EVALUATION OF WATER SAMPLE SITES FOR POSSIBLE NITRATE CONTAMINATION SOURCES

Arkansas Department of Pollution Control & Ecology
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ABSTRACT

The Department of Pollution Control & Ecology in conjunction with the University of Arkansas Cooperative Extension Service conducted site evaluations at 6 sites in Washington County, Arkansas. The purpose of the evaluations was to investigate potential sources of nitrate contamination of sites at which previous sampling had demonstrated high concentrations of nitrate (>7 mg/L as NO_3-N).

Results of the site evaluations demonstrated that the main sources of pollution include septic tanks in close proximity to the wellhead, application of chicken litter to onsite pastureland, presence of abandoned or in-use chicken houses, and ranging of beef cattle. All sources of contamination appear to have been local to each site based on hydrologic separation from other sources and/or lack of contamination in nearby wells within the same strata and at the same or similar depth.

The study also demonstrated that high concentrations of inorganic constituents such as chloride, sodium, potassium, sulfate, and total dissolved solids can result from poor quality background waters rather than anthropogenic sources.

INTRODUCTION

BACKGROUND

The 106 Groundwater FY92 budget submitted to the EPA on March 26, 1992 contained a provision for resampling of water wells in southwestern and northwestern Arkansas that were found contaminated above SDWA standards for nitrate. The primary intent of the sampling episode was to identify possible sources of the high nitrate concentrations in the wells.

The initial approach to the project involved a review of all previous investigations concerning nitrate contamination in Arkansas in addition to interviews with other agencies and organizations conducting nitrate studies. During an interview with the University of Arkansas Cooperative Extension Service (CES) concerning an extensive nitrate data base produced by the CES from 1989 to 1991, it was learned that CES was proposing the same type of resampling program as defined in the ADPC&E proposal to the EPA. In subsequent discussions with the CES concerning the need to avoid duplication of effort and the benefits to gained through cooperation between the agencies, it was decided that the ADPC&E geologist would assist in the 1992 study as proposed by the CES.

The reasons for assisting the CES in their proposed study were as follows;

1) The study was located in Washington County; a county of special interest to the ADPC&E because of its high concentration of poultry operations and a previous data base obtained by the ADPC&E demonstrating wells with high concentrations of nitrate in the county.

2) A cooperative effort between the two agencies directly reflected on EPA policies concerning a comprehensive and cooperative effort toward ground-water protection on a statewide basis.

3) A cooperative effort avoided needless duplication of effort and information.

4) A combined effort brought together increased resources and a diversity of disciplines that would not be available to either study as an individual effort.

5) The basic format and activities outline had been written for the CES study.

After a series of meetings and conversations with members of the Little Rock Branch of the CES, it was decided that the ADPC&E geologist would accompany CES staff on an evaluation of eight sites in Washington County during the week of January 20, 1992. The objective of the geologist was to identify and/or verify the onsite geology, subsurface hydrology and background water quality for the aquifer penetrated by the individual wells. A report of the same was to be submitted to the CES following the site tour. Although eight sites were visited during the evaluation, only six of these sites were evaluated according to the draft procedures because of time constraints.

ACTIVITIES

The objectives of the CES study were similar in scope to the objectives of the ADPC&E and are as follows (CES, 1992c):

1) Develop an onsite procedure for determining possible sources of nitrate contamination.

2) Provide users of high nitrate waters with risk information and options.

3) Publish site evaluation procedures and make them available to agencies involved in water quality.

In order to accomplish these objectives, a draft set of procedures was developed for the initial site evaluations with the intent of upgrading as experience was gained during the project. A draft of the evaluation procedures is included in Appendix I. Basically, each site evaluation included a visual inspection of the local topography; location of all possible sources of nitrate contamination; measurement of the elevations, compass bearings and distance of sources relative to the wellhead; observation of soils and geology; and the extraction of water samples for water quality analysis.

SOILS

Soil types vary so widely in slope, degree of erosion, and number and size of stones across Washington County, that it is difficult to make a general statement about any typical soil type in a large region of the county. However, some general statements can be made about the differences within the physiographic regions of the county.

The southern two-thirds of Washington County is within the Boston Mountains physiographic region, which is represented by steep, stony mountainsides covered with hardwoods. The Boston Mountains are formed of sandstones, siltstones and shale, and the soils represent eroded sections of alluvium derived from these rock types.

The northern third of Washington County is within the Springfield Plateau physiographic region, which is underlain almost entirely by the Boone Formation. The region consists of broad areas of deep, nearly level to gently sloping soils dissected by steep, V-shaped draws (USDA, 1969). The soils formed in this region are typically loamy to stiff, red clays with varying amounts of chert pebbles. Specific soil types for each site are listed in each site evaluation.

GEOLOGY

The rocks represented in Washington County at each of the sites include only a portion of the total column represented in northwest Arkansas. Table 1 lists the strata represented at the evaluation sites in Washington County.

Most of these rock formations do not approach the maximum thickness in the area of study. In the site evaluation areas for the present study, the Boone is closer to 250 - 300 feet thick and the Batesville, where present, is closer to 20 feet thick (Caplan, 1957).

Table 1. Strata encountered at evaluation sites

AGE	FORMATION	MAXIMUM THICKNESS (ft)
Pennsylvanian	Bloyd Shale	350
	Hale Formation	250
	Prairie grove Mbr.	
	Cane Hill Mbr.	
Mississippian	Pitkin Limestone	200
	Fayetteville Shale	350
	Batesville Sandstone	75
	Boone Formation	400

GROUND-WATER RESOURCES

All of the wells used in the present study receive water from either the Boone Formation or the Fayetteville Shale/Batesville Sandstone unit. Both units act as low-yield aquifers; the conductivities of which are dependent on the degree of secondary porosity formed from the fractures and solution channels within the units. The Fayetteville/Batesville unit yields are expected to be on the order of 2-5 gpm; however, along highly fractured zones and bedding planes, yields of up to 25 gpm may be obtained. The Boone Formation, especially where exposed, historically has been widely used as a source of shallow domestic water supply. The yields are similar to the Fayetteville/Batesville aquifer zone; 2-5 gpm are the average yield with greater yield (25+ gpm) occurring where large fractures and solution channels are present (Lamonds, 1972).

Because the wells in the area of study receive water from these aquifer sources, it is useful to compare the chemistry of waters in each of these units. Table 2 lists an average of published water quality analyses from the Boone Formation in Washington County and one analysis from a well drilled into the Fayetteville. Although a complete water quality analysis was not performed on the water samples taken from the wells at the sites included in this study, an inspection of some of the parameters might indicate the influence of a certain rock type on the water quality. This is a useful procedure in analyzing the impact from anthropogenic sources versus natural background water quality.

Because metals were not analyzed in the present study, they are not included in Table 2. It should be noted that iron, manganese, and other metals would be significantly higher in the Fayetteville Shale than in the Boone Formation. A review of Table 2 suggests that in cases where sodium, potassium, sulfate, and chloride are elevated in analysis of any one water sample, the influence of the shale (where present at the site) might possibly be the cause rather than anthropogenic sources.

Table 2. Average analysis of waters from Boone Formation versus Fayetteville Shale.

PARAMETER	BOONE FORMATION	FAYETTEVILLE SHALE
pH	7.2	6.8
Conductivity, μS/cm	375	1000+
Dissolved Solids,mg/L	-----	960
Alkalinity, mg/L	183	-----
Calcium, mg/L	75	88
Magnesium, mg/L	3.0	28
Sodium, mg/L	4.6	88
Potassium, mg/L	0.95	3.4
Chloride, mg/L	10.3	50
Sulfate, mg/L	2.7	50
Bicarbonate, mg/L	285	350

SOURCES OF NITRATE CONTAMINATION

Although there are many chemical and biological processes in nature that transfer nitrogen to and from the lithosphere, atmosphere, hydrosphere, and biosphere, these processes combined will normally not raise the concentration in water beyond a few tenths of a mg/L. Concentrations in ground water above 1-2 mg/L should be suspected of being influenced by anthropogenic sources. Sources of nitrate contamination in the wells evaluated for the present study included onsite septic systems, abandoned and ongoing confined chicken operations, application of chicken litter to onsite pastureland, and free range beef cattle.

Septic systems are extensively used in all rural parts of Arkansas and most all Washington County rural residents utilize individual septic systems. Nitrogen in septic tank effluent is present mainly in the reduced forms of organic (20 - 25%) and ammonium-nitrogen (75 - 80%). Although the total nitrogen in effluent can be as high as 100 mg/L, the average amount is generally in the range of 35 to 45 mg/L. Through nitrification most all of the nitrogen is converted to nitrate, which passes easily through the soil with recharge water. Biological and chemical denitrification is the only mechanism in the soil which can significantly reduce the amount of nitrate in the percolating effluent, although favorable conditions must exist for this to occur. Therefore, the only mechanism which reduces the concentration of nitrate in most cases is dilution by recharge water or higher quality ground water (Hantzsche and Finnemore, 1991). Robertson and others (1989) found 50% of the source concentration of nitrate from a septic system occurring in a plume for a distance of more than 100 meters. The study demonstrated that a long plume of impacted ground water can occur in aquifers with low dispersive capacities. The need for effective restrictions on development density of housing units using septic systems is evident according to the above studies.

Poultry is a large industry in Washington County and the associated poultry litter is a valuable source of fertilizer for use on agricultural lands. In 1988, Washington County produced over 113.6 million broilers, which in turn produced 113,600 tons of poultry litter (Steele and McCalister, 1990). A summary of 60 broiler litter samples analyzed by the CES (1991a) found an average of 51 lbs of total nitrogen for each ton of litter. Because application rates will vary according to the amount of available pastureland, instances can occur where the amount of applied litter exceeds the capacity of the soil and plants to utilize the nitrogen.

Scott and others (1992), studying the fate of nitrogen on fields which had litter applied at rates of 4, 8, 16, and 40 tons/acre, found that volatilization, runoff, and plant uptake accounted for only 17 - 52% of the applied nitrogen. Soil storage, additional plant uptake and/or volatilization, and denitrification will normally account for some additional losses; however, it is apparent that large amounts of nitrogen (mainly in the form of nitrate) can migrate with recharging surface water into the zone of saturation. The CES (1992a) found NO_3-N concentrations in a soil profile from an abandoned chicken house (only the pad remained) ranging from 500 to 650 mg/L to a depth of 3 feet. This situation demonstrates that in addition to land application, chicken pads can serve as a source for gross contamination of soils and, ultimately, a source of ground-water contamination.

Grazing beef cattle were also noted at some of the sites and represent a historical agricultural practice in Washington County. Although cattle manure is a source of nitrate, the potential impact from the manure would be expected to be much lower than the above-mentioned sources. This assumption is based on the fact that the animals are not confined and the numbers are limited by the available pastureland. Manure is distributed in a fairly uniform manner as dictated by grazing practices, and the increased surface area associated with each pad leads to increased volatilization and plant utilization. In cases where the soil is thin and/or permeable, recharging surface water can carry nitrogen to the saturated zone. However, because of dilution and assimilation within the soil zone, the concentration would be significantly lowered. It is also interesting to note that the nitrogen concentration in chicken waste is 2 to 3 times higher than in beef manure. Table 3 shows a breakdown of waste for chicken versus cattle. The important factor when evaluating impact from animals is the density of animals per unit of land. As the density of cattle approaches confined conditions (such as dairy operations), then proper waste management becomes increasingly important.

Table 3. Waste characterization - cattle vs. chicken (adapted from USDA, 1992)

NUTRIENT	UNIT	CHICKENS		CATTLE		
		LAYERS	BROILERS	FEEDER 750+ lbs	FEEDER 450-750 LBS	COW
Nitrogen	lb/d/1000#	0.83	1.10	0.31	0.30	0.33
Phosphorus	"	0.31	0.34	0.11	0.10	0.12
Potassium	"	0.34	0.46	0.24	0.20	0.26

lbs/d/1000# = pounds per day per 1000 pounds of animal

SITE EVALUATION SUMMARIES

This section summarizes the findings at each of the evaluation sites. Figure 1 shows the general location within the county of the sites described in the following sections. Of the six sites evaluated for the present study, three of the sites housed a well which penetrated the Boone Formation, two sites having wells penetrating the Fayetteville Shale, and one in which the source was a spring which emanated from the contact between the Pitkin Formation and the overlying Hale Formation. The sites are listed by an identification number which contains the prefix WAS (WAShington County) followed by a number.

WAS - 1

This site is 1.5 miles northwest of Prairie Grove, Arkansas (see figure 1). The well is near the residence about 1/2 mile east of the Muddy Fork Creek, and one mile northeast of the confluence of a north-south intermittent stream with an east-west tributary of the Muddy Fork. Ground surface in the vicinity of the well is between 1120 - 1130 feet and slopes gently with steepest descent northeast to southwest. Average slope over a horizontal distance of 800 to 1200 feet is 1.5 to 2.5%.

In the region surrounding Prairie Grove, both the Boone and Fayetteville sections are exposed at the surface. A major fault lies immediately south of the site, trending in an approximate east-west direction. On the north side of the fault, the Fayetteville Shale is downthrown against the southern-exposed Boone Formation. Because the fault intersects the highway at Living Water Springs, it is possible that this fault drains much of the ground water in the area. Based on this supposition and the fact that the land gently slopes toward the area of the fault, it is likely that ground water flows in a southerly direction across the site towards the fault. Because the well is at an approximate elevation of 1120+ feet and the Boone is exposed at an elevation of <1120 feet in a nearby creek (2 miles north of Prairie Grove), the Fayetteville is obviously thin across the site and water is most likely derived from the Boone Formation. Appendix 2 contains geologic quadrangle sheets for each of the sites. The sheets are listed in the order of the site evaluations for easy reference.

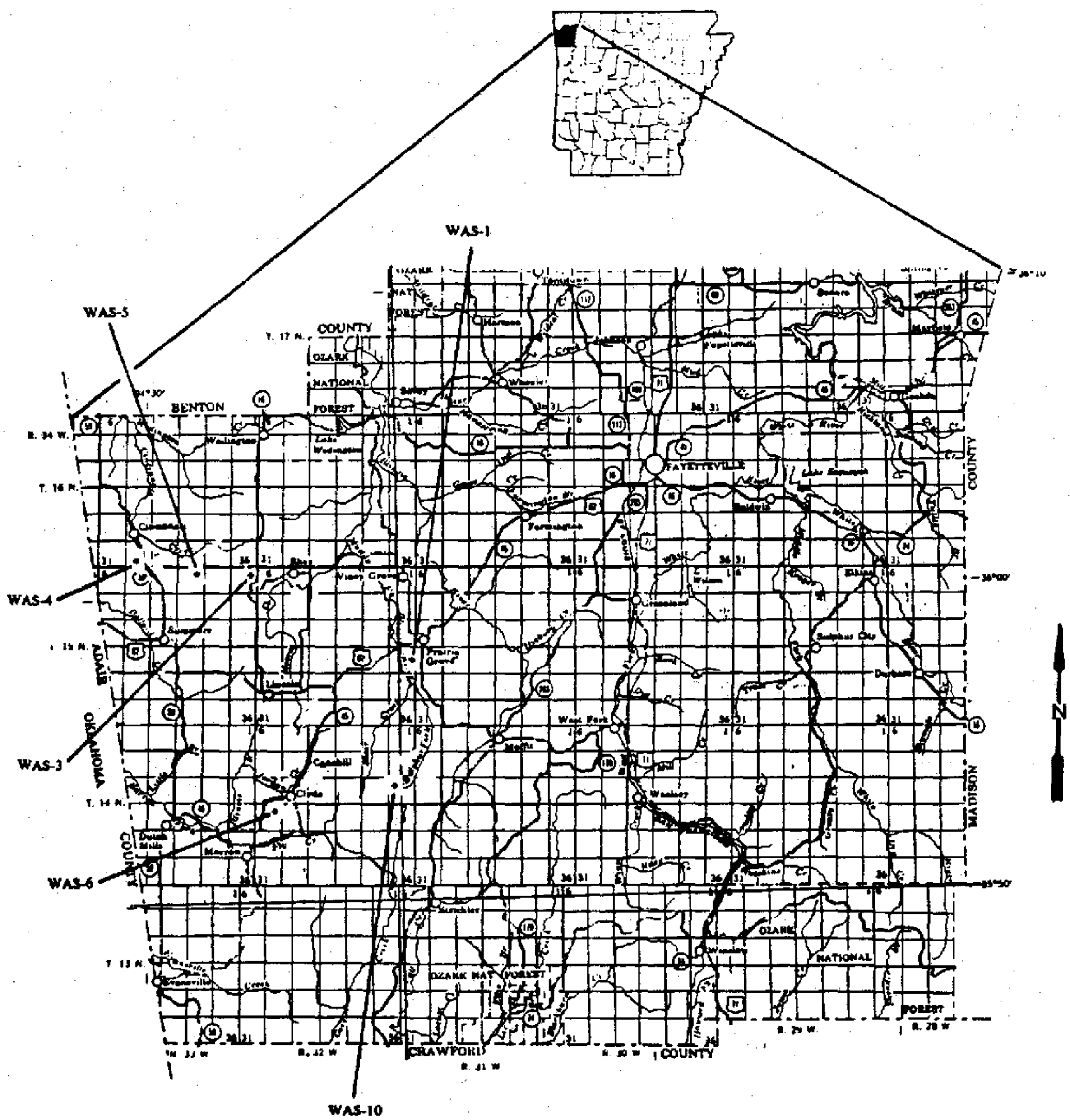

Figure 1. General county location map of sites

The soil at the site substantiates the fact that a thin veneer of Fayetteville overlies the Boone in the site area. The soil is a Cherokee silt loam, which is derived from acid sandstone, siltstone, and shale. Its subsoil is high in clay and severely restricts water movement at depths of two to five feet below the surface. The puddled water and soil samples observed to a depth of three feet and more appeared to confirm the report description.

Nearby sources of nitrate included a septic tank, an old outhouse (no longer in use), two poultry houses (one operational and one that was not operational), and 35 head of cattle. The septic tank is south of the residence about 200 feet southeast and downslope from the well. The septic effluent passes through buried lines into a grassed filter field downslope from the tank. The chicken houses are located 50 feet west and northwest of the wellhouse. Unprotected poultry litter (estimated 15 tons) was winrowed 60 feet upslope to the northwest of the wellhouse (Figure 2).

The water well is about 30 feet deep with water approximately 10-12 feet below the surface. Table 4 lists the chemical analyses from the sites evaluated for the present study. Samples taken in June, 1989, yielded 17 mg/L NO_3-N; a sample taken in January, 1990 showed 7 mg/L NO_3-N; and the sample taken for the present study (January, 1992) contained 21 mg/L NO_3-N. Sodium, sulfate and chloride concentrations were also in high concentration in the well water. These parameters might possibly be derived from the overlying shale (see Table 2) rather than from a surface contamination source. Because the septic tank is topographically downgradient from the well house and most likely hydraulically downgradient based on an assumed ground-water flow direction, the chicken litter would present the most severe nitrate contamination threat to the water quality.

Although the soils on the site exhibit low permeabilities, they are capable of transmitting large amounts of water over time to the underlying aquifer. For instance, a soil having a permeability of 1×10^{-6} cm/sec is able to transmit 990 gal/day/ft of water. However, it should be noted that chemical analysis of soil profiles taken at the site to a depth of over 4 feet showed no excess of either nitrogen or phosphorus. Water analysis of a well directly across the road from the WAS-1 site had 0.0 mg/L NO_3-N on three separate occasions. This fact would

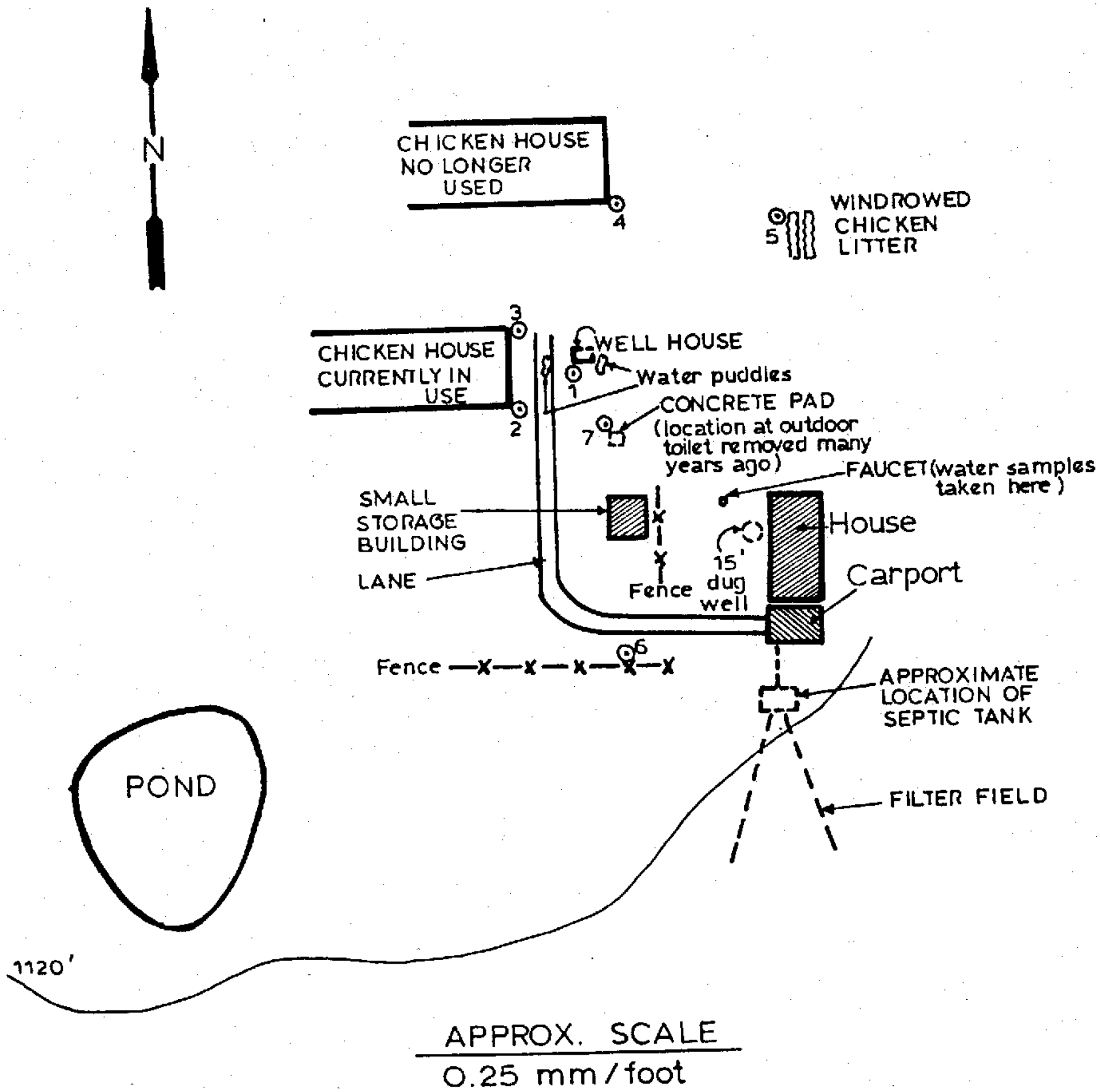

Figure 2. Site map for WAS-1 (CES, 1992b)

Table 4. Water quality analyses of site samples.

	WAS-1	WAS-3 DW Well	WAS-4	WAS-5 Well Spr.	WAS-6	WAS-10
Cond.	900	250 525	496	750 275	480	590
pH	7.2	7.3 4.4	6.9	7.8 7.4	7.8	8.4
Alk.	114	18 23	---	159 45	114	159
Hardness	229	57 57	---	218 80	149	46
NO_3	21.7	7.5 40	4	16 3.1	7.4	0.9
Na	2.9	9.9 23	---	14 3.9	2.9	91
K	<1	5.1 38	---	3.5 <1	<1	2.0
Cl	60.6	30 182	---	60 5.3	30	59
SO_4	88.6	5.3 11	---	27 22	2.8	54
HCO_3	139	22 28	---	194 55	139	194

Cond. = Conductivity, μS/cm
Alk. = Alkalinity, mg/L (as $CaCO_3$)
Hardness, mg/L (as $CaCO_3$)
NO_3 = Nitrate, mg/L
Na = Sodium, mg/L
K = Potassium, mg/L
Cl = Chloride, mg/L
SO_4 = Sulfate, mg/L
HCO_3 = Bicarbonate, mg/L (as $CaCO_3$)

DW = Dug Well not in use
Spr. = Spring
Well = Domestic well in use

strongly suggest that the source for nitrate is local and most likely the chicken litter or another on-site source. Because the well is old, poorly constructed and has inadequate casing, surface sources of contamination might possibly enter the well directly through the well housing.

WAS-3

This site is located northwest of Lincoln Lake and directly west of Rhea, Arkansas (see Figure 1). It is near the upper extreme of a ridge that descends steeply to the southeast toward the lake. The farm site itself, however, slopes downward to the north and west. Average slope is about 5% over 175 to 350 feet.

The elevation of the well is between 1540 and 1550 feet. Because the top of the Boone occurs at an elevation of approximately 1260 feet, a shallow well would derive water entirely from the Fayetteville/Batesville unit. A major fault trends northeast-southwest at the base of ridge immediately northwest of Lincoln Lake. The Fayetteville/Batesville is downthrown on the south side of the fault and rests against the Boone to the north of the fault. The ridge acts as a ground-water divide with water flowing northwest and southeast away from the ridge. Although ground water likely flows to the north from the area of the wellhead, sources of nitrate downslope from the well could possible enter the well because of its proximity to the divide, dipping strata, or due to an extended cone of influence.

The soil at this site is Appison silt loam - 3 to 8% slopes. These soils are moderately permeable and are reportedly only 2 - 4 feet thick. Subsoils are loam, clay loam, or silty clay loam, and the lower parts of the subsoil contain 0 - 30% gravel.

The septic tank is on the southwest corner of the house, and both the tank and lines leading away from it are 100 feet downslope from the wellhouse. A grease trap and line is on the southeast corner of the house. About 40 head of cattle are fed on 75 acres of pasture and hay. Two abandoned chicken house pads and an abandoned dead bird disposal pit are located 175 to 350 feet south and upslope from the well (Figure 3).

Two water quality samples were taken at the site; one from the well in use and one from an abandoned dug well behind the residence (marked #5 and #1, respectfully, on Figure 3). The high values for conductivity, sodium, potassium, and chloride

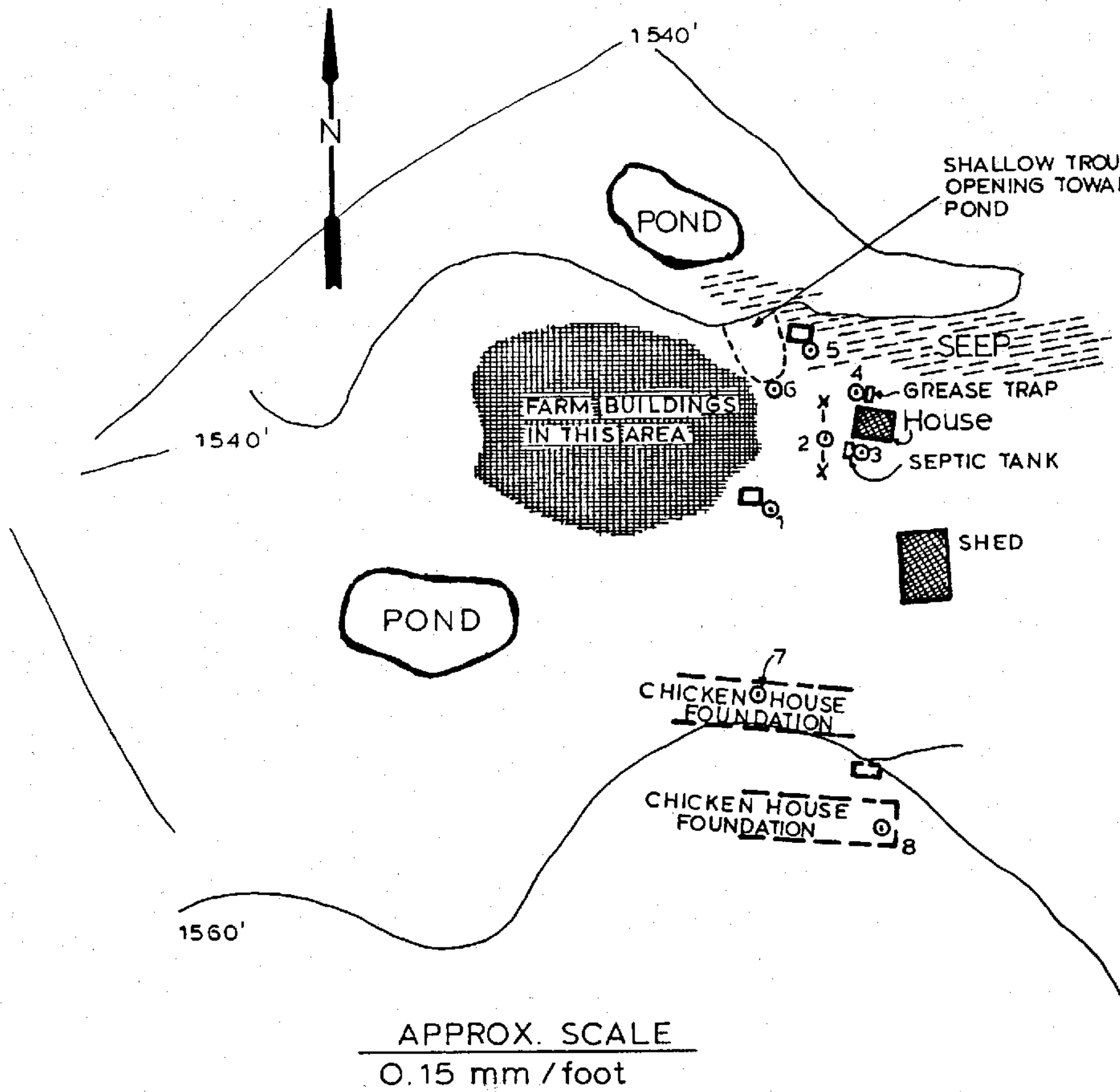

Figure 3. Site map for WAS-3 (from CES, 1992b)

in the domestic well most likely are due to the natural quality of the water within the Fayetteville Shale (Table 4). The low values for the alkalinity and hardness partially explain the low pH of the water. Without sufficient buffering capacity the pH of the water in the Fayetteville Shale can be quite low. The difference in the well water chemistry between the dug well and the well in use is apparently the result of the influence of the ponded grey water from the house and infiltration of rain water runoff. It is unlikely that the dug well water chemistry is representative of water within the Fayetteville Shale. The nitrate concentration of 40 mg/L in the domestic well is representative of a nearby source of gross nitrate contamination. It is apparent from the location that the only sources of contamination are on-site sources. The open chicken pads are certainly one such nearby source. The high nitrate concentration also reflects the inability of the more-permeable soil type in abating surface sources of pollution.

WAS-4

This site is south of Cincinnati in western Washington County (Figure 1). It is in a gently sloping region on the north side of Bell Mountain, and near the upper extreme of a south to north surface drainage way. The well is located in the upper extreme of this trough. Steepest climb away from the well is to the southwest, with average slopes 4 to 5% over 400 to 500 feet. Slopes are steeper to the immediate southwest of the well, and a soil berm was recently constructed to divert surface water around the wellhouse. The residence is also higher in elevation than the well, but not directly upslope from it. The line of steepest descent from the residence intersects the trough axis north and downslope from the well.

The site rests geologically on the Boone Formation, although it is near the contact of the Mississippian Pitkin/Fayetteville/Batesville complex with the Boone. The elevation of the well is approximately 1180 feet and the elevation of the contact near Bell Mountain is approximately 1210 feet. The strong smell of sulfur is indicative of water contribution from the overlying shale. Without a review of the total chemistry, it is difficult to quantify or evaluate the contribution from the shale; however, the pH value is lower than average for the Boone and the conductivity, although within typical ranges of Boone-type water, is somewhat high for such a shallow well in the Boone. Flow across the site is most probably north and northwest towards tributaries draining the site and fault systems north of the site (see Appendix 2).

The soils near the well are mapped as Pickwick silt loam and Baxter silt loam. The soil observed upslope from the wellhouse appeared to match report descriptions of the Pickwick. Both soils tend to reflect and verify the on-site geology. The Pickwick is cited as developing in deeply weathered residuum from siltstone and cherty limestone and in material washed from uplands underlain by sandstone, siltstone, shale, and limestone; which matches the geologic and topographic profile at the site. The Baxter is typical of soils developed in residuum derived from cherty limestone (USDA, 1969). The Pickwick soil is moderately permeable with clay loam or silty clay loam subsoil horizons. It ranges from 3 to 7 feet to bedrock.

The septic tank is on the northeast corner of the residence, about 200 feet northwest and upslope from the wellhouse. However, topography is such that surface and subsurface drainage from the tank area and filter field appear to possibly intersect the trough north and downslope from the well. In the past the farm operated a small dairy. The old milkhouse is less than 100 feet north of the well. At the present date, there are 100 beef cattle grazed on 175 acres of fescue and bermuda pastures. Poultry litter has been applied to the pastures for several years.

The well is a dug well about 100 years old and is 18 to 20 feet deep. The water surface is usually 16 to 18 feet below ground surface. Two earlier water samples from the well, taken in June, 1989, and in December, 1990, both showed 7 mg/L NO_3-N. Although no lab analysis was performed, a field test electrode used during the site visit for this study showed a concentration of 4 mg/L.

WAS-5

This site is east of Cincinnati in western Washington County. The farm is located in the watershed of a northwest flowing tributary of Cincinnati Creek, and is less than 1/2 mile from the creek (Figure 1). The direction of steepest descent is approximately east-west, and the average slope is about 5% over 200 to 250 feet either side of the well. This average slope is a composite of breaks between terraces and more gently sloping areas within terraces. Slopes are more gentle in the immediate vicinity of the well.

Driving down to the Gilbreath site from the Wedington Mountains, one can see well-exposed sections of Fayetteville Shale. The site rests geologically on exposed

Boone at an elevation of approximately 1170 feet. The contact between the Fayetteville/Batesville section and the Boone is at approximately 1270 feet and as such the well should penetrate only the Boone Formation. Limestone was well-exposed in the stream segment near the house and at various locations east of the house in the field. Springs and seeps emanated from the limestone at several places associated with fractures and/or bedding planes. The fresh surfaces of the limestones are representative of the upper Boone and consisted of a dark grey, predominantly bryzoan grain-supported limestone.

The soils nearest the well are mapped Razort loam (well location) and Elsah (stream beds and terraces downslope from the well). Razort loam is a moderately permeable soil with 5" to 12" loamy surface horizon, and loam, silt loam, or clay loam subsurface horizons. Depth to bedrock ranges typically from 5 - 12 feet, although the soil was possibly more shallow at the site as evidenced from the abundance of rock outcropping. The Elsah soils are very rocky, even on the surface.

The septic tank is 83 feet north and upslope from the well. A grease trap for grey water is 52 feet upslope from the well toward the septic tank. A line from the grease trap feeds the septic tank, and a single line from the septic tank carries the effluent to a chert-filled pit 135 feet north of the wellhead. One hundred head of cattle are fed on 300 acres of fescue/bermuda. There is a large swine breeder operation approximately 3/4 mile northeast of his site and 30 to 40 feet higher in elevation. However, Cincinnati Creek passes between the swine facility and the site (Figure 4).

There are two wells in use at the site location. The domestic water supply is from a 60 year old drilled well, which is 115 feet deep, and cased and sealed with an unvented cap. The top of the casing and cap are recessed below ground surface in a concrete-lined cavity with a removable lid. Both the enclosure walls and the outside of the cap were coated with sediment. A second well is approximately 100 feet downslope from the domestic well. The water from this well, used only for livestock, has a strong hydrogen sulfide odor.

There is an old hand-dug well (spring) approximately 1/2 mile east of the residence. The well overflows and feeds a nearby pond. The pond overflow reenters the ground water a short distance downslope toward the residence. Other smaller seeps were noted upgradient from the well. The conductivity of the spring

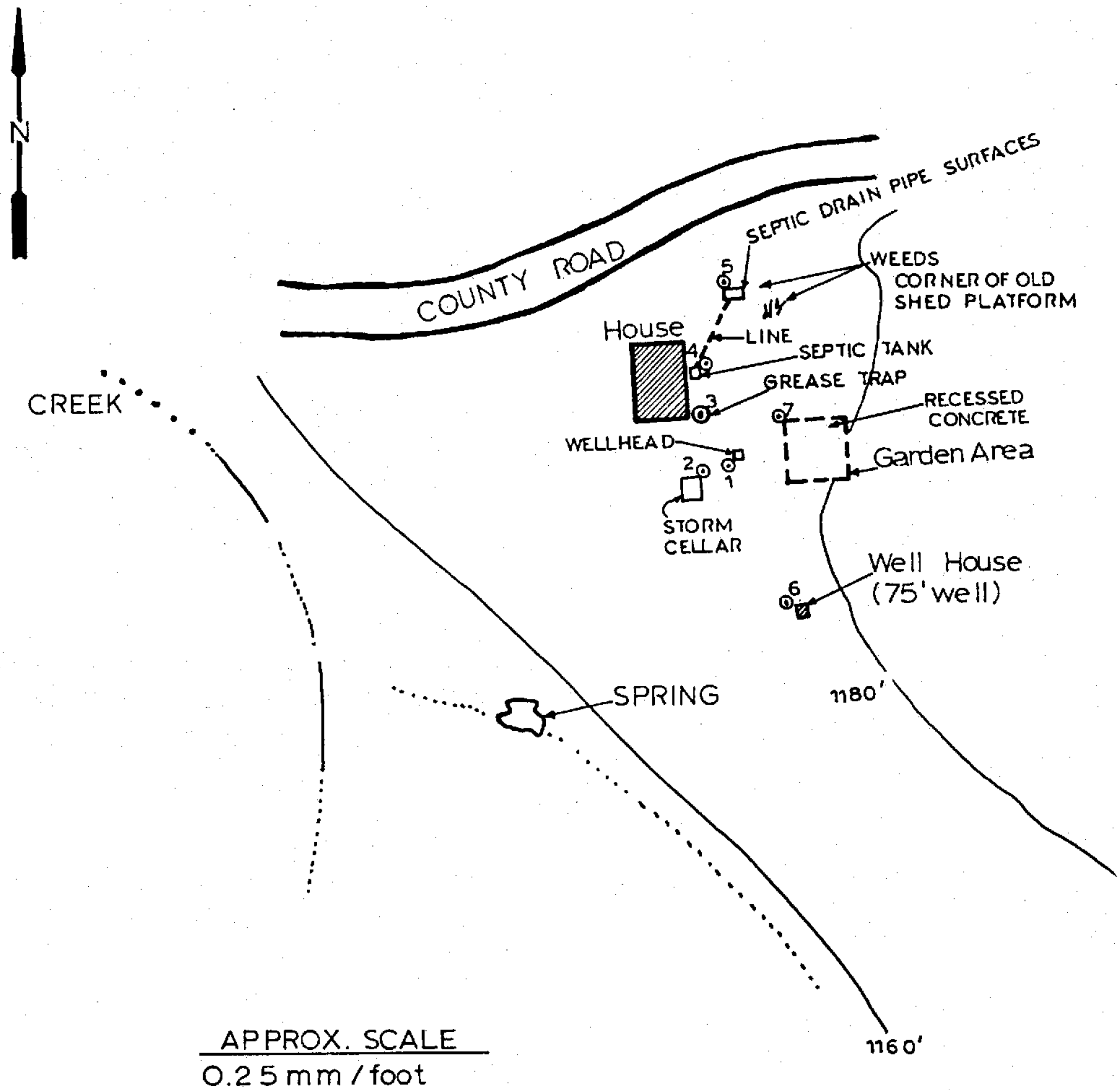

Figure 4. Site map for WAS-5 (from CES, 1992b)

was 222 μS/cm versus 1011 μS/cm for the domestic well. The conductivity of the spring indicates water that has not been in the system for a long period of time and as such has not had the time to dissolve bedrock material. It is most likely a shallow subflow system as opposed to the more regional flow which contributes to the well and is reflected by a high conductivity value. The spring also seemed to flow along bedding planes and exposed surfaces of the Boone and possibly is a local perched system. The moderately high values for chloride, sulfate, sodium, and potassium appear to indicate that the ground water is vertically recharged by the overlying shale into the Boone. The odor of hydrogen sulfide in the old well is typical of dissolution of pyrite nodules within the shale unit.

Water samples taken from the domestic well in June, 1989, and January, 1990, showed NO_3-N concentrations of 16 mg/L and 13 mg/L, respectively. The sample obtained on the site visit showed 17 mg/L. The thin and moderately-permeable, gravelly soils at the site appear inadequate for preventing infiltration of surface sources of pollution. The fact that the septic tank is upgradient from the well and in close proximity to the well strongly suggests that the tank is one major cause of the nitrate contamination in the well.

WAS-6

This site is located southwest of Clyde in west-central Washington County. The farm house and the spring which supplies the house are at elevations between 1360 and 1380 feet, but on opposite sides of a mountain with maximum elevation of 1500+ feet. The horizontal distance separating the spring and house is about 1/2 mile. The slope immediately above the spring averages 25% over a horizontal distance of 250+ feet; the steepest descent which is northwest to southeast. Slopes below (southeast) the spring are gentler, leveling toward a shelf of the mountain side. In this shelf region average slope over a distance of 1/4 mile is about 3%.

The spring at the site forms at the contact between the Pitkin Formation and the overlying Hale Formation (which includes the Prairie Grove and Cane Hill members). Both units were well exposed in the stream segment from which the spring emanates. The hardness, alkalinity, and pH values are reflective of the dissolution of limestone (Table 4). In addition to the influence of the Pitkin limestone, the Prairie Grove is calcareous in nature (calcite-cemented sandstone) and possibly contributes to the concentration of these parameters. The high concentrations of chloride and nitrate certainly represent an anthropogenic form of pollution.

The soil surrounding the spring is mapped Fayetteville stoney, fine sandy loam - 12 to 35% slopes. Description of this soil in the SCS Soil Survey (1969) reflect dissolution of the Prairie Grove; a red soil that developed in residuum derived from massive, soft, calcareous sandstone. Soil in the immediate vicinity of the spring is severely eroded with depths to limestone 0 - 12 inches.

Although no poultry has been produced on the farm since 1989, there are several abandoned chicken houses a few hundred feet from the residence (opposite side of the mountain from the spring). The owner applied poultry litter freely to pasture regions above the spring for several years. Beef cattle are grazed in the open regions a few hundred feet upslope from the spring. Poultry litter is used as a food source for the cattle. Much fresh cow manure was observed in the clearing directly above the spring near rock outcrops (Figure 5).

The spring, as mentioned above, issues from an exposed limestone shelf underneath a metal shed that also covers a shallow cistern. This cistern receives water from the spring and maintains a steady overflow. Except for the roof of the metal shed, the cistern is uncovered. It is equipped with a submerged pump that supplies water through a line extending to the farm house. Water samples taken June, 1989, January, 1990, and December, 1990, had NO_3-N concentrations of 13, 13, and 18 mg/L, respectively. A sample taken on the site visit showed 8 mg/L.

WAS-10

This site is east of Blair Creek near the southern end of Lake Prairie Grove in southern Washington County. Its position at the foot of a mountain (to the southeast) has an elevation of 1220+ feet, while the mountain itself has maximum elevations of 1700+ feet. The site is near the mouth of a draw and tributary of Blair Creek that flows southeast to northwest down the mountainside, so steepest descent at the site follows the sideslope of the draw region, rather than the general southeast to northwest slope of the mountainside. Steepest descent at the site is northeast to southwest, with an average slope of 9% over distances 120 feet either side of the residence. Further up the side of the draw to the northeast, the average slope increases to 20% for 600 to 700 feet. Slopes are more gentle (than 9% indicates) in the yard area.

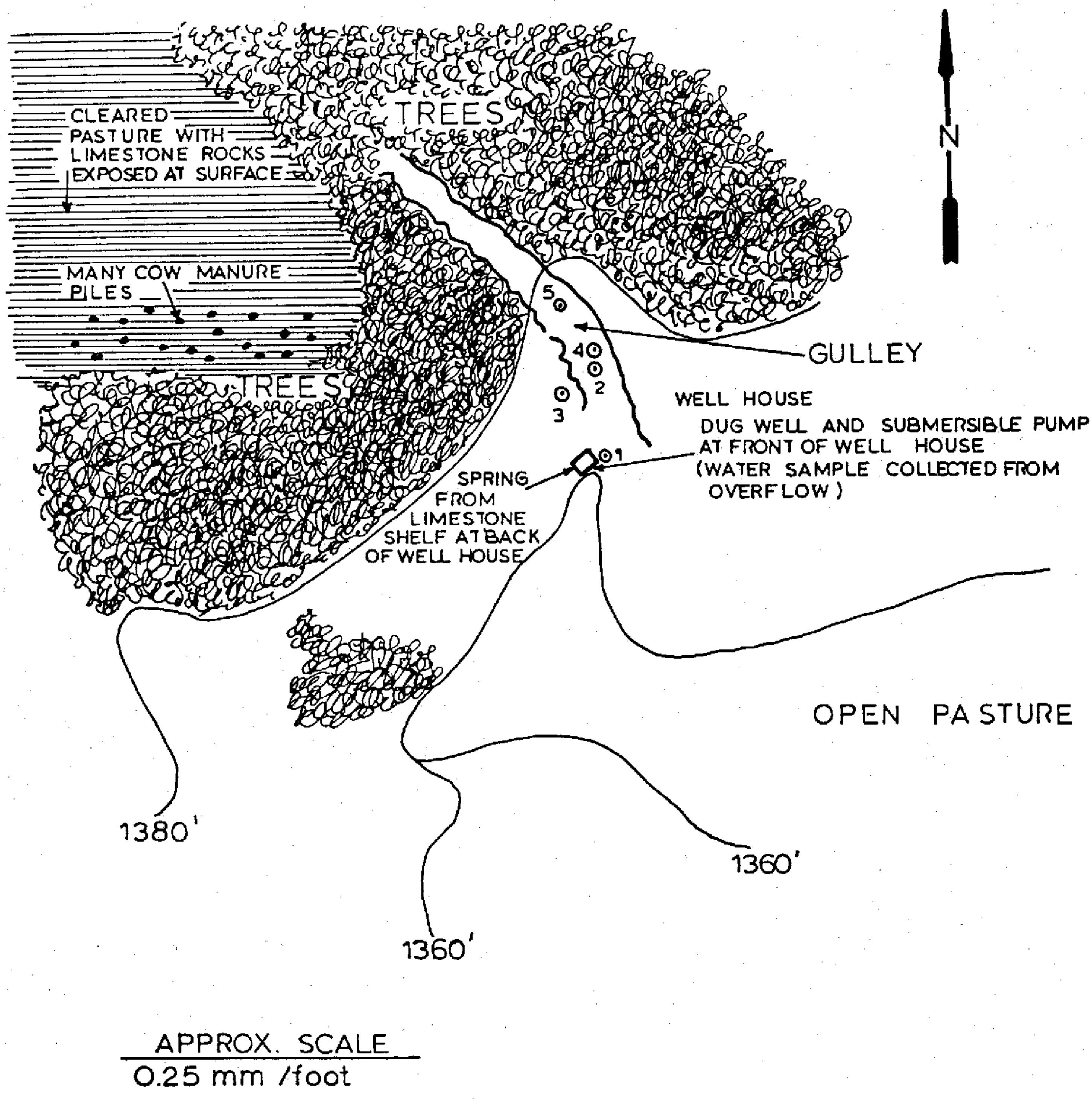

Figure 5. Site map for WAS-6 (from CES, 1992b)

The entire area surrounding the site is underlain by the Pitkin/Fayetteville/Batesville units, except on the hilltops which are represented by the Pennsylvanian-aged Bloyd and Hale Formations. Immediately south of the site is a fault where the upper Pennsylvanian units are downthrown against lower Mississippian strata.

The soils are made of residuum from the above-listed strata. They are mapped as Savannah fine sandy loam, 3 to 8% slopes. The Savannah soil has a sandy loam surface horizon less than 5 inches thick with loam, clay loam, or silt loam subsurface horizons. It has fragipan horizons below 30 inches to a depth of 70+ inches and in many of these soils there is one to two feet thick C horizon of stratified sandy loam and loam materials that contain sandstone fragments. The fragipan would act to retard downward movement of percolating water.

The location of the septic tank was tentatively identified at the southwest corner of the residence, and either septic or grey water effluent was surfacing about 90 feet west and downslope from the wellhouse. The local topography is such that all surface drainage affecting the tank area and filter field appears to be away from the well. There were only a few cattle and one or two horses with temporary confinement and barn area immediately behind the well house (Figure 6).

The drilled well, eleven years old, is of unknown depth. It is cased and in good condition, sealed with a vented cap, and enclosed in a wellhouse. A water sample taken on the site visit showed less than 1 mg/L NO_3-N. Past samples submitted by the well owner had showed high concentrations of nitrate, and subsequent discussions with the owner revealed that the original samples were actually from another source. The high chloride, sodium, sulfate, and moderately high potassium value would indicate that the well derives water from or is strongly influence by the Fayetteville Shale. This is supported by the site geology.

CONCLUSIONS

Investigations at 6 sites in Washington County were evaluated according to a draft set of procedures for identifying sources of nitrate contamination and the elevation of these sources in relation to the wellhead. Of importance to the study were the types and thickness of the soils, the hydrogeology of the area, and the appearance of the well construction. The premise of the investigation was that contaminated surface water either percolates downward through thin and permeable soils to the

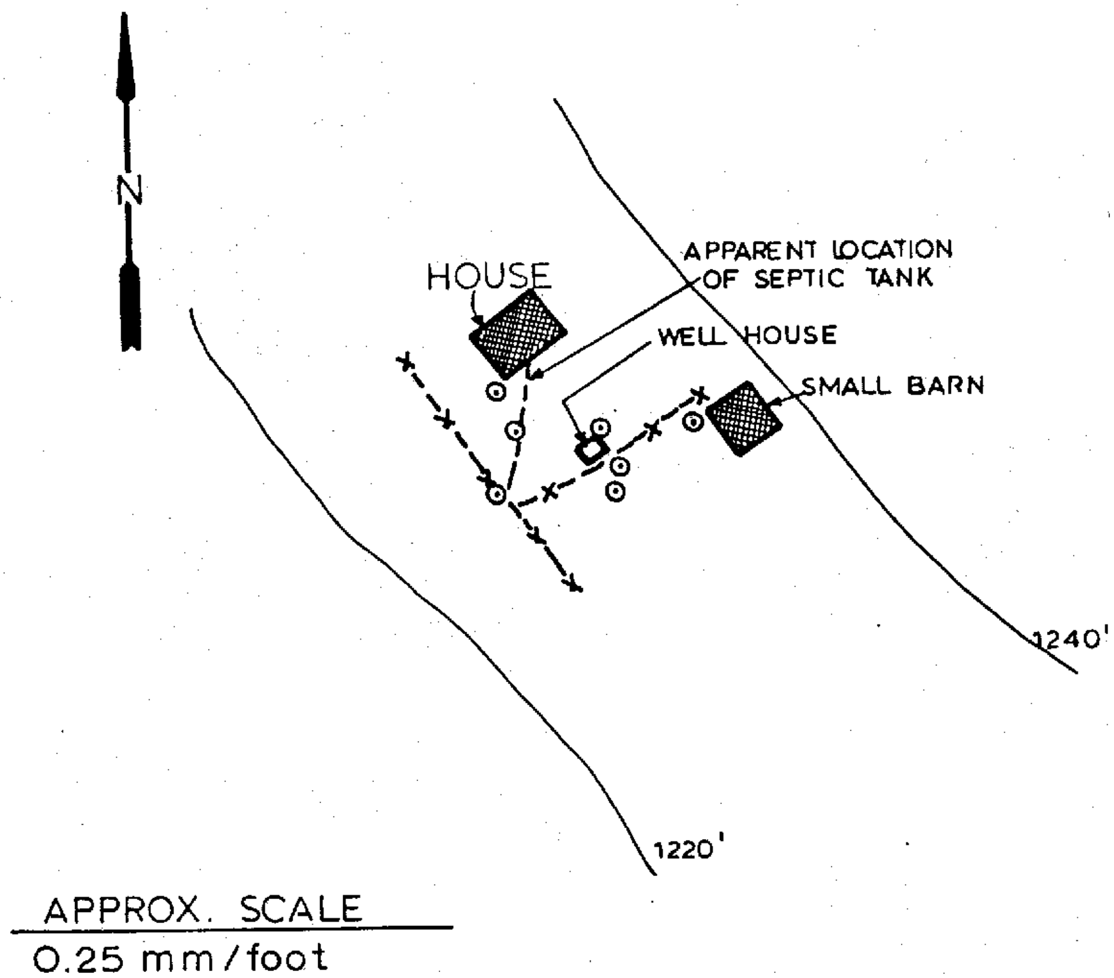

Figure 6. Site map for WAS-10 (from CES, 1992b)

water table or enters the borehole directly through channels next to the well formed from poor construction and/or inadequate or non-existent casing.

Sources of nitrate varied at the sites and included confined and free-range animal operations, septic tank, and use of chicken litter on pastures and fields. In places where the septic tank was close to and upgradient from the wellhead, especially at sites were thin and permeable soils existed, contribution from the septic tank was certainly one major source of contamination. Improper use of chicken litter for fertilizer and confined poultry operations near the household were obvious sources of nitrate contribution to the water quality, especially in cases where the septic systems where downgradient and a safe distance from the wellhead. In order to more accurately define which source is the major contributor to nitrate contamination, it is obvious that dye traces from the septic system together with the installation of monitoring wells to better define the plume will be necessary. However, the procedures served well in qualitatively defining major sources of contamination.

The study also demonstrated that poor quality ground water found in the Fayetteville Shale can be a major contributor of high concentrations of chloride, sodium, potassium, sulfate, and total dissolved solids (represented by conductivity values). A close inspection of the hydrogeology and formations penetrated by each well is necessary when evaluating surface sources of contamination.

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APPENDIX I

Site Evaluation Procedures (from CES, 1992c)

Site Evaluation Procedures
(First Draft)

Prior to Visit

(1) Notify the district director and county staff chairman of our plans and obtain permission to visit locations in a particular county and request their assistance.

(2) Work out a mutually agreeable time frame with the staff chairman and seek permission from well owners.

(3) Verify the reported location of the well or spring with the staff chairman and locate it on the soil survey report for that county. (Reports have not been published for two of the counties we need to visit.)

(4) Obtain topographical maps from the Arkansas Geological Commission for the verified locations.

(5) Meet the staff chairman at the county Extension office at an agreeable time and go from there to the first site. At this point, it appears that two to three hours (actually at the site) should be allowed for each visit. Hopefully, there will be occasions when less time is required.

On-Site Observations

(1) Visually check the local topography, including the position of the well on the landscape and its position relative to nearby structures. Check for gulleys or rills and observe vegetation in the vicinity of the well. Make notes, and in some cases, obtain photographs.

(2) Visually determine the direction of steepest surface climb away from the well and compare with contour indications from the topographical map.

(3) Flag at least two positions in the upslope direction and determine the compass bearing of the reference direction away from the well. If the direction of steepest climb is not obvious, another convenient reference direction is chosen.

(4) Find the septic tank and stake at least one corner.

(5) Flag at least one corner of each structure within 100 feet of the well and at least one corner of any feedlot, waste storage facility, poultry house or pad, or structure known to be used for fertilizer storage or mixing. Be sure that any potential nitrate source mentioned by the well owner is included in the staking.

(6) Determine a suitable point within 20 feet of the wellhead and set up the tripod and transit.

(7) Determine the compass bearing of each of the flagged positions from the tripod position. The wellhead is the first position observed. Mark on sketch and label bearing.

(8) Check for fractures in the well casing and for gaps between the well casing and soil.

(9) Measure the height of the well casing above ground surface and the casing diameter. Remove the well cap and listen for water flow into the well.

(10) Observe the soil and compare observations with the soil survey report. Note any questions or apparent discrepancies.

a. Top soil
b. Subsoil
c. Any apparent restrictions to water movement
d. Condition of and depth to bedrock if it is observed

(11) Obtain two water samples.

a. One for nitrate analysis
b. One for biological analysis

(12) Estimate well position on the quadrangle map and estimate surface elevation of the well from the position on the map.

(13) After measurements are completed, samples are obtained, and questions of the well owner are answered to the extent possible, collect tools and flags, and depart.

Following the Visit

(1) Prepare a scaled sketch using notes and measurements from the site.

(2) Summarize the observations and information obtained from the well owner.

(3) Identify and prioritize potential sources of nitrate contamination.

(4) Mail or deliver water samples to the respective laboratories for nitrate and biological analysis.

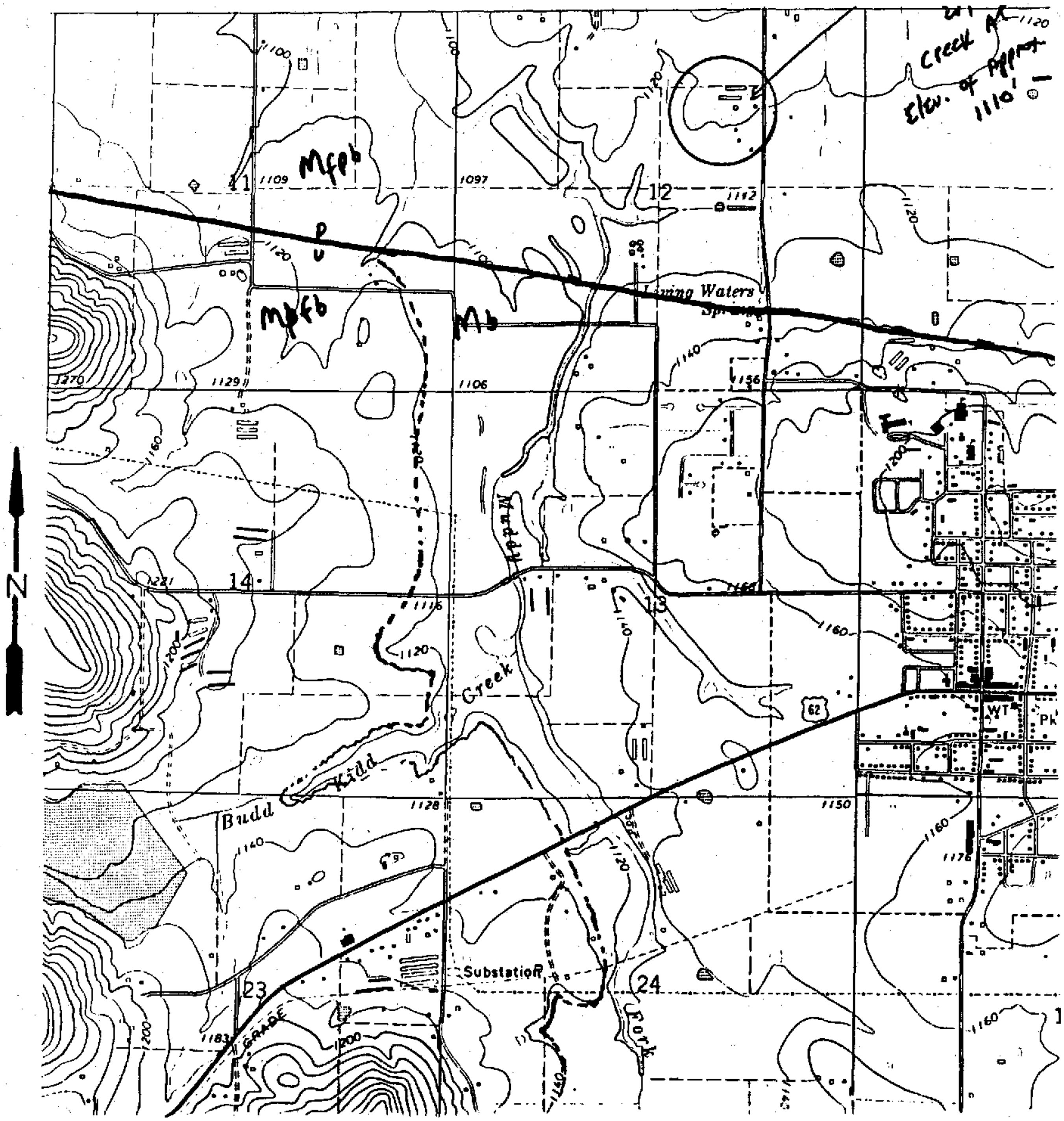
(5) Draw up recommendations to the well owner, following receipt of the laboratory reports.

APPENDIX II

Geology of Evaluation Sites for Washington County

Abbreviations used in Appendix II:

Mpfb = Mississippian-aged Pitkin, Fayetteville, and Batesville Formations
Pch = Pennsylvanian-aged Cane Hill
Pbh = Pennsylvanian-aged Bloyd and Hale Formations
Mbn = Mississippian-aged Boone Formation
Mfb = Mississippian-aged Fayetteville and Batesville Formations



SCALE 1:24 000

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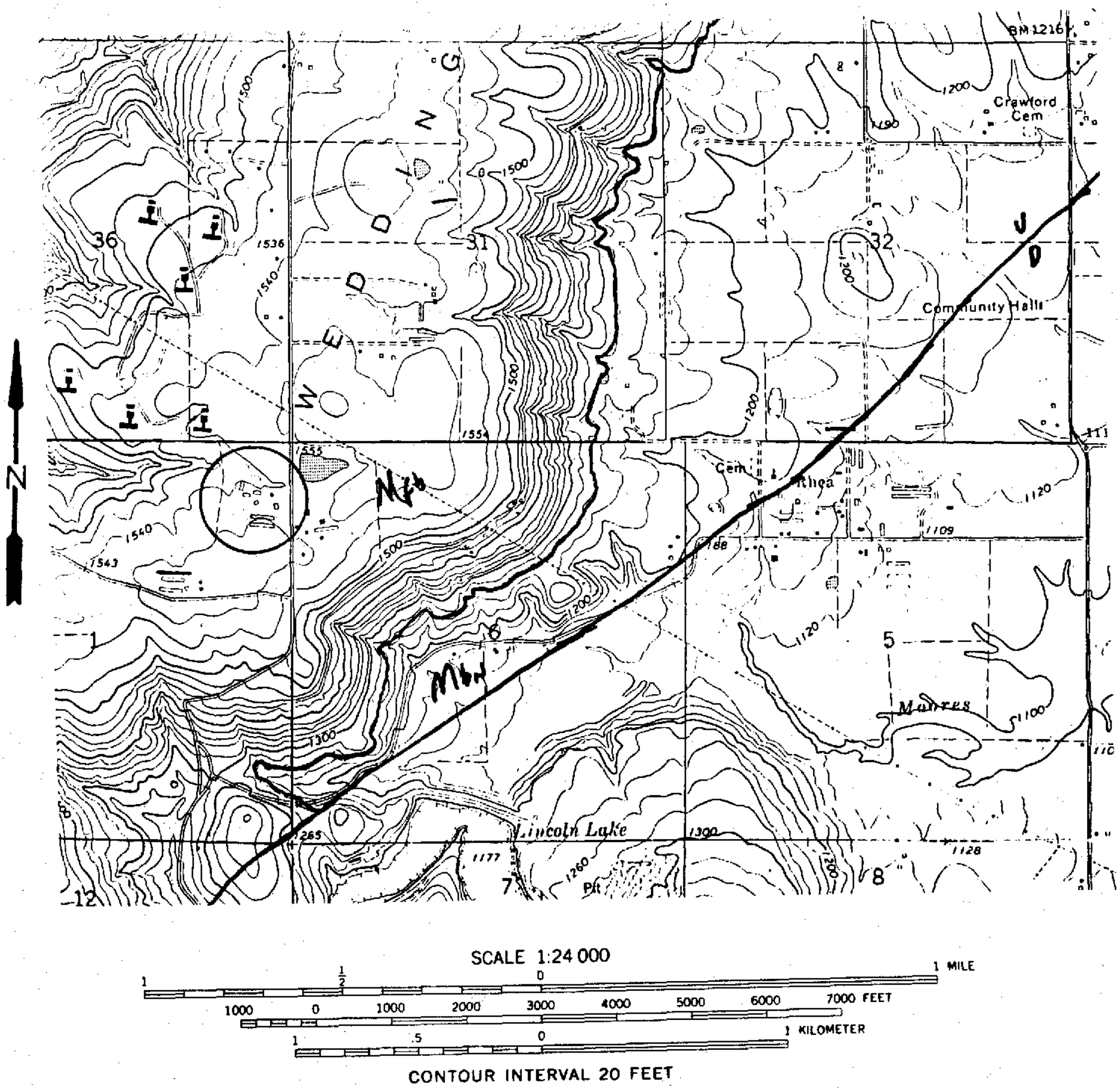
CONTOUR INTERVAL 20 FEET

Geology for WAS-1 Site



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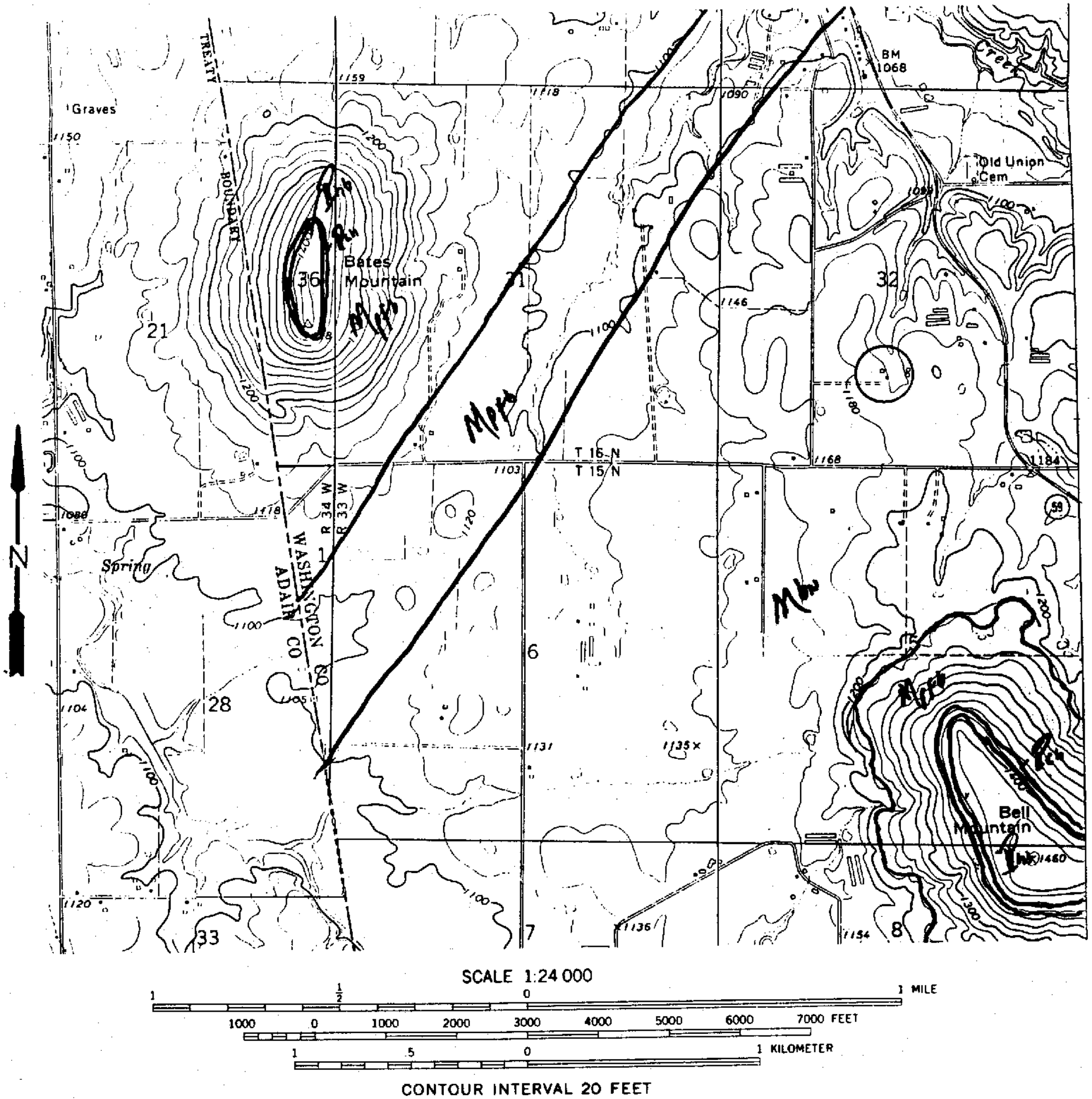

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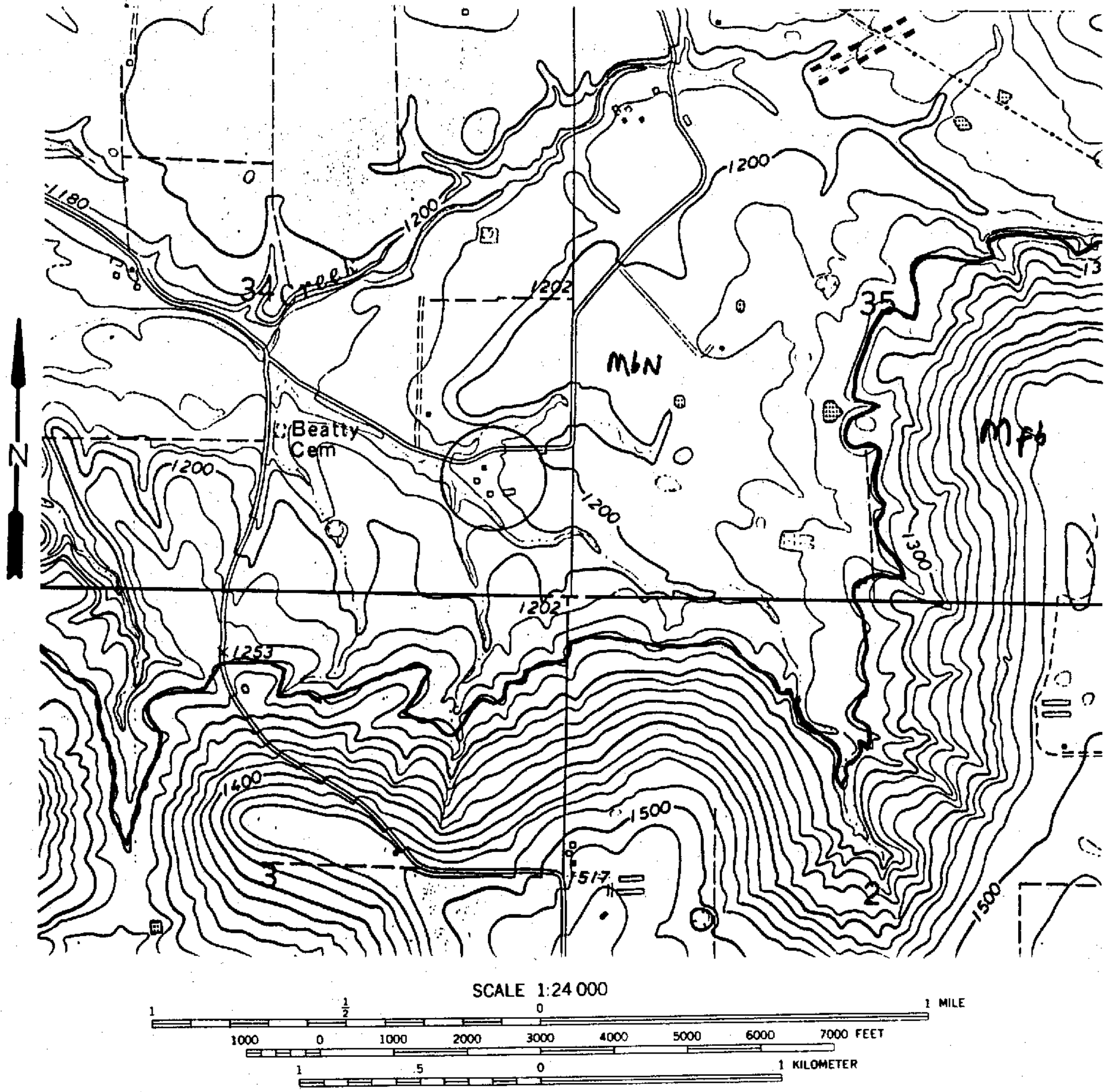
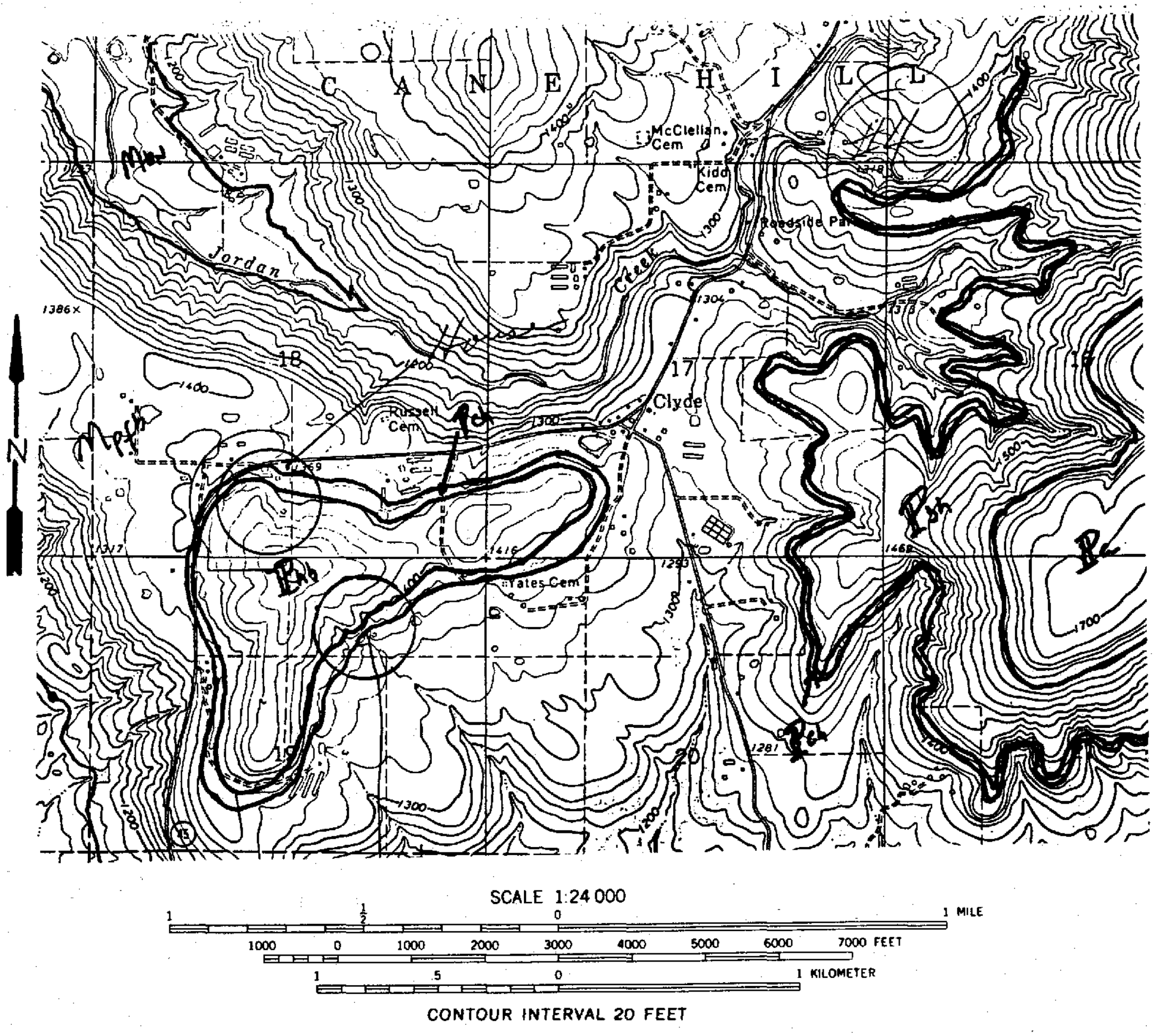


Geology for WAS-5 Site



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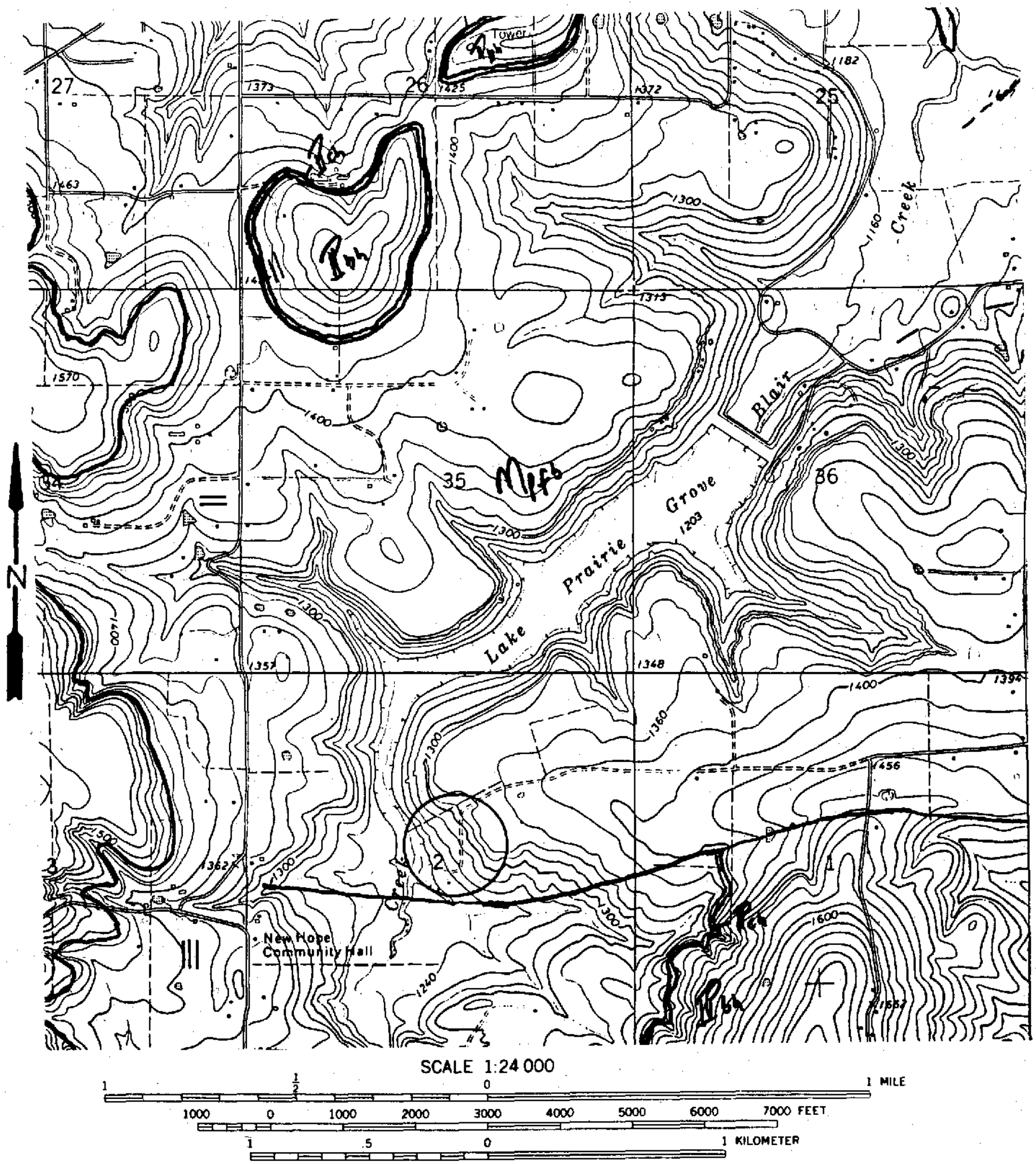
CONTOUR INTERVAL 20 FEET

Geology for WAS-6 Site



Geology for WAS-10 Site