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Brenda K. Nations
IDNR-Geological Survey Bureau

George R. Hallberg
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Water Quality Monitoring (1988 to 1991) At The Iowa Academy of Science's Parish Farm, Grundy County, Iowa

BRENDA K. NATIONS[1] and GEORGE R. HALLBERG[2]

IDNR-Geological Survey Bureau, 109 Trowbridge Hall, Iowa City, Iowa 52242-1319

In May 1988 sampling was initiated to evaluate water quality in relation to management practices at Parish Farm, which is owned by Iowa Academy of Science. Initial results showed tile-line effluent to have high concentrations of nitrate-nitrogen (NO_3-N). Twelve monitoring wells were installed over a one year period to analyze shallow groundwater at the farm. The wells, tile lines, and surface water were sampled monthly, through October, 1991, and the water analyzed for NO_3-N and some pesticides. NO_3-N concentrations varied, related to landuse and management of adjacent areas. Greater NO_3-N concentrations were detected from row-cropped areas than in the restored wildlife-vegetation buffer strip and prairie areas. The greatest concentrations (up to 79 mg/L) were associated with greater amounts of fertilized corn in the cropping sequence. Concentrations of pesticides were dependent on various factors such as chemical properties, season, hydrologic events, and patterns of use. Atrazine was the pesticide most often detected and was present in 46% of the samples. Seven agricultural pestices used on the farm were detected in water samples with a maximum detected concentration of 6.9 µ/gL (for alachlor). Pesticde and high NO_3-N concentrations were detected in wells beneath the restored natural vegetation buffer areas, probably as a result of groundwater transport from application areas upgradient. The data suggest that the buffer strips were not effective at removing NO_3-N or pesticides from the groundwater flowing through these areas. NO_3-N concentrations were high (often over 25 µg/L) during the study, in spite of improved N management on the farm. The high concentrations may be related to mobilization of excess residual NO_3-N that accumulated during the dry years prior to the monitoring.

INDEX DESCRIPTORS: Water Quality, Nitrate-nitrogen, Pesticides, Non-point Source Pollution, Parish Farm, Grundy County

Parish Farm is a 240 acre (97 ha) farm in Grundy County (Fig. 1) owned by the Iowa Academy of Science since August 1960. The farm was given to the Academy by Dr. Jessie Parish who joined IAS in 1922 (Horner, 1975, 1987). Corn and soybeans, in rotation, have been the primary crops grown on the farm and, since 1981, seed corn has been the dominant crop. Since 1974 various conservation measures have been implemented such as the addition of 15,750 feet (4,800 m) of terraces, 9,668 feet (2,947 m) of tile drainage, 1,700 feet (518 m) of grassed waterways, as well as contour tillage and planting. Understanding and mitigating the impact of agriculture on water quality has been a major program emphasis for Iowa (Hallberg et al., 1991, Hoyer et al, 1987). Because the Academy has encouraged using environmentally sound management practices on the farm, this study was initiated to assess the water quality in relationship to the agricultural management practices, parallel to these other efforts. This study has been supported, in part, by the integrated Farm Management Demonstration Project, through the Iowa Department of Agriculture and Land Stewardship, Division of Soil Conservation.

The Iowa Department of Natural Resources-Geological Survey Bureau began monitoring water quality at Parish Farm in May 1988. During initial analyses of tile-line effluent, some pesticides as well as high concentrations of NO_3-N were detected. While sampling tile lines can be very useful for studying shallow groundwater quality in relation to agricultural management practices Hallberg et al., (1986), most of the tile lines at Parish Farm are linked to surface-water intakes in the erosion control terraces. Monitoring wells were installed in 1989 and 1990 to refine the shallow groundwater monitoring at the farm. Wells were located adjacent to cropland on the farm to assess water quality in relation to row cropped areas, and in the prairie and wildlife areas to assess the water quality in the areas that are not used for crop production purposes.

PARISH FARM LANDUSE AND MANAGEMENT

Seed corn was the predominant crop on the farm for the 1979-1991 period. Cropping also included corn/soybean rotation, as well as some set-aside acres in which oats and sometimes alfalfa and clover were planted. N fertilizer was applied on corn as a granular N-P-K mix, as urea, and as anhydrous ammonia. Varying fertilizer rates were used, set on a field by field basis, related to crop type and crop yield-goals. Average N application rates for corn decreased from 160 lb/ac (179 kg/ha) when the study began in 1988 to 125 lb/ac (140 kg/ha) in 1990. In 1990, Hertz Farm Management used the late-spring soil nitrate test, developed by Iowa State University (ISU) for implementation in Iowa, to determine fertilizer rates for corn on the farm. The test was calibrated at ISU to test soils for available NO_3-N content, to improve N management and reduce excess applications, (Blackmer et al., 1992; Magdoff, 1991). In the wet springs of 1990-1991, the testing showed that little residual N was available and corn-following-corn required a full rate of N fertilizer for optimal corn yields; corn following soybeans required 80% of the recommended rates, based on yield goals.

Terraces with tile intakes were constructed to control soil erosion beginning in 1974. In the seven-year period from 1974 to 1981, 15,750 feet (4,800 m) of terraces and 9,668 feet (2,947 m) of tile were added. Contour tillage and planting are also practiced. In 1991, a 1.8 acre (0.7 ha) filter strip of oats was planted as CRP (Conservation Reserve Program) land along the west side of the unnamed creek. Such filter strips serve many purposes, such as to stabilize the stream bank, reduce chemical application next to the creek, and to decrease runoff, sediment, and chemical delivery to the creek from the adjacent cropped field.

A native prairie plot was established north of the wooded area in 1973 (Fig. 1) covering approximately 6.7 acres (2.7 ha) of the farm. In 1978, the Grundy County Conservation Board signed a lease to develop a 6.3 acre (2.5 ha) wildlife and conservation area along the east side of the unnamed creek. Trees, shrubs, and brome grass were planted for wildlife cover in this area. Fertilizers and herbicides were not routinely used on the prairie and wildlife areas. On occasion, 2-4-D was used to control thistle in the wildlife area.

HYDROGEOLOGICAL SETTING

Parish Farm is in Grundy County, 1 1/2 miles (14.5 km) north of

[1] Current address: U.S. Geological Survey-WRD, 400 S. Clinton St., Iowa City, IA 52240

[2] Current address: Univ. of Iowa Hygienic Laboratory, 102 Oakdale Campus, Iowa City, IA 52242

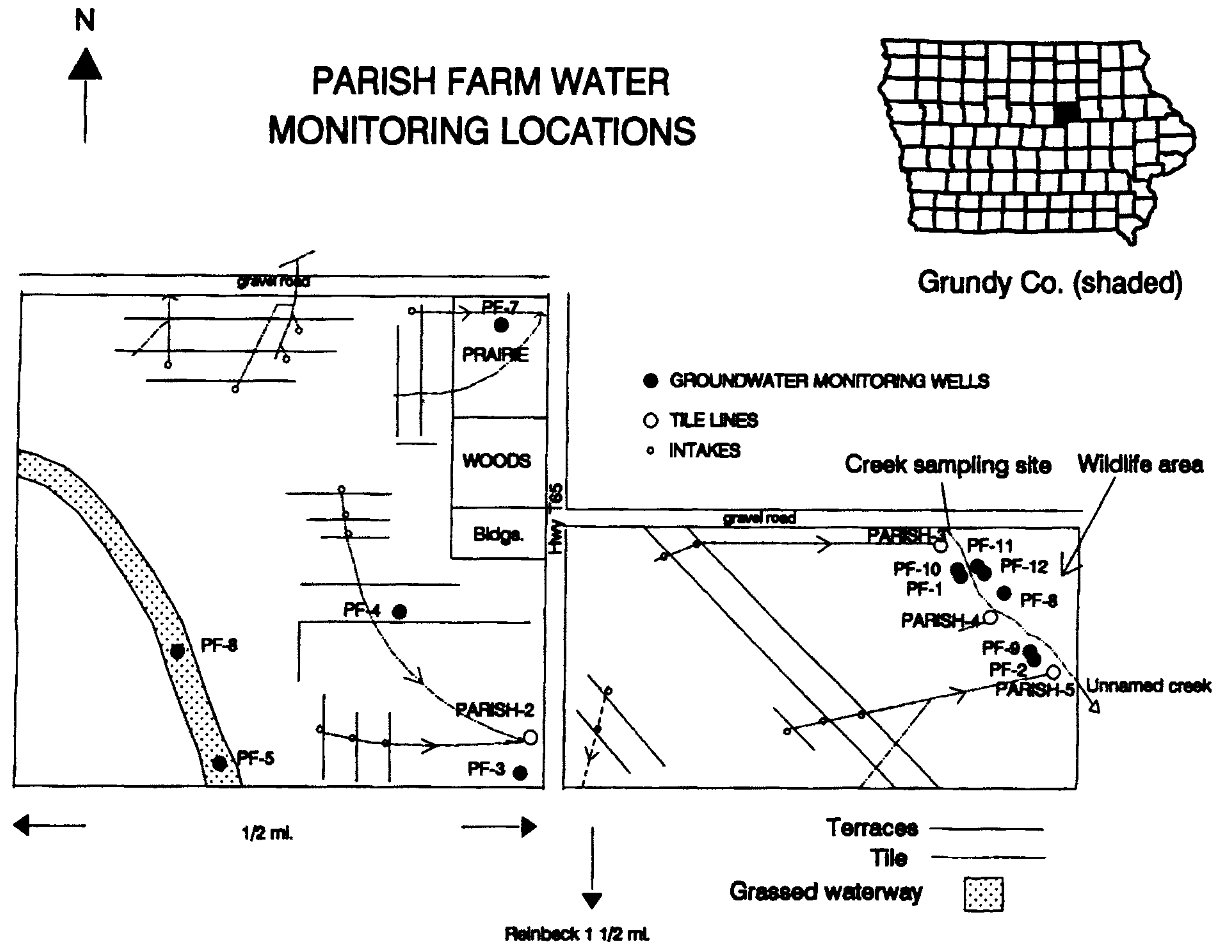

Fig. 1. Map of Parish Farm showing location of sampling sites.

Reinbeck, Iowa (Fig. 1). It is located in the Iowan Surface landform region, an area characterized by gently rolling terrain, underlain by thin, discontinuous loess over glacial till (Prior, 1991). Soils on the farm are mapped as Tama, Dinsdale, Ely, and Sawmill series, in the Grundy County Soil Survey (Andrews, 1977). Tama soils are mapped on the upland divide and are developed in loess (Peoria Loess). Dinsdale soils are on the sloping areas of the uplands and are developed in thin loess (30 inches, 762 mm) over glacial till (Pre-Illinoian age, likely the Wolf Creek Formation). Alluvial soils are mapped as the Sawmill and Ely series in the low-order drainage ways and in the valley of the larger, unnamed creek that cuts across the northeastern portion of the farm (Fig. 1). All monitoring wells were placed in alluvial soils mapped as Sawmill, except one in the prairie (PF-7), which is mapped as Ely.

Relief on the farm is approximately 40 feet (12.2 m). Terraces were installed in 1974, 1977, and 1980 to control runoff and soil erosion of the sloping areas. The drainage pattern on the farm are indicated by arrows in figure 1. The study area lies within the drainage area of Black Hawk Creek, which is a tributary of the Cedar River.

Twelve wells were installed in a variety of landscape and landuse settings to sample shallow groundwater: five were set in local side-valley alluvium in small, low-order drainage ways (PF-3,4,5,6 and 7); the other seven wells were installed in thicker valley fill alluvium along the unnamed creek (Fig. 1). The soil cores taken during well installation provide information on the stratigraphy of the alluvial deposits. The alluvium is part of the DeForest Formation, which is Holocene in age (Bettis, et al., 1992). Three members of the formation were identified: Camp Creek, Roberts Creek, and Gunder members. All wells were finished in oxidized, in-channel sand and gravel of the Gunder member. The depth to the screened intervals of the monitoring wells ranged from 3 to 12 feet (0.9 to 3.7 m) in depth. The total thickness of Quaternary deposits in this area (including multiple glacial tills) is about 130 to 160 feet (39.6 to 48.8 m). The upper-most bedrock unit is Devonian-age Lime Creek formation, part of the regional Devonian aquifer.

METHODS

Monitoring wells were installed using a Giddings hydraulic soil coring machine. Three inch (7.6 cm) cores were drilled to a depth of 1.5 ft (0.5 m) below the average seasonal water table, which was determined from the interpretation of soil mottling and color patterns (Hallberg et al., 1978). Depths of wells ranged from 4.82 ft (1.5m) to 14 ft (4.3m). Soil cores were collected at each well site and described to provide a detailed record of the deposits. Wells were constructed using 1 1/4 inch (5.1 cm) diameter, flush threaded, schedule 40 PVC pipe. Two-foot (0.6 m) long PVC slotted screens (0.01 slot size) were filter wrapped and attached to the bottom of the well pipe. Sand was filled in around the screened interval and then bentonite was used to seal the annulus of the borehole.

Water from monitoring wells, surface water and tile lines was sampled monthly from January 1990 through October 1991. Wells were purged and then sampled after recovery, using PVC bailers or a handheld vacuum pump with Tygon plastic tubing. Sampling equipment was rinsed with distilled water between sites.

Water-quality analyses were performed by the University Hygienic Laboratory in Iowa City, which is a United States Environmental Protection Agency (USEPA) certified laboratory. Samples of NO_3-N were collected in 100 ml brown glass bottles and analyzed by cadmium reduction using a Technicon auto-analyzer system (Method 353.2; USEPA, 1983). Analyses included nitrate (NO_3) plus nitrite (NO_2); the quantitation limit for NO_3-N was 0.2 mg/L (ppm). Pesticide samples were collected in 1-L glass jars with Teflon lined lids. Samples were analyzed for 18 pesticides using multi-residue, dual-column gas chromatography with nitrogen and phosphorus detectors, following standard USEPA methods (USEPA, 1980, 1986). Quantitation limits for all pesticides analyzed were 0.10 µg/L (ppb).

HYDROLOGIC MONITORING

Precipitation

Climatic data for the area came from the weather station at Grundy Center, located 9 miles (14.5 km) east of Parish Farm (Climatological Data Iowa, 1986-1988; Iowa Climate Review 1988-1991). Average annual precipitation for the area is 32.1 inches (816 mm) based on the period of record from 1951 to 1980. During the initial part of the study the area experienced below normal precipitation (Fig. 2). Precipitation for 1988 and 1989 was 18.95 and 21.40 inches (481 and 544 mm) (Table 1). Greater than normal precipitation occurred in1990 (48.81 inches; 1,240 mm) and 1991 (46.36 inches; 1,178 mm), and significant runoff and flooding affected Grundy County these 2 years.

Groundwater

The initial water-quality study began with sampling of tile lines at Parish Farm in May of 1988. During the period from May 1988 to November 1989 the tile lines only flowed while it was raining or shortly thereafter, making sampling sporadic and difficult. For more consistent sampling of the shallow groundwater, six monitoring wells (PF-1-6) were installed on the farm in December 1989 (Fig. 1). In May of 1990, wells were installed in the prairie (PF-7) and in the wildlife area (PF-8) to collect background water quality data from areas that were not farmed. In November of 1990, two water table wells (PF-9, and PF-10) were added at shallower depths next to pre-existing wells, to examine vertical water quality differences. Two additional wells (PF-11 and PF-12) were added at this time in the wildlife area because atrazine had been detected in the first well in that area.

With the onset of greater precipitation in 1990, the tile lines flowed more consistently. The data for Parish-3 are not included in the summary because the stream bank slumped, making the tile inaccessible for sampling. Water levels were measured in all wells to assess local hydrologic conditions relative to the water-quality data. The elevation of the water levels fluctuated in these wells; all rose sharply, typically several feet, between February and March 1990, when the change from the dry conditions of 1988-1989 to the greater precipitation of 1990 recharged groundwater. Thereafter the hydraulic heads fluctuated in all wells, and remained higher through 1991, than previously.

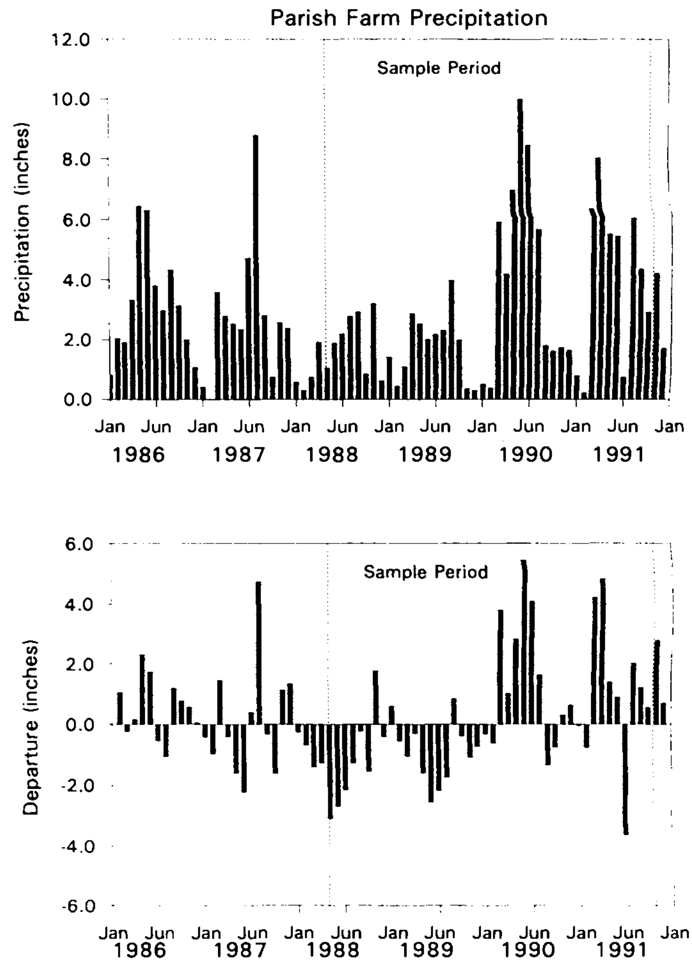

Fig. 2. Graph of monthly precipitation and departure from normal for Parish Farm area; data from Grundy Center weather station.

Table 1. Precipitation totals by calendar year for the Parish Farm area.

Year	Precipitation inches (mm)	Departure from Normal* inches (mm)
1986	38.15 (969)	+6.02 (+153)
1987	33.64 (854)	+1.15 (+ 29)
1988	18.95 (481)	−13.18 (−335)
1989	21.40 (544)	−10.73 (−273)
1990	48.82 (1240)	+16.69 (+424)
1991	46.36 (1178)	+14.23 (+361)

*Normal annual precipitation is 32.13 inches (816 mm).

RESULTS

Nitrate-nitrogen

Results of NO_3-N monitoring for all sites are summarized in Table 2. The sites are ordered by location; both by their relative proximity, and their location within field areas of similar crop and management sequences that would influence their resultant water quality.

The unnamed creek was dry during the low rainfall and drought conditions in 1988-1989. It began to flow more consistently in 1990, and beginning May 1990, the surface water from the creek was sampled. Tile lines Parish-4 and Parish-5 discharge directly into this creek below where surface water was sampled. The creek was sampled where the creek enters the farm from the north and the surface water quality primarily reflects the influence of farming practices in the drainage basin upstream from Parish Farm. NO_3-N concentrations of the surface water ranged from 1.8 to 42.2 mg/L with a mean of 30 mg/L for 16 samples.

Sampling of the tile lines began in May 1988. Two of the tile lines sampled (Parish-4 and Parish-5) are located on the eastern part of the

Table 2. Summary of NO_3-N concentrations data; monitoring sites grouped by location and similar landuse/management influence.

Site	Depth ft.	Location	NO_3-N mean (mg/L)	max (mg/L)	min (mg/L)	no. samples n
Surface water, unnamed creek:						
PF-SURF		upstream of tiles	29.8	42.2	1.8	16
Restored natural areas:						
PF-7	9.50	prairie	4.0	9.1	0.2	19
PF-8	7.83	wildlife area	0.4	3.3	0.0	19
PF-12	6.00	wildlife area	6.2	15.8	0.0	10
PF-11	9.00	wildlife area	9.8	16.4	0.7	10
Set aside / soybeans / corn:						
		in grassed waterway;				
PF-6	4.82	upslope	1.3	12.4	0.0	24
PF-5	10.00	downslope	23.1	43.1	9.1	24
PF-3	10.04	downslope of row crop	24.4	40.9	15.6	25
Most soybeans in 5 year C-Sb sequence:						
PF-9	6.00	row crop	13.8	23.6	5.1	9
PF-2	14.00	by stream	10.4	35.1	0.0	25
Parish-5		tile	24.4	32.7	4.2	13
Corn / soybeans:						
PF-10	6.00	row crop	15.1	26.2	2.4	10
PF-1	13.08	by stream	26.0	37.1	8.4	25
Parish-4		tile	23.8	31.6	14.4	19
Most corn in 5 year sequence:						
PF-4	8.83	in terrace/ row crop	52.2	75.8	30.2	15
Parish-2		tile	38.7	56.4	21.8	17

farm and one (Parish-2) in the western section (Fig. 1). These tiles have surface intakes that transport surface runoff ponded by the agricultural terraces; hence the tile-line data reflect a mix of both shallow groundwater quality and local runoff water quality. Forty-nine tile-line samples were analyzed for NO_3-N during the sample period. NO_3-N data for the tiles ranged from 4.2 mg/L to 56.4 mg/L with a mean of 29 mg/L for the three sites.

NO_3-N concentrations in monitoring wells varied according to location, with mean concentrations ranging from 0.4 to 52 mg/L. Well PF-4, placed in the backside of an agricultural terrace, had the highest concentrations, with a mean of 52.2 mg/L and a maximum of 75.8 mg/L. This area had the most years of corn in the cropping sequence since 1986. Well PF-8, in the wildlife area, had the lowest mean NO_3-N concentration of 0.4 mg/L.

In general, the monitoring wells located in non-row crop areas had lower concentrations of NO_3-N than those placed in, or adjacent to row crops. With one exception, the four wells installed in the prairie (PF-7) and the wildlife areas (PF-8, PF-11, and PF-12) showed the lowest NO_3-N, with mean concentrations ranging from 0.4 to 6.2 mg/L (Table 2).

Well PF-6 is in a poorly-drained, upslope position, in a grassed waterway. While surrounded by row-cropped fields, it had a mean NO_3-N concentration of only 1.3 mg/L. This was the shallowest of all the wells with the screened interval at 2.8 feet (0.8 m) and the water level in the well was often within one to two feet (0.3-0.6 m) of the land surface. Mean NO_3-N concentrations for the other wells in the cropped areas ranged from 10.0 to 26.0 mg/L, with the maximum of 52.0 mg/L at PF-4, as noted.

Four wells were located in two nests along the row-cropped areas west of the creek. The two shallow, water-table wells, PF-9 and PF-10, had similar NO_3-N, with mean concentrations of 13.8 and 15.1 mg/L, respectively. The two deeper wells, that were about 13-14 ft. (4-4.2 m) deep, showed very different results. PF-1 had an average of 26 mg/L of NO_3-N, but PF-2 had an average of only 10 mg/L. Well PF-2 had the greatest hydraulic conductivity of all the wells; it was the only well that could not be pumped dry during purging before sampling.

Pesticides

Water samples were initially analyzed for 18 commonly-used pesticides (Table 3). Of these 18 pesticides, 8 had been used at the farm. Seven of these were detected in water samples collected during the study; the remaining pesticide not detected, fonofos, was used only in the last year of sampling. Metribuzin was detected twice, but had not been applied on the farm since 1985. Other compounds detected were currently in use.

Table 3. Pesticides determined in Parish Farm water samples.

HERBICIDES Common chemical name	Typical product name	INSECTICIDES Common chemical name	Typical product name
alachlor[a]	Lasso	chlorpyrifos[b]	Lorsban
atrazine[a]	Aatrex	diazinon[b]	Many product names
butylate[b]	Sutan	dimethoate[b]	Cygon
cyanazine[a]	Bladex	ethoprop[b]	Mocap
metolachlor[a]	Dual	fonofos[d]	Dyfonate
metribuzin[c]	Sencor, Lexone	malathion[b]	Many product names
pendimethalin[b]	Prowl	parathion[b]	Many product names
propachlor[b]	Ramrod	phorate[b]	Thimet
trifluralin[a]	Treflan	terbufos[a]	Counter

[a]Used on Parish Farm and detected in water samples.
[b]Not used at Parish Farm during sample period 1988-1991, not detected.
[c]Not used at Parish Farm since 1985, detected twice during sampling period.
[d]Fonofos used in 1991 for first time during study, not detected in water samples.

After March 1991, samples were analyzed for only 7 herbicides, 6 which had been found in Parish Farm samples (Table 4); butylate was not used and was never detected. Terbufos (an insecticide) was the only pesticide that had been previously found (2 detections) that was no longer included in the analytical methods after this time. Other herbicides were applied at the farm that were not analyzed for; these include the active ingredients bentazon, dicamba, aciflourfen, bromoxynil, sethoxydim, clomazone, and nicosulfuron. In the wildlife area, 2,4-dichlorophenoxyacetic acid (2,4-D) was occasionally spot applied to control thistles; this herbicide was not included in pesticide analysis.

Atrazine was the most commonly detected pesticide at Parish Farm (Table 4), which is consistent with other studies across Iowa and the Midwest (Hallberg, 1989a; Kross et al., 1990; Libra et al., 1991; Seigley and Hallberg, 1991). Of the 245 samples taken during the study, 46% (112) were positive for atrazine: 43% of the tile line samples; 81% of the surface water samples; and 42% of the monitoring well samples. Metolachlor was present in 11% of the total samples and alachlor was the third most commonly detected pesticide, occurring in 7% of the samples. Concentrations detected ranged from the detection limit of 0.10 µg/L to 6.90 µg/L (for alachlor). Pesticides were detected more in surface water and the tile lines than in the groundwater.

Table 4. Pesticide determined in Parish Farm groundwater and surface water.

TILE LINES Sample period May 1988 to October 1991

Pesticide analyzed	Typical product name	Maximum detection µg/L	Detection Mean µg/L	# Detections/ # analyses	Percent Detected	USEPA Lifetime Health Advisory Level µg/L
HERBICIDES						
alachlor	Lasso	6.90	1.33	9/49	18%	2[a]
atrazine	Aatrex	3.60	0.47	21/49	43%	3
cyanazine	Bladex	0.80	0.36	3/49	6%	1
metolachlor	Dual	6.20	1.47	7/49	14%	100
metribuzin	Sencor	0.36	0.36	1/49	2%	200
trifluralin	Treflan	0.18	0.14	3/49	6%	5
INSECTICIDES						
terbufos	Counter	1.00	1.00	1/36	3%	0.9

SURFACE WATER Sample period May 1990 to October 1991

Pesticide analyzed	Typical product name	Maximum detection µg/L	Detection Mean µg/L	# Detections/ # analyses	Percent Detected	USEPA Lifetime Health Advisory Level µg/L
HERBICIDES						
alachlor	Lasso	6.40	6.40	1/16	6%	2[a]
atrazine	Aatrex	0.76	0.31	13/16	81%	3
cyanazine	Bladex	0.21	0.17	2/16	13%	1
metolachlor	Dual	1.00	0.52	8/16	50%	100
metribuzin	Sencor	Not detected		0/16	0%	200
trifluralin	Treflan	0.10	0.10	1/16	6%	5
INSECTICIDES						
terbufos	Counter	1.00	1.00	1/9	11%	0.9

MONITORING WELLS Sample period January 1990 to October 1991

Pesticide analyzed	Typical product name	Maximum detection µg/L	Detection Mean µg/L	# Detections/ # analyses	Percent Detected	USEPA Lifetime Health Advisory Level µg/L
HERBICIDES						
alachlor	Lasso	3.30	0.75	7/180	4%	2[a]
atrazine	Aatrex	5.00	0.45	78/180	43%	3
cyanazine	Bladex	0.29	0.21	2/180	1%	1
metolachlor	Dual	1.40	0.56	13/180	7%	100
metribuzin	Sencor	0.25	0.25	1/180	0.5%	200
trifluralin	Treflan	Not detected		0/180	0%	5
INSECTICIDES						
terbufos	Counter	Not Detected		0/99	0%	0.9

[a]-Maximum Contaminant Level

DISCUSSION

Shallow groundwater quality can be directly related to agricultural management practices in controlled studies, where small to moderate-sized plots of uniform management are isolated from one another. Water samples can be collected from the water table directly beneath the plot using tile-drainage lines, wells, or other equipment; deeper samples can be collected from wells. At a site such as Parish Farm, where instrumentation must be installed to avoid interfering with farm operations, it is difficult, often impossible, to isolate the monitoring points in relation to the various cropping and management used on adjacent fields. Such observations, while not from controlled experiments, still provide important observations on general water-quality conditions related to farm management, in a "real-world" setting.

The water quality seen in monitoring wells may be influenced by the management practices from both the immediately adjacent/overlying fields, through vertical recharge and subsequent transport to the well, and from fields "upgradient" from the wells. Without a significantly larger monitoring network, it is not possible to define the exact area contributing recharge to an individual well, although in a water-table setting the recharge area can generally be delineated based on the configuration of the landscape and surface drainage patterns. Although tile lines at the farm have a clearly defined drainage route, water quality observations are also confounded because they generally drain multiple fields with different crops and varying fertilizer and pesticide management. Also, these tiles did not just drain groundwater; they included surface intakes on the backside of the agricultural terraces. During prolonged periods between rainfall events tile effluent primarily consisted of shallow groundwater. The intakes transported surface runoff water into the tile system during runoff events, complicating the interpretation of water-quality data from the tile drains.

Even with these conditions some general observations can be made about the water quality observed at the farm. NO_3-N concentrations generally varied in relation to the landuse and management factors. As noted, the monitoring wells located in non-row crop areas had significantly lower concentrations of NO_3-N than those placed in, or adjacent to row crops (with one exception); the four wells installed in the prairie and wildlife areas showed mean concentrations ranging from 0.4 to 6.2 mg/L.

Tile-line Parish-2 and well PF-4 have the highest mean (39 and 52 mg/L), and highest minimum and maximum NO_3-N concentrations (Table 2). Both sites were associated with fields with the most corn in the cropping sequences. It is believed that prior to 1970 there was a cattle lot south of the buildings, just upslope of these sampling sites, which also could partially be responsible for the higher NO_3-N concentrations. Other sites (except PF-6) were intermediate, in NO_3-N concentrations and landuse, having more soybeans, and some oats and set-aside in their rotations. With these sites, there is a general trend toward higher NO_3-N concentrations with increasing years in corn production. This fits an expected pattern; fertilizer N is used in large quantities on corn, with little, if any applied to soybeans or oats at the farm. Approximately 80% of the fertilizer N applied in Iowa is used on corn (Hallberg et al., 1991). More controlled studies suggest that NO_3-N concentrations in shallow groundwater under corn production is often proportional to the N applied (Baker and Laflen, 1983; Hallberg, 1987, 1989b).

Pesticide detections, as in most studies, exhibited a seasonal pattern in shallow groundwater and surface waters; with the greatest concentrations and proportion of detections occurring during the application season in May and June. Also, the highest concentrations of all the pesticides, except atrazine, were detected in surface-water runoff, from the creek or in the tile-line effluent. Pesticides are far less mobile in leaching water than NO_3-N because they are less soluble and more highly adsorbed to the soil, and hence, are typically more concentrated in surface-water runoff.

Trifluralin and the insecticide terbufos, relative to the other herbicides detected, are more highly adsorbed to the soil. They were only detected in a very few surface water samples from the creek and tile lines. Trifluralin was only detected from areas where it was used on soybeans.

As in other studies, the presence and persistence of atrazine is noteworthy. Atrazine was detected from all sites, in all years, even where it had not been applied for several years. The detection of atrazine in 80 to 100% of well samples from the wildlife area suggests its persistence in lateral transport with groundwater from upflow areas.

Metribuzin was detected in one tile-line (Parish-4) sample and one well (PF-6) sample, even though metribuzin had not been used on site since 1985. PF-6 is a very shallow well, only slightly deeper than the tile-lines. The two sites are in separate areas of the farm and the detections occurred during different sampling periods. This might suggest an unusual occurrence or persistence but it could also be related to its deposition in rainfall at the site. Nations and Hallberg (1992 and 1993) have illustrated the common occurrence of many herbicides, including metribuzin, in Iowa rainfall and point out that this can account for detections in areas of non-use.

Hydrologic Factors And Water Quality

The findings noted above illustrate relationships between water quality and landuse and management factors, such as the amount of fertilizer N used, and also with chemical properties, such as the differences in mobility and adsorption between NO_3-N and pesticides, or among the various pesticides detected.

Site PF-6 had a very low mean NO_3-N concentration of only 1.3 mg/L, and NO_3-N was commonly not detectable even though the site is surrounded by row-cropped areas. This is likely related to denitrification in this setting. Well PF-6 is in a poorly-drained, upslope position, in a grassed waterway. This was the most shallow of the wells (4.8 feet) and water levels were often within one to two feet (0.3-0.6 m) of the land surface, within the upper part of the soil profile where organic matter is abundant and significant biological activity, such as denitrification, could be expected (Hallberg and Keeney, 1993; Groffman et al., 1991). Further, atrazine was detected in the water, even when NO_3-N was below detection, further suggesting denitrification. Water levels in several other wells rose to within 1-1.5 feet (0.3-0.4 m) of the land surface in June 1990. All these wells had minimum NO_3-N concentrations at this time.

Site PF-5 is located in the same grassed waterway as PF-6, but further downslope and the water level was more typically about 3.5 feet (1.1 m) below the land surface — in the lowermost portion of the soil profile, where organic carbon and biological activity would be more limited. Here, with deeper water levels, where denitrification would be less likely, concentrations averaged 23 mg/L, with a *minimum* value of 9 mg/L.

Also noteworthy, was that, except for the unusual single detection of metribuzin at PF-6, only atrazine was detected at these two sites (PF-5 & PF-6), even though other pesticides were used in surrounding fields. This may suggest, though it is hardly conclusive, that the grassed waterway may have enhanced the immobilization (e.g., adsorbtion and/or plant uptake) of other herbicides.

Hydrologic events also affect the timing of water-quality changes. In the tile lines, the highest pesticide concentrations were associated with lower NO_3-N concentrations, typical of discharge related to true runoff and surface water inputs. When runoff subsides and the tile flow is dominated by groundwater, NO_3-N concentrations rise while pesticide concentrations decline.

As noted, the occurrence and persistence of atrazine in the groundwater from the wildlife and prairie areas may be related to lateral transport from adjacent areas. Alachlor was also detected in the wildlife area. While the minimum and mean NO_3-N concentrations from these wells were relatively low, the maxima are not typical of natural areas, Also, NO_3-N concentrations at most of the sites tended to increase into 1991, after renewed recharge had raised water levels which probably would have increased lateral flow from adjacent cropped areas toward the creek and these wells.

One implication of these data is that these buffer strip areas were not highly effective at removing NO_3-N or pesticides from the groundwater moving laterally beneath the areas. In some settings, riparian buffers have been cited for their benefits on groundwater quality, as well as their ability to reduce runoff and trap sediments and pollutants in overland flow (Jacobs and Gilliam, 1985; Peterjohn and Correll, 1984). While NO_3-N concentrations in these wells are lower than in the immediate vicinity of cropped fields, this is partly related to vertical recharge from the natural areas that would be very low in NO_3-N and would dilute inflowing water. Table 5 summarizes the NO_3-N extracted from soil cores from the wildlife area and adjacent row-cropped areas. The NO_3-N in the soil reflects the amount potentially available for leaching; at all times during the year, at all depths there is more NO_3-N in the profiles under cropped fields (even under soybeans, in a fertilized-corn soybean rotation) than in the restored, natural vegetation area, particularly in the fall after harvest.

At three sites near the creek there were two wells nested at different depths that, as noted, showed different water quality (e.g., PF-11 and 12; PF-2 and 9; and PF-1 and 10). In general, head gradients were low, indicating primarily lateral flow conditions, toward the creek. At the two sites in the cropped areas west of the creek, when vertical gradients were apparent, they indicated different conditions. At PF-10 and 1, the heads always indicated a downward flow component; while at PF-9 and 2 heads fluctuated from lateral flow to upward flow. The

Table 5. NO_3-N concentration in soil samples, from replicate core samples from Parish Farm sites; from the row-crop areas and the wildlife area, during 1991 (- not sampled).

	Wildlife area -----4/2/91-----	Row-Crop	Wildlife area -----6/13/91-----	Row-crop	Wildlife area -----11/21/91-----	Row-crop
Mid-point sample-depth interval	Soil NO_3-N range	Sb-Corn Soil NO_3-N range	Soil NO_3-N range	Sb-Corn Soil NO_3-N range	Soil NO_3-N range	Sb-Corn Soil NO_3-N range
inches	(mg/kg) ppm	(mg/kg) ppm	(mg/kg) ppm	(mg/kg) ppm	(mg/kg) ppm	(mg/kg) ppm
3	<1-2.8	1.4-5.7	2.4-4.3	10.8-33.2	1.9-2.3	3.3-20.3
9	<1-1.7	2.9-7.9	2.4-2.7	6.5-10.9	<1	5.1-22.5
15	<1-2.9	2.9-5.8	<1-1.6	5.6-9.7	<1-1.2	5.1-10.0
21	<1-2.9	2.7-5.7	1.0-1.1	4.3-7.5	<1	4.4-8.6
30	1.0-2.8	2.5-6.2	1.3-1.6	3.8-5.4	<1	5.4-6.6
36	1.0-3.0	2.5-6.2	-	-	-	-
48	<1-3.2	2.5-6.5	-	-	-	-
62	<1-3.1	2.8-6.0	-	-	-	-

water quality relationships were also different: at PF-10-1 (with some downward flow), the NO_3-N concentration was nearly always greater in the deeper well; at PF-9-2 (with upward flow), NO_3-N was usually greater in the shallow well. These might indicate some temporal aspects, with higher NO_3-N in older waters, possibly related to previous management conditions, or mobilization from the earlier drought conditions. Without a longer period of record, and a more detailed understanding of the flow-system, it is difficult to draw many conclusions from these relationships.

CONCLUSIONS

Monitoring water-quality at a "real-world" site such as Parish Farm, affords few unequivocal observations relating water quality to cropping and management. The general associations observed among the water quality, landuse and management, chemical properties, and hydrologic factors, however provide some important perspectives for more controlled experiments and research, as well as regional water-quality monitoring.

Over the last two decades, a variety of improved management practices have been implemented at Parish Farm. The farm is intensively cropped, typical of Iowa corn and soybean production systems. Good soil conservation measures are in use and nutrient and pesticide use follow generally recommended practice. To continue improvements, the late spring soil nitrate test has been used in recent years to attempt to fine tune N use.

Even with this level of management high NO_3-N concentrations and common herbicide detections occur. This, in part, illustrates the dilemma of intensive row crop production under even good management; losses of NO_3-N and some pesticides will occur because of the relative inefficiencies in the system. Only in the past decade have we begun to understand the magnitude and nature of such losses (Hallberg 1989a, b).

Although NO_3-N concentrations seem high, the water quality findings at Parish Farm are complicated by the climatic variations during the period of record. During this study, precipitation varied from 10 or more inches (254 mm) below average in the beginning of the study to greater than 14 inches (>355 mm) above normal after the monitoring wells were installed. NO_3-N concentrations, and the concentrations of many herbicides in shallow groundwater, typically increase with greater water flux (Hallberg, 1989b). This is particularly the case for NO_3-N when relatively wet conditions, and increased water flux, follow relatively dry conditions that allow the buildup of residual NO_3-N (e.g., Hallberg et al., 1993). Figure 3 provides an illustration from an instrumented tile-line groundwater site in the Big Spring basin. The 11-year record illustrated shows the significant increase in NO_3-N that occurs with increased water flux, in 1991-92, following the relatively dry years of 1988-1990. NO_3-N concentrations increased from values averaging about 15 mg/L to peaks over 50 mg/L NO_3-N in 1991-92. This substantial increase occurred in spite of improved N management at the site over time. Hence, while the observations and trends among sites at Parish Farm provide valid comparisons, as discussed above, it is difficult to make many relative judgments compared to other data or management scenarios because of the climatic variations.

Nutrient and pest management could be further fine tuned at the farm, through greater use of innovative Integrated Crop Management (ICM) approaches that have been under development and refinement in Iowa (Brown et al., 1993). ICM makes further use of scouting and is closely tied to the soils and their capability. ICM has proven its ability to improve profitability and provide pollutant source reduction benefits, as well, through the Integrated Farm Management and Model Farm Demonstration Projects (Hallberg et al., 1991).

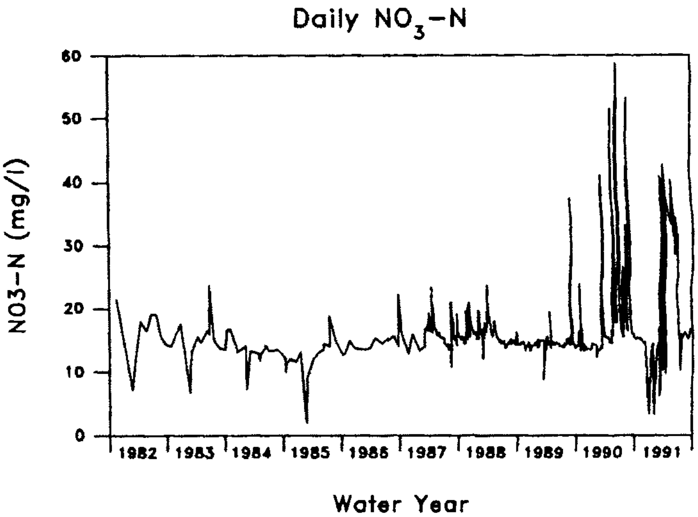

Fig. 3. Graph of weekly NO_3-N at an instrumented tile-line groundwater site, Big Spring basin, northeast Iowa.

The shallow groundwater sampled in this study is not used directly for drinking water but it is important to understand the movement of groundwater through the hydrologic system, since it does affect drinking water resources in many settings. The drinking water source for virtually all of Grundy County is groundwater. The principal groundwater sources are surficial aquifers, although several deep rock aquifers exist as well (Thompson, 1988). Both the shallow groundwater flow, as well as the runoff water quality, affect the ecological integrity of Iowa's surface waters. It is important that we continue to work to develop and implement improved farm management technologies that improve the environmental performance of agriculture and that maintain profitable crop production.

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REFERENCES

ANDREWS, W.F. 1977. Soil survey of Grundy County U.S. Department of Agriculture, Soil Conservation Service, 84 p.

BAKER, J.L. and J.M. LAFLEN. 1983. Water quality consequences of conservation tillage. Journal of Soil and Water Conservation, v. 38, p. 186-193.

BETTIS, E.A. III, R.G. BAKER, W.R. GREEN, M.K. WHELAN and D.W. BENN. 1992. Late Wisconsinan and Holocene alluvial stratigraphy, paleoecology, and archaeological geology of East-Central Iowa. Iowa Department of Natural Resources, Geological Survey Bureau, Guidebook Series no. 12, 82 p.

BLACKMER, A.M., T.F. MORRIS and G.D. BINFORD. 1992. Predicting N fertilizer needs for corn in humid regions: Advances in Iowa. *In:* Bock, B.R. and K.R. Kelley (eds), Predicting N fertilizer needs for corn in humid regions. Bulletin Y-226. National Fertilizer and Environmental Research Center, Tennessee Valley Authority, Muscle Shoals, Alabama, p. 57-72.

BROWN, S.S., K.A. CONNELLY, G.A. MILLER. 1993. Handbook for integrated crop management. Version 1. Iowa State University Extension, Ames, IA.

GROFFMAN, P.M., E.A. AXELROD, J.L. LEMUNYON and W.M. SULLIVAN. 1991. Denitrification in grass and vegetated filter strips. Journal of Environmental Quality, v. 20, p. 671-674.

HALLBERG, G.R. 1989a. Pesticide pollution of groundwater in the humid United States; *In:* Bouwer, H., and R.S. Bowman, (eds.), Effect of Agriculture on Groundwater: Agriculture, Ecosystems, and Environment, v. 26, p. 299-367.

HALLBERG, G.R. 1989b. Nitrate in groundwater in the United States; *In:* Follett, R.F., (ed.), Nitrogen Management and Groundwater Protection. Elsevier Science Publications, Amsterdam, The Netherlands, Chapter 3, p. 35-74.

HALLBERG, G.R. 1987. Nitrates in groundwater in Iowa; *In:* D'Itri, F.M. and L.G. Wolfson, (eds.), Rural Groundwater Contamination, Lewis Publish., Inc. Chelsea, Michigan, Chapter 3, p. 23-68.

HALLBERG, G.R., J.L. BAKER and G.W. RANDALL. 1986. Utility of tile-line effluent studies to evaluate the impact of agricultural practices on groundwater. Agricultural impacts on groundwater, National Water Well Association, Association of Ground Water Scientists and Engineers, Worthington, Ohio, p. 298-326.

HALLBERG, G.R., C.K. CONTANT, C.A. CHASE, G.A. MILLER, M.D. DUFFY, R.J. KILLORN, R.D. VOSS, A.M. BLACKMER, S.C. PADGITT, J.R. DEWITT, J.B. GULLIFORD, D.A. LINQUIST, L.W. ASELL, D.R. KEENEY, R.D. LIBRA and K.D. REX. 1991. A progress review of Iowa's agricultural-energy-environmental initiatives: Nitrogen management in Iowa: Iowa Department Natural Resources, Geological Survey Bureau, Technical Information Series 22, 29 p.

HALLBERG, G.R., T.E. FENTON and G.A. MILLER. 1978, Part 5. Standard weathering zone terminology for description of Quaternary sediments in Iowa, in Standard procedures for the evaluation of Quaternary materials in Iowa, Iowa Geology Survey Technical Information Series, no. 89, p. 75-109.

HALLBERG, G.R. and D.L. KEENEY. 1993. Nitrate. In Alley, W.A., Regional Groundwater Quality; Chapter 2, p. 297-322: Van Nostrand Reinhold, New York, NY.

HALLBERG, G.R., R.D. LIBRA, Z-J. LIU, R.D. ROWDEN and K.D. REX. 1993. Watershed-scale water-quality response to changes in landuse and nitrogen management. Proceedings, Agricultural Research to Protect Water Quality, p. 80-84. Soil and Water Conservation Society, Ankeny, IA.

HORNER, H.T. 1987. The Iowa Academy of Science Parish farm: its past, present and future — A 25 Year Overview. Proceedings Iowa Academy of Science, v. 94, no. 1, p. 1-18.

HORNER, H.T., Jr. 1975. The Iowa Academy of Science Parish farm: A dream about tomorrow. Proceedings Iowa Academy Science, v. 82, no. 1, p. 33-46.

HOYER, B.E., J.E. COMBS, R.D. KELLEY, C. COUSINS-LEATHERMAN, J.H. SEYB. 1987. Iowa groundwater protection strategy 1987. Des Moines, Iowa: Environmental Protection Commission, Iowa Department of Natural Resources. 106 p.

JACOBS, T.C. and J.W. GILLIAM. 1985. Riparian losses of nitrate from agricultural drainage waters. Journal of Environmental Quality, v. 14, p. 472-478.

KROSS, B.C., G.R. HALLBERG, D.R. BRUNER, R.D. LIBRA, K.D. REX, L.M.B. WEIH, M.E. VERMACE, L.F. BURMEISTER, N.H. HALL, K.L. CHERRYHOLMES, J.K. JOHNSON, M.I. SELIM, B.K. NATIONS, L.S. SEIGLEY, D.J. QUADE, A.G. DUDLER, K.D. SESKER, M.A. CULP, C.F. LYNCH, H.F. NICHOLSON and J.P. HUGHES. 1990. The Iowa state-wide rural well-water survey water-quality data: Initial analysis. Iowa Department of Natural Resources, Geological Survey Bureau Technical Information Series 19, 142 p.

LIBRA, R.D., G.R. HALLBERG, J.P. LITTKE, B.K. NATIONS, D.J. QUADE and R.D. ROWDEN. 1991. Groundwater monitoring in the Big Spring basin 1988-1989: A summary view. Iowa Department of Natural Resources, Geological Survey Bureau Technical Information Series 21, 29 p.

MAGDOFF, F. 1991. Understanding the Magdoff pre-sidedress nitrate test for corn. Jounral of Production Agriculture., v. 4, no. 3, p. 297-305.

NATIONS, B.K. and G.R. HALLBERG. 1992. Pesticides in Iowa precipitation: Journal of Environmental Quality, v. 21, p. 486-492.

NATIONS, B.K., G.R. HALLBERG, R.D. LIBRA, R.S. KANWAR and E.C. ALEXANDER. 1993. Pesticides in precipitation: Implications for water quality monitoring. Proceedings, Agricultural Research to Protect Water Quality, p. 142-145. Soil and Water Conservation Society, Ankeny, IA.

PETERJOHN, W.T. and D.L. CORRELL. 1984. Nutrient dynamics in an agricultural watershed: observations on the role of a riparian forest. Ecology, v. 65; p. 1466-1475.

PRIOR, J.C. 1991. Landforms of Iowa. University of Iowa Press, Iowa City, Iowa, 154 p.

SEIGLEY, L.S. and G.R. HALLBERG. 1991. Groundwater quality observations from the Bluegrass watershed Audubon county, Iowa. Iowa Department of Natural Resources, Geological Survey Bureau, Technical Information Series 20, 50 p.

THOMPSON, C.A. 1988. Groundwater resources Grundy County. Iowa Department of Natural Resources Geological Survey Bureau, GWR-38, 35 p.

USEPA. 1980. Manual of analytical methods for the analysis of pesticides in humans and environmental samples. EPA-600/8-80-038. U.S. Environmental Protection Agency, Washington, D.C.

USEPA. 1986. Methods for the evaluation of solid waste. p. 1-16. 8140-organophosphate pesticides. Environmental monitoring and support laboratory, U.S. Environmental Protection Agency, Washington, D.C.

USEPA. 1983 (revised). Methods for chemical analysis of water and wastes: Cincinnati, Ohio, Environmental monitoring and support laboratory, U.S. Environmental Protection Agency, EPA 600/4-79-020.