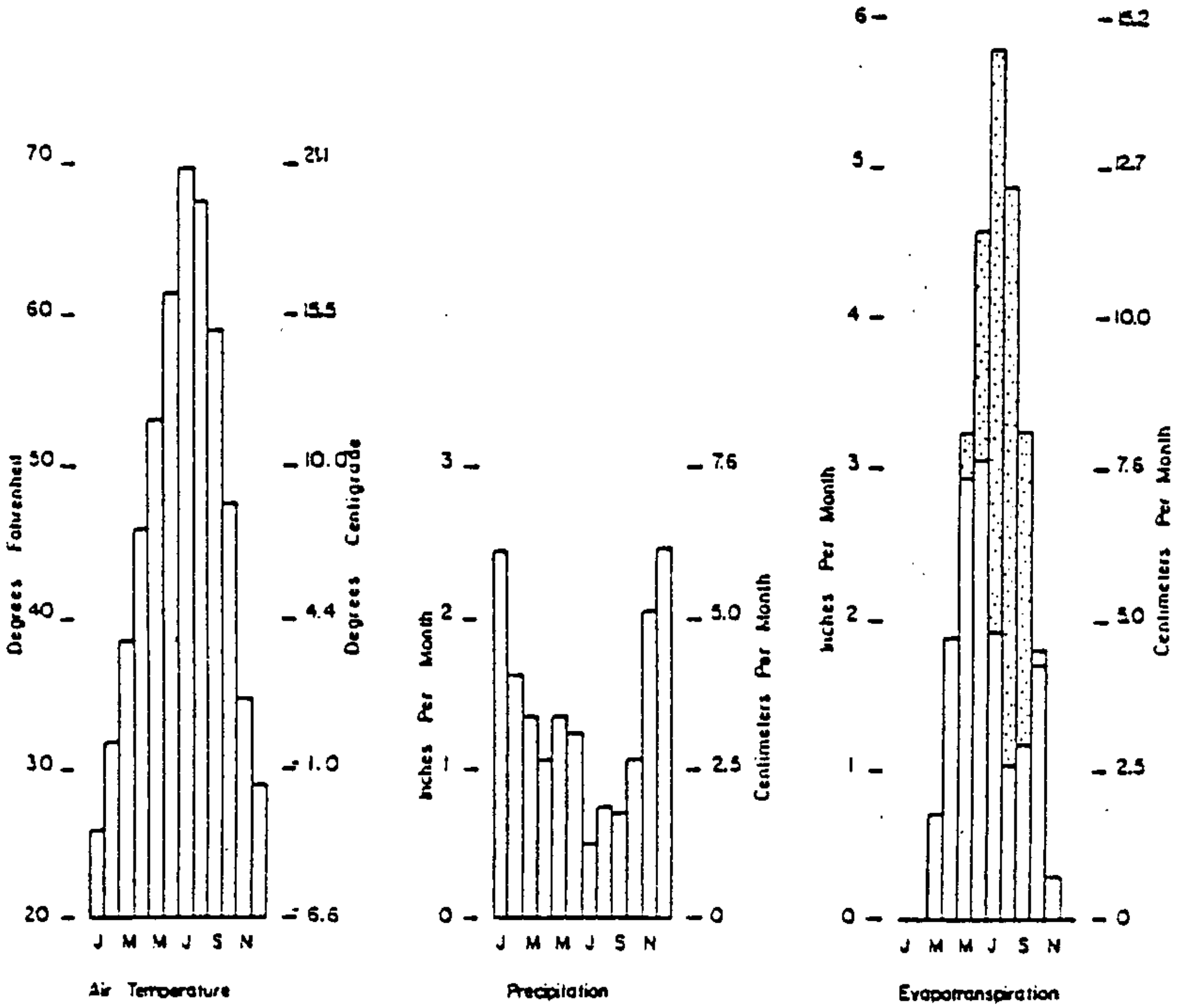


Figure 8. Air temperature, precipitation and evaporation within the study area. Graphs show average monthly values at Spokane International Airport, for the period 1931-1985. Evapotranspiration graph shows actual depth (plain) and potential depth (plain plus stippled) (After Cline, 1969).

to Cline (1969), is approximately 12 to 18 inches (30 to 45 cm) and may exceed 30 inches (76 cm) during extremely cold winters. Warm winds (chinooks) accompanied by rains may occasionally cause the snow to melt rapidly, which causes much of the moisture to be lost as runoff.

The summer months are generally warm and dry with the higher temperatures occurring in the months from June to August (Figure 8). Temperatures for these months may range from 80° to 90° F (26° to 32° C). The average relative humidity for the summer months is approximately 20 percent during the day (Data supplied by Spokane International Airport, 1985).

During the winter months, average temperatures are near freezing with minimum temperatures ranging from 16° to 23° F (-8° to -5° C) (Data supplied by Spokane International Airport, 1985). Occasionally, long cold spells with very low temperatures of -10° F (-23° C) can occur. Relative humidity during the winter months averages 77 percent.

Aquifer

An aquifer as defined by Fetter (1980) is a geologic unit that can store and transmit groundwater at rates fast enough to supply reasonable amounts to wells. Two basic types of aquifers have been defined: unconfined or water table aquifers and confined or artesian aquifers (Figure 9). Unconfined aquifers lie under permeable earth materials so that water can percolate from the surface

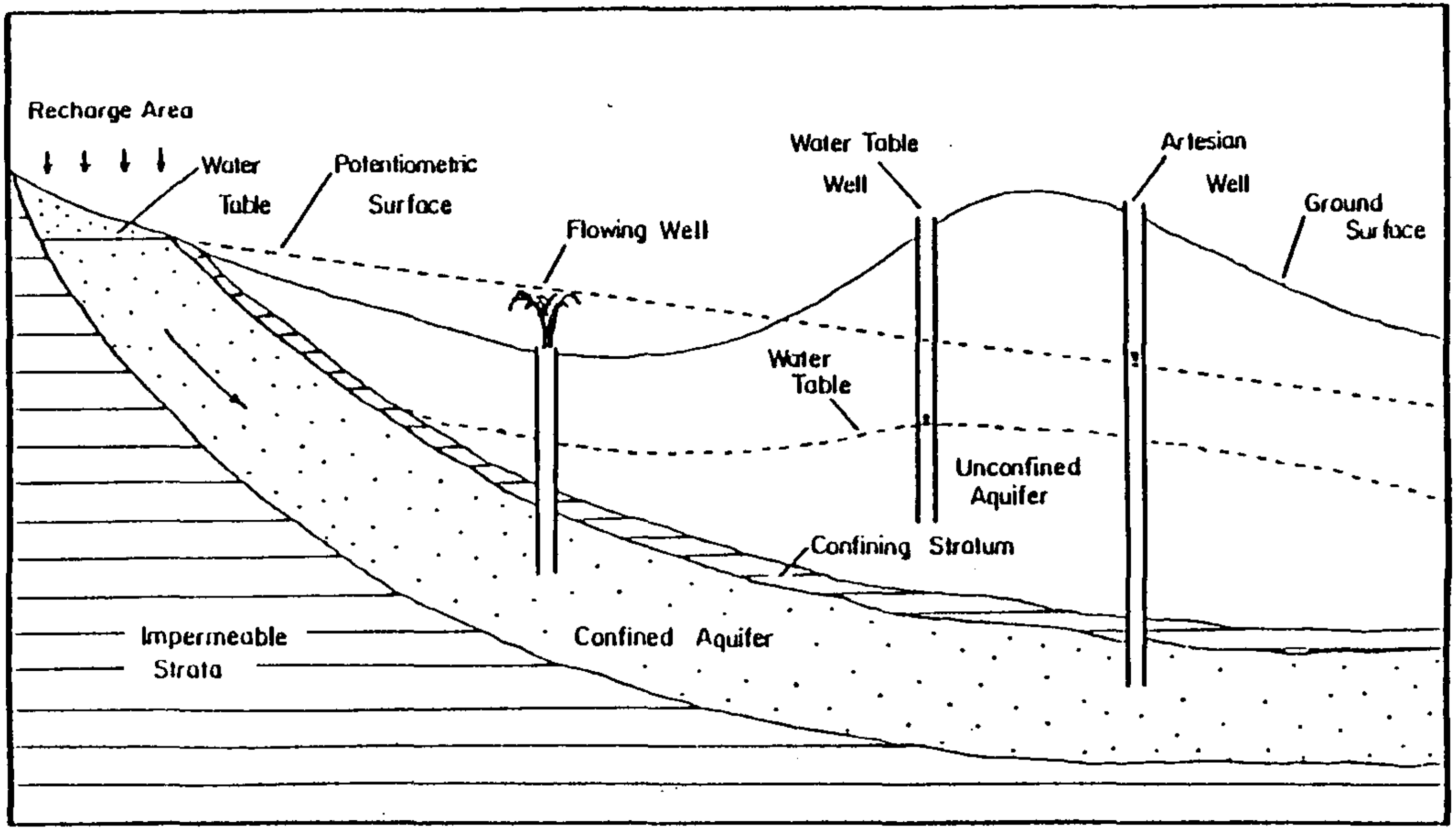


Figure 9. Schematic diagram depicting confined and unconfined aquifers. (Modified after Barrett, 1986).

through the natural pore spaces to the saturated zone. The water table refers to the upper surface of the saturated zone in the aquifer. In most cases, water table aquifers are fairly shallow, and they communicate with local rivers and creeks, which either receive water from the aquifer or recharge the aquifer. Artesian aquifers are confined by impermeable layers (aquicludes) such as clay or shale. In this type of aquifer, water will rise above the top of the aquifer to a level known as the potentiometric surface. The amount of water level rise depends on the hydrostatic pressure at that point.

In the study area, two types of aquifers were determined to exist. These include a deep semiconfined basalt aquifer and a relatively shallow unconfined aquifer developed primarily in the surficial unconsolidated deposits. Figure 10 shows the interface between the top of the basalt flows and the overlying unconsolidated sediments. The basalt tends to restrict the downward movement of pore water; consequently, it may collect in the unconsolidated sediment and in the jointed zone at the top of the basalt flows exhibiting water table aquifer characteristics. Water can move through the vertical joints and cross fractures of the basalt flows (Cline, 1969). The broken, fractured and rubbly nature of the interflow zones separating the basalt flows provides adequate permeability to transmit large quantities of groundwater

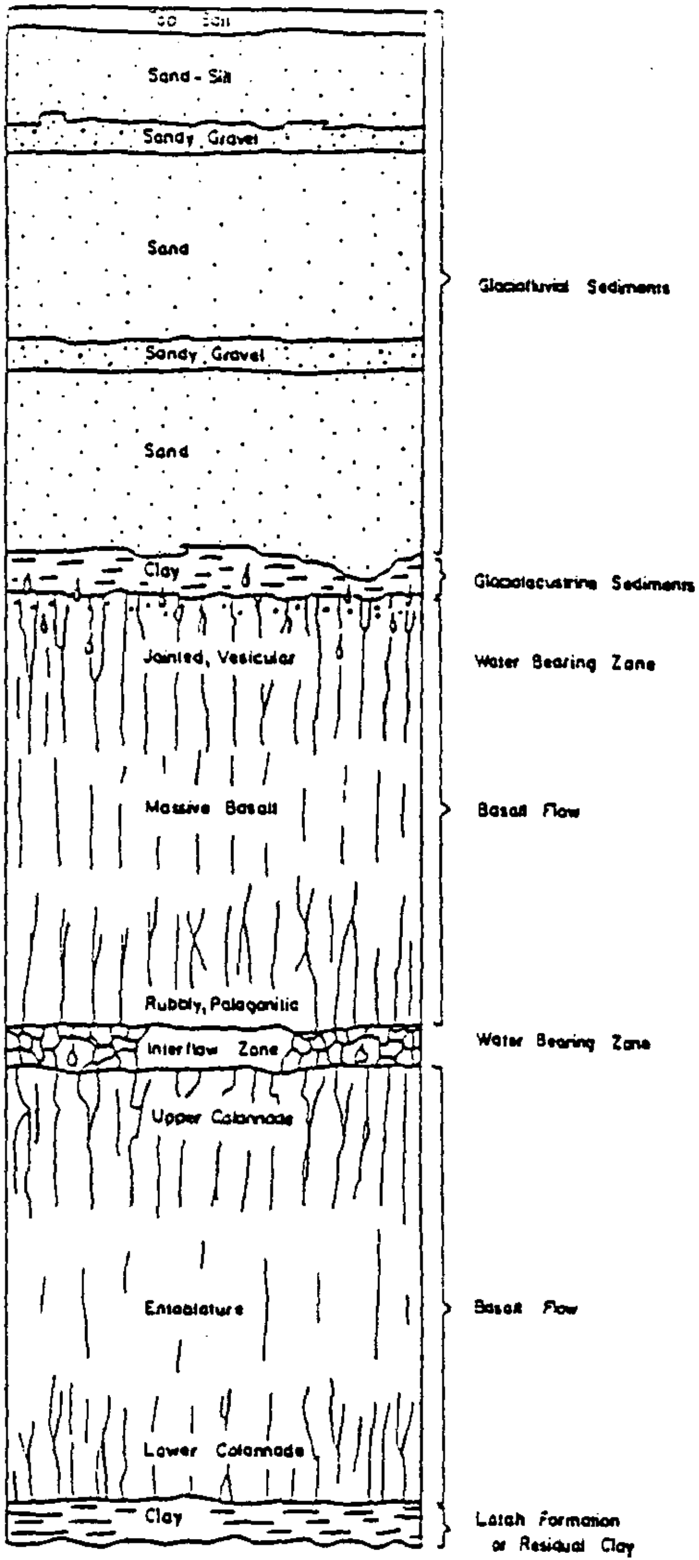


Figure 10. Schematic cross-section of basalt aquifer commonly found in the study area. Water bearing zones normally associated with jointed, vesicular basalt or interflow contacts. Highly variable yields ranging from 1 gpm to 140 gpm (0.06 l/sec to 8.4 l/sec). The maximum to be expected is approximately 35 gpm (2.1 l/sec) (Cline, 1969).

(Cline, 1969). Wells drilled to the basalt interflow zones or contacts may experience semiconfined aquifer characteristics. Fetter (1980) describes semiconfined aquifers as systems that can leak groundwater through semipervious layers either above or below the aquifer. Cline (1969) notes artesian conditions in a well four miles (6 km) south of Deer Park as having penetrated the granite beneath the basalt and that, apparently, the basalt restricts the upward movement of groundwater toward nearby Dragoon Creek. No artesian or semiconfined aquifer characteristics were described in the well logs. Interflow zones are difficult to decipher from well logs, but descriptions such as extensively fractured (water bearing), yellow sandy clay zones, pillow lavas, and vuggy vesicular zones can be used to interpret flow contacts. These interflow zones yield approximately 1 to 140 gallons per minute (0.06 to 8.4 liters per second), with a potential maximum yield of 35 gpm (2.1 l/sec) (Cline, 1969).

Wells tapping the glaciofluvial-glaciolacustrine deposits in the study area may locate an unconfined aquifer as depicted in Figure 11. Glaciofluvial-glaciolacustrine sediments may yield enough water for irrigation and municipal use (Cline, 1969). As noted from the well logs, yields vary from approximately 5 to 600 gpm (0.03 to 36 l/sec). Those wells yielding larger volumes of

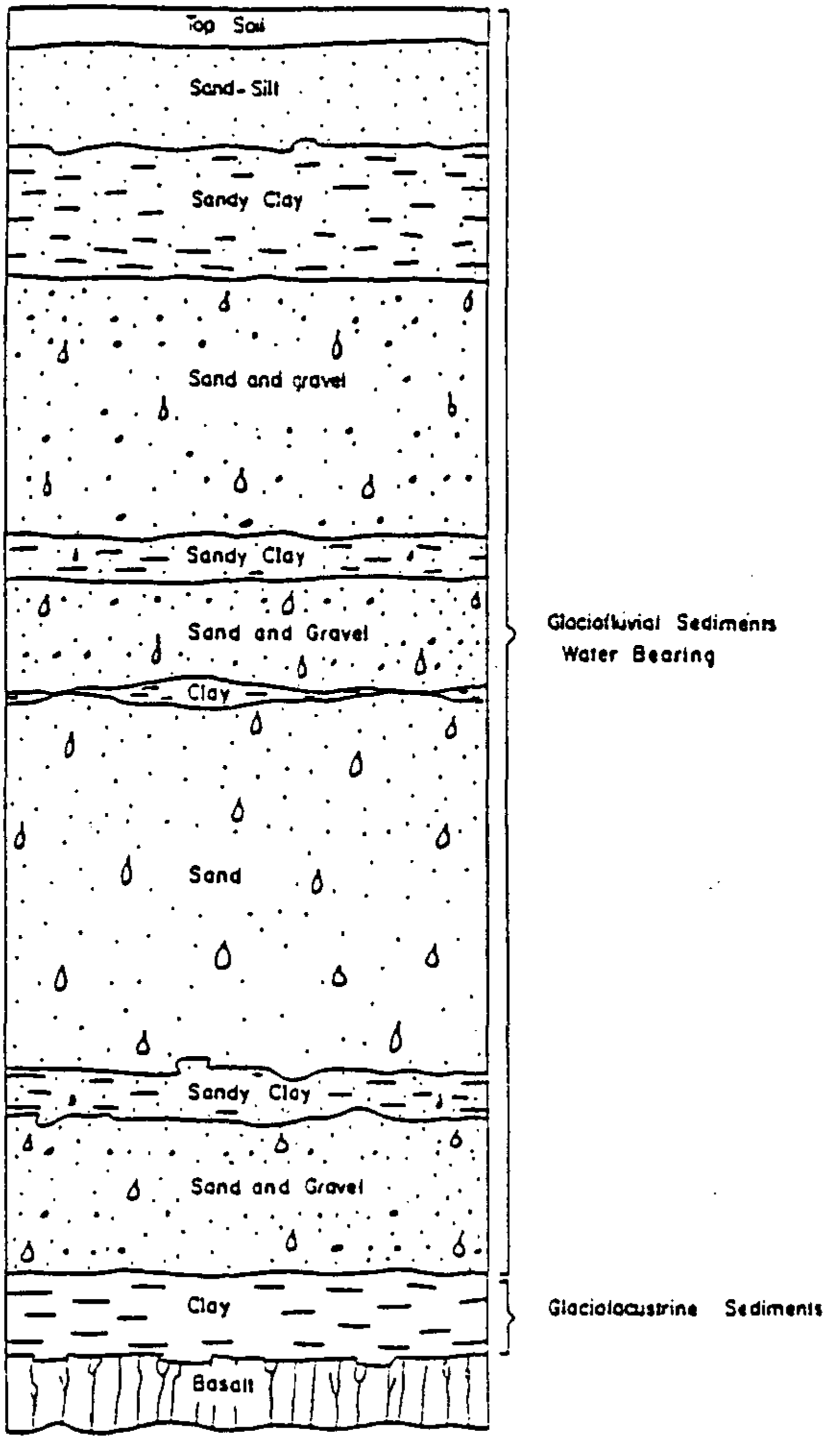


Figure 11. Schematic cross section of glaciofluvial-glaciolacustrine aquifer of the study area. Reported yields up to 600 gpm (36 l/sec) with full recovery after five minutes (Cline, 1969).

groundwater are found on the flanks of buried basalt flows and in depressions cut into the basalts. The largest aquifer yields in the study area are obtained in the glaciofluvial deposits (Cline, 1969).

Groundwater Movement

The water table map (Figure 12) shows the elevation of groundwater in the study area of both aquifers. The groundwater surface was established by using the static water level reported by the well driller. The distance from mean sea level to the water table for each well was plotted and contoured.

Groundwater flow occurs from areas of high potential to low potential and in a direction perpendicular to equipotential or water table contour lines. Groundwater in the study area flows primarily in a southerly direction. The southerly flow is distorted near the southwestern border of the study area and southwest of the Deer Park city limits. Just west and south of Deer Park, groundwater flow is in an easterly direction. A broad, flat water table exists throughout much of the area beneath the city of Deer Park. Groundwater movement through this area is to the south and would be slow as the hydraulic gradient is low. This area probably represents the former valley of Dragoon Creek which now flows abruptly to the west going around a basalt highland before continuing south. The

EXPLANATION

H1 ○ 2104	Well	Capital letter and number is well number. Number is altitude of water level, in feet above sea level, to obtain metric equivalent multiply value by 0.3048 meter. Well with no number indicates water level was not recorded. All water levels are reported.
J1 △ 2147	Well	Well data, Cline (1969).
—2000—┬↓		Water table contour. Shows altitude of water table. Contour interval is 20 feet. Arrow shows direction of groundwater movement. Dashed where inferred.

Figure 12. Explanation for water table contour map and direction of groundwater flow.

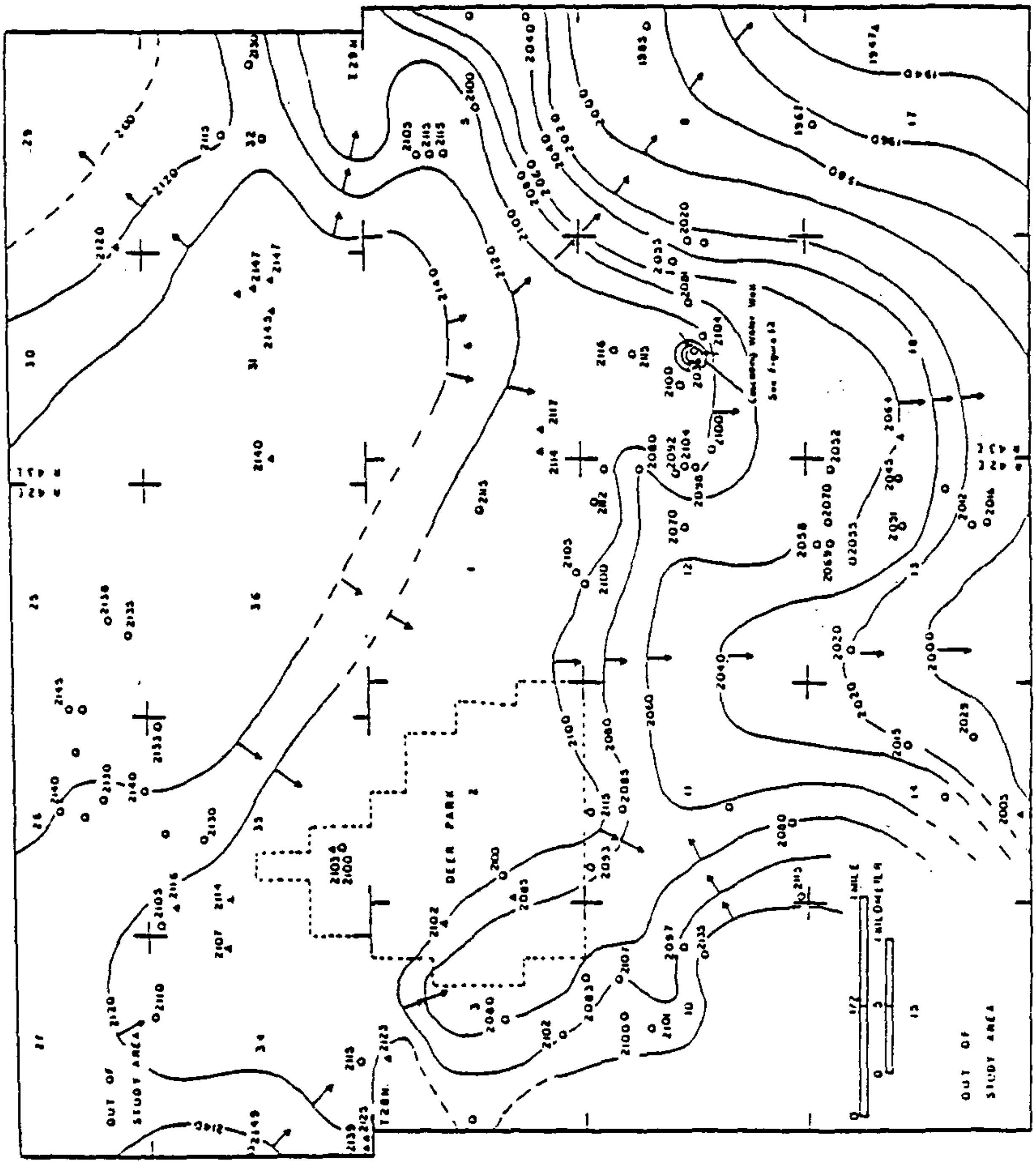


Figure 12a. Water table contour map.

abandonment of its previous stream channel would indicate that Dragoon Creek aggraded until a new western direction was assumed. Deposits of silts, sands and gravels with minor clays filled the paleovalley of Dragoon Creek in which three of Deer Park's municipal water wells are situated (Figures 2 and 7).

In Section 7, T.28N., R.43E., well 28/43-7L1 depicts an example of "cascading water" in a basalt aquifer. The converging flow lines indicate that groundwater discharge is occurring; this is graphically shown in Figure 13. Gilmour and Bacon (1974) and Luzier and Burt (1974) describe "cascading water" in basalt aquifers as a source of recharge and possible contamination by allowing perched water to move down an uncased bore hole and into subsequent interflow aquifers.

Determinations of hydraulic characteristics of transmissivity, hydraulic conductivity and storativity were based on specific capacity (gallons per minute of water produced for each foot of water level decline during testing) tests performed by the well drillers. Transmissivity is the rate at which groundwater is transmitted through a unit width of an aquifer under a unit hydraulic gradient. Hydraulic conductivity is the rate at which water can move through a permeable medium. Storativity is the volume of water an aquifer releases from or takes into storage per unit surface area of the

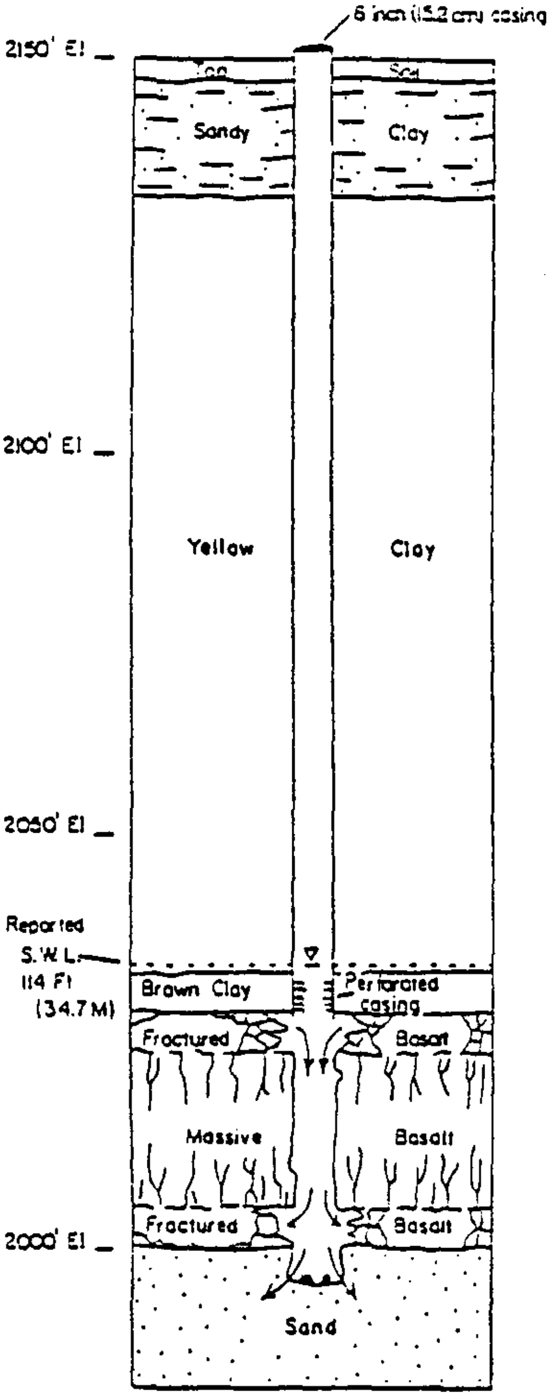


Figure 13. Cross-section of well 28/43-7Li, showing "cascading water" from fractured zones in basalt to permeable sand body underlying basalt flow. Arrows indicate direction of water movement in the bore-hole under nonpumping conditions (see Figure 12, groundwater table map).

aquifer per unit change in head. Because the transmissivity and storage values have not been confirmed by aquifer pump tests, these values should be considered as only approximations and subject to change.

Transmissivity values for the aquifer developed within the Yakima (?) basalt were calculated on the basis of specific capacity for wells collared in basalt or where the sediments were cased off. Approximate transmissivities were calculated by multiplying the specific capacity of the well by 270; units are in feet squared per day (Tanaka and others, 1974). To obtain transmissivity values in gallons per day per foot, multiply feet squared per day times 7.48 (there are 7.48 gallons per cubic foot). The transmissivity for the basalt varied from a single high value of 2000 gpd/ft (24.8 square meters per day), to a low of 66 gpd/ft (0.82 square meter per day) and an average value of 370 gpd/ft (4.5 square meters per day). With the exception of the high value, the transmissivity of the basalt aquifer of the study area is much lower than the values determined by Tanaka and others (1974); however, they state that transmissivity in basalt aquifers on a local scale may vary over a wide range. The transmissivity of the unconsolidated sediment aquifer also varies, but an average value of 6500 gpd/ft (80.7 square meters per day) is in accord with Tanaka (D.O.E. memorandum, 1980). A high value of 28,000 gpd/ft (348 square meters per day) probably represents a transmissivity of the glaciofluvial sediments, and a lower value of 4800 gpd/ft (60 square meters per day) represents that typical of the glaciolacustrine sediments. Table 1 summarizes transmissivity values of basalt and glaciofluvial-glaciolacustrine aquifers.

Pump tests are needed to determine the values for storativity of the two aquifers. However, by using a coefficient of 0.0025 supplied by Luzier and Burt (1974) in their work on the basalt aquifers of east-central Washington, storativity of the basalt aquifer in the study area can be calculated. Assuming an aquifer of 12,800 acres (5180 ha) with an average saturated thickness of 100 feet (30.4 m) as measured from the geologic cross-sections and a storage coefficient of 0.0025, about 3200 acre-feet (3.9 x 10^6 m^3) of groundwater is calculated to be contained in the basalt aquifer. Using a storativity coefficient of 0.15, as described by Tanaka and others (1974), and assuming an average saturated thickness of 42 feet (12.8 m) over an aquifer of 12,000 acres (5180 ha), a volume of approximately 80,600 acre-feet (9.9 x 10^7 m^3) of groundwater is calculated to be contained in the unconsolidated sediments of the study area. Total water in storage for both aquifers is approximately 83,800 acre-feet (1.0 x 10^8 m^3).

Within the surficial unconsolidated aquifer the average velocity or hydraulic conductivity of groundwater is lower

Table 1. Summary of transmissivity values in the basalt and glaciofluvial-glaciolacustrine aquifers based on specific capacity tests of wells in project area.

Aquifer Type	Average Transmissivity	
	GPD/ft	ft^2/day
Basalt (Deer Park, Washington)	370	50
Basalt (Columbia Basin, Washington) (Tanaka and others, 1974)	19,500	2,600
Basalt (East-Central Washington) (Luzier and Burt, 1974)	30,000	4,000
Basalt (Five Mile Prairie, Washington) (Olson, 1979)	1,500	200
Unconsolidated Sediments (Deer Park, Washington)	6,500	869
Unconsolidated Sediments (Chattaroy, Washington) (Tanaka, DOE memorandum, 1980)		
Glaciofluvial Aquifer	50,000	6,700
Glaciolacustrine Aquifer	5,000	670

in the glaciolacustrine sediments than in the glaciofluvial deposits. Assuming an average saturated thickness of 42 feet (12.8 m), a transmissivity of 36 ft^2/day (3.3 m^2/day) for the glaciolacustrine sediments and 2094 ft^2/day (194 m^2/day) for the glaciofluvial sediments, an average water table gradient of 0.016, and an assumed porosity of 30 percent, the calculated velocity ranges between a minimum of 0.5 ft/day to a maximum of 2.6 ft/day (0.15 m/day to 0.79 m/day). Well log descriptions denoting clays and silts were used to determine hydraulic conductivities for the glaciolacustrine sediments, while sand and gravels were used to determine hydraulic conductivities for the glaciofluvial sediments. LeBlanc (1982) determined that the average groundwater velocity in an aquifer developed within a very fine sand to gravelly outwash plain in Cape Cod, Massachusetts, is between a minimum of 0.8 to a maximum of 2.3 ft/day (0.24 to 0.7 m/day). Drost and Seitz (1978), noted high groundwater velocities of between 41 to 64 ft/day (12 to 19 m/day) in the Spokane-Rathdrum Prairie aquifer. Table 2 shows comparative values of hydraulic conductivities of some aquifers developed within glacial deposits.

Aquifer Recharge

Groundwater recharge of the study area is derived from precipitation that falls on the land surface as snow or

Table 2. Hydraulic conductivity of glaciofluvial-glaciolacustrine sediments in the Deer Park area compared with other glacial aquifers.

Aquifer Type	Hydraulic Conductivity (ft/day)	(m/day)
Glaciofluvial-glaciolacustrine sediments of Deer Park, Washington	0.05-2.6	0.15-0.79
Glacial outwash plain, Cape Cod, Massachusetts (LeBlanc, 1982)	0.8-2.3	0.24-0.7
Spokane-Rathdrum Prairie (Drost and Seitz, 1978)	41-64	12-19

winter rains (Cline, 1969). As noted earlier and shown in Figure 8, precipitation ranges between 15 and 20 inches (38 to 50 cm). Conditions that reduce recharge include low precipitation, rapid snow-melt or rain falling on frozen ground and/or exposed rock outcrop at the land surface (Olson, 1979). The quantity of recharge probably varies from year to year, but Cline (1969) noted that water levels from 1947 to 1965 showed no significant net change. Wells drilled in the 1960's show little difference in water levels from nearby wells drilled in the 1980's. The Spokane County Health Department, Environmental Health Division has sounded wells in the study area and has found no change in water levels (LaScuola, personal communication, 1986). Seasonal fluctuations of water tables can be expected in unconfined aquifers (Fetter, 1980). Tanaka (D.O.E. memorandum, 1980) reported no unusual reduction in recharge of a small basin southeast of the study area.

Evapotranspiration is another factor that can regulate recharge to the saturated zone of the aquifer. As illustrated in Figure 14, most of the precipitation is returned to the atmosphere by evaporation and transpiration of plants. For annual recharge to be adequately documented, careful records of precipitation, evapotranspiration, stream flow of Dragoon Creek, and fluctuations in water wells would have to be conducted over a period of years. Tanaka (D.O.E. memorandum, 1980) has estimated that approximately

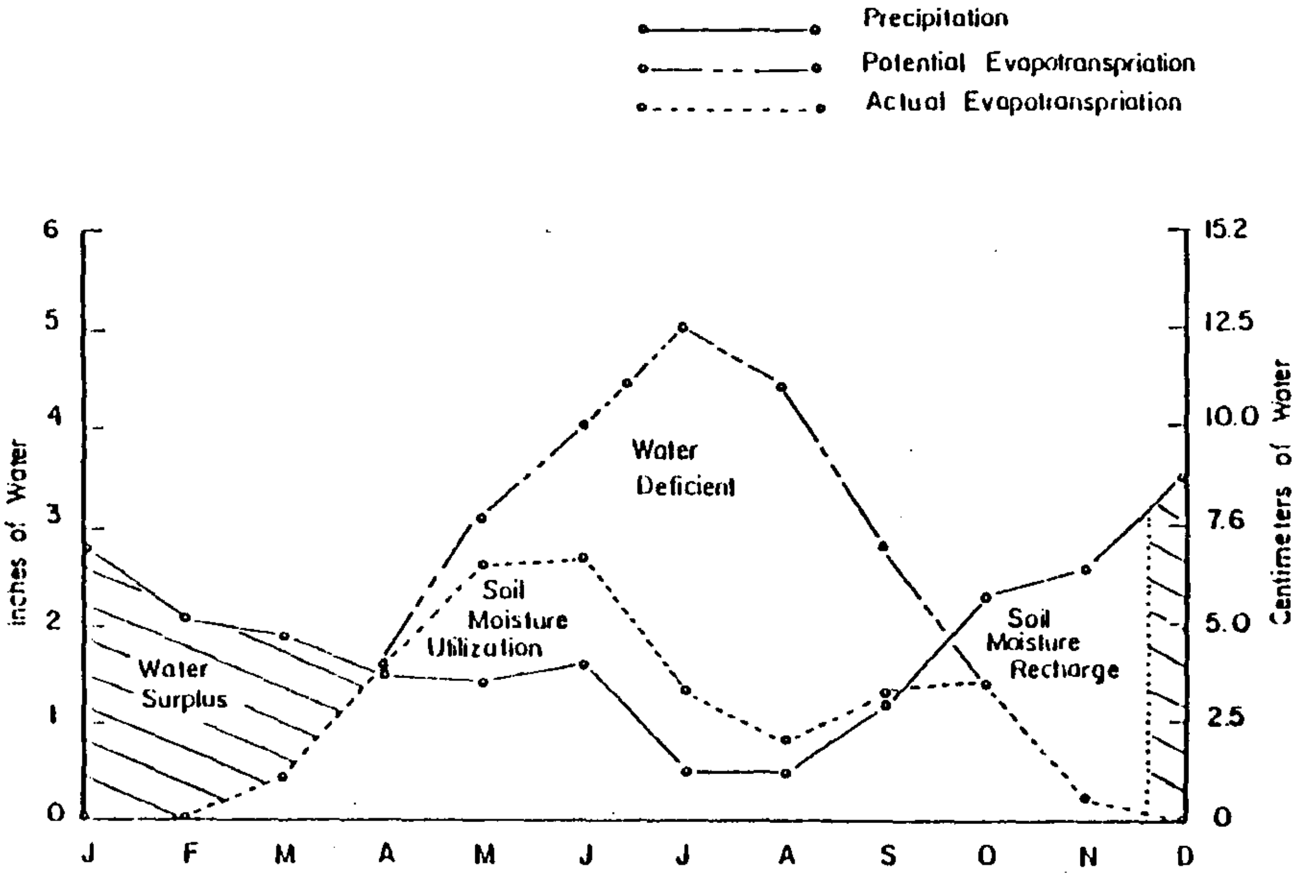


Figure 14. Mean annual water budget of Deer Park, Washington, showing months of potential groundwater recharge. (Modified after Olson, 1979) (Data taken from Tanaka, D.O.E. memorandum, 1980).

18 percent of total annual precipitation is available for groundwater recharge. Thus, the mean annual recharge of three inches (7.6 cm) (that is, 18 percent of average rainfall for 1984 and 1985) over the 20 square miles (51.8 square kilometers) of the study area is 3200 acre-feet (4.0×10^6 m^3) of water available for recharge of the aquifers in the study area.

Aquifer Discharge

Natural discharge of groundwater includes evapotranspiration, springs, probable seepage to Dragoon Creek, and intermittent surface streams. Domestic, municipal and irrigation wells also discharge water from the aquifer. Part of this artificially discharged water returns to the groundwater reservoir by percolation. The quantity and quality of this recycled water depends on its original use. Cline (1969) reports that much of the water used for irrigation is lost to evapotranspiration and that some of the water from septic tanks will probably return to the aquifer.

Evapotranspiration is limited to places where the water table intersects the land surface, such as streams, springs and marshes (Cline, 1969). When the water table is deeper than 10 feet (3 m), little water is lost by evapotranspiration except where deep-rooted vegetation such as alfalfa can draw water from lower depths (Cline, 1969).

SOILS

Soil distribution in the Deer Park area is shown in Figure 15 as a map modified from the Spokane County Soil Conservation Service. Soils near Deer Park principally include the Bonner, Hagen, Hesseltine, Bridgestone and Wethey series. Parameters for these and other soil profiles described are from a measured depth of 60 inches (152 cm) (S.C.S.C., 1985).

The Bonner series is a terrace loam that occupies most of the higher area east of Deer Park. Loamy fine sand and loamy sand of the Bonner family grade into medium sand, with permeabilities ranging from 2 to 20 inches per hour (5 to 50 cm/hr) (S.C.S.C., 1985).

The town site of Deer Park is situated primarily on Clayton fine sandy loam, which consists of very deep well-drained soils of moderately coarse glaciofluvial deposits. Permeabilities of the Clayton series range from 0.6 to 6 inches per hour (1.5 to 15 cm/hr) (S.C.S.C., 1985).

The Hesseltine soils are a very rocky series which occur over and in juxtaposition to rock outcrops. The Hesseltine soils are moderately deep over basalt. Surface layers are stony silt loam grading into gravelly to very gravelly coarse sandy loam sublayers. Permeabilities

EXPLANATION

BvB	Bonner Loam
By	Bridgeson Silt Loam
Bz	Bridgeson Silt Loam, drained
CsA	Clayton Fine Sandy Loam
CsB	Clayton Fine Sandy Loam
ClA	Clayton Loam
EkB	Elcika Silt Loam
Hfc	Hagen Loamy Fine Sand
HgB	Hagen Sandy Loam
HnB	Hesseltine Silt Loam
HvC	Hesseltine Very Rocky Complex
LeA	Laketon Silt Loam
We	Wethey Loam
Wh	Wethey Loamy Sand
Wo	Wolfeson Very Fine Sandy Loam

Figure 15. Explanation for map showing soil types and drainage pattern of study area.

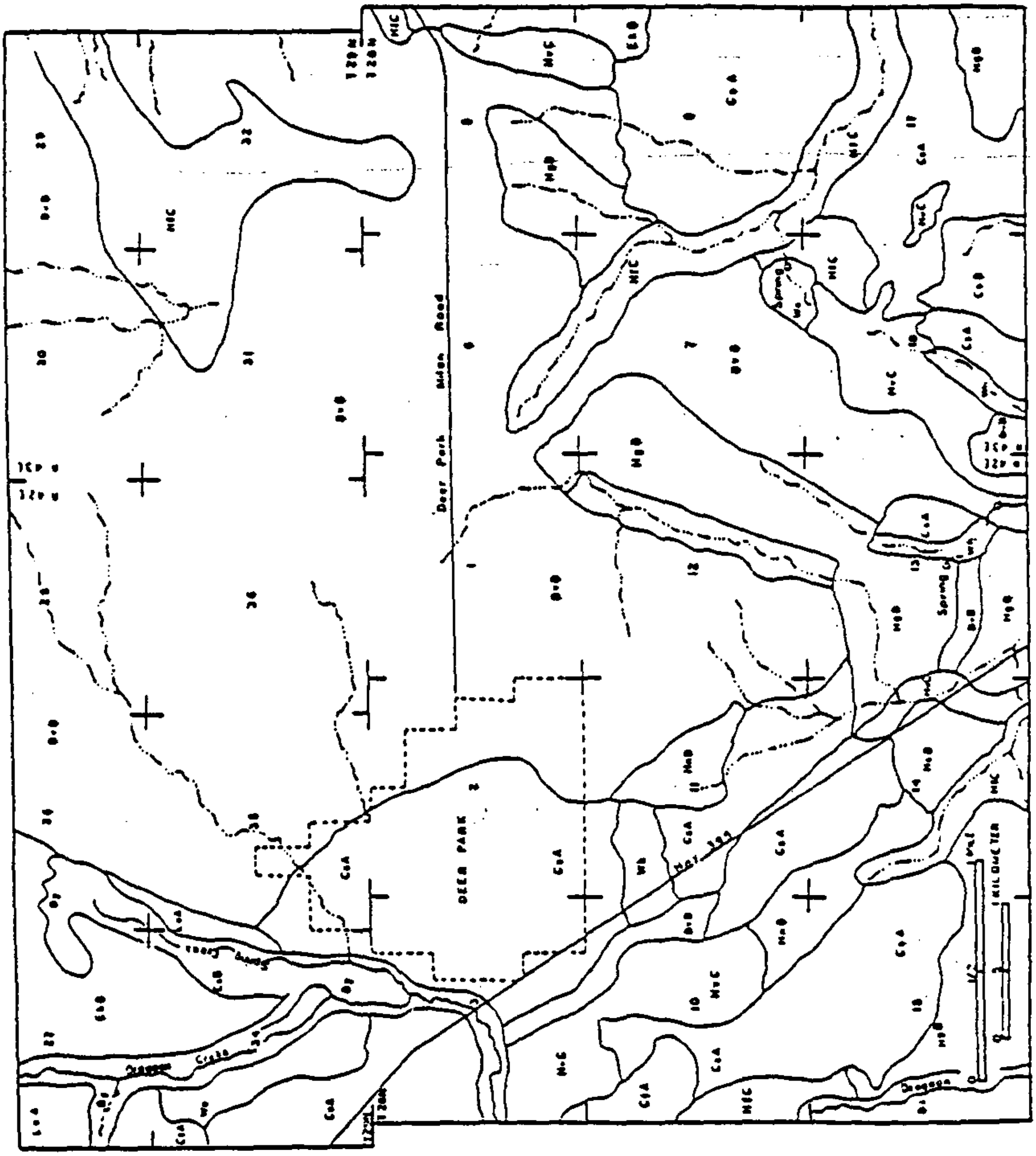


Figure 15a. Map showing soil types and drainage pattern of study area. (Modified from Spokane County Soil Conservation Service, 1985).

for the Clayton series range from 0.6 to greater than 20 inches per hour (1.5 to 50 cm/hr) (S.C.S.C., 1985).

The Bridgestone series consists of very deep, poorly drained soils formed in alluvium on nearly level drainageways (S.C.S.C., 1985). Surface layers are silt loam becoming silty clay loam. The series is found along the Spring Creek and Dragoon Creek drainageways west of Deer Park. Permeabilities for the Bridgestone family range from 0.6 to 2 inches per hour (1.5 to 5 cm/hr) (S.C.S.C., 1985).

The other soil types in the study area are mainly silty loam to loamy sand. Most of these soils are well-drained to the measured depth of 60 inches (152 cm) and have permeabilities that are rapid to very rapid.

Several authors, including Piskin (1973), have reported that soil fertility, farming practices and moderate permeability (0.6 to 2.0 inches per hour, 1.5 to 5 cm/hr) of soils are among the factors relating to high levels of nitrates in groundwater. Thus, soils with rapid hydraulic conductivities over a shallow water table, coupled with certain farming and waste disposal practices, could increase the potential of leaching nitrates to the groundwater. In contrast, impervious clay-rich soils will not percolate conservative contaminants such as nitrates and chlorides as rapidly as more permeable soils. Stone (1953) indicates that cultivation reduces percolation rates, but that soil type, operating conditions and rainfall limit the amount of spread effluent (treated municipal wastes) that can be applied to a soil.

WATER QUALITY

Introduction

The sources of high nitrate concentrations in drinking water are many and varied. LeGrand (1965), Engberg (1967), Stewart (1967), Patterson (1971), Viets and Hageman (1971) and Walker (1973) have studied the sources and effects of high concentrations of nitrates in groundwater. In 1970, Goldberg reviewed existing research, field and laboratory studies of nitrogen sources, including atmospheric and geologic factors, rural and urban runoff, septic tanks and sewage irrigation, animal feedlots and industrial wastes.

Shuval and Gruener (1977) reported on the health effects of nitrates in Israel and infant methemoglobinema. The National Interim Primary Drinking Water Regulations (1976) summarized serious and fatal poisonings of infants following ingestion of well waters shown to contain nitrate contaminations greater than 10 mg/l nitrate-nitrogen.

Nitrates

The presence of nitrates in groundwater is a potential health hazard and should be of concern to the public. Nitrate concentrations are reported in many ways, and much confusion results from lack of uniformity. Units used have been nitrate (NO_3), nitrate as nitrogen (NO_3-N), potassium nitrate (KNO_3) and sodium nitrate ($NaNO_3$) (Viets and Hageman, 1971). The U.S. Public Health Service Drinking Water Standards (1962) has set limits on the concentration of nitrate as nitrogen in public water supplies as 10 mg/l (10 ppm) or nitrate at 45 mg/l. To convert mg/l nitrate to nitrate as nitrogen, divide nitrate values by 4.428.

Nitrogen is a gaseous element making up 79 percent of the earth's atmosphere. It is relatively inert to chemical reaction and does not ordinarily occur abundantly in rocks or water (Engberg, 1967). Growth of all organisms requires nitrogen. Photosynthetic organisms, both aquatic and terrestrial, require nitrogen either as ammonium or nitrate (Viets and Hageman, 1971). Certain soil bacteria and nitrogen-fixing legumes can remove nitrogen from the atmosphere. Engberg (1967) cites decomposing plant and animal residues, animal and human wastes, nitrate fertilizers and lightning as sources of nitrogen compounds in the soil.

Smith (1969) depicts the oxidation (nitrification) of nitrogen as: organic nitrogen $\longrightarrow NH_4^+ \longrightarrow NO_2^- \longrightarrow NO_3^-$. Most soils in nature possess a net negative charge which provides the capacity to attract and hold cations; thus, the ammonia form (NH_4^+) may be adsorbed by clayey soils (Polta, 1969). Nitrites (NO_2^-) are unstable and are not normally found in high concentrations (Viets and Hageman, 1971). Nitrates are negatively charged anions and are not readily adsorbed by the soil. Nitrates are quite mobile in porous sediments and, as summarized by Smith (1969), Apgar and Langmuir (1971), Kimmel and Braids (1980) and LeBlanc (1982), movements of contamination plumes containing nitrates have traveled great distances from their sources. In a study or returning wastes to the land, Bouwer (1968) noted that nitrates may travel through fine loamy sand at three to four feet per day (3-4 ft/day) (1-1.2 m/day).

The process of oxidation or nitrification by soil bacteria (Nitrobacter ssp) to form nitrates takes place in an aerobic environment, where the bacteria derive energy from elemental oxygen (Viets and Hageman, 1971). The formation of nitrates in an aerobic environment becomes more rapid in temperatures above 60° F (16° C) (Smith, 1969).

Nitrogen compounds can be removed from waste water moving through the soil by various processes. Among the most effective are volatilization of ammonia and denitrification (Bouwer and others, 1972). Ammonia is easily volatized and can be detected by the pungent odor associated with concentrated animal wastes. Under anaerobic conditions, some bacteria can utilize nitrate, along with organic carbon compounds as a source of energy (Polta, 1969). The end products of this reaction are chiefly nitrogen gas and some gaseous oxides of nitrogen, which can escape to the atmosphere (Bouwer, 1968). The process of denitrification requires organic carbon, nitrate, nitrate-reducing bacteria (Pseudmona ssp and Micrococus ssp), absence of oxygen and favorable temperatures (Stevenson and Wager, 1971). Smith (1969) has shown the denitrification process as:(Nitrate) $NO_3^- \longrightarrow NO_2^- \longrightarrow NO \longrightarrow N_2O \longrightarrow N_2$, in his study on fertilizers and water pollution.

Chlorides

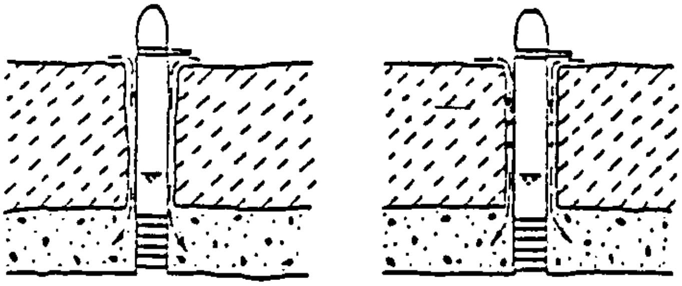
Chlorides are found in practically all natural waters. Water Quality Criteria of 1963 notes that chlorides may be of natural origin or derived from sea water contamination, human or animal sewage and industrial effluents. Ulrich (1955) studied chloride contamination of groundwater in Ohio and reported that once chlorides are added to subsurface waters, they are not reduced by natural purification, nor can they be economically removed. In his study at the Rocky Mountain arsenal, Konikow (1977) described the complex movement of chlorides in an alluvial aquifer. LeBlanc (1982) reported that shallow wells downgradient from roads that were treated with de-icing salts showed elevated levels of chlorides.

Chlorides in drinking water are generally not harmful to human beings until high concentrations are attained, and thus the primary concern is economic damage rather than public health (Water Quality Criteria, 1963). The U.S. Public Health Service Drinking Water Standards of 1962 recommends that levels of chlorides do not exceed 250 mg/l. Groundwater with high chloride concentrations will impart a salty taste, and individuals not accustomed to high levels may develop diarrhea (National Interim Primary Drinking Water Regulations, 1976). If the level of chloride concentration in groundwater increases suddenly, an indication of pollution is suggested (Water Quality Criteria, 1963). Chloride concentrations may be diminished by dispersion and dilution (Konikow, 1977).

Mechanism of Groundwater Contamination

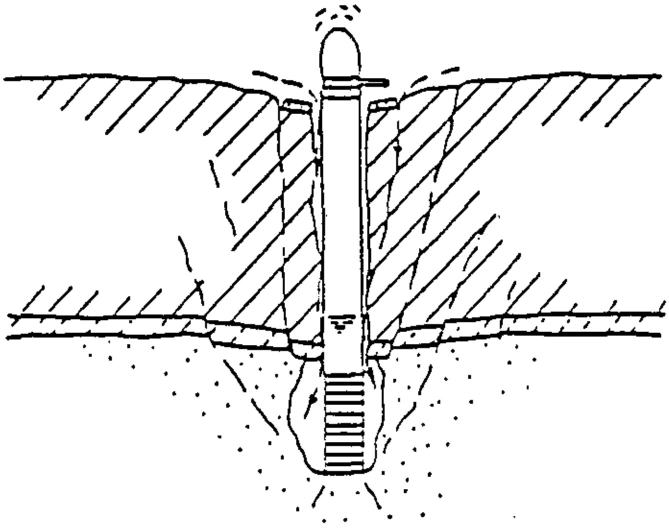
Contamination of groundwater occurs by many avenues; the most significant is due to improper well construction. The connection between groundwater pollution problems and well construction has been explored in recent years. A factor in well-contributed contamination of groundwater is the introduction of an artificial condition in the form of a hole extending from the ground surface to the aquifer (Ham, 1971). Gilmour and Bacon (1974) discussed the potential of an aquifer or aquifers becoming contaminated by the effects of "cascading water" in the Channeled Scablands. A well may by-pass the natural protection afforded by overlying materials that can filter out or retard percolating contaminants. Crosby and others (1968) reported coliform bacteria at a depth of 31 feet (9.5 m) in a glacial outwash environment in the Spokane Valley, due to leakage along the well casing that did not effectively seal off contaminants from higher levels. Coliform bacteria are effectively filtered by five to ten feet (1.5 to 3 m) of porous materials (Bouwer, 1968). Deutsch (1965) noted that among other factors aquifers may be contaminated directly via water wells.

Design and construction of the water well is important to reduce the potential for groundwater contamination. As shown by Ham (1971) in Figure 16, the following conditions of well construction and operation can cause contamination of groundwater: leakage along the disturbed zone surrounding the casing and through the gravel pack around the casing, subsidence due to sand pumping may reduce the effectiveness of the grout seal, dessication, shrinkage and cracking of the grout material, and breaks in welds or erosion of the casing. Engberg (1967) points out that shallow hand-dug wells, particularly those walled with

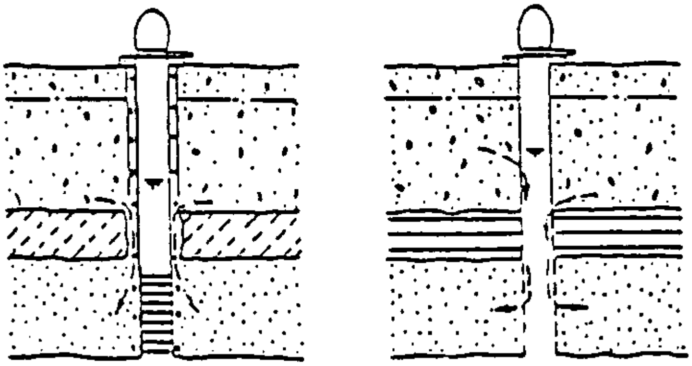


Around the casing

Through the gravel pack



Resulting from subsidence



Shrinkage of grout

Through the casing

Figure 16. Diagrams showing entrance of contaminants due to changing conditions often resulting from improper design or construction, operation, or lack of maintenance that would lead to negate protective techniques (Ham, 1971).

wood, stone, brick or jointed tile, are very likely to be polluted if situated near sources of contamination. All surface well openings should be higher than the ground surface to prevent contaminants from directly entering the well.

NITRATE CONTAMINATION IN THE DEER PARK AREA

Chemical Analyses of Groundwater

Water samples collected during this study were analyzed for nitrate-nitrogen and will later be tested for chlorides. These chemical constituents were selected because of their conservative behavior and because they are an integral component of effluent that is derived from animal and human wastes (LeBlanc, 1982).

Chemical analyses for nitrate-nitrogen were made at the Spokane County Health District, Environmental Health Division, by ion specific electrode. The ion specific electrode is an acceptable field screening method for concentrations of nitrates (Crouse, personal communication, 1986). Samples with very high values (greater than 100 mg/l) may be sent to a private laboratory to determine concentrations of nitrate-nitrogen.

Sampling procedures were standardized to promote uniformity in results. Water samples were taken at the nearest point to the well site after a purging period which normally lasted greater than five minutes. A 125 milliliter narrow-mouthed glass container was used to take the sample. The bottle was completely filled to avoid any air being trapped with the water sample.

Techniques for preservation of the nitrogen species in water samples between time of sampling and time of analyses have been questioned in recent years (Kimmel and Braids, 1980). Samples were kept cool in a small plastic ice chest during the sampling period and were analyzed the following day. Results from the electrode method did not differ significantly from analyses reported by private laboratories of samples taken earlier from the same wells (Crouse, personal communication, 1986).

Nitrate Concentrations in the Study Area

The wells sampled during the nitrate survey are primarily domestic wells, the exception being four municipal water wells in Deer Park, Washington. Initial data show that 16 out of the 85 wells sampled contain more than 10 mg/l nitrate-nitrogen. Figure 17 summarizes chemical data collected during April 1986, from wells within the study area.

Previous analyses of groundwater samples from wells in the study area show a wide range of nitrate-nitrogen concentrations. Van Denbaugh and Santos (1965) and Cline (1969) published chemical analyses of groundwater from

EXPLANATION

○ Well with nitrate-nitrogen less than 10 mg/l.

● Well with nitrate-nitrogen greater than 10 mg/l.

2.1	Concentration of nitrate-nitrogen
110	Depth of well in feet

Deer Park's municipal water wells are labeled.

Figure 17. Water quality map showing concentrations of nitrate-nitrogen and depths of water wells in the study area (After Engberg, 1967).

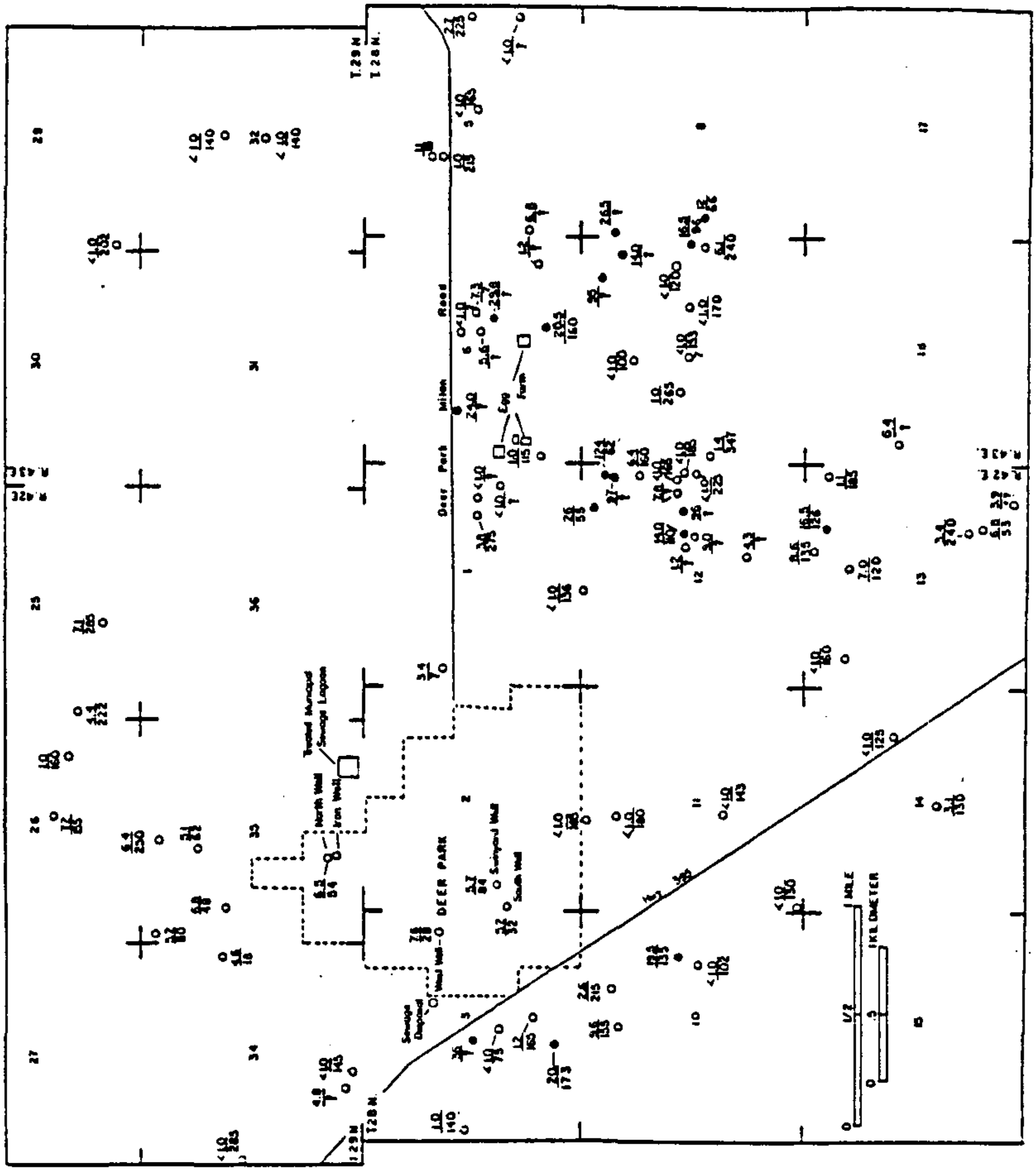


Figure 17a. Water quality map of study area showing concentrations of nitrate-nitrogen and depths of wells.

Stevens and Spokane counties, inclusive of the study area, as ranging from <1.0 to 96 mg/l nitrate (<1.0 to 21.6 mg/l nitrate-nitrogen). LeBlanc (1982) uses a nitrate-nitrogen level of 2 mg/l to delineate a contamination plume of the Otis Air Force Base, Cape Cod, Massachusetts. Background values for nitrate-nitrogen concentrations in the study area are considered to be less than 1.0 mg/l.

Two areas of concern for nitrate-nitrogen contamination exist in the study area. These include the area north of, and including, the city of Deer Park, as well as the area south of and including Section 6, T.28N., R.43E. (Figure 17). In general, it appears that shallow wells situated in the more porous glaciofluvial sediments are more prone to contamination if located near a source of nitrates. The Swinyard and South wells in Deer Park (Figure 17) are shallow wells developed in the surficial unconsolidated sediments and have elevated nitrate-nitrogen values, whereas the deeper wells in basalt to the south show values less than 1.0 mg/l nitrate-nitrogen. The southern wells are in the basalt aquifer and have cased off the nitrate-rich groundwater, and as a result should remain contamination free. The West well of Deer Park had a nitrate-nitrogen level of 7.6 mg/l and is located approximately 1700 feet (518 m) east of a sewage disposal site. Again, the elevated nitrate concentrations are presumably due to the shallow well being constructed within the unconsolidated surficial sediments.

Well 28/42-10H1 (Figure 17) is south of Deer Park and exceeds U.S.P.H.S. (1962) recommended drinking water standards of 10 mg/l nitrate-nitrogen. This well is located on the eastern flank of a basalt highland and, with a groundwater flow direction to the east (Figure 12), is probably not receiving nitrate-nitrogen contamination from the north. A local nitrate source such as repeated heavy application of animal wastes and/or poor well construction is suspected for this site's being contaminated.

The area north of Deer Park has a type of coarse sediment hosted aquifer similar to that found in Deer Park. Wells in this area with anomalous nitrate-nitrogen levels are generally found in the surficial unconsolidated sediment aquifer. Deer Park's North well has a nitrate-nitrogen level of 6.5 mg/l and is in the unconsolidated sediment aquifer. Deep wells that were drilled in the basalt aquifer and have nitrate-nitrogen levels geater than 5.0 mg/l may be receiving contaminated recharge due to poor well construction. Well 29/42-25P1 is drilled into the basalt aquifer and has a nitrate-nitrogen level of 7.0 mg/l. Two other wells drilled nearby were abandoned due to low water yield. These two abandoned wells may be leaking contaminants to the pumping well. There is no obvious source for the nitrate contamination in this area.

In Section 6, T.28N., R.43E., an egg ranch has been in production for approximately 25 years. Of the six wells tested on the egg ranch, two exceed 10 mg/l nitrate-nitrogen, two nearly exceed the standard, and two have background values. Water well logs are not available to discern the subsurface geology or well depths. Application of poultry wastes to the land surface is suspected for the nitrate-nitrogen contamination of these wells. To the southwest and southeast of the egg farm, several wells exceed the U.S. Public Health Service (1962) recommended drinking water standard. The contaminated wells are constructed in the unconsolidated sediment aquifer and lie in a structural low on the sides of a north-south trending basalt highland (Figure 7). Pollutants entering the aquifer would move in a southerly direction with the groundwater flow around this basalt highland (Figure 12). Groundwater velocity for the unconsolidated sediments ranges between a minimum of 0.05 ft/day to a maximum of 2.6 ft/day (0.15 m/day to 0.79 m/day). In this area, then, the nitrate-nitrogen concentrations show a very crude plume emanating from a point source. Kimmel and Braids (1980) and LeBlanc (1982) studied landfills in glacial outwash sediments and found that concentration values of contaminants decrease in value down gradient and laterally from the point of contamination. Similarly, the highest nitrate-nitrogen value of 126 mg/l (Figure 17) was recorded in one of the wells (28/42-12A2) closest to the egg farm on March 19, 1986. Other shallow contaminated wells in the surficial unconsolidated sediment aquifer show decreasing nitrate-nitrogen levels in a southerly direction. There are wells in the basalt aquifer within this area that have background values of nitrates.

All other wells exceeding the 10 mg/l nitrate-nitrogen concentration level or showing elevated levels are considered to be locally contaminated. Detailed historic land use and well construction reports may reveal reasons for nitrate contamination of these wells.

Sources of nitrate contaminants in the study area may result from domestic and municipal wastes, animal wastes, farm fertilizers and crop residues (Dawes and others, 1969). Walker (1973) reported that of the 263 farm-supply wells sampled, the median nitrate-nitrogen concentration was 32 mg/l nitrate-nitrogen, and over 73 percent of the wells contained nitrate levels greater than 10 mg/l. Walker (1973) stated that most of the polluted wells were situated adjacent to barnyards, septic tank tile fields or farm fields. Engberg (1967) sampled 71 wells in northern Holt county, Nebraska, and found that 22 of the 71 wells contained nitrate-nitrogen concentrations greater than 10 mg/l, and that barnyards and feedlots were the principal source of the contamination. Septic tanks and sewage outlets were suspected for those wells not having obvious sources of contamination (Engberg, 1967).

Top soils in the study area are basically sandy loams overlying porous unconsolidated sediments. Unless the ground is frozen or precipitation is unusually heavy, most of the rainfall will infiltrate the soils rapidly. Walker (1973) suggests that water polluted with nitrates will infiltrate downward as a bulb-like mass until it reaches the groundwater table where it then spreads laterally. Taylor and Bigbee (1973) describe the movement of subsurface contaminants as chiefly vertical in the zone of aeration until the water table is reached; then lateral dispersion predominates in the direction of groundwater flow. The downward movement of pollutants may be retarded by less permeable earth materials such as clay. These fine-grained impermeable materials form aquicludes. From cross-sections (Plates 1-7), clays were noted as lenses and not as continuous units. Thus, the clay lenses in the Deer Park area would act as obstacles and buffers in the downward and lateral movement of contaminants. Taylor and Bigbee (1973) state that the requisite conditions for nitrate concentrations in an aquifer in semi-arid climates include permeable soils, the absence of an aquiclude between land surface and the zone of saturation, and adequate moisture for downward percolation. Since the water table level has not significantly changed over the past years (Tanaka, D.O.E. memorandum, 1980), recharge is reaching the groundwater table. Adriano and others (1971) note that serious problems of nitrate contamination can arise if the sediment is sandy. Keeny and Walsh (1972) summarize that water that infiltrates into the soil ultimately either evaporates, transpires, seeps along impervious layers or percolates to the water table, and that leaching of inorganic species at a particular location is largely related to conditions affecting evapotranspiration, to physical soil conditions and to precipitation distribution and intensity.

Well depth, construction and position, as discussed by Engberg (1967), play a critical role in the potential nitrate-nitrogen contamination of rural domestic water supplies. As shown in Figure 18, groundwater containing inorganic contaminants will disburse laterally in the direction of groundwater movement. Walker (1973) states that there is little mixing of nitrogen species with native groundwater and, for this reason, fairly small quantities of pollution may enter a well at higher concentrations long after initial entry into the aquifer. Figure 18 shows that the groundwater from any well located within the pathway of

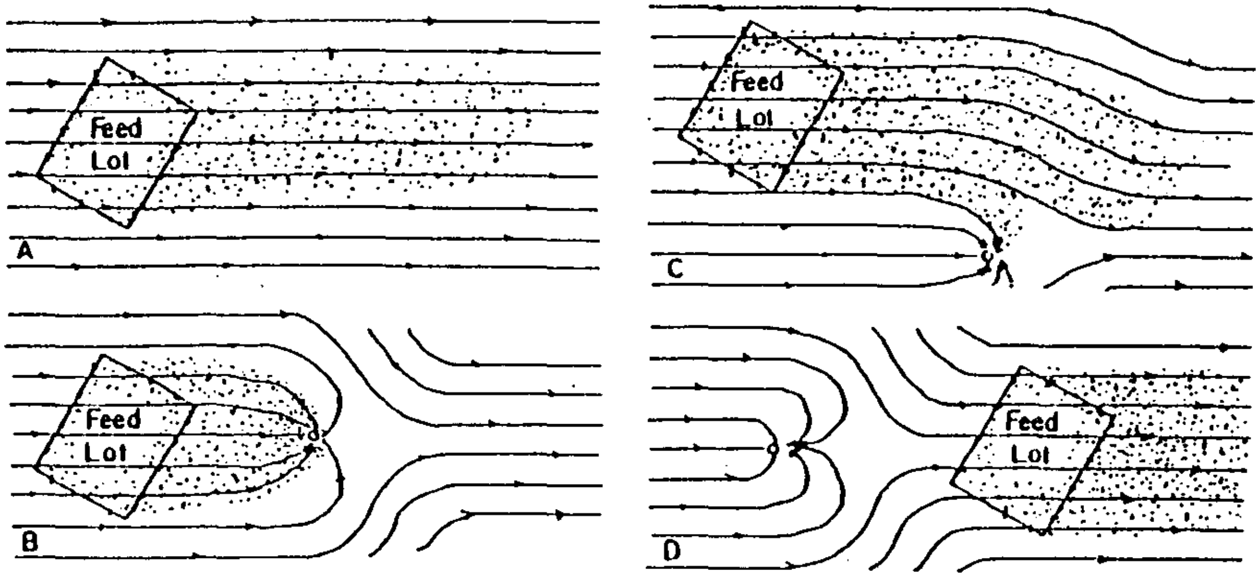


Figure 18. A, undisturbed lateral movement of high-nitrate water in direction of groundwater movement; B and C, well locations where pumping induces movement of high-nitrate water into well; D, well location where pumping does not induce movement of high-nitrate water into well (Engberg, 1967).

advancing plumes will begin to show an increase in contamination. The amount of increase will depend on the distance from the nitrate source to the well site and the rate of groundwater movement. Engberg (1967) notes that, in the immediate vicinity of heavily pumped wells, the rate of advance will be faster.

As reported by Engberg (1967), in order for one to predict whether a certain well is likely to experience nitrate-nitrogen contamination derived from a nearby source, the rate at which the well will be pumped and the direction of groundwater movement need to be known. As illustrated in Figure 19, wells positioned down gradient from the nitrate source are likely to yield high nitrate water, even if not heavily pumped, and wells positioned up gradient would be less likely to produce high nitrate water.

Removal of nitrates from rural groundwater supplies is generally prohibitive. Amant and Beck (1970) discuss two methods for removing nitrate-nitrogen from agricultural waste water termed "bacteria denitrification" and "algae stripping." Boiling kills bacteria in the contaminated water, but it concentrates the nitrates. Engberg (1967), along with other authors, notes that in rural water supplies it may be necessary to drill a new well in a less convenient place or to deepen the existing well and case out the high nitrate water. Any action taken should insure that the new well or addition to an existing well be done in

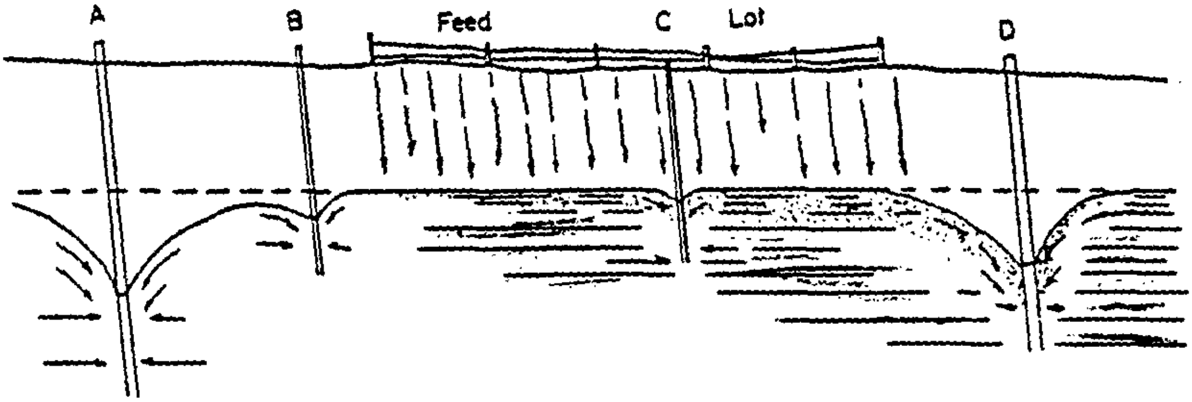


Figure 19. Wells A and B yield low nitrate water, C and D yield high-nitrate water (Engberg, 1967).

accordance to standards set by the Department of Ecology (Minimum Standards for Construction and Maintenance of Water Wells, 1985).

SUMMARY

Several domestic wells in the Deer Park area have exceeded the U.S. Public Health Service (1962) recommended drinking water standard of 10 mg/l for nitrate-nitrogen. The municipal water supply wells of Deer Park also show high threshold contamination levels of nitrate-nitrogen. No definitive source(s) for the nitrate contamination are indicated at this time; however, suspected nitrate sources are septic tanks, barnyards, commercial fertilizers, animal (poultry) wastes and municipal sewage.

The general geology of the Deer Park area is fairly complex. Cross-sections of the study area (Plates 1-7) depict the pre-Tertiary terrain as essentially flat lying or gently rolling (Figure 4a). Three basalt flows have been described by well drillers in the Deer Park area. The basalt probably covered the lower areas flowing around the higher structures of the pre-Tertiary paleosurface. The basalt flows terminate in the northeastern part of the study area. Distinct basalt highlands were noted from the structure contour map (Figure 7a). The tops of the basalt highlands consistently range between 2140 and 2160 feet (652-658 m) in elevation. The basalt surface tends to affect the flow of groundwater by controlling the direction and velocity of groundwater flow (Figures 7a and 12a). The upper basalt flow(s) have been cut and filled with sands and gravels, and it appears that the present drainage pattern mimics the incised basalt surface (Plates 1-7). The city of Deer Park appears to be situated over a basin-like structure cut into the basalt. Groundwater appears to flow into this basin from virtually all directions (Figure 12a).

Determinations of hydraulic characteristics of transmissivity, storativity and hydraulic conductivity were based on specific capacity tests performed by the well drillers. Average transmissivity values for the basalt and unconsolidated sediment aquifers are calculated to be 370 gpd/ft (4.5 m^2/day) and 6500 gpd/ft (80.7 m^2/day), respectively (Table 1). Total water in storage for both aquifers is approximately 83,000 acre-feet (1.0×10^8 m^3). The hydraulic conductivity of the unconsolidated sediments ranges between a minimum of 0.05 ft/day to a maximum of 2.6 ft/day (0.15 m/day to 0.79 m/day) (Table 2). At this time, the nitrate-nitrogen pollution is generally confined to the shallow unconsolidated sediment aquifer. Downward movement of the nitrate-rich groundwater is somewhat restricted by the underlying basalt and granitic rocks. The basalt aquifer is generally not contaminated with nitrates at this time. The porous nature of the unconsolidated sediments does little to retard pollution of the groundwater from such conservative contaminants as nitrates and chlorides. Movement of nitrate-rich groundwater is in the direction of groundwater flow; therefore, wells drilled in the unconsolidated sediments down the hydraulic gradient from sources of nitrates can expect elevated levels of nitrate-nitrogen. The saturated thickness of the unconsolidated surficial aquifer is approximately 42 feet (12.8 m). There are no data available to determine if the full thickness of the aquifer is contaminated, but Kimmel and Braids (1980) state that movement of leachate to the bottom of the aquifer may be typical of aquifers of high permeabilities. Distribution of the nitrates results from several processes within the aquifer. Kimmel and Braids (1980) and LeBlanc (1982) note that contaminants are distributed in earth materials by 1) recharge from precipitation at the contaminant source, 2) biological activity within the soils, 3) mixing of nitrate "slug" and incoming groundwater, 4) sorption of dissolved ions in the aquifer, 5) changes in physical properties of the water, and 6) dispersion of the contaminants.

Contamination could move with groundwater flow towards the center of the basin area. Most of Deer Park's municipal wells are located in the unconsolidated surficial sediments within the basin structure (Figures 7a and 17a). Water supplies that are not contaminated with nitrates may eventually have to come from the basalt aquifer or from a distant unconsolidated sediment aquifer.

In Section 6, T.28N., R.43E., an egg farm has been in production for approximately 25 years. On-site disposal of poultry wastes has probably led to degradation of nearby wells constructed in the unconsolidated sediment aquifer (Figure 17a). Groundwater flow in this area is to the south (Figure 12a). A north-south trending basalt highland diverts the groundwater flow to the southwest and southeast (Figure 7a). Wells drilled in the unconsolidated sediments to the east and west of this basalt highland can expect increased levels of nitrate-nitrogen concentrations. Wells constructed in the basalt aquifer do not show high levels of nitrate-nitrogen (Figure 17a).

High nitrate-nitrogen concentrations in groundwater are not peculiar to the Deer Park area. Several counties in Washington are also reporting high nitrate levels due to irrigation runoff and landfills (Kroll, personal communication, 1986). Widespread nitrate contamination of rural areas is compounded by farming activities along with on-site waste disposal and the need to have a close supply of water. It is important, then, to select a well site that will not be located near possible sources of nitrates. After the best well site has been located, precaution should be taken during drilling to insure a sanitary well. Proper maintenance and operation of the well and well site need to be practiced until the well is abandoned.

APPENDIX A

CONSTANTS AND CONVERSION FACTORS

Volume

1 gallon (g)	= 3.785 liters 3.785 x 10^{-3}m^3
1 cubic foot (cu ft)	= 7.481 gal 28.32 liters
1 acre-foot (acre-ft)	= 3.259 x 10^5 gal 1,234 m^3
1 liter (l)	= 0.2642 gal 1,000 cm^3
1 cubic meter (cu m)	= 264.2 gal 1,000 liters
1 cubic hectometer (cu hm)	= 10^6m^3
1 barrel (oil)	= 42 gal
1 million gallons	= 3.069 acre-feet 3,785.4 m^3

Flow Rate

1 gallon per minute (gpm)	= 0.0631 l/sec 5.42 m^3/day
1 million gallons per day (mgd)	= 43.7 l/sec 3,785 m^3/day
1 billion gallons per day (bgd)	= 3.785 hm^3/day
1 cubic foot per second (cfs)	= 449 gpm 28.3 l/sec
1 acre-foot per day	= 14.2 l/sec
1 liter per second (l/s)	= 15.9 gpm 86.4 m^3/day
1 cubic meter per second (cu m/s)	= 22.8 mgd 35.3 cfs
1 cubic meter per day (cu m/d)	= 0.183 gpm
1 cubic hectometer per day (cu hm/d)	= 264.2 mgd

Pressure

1 pound per square inch (psi)	= 0.07031 kg/cm^2
1 kilogram per square centimeter (kg sq cm)	= 14.22 lb/in^2

Transmissivity

1 sq m/day	= 80.5 gpd/ft

Length

1 inch (in) = 2.54 cm
1 foot (ft) = 30.48 cm
1 mile (mi) = 1.609 km
1 centimeter (cm) = 0.3937 in
10 mm
1 meter (m) = 39.37 in
3.2808 ft
100 cm
1 kilometer (km) = 0.621 mi
1,000 m
10 hm

Area

1 acre = 0.4047 hectare
1 square mile (sq mi) = 2.590 km^2
1 hectare (ha) = 2.471 acres
1 square kilometer (sq km) = 247.1 acres
0.3861 mi^2
100 hectares

Weight

1 pound (lb) = 0.4536 kg
1 short ton = 2,000 lb
0.9072 metric ton
1 metric ton = 1,000 kg
1 kilogram (kg) = 2.205 lb

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VITA

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NITRATE IN DRINKING WATERS

The direct concentration nitrate method by electrode has been approved by the EPA for use in NIPDWR compliance monitoring in potable waters. There are no turbidity or color interferences. It is applicable in the range of 1.0 to 100 mg/liter (ppm). Higher concentrations can be analyzed after dilution. The method requires very little time - only a minute or two per sample. Species present in samples which can interfere with the measurement are minimized by use of an interference suppressor solution which is mixed 1:1 with the sample before measurement.

Recommended Equipment

1. Direct concentration readout ISE meter. Other suitable meters with millivolt accuracy to 0.1 MV may be used; calibration curves will be required.

2. ORION Nitrate Electrode, Model 9307. Double Junction Reference Electrode, Model 9002.

3. Volumetric glassware and beakers.

4. Magnetic stirrer and stir bars.

Required Solutions

1. ORION Cat. No. 930710, Nitrate Interference Suppressor Solution.

2. ORION Cat. No. 920707, Nitrate Standard 1000 ppm as nitrate nitrogen.

3. Reference Electrode Filling Solution: 0.53g/100 ml ammonium sulfate solution. Dilute ORION Cat. No. 930711, Nitrate Ionic Strength Adjustor in the following manner: Into a 100 ml volumetric flask pipet 2.0 ml Ionic Strength Adjustor, fill to the mark with distilled or deionized water, and mix.

4. Distilled or deionized water.

Set up

1. Connect electrodes to meter according to the meter instruction manual.

2. Assemble and check operation of both nitrate and reference electrodes as described in the electrode instruction manual. The double junction reference electrode, however, should be filled with the reference electrode filling solution described above in the outer chamber.

3. Prepare a 100 ppm nitrate nitrogen standard by pipetting 10 ml of the 1000 ppm standard, ORION Cat. No. 920707 into a 100 ml volumetric flask. Dilute to the mark with distilled or deionized water.

3A. Prepare a 50 ppm NO_3 standard by diluting 100 ppm standard - 1:1 with distilled water.

4. Prepare a 10 ppm nitrate nitrogen standard by pipetting 10 ml of the 100 ppm standard into a 100 ml volumetric flask. Dilute to the mark with distilled or deionized water.

5. Prepared a 1 ppm nitrate nitrogen standard by pipetting 1 ml of the 100 ppm standard into a 100 ml volumetric flask. Dilute to the mark with distilled or deionized water.

Preparation

1. Using a graduated cylinder, measure 10 ml of each of the prepared standards into a separate 50 ml beaker.

2. To each of the beakers add 10 ml interference suppressor solution.

3. Using a graduated cylinder, measure 10 ml of each of the samples into a separate 50 ml beaker.

4. To each of the beakers add 10 ml interference suppressor solution.

Analysis

For instruments with direct concentration readout capability, consult meter manual for correct direct measurement procedures.

1. Calibrate meter using prepared standards, stirring samples at a uniform rate. Stir for two minutes. Immerse electrodes and record mV reading after one minute.

2. Rinse electrodes with distilled or deionized water between measurements.

3. Measure samples, stirring at the same uniform rate used in the standards, and rinsing electrodes in distilled or deionized water between measurements.

Special Considerations

1. Samples that have been preserved with sulfuric acid should be adjusted to pH 7, using sodium hydroxide solution prior to analysis.

2. Common interferences to the method include chloride and carbonate. Less significant interferences are bromide, cyanide, sulfide, nitrite, and some organic anions. The interference suppressor solution contains ingredients to reduce interferences commonly encountered in samples.

3. Chlorate and perchlorate ions are potential interferences, but do not normally occur at significant levels in potable and ground waters, except where chlorine dioxide has been used as a disinfectant.

Interferences

Some other anions, if present at high enough levels, are electrode interferences and cause measurement errors or electrode malfunction. Table 5 indicates levels of common anions that will cause 10% error at three levels of nitrate. The top half of the table shows interference levels in moles per liter at 10^{-4}, 10^{-3}, and 10^{-2} M concentrations of nitrate. The bottom half of the table shows interference levels in ppm at 100, 10, and 1 ppm nitrate nitrogen.

Many of the interferences can be removed by the following procedures (letters refer to letters in table 5):

a) Carbonate and bicarbonate can be removed by acidifying the sample to pH 4.5 with sulfuric acid, converting the ions to carbon dioxide.

b) These interferences can be removed by precipitation with silver. Dissolve solid silver sulfate in samples to effect removal.

c) Nitrate can be removed by adding sulfamic acid to samples.

d) These interferences cannot be removed. Convert nitrate to nitrite with a reduction column and measure nitrite levels with a nitrogen oxide electrode (ORION Model 95-46). For more information contact ORION Technical Services.

e) Many organic (carboxylic) anions also interfere with the nitrate electrode. These anions can be removed by using a 1 M ISA containing aluminum sulfate.

Note: Use of any of the above procedures requires similar treatment of standards as well as samples.

ORION manufactures a general nitrate extract solution (Cat. No. 930710) for removal of a variety of interfering anions present in samples such as soils or plant tissues. To prepare independently, see the 93 Series Methods Manual or contact Technical Services at ORION.

In cases where interferences are not removed, and the electrode is exposed to high levels of interfering ions, it may become drifty and sluggish in response. When this happens, restore normal performance by soaking for an hour in distilled water, then for a few hours in nitrate standard solution.

Table 5

Levels of possible interferences causing a 10% error at various levels of sodium nitrate with a background ionic strength of 0.12 M $(NH_4)_2SO_4$ as NO_3^-.

Interferences (moles per liter)	10^{-4} M	10^{-3} M	10^{-2} M
(d) CIO_4^-	1×10^{-8}	1×10^{-7}	1×10^{-6}
(b) I^-	5×10^{-7}	5×10^{-6}	5×10^{-5}
(d) CIO_3^-	5×10^{-6}	5×10^{-5}	5×10^{-4}
(b) CN^-	1×10^{-5}	1×10^{-4}	1×10^{-3}
(b) Br^-	7×10^{-5}	7×10^{-4}	7×10^{-3}
(c) NO_2^-	7×10^{-5}	7×10^{-4}	7×10^{-3}
(b) HS^-	1×10^{-4}	1×10^{-3}	1×10^{-2}
(a) HCO_3^-	1×10^{-3}	1×10^{-2}	0.1 M
(a) $CO_3^=$	2×10^{-3}	2×10^{-2}	0.2 M
(b) CI^-	3×10^{-3}	3×10^{-2}	0.3 M
(b) $H_2PO_4^-$	5×10^{-3}	5×10^{-2}	0.5 M
(b) $HPO_4^=$	5×10^{-3}	5×10^{-2}	0.5 M
(b) PO_4^{3-}	5×10^{-3}	5×10^{-2}	0.5 M
(e) OA_c^-	2×10^{-2}	0.2 M	2 M
F^-	6×10^{-2}	0.6 M	6 M
$SO_4^=$	0.1 M	1.0 M	10 M

Interferences (ppm)	1 ppm	10 ppm	100 ppm N
(d) CIO_4^-	7×10^{-4}ppm	7×10^{-3}ppm	7×10^{-2}ppm
(b) I^-	4×10^{-2}ppm	0.4	4
(d) CIO_3^-	0.3 M	3	30
(b) CN^-	0.2	2	20
(b) Br^-	4	40	400
(c) NO_2^-	2	23	230
(b) HS^-	2	23	230
(a) HCO_3^-	44	440	4,400
(a) $CO_3^=$	86	860	8,600
(b) CI^-	76	760	7,600
(b) $H_2PO_4^-$	346	3,464	34,640
(b) $HPO_4^=$	343	3,430	34,300
(b) PO_4^{3-}	339	3,390	33,700
(c) OA_c^-	1,042	10,420	100,420
F^-	814	8,140	81,400
$SO_4^=$	6,857	68,570	685,700

CHLORIDE IN DRINKING WATER, WASTEWATERS, AND BRINES

This procedure may be used to measure chloride ion in drinking water, wastewaters, and brines over the range of 1 to 1000 ppm chloride. Higher concentrations are measured simply after preliminary dilution. No titration is involved and the electrodes are not affected by sample color or turbidity. By using the specified ion strength adjustor, potential interferences from up to 500 ppm sulfide, 1000 ppm bromide or iodide, 100 ppm ammonia, or 100 fold excess of cyanide over chloride are virtually removed.

Recommended Equipment

1) Direct concentration readout ISE meter. Other suitable meters with millivolt accuracy to 0.1 mV may be used; calibration curves will be required.

2) ORION Chloride Electrode, Model 9417B. Standard silver chloride/silver sulfide electrodes including the old ORION Model 9417A should not be used as the ionic strength adjustor will destroy the sensing membrane. Double Junction Reference Electrode, Model 9002.

3) Volumetric glassware and beakers.

4) Magnetic stirrer and stir bars.

Required Solutions

1) ORION Cat. No. 941709, Chloride Ionic Strength Adjuster, CISA. Prepare according to the package directions.

2) ORION Cat. No. 941708, Chloride Standard 100 ppm.

3) Reference Electrode Filling Solutions: use the inner chamber fill solution shipped with the Reference Electrode, Cat. No. 900002. Do not use the outer chamber filling solution shipped with electrode. Instead dilute prepared CISA 1:1 with distilled or deionized water and use this solution as a filling solution.

4) Distilled or deionized water.

Set Up

1) Connect electrodes to meter according to the meter instruction manual.

2) Assemble and check operation of both chloride and reference electrodes as described in the electrode instruction manual.

3) The 100 ppm chloride standard will be used undiluted. Prepare a 10 ppm chloride standard by pipetting 10 ml of the 100 ppm standard into a 100 ml volumetric flask. Dilute to the mark with distilled or deionized water.

Preparation

1) Using a graduated cylinder, measure 10 ml of each of the prepared standards into a separate 50 ml beaker.

2) To each of the beakers add 10 ml CISA.

3) Using a graduated cylinder, measure 10 ml of each of the samples into a separate 50 ml beaker.

4) To each of the beakers add 10 ml CISA.

Analysis

For instruments with direct concentration readout capability, consult meter manual for correct direct measurement procedures.

1) Calibrate meter using prepared standards, stirring samples at a uniform rate. Stir for one minute. Immerse electrodes and record mV reading after one minute.

2) Rinse electrodes with distilled or deionized water between measurements.

3) Measure samples, stirring at the same uniform rate used in the standards, and rinsing electrodes in distilled or deionized water between measurements.

Reproducibility

Reproducibility is limited by factors such as temperature fluctuations, drift, and noise. Within the electrode's operating range, reproducibility is independent of concentration. With calibration every hour, direct electrode measurements reproducible to ± 2% can be obtained.

Interferences

High levels of ions which form very insoluble salts of silver may deposit a layer of salt on the membrane, causing electrode malfunction. In addition, strongly reducing solutions may form a surface layer of silver. In either case, restore performance by polishing.

Mercury must be absent from samples.

Measurements can be made in solutions containing oxidizing agents such as Cu^{++}, Fe^{+++}, and MnO_4^-.

Table 4 gives the maximum allowable concentration of the more common interfering ions, expressed as the ratio of the interfering ion molarity to the sample chloride molarity. If the ratio is exceeded, readings will be in error. If the ratio is less than that listed in the table, neither accuracy of the measurement nor surface of the electrode membrane will be affected.

Table 4

Maximum allowable ratio of interfering ion to chloride

Interference	Maximum allowable ratio $\frac{\text{Interference}}{\text{Chloride}}$
(a) OH^-	80
(b) Br^-	3×10^{-3}
(b) I^-	5×10^{-7}
(c) $S^=$	10^{-6}
(c) CN^-	2×10^{-7}
(d) NH_3	0.12
(d) $S_2O_3^=$	0.01

(a) Hydroxide interference can be removed by acidifying to pH 4 with 1 M HNO_3.

(b) Mixed halides in solution can be measured using CISA to remove interferences or by a Gran's plot titration. A procedure for using CISA can be found on the following page. Write or call ORION's Technical Service Group for information.

(c) Sulfide and cyanide may be removed by adding a nickel (+ 2) solution or by using CISA.

(d) Represents a complexing species. Maximum level can be exceeded without electrode damage. Value shown is for 1% error.

ORION Application Information Procedure No. 507 provides specific instructions for using an oxidizing reagent to eliminate most interferences. This procedure is summarized below.

Use of CISA

Interferences to the chloride measurement may be removed by addition of CISA, and oxidizing agent which will oxidize up to 500 mg/l S^{-2}, 100 mg/l Br^- or 1^-, 100 mg/l NH_3, or a 100-fold excess of CN^- over CI^-.

Chloride can be measured in the presence of other halides without the need for a Gran's Plot titration. Since the reagents used are strong oxidizing agents, solutions should be handled in a well-ventilated area, preferably a hood.

CISA: ORION Cat. No. 941709, 1 $MHNO_3$ and 0.1 M $NaBrO_3$.

Procedure: Mix CISA in equal quantities with both standards and samples. Allow solutions to stand ten minute before measuring. Standards mixed with CISA should be discarded after measuring since chloride will be oxidized upon prolonged standing. Prepare a fresh mixture of standard and CISA for each calibration. Follow procedures for direct measurement after adding CISA.

TABULATION OF GROUNDWATER NITRATE DATA, 1986

Findings: Statistics

Each sampling round was allowed a maximum of 100 samples.

As each round was preformed, area residents and neighbors became aware of the study and their concern aided in establishing more sampling points. There were 94 sampling points, which due to well malfunction, shut down, or non accessibility had to be omitted during certain collection times. Therefore, accounting for the varying number of samples collected for each round.

Sampling Schedule:

Round #1	April 14 - May 29
Round #2	June 13 - July 2
Round #3	August 4 - 15
Round #4	September 15 - 26
Round #5	October 20 - 31
Round #6	December 1 - 12

Round #1	Samples Taken:	75
Round #2	Samples Taken:	90
Round #3	Samples Taken:	87
Round #4	Samples Taken:	92
Round #5	Samples Taken:	88
Round #6	Samples Taken:	86
	Total:	518

Other samples were drawn by request of Deer Park area residents who were not included for survey due to absence of well log data or because samples were not drawn under control techniques. All these samples displayed values which did not display elevated nitrate levels.

Total:	12
Lab Total:	530

(Reference to definition [figure illustration] of site coding [Figure #5])

A breakdown of sampling points by section, township, and range displaying overall range of nitrate levels*, overall average for all samples taken, and depth of well and static water level are as follows:

*See Figure #1A for sampling site locations)

APPENDIX E

Section 1 - Township 28 - Range 42

Sampling Points	Range mg/l	Average mg/l	Depth in feet	Static Water Level Below Well Collar
E-1	3.4 - 6.8	5.0	106	50
H-1	3.8 - 7.5	5.6	275	57
H-2	1.0 - 1.4	1.0	279	56

Section 2 - Township 28 - Range 42

Sampling Points	Range mg/l	Average mg/l	Depth in feet	Static Water Level Below Well Collar
M-1	5.2 - 11.0	7.5	136	--
M-2	5.6 - 11.0	9.0	84	25

Section 3 - Township 28 - Range 42

	Sampling Points	Range mg/l	Average mg/l	Depth in feet	Static Water Level Below Well Collar
	E-1	1.0 - 1.3	1.0	140	--
	K-1	1.0 - 4.2	2.0	75	20
	K-2	5.2 - 9.0	7.2	80?	22
Susp.	H-2	6.5 - 10.5	8.0	30?	18
*36.0	L-1	1.7 - 5.4	3.3	?	12
Error	L-2	1.0 - 1.3	1.0	?	20
	P-1	Insufficient data			
	Q-1	1.0 - 1.4	1.0	165	4
	Q-2	2.4 - 4.1	3.6	?	?

Section 10 - Township 28 - Range 42

	Sampling Points	Range mg/l	Average mg/l	Depth in feet	Static Water Level Below Well Collar
	B-2	2.1 - 5.4	3.9	215	23
	B-3	3.9 - 9.6	7.5	155	40
	H-1	1.3 - 3.5	2.4	?	30
*19.5	H-2	1.0 - 2.4	1.4	135	33
	J-1	1.0 - 1.2	1.0	102	15

Section 11 - Township 28 - Range 42

Sampling Points	Range mg/l	Average mg/l	Depth in feet	Static Water Level Below Well Collar
C-2	1.0 - 1.3	1.0	180	40
C-1	1.0 - 7.2	3.8	165	20
L-1	1.0 - 1.3	1.0	143	?

Section 12 - Township 28 - Range 42

Sampling Points	Range mg/l	Average mg/l	Depth in feet	Static Water Level Below Well Collar
A-1	23.8 - 31.5	26.2	57	38
A-2	36.5 - 158.0	104.0	?	?
A-3	124.0 - 250.0	180.5	62	48
C-1	1.0 - 1.5	1.0	136	60
H-1	1.0 - 6.4	1.9	160	70
H-2	1.0 - 3.5	1.5	165	57
H-3	1.0 - 1.5	1.0	185	46
J-1	1.0 - 7.5	4.6	225	52
H-4	96.0 - 194.0	137.0	?	?
H-5	7.8 - 19.0	13.4	83	50
G-1	10.8 - 14.6	12.3	110	70
G-2	7.6 - 13.6	9.9	65	?
G-3	1.0 - 1.7	1.3	82-94	42
K-1	4.3 - 7.4	6.1	57	33

Section 13, Township 28 - Range 42

Sampling Points	Range mg/l	Average mg/l	Depth in feet	Static Water Level Below Well Collar
A-1	1.1 - 12.4	5.7	?	?
B-1	6.6 - 14.8	10.0	135	62
B-2	8.9 - 19.1	14.9	126	40
B-4	4.6 - 8.7	6.9	120	35
D-1	1.0 - 2.0	1.1	160	80
K-1	3.3 - 5.4	4.0	240	18
Q-1	3.6 - 6.8	5.3	52	9
R-1	3.9 - 6.8	4.5	59	30

Section 14 - Township 28 - Range 42

Sampling Points	Range mg/l	Average mg/l	Depth in feet	Static Water Level Below Well Collar
H-1	1.1 - 3.3	2.2	125	35
K-1	1.1 - 3.1	1.2	230	--
K-2	1.0 - 1.0	1.0	150	--

Section 25 - Township 29 - Range 42

Sampling Points	Range mg/l	Average mg/l	Depth in feet	Static Water Level Below Well Collar
P-1	3.5 - 7.0	5.6	285	62
M-2	2.1 - 4.6	3.7	222	80

Section 26 - Township 29 - Range 42

Sampling Points	Range mg/l	Average mg/l	Depth in feet	Static Water Level Below Well Collar
K-1	3.5 - 10.0	7.2	55	30
J-1	1.0 - 1.0	1.0	160	40

Section 34 - Township 29 - Range 42

Sampling Points	Range mg/l	Average mg/l	Depth in feet	Static Water Level Below Well Collar
E-1	1.0 - 1.0	1.0	285	41
P-1	1.0 - 1.4	1.1	145	35
P-2	3.6 - 4.8	4.4	85	18

Section 35 - Township 29 - Range 42

Sampling Points	Range mg/l	Average mg/l	Depth in feet	Static Water Level Below Well Collar
C-1	5.0 - 10.0	7.6	250	38
C-2	3.2 - 6.8	5.18	62	40
D-2	3.7 - 9.4	6.7	80	20
E-1	6.8 - 17.9	11.3	48	24
P-1	6.3 - 10.5	7.5	210	40
P-2	1.0 - 1.3	1.1		

Section 5 - Township 28 - Range 43

Sampling Points	Range mg/l	Average mg/l	Depth in feet	Static Water Level Below Well Collar
M-1	5.7 - 9.7	7.5	133	10
C-2	1.0 - 1.9	1.4	81	10
F-1	1.0 - 1.4	1.2	215	50
G-1	1.0 - 2.0	1.0	165	70
G-2	1.0 - 3.4	3.0	--	--
H-1	1.5 - 4.2	2.7	225	190
J-2	1.0 - 1.6	1.1	124	74

Section 6 - Township 28 - Range 43

Sampling Points	Range mg/l	Average mg/l	Depth in feet	Static Water Level Below Well Collar
M-1	1.0 - 1.3	1.0	115	42
K-1	20.5 - 41.0	31.0		
K-2	5.6 - 57.0	26.0		
K-3	29.8 - 52.0	41.4		
K-4	7.3 - 15.0	11.4		
K-5	1.0 - 2.0	1.2		
J-1	1.0 - 1.9	1.4		
L-1	21.5 - 41.0	28.8	40-60	32

Section 7 - Township 28 - Range 43

Sampling Points	Range mg/l	Average mg/l	Depth in feet	Static Water Level Below Well Collar
H-3	14.0 - 29.8	19.9	--	--
G-2	1.0 - 1.3	1.0	100	35
F-1	1.0 - 1.3	1.0	265	60
G-1	1.0 - 2.0	1.0	170	49
H-1	1.0 - 1.9	1.2	120	35
H-2	3.0 - 19.0	11.5	96	50
J-1(a)	4.5 - 6.1	5.3	--	--
J-1(b)	16.6 - 23.0	19.5	240	--
L-1	1.0 - 1.3	1.1	153	114
M-1	1.0 - 1.6	1.3	347	50
A-1	35.5 - 95.0	60.7	Spring	1

Section 8 - Township 28 - Range 43

Sampling Points	Range mg/l	Average mg/l	Depth in feet	Static Water Level Below Well Collar
D-1(a)	26.5 -	26.5	20	12
D-1(b)	1.1 - 1.6	1.3	180	--
M-1	11.0 - 14.0	12.2	66	46
M-2	1.0 - 1.5	1.1	--	--

Section 18 - Township 28 - Range 43

Sampling Points	Range mg/l	Average mg/l	Depth in feet	Static Water Level Below Well Collar
E-1	6.4 - 10.6	8.7	80	45

Section 29 - Township 29 - Range 43

Sampling Points	Range mg/l	Average mg/l	Depth in feet	Static Water Level Below Well Collar
N-1	1.0 - 1.3	1.0	192	88

Section 32 - Township 29 - Range 43

Sampling Points	Range mg/l	Average mg/l	Depth in feet	Static Water Level Below Well Collar
G-1	1.0 - 1.3	1.0	140	80
G-2	1.0 - 1.1	1.0	140	--

Chlorides

Chloride analysis was performed from the same samples for nitrates in Round 2, 3, and 6.

Chlorides serve as a indication of well contamination. The excessive amounts of chlorides were not found in any of the samples.

Chloride results as follows:

Section 1 - Township 28 - Range 42

Sampling Points	Round #2 mg/l	Round #3 mg/l	Round #6 mg/l	Annual Average NO_3 mg/l
E-1	2.3	2.1	3.1	5.0
H-1	1.5	1.4	1.9	5.6
H-2	1.7	1.5	1.8	1.0

Section 2 - Township 28 - Range 42

Sampling Points	Round #2 mg/l	Round #3 mg/l	Round #6 mg/l	Annual Average NO_3 mg/l
M-1		5.0	5.0	7.5
M-2		17.0	2.3	9.0

Section 3 - Township 28 - Range 42

Sampling Points	Round #2 mg/l	Round #3 mg/l	Round #6 mg/l	Annual Average NO_3 mg/l
E-1	2.7	1.6	3.4	1.0
K-1	4.7	5.8	5.8	2.0
H-2		5.5	4.4	8.0
L-1	8.4	7.9	6.6	3.3
L-2	4.0	7.0	6.9	1.0
P-1	14.0		---	22.0
Q-1	55.0	3.7	---	1.0
Q-2	3.1	1.8	5.0	3.6
K-2	7.3	7.4	7.9	7.2

Section 10 - Township 28 - Range 42

Sampling Points	Round #2 mg/l	Round #3 mg/l	Round #6 mg/l	Annual Average NO_3 mg/l
B-2	3.0	2.0	3.1	3.9
B-3	4.5	4.5	5.6	7.5
H-2	9.4	8.3	7.6	1.4
H-1		8.6	---	2.4
J-1	2.0	2.1	2.3	1.0

Section 11 - Township 28 - Range 42

Sampling Points	Round #2 mg/l	Round #3 mg/l	Round #6 mg/l	Annual Average NO_3 mg/l
C-2	2.1	2.0	1.0	1.0
C-1	3.2	1.5	---	3.8
L-1	4.7	4.8	2.4	1.0

Section 12 - Township 28 - Range 42

Sampling Points	Round #2 mg/l	Round #3 mg/l	Round #6 mg/l	Annual Average NO_3 mg/l
A-1		4.4	2.8	26.2
A-2		26.0	27.0	104.0
A-3		36.0	35.8	180.5
C-1		1.6	1.0	1.0
H-1		1.6	1.8	1.9
H-2	1.6	1.5	1.8	1.5
H-3	1.6	1.6	1.8	1.0
J-1	2.0	1.9	2.0	4.6
H-4		29.0	30.5	137.0
H-5		2.3	2.4	13.4
G-1	2.2	2.1	1.2	12.3
G-2	2.5	2.8	1.4	9.9
G-3	1.4	1.6	1.0	1.3
K-1	1.9	2.6	1.2	6.1

Section 13 - Township 28 - Range 42

Sampling Points	Round #2 mg/l	Round #3 mg/l	Round #6 mg/l	Annual Average NO_3 mg/l
A-1	2.2	1.8	2.1	5.7
B-1	2.3	2.2	2.6	10.0
B-2	3.3	3.3	3.1	14.9
B-4	2.3	2.0	1.1	6.9
D-1	1.8	1.9	1.1	1.1
K-1	1.6	1.8	1.9	4.0
Q-1	2.2	2.0	2.5	5.3
R-1	1.9	2.0	2.9	4.5

Section 14 - Township 28 - Range 42

Sampling Points	Round #2 mg/l	Round #3 mg/l	Round #6 mg/l	Annual Average NO_3 mg/l
H-1	4.0		---	2.2
K-1	2.9	1.9	2.1	1.2
K-2		1.5	3.4	1.0

Section 25 - Township 29 - Range 42

Sampling Points	Round #2 mg/l	Round #3 mg/l	Round #6 mg/l	Annual Average NO_3 mg/l
P-1	1.6	1.7	2.2	5.6
M-2	1.4	1.6	1.9	3.7

Section 26 - Township 29 - Range 42

Sampling Points	Round #2 mg/l	Round #3 mg/l	Round #6 mg/l	Annual Average NO_3 mg/l
K-1	1.5	2.1	2.8	7.2
J-1	1.7	1.8	2.9	1.0

Section 34 - Township 29 - Range 42

Sampling Points	Round #2 mg/l	Round #3 mg/l	Round #6 mg/l	Annual Average NO_3 mg/l
E-1	2.2		---	1.0
P-1	2.4	2.2	3.4	1.1
H-2	--	--	---	
P-2	3.9	4.2	2.6	4.4

Section 35 - Township 29 - Range 42

Sampling Points	Round #2 mg/l	Round #3 mg/l	Round #6 mg/l	Annual Average NO_3 mg/l
C-1	2.8	3.2	4.0	7.6
C-2	2.4	2.2	---	5.18
D-2	2.7	2.7	3.6	6.7
E-1	2.4	2.6	4.5	11.3
P-1		3.4	---	7.5
P-2		2.3	---	1.1

Section 5 - Township 28 - Range 43

Sampling Points	Round #2 mg/l	Round #3 mg/l	Round #6 mg/l	Annual Average NO_3 mg/l
M-1	--	3.8	---	7.5
C-2	--	--	1.8	1.4
F-1	1.5	1.6	1.7	1.2
G-1	1.4	1.6	1.7	1.0
G-2		2.0	---	3.0
H-1	3.2	2.7	3.8	2.7
J-2	1.6	1.5	1.7	1.1

Section 6 - Township 28 - Range 43

Sampling Points	Round #2 mg/l	Round #3 mg/l	Round #6 mg/l	Annual Average NO_3 mg/l
M-1		1.7	1.8	1.0
K-1	10.0	9.2	6.7	31.0
K-2	4.5	18.0	6.4	26.0
K-3	19.0	17.5	14.0	41.4
K-4	8.6	5.9	2.6	11.4
K-5	2.4	2.0	1.0	1.2
J-1	1.9	2.1	1.9	1.4
L-1	21.0	14.2	14.9	28.8

Section 7 - Township 28 - Range 43

Sampling Points	Round #2 mg/l	Round #3 mg/l	Round #6 mg/l	Annual Average NO_3 mg/l
H-3	20.0	12.0	12.5	19.9
G-2	1.6	1.6	1.9	1.0
F-1	2.2	1.9	1.9	1.0
G-1	1.7	1.7	2.0	1.0
H-1	1.6	1.7	1.9	1.2
H-2	8.5	7.9	3.0	11.5
J-1	4.8	4.7	6.0	5.3/19.5
L-1	1.5	1.6	1.8	1.1
M-1	1.6	58.0	1.8	1.3
A-1	15.0	10.0	8.4	60.7

Section 8 - Township 28 - Range 43

Sampling Points	Round #2 mg/l	Round #3 mg/l	Round #6 mg/l	Annual Average NO_3 mg/l
D-1	6.6	1.8	1.9	26.5/1.3
M-1	7.4	6.6	6.0	12.2
M-2	1.3	1.4	1.8	1.1

Section 18 - Township 28 - Range 43

Sampling Points	Round #2 mg/l	Round #3 mg/l	Round #6 mg/l	Annual Average NO_3 mg/l
E-1	4.5	4.6	3.9	8.7

Section 29 - Township 29 - Range 43

Sampling Points	Round #2 mg/l	Round #3 mg/l	Round #6 mg/l	Annual Average NO_3 mg/l
N-1	1.6	1.7	1.8	1.0

Section 32 - Township 29 - Range 43

Sampling Points	Round #2 mg/l	Round #3 mg/l	Round #6 mg/l	Annual Average NO_3 mg/l
G-1	1.5	4.0	1.6	1.0
G-2	1.5	1.4	1.6	1.0

In view of the nitrate averages, chlorides display small proportional increases as the nitrate level increases.

Mode: 1.6 mg/l most frequent value Cl_2

NO_3 Annual Averages	Average Cl_2 Displayed
Range 1.0 mg/l - 4.9 mg/l	2.57 mg/l
Range 5.0 mg/l - 9.9 mg/l	3.46 mg/l
Range 10.0 mg/l - 19.9 mg/l	6.34 mg/l
Range 20.0 mg/l - 49.9 mg/l	12.58 mg/l
Above 50 mg/l nitrate displayed at:	
60.0 mg/l	12.5 mg/l
104.0 mg/l	26.0 mg/l
137.0 mg/l	29.0 mg/l
180.5 mg/l	36.0 mg/l