TORRINGTON AREA WELLHEAD GROUNDWATER PROBLEM IDENTIFICATION

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Final Report

Submitted to

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FINAL REPORT

This final report contains a listing of the tasks to be performed by the project followed by the results obtained from the project in terms of these tasks.

It was the purpose of this project to develop detailed technical information to aid in the identification of existing and future pollution potential sources of groundwater in the area in and surrounding Torrington, Wyoming and to suggest management practices which might help protect the alluvial groundwater aquifer and wells in the recharge area from possible future contamination. The specific tasks identified for this project are detailed below.

Task One: Inventory Database of Groundwater Quantities

The specific deliverables under Task 1 were: (1) a literature review on aquifer soil materials in and surrounding Torrington to handle possible contaminants produced in the area; (2) a set of maps describing the hydrogeology and land use of the area; and (3) a database on groundwater wells, aquifer characteristics and water quality of the area.

Task Two: Mapping of Groundwater and Pollution

The specific deliverables under Task 2 were: (1) a set of maps describing the location of wells, especially those used for public water supplies, along with water quality information; and (2) a groundwater aquifer water table map.

Task Three: Identification of Possible Groundwater Pollution Areas

The specific deliverable under Task 3 is a report on existing and possible groundwater pollution areas which are or may affect the City of Torrington public water supply and other public water supplies in the area.

Task Four: Suggested Management Practices

The specific deliverable under Task 4 is a report suggesting management practices which the Town of Torrington and DEQ can consider to help develop possible guidelines for a wellhead protection strategy for the area.

RESULTS OF THE PROJECT BY TASK:

Task 1 Results:

Deliverable 1:

The problem of nitrate contamination in the Town of Torrington groundwater supply was first observed in 1986 when, through routine sampling, it was found that nitrate levels had increased in several of the towns wells (Baker, 1989). The increase was slight and none of the wells were exceeding the EPA recommended maximum contaminant level (MCL) of 10 parts per million (ppm) Nitrate-Nitrogen (NO_3-N) (40 CFR 141.23). By the spring of 1988, however, several of the wells had shown a dramatic increase in the levels of nitrate and some were exceeding the 10 ppm NO_3-N limit. By November, 1988 most of the municipal wells were approaching the MCL. In accordance with EPA guidelines, the town had developed a contingency plan to provide bottled water to pregnant women and infants under one year of age if the MCL was exceeded in the town's water supply. A more permanent solution to the problem was desired. Discussion of the development of a wellhead protection area (WHPA) to protect the groundwater supply was deemed to be the most desirable method.

From sampling done during this project, it was determined that the main contaminant to the groundwater at the present time is nitrates. A discussion on nitrates and their characteristics in the soil cycle are detailed in the following paragraphs. Since no other contaminants have been determined to be a concern in the area at this time, only nitrate will be discussed in relation to soils of the area.

The toxicology of nitrate has been extensively studied and a definitive review of the voluminous literature is significant on the subject (Ridder and Oehme, 1974; Shirley, 1975). Nitrate itself is essentially non-toxic to humans but it can be reduced to nitrite in the gastrointestinal tract of human infants and by the microflora of the human mouth. The nitrite presents a direct toxic hazard, and has also been suspected for many years of forming carcinogenic N-nitroso compounds (nitrosamine) by reaction with amino compounds (Swann, 1975).

Nitrogen is ubiquitous in the natural environment and is essential for plant and animal growth as it is incorporated in amino acids and proteins of all living organisms. In the broadest sense the nitrogen cycle describes the movement of nitrogen through all parts of the earths surface and the atmosphere. Figure 1 indicates how complex the nitrogen cycle is and why research often focuses on one aspect of the cycle (Bremner, 1967; Campbell and Lees, 1967; Keeney, 1983).

The agricultural nitrogen cycle (Figure 2) has been extensively studied with the scope of investigations ranging in

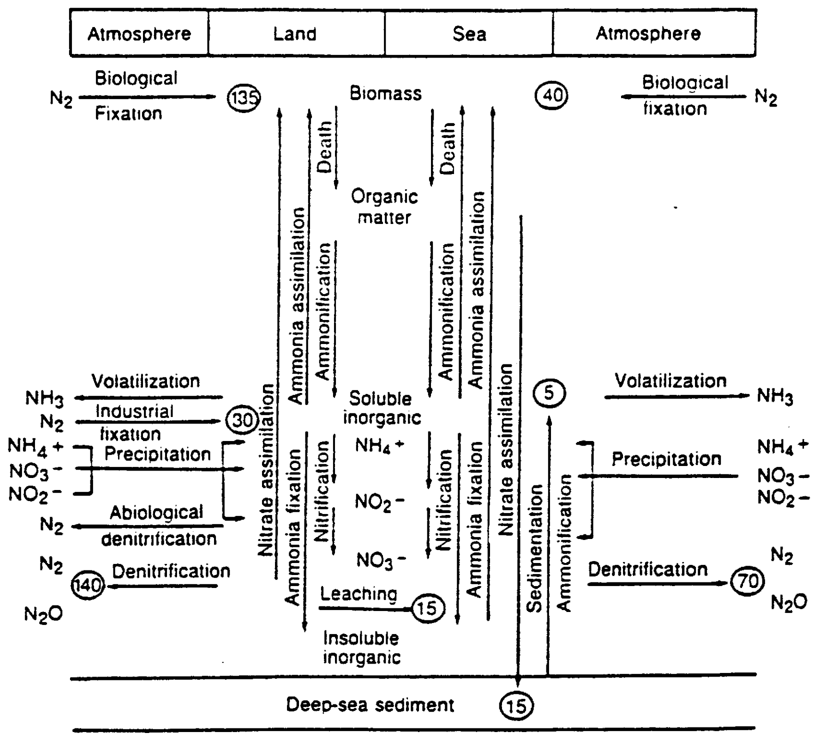

Figure 1. The Nitrogen Cycle (From Burns and Hardy, 1975).

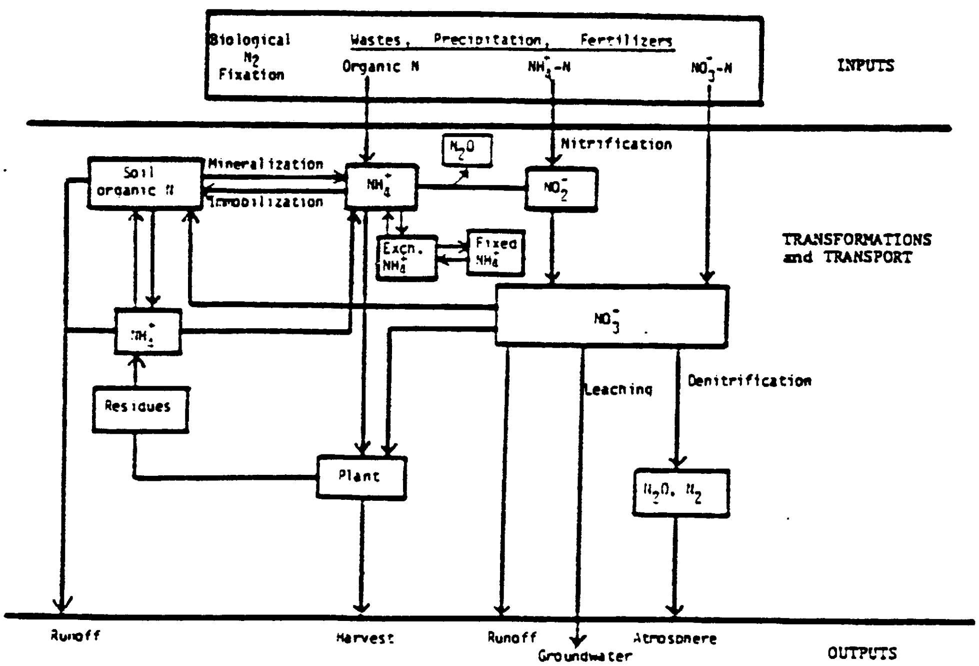

Figure 2. An Agricultural Nitrogen Cycle (From Keeney, 1983).

size from statewide groundwater investigations (Adelman et al., 1985; Hallberg, 1987a) to detailed studies of virtually all aspects of the cycle itself under almost every conceivable set of conditions (Hergert, 1986; Riha et al., 1986; Rosenberg et al., 1986).

The intensive study of the agricultural nitrogen cycle in recent years has been prompted by increasing evidence that indicates excessive use of nitrogen fertilizer has a direct impact on shallow groundwater supplies (Baker and Johnson, 1981; Baker and Lafen, 1983; Keeney, 1986b; Halberg, 1987a). The threat to water quality of groundwater supplies by nitrogen is due to the transformation (nitrification) of applied nitrogen fertilizer to nitrate by microorganisms that thrive in soils. This transformation mobilizes the nitrogen which may then be readily leached into the groundwater system (Keeney, 1986a).

The soil nitrification process is illustrated in Figure 3. The conversion and mobilization of organic forms of nitrogen to nitrite in the soil column is a biologically mediated process. The first step in the transformation of organic nitrogen to nitrate, ammonium oxidation, is carried out in large part by <u>Nitrosomonas</u> bacteria. The second step, nitrite oxidation, is performed by <u>Nitrobacter</u> bacteria. With the exception of minor transformations that occur in the atmosphere, this process is the only source of nitrate to the biosphere (Payne, 1981) and a sense of the dominance of these two bacteria over other species is shown in Table 1.

Once formed, nitrate is highly mobile and is often found at greater concentrations in the soil solution than on soil particles and colloids (Bohn et al., 1979). This characteristic is due in large part to the anionic nature of both the nitrate ion and typical soil particles which, being of the same charge, tend to repel one another.

As a result in groundwater nitrate can essentially behave as a tracer (Thomas, 1970) and a knowledge of the movement of water through soil and groundwater systems enables the prediction of nitrate movement (MacGregor, et al., 1973). These characteristics provide the justification for utilizing a groundwater flow model as a means of determining the movement of nitrate contaminants in aquifers which supply the Town of Torrington with drinking water.

<u>Deliverable 2:</u>

<u>A. Hydrogeology</u>

Numerous investigations with respect to groundwater and geology have been conducted in the area. Early investigations were concerned with determining the geology (Adams, 1902) and mineral resources found within Goshen County. Later investigations (Rapp

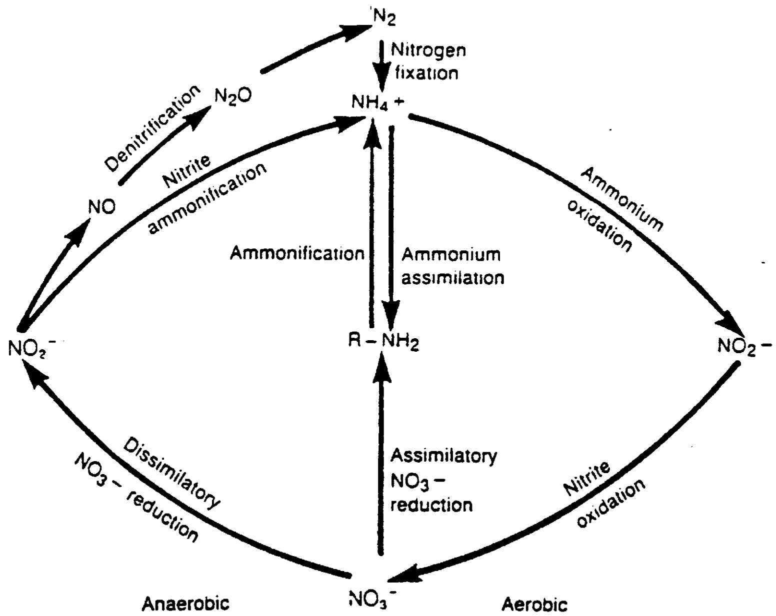

Figure 3. The Nitrification Process (From Atlas and Bartha, 1987).

Table 1. Nitrification Rates (From Focht and Verstreate, 1977).

Organism	Substrate	Product	Rate of formation (μgN/day/g dry cells)	Max. product accumulation (μgN/ml)
Arthrobacter (heterotroph)	NH_4^+	nitrite	375–9000	0.2–1
Arthrobacter (heterotroph)	NH_4^+	nitrate	250–650	2–4.5
Aspergillus (heterotroph)	HN_4^+	nitrate	1350	75
Nitrosomonas (autotroph)	NH_4^+	nitrite	1–30 million	2000–4000
Nitrobacter (autotroph)	NO_2^-	nitrate	5–70 million	2000–4000

et al., 1957) focused on the determination of the groundwater resources in the entire Goshen County area and an evaluation of the development of the water. The most recent investigations have been on evaluation of the hydrologic mass balance of the North Platte Irrigation District (Crist, 1975) and the evaluation of the impact of increased groundwater withdrawals upon the water quality and quantity in the alluvial aquifer of the North Platte Irrigation District (Herrmann, 1976).

The study area is located in the east-central portion of Goshen County, Wyoming, within the high plains section of the Great Plains physiographic province of the western United States. The area extends for 10 miles along the valley of the North Platte River which flows eastward into Nebraska. Included within the boundaries of the area is the town of Torrington, Wyoming and its outlying rural population (Appendix A).

The topography is typical of alluvial valleys in Wyoming and the western United States. Principle features include the currently active floodplain of the North Platte River located along the southern boundary of the area and a series of terraces sweeping away from the present channel. The terraces eventually grade into upland areas. Elevations range from 4075 ft. along the North Platte to 4250 ft. in the upland areas along the northern boundary of the area.

An extensive review of the geologic history of Goshen County is provided by Rapp et al. (1957). A brief summary of the history of the North Platte River and Rawhide Creek, which enters the North Platte River west of the study area, is given due to the relevant nature of this information to this study.

The North Platte River has existed for several million years and during middle Pliocene time (Figure 4) it was one of many river channels that meandered slowly across mudflats that existed in the area. Towards the end of Pliocene time, tectonic activity to the west resulted in increased erosive activity of the river, and the North Platte is thought to have established itself in essentially its present course at this time.

By middle Pleistocene time the river had cut through about 1100 feet of sedimentary material to a level approximately 200 feet above its current elevation. During late Pleistocene time, the North Platte cut a channel nearly 200 feet below its current elevation. During this time the Rawhide Creek tributary flowed through the area in a channel parallel to, and north of, the North Platte River. This channel can be identified in the bedrock contour map of the area (Figure 5). A continuous ridge of bedrock separated the two channels in the study area.

After the erosional event, the valleys were refilled 180 feet to the level of the highest, or third, terrace. The erosive power

Geologic Time Scale

Eon	Era	Period		Epoch	Time (Millions of years)
Phanerozoic	Cenozoic	Quaternary		Holocene	0.01
				Pleistocene	1.6
		Tertiary	Neogene	Pliocene	5.3
				Miocene	23.7
			Palaeogene	Oligocene	36.6
				Eocene	57.8
				Paleocene	66.4
	Mesozoic	Cretaceous		late Cretaceous	97.5
				early Cretaceous	144
		Jurassic		late Jurassic	163
				middle Jurassic	187
				early Jurassic	208
		Triassic			245
	Palaeozoic	Permian			286
		Carboniferous		Pennsylvanian	320
				Mississippian	360
		Devonian			408
		Silurian			438
		Ordovician			505
		Cambrian			570
Proterozoic	Precambrian				
Archaean					4,600

Figure 4. Geologic Time Scale Showing Pleistocene Time.

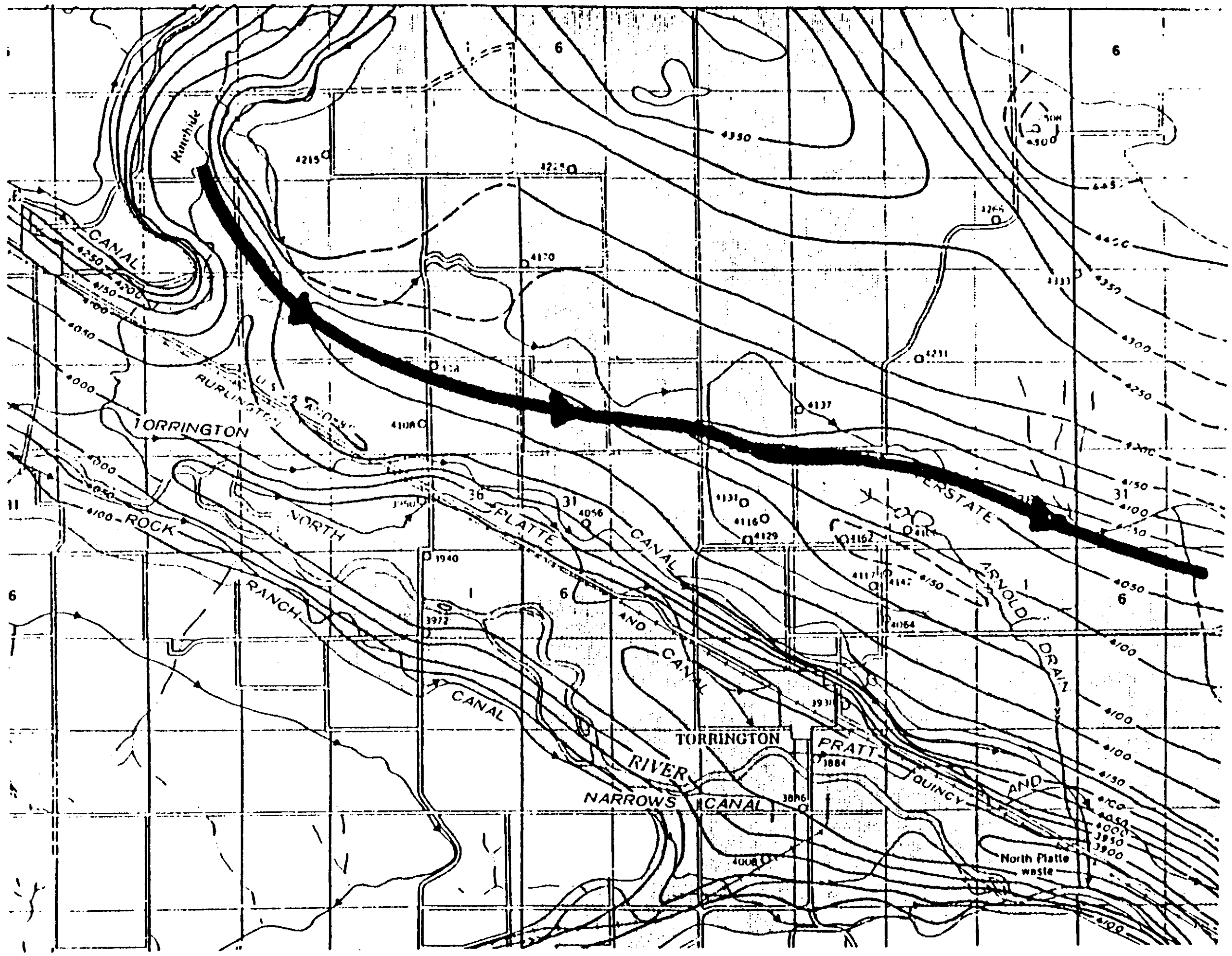

Figure 5. Bedrock Contour Map of the Study Area (Rapp et al., 1957). The previous channel of Rawhide Creek is indicated by the heavy black line.

of the stream once again increased and the stream incised into and reworked parts of the third terrace to form the second terrace deposits. Further periods of erosion have resulted in the development of the deposits of the first terrace and the currently active floodplain of the river in recent times.

At sometime during these events, the bedrock separating the two river channels was breached. The only breach mapped by Rapp et al. (1957) is located in the western part of the study area and is clearly evident when the bedrock contour map is viewed in three dimensions (Figure 6). This breach reflects the position of Rawhide Creek as it shifted towards it current location west of the study area. However, it may also reflect a place where the main channel of the North Platte was captured by the Rawhide Creek tributary. The mechanisms for the capture of a main channel by a tributary are well documented by Ritter, 1978.

Regardless of origin, the most important consequence of this breach is that, where it occurs, a direct hydraulic connection exists between the deposits of the third terrace and those of the valley fill (Figure 7). Where the bedrock remains intact, it acts as a subsurface dam which hinders the movement of groundwater flow between these two deposits (Figure 8). Rapp et al. (1957) does not indicate some smaller breaches which have occurred in the Brule Formation on the north end of Torrington (Figure 9 and Table 2). The representation of the Brule Formation north of Torrington given by Crist (1975) is similar to Rapp et al. (Figure 10); the outcrop of the Brule is indicated as continuous in the area. Detailed investigation in this area by Parks (1991) indicates that a smaller breach exists on the northern edge of Torrington.

Parks (1991) indicates that a principle characteristic of the Brule formation is that, where it occurs at or near the land surface, it forms a distinctive ridge which appears as a well defined break in slope on a topographic map. However, where breaches in the Brule exist, as is the case west of Torrington, this sharp break in slope is not evident and the area is characterized by gentle slopes and gullies. The similarity between features found in this area and those found north of Torrington, where the Brule appears to be ill-defined, indicates that the Brule is not present at this location either and that this area marks the location of a previously unmapped breach section.

To support this conclusion, well logs adjacent to the breach area were obtained and analyzed (Figure 11 and Table 3). All of the wells indicated on Figure 11 are completed in sand and gravel deposits and reach depths of up to 151 feet. The presence of deposits of this depth adjacent to a bedrock outcrop is unlikely. Based on this evidence, the surface and bedrock geology of the area is as shown in Figures 12 and 13.

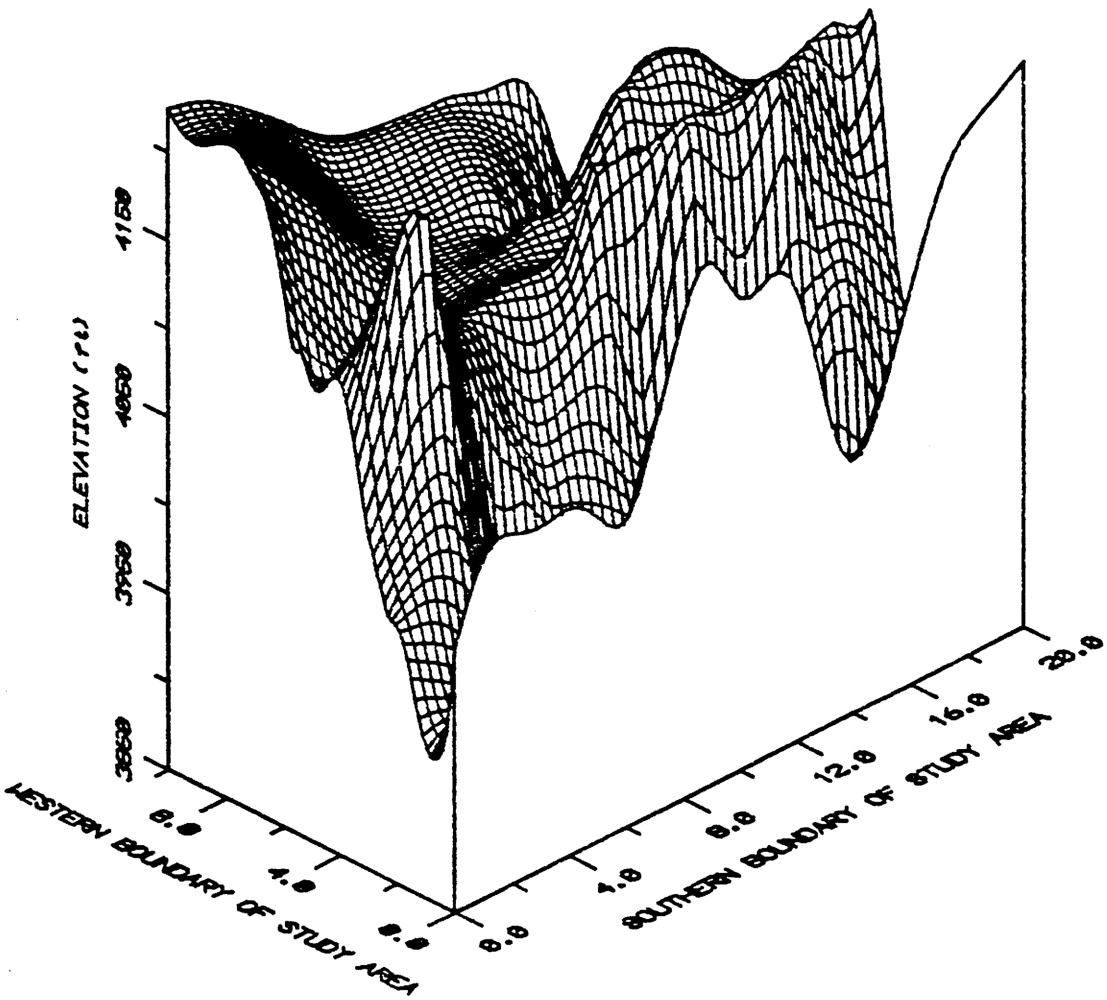

Figure 6. Computer Generated 3-D View of Bedrock Showing Breach. Data derived from Rapp et al., 1957. Arrow indicates location of large breach in the bedrock outcrop.

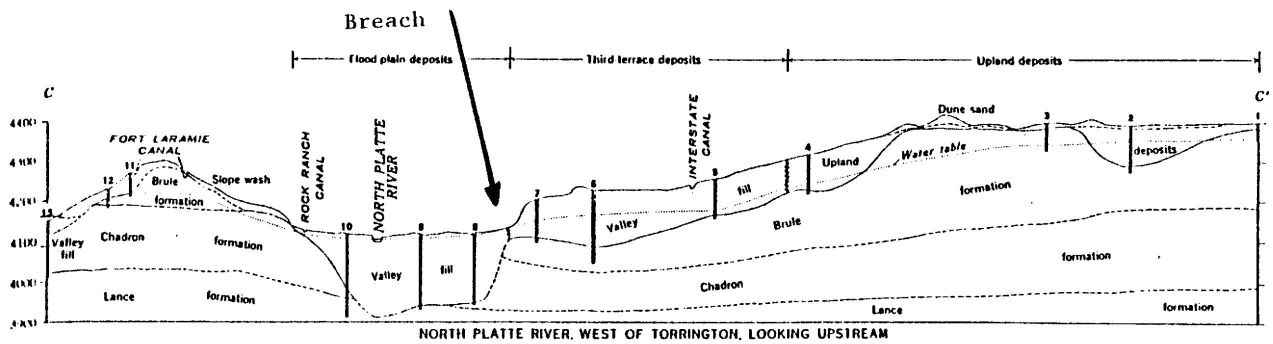

Figure 7. Cross Sectional View of Breach illustrating Hydraulic Connection between Deposits of the Third Terrace and Valley Fill (arrow). From Rapp et al., 1957.

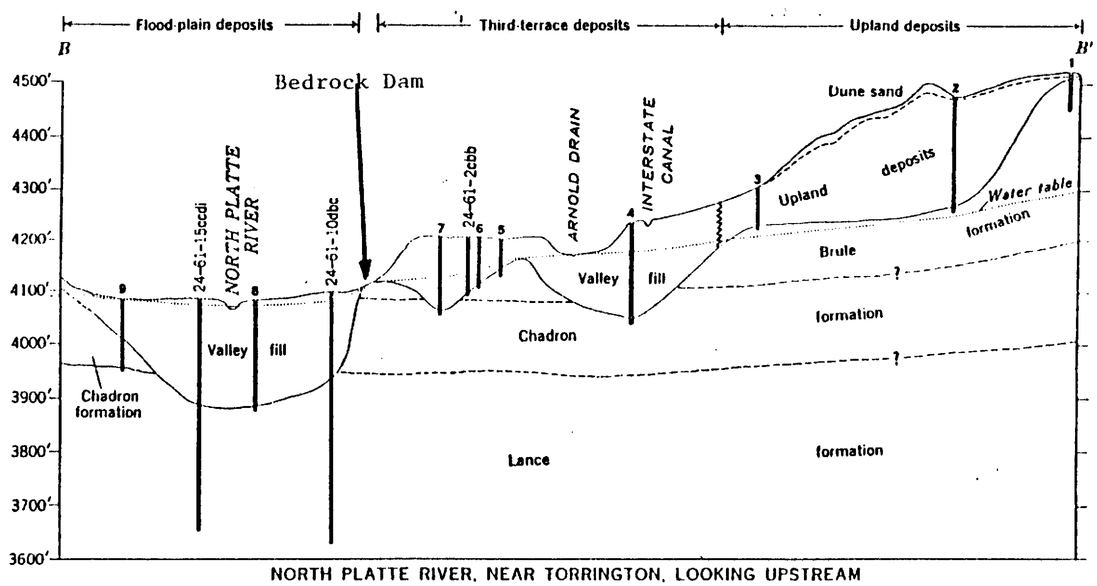

Figure 8. Cross Sectional View showing Bedrock acting as a Subsurface Dam (arrow). From Rapp et al., 1957.

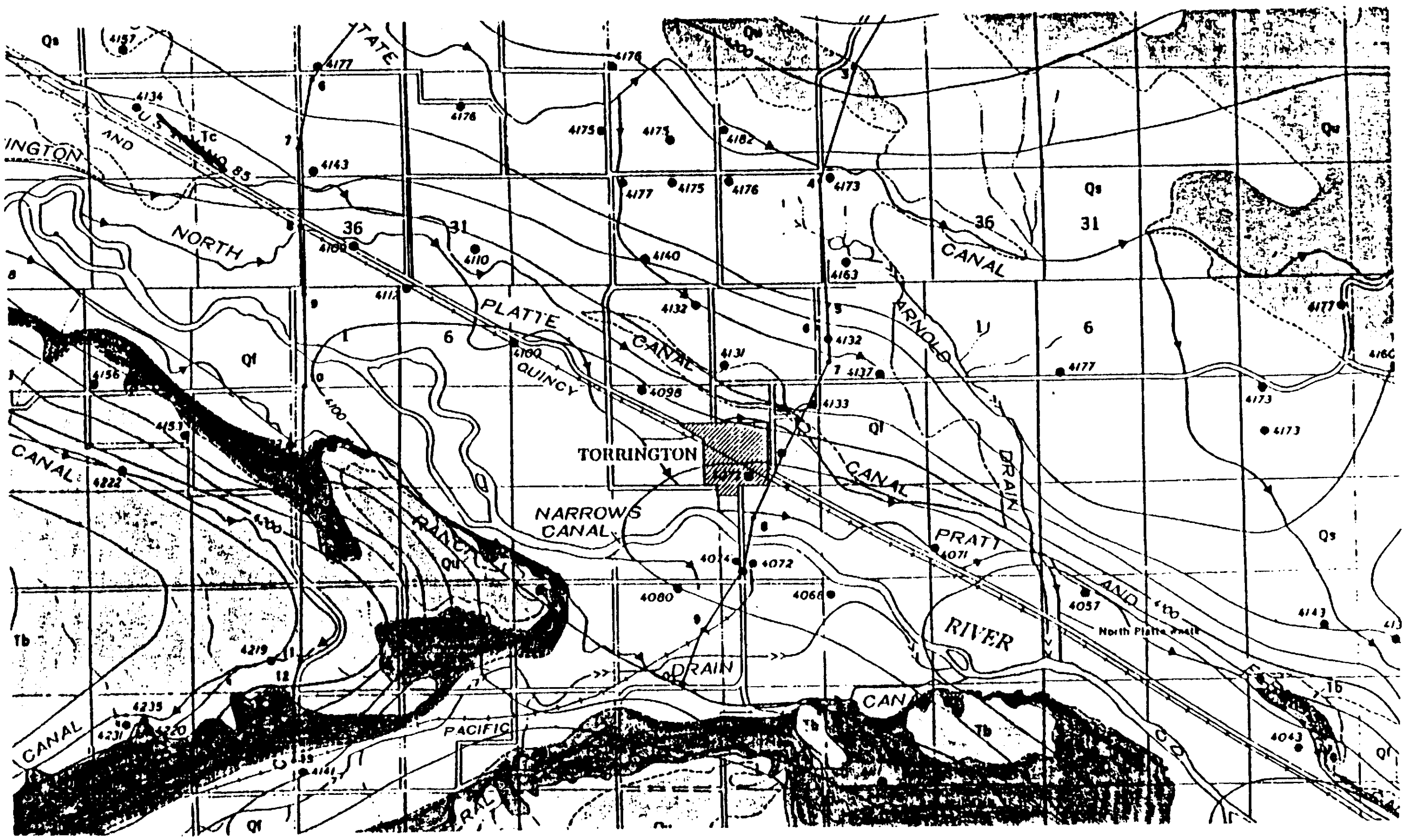

Figure 9. Geology of Study Site (From Rapp et al., 1957).

Table 2. Description of Geologic Units (From Rapp et al., 1957).

System	Series	Symbol	Unit	Description
QUATERNARY	Recent	Qs	Dune sand	*Fine-grained windblown sand; serves as excellent infiltration medium for recharge from precipitation*
QUATERNARY	Pleistocene and Recent	Qf	Valley fill	*Includes deposits beneath the third, second, and first terraces and the present flood plain. Sand and gravel containing lenses and beds of fine sand, silt, and clay, large chunks of siltstone, lenses of siltstone pebbles, and cobbles and boulders. Yields water to many domestic and stock, irrigation, municipal, and industrial wells*
QUATERNARY	Pleistocene	Qu	Upland deposits	*Sand and gravel containing lenses and beds of fine sand, silt, and clay, and lenses of siltstone pebbles. Some of these deposits in the northern part of the area would yield enough water for irrigation if a sufficient saturated thickness were reached. May include deposits of Pliocene age*
TERTIARY	Oligocene	Tb	Brule formation	*Moderately hard, brittle argillaceous siltstone. Yields small quantities of water to domestic and stock wells from fractures and from lenses of sandstone*
TERTIARY	Oligocene		Chadron formation	*Consists mainly of green, brown, red, or buff loosely to moderately cemented clay and silt that contains channel deposits of sandstone and conglomerate. Contains a lower unit consisting of variegated fluviatile deposits. Yields water under artesian pressure from coarse-grained channel deposits to many domestic and stock wells*

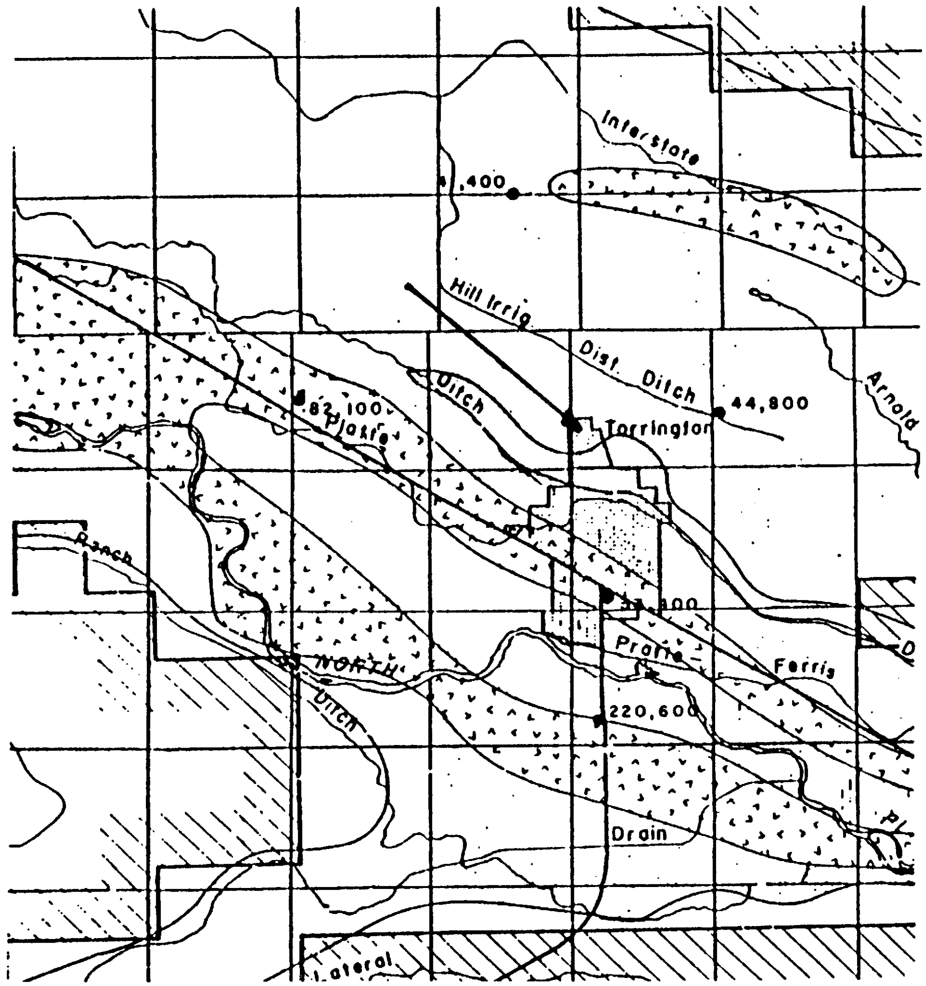

Figure 10. Geology of the Area (From Crist, 1975). Representation of Brule outcrop north of Torrington (arrow) is identical to that of Rapp et al., 1957.

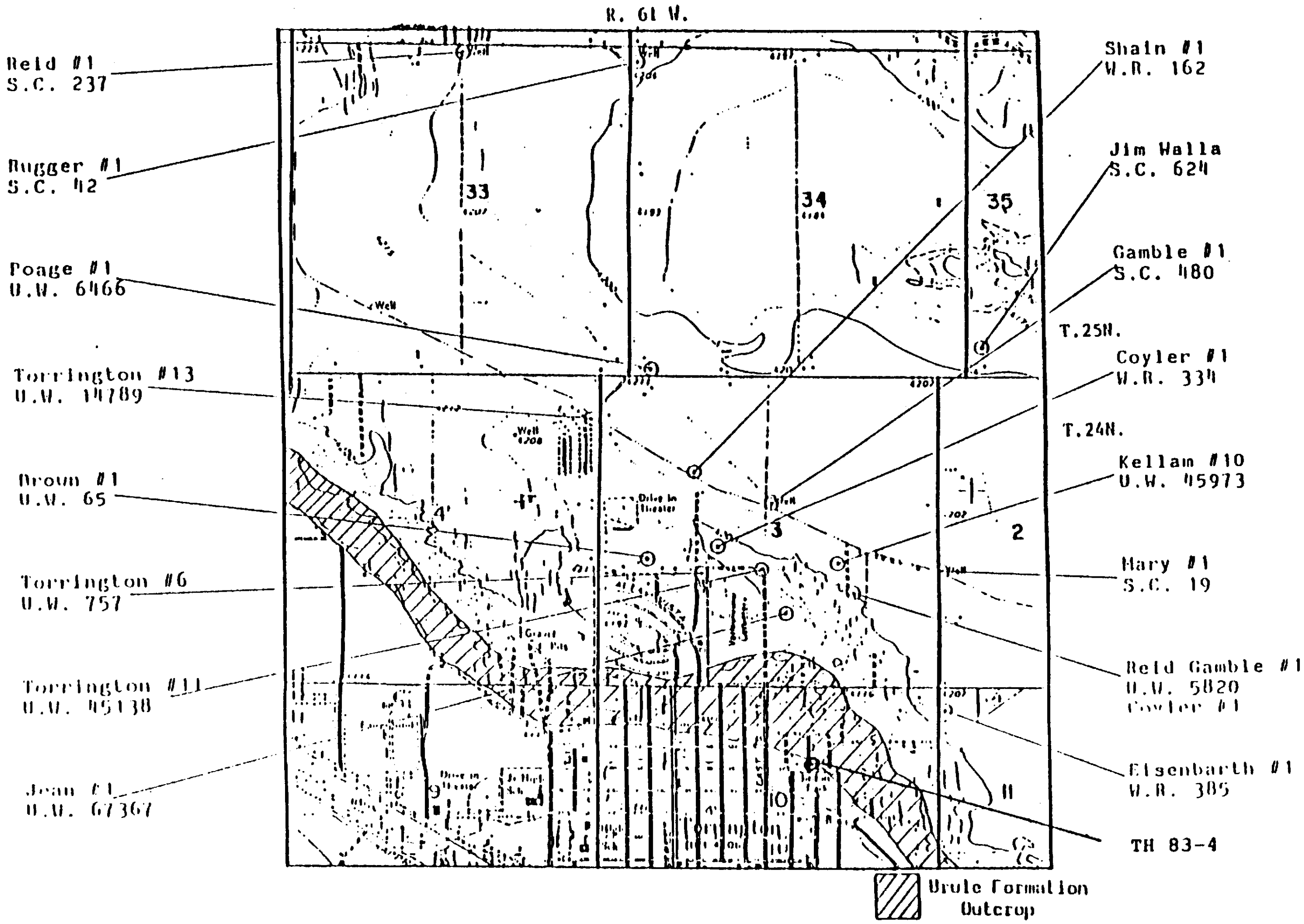

Figure 11. Location of Wells North of Torrington Completed in Sand and Gravel (Compiled from data supplied by Baker and Associates, 1983 and the Wyoming State Engineer's Office, 1984).

Table 3. Well Completion Data (Compiled from data supplied by Baker and Associates, 1983 and the Wyoming State Engineer's Office, 1984).

NAME OF WELL (OWNER)	LOCATION	PERMIT NO.	TOTAL DEPTH	DEPTH AT TIME OF COMPLETION	DEPTH TO WATER Sept. 1983	DEPTH TO WATER Sept. 1984
Mary #1 (Jim Gamble)	NWSW 2-24-61	S.C. 19	112 ft.	74 ft. (1940)	83 ft.	78.15 ft.
Gamble #1 (Jim Gamble)	SWNE 3-24-61	S.C. 480	137 ft.	70 ft. (1946)		84.92 ft.
Shain #1 (Dale Harris)	SENW 3-24-61	W.R. 162	170 ft.	69 ft. (1952)	93 ft.	85.7 ft.
Coyler #1 (Bob Fitch)	NESW 3-24-61	W.R. 334	100 ft.	73 ft. (1954)	85 ft.	80.02 ft.
#6 (City of Torrington)	NESW 3-24-61	U.W. 757	132 ft.	68 ft. (1962)	95 ft.	84.18 ft.
Brown #1 (Don Jones)	NWSW 3-24-61	U.W. 65	113 ft.	80 ft. (1958)	95 ft.	89.92 ft.
Kellam #10 (Dave Kellam)	NWSE 3-24-61	U.W. 45973	151 ft.	80 ft. (1979)	85 ft.	
Jean #1 (Dave Kellam)	NWSE 3-24-61	U.W. 67367	150 ft.	(1984)		75.90 ft.
Eisenbarth #1 (Bill Ring)	NWNW 11-24-61	W.R. 385	114 ft.	80 ft. (1955)	80.5 ft.	79.62 ft.
Poage #1 (Bill Poage)	SWSW 34-25-61	U.W. 6466	124 ft.	82 ft. (1970)	87 ft.	85.9 ft.
Reid #1 (Ken Morgheim)	NWNE 33-25-61	S.C. 237	92 ft.	36 ft. (1940)	40 ft.	
Rugger #1 (Verde Corp.)	NWNW 34-25-61	S.C. 42	90 ft.	31 ft. (1940)	31 ft.	
(Jim Walla)	SWSW 35-25-61	S.C. 624	84 ft.	22 ft. (1946)	22 ft.	
TH 83-4	SWNE 10-24-61		70 ft.	14.5 ft (1983)		

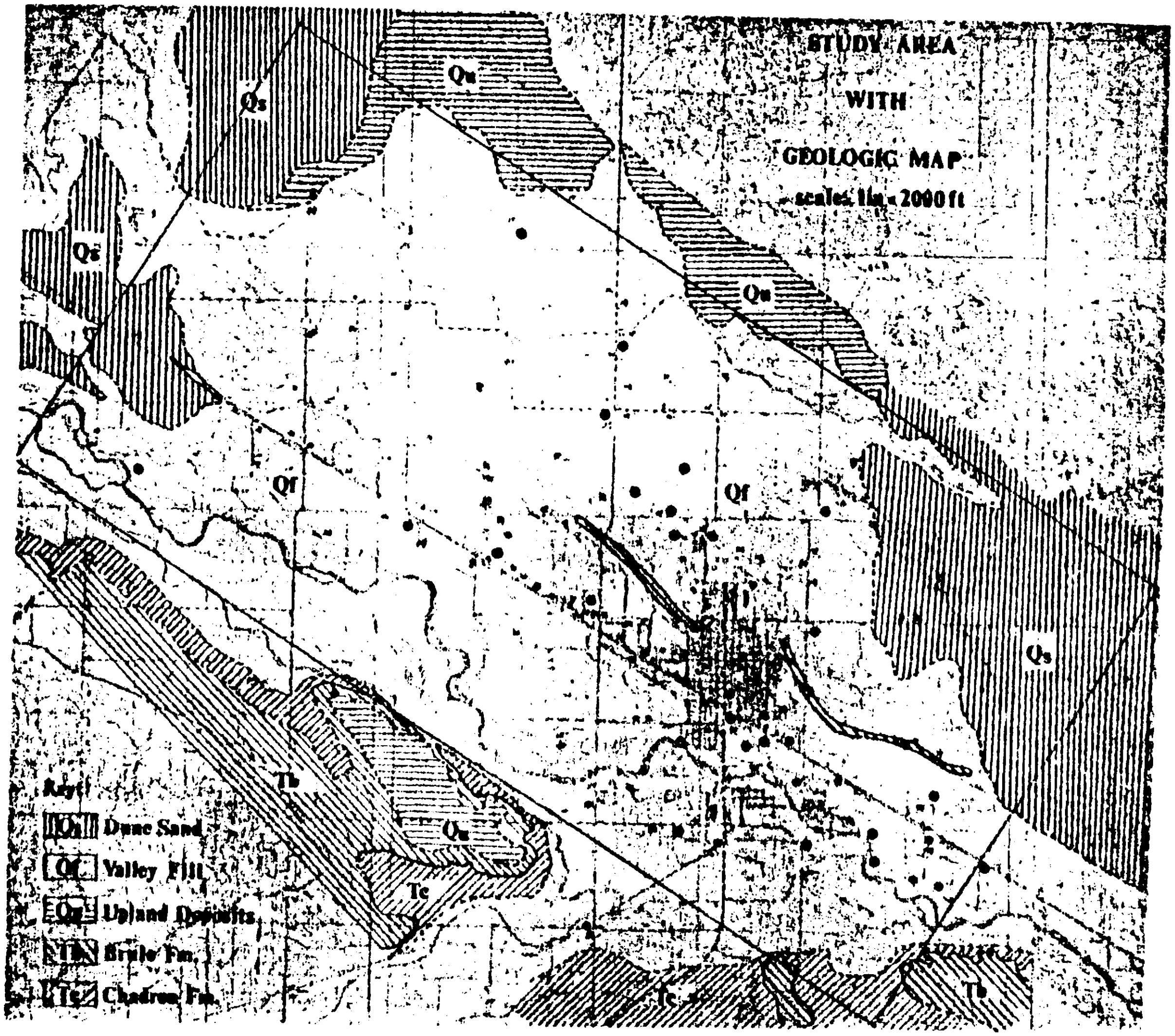

Figure 12. Modified Geologic Map showing Breach North of Torrington.

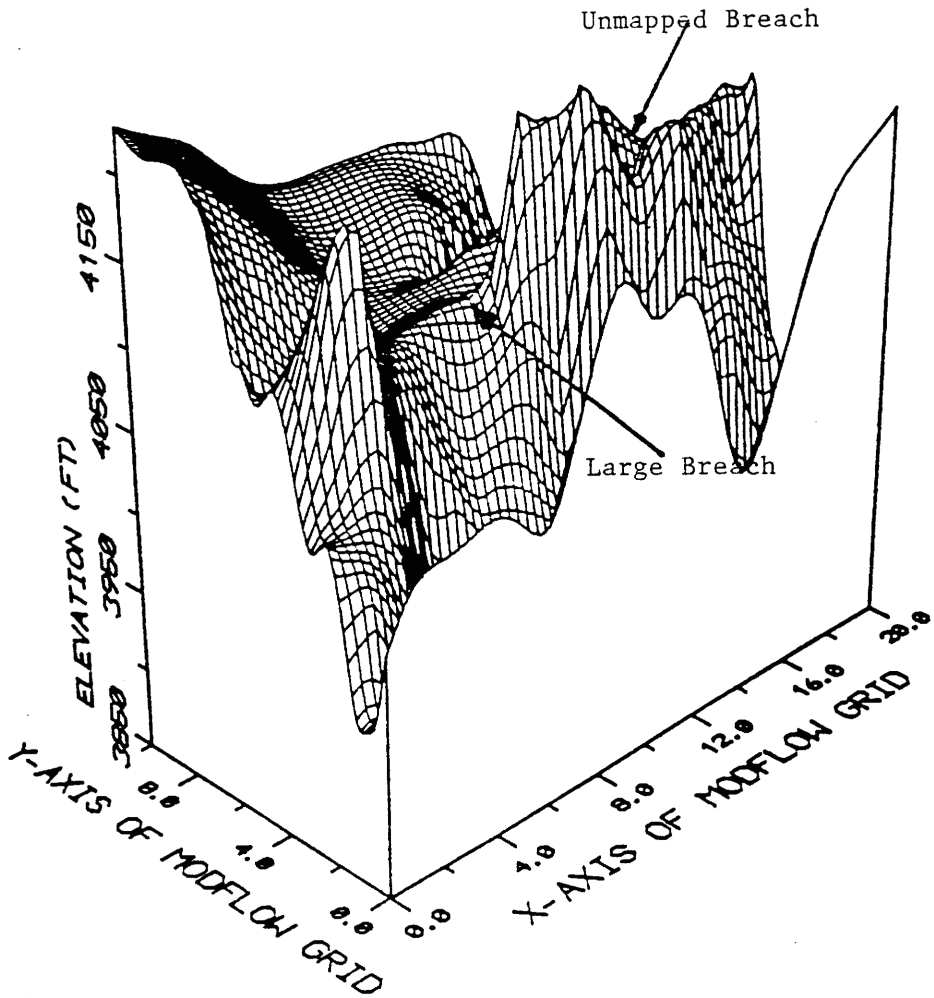

Figure 13. Modified Bedrock Geology.

B. Soils and Land Use

The Soil Conservation Service identified thirty-two soil mapping units in the study area (SCS, 1971). These units were reduced to two principal associations as indicated on Figure 14. The principal differences in the associations are a function of the locations and parent material upon which they have developed. The Haverson-Bankard association series soils developed on the floodplain and lower parts of terraces while the Valentine-Dwyer association series soils developed on upper terrace surfaces, upland, and eolian material.

Both of the associations are recent in age and therefore classified as Entisols (SCS, 1971). Soils of the Valentine-Dwyer association are further classified as psamments (from Greek, psamm = sand) due to their sandy texture which reflects the nature of the parent material. Soils of the Haverson-Bankard association are further classified as fluvents in deference to the origin of the parent material from river (fluvial) deposition (Brady, 1974). A detailed description of the principle soils in these associations is given in Appendix B.

Land use maps (Appendix B) of the area were completed by Baker and Associates of Torrington and Scottsbluff, Nebraska for the Torrington area for the growing seasons of 1989 and 1990. These maps were assembled from information obtained from the SCS through their voluntary reporting program on crops grown as reported by individual farmers in the area and aerial photographs flown over the area during these two years. Information was also obtained on the different crops grown in the area during individual 5 year periods within the study area for this project beginning with 1975 and going through 1990. However, the information on cropping patterns could not be fully defined because the method of reporting to the SCS is voluntary and as a result does not give information on actual crops grown for the <u>entire</u> area during the specific 5 year periods requested to be inventoried for production of a percentage usage table. As a result of this determination on land use, only an idea of the change in cropping can be inferred from the data. A suggestion would be to require individuals in areas identified as having a high aquifer contamination vulnerability to report their cropping patterns and fertilizer and pesticide usage to an appropriate agency such as the SCS. This information could then be used in assessment of the water quality of the individual aquifer and allow for better quantification of any problems that may arise with the aquifer. The results of our study of land use and cropping patterns does not allow for a detailed definition of potential problem areas resulting from land use practices because of the above indicated problem.

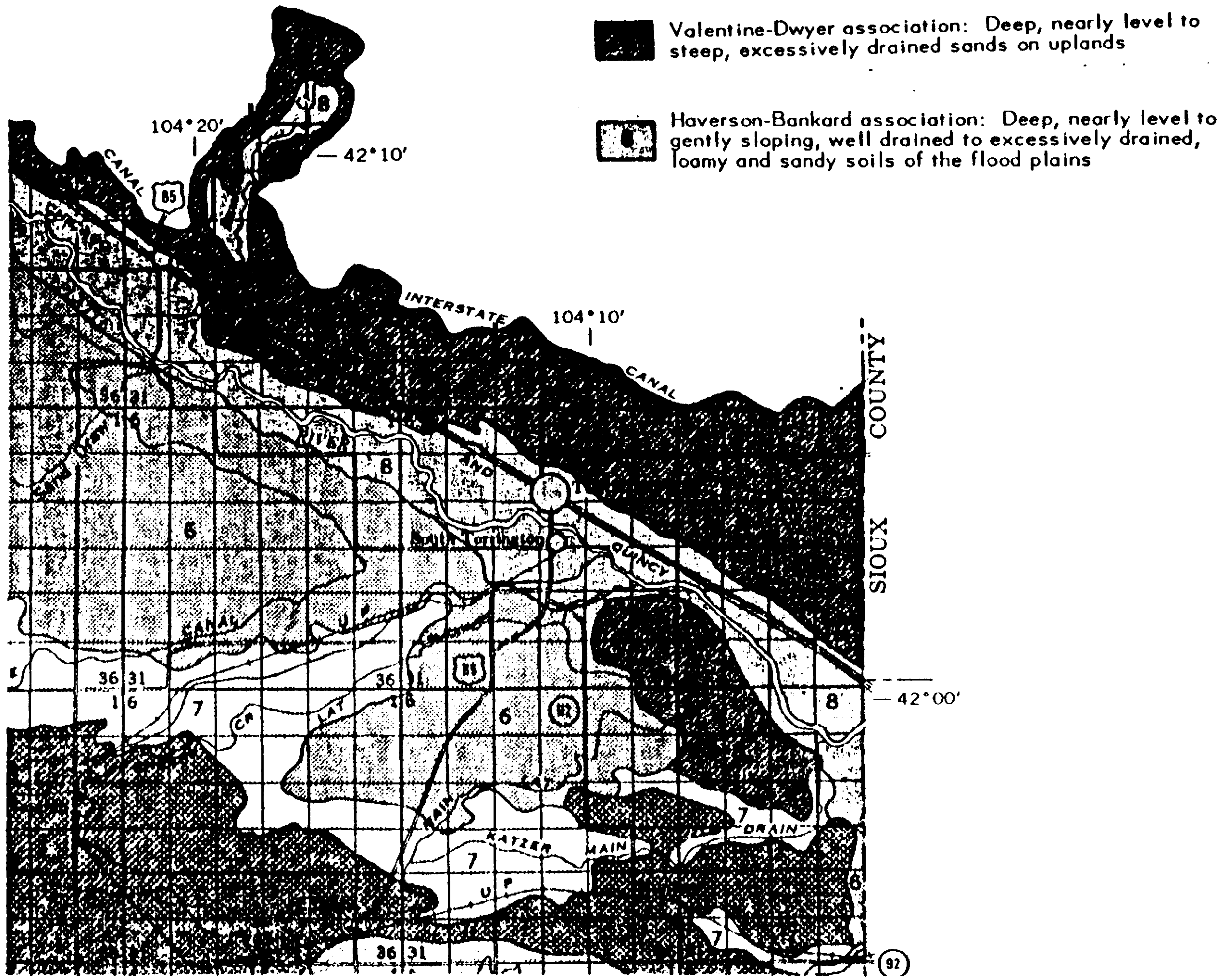

Figure 14. Soil Associations in the Study Area. From SCS, 1971.

Deliverable 3:

A database format was devised using the software Paradox. Over 100 wells were identified in the area for which data were gathered. The data on physical characteristics of the wells and the aquifer were obtained from the State Engineer's Office and files held by Baker and Associates. A copy of the data contained in the database is given in Appendix C. A disk is attached to this report in Appendix C which contains the entire contents of the database under the Paradox design.

Task 2 Results:

Deliverable 1:

The location of all public water supply sources are indicated on Figure 11 and the map contained in Appendix A. The map in Appendix A shows the location and Appendix C indicates the characterization of all individual domestic water supplies and irrigation wells used in this study to the extent possible from records of owners and State Engineer's Office records.

The wells on which information was collected were the wells that were also used for water quality sampling. Samples were collected at sites 1 through 66 (Appendix A) during the initial sampling event conducted by the Torrington Department of Public Works in the fall of 1989. These sites included the 11 municipal wells and two points within the distribution system, 51 domestic wells, the Interstate Canal and North Platte River. In terms of the domestic wells, the majority of sampling sites were where the population density is greatest to the west, northwest of Torrington. In order to provide better control in the eastern part of the study area, 14 additional domestic wells, sites 67 through 80, were incorporated into the sampling program in the spring of 1990. These 80 sites formed the basis for the majority of biannual samplings through 1991. Twenty-six large capacity irrigation wells and the Interstate Canal, sites 81 through 107, were sampled in July of 1990. Samples were also obtained from 23 of these same irrigation well sites in August of 1990. Parks (1991) summarizes the sampling, analysis and assurance procedures followed.

The water quality information obtained from sampling and Town of Torrington records is contained in the database files (Task 1, Deliverable 3) and has been developed into several overlay maps in terms of nitrate concentrations. Figures 15 through 19 shown the spring and fall variations in nitrate levels in the study area over a 2 and 1/2 year period. Discussion of the results of sampling and movement of groundwater are contained under Task 3.

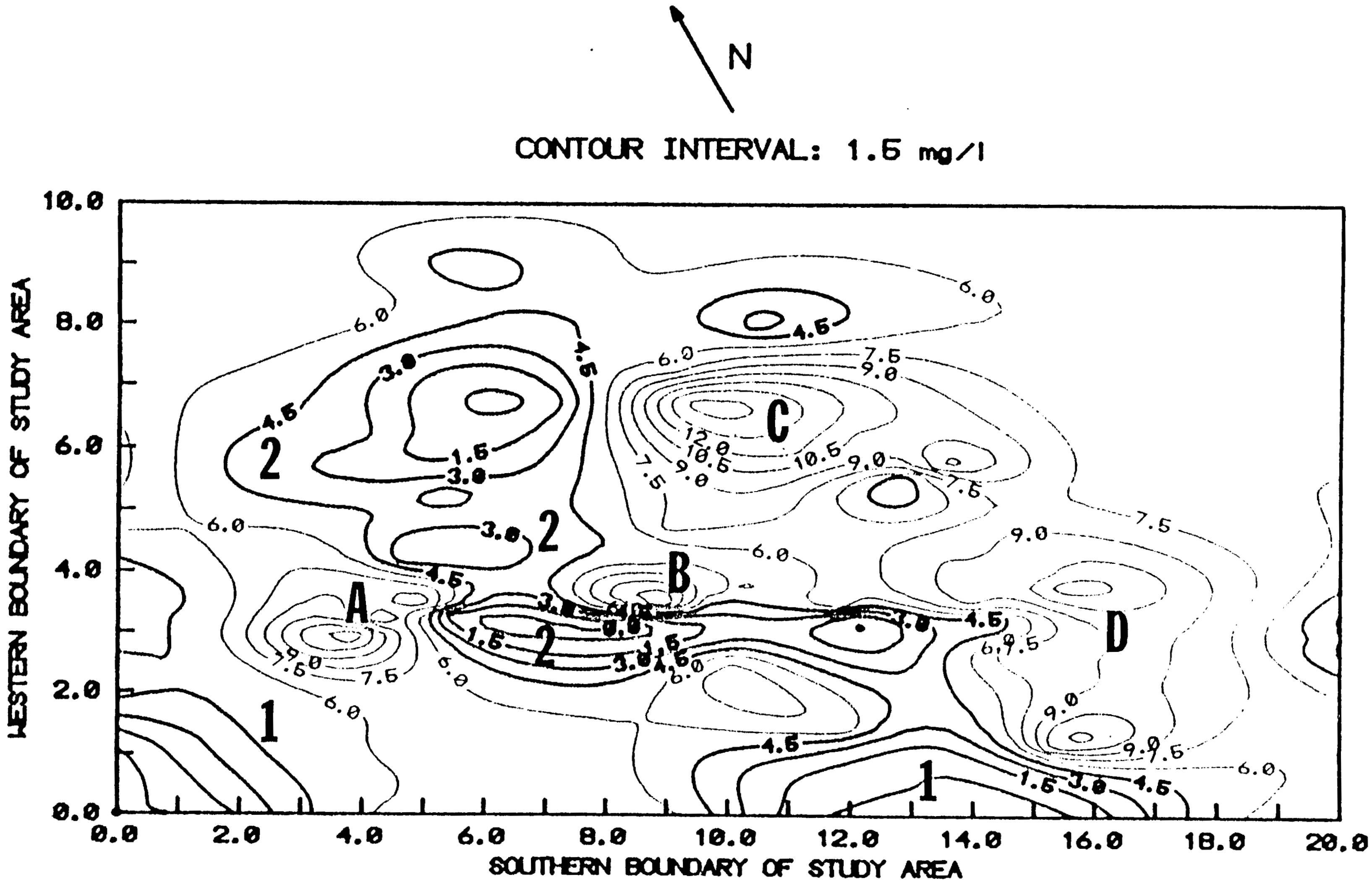

Figure 15. Distribution of Nitrate in the Fall of 1989.

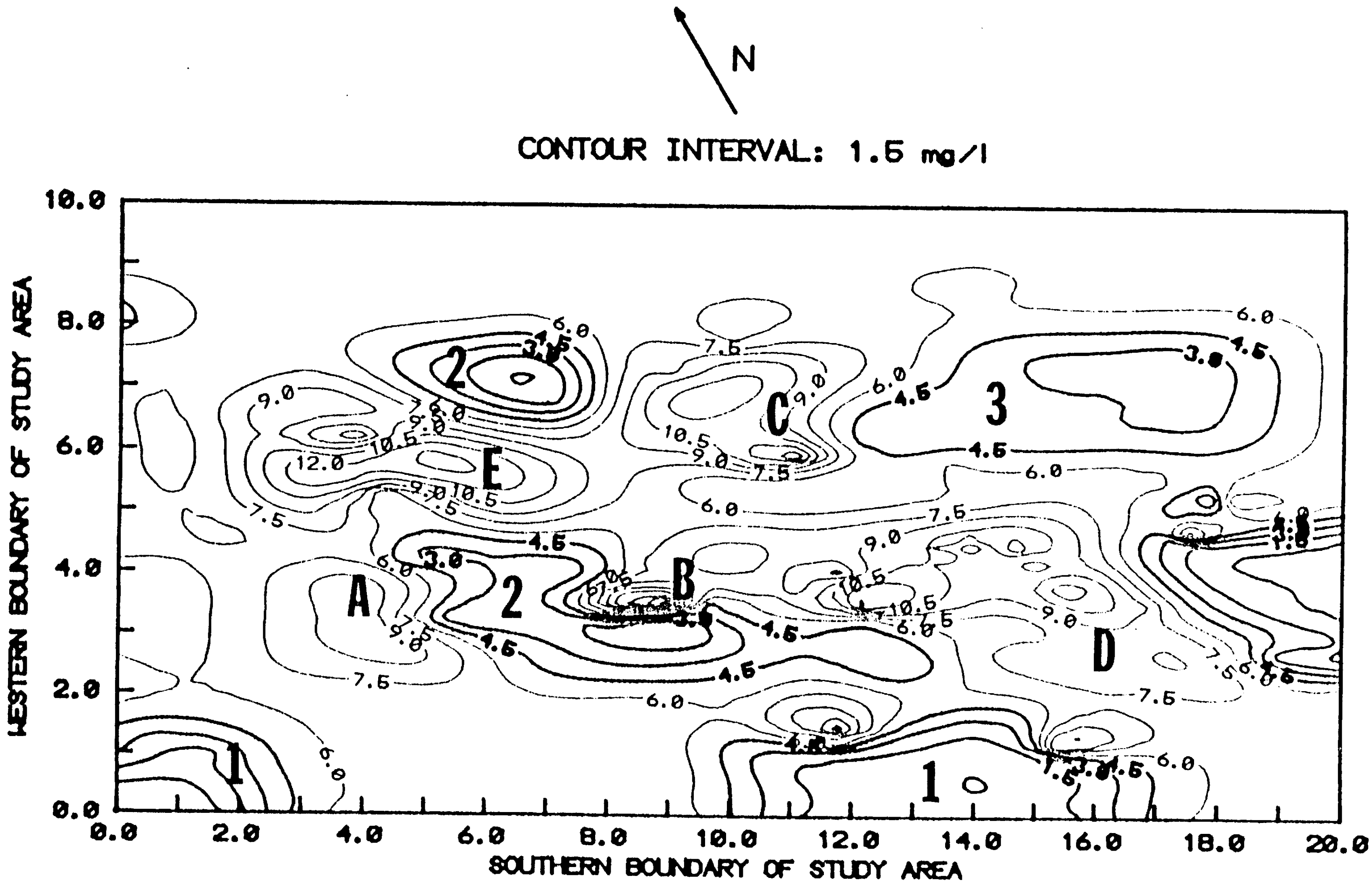

Figure 16. Distribution of Nitrate in the Spring of 1990.

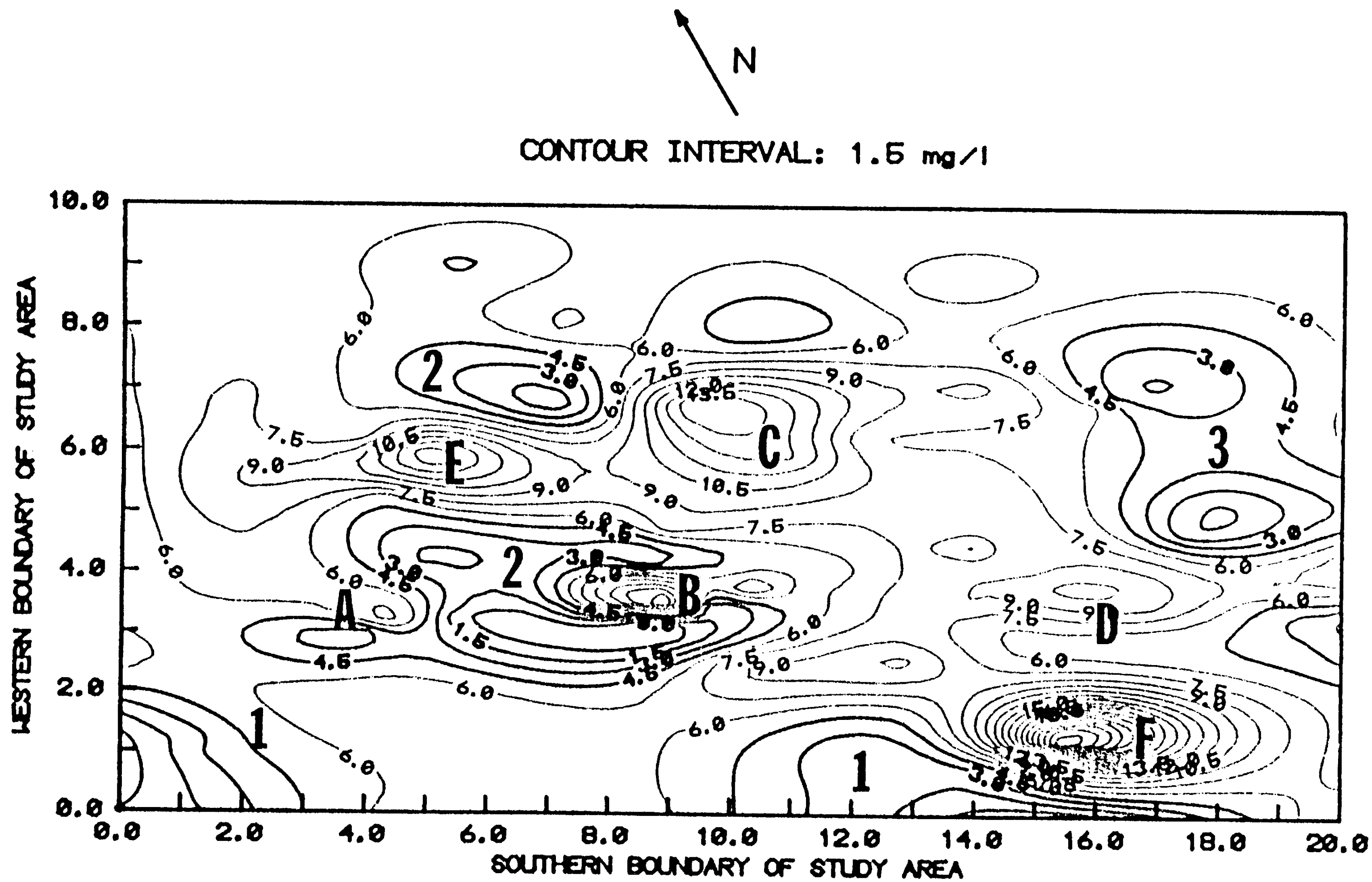

Figure 17. Distribution of Nitrate in the Fall of 1990.

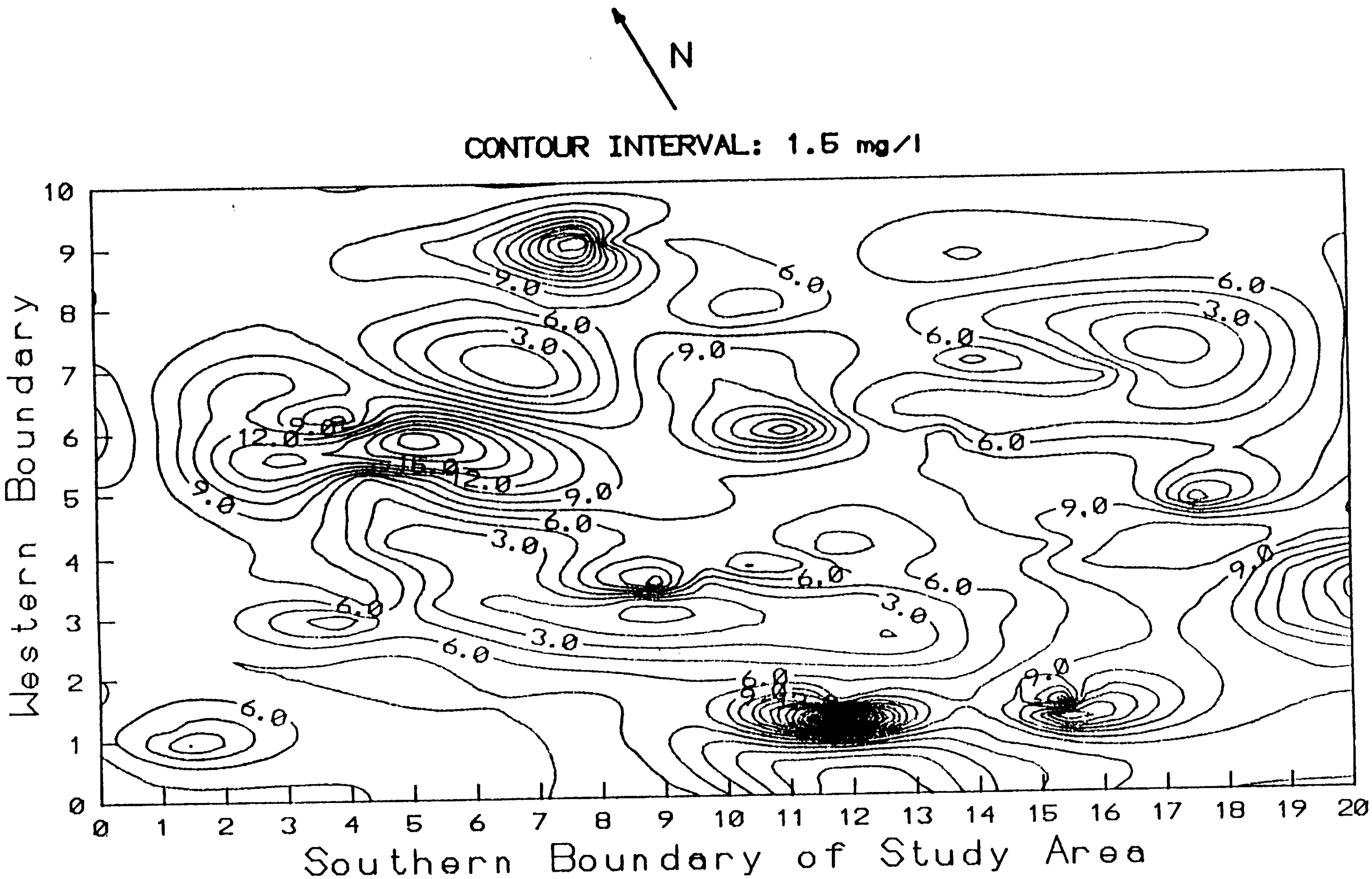

Figure 13. Distribution of Nitrate in the Spring of 1991.

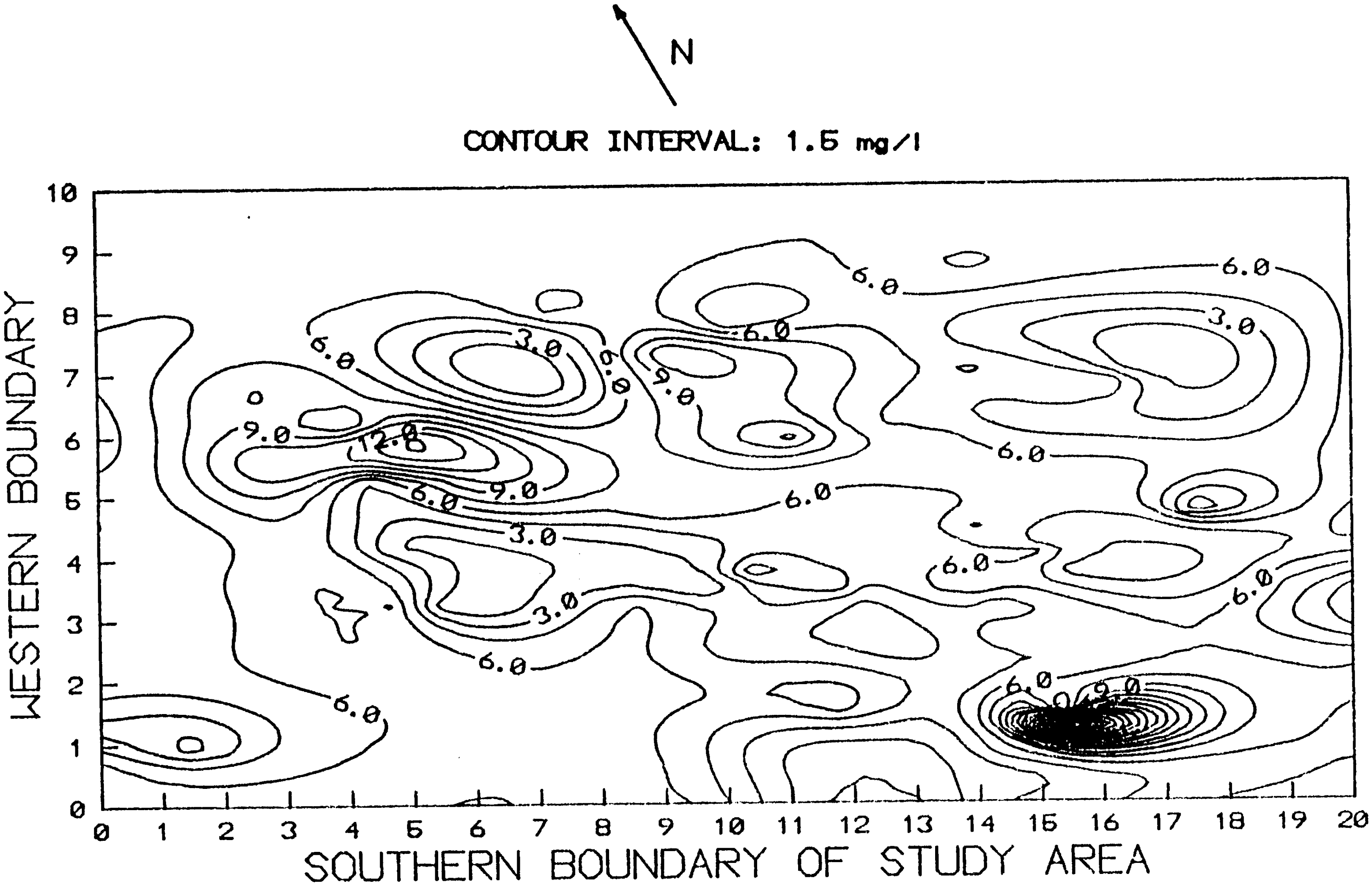

Figure 19. Distribution of Nitrate in the Fall of 1991.

Deliverable 2:

A groundwater aquifer water table map as an overlay to the base map was produced from 1970's data (1975) from the USGS. Some depth to water table data values were collected during April and May of 1991 to indicate present conditions within the alluvial aquifer. The necessary physical characteristics data necessary within the aquifer area under study were completed to the extent possible from records on the wells in the State Engineer's Office, information provided by owners of the wells and consultants or well drillers and pump tests performed in the area. Groundwater aquifer water table maps of the area for 1975 and 1991 (computer generated) are indicated on Figures 20 and 21. Figure 21 is a result of modeling the aquifer to produce present conditions using well levels at several locations in the study area from approximately the same time during the winter period. The computer generated water table contour map for the summer period of 1991 is shown in Parks (1991). A combination of the modeling results and the nitrate sampling results will be used in Task 3 to identify areas of nitrate contamination.

Task 3 Results:

A USGS numerical finite-difference groundwater flow model (MODFLOW - McDonald and Harbaugh, 1984) was tested, calibrated and used for simulation of groundwater flow for the Torrington study area (Parks, 1991). Parks (1991) gives a detailed description of the model and how it was tested, calibrated and used to simulate the Torrington study area. Two stress periods were used in the model: a winter stress period and a summer stress period.

The simulation model indicates that the North Platte River has changed significantly in its flow patterns near the river since 1975 due to extensive irrigation by center pivot systems and water utilization by Torrington (Parks, 1991). This can be seen by comparison of Figures 20 and 21. From these figures, it can be seen that the general flow patterns in the areas away from the river are still somewhat similar with the past. The present water table map indicates that the North Platte River is now a losing stream in the area during the winter months, whereas in 1975, the river was gaining in the area during all months.

The single most important feature controlling the configuration of the potentiometric surface and the direction of flow in the aquifer is the presence of the Brule formation outcrops that occur near Torrington and to the east of Torrington. These outcrops can be identified by steep gradients, up to 120 ft/mi, in the potentiometric surface. The relationship between these gradients and the location of Brule bedrock is shown on Figure 22. As recharge enters the area immediately north of the bedrock outcrops, it appears to stagnate, as indicted by the modest

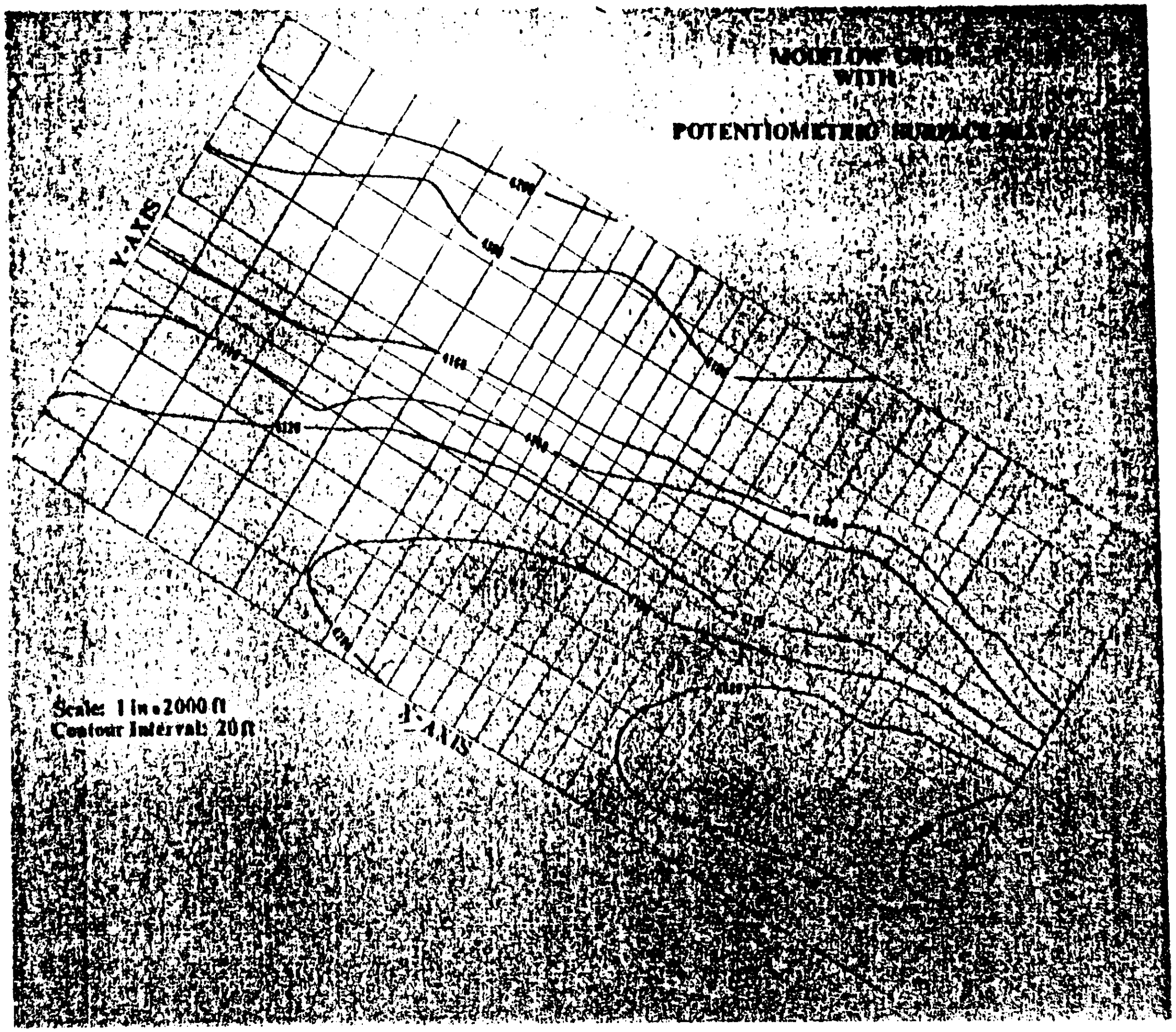

Figure 20. Modflow Grid with Potentiometric Surface Map in 1975.

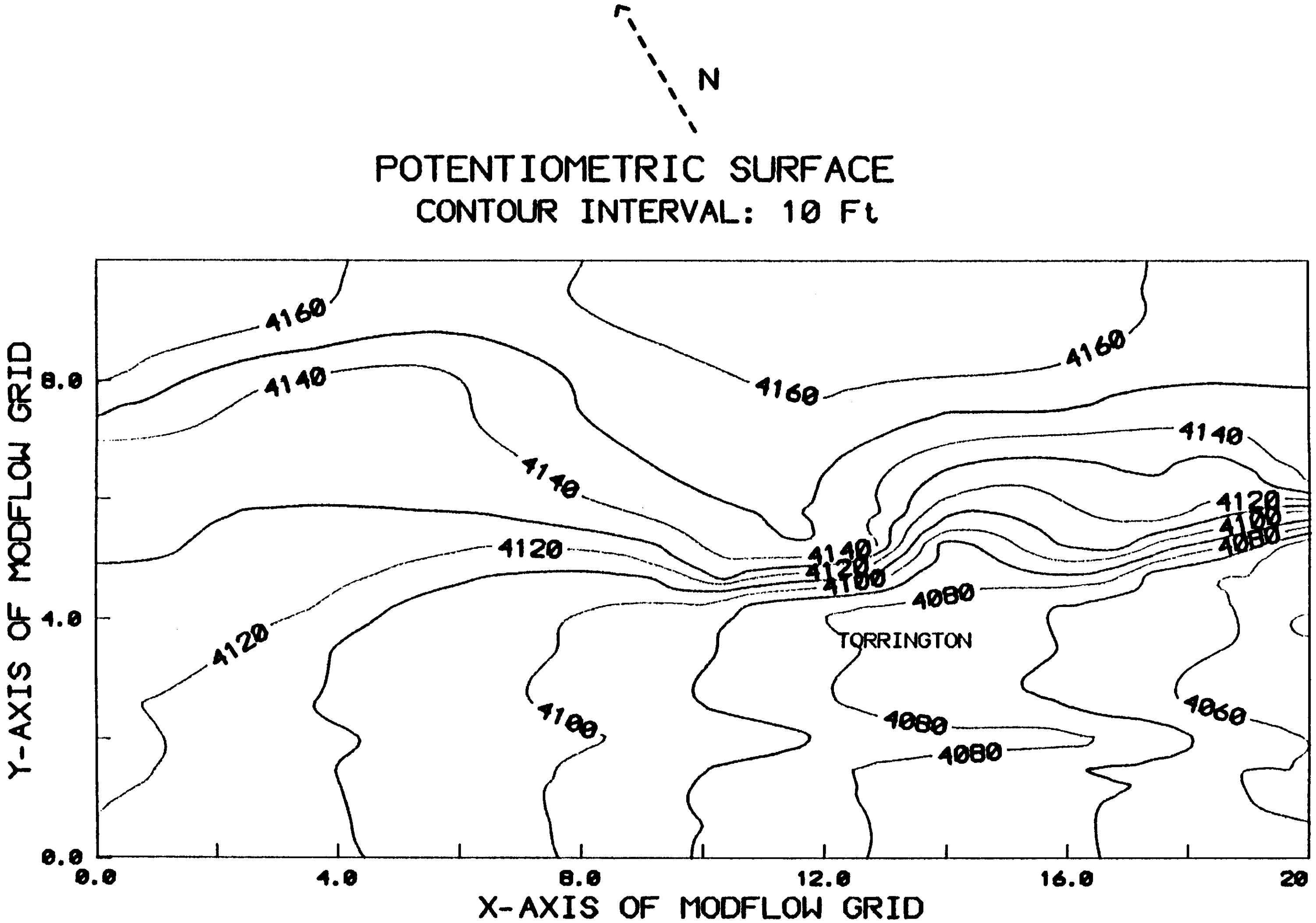

Figure 21. Potentiometric Surface Map of Alluvial Aquifer in 1991.

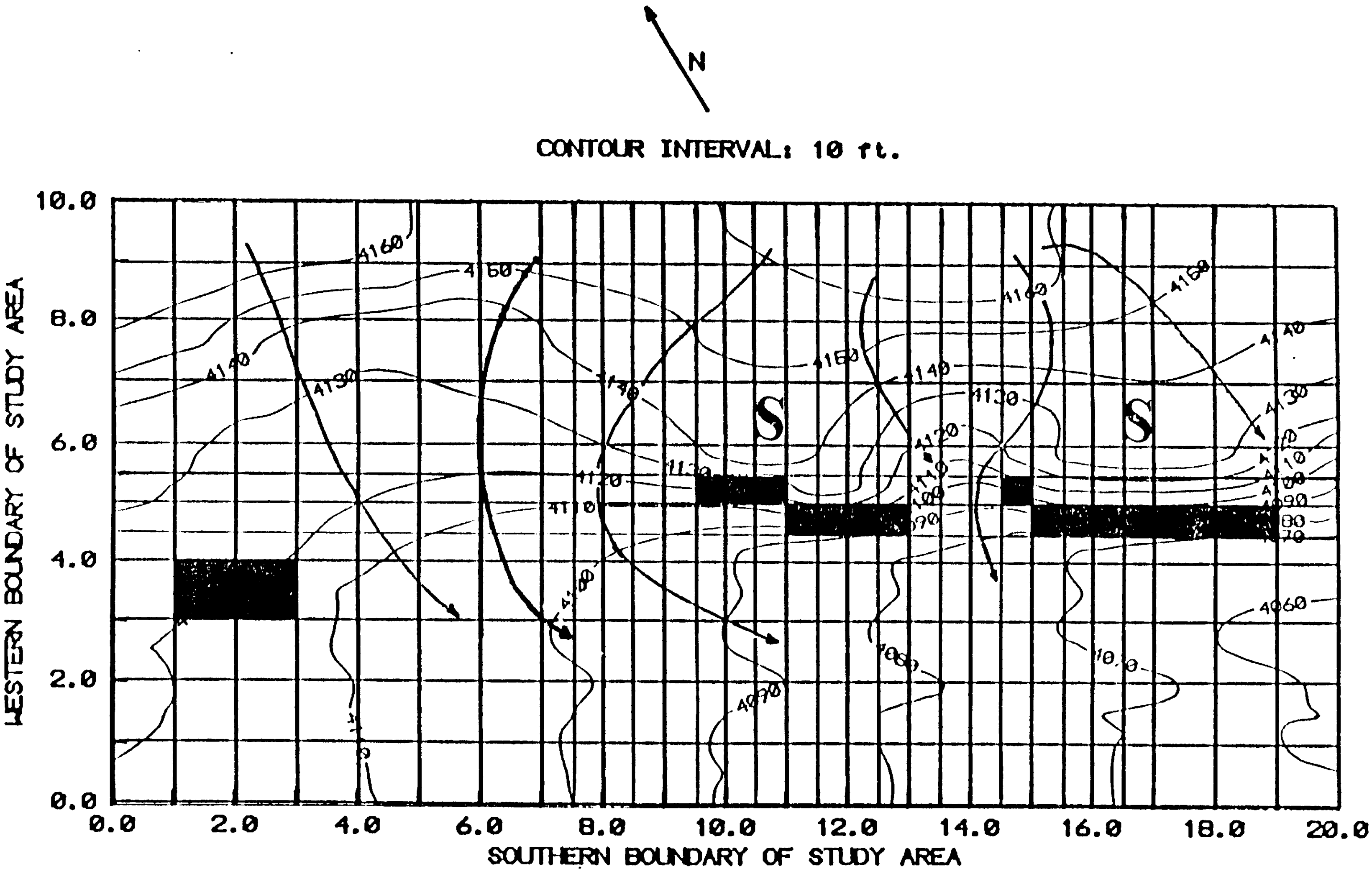

Figure 22. Areas of Stagnation (S) and Direction of Flow (arrows) in the Aquifer Following the Winter Stress Period.

gradients present in these areas (Figure 22), and to be diverted laterally toward the breaches in the bedrock. At the breaches in the Brule bedrock, groundwater moves unhindered from the third terrace into the floodplain aquifer as the flow arrows indicate on Figure 22. The breaches apparently act as spillways between the two aquifers concentrating the flow in these areas.

In the extreme northeastern part of the area, flow is directed toward Arnold Drain. Flow entering the area from the northwest moves directly toward the North Platte River through the breach in the west-central part of the study area.

The model simulation indicates that variations occur in the elevation of the water table as well as the direction of flow on a seasonal basis. Stagnation occurs behind the Brule bedrock dams and groundwater flow is directed preferentially toward the breaches that occur in this dam where it can readily move from the third terrace to the floodplain aquifer. Figure 22 indicates that the principal sources of recharge to the Town of Torrington municipal wellfield is water entering the floodplain aquifer from the third terrace through the breaches that exist near the areas of stagnation to the north of Torrington. This is significant in terms of the high nitrate levels found in many of the Torrington municipal wells.

When the groundwater flow map representation (Figure 22) is compared with the nitrate concentration maps (Figures 15 through 19), potential source areas of high and low nitrate levels and why they occur where they do can be identified. The areas of low and high nitrate concentration are discussed below.

In general, the areas of low nitrate concentration are found along the southern boundary and the west-central part of the study area; locations 1 and 2, respectively, on Figures 15, 16 and 17. The areas of low nitrate concentrations at location 1 are the result of groundwater dilution by recharge derived from the North Platte River. The Laramie Canal, located just south of the study area, may also be a source of recharge and dilution to these areas. However, because this canal is located in low permeability bedrock, the contribution from this source is likely to be small when compared to other potential sources.

In terms of aerial extent, the most significant area of consistently low levels of nitrate are locations 2 in the west-central parts of the study area. Of particular interest is the relationship between the low levels of nitrate and the large breach area in the Brule bedrock found in this area. This indicates that where the flow of groundwater is unhindered by subsurface dams the aquifer system in the area is capable to a great extent of flushing itself with low nitrate level recharge waters. The main source of recharge water in this area is the Interstate Canal which has a noticeable effect on the water table of the third terrace during the irrigation season.

At location 3 the size of the area of low nitrate concentration appears to expand and contract seasonally. This is likely a function of the variations in the direction of flow that occur between winter and summer with the winter recharge derived from the upland and dune sands to the north with this water likely to contain low concentrations of nitrate as these lands are relatively uncultivated while the summer recharge to the area is from intensively cultivated and fertilized parts of the third terrace from the west.

In general, three consistent areas of high nitrate concentration exist within the study area (location B, C and D on Figures 15, 16 and 17) with local hot spots occurring from time to time in other areas (locations A, E and F on Figures 15, 16 and 17).

Location B is unique in the fact that the level and distribution of nitrate in this area remained essentially constant throughout the entire three year period. Wells sampled in this area are located on or adjacent to property owned by the University of Wyoming and occupied by the Torrington Agricultural Experimental Station. Investigation of this area revealed that the soil type found at this location is unique to the study area. This soil, the Vetal Series, contains relatively large amounts of organic matter and is moderately to extremely permeable. This soil along with the activities of the Experiment Station are most likely the reasons for elevated levels of nitrate in this area.

Persistently high levels of nitrate at location C are not surprising when the proximity of the Brule bedrock outcrop (subsurface dam) in this area is taken into account. From Figures 15 through 19, it can be seen that nitrate contamination levels are highest in the area of stagnation formed in the groundwater system behind the Brule bedrock outcrops. The nitrate is most likely derived from the intensive agricultural activities that occur in this area. Since the flow in this area is directed toward the breaches in the bedrock, this area is one of the most important in terms of the impact to the municipal groundwater supply for Torrington.

Elevated levels of nitrate at location D are centered around wells located downgradient from the town itself. Contamination levels of nitrate in this location are as high or higher than the level of nitrates entering the municipal wellfield area from the third terrace. This indicates that the town is also contributing to the high nitrate levels. Some of this may be a result of excessive lawn fertilization and overwatering of the lawn grasses.

Hot spots which appear and then subside (locations A, E and F) are discussed in detail in Parks (1991). These areas may be a result of feedlot operations, industrial tank farm lot spills and similar activities within these areas.

Figure 19 indicates a significant decrease in the nitrate levels (approximately 2-3 mg/l average). It is believed that this is a result of the significant amount of rain (over 4 inches) that fell in two different large thunderstorms during July and August in the area which most likely resulted in the dilution and flushing of the groundwater system in the area.

Overall, it is believed that nitrate contamination of the municipal water supply of Torrington is due to the unique geologic features, agricultural, urban and other activities in the area. The persistence and fate of nitrate in the groundwater system is determined by the particular properties of the aquifer in the vicinity of the well. In areas where the flow of groundwater is hindered by the presence of subsurface dams, contaminant levels rise dramatically and persist for extended periods of time. In areas where groundwater flow is unhindered the aquifer appears to be able to dilute itself to lower levels as long as the recharge water is at a lower level of contamination than the groundwater as manifest by recharge from the canals in the area and large thunderstorm events. The immediate problem in Torrington is the result of the flushing of the areas of high nitrate contamination in the third terrace north of town into the municipal wellfield areas and the contamination originating from the town itself.

Task 4 Results:

Some suggested possible strategies for management of the alluvial aquifer and recharge area serving Torrington to control point and non-point sources of contamination (nitrate) to improve water quality will be discussed in the following paragraphs. It should be indicated that under the present situation existing in the area, it would be impossible to protect the aquifer from nitrate intrusion. However, the town and county can take several steps to help decrease the high levels of nitrate which presently exist.

It should be pointed out that numerous processes exist which can effectively remove nitrates from water (Bouwer, 1990). However, when economic factors and technical problems are taken into consideration, the number of viable treatment options available to Torrington becomes extremely limited. For example, reverse osmosis is an excellent method for removing nitrates from water but the enormous costs of this type of a system precludes its use in a small community with limited resources. Currently, available ion exchange resins are generally incompatible with the high sulfate waters found in the Torrington area. Treating the water in a treatment plant designed for surface water would negate all of the benefits derived from using groundwater.

In light of these problems, only two viable alternatives are given. These two alternatives are the relocation of wells to areas with persistently low levels of nitrate contamination and/or the initiation of management programs designed to monitor and limit the amount of nitrate entering the groundwater system through a wellhead protection design based on flow direction and travel times to the municipal wells. The management programs must be established in both the rural and urban areas around Torrington to contribute to a solution of lowering the nitrate levels in the aquifer to acceptable levels. A separate grant to the University of Wyoming is evaluating the upstream contributing area to pollutants reaching each of the Torrington municipal wells for different travel times.

If the town should decide to relocate several or all of their wells, the three most promising sites are in the west-central, extreme northeastern and southwestern (on the south side of the North Platte River) part of the study area in those areas indicted with low nitrate levels (Figures 15 through 19). Regardless of the site selected, a management program using wellhead protection guidelines of the EPA would be required to be established in the upstream flow area contributing to these new wells to ensure future contamination free water.

From a purely economic standpoint, either the west-central area or the extreme northeastern area would be the most suitable sites with each having its benefits from a cost standpoint. The northeastern site does have the advantages of easier land restrict capabilities and being fed into the town by gravity. The main drawback to this northeastern area is the potential impact of extensive groundwater withdrawals under limited recharge and the possible effects on Arnold Drain which is most likely considered a wetland. The west-central area would have the most reliable source of groundwater because of its location with respect to the North Platte River and surrounding canal system. This area would, however, require booster pump stations throughout the distribution system and has a higher possibility of future contamination.

The management program alternative to reduce nitrate movement into the groundwater system has the most likelihood of producing the greatest long term benefits with the least total cost if implemented in a positive and correct manner. To accomplish this program the rates of nitrate fertilizer application must be reduced and amount and timing of applications of the nitrate fertilizer must be done. This will require extensive education of the public and agricultural sectors to ensure best management practices are followed. The management program must include the agricultural areas to the north and northwest of Torrington as well as the town itself in order for such a program to be effective. Several examples of control programs to control nitrate movement below the root zone of plants have been implemented in other parts of the United States where nitrate contamination has been a problem

(Ferguson et al., 1990; Logan, 1990; Yanggen and Born, 1990).

While the agricultural community may resist any further regulation of its activities, both cost and health benefits may be realized by the agricultural community as well as the town by reducing the amount of fertilizer being applied over the growing season. The farmer will realize reduced fertilizer purchases with essentially no loss of yield if best management practices are strictly followed. The health benefits would be realized by the farmer and his wife and children who are currently consuming water which contains some of the highest nitrate levels found in the area. The program will require routine nitrate sampling of fields several times each year to determine the amount of nitrate fertilizer to be applied each time (the number of applications will most likely increase over previous practices). An educational program sponsored by the local extension people, fertilizer companies and SCS which discusses the benefits of such a program will go a long ways in convincing the agricultural community to modify its current fertilizer practices.

Within the town limits, a program to voluntarily reduce the amounts of fertilizer being applied to lawns and gardens must be initiated. The nitrate sampling program used by agriculture could also be utilized in the town. If this is not effective, then raising water rates to homeowners to a level that reduces lawn and garden watering is another alternative.

It is believed by the authors of this report that the management program alternative can work effectively in Torrington to bring the nitrate levels in the aquifer down to acceptable levels (3 to 5 ppm) within a two to five year period if the agricultural community and the town cooperate using best management practices in all areas but especially those where high levels presently exist. The decrease indicated by large recharge events in the area gives substance to this recommendation.

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APPENDIX A

is not available

for information contact

Victor Hasfurther
in the
Civil Engineering Department

APPENDIX B

LOCATION HAVERSON

CO+MT NE NM SD UT WY

Established Series
GB 6/85

HAVERSON SERIES

The Haverson series consists of deep, well drained soils that formed in alluvium from mixed sources. Haverson soils are on floodplains and low terraces and have slopes of 0 to 9 percent. The mean annual precipitation is about 16 inches and the mean annual temperature is about 52 degrees F.

TAXONOMIC CLASS: Fine-loamy, mixed (calcareous), mesic Ustic Torrifluvents

TYPICAL PEDON: Haverson loam, grassland. (Colors are for dry soil unless otherwise noted.)

A--0 to 6 inches; light brownish gray (10YR 6/2) loam, dark grayish brown (10YR 4/2) moist; moderate very fine granular structure; soft, very friable; calcareous; moderately alkaline (pH 8.2); clear smooth boundary. (4 to 8 inches thick)

C--6 to 60 inches; light brownish gray (10YR 6/2) loam stratified with thin lenses of clay loam and fine sandy loam, dark grayish brown (10YR 4/2) moist; weighted average texture approximately a loam; massive; slightly hard, very friable; a very small inconsistent amount of secondary calcium carbonate as soft concretions; calcareous; moderately alkaline (pH 8.2)

TYPE LOCATION: Prowers County, Colorado; approximately 0.8 mile south and 0.1 mile east of NW corner sec. 29, T. 22 S. R. 45 W.

RANGE IN CHARACTERISTICS: Organic carbon ranges from .6 to 1.5 percent in the surface horizon but decreases irregularly with depth. The control section is stratified with strata ranging from sandy loam to clay loam, but averaging approximately loam. On a weighted average basis clay ranges from 18 to 35 percent, silt from 10 to 50 percent, and sand from 20 to 60 percent with more than 15 percent but less than 35 percent being fine or coarser sand. Rock fragments are generally less than 5 percent and range from 0 to 20 percent. Some visible calcium carbonate may occur at any depth in these soils, but it is not concentrated into any consistent horizon of accumulation. Mean annual soil temperature ranges from 47 to 58 degrees F. and mean summer soil temperature ranges from 59 to 78 degrees F. This soil is not dry in all parts of the moisture control section for more than one-half the time the soil temperature is above 41 degrees F. (240 to 250 days) and is not dry for 45 consecutive days following July 15. The A horizon has hue of 2.5Y or 10YR, value of 5 or 6 dry, 3 through 5 moist and chroma of 2 or 3. When the value of the surface horizon is as dark as 5 dry and 3 moist, the horizon is thin enough so that if mixed to 7 inches it is too light colored or contains too little organic carbon to qualify as a mollic epipedon or are finely statified. The A horizon usually has granular primary structure but it has subangular blocky structure in some pedons. It is soft or slightly hard. It is neutral through moderately alkaline.

The C horizon has hue of 2.5Y through 7.5YR value of 5 or 6 dry, 4 or 5 moist and chroma of 2 or 3. It is mildly alkaline to strongly alkaline. It has from less than 1 to about 15 percent calcium carbonate equivalent which differs erratically from stratum to stratum.

COMPETING SERIES: These are the Barnum, Haverdad, Hysham, Navacity (T), Panitchen, San Mateo and Tropic (T) soils. Barnum soils have lithochromic hue of 5YR or redder. Hysham soils are very strongly alkaline and have a very hard or extremely hard Bw horizon. Haverdad soils receive over one-half of their precipitation during April to June and are dry in all parts for at least 60 consecutive days before July 15 to October 25 and for at least 90 consecutive days during this period. Navacity (T) soils are not clearly differentiated, overlapping in clay in the particle size control section. Panitchen soils are dry in the moisture control section for 15 consecutive days from May 15 to July 15 when the soil temperature at 20 inches is greater than 41 degrees F. It is not dry in all parts of the moisture control section for at least 45 consecutive days following the summer solstice to October 20, and for at least 90 cummulative days during that period. Tropic (T) soils have 15 to 40 percent calcium carbonate equivalent in the C horizon. San Mateo soils are dry in all parts for 30 consecutive days from May 15 to July 1 and are dry in all parts for 45 consecutive days from July 15 to October 25.

GEOGRAPHIC SETTING: The Haverson soils are on floodplains and low terraces of major rivers. Slope is 0 to 9 percent. The soils formed in highly statified, calcareous, recent alluvium derived from mixed sources. At the type location the average annual precipitation is 16 inches with peak periods of precipitation occuring during the early spring and summer. The average annual temperature is 52 degrees F. and the average summer temperature is 77 degrees F. The frost-free season is 125 to 180 days.

GEOGRAPHICALLY ASSOCIATED SOILS: These are the Bankard and Glenberg soils. Bankard and Glenberg soils have less than 18 percent clay in the series control section.

DRAINAGE AND PERMEABILITY: Well drained; slow runoff; moderate permeability.

USE AND VEGETATION: These soils are used as native pastureland, dry farm land or irrigated cropland. Native vegetation is mixed grasses, cottonwoods and brush.

DISTRIBUTION AND EXTENT: Eastern Colorado and Wyoming, northestern New Mexico and adjacent states. This soil is of large extent.

REMARKS: Differentation from Navacity (T) needs further study.

National Cooperative Soil Survey
U.S.A.

LOCATION BANKARD

CO+KS MT NE NM SD UT WY

Established Series
Rev. AJC/GB
6/86

BANKARD SERIES

The Bankard series consists of deep, well to somewhat excessively drained soils that formed in alluvium from a variety of rocks. Bankard soils are on flood plains and low terraces and have slopes of 0 to 6 percent. The mean annual precipitation is about 14 inches and the mean annual temperature is about 48 degrees F.

TAXONOMIC CLASS: Sandy, mixed, mesic Ustic Torrifluvents

TYPICAL PEDON: Bankard loamy sand - grassland. (Colors are for dry soil unless otherwise noted.)

A--0 to 5 inches; light brownish gray (2.5Y 6/2) loamy fine sand, grayish brown (2.5Y 5/2) moist; weak fine granular structure; soft, very friable; calcareous; moderately alkaline (pH. 8.0); clear smooth boundary. (4 to 8 inches thick)

C--5 to 60 inches; light yellowish brown (2.5Y 6/3) loamy very fine sand stratified with thin layers of sand, sandy loam, and loam, light olive brown (2.5Y 5/3) moist; the weighted average texture is loamy fine sand; single grained; soft, very friable, calcareous; moderately alkaline (pH 8.2).

TYPE LOCATION: Morgan County, Colorado; 100 feet south and 210 feet east of the northwest corner of Sec. 30, T. 4 N., R. 56 W.

RANGE IN CHARACTERISTICS: The soils are typically calcareous throughout but are noncalcareous in the upper few inches in some pedons. Organic carbon in the A horizon ranges from .6 to 1.5 percent and decreases irregularly with increasing depth. The control section is variable in texture due to the stratification, but loamy fine sand predominates above 40 inches. Rock fragments range from 0 to 15 percent, but are typically less than 5 percent. Weak accumulations of secondary carbonate as soft concretions or seams is present in some pedons. Mean annual soil temperature ranges from 47 to 58 degrees F., and mean summer soil temperature ranges from 60 to 78 degrees F. In some pedons, gravel ranges from 0 to 35 percent below depths of 40 inches. The moisture control section is moist in some or all parts for as long as 60 consecutive days when the soil temperature at 20 inches is 41 degrees F., which occurs in April.

The A horizon has hue of 2.5Y through 5YR, value of 5 or 6 dry, 3 through 5 moist, and chroma of 2 through 6. Typically the horizon has granular or crumb structure but is subangular blocky in some pedons. It is soft or slightly hard and is mildly alkaline or moderately alkaline.

The C horizon has hue of 2.5Y through 5YR. It is mildly alkaline to strongly alkaline. Calcium carbonate equivalent ranges from less than 1 to 10 percent depending upon character of individual strata, but there is no distinct continuous horizon of calcium carbonate accumulation.

COMPETING SERIES: These are the Draknab, Dwyer, and Ellicott series. Draknab soils are never moist in some or all parts for as long as 60 consecutive days when the soil at 20 inches is 41 degrees or more. Dwyer soils have uniform texture in which organic carbon decreases uniformly with depth. Ellicott soils are noncalcareous and contain a high proportion of medium and coarse angular granite sand and fine and very fine angular granite gravel.

GEOGRAPHIC SETTING: These soils are on flood plains and low terraces. Slope gradients range from 0 to about 6 percent. The soils formed in calcareous highly stratified but predominantly coarse textured recent alluvium derived from a variety of rocks. At the type location, the aveage annual temperature ranges from 48 to 51 degrees F., the average summer temperature is 70 degrees F., and the average annual precipitation is 10 to 14 inches with peak periods of precipitation in the spring and early summer.

GEOGRAPHICALLY ASSOCIATED SOILS: These are the Glenberg and Haverson soils. Glenberg soils have a coarse-loamy control section. Haverson soils have a fine-loamy control section.

DRAINAGE AND PERMEABILITY: Well to somewhat excessively drained; slow or very slow runoff; rapid or very rapid permeability.

USE AND VEGETATION: These soils are used chiefly as native pastureland; however, they are tilled in some localities. Native vegetation consists of scattered cottonwood, grass, and brush.

DISTRIBUTION AND EXTENT: The flood plains and low terraces of the major streams in Colorado, Kansas, Wyoming, New Mexico, and parts of Montana, South Dakota, Nebraska, and eastern Utah.

SERIES ESTABLISHED: Red Willow County, Nebraska, 1965.

National Cooperative Soil Survey
U.S.A.

LOCATION VALENTINE

NE+CO KS MT NM SD TX WY

Established Series
Rev. MAP-MLD
2/90

VALENTINE SERIES

The Valentine series consists of very deep, excessively drained, rapidly permeable soils formed in eolian sands. These upland soils have slopes ranging from 0 to 60 percent. Mean annual temperature is about 51 degrees F, and mean annual precipitation is about 20 inches.

TAXONOMIC CLASS: Mixed, mesic Typic Ustipsamments

TYPICAL PEDON: Valentine fine sand - on an 8 percent convex northwest-facing slope in rangeland. When described the soil was moist throughout. (Colors are for dry soil unless otherwise stated.)

A--0to 5 inches; grayish brown (10YR 5/2) fine sand, dark grayish brown (10YR 4/2) moist; weak fine granular structure parting to single grained; loose; slightly acid; abrupt smooth boundary. (2 to 9 inches thick)

AC--5 to 9 inches; brown (10YR 5/3) fine sand, grayish brown (10YR 5/2) moist; weak, coarse prismatic structure parting to single grained; loose; slightly acid; clear smooth boundary. (0 to 8 inches thick)

C1--9 to 17 inches; pale brown (10YR 6/3) fine sand, pale brown (10YR 6/3) moist; weak coarse prismatic structure parting to single grained; loose; slightly acid; gradual smooth boundary. (0 to 12 inches thick)

C2--17 to 60 inches; very pale brown (10YR 7/3) fine sand, pale brown (10YR 6/3) moist, single grained, loose; neutral.

TYPE LOCATION: Logan County, Nebraska; about 12 1/2 miles north of Stapleton, Nebraska; 1060 feet north and 530 feet west of the center of sec. 36, T.20 N., R. 28 W.

RANGE IN CHARACTERISTICS: Texture of the profile typically is fine sand or loamy fine sand, but includes sand and loamy sand having less than 35 percent medium sand and less than 10 percent coarse or very coarse sand. The soil is medium acid or neutral throughout the profile.

The A horizon has hue of 10YR, value of 4 through 6 and 3 through 5 moist, and chroma of 2 or 3.

Where present, the AC horizon has hue of 10YR, value of 5 through 7 and 4 through 6 moist, and chroma of 2 or 3.

The C horizon has hue of 10YR, value of 6 or 7 and 5 or 6 moist, and chroma of 2 through 4. In some pedons, dark colored loamy textured strata ranging from 1/8 to 2 inches in thickness are below depths of 20 inches. When Valentine soils are associated with clayey soils, clayey substratum phases are recognized at 40 to 60 inches.

COMPETING SERIES: These are the Duda, McKelvie, Roysa, Simeon, and Tonalea series in the same family. A similar soil is Valent. Duda and Tonalea soils have weakly cemented sandstone between a depth of 20 to 40 inches. McKelvie soils have sandstone fragments in their sola. Royosa soils have drier climate with less than 16 inches mean annual precipitation. Simeon soils have a control section of loamy coarse sand, loamy sand, sand or coarse sand and it contains more than 35 percent medium and coarse sand and less than 50 percent fine or very fine sand, and up to 15 percent by volume of gravel. Valent soils have a drier climate.

GEOGRAPHIC SETTING: Valentine soils are on nearly level to slightly hummocky to steep, hilly uplands. Slope gradient ranges from 0 to 60 percent. Relief ranges from 1 to over 100 feet. Soils formed in eolian sands. The mean temperature ranges from 47 to 59 degrees F, and mean annual precipitation ranges from about 16 to 25 inches.

GEOGRAPHICALLY ASSOCIATED SOILS: These are the competing Duda and Simeon soils and the Doger, Dunday, Els, Elsmere, Gannett, Hersh, Loup, Ord, Ovina, and Tryon soils. Duda soils occur below Valentine soils. Simeon soils occur on nearly level to steep slopes below areas of Valentine soils. Doger and Dunday soils have mollic epipedons and occur on nearly level to strongly sloping areas below Valentine. The somewhat poorly drained Els, Elsmere, Ord, Ovina, and the poorly or very poorly drained Gannett, Loup, and Tryon soils occur in sandhill valleys and along bottom lands. Hersh soils have a coarse-loamy control section and occur below areas of Valentine.

DRAINAGE AND PERMEABILITY: Excessively drained. Runoff is slow or very slow because of rapid infiltration; permeability is rapid. Capacity to hold water is low.

USE AND VEGETATION: These soils are dominantly in native grass and used for grazing or hay. The main grasses are prairie sandreed, little bluestem, sand bluestem, switchgrass, sand lovegrass, needleandthread, blue grama and hairy grama. Some of these soils have been cultivated but unless irrigated, have been returned to grass.

DISTRIBUTION AND EXTENT: Principally north-central Nebraska, but also extending into South Dakota and Kansas. The series is of large extent. Estimated acreage is over 5,000,000 acres.

SERIES ESTABLISHED: Reconnaissance Survey of Western Nebraska, 1911.

REMARKS: The Valentine soils are classified as Regosol in the former system. They presently include much of the area formerly mapped as Dune sand.

ADDITIONAL DATA: Samples No. S54-Neb-16-1 and 2; MSL No. 2440-2444 and 2445-2449, as published in Soil Survey Investigations No. 5.

National Cooperative Soil Survey
U.S.A.

LOCATION DWYER

WY+CO KS MT NE SD

Established Series
Rev. PSD
1/83

DWYER SERIES

The Dwyer series consists of deep, excessively drained soils that formed in eolian sand. Dwyer soils are on dune-like forms frequently on or near the edges of alluvial terraces and have slopes of 0 to 25 percent. The mean annual precipitation is about 14 inches, and the mean annual temperature is about 48 degrees F.

TAXONOMIC CLASS: Mixed, mesic Ustic Torripsamments

TYPICAL PEDON: Dwyer fine sand - grassland. (Colors are for dry soil unless otherwise stated.)

A1--0 to 6 inches; pale brown (10YR 6/3) fine sand, dark grayish brown (10YR 4/2) moist; single grained; loose; calcareous; moderately alkaline (pH 8.0); gradual smooth boundary. (4 to 8 inches thick)

C--6 to 60 inches; very pale brown (10YR 7/3) fine sand, grayish brown (10YR 5/2) moist; single grained; loose; calcareous; moderately alkaline (pH 8.2).

TYPE LOCATION: Goshen County, Wyoming; approximately 200 feet south and 100 feet west of NE corner of SE1/4, NE1/4 of sec. 26, T. 22 N., R. 61 W.

RANGE IN CHARACTERISTICS: Typically, this soil is calcareous throughout but is leached in the upper part of the series control section in some pedons. The control section is sand, loamy sand, fine sand, or loamy fine sand. Coarse fragments range from 0 to 15 percent but are commonly less than 3 percent. These soils may have a weak and inconsistent accumualation of secondary calcium carbonate at any depth but are not considered to have a continuous Bk horizon. The soil is dry in the moisture control section more than half the time cumulative that the soil temperature at a depth of 20 inches is 41 degrees F. and is never moist in some or all parts for as long as 60 consecutive days when the soil temperature at a depth of 20 inches is 41 degrees F., which occurs about April 21-27, but is dry in all parts of the moisture control section for at least 60 consecutive days from July 15 to October 25 and for at least 90 cumulative days during this period. The mean annual soil temperature is 47 to 53 degrees F., and the soil temperature at a depth of 20 inches is 41 degrees F. or more for 175 to 192 days. Bedrock is deeper than 60 inches.

The A horizon has hue of 2.5Y or 10YR, value of 5 through 7 dry, 3 through 5 moist, and chroma of 2 or 3. The horizon is usually mildly alkaline through strongly alkaline but is slightly acid or neutral in some pedons. It is soft to loose. An AC horizon of loamy fine sand or fine sand is in some pedons.

The C horizon has hue of 2.5Y through 7.5YR, value of 5 through 7 dry, 3 through 5 moist, and chroma of 2 through 4. It is moderately alkaline or strongly alkaline and may contain few small carbonate concretions or seams of calcium carbonate erratically at any depth.

COMPETING SERIES: These are the Curtis Siding, Orpha, Mespun, Tullock, Valent, and Wigton series. Curtis Siding soils have greater than 15 percent coarse fragments in the control section. Orpha soils are noncalcareous above a depth of 30 inches. Mespun soils have a control section that dominantly has hue of 5YR and has chroma of 4 through 8. Tullock soils have a paralithic contact between 20 and 40 inches. Valent and Wigton soils are moist in some or all parts for 60 consecutive days following July 15 and are moist in some parts for at least 90 cumulative days when the soil temperature at a depth of 20 inches is 41 degrees F. or more and also have soil temperatures warmer than 41 degrees F. for 195 to 210 days or more. Wigton soils also have a dry consistence of hard or very hard.

GEOGRAPHIC SETTING: Dwyer soils are on dune-like forms frequently on or near the edges of alluvial terraces. Slopes are irregular, ranging from 0 to 25 percent. Elevation ranges from 3,500 to 5,600 feet. Dwyer soils formed in eolian sand. At the type location average annual precipitation is 14 inches with about half of the precipitation occurring in April, May, and June. The mean annual precipitation ranges from 10 to 16 inches. The mean annual temperature is 48 degrees F., and the mean summer temperature is 68 degrees F. The frost-free season is 110 to 130 days.

GEOGRAPHICALLY ASSOCIATED SOILS: These are the competing Orpha soils and the Draknab and Hiland soils. Draknab soils have a stratified control section in which organic matter decreases irregularly with increasing depth. Hiland soils have a sandy loam control section and argillic horizons.

DRAINAGE AND PERMEABILITY: Excessively drained; very slow to medium runoff depending on slope and compaction; rapid permeability.

USE AND VEGETATION: Used principally as native pastureland. Native vegetation is short and tall grasses and sage.

DISTRIBUTION AND EXTENT: Wyoming, Nebraska, South Dakota, and Colorado. The soil has moderate extent.

SERIES ESTABLISHED: Wheatland Area, Wyoming: 1926.

National Cooperative Soil Survey
U.S.A.

APPENDIX C

WELL I.D.#	TOWNSHIP	RANGE	SECTION	1/4,1/4	PERMIT #	DEPTH(FT)	STATIC WATER LEVEL (FT/YR)	TOP OF SCREEN(FT)	SCREENED INTERVAL(FT)	CASING TYPE	DIAMETER(IN)	DISCHARGE(GPM)	USE	DRILL LOG(Y/N)
1	25	62	25	NWNW	NF*	130	65/1982	65	60	NR**	8	20	D****	N
2	24	61	10	SWSW	WR156	90	19/1952	NR	30	STL***	18	750	M	Y
3	25	62	20	SENE	16715	60	40/1968	40	20	STL	5.5	50	D	Y
4	25	62	24	SWSE	NF	120	70/NR	NR	NR	NR	5	20	D	N
5	24	61	10	SESE	NF	NR	NR	NR	NR	NR	NR	NR	D	N
6	24	61	15	NENE	65949	70	15/1984	53	15	STL	16	900	M	Y
7	25	61	29	SESW	19760	137	80/1982	117	20	PLA	8	6	D	Y
8	24	61	5	SWSE	NF	NR	NR	NR	NR	NR	NR	NR	NR	N
9	25	61	28	SESW	19530	123	45/1988	106	17	PVC	5	25	D	Y
10	24	61	9	NENW	7097	46	16/1971	20	26	STL	5.5	15	D	Y
11	24	61	9	SWSE	NF	60	12/NR	NR	NR	NR	6	NR	D	N
12	24	61	9	SENW	NF	NR	NR	NR	NR	NR	NR	NR	D	N
13	24	61	9	NWNW	55312	60	25/1981	40	20	PLA	5	9	D	Y
14	25	61	17	NESE	4035	52	34/1917	NR	NR	STL	6	5	D	N
15	24	61	14	NESE	31932	60	11/1976	50	10	STL	8	50	D	Y
16	24	61	9	SENW	29546	50	30/1975	40	10	PLA	6	25	D	Y
17	25	61	29	NENW	6692	140	78/1978	124	16	STL	5.5	20	D	Y
18	24	61	6	NESE	60952	80	17/1982	17	63	PLA	6	20	D	Y
19	25	61	31	SWSW	NF	NR	NR	NR	NR	NR	NR	NR	D	N
20	24	61	4	NENE	14789	175	90/1974	115	60	STL	16	2000	M	Y
21	25	62	25	SENE	NF	NR	NR	NR	NR	NR	NR	NR	D	N
22	24	61	21	NENW	NF	40	30/NR	NR	NR	NR	6	NR	D	N
23	24	61	24	NESW	34569	40	15/1972	NR	NR	NR	6	25	D	Y
24	24	61	9	SESW	NF	80	12/NR	NR	NR	NR	6	NR	D	N
25	24	61	15	NWNW	84580	120	19/1985	102	15	STL	36	NR	M	Y
26	25	61	21	SESE	20272	380	72/1973	280	100	PLA	4.5	10	D	Y
27	24	61	10	SESE	45139	65	20/1979	25	40	STL	16	1000	M	Y
28	25	61	21	SWSW	3746	260	140/1918	NR	NR	NR	NR	6	D	N
29	25	61	19	NENE	3750	275	160/1920	NR	NR	STL	4	5	D	N
30	24	61	8	NWNW	NF	NR	NR	NR	NR	NR	NR	NR	D	N
31	25	62	36	NENW	34284	100	45/1976	40	60	STL	6	18	D	Y
32	24	61	5	NESW	NF	72	NR	52	20	NR	5	NR	D	N
33	25	62	27	SENW	NF	65	27/NR	NR	NR	NR	NR	NR	D	N
34	25	62	25	SESE	47164	90	32/1979	70	20	PLA	5	20	D	Y
35	24	61	5	SESE	29188	47	27/1975	NR	NR	STL	5	35	D	Y
36	24	61	10	SWSE	NF	80	24/NR	NR	30	STL	16	521	M	Y
37	25	61	32	NENE	NF	NR	NR	NR	NR	NR	NR	NR	D	N
38	24	61	6	NENE	NF	NR	NR	NR	NR	NR	NR	NR	D	N

* NF = Not found. Where information is given but a permit # is NF, the information was supplied by the well owner.
** NR = Not recorded on permit.
*** STL = steel; PLA (PVC) = plastic; CON = concrete
**** D = domestic; M = municipal; IR = irrigation
***** NA = Not applicable

WELL I.D.#	TOWNSHIP	RANGE	SECTION	1/4,1/4	PERMIT #	DEPTH(FT)	STATIC WATER LEVEL (FT/YR)	TOP OF SCREEN(FT)	SCREENED INTERVAL(FT)	CASING TYPE	DIAMETER(IN)	DISCHARGE(GPM)	USE	DRILL LOG(Y/N)
39	24	61	17	SWNE	79681	75	13/1975	35	40	STL	16	1400	IR	Y
40	24	61	5	NESW	19784	37	20/1970	30	7	STL	4.5	5	D	Y
41	24	61	15	NWNW	2629	100	8/1969	60	40	STL	16	1000	M	Y
42	24	61	3	NESW	45138	125	60/1979	65	60	STL	16	1000	M	Y
43	25	62	35	SWNW	80977	30	14/1971	NR	NR	PLA	8	5	D	N
44	25	62	35	SENE	51411	80	10/1980	60	20	PLA	5	15	D	Y
45	25	61	33	SESW	48785	170	80/1979	140	30	PLA	5	8	D	Y
46	24	61	10	NESW	NA*****	NA	NA	NA	NA	NA	NA	NA	M	N
47	25	61	30	NESE	8828	153	90/1971	135	18	STL	5.5	10	D	Y
48	24	61	22	NWNW	SC199	26	10/1947	NR	NR	NR	18	300	D	N
49	25	61	32	SESW	49382	75	44/1975	55	20	PLA	5	4	D	Y
50	25	62	25	SWNW	63435	NR	NR	NR	NR	NR	NR	NR	IR	N
51	24	61	3	NESW	757	132	68/1962	80	50	STL	30	1200	M	Y
52	24	61	6	SENE	80987	80	18/1989	70	10	PVC	6	18	D	Y
53	25	62	33	SENE	3298	40	12/1960	20	20	STL	4	20	D	Y
54	25	62	33	SENE	3299	40	18/1965	20	20	STL	4	20	D	Y
55	24	61	17	SESE	33448	60	12/1982	40	20	PLA	5	5	D	Y
56	24	61	10	NESW	SC440	60	20/1952	NR	NR	CON	48	1000	M	N
57	25	62	36	SWNE	NF	NR	NR	NR	NR	NR	NR	NR	D	N
58	24	61	14	NESW	71163	100	12/1986	80	20	STL	5	10	IN	Y
59	24	61	16	NENE	NA	NA	NA	NA	NA	NA	NA	NA	NA	N
60	24	61	5	SESE	41826	66	20/1979	56	10	PVC	6	35	D	Y
61	24	61	10	SENW	SC439	60	20/1952	NR	NR	CON	48	750	M	N
62	25	62	36	NESW	NF	NR	NR	NR	NR	NR	NR	NR	D	N
63	24	61	9	NENE	NA	NA	NA	NA	NA	NA	NA	NA	M	N
64	24	61	17	NWNW	NF	NR	NR	NR	NR	NR	NR	NR	IR	N
65	25	61	28	SESE	NF	NR	NR	NR	NR	NR	NR	NR	D	N
66	25	61	28	SWNW	NA	NA	NA	NA	NA	NA	NA	NA	IR	N
67	24	61	29	NENE	NF	NR	NR	NR	NR	NR	NR	NR	D	N
68	24	61	20	SESE	NF	NR	NR	NR	NR	NR	NR	NR	D	N
69	24	61	2	SESE	NF	NR	NR	NR	NR	NR	NR	NR	D	N
70	24	61	1	SWSW	NF	NR	NR	NR	NR	NR	NR	NR	D	N
71	24	61	13	SWSW	NF	NR	NR	NR	NR	NR	NR	NR	D	N
72	24	61	14	NENE	NF	NR	NR	NR	NR	NR	NR	NR	D	N
73	24	61	13	NWNW	NF	NR	NR	NR	NR	NR	NR	NR	D	N
74	24	61	13	SWNE	57923	200	70/1981	97	103	PLA	5	19	D	Y
75	24	61	24	NWNW	65624	60	10/1984	40	20	PVC	5	20	D	N
76	24	61	24	NWNW	NF	NR	NR	NR	NR	NR	NR	NR	D	N
77	24	61	24	SWNW	NF	90+	5/NR	NR	NR	NR	NR	NR	D	N
78	25	61	35	SENW	NF	NR	NR	NR	NR	NR	NR	NR	D	N
79	24	61	2	SWNW	NF	NR	NR	NR	NR	NR	NR	NR	D	N
80	24	61	3	SENE	NA	275	NR	NR	NR	NR	5.5	NR	D	Y
81	25	62	26	SESE	80342	109	75/1990	69	40	NR	26	450	IR	Y
82	25	62	13	SWSW	716	185	75/1962	NR	NR	NR	20	1454	IR	N
83	25	62	24	NWNW	496	165	67/1956	NR	NR	STL	30	950	IR	Y

WELL I.D.#	TOWNSHIP	RANGE	SECTION	1/4,1/4	PERMIT #	DEPTH(FT)	STATIC WATER LEVEL(FT/YR)	TOP OF SCREEN(FT)	SCREENED INTERVAL(FT)	CASING TYPE	DIAMETER(IN)	DISCHARGE(GPM)	USE	DRILL LOG(Y/N)
84	25	62	25	SENW	46298	120	63/1979	80	40	STL	13	400	IR	Y
85	25	62	25	NENE	596	129	77/1961	NR	NR	STL	18	1500	IR	Y
86	25	61	31	NWSE	SC10	95	35/1946	NR	NR	STL	18	1200	IR	Y
87	25	61	32	SENW	15518	123	88/1973	41	82	STL	28	1110	IR	Y
88	25	61	30	SWSE	7907	120	75/1971	80	40	STL	16	1000	IR	Y
89	25	61	31	NWSE	7908	80	35/1971	40	40	STL	16	1000	IR	Y
90	25	62	32	NESE	33186	65	24/1976	26	39	NR	16	1200	IR	Y
91	24	61	5	NWNE	376G	80	23/NR	NR	NR	NR	32	1800	IR	Y
92	24	61	5	NWSW	SC43	93	25/1946	NR	NR	STL	18	1200	IR	Y
93	24	61	5	NWNW	343	80	26/1960	50	30	STL	32	1500	IR	Y
94	25	61	29	NESE	NF	112	63/1951	NR	NR	STL	18	860	IR	N
95	25	61	28	SWNW	NA	NA	NA	NA	NA	NA	NA	NA	IR	N
96	25	61	33	NWNE	SC237	92	36/1940	47	45	STL	24	1025	IR	Y
97	25	61	34	NWNW	SC42	90	31/1940	NR	NR	STL	24	1500	IR	Y
98	25	61	27	NWSE	91G	86	30/1950	46	40	STL	18	1225	IR	Y
99	25	61	28	NWSE	SC101	105	48/1940	45	60	STL	24	975	IR	Y
100	25	61	28	SWSW	13956	120	59/NR	NR	NR	NR	NR	950	IR	N
101	25	61	33	NWNW	SC625	117	NR	NR	NR	NR	NR	950	IR	N
102	24	61	2	NWSW	SC19	112	74/1940	NR	NR	STL	24	1150	IR	Y
103	24	61	3	SWNE	SC480	137	70/1946	NR	NR	STL	30	1200	IR	Y
104	24	61	3	SENW	WR162	170	69/1952	NR	NR	STL	30	1200	IR	Y
105	24	61	1	NENW	5077	60	11/1970	30	30	NR	25	1800	IR	Y
106	24	61	1	NWNE	1692	35	15/1950	15	20	STL	18	1800	IR	Y
107	24	61	6	SWNW	370G	55	14/1951	45	10	STL	30	1500	IR	Y

WELL I.D. #	DATE	NH4-N(MG/L)	NO3+NO2-N(MG/L)	NO2-N(MG/L)
1	10/30/89	<0.3	3.6	<0.1
1	5/22/90	<0.3	4.2	<0.1
1	10/30/90	N/A	5.2	N/A
1	5/22/91	N/A	5.6	N/A
1	9/30/91	N/A	4.4	N/A
1	6/18/92	N/A	4.7	N/A
2	10/30/89	<0.3	9.2	<0.1
2	5/22/90	<0.3	9.1	<0.1
2	7/02/90	N/A	7.8	N/A
2	7/10/90	N/A	5.7	N/A
2	10/30/90	N/A	9.0	N/A
2	5/22/91	N/A	7.2	N/A
2	9/30/91	N/A	7.5	N/A
2	6/18/92	N/A	8.5	N/A
3	10/30/89	<0.3	9.7	<0.1
3	5/22/90	<0.3	11.7	<0.1
3	10/30/90	N/A	7.5	N/A
4	10/30/89	<0.3	3.9	<0.1
4	5/22/90	<0.3	2.6	<0.1
4	10/30/90	N/A	5.7	N/A
4	5/22/91	N/A	3.2	N/A
4	9/30/91	N/A	4.7	N/A
4	6/18/92	N/A	3.6	N/A
5	10/30/89	<0.3	6.8	.6
5	5/22/90	N/A	8.2	N/A
5	10/30/90	N/A	8.4	N/A
5	5/22/91	N/A	73	N/A
5	9/30/91	N/A	12.0	N/A
6	10/30/89	<0.3	13.0	0.2
6	5/22/90	<0.3	13.5	<0.1
6	7/02/90	N/A	12.1	N/A
6	7/10/90	N/A	12.8	N/A
6	10/30/90	N/A	11.0	N/A
6	5/22/91	N/A	11	N/A
6	9/30/91	N/A	10.0	N/A
7	10/30/89	<0.3	6.3	<0.1
7	5/22/90	<0.3	7.9	<0.1
7	10/30/90	N/A	6.2	N/A
8	10/30/89	<0.3	6.2	<0.1
8	5/22/90	N/A	9.7	N/A
8	10/30/90	N/A	10.0	N/A
8	5/22/91	N/A	10	N/A
8	9/30/91	N/A	9.5	N/A
8	6/18/92	N/A	12.0	N/A
9	10/30/89	<0.3	5.3	<0.1
9	5/22/90	N/A	5.6	N/A
9	10/30/90	N/A	4.5	N/A
9	5/22/91	N/A	4.3	N/A

WELL I.D. #	DATE	NH4-N(MG/L)	NO3+NO2-N(MG/L)	NO2-N(MG/L)
9	9/30/91	N/A	3.7	N/A
9	6/18/92	N/A	3.8	N/A
10	10/30/89	<0.3	6.3	<0.1
10	5/22/90	<0.3	4.5	<0.1
10	10/30/90	N/A	5.5	N/A
10	5/22/91	N/A	3.0	N/A
10	9/30/91	N/A	5.2	N/A
10	6/18/92	N/A	7.3	N/A
11	10/30/89	<0.3	2.6	<0.1
11	5/22/90	<0.3	4.0	<0.1
11	10/30/90	N/A	5.8	N/A
11	5/22/91	N/A	1.7	N/A
11	9/30/91	N/A	1.9	N/A
12	10/30/89	<0.3	4.6	<0.1
12	5/22/90	N/A	14.4	N/A
12	10/30/90	N/A	7.2	N/A
12	5/22/91	N/A	11	N/A
12	9/30/91	N/A	4.1	N/A
12	6/18/92	N/A	9.6	N/A
13	10/30/89	<0.3	6.9	<0.1
13	5/22/90	<0.3	9.5	<0.1
13	10/30/90	N/A	6.2	N/A
13	5/22/91	N/A	5.3	N/A
13	9/30/91	N/A	6.9	N/A
13	6/18/92	N/A	7.8	N/A
14	10/30/89	<0.3	12.3	<0.1
14	5/22/90	N/A	11.8	N/A
14	10/30/90	N/A	12.0	N/A
14	5/22/91	N/A	5.6	N/A
14	6/18/92	N/A	9.8	N/A
15	10/30/89	<0.3	9.0	<0.1
15	5/22/90	N/A	8.2	N/A
15	10/30/90	N/A	5.4	N/A
15	5/22/91	N/A	8.6	N/A
15	6/18/92	N/A	9.6	N/A
16	10/30/89	<0.3	<0.1	<0.1
16	5/22/90	<0.3	4.8	<0.1
16	10/30/90	N/A	N/A	N/A
16	5/22/91	N/A	2.2	N/A
16	9/30/91	N/A	2.9	N/A
16	6/18/92	N/A	4.5	N/A
17	10/30/89	0.3	4.0	<0.1
17	5/22/90	N/A	5.9	N/A
17	10/30/90	N/A	7.7	N/A
17	5/22/91	N/A	7.5	N/A
17	9/30/91	N/A	7.8	N/A
17	6/18/92	N/A	7.2	N/A
18	10/30/89	<0.3	13.0	<0.1
18	5/22/90	<0.3	21.5	<0.1
18	10/30/90	N/A	17.0	N/A
18	5/22/91	N/A	13	N/A
18	9/30/91	N/A	2.9	N/A

WELL I.D. #	DATE	NH4-N(MG/L)	NO3+NO2-N(MG/L)	NO2-N(MG/L)
18	6/18/92	N/A	7.6	N/A
19	10/30/89	0.3	2.9	<0.1
19	5/22/90	<0.3	3.3	<0.1
19	10/30/90	N/A	2.4	N/A
19	5/22/91	N/A	2.8	N/A
19	9/30/91	N/A	1.6	N/A
19	6/18/92	N/A	1.6	N/A
20	10/30/89	<0.3	10.3	<0.1
20	5/22/90	<0.3	3.9	<0.1
20	7/02/90	N/A	5.2	N/A
20	7/10/90	N/A	5.7	N/A
20	10/30/90	N/A	8.3	N/A
20	5/22/91	N/A	5.9	N/A
20	9/30/91	N/A	6.4	N/A
20	6/18/92	N/A	7.7	N/A
21	10/30/89	<0.3	0.9	<0.1
21	5/22/90	<0.3	13.5	<0.1
21	10/30/90	N/A	16.0	N/A
21	5/22/91	N/A	20	N/A
21	9/30/91	N/A	15	N/A
21	6/18/92	N/A	12.0	N/A
22	10/30/89	<0.3	0.7	<0.1
22	5/22/90	N/A	1.6	N/A
22	10/30/90	N/A	3.3	N/A
22	5/22/91	N/A	5.6	N/A
22	9/30/91	N/A	4.4	N/A
22	6/18/92	N/A	5.6	N/A
23	10/30/89	<0.3	4.2	<0.1
23	5/22/90	N/A	2.4	N/A
23	10/30/90	N/A	2.7	N/A
23	5/22/91	N/A	2.0	N/A
23	9/30/91	N/A	1.7	N/A
23	6/18/92	N/A	1.3	N/A
24	10/30/89	<0.3	2.4	0.1
24	5/22/90	<0.3	1.5	<0.1
24	10/30/90	N/A	16.0	N/A
24	5/22/91	N/A	1.3	N/A
24	9/30/91	N/A	1.9	N/A
24	6/18/92	N/A	2.2	N/A
25	10/30/89	<0.3	3.4	0.4
25	5/22/90	<0.3	6.9	<0.1
25	7/02/90	N/A	7.3	N/A
25	7/10/90	N/A	7.9	N/A
25	10/30/90	N/A	6.4	N/A
25	5/22/91	N/A	5.5	N/A
25	9/30/91	N/A	4.3	N/A
25	6/18/92	N/A	4.6	N/A
26	10/30/89	<0.3	30.3	<0.1
26	5/22/90	N/A	27.7	N/A
26	10/30/90	N/A	26.0	N/A
26	5/22/91	N/A	28.0	N/A
27	10/30/89	<0.3	9.8	<0.1

WELL I.D. #	DATE	NH4-N(MG/L)	NO3+NO2-N(MG/L)	NO2-N(MG/L)
27	5/22/90	<0.3	8.2	<0.1
27	7/02/90	N/A	9.2	N/A
27	7/10/90	N/A	6.4	N/A
27	10/30/90	N/A	8.3	N/A
27	5/22/91	N/A	9.1	N/A
27	9/30/91	N/A	8.4	N/A
28	10/30/89	<0.3	8.5	<0.1
28	5/22/90	N/A	4.6	N/A
28	10/30/90	N/A	7.0	N/A
28	5/22/91	N/A	5.9	N/A
29	10/30/89	<0.3	3.4	0.4
29	5/22/90	N/A	7.0	N/A
29	10/30/90	N/A	4.1	N/A
29	5/22/91	N/A	10.0	N/A
30	10/30/89	<0.3	8.0	<0.1
30	5/22/90	<0.3	3.9	<0.1
30	10/30/90	N/A	8.7	N/A
30	5/22/91	N/A	2.8	N/A
30	9/30/91	N/A	3.7	N/A
30	6/18/92	N/A	2.0	N/A
31	10/30/89	<0.3	1.0	,0.1
31	5/22/90	<0.3	1.6	<0.1
31	10/30/90	N/A	1.1	N/A
31	5/22/91	N/A	1.7	N/A
31	9/30/91	N/A	.9	N/A
31	6/18/92	N/A	1.8	N/A
32	10/30/89	<0.3	3.4	<0.1
32	5/22/90	N/A	5.5	N/A
32	10/30/90	N/A	2.2	N/A
32	5/22/91	N/A	4.4	N/A
32	9/30/91	N/A	2.3	N/A
32	6/18/92	N/A	2.8	N/A
33	10/30/89	<0.3	4.4	0.2
33	5/22/90	N/A	5.8	N/A
33	10/30/90	N/A	5.5	N/A
33	5/22/91	N/A	6.6	N/A
33	9/30/91	N/A	5.1	N/A
33	6/18/92	N/A	5.9	N/A
34	10/30/89	<0.3	5.5	0.4
34	5/22/90	<0.3	8.1	<0.1
34	10/30/90	N/A	8.3	N/A
34	5/22/91	N/A	8.8	N/A
34	9/30/91	N/A	7.7	N/A
34	6/18/92	N/A	7.1	N/A
35	10/30/89	<0.3	6.4	,0.1
35	5/22/90	<0.3	6.6	<0.1
35	10/30/90	N/A	N/A	N/A
35	5/22/91	N/A	11	N/A
35	9/30/91	N/A	7.7	N/A
35	6/18/92	N/A	9.1	N/A
36	10/30/89	<0.3	9.5	<0.1
36	5/22/90	<0.3	9.5	<0.1

WELL I.D. #	DATE	NH4-N(MG/L)	NO3+NO2-N(MG/L)	NO2-N(MG/L)
36	7/02/90	N/A	8.5	N/A
36	7/10/90	N/A	6.4	N/A
36	10/30/90	N/A	9.1	N/A
36	5/22/91	N/A	6.3	N/A
36	9/30/91	N/A	5.5	N/A
36	6/18/92	N/A	6.9	N/A
37	10/30/89	<0.3	15.0	<0.1
37	5/22/90	<0.3	13.0	<0.1
37	10/30/90	N/A	16.0	N/A
37	5/22/91	N/A	10.0	N/A
37	9/30/91	N/A	9.4	N/A
37	6/18/92	N/A	11.0	N/A
38	10/30/89	<0.3	5.0	<0.1
38	5/22/90	<0.3	7.5	<0.1
38	10/30/90	N/A	1.4	N/A
38	5/22/91	N/A	6.1	N/A
38	9/30/91	N/A	3.2	N/A
38	6/18/92	N/A	3.6	N/A
39	10/30/89	<0.3	4.2	<0.1
39	5/22/90	N/A	7.0	N/A
39	10/30/90	N/A	N/A	N/A
39	5/22/91	N/A	6.8	N/A
39	6/18/92	N/A	6.2	N/A
40	10/30/89	<0.3	6.1	,0.1
40	5/22/90	<0.3	2.5	<0.1
40	10/30/90	N/A	3.4	N/A
40	5/22/91	N/A	1.7	N/A
40	9/30/91	N/A	1.2	N/A
40	6/18/92	N/A	2.0	N/A
41	10/30/89	1.7	8.5	<0.1
41	5/22/90	<0.3	8.3	<0.1
41	7/10/90	N/A	7.7	N/A
41	10/30/90	N/A	6.0	N/A
41	5/22/91	N/A	6.6	N/A
41	9/30/91	N/A	5.8	N/A
41	6/18/92	N/A	6.2	N/A
42	10/30/89	<0.3	12.5	<0.1
42	5/22/90	<0.3	6.5	<0.1
42	7/02/90	N/A	11.3	N/A
42	7/10/90	N/A	7.9	N/A
42	10/30/90	N/A	8.3	N/A
42	5/22/91	N/A	11	N/A
42	9/30/91	N/A	7.5	N/A
42	6/18/92	N/A	9.4	N/A
43	10/30/89	<0.3	15.5	<0.1
43	5/22/90	N/A	9.7	N/A
43	10/30/90	N/A	1.4	N/A
43	5/22/91	N/A	.9	N/A
44	10/30/89	<0.3	6.0	<0.1
44	5/22/90	<0.3	9.1	<0.1
44	10/30/90	N/A	7.9	N/A
44	5/22/91	N/A	7.9	N/A

WELL I.D. #	DATE	NH4-N(MG/L)	NO3+NO2-N(MG/L)	NO2-N(MG/L)
44	9/30/91	N/A	7.3	N/A
44	6/18/92	N/A	7.6	N/A
45	10/30/89	<0.3	12.5	<0.1
45	5/22/90	<0.3	17.0	<0.1
45	10/30/90	N/A	14.0	N/A
45	5/22/91	N/A	19.0	N/A
45	9/30/91	N/A	13	N/A
45	6/18/92	N/A	17.0	N/A
46	10/30/89	<0.3	9.9	<0.1
46	5/22/90	<0.3	9.0	<0.1
46	10/30/90	N/A	8.9	N/A
46	5/22/91	N/A	8.2	N/A
46	9/30/91	N/A	4.3	N/A
46	6/18/92	N/A	4.8	N/A
47	10/30/89	<0.3	0.4	<0.1
47	5/22/90	<0.3	1.2	<0.1
47	10/30/90	N/A	0.52	N/A
47	5/22/91	N/A	0.6	N/A
47	9/30/91	N/A	.5	N/A
47	6/18/92	N/A	0.5	N/A
48	10/30/89	<0.3	13.5	<0.1
48	5/22/90	<0.3	14.5	<0.1
48	10/30/90	N/A	32.0	N/A
48	5/22/91	N/A	20.0	N/A
48	9/30/91	N/A	40	N/A
48	6/18/92	N/A	14.0	N/A
49	10/30/89	<0.3	8.0	<0.1
49	5/22/90	N/A	7.2	N/A
49	10/30/90	N/A	8.3	N/A
49	5/22/91	N/A	9.2	N/A
49	9/30/91	N/A	7.2	N/A
49	6/18/92	N/A	8.8	N/A
50	10/30/89	<0.3	9.5	<0.1
50	10/30/90	N/A	N/A	N/A
51	10/30/89	<0.3	2.7	<0.1
51	5/22/90	<0.3	5.5	<0.1
51	7/10/90	N/A	4.5	N/A
51	10/30/90	N/A	N/A	N/A
52	10/30/89	<0.3	1.1	<0.1
52	5/22/90	<0.3	2.1	<0.1
52	10/30/90	N/A	<0.2	N/A
52	5/22/91	N/A	1.1	N/A
52	9/30/91	N/A	6.0	N/A
52	6/18/92	N/A	5.0	N/A
53	10/30/89	<0.3	2.3	<0.1
53	5/22/90	N/A	3.0	N/A
53	10/30/90	N/A	1.9	N/A
53	5/22/91	N/A	5.6	N/A
53	9/30/91	N/A	2.3	N/A
53	6/18/92	N/A	4.0	N/A
54	10/30/89	N/A	N/A	N/A
54	5/22/90	N/A	0.3	N/A

WELL I.D. #	DATE	NH4-N(MG/L)	NO3+NO2-N(MG/L)	NO2-N(MG/L)
54	10/30/90	N/A	2.9	N/A
54	5/22/91	N/A	0.6	N/A
54	9/30/91	N/A	<.2	N/A
54	6/18/92	N/A	0.7	N/A
55	10/30/89	<0.3	<0.1	<0.1
55	5/22/90	N/A	1.1	N/A
55	10/30/90	N/A	2.1	N/A
55	5/22/91	N/A	0.7	N/A
55	9/30/91	N/A	.5	N/A
56	10/30/89	<0.3	9.8	<0.1
56	5/22/90	<0.3	14.5	<0.1
56	7/02/90	N/A	9.3	N/A
56	7/10/90	N/A	7.9	N/A
56	10/30/90	N/A	8.8	N/A
56	5/22/91	N/A	8.6	N/A
56	9/30/91	N/A	6.8	N/A
57	10/30/89	<0.3	8.0	<0.1
57	5/22/90	N/A	6.1	N/A
57	10/30/90	N/A	7.0	N/A
57	5/22/91	N/A	6.3	N/A
57	9/30/91	N/A	7.4	N/A
57	6/18/92	N/A	7.1	N/A
58	10/30/89	<0.3	10.5	<0.1
58	5/22/90	N/A	9.7	N/A
58	10/30/90	N/A	9.7	N/A
58	5/22/91	N/A	9.8	N/A
58	9/30/91	N/A	8.8	N/A
58	6/18/92	N/A	9.8	N/A
59	10/30/89	<0.3	0.7	<0.1
59	5/22/90	<0.3	1.3	<0.1
59	10/30/90	N/A	1.5	N/A
59	5/22/91	N/A	0.4	N/A
59	9/30/91	N/A	.7	N/A
59	6/18/92	N/A	1.8	N/A
60	10/30/89	<0.3	4.3	<0.1
60	5/22/90	<0.3	6.2	<0.1
60	10/30/90	N/A	5.9	N/A
60	5/22/91	N/A	6.1	N/A
60	9/30/91	N/A	6.1	N/A
60	6/18/92	N/A	7.7	N/A
61	10/30/89	<0.3	8.0	<0.1
61	5/22/90	<0.3	6.5	<0.1
61	7/10/90	N/A	7.7	N/A
61	10/30/90	N/A	5.5	N/A
61	9/30/91	N/A	8.0	N/A
61	6/18/92	N/A	8.9	N/A
62	10/30/89	<0.3	<0.1	<0.1
62	5/22/90	<0.3	1.4	<0.1
62	10/30/90	N/A	<0.2	N/A
62	5/22/91	N/A	2.0	N/A
62	9/30/91	N/A	.3	N/A
62	6/18/92	N/A	2.2	N/A

WELL I.D. #	DATE	NH4-N(MG/L)	NO3+NO2-N(MG/L)	NO2-N(MG/L)
63	10/30/89	<0.3	9.5	<0.1
63	5/22/90	N/A	7.2	N/A
63	10/30/90	N/A	8.7	N/A
63	5/22/91	N/A	9.0	N/A
63	9/30/91	N/A	7.0	N/A
63	6/18/92	N/A	8.5	N/A
64	10/30/89	<0.3	7.5	<0.1
64	5/22/90	N/A	13.5	N/A
64	10/30/90	N/A	N/A	N/A
64	5/22/91	N/A	6.9	N/A
64	9/30/91	N/A	6.4	N/A
64	6/18/92	N/A	6.3	N/A
65	10/30/89	<0.3	2.2	<0.1
65	5/22/90	<0.3	3.9	<0.1
65	10/30/90	N/A	3.4	N/A
65	5/22/91	N/A	3.7	N/A
65	9/30/91	N/A	3.4	N/A
65	6/18/92	N/A	4.4	N/A
66	10/30/89	<0.3	0.3	<0.1
66	10/30/90	N/A	N/A	N/A
66	5/22/91	N/A	5.7	N/A
66	9/30/91	N/A	<.2	N/A
67	5/22/90	<0.3	13.5	<0.1
67	10/30/90	N/A	0.3	N/A
68	5/22/90	<0.3	7.1	<0.1
68	10/30/90	N/A	<0.2	N/A
68	9/30/91	N/A	4.7	N/A
69	5/22/90	<0.3	3.4	<0.1
69	10/30/90	N/A	6.1	N/A
69	5/22/91	N/A	6.9	N/A
69	9/30/91	N/A	6.3	N/A
69	6/18/92	N/A	7.0	N/A
70	5/22/90	<0.3	2.7	<0.1
70	10/30/90	N/A	1.7	N/A
70	5/22/91	N/A	0.3	N/A
70	9/30/91	N/A	.9	N/A
71	5/22/90	<0.3	<0.1	<0.1
71	10/30/90	N/A	6.9	N/A
71	5/22/91	N/A	11.0	N/A
71	9/30/91	N/A	8.1	N/A
71	6/18/92	N/A	8.2	N/A
72	5/22/90	<0.3	10.0	<0.1
72	10/30/90	N/A	<0.2	N/A
72	5/22/91	N/A	0.2	N/A
72	9/30/91	N/A	<.2	N/A
72	6/18/92	N/A	0.2	N/A
73	5/22/90	<0.3	<0.1	<0.1
73	10/30/90	N/A	<0.2	N/A
74	5/22/90	<0.3	10.0	<0.1
74	10/30/90	N/A	<0.2	N/A
75	5/22/90	<0.3	<0.1	<0.1
75	10/30/90	N/A	7.3	N/A

WELL I.D. #	DATE	NH4-N(MG/L)	NO3+NO2-N(MG/L)	NO2-N(MG/L)
75	5/22/91	N/A	5.8	N/A
75	9/30/91	N/A	5.5	N/A
76	5/22/90	<0.3	<0.1	<0.1
76	10/30/90	N/A	3.7	N/A
76	5/22/91	N/A	4.1	N/A
76	9/30/91	N/A	4.0	N/A
76	6/18/92	N/A	3.1	N/A
77	5/22/90	<0.3	<0.1	<0.1
77	10/30/90	N/A	3.8	N/A
77	5/22/91	N/A	3.8	N/A
77	9/30/91	N/A	3.7	N/A
77	6/18/92	N/A	4.4	N/A
78	5/22/90	<0.3	5.0	<0.1
78	10/30/90	N/A	8.9	N/A
78	5/22/91	N/A	9.6	N/A
78	9/30/91	N/A	8.1	N/A
79	5/22/90	<0.3	4.0	<0.1
79	10/30/90	N/A	9.6	N/A
79	5/22/91	N/A	10.0	N/A
79	9/30/91	N/A	6.3	N/A
79	6/18/92	N/A	4.6	N/A
80	5/22/90	<0.3	3.4	<0.1
80	10/30/90	N/A	8.1	N/A
80	5/22/91	N/A	7.5	N/A
81	7/10/90	N/A	4.9	N/A
81	8/30/90	N/A	<0.2	N/A
81	5/22/91	N/A	5.6	N/A
82	7/10/90	N/A	2.6	N/A
82	8/30/90	N/A	2.0	N/A
82	5/22/91	N/A	1.6	N/A
82	7/31/91	N/A	1.5	N/A
83	7/10/90	N/A	3.8	N/A
83	8/30/90	N/A	1.1	N/A
83	5/22/91	N/A	14	N/A
83	7/31/91	N/A	3.9	N/A
84	7/10/90	N/A	1.8	N/A
84	8/30/90	N/A	7.8	N/A
84	5/22/91	N/A	0.5	N/A
84	7/31/91	N/A	0.2	N/A
85	7/10/90	N/A	1.1	N/A
85	8/30/90	N/A	1.8	N/A
86	7/10/90	N/A	8.9	N/A
86	8/30/90	N/A	12.3	N/A
87	7/10/90	N/A	9.1	N/A
87	8/30/90	N/A	N/A	N/A
87	7/31/91	N/A	0.2	N/A
88	7/10/90	N/A	5.9	N/A
88	8/30/90	N/A	5.6	N/A
88	7/31/91	N/A	4.9	N/A
89	7/10/90	N/A	7.7	N/A
89	8/30/90	N/A	8.8	N/A
89	7/31/91	N/A	6.9	N/A

WELL I.D. #	DATE	NH4-N(MG/L)	NO3+NO2-N(MG/L)	NO2-N(MG/L)
90	7/10/90	N/A	6.9	N/A
90	8/30/90	N/A	8.9	N/A
90	7/31/91	N/A	6.2	N/A
91	7/10/90	N/A	9.1	N/A
91	8/30/90	N/A	N/A	N/A
91	7/31/91	N/A	11.0	N/A
92	7/10/90	N/A	2.4	N/A
92	8/30/90	N/A	2.9	N/A
92	7/31/91	N/A	2.7	N/A
93	7/10/90	N/A	2.5	N/A
93	8/30/90	N/A	3.9	N/A
93	7/31/91	N/A	3.1	N/A
94	7/10/90	N/A	7.9	N/A
94	8/30/90	N/A	7.8	N/A
94	7/31/91	N/A	8.4	N/A
95	7/10/90	N/A	6.6	N/A
95	8/30/90	N/A	0.25	N/A
95	7/31/91	N/A	0.2	N/A
96	7/10/90	N/A	4.1	N/A
96	8/30/90	N/A	N/A	N/A
96	7/31/91	N/A	4.8	N/A
97	7/10/90	N/A	5.4	N/A
97	8/30/90	N/A	10.5	N/A
97	7/31/91	N/A	5.1	N/A
98	7/10/90	N/A	2.4	N/A
98	8/30/90	N/A	2.1	N/A
99	7/10/90	N/A	7.4	N/A
99	8/30/90	N/A	.67	N/A
99	7/31/91	N/A	5.8	N/A
100	7/10/90	N/A	23.1	N/A
100	8/30/90	N/A	10.3	N/A
100	7/31/91	N/A	12.0	N/A
101	7/10/90	N/A	6.2	N/A
101	8/30/90	N/A	8.6	N/A
101	7/31/91	N/A	7.3	N/A
102	7/10/90	N/A	8.7	N/A
102	8/30/90	N/A	9.5	N/A
103	7/10/90	N/A	9.1	N/A
103	8/30/90	N/A	12.0	N/A
103	5/22/91	N/A	21	N/A
103	7/31/91	N/A	6.0	N/A
104	7/10/90	N/A	14.3	N/A
104	8/30/90	N/A	16.0	N/A
104	7/31/91	N/A	13.0	N/A
105	7/10/90	N/A	0.1	N/A
105	8/30/90	N/A	7.3	N/A
105	7/31/91	N/A	6.1	N/A
106	7/10/90	N/A	6.8	N/A
106	8/30/90	N/A	6.8	N/A
107	7/10/90	N/A	5.8	N/A
107	8/30/90	N/A	5.5	N/A
107	7/31/91	N/A	4.6	N/A

WELL I.D. #	DATE	NH4-N(MG/L)	NO3+NO2-N(MG/L)	NO2-N(MG/L)
110	5/22/91	N/A	8.4	N/A
110	9/30/91	N/A	6.9	N/A
110	6/18/92	N/A	8.1	N/A
112	5/22/91	N/A	14.0	N/A
112	9/30/91	N/A	14.0	N/A
112	6/18/92	N/A	14.0	N/A
113	5/22/91	N/A	10.0	N/A
114	5/22/91	N/A	8.5	N/A
115	5/22/91	N/A	4.4	N/A
115	9/30/91	N/A	6.4	N/A
115	6/18/92	N/A	4.1	N/A
116	5/22/91	N/A	15.0	N/A
116	9/30/91	N/A	12.0	N/A
116	6/18/92	N/A	16.0	N/A
117	5/22/91	N/A	4.0	N/A
117	9/30/91	N/A	3.0	N/A
117	6/18/92	N/A	3.2	N/A
119	5/22/91	N/A	1.0	N/A
119	9/30/91	N/A	.6	N/A
119	6/18/92	N/A	1.7	N/A