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TEMPORAL CHANGES IN NITRATES IN GROUNDWATER IN NORTHEASTERN IOWA

George R. Hallberg
Chief, Geological Studies Division

Robert D. Libra
Hydrogeologist, Geological Studies Division

Gale G. Ressmeyer
Research Geologist, Geological Studies Division

E. Arthur Bettis, III
Research Geologist, Technical Services Group

Bernard E. Hoyer
Chief, Technical Services Group

Iowa Geological Survey
Donald L. Koch, Director
123 North Capitol Street
Iowa City, Iowa 52242

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INTRODUCTION

In prior reports, the authors have discussed the limited data available to describe changes in groundwater quality that have occurred over the past several decades. Hallberg and others (1983b) discussed historic groundwater quality data from the Big Spring, which showed that nitrate concentration in groundwater from Big Spring had increased approximately 230% between 1968 and 1982. Hallberg and Hoyer (1982) and Hallberg and others (1983a) discussed data on nitrate concentrations in rural, domestic water-supply wells from samples collected in Clayton, Allamakee, and Winneshiek Counties in 1975 by Iowa Geological Survey (IGS) staff. While none of these wells were located in the Big Spring basin, all of them are located in similar geological settings to those found in the Big Spring basin, and many were located within the Turkey River drainage basin. To provide some further background data and perspective on the temporal changes of water quality in this region, 50 of the wells originally sampled in October, 1975 were selected to be re-sampled in October, 1983.

On October 6-8, nearly eight years to the day of their sampling in 1975, these wells were re-sampled by IGS staff. The water samples were analyzed for nitrate by the University Hygienic Laboratory (UHL) using standard cadmium-reduction technique (see Hallberg et al., 1983b). The water samples were collected at hydrants at or very near the well head. None of the water samples were affected by water treatment, such as household softeners, etc., or by the use of cisterns (see Hallberg et al., 1983b). Sampling techniques and procedures are described in Hallberg and others (1983b). In short, the wells were pumped until the water samples stabilized in terms of temperature and

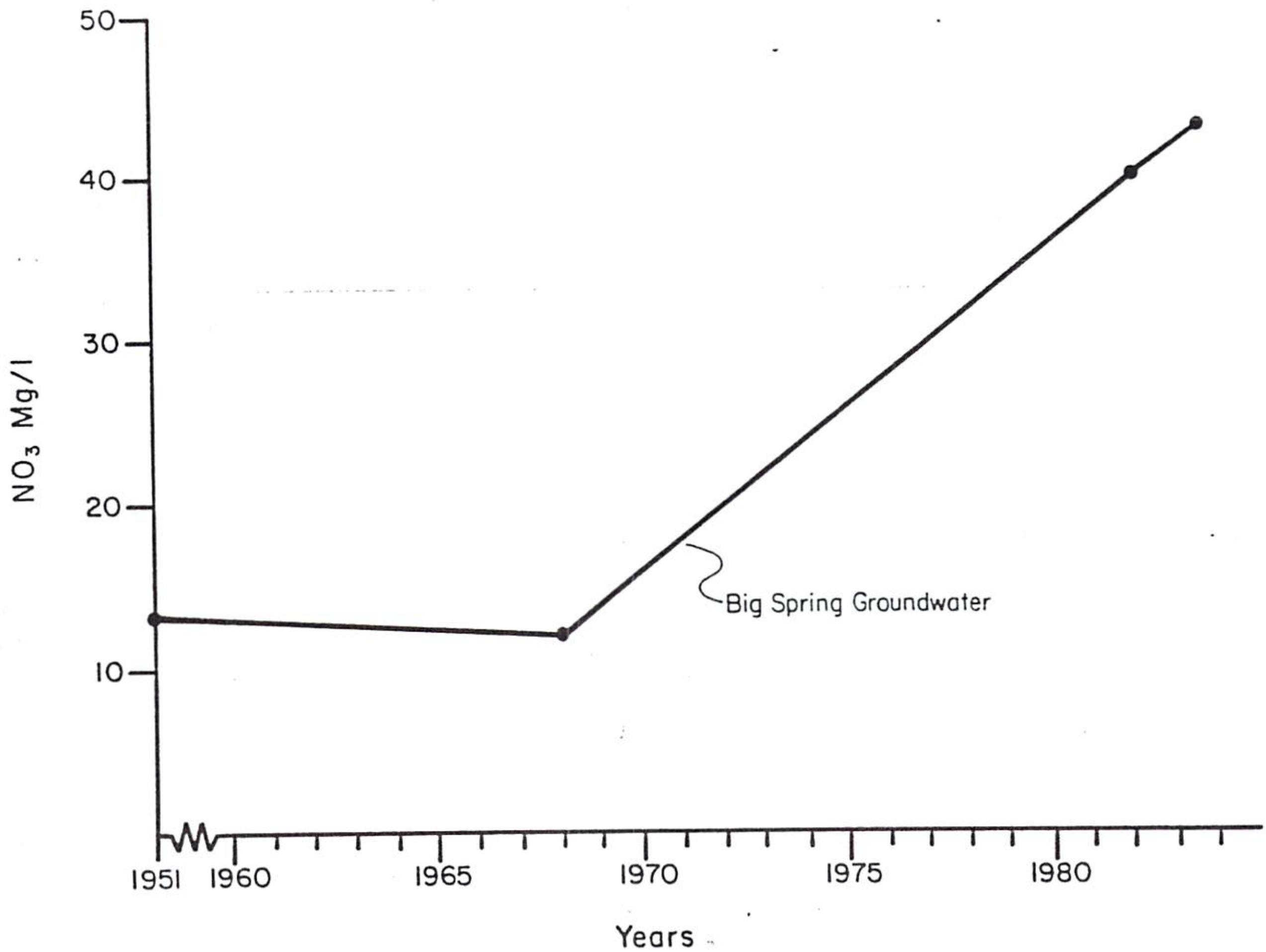

Figure 1. Change in mean nitrate concentration in groundwater from Big Spring, Clayton County, Iowa (after Hallberg et al., 1983b).

conductivity before the samples were collected. Two samples from wells finished in shallow-carbonate aquifers were also analyzed for pesticides. Well owners were interviewed for any information they might have regarding historic changes in water quality in their wells. Three were able to provide analyses taken at various times in the past.

Background Water Quality

Hallberg and others (1983b) have shown that the groundwater discharging from Big Spring in Clayton County integrates, and thus is a good measure of the groundwater quality for its 103-mile square (267 sq. km) basin. Figure 1 shows graphically the change with time in the mean-nitrate concentration in the groundwater at Big Spring. In 1968 the mean concentration was 12 mg/l and in 1982 the mean was 40 mg/l (Hallberg et al., 1983b). The mean of analyses for 1983 was 45 mg/l (Hallberg et al., in preparation). There are obvious uncertainties in showing a temporal trend in groundwater quality with data for so few years. Thus, it was hoped that this re-sampling of a large number of wells could provide some additional insights concerning temporal changes in nitrate in groundwater from the same geologic region.

Nitrate concentrations in groundwater fluctuate seasonally (see Hallberg et al., 1983b; Hallberg and Hoyer, 1982). Late September through early October is a good time of the year to take an individual sample for water-quality analysis, however. This time period is at the end of the summer growing season (with high rates of evapotranspiration) and generally before the beginning of late fall-winter recharge events which may cause water-level and water-quality fluctuations. From past monitoring, nitrate concentrations from this seasonal period tend to be near or below the yearly mean, and well below the yearly maximums. For example, in October of 1982 and 1983, Big Spring showed nitrate concentrations of 34 and 41 mg/l, compared to yearly averages of 40 and 45 mg/l respectively. The Big Spring monitoring-well network showed similar results. Thus, comparative sampling in early October should provide a representative (perhaps conservative) analysis of groundwater quality.

The relationship between Big Spring and the Turkey River (Hallberg et al., 1983b) shows that the water quality in the Big Spring basin is typical for the Turkey River basin and probably for northeast Iowa as well. Thus, the resampled well network should be useful for comparison with the temporal changes at Big Spring. A variety of information was available for the wells sampled in 1975. Information such as well depth, geology, and casing depth made these useful data sets (see Hallberg and Hoyer, 1982; Hallberg et al., 1983a). From these wells, 50 were selected to be resampled, based on their proximity to the Big Spring-Turkey River areas, their geologic setting, and quality of information available for the wells. Of the 50 selected, only 40 samples were actually collected. Ten of the wells were no longer available for sampling; a few were abandoned, and several were dismantled because new wells had been drilled because of water-quality problems.

COMPARISON OF 1975 AND 1983 WATER-QUALITY DATA

The 1975 and 1983 nitrate concentrations are shown on Tables 1 and 2. The samples are grouped by the geologic setting of the wells. Two groups provide background control from areas naturally "protected" from the short-term infiltration of near-surface waters. These are: 1. Galena aquifer wells, located in areas where a cap of Maquoketa shale covers the aquifer and casings go through the shale (Galena wells, with shale cap); and 2. other wells finished in buried or deep aquifers (St. Peter, Prairie du Chien, Jordan) where the casing is finished deeply enough to screen out the surficial aquifers (Buried aquifer--deep casing). The other three groupings show the impact of surficial activities. These are wells finished in: 1. the Galena; (Galena--surficial aquifer); or 2. other carbonate aquifers, where these are the surficial aquifers and are at a shallow depth (<50 feet, 15 m) below the land surface (Other surficial carbonate aquifers). The third group represents wells drilled into deep or buried aquifers, but the casing is shallow and allows the influx of groundwater from the surficial aquifers into the well (Buried aquifer--shallow casing).

Table 1. Comparison of nitrate concentrations in water samples from 1975 and 1983 for individual wells grouped by geologic settings.

Well I.D. Number	1975 nitrate, mg/l		1983 nitrate, mg/l
Galena wells, with shale cap			
2	<5		<5
4	<5		<5
4A	<5		<5
12A	<5		<5
22-4A	<5		<5
22-4C	<5	(3/11/82:4)*	<5
Buried Aquifer - Deep Casing			
9	<5		<5
9A	<5		<5
14	<5		<5
14A	<5		<5
14B	<5		<5
Galena, Surficial Aquifer			
1A	25		23
3A	12		13
6	20		45
6A	14		30
8	25		63
8B	16		42
12C	10		28
13	40		66
Other Surficial Carbonate Aquifers (Elgin-Galena, Silurian, or Cedar Valley Aquifers)			
2A	35	(11/8/81:61)	45
3B	25		40
7A	40		28
11A	25		52
22-1	45		37
22-2A	30		39
22-2B	70		67
22-2	10		12
Buried Aquifer-Shallow Casing Open to Surficial Aquifer			
5	30		33
5A	40		42
8A	18		24

Table 1. continued

Well I.D. Number		1975	1983
9B		20	19
10A		14	17
11		8	21
11B		10	38
12B		16	20
12E		20	34
13A	(1963:9)	20	29
13B		16	35
13C		40	50
15A		25	27

*Values in parentheses are the date and value of nitrate in mg/l, for water analyses provided by well owners.

Table 1 shows the comparative data for the individual wells by groups. The 11 background wells (28%) from protected areas show no change--they all show less than detectable levels of nitrate. In the other areas, five wells (12%) showed decreases in nitrate concentrations, ranging from 1 to 12 mg/l. The majority, or 24 wells (60%) showed increases ranging from 1 to 38 mg/l, with a mean increase of 14 mg/l.

Table 2 provides a statistical summary of the change in nitrate concentrations by groups. As noted, groundwater in the protected wells shows no change. However, no matter how the remaining data is summarized, a substantial increase (ranging from 21 to 100%) is evident in the mean or median nitrate concentrations. The means for all the data (category 1, Table 2, which include all the background wells with less than detectable nitrates) and for all surficial aquifer data (category 6) are shown on figure 2 (x and s respectively), and as shown the magnitiude or slope of the change is essentially the same as predicted at Big Spring.

Table 2. Summary statistics for 1975 and 1983 nitrate concentrations, grouped by geologic settings.

Year	N	Mean	s.d.	Median	Q1	Q3	Range
		Nitrate, Concentration, mg/l					
		1. All Data					
1975	40	19*	15	16	<5	25	<5-70
1983	40	26*	19	27	<5	39	<5-67
		2. Galena wells, with shale cap, and other buried aquifers with deep casing					
1975	11	<5		<5	<5	<5	
1983	11	<5		<5	<5	<5	
		3. Galena, Surficial Aquifer					
1975	8	20	10	18	12	25	10-40
1983	8	39	19	36	23	63	13-66
		4. Other Surficial Carbonate Aquifers					
1975	8	33	17	32	25	45	10-70
1983	8	40	16	40	28	52	12-67
		5. Buried Aquifer--Shallow Casing					
1975	13	21	10	20	15	27	8-40
1983	13	30	10	30	20	38	17-50
		6. All Surficial Aquifers (3+4)					
1975	16	28	15	25	16	40	10-70
1983	16	39	17	40	28	52	12-67
		7. All Surficial Aquifers, plus Shallow Casing (3+4+5)					
1975	29	25	13	20	16	32	8-70
1983	29	35	15	35	23	45	12-67

*Assumes a value of 4 mg/l for analyses of <5 mg/l.

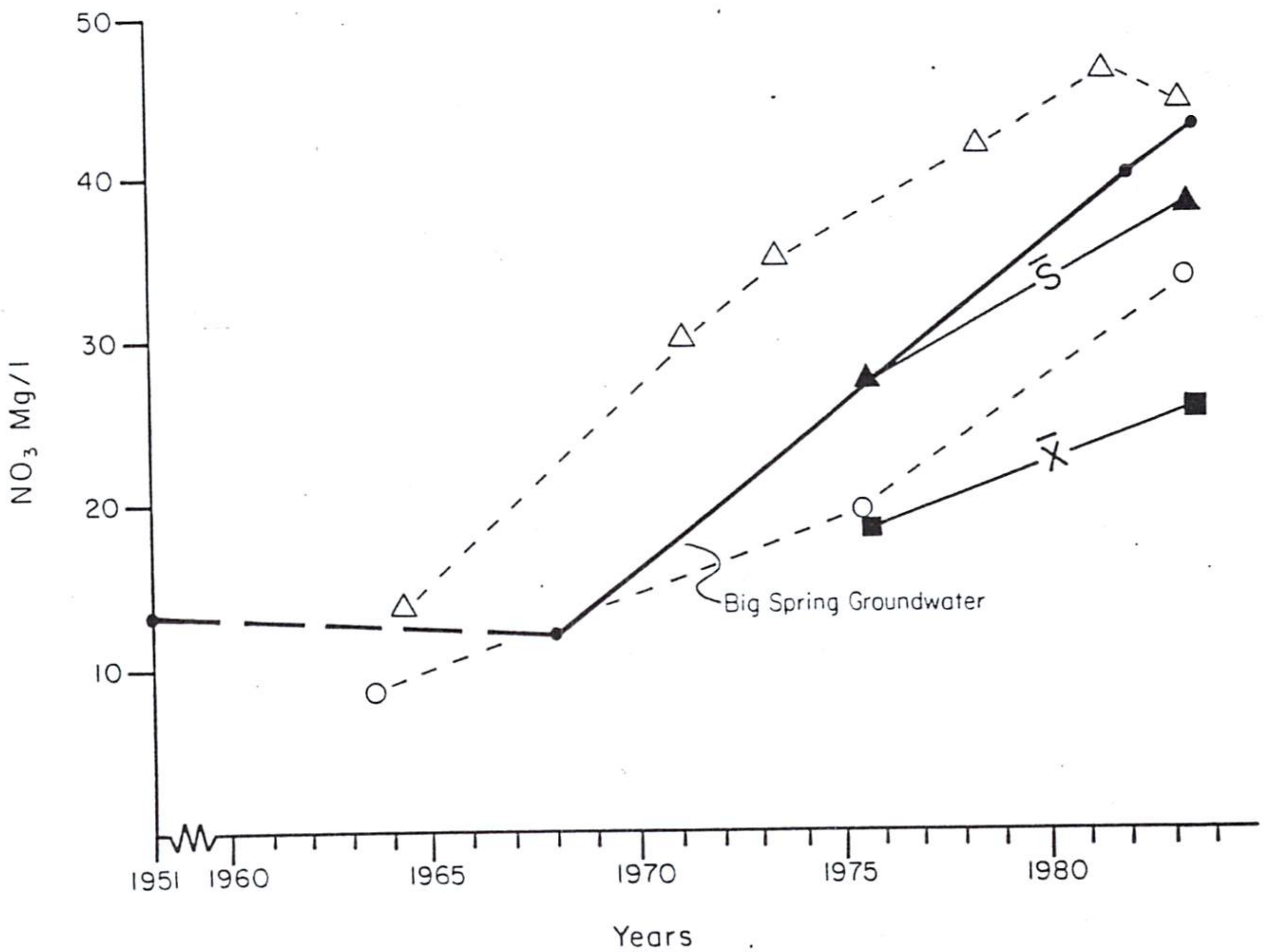

Figure 2. Change in mean nitrate concentration in groundwater from Big Spring, the total well network ($\bar{x}$, solid squares) the surficial-aquifer wells ($\bar{s}$, solid triangles) and two individual wells (open circles and triangles). The open-triangle data is from Hallberg and others (1983b, p. 159).

Data from two individual wells with more additional water-quality analyses over time, which were provided by the landowners, are also shown on figure 2. Again, these individual records show almost the same trend, and bracket the Big Spring results.

Samples from two wells in surficial-carbonate aquifers were analyzed for pesticides. Prior to sampling, four wells were simply picked from the lot to be sampled. Two of these wells were no longer in service and thus, only two

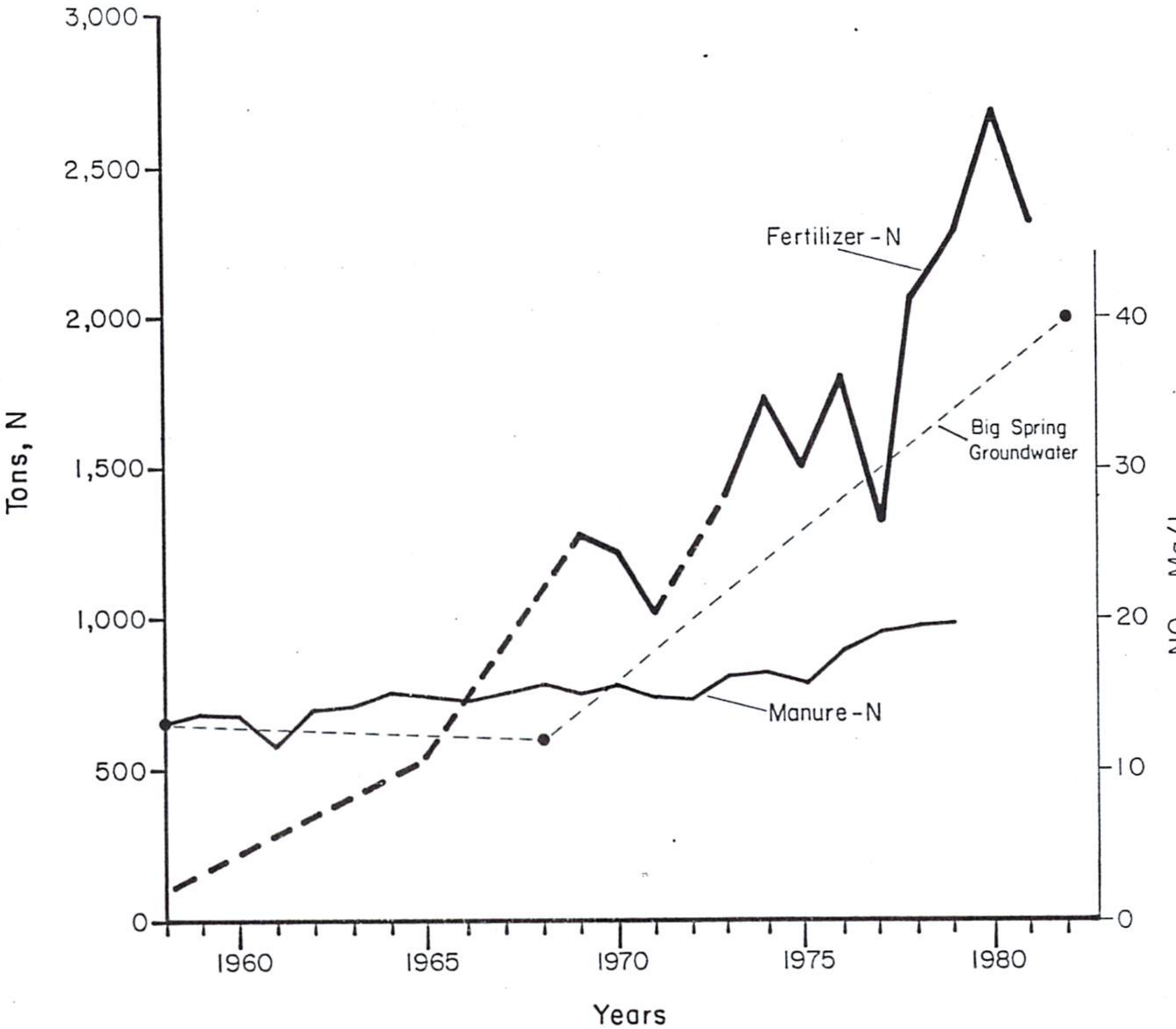

Figure 3. Estimated tons of fertilizer and manure nitrogen applied in the Big Spring basin and mean nitrate concentration (right axis) in groundwater from Big Spring (from Hallberg et al., 1983b).

samples were collected. In one (No. 6), no pesticides were detected; in the other (No. 12C), 1.1 µg/l atrazine was detected. At this same time, 3 wells in the Big Spring Basin were sampled which have had detectable levels of pesticides intermittently in the past. In two of the wells none were detected; in the third, 0.19 µg/l atrazine was detected.

Land-use and land-treatment patterns in Clayton County and the Big Spring basin are typical for northeast Iowa (see Hallberg and Hoyer, 1982; Hallberg et al., 1983b). The data presented here reinforces the conclusions of Hallberg and others (1983b), summarized in figure 3, that a direct relationship can be shown between the increase in total chemical fertilizer nitrogen applied and the increase in nitrate concentrations in unprotected, shallow groundwater supplies.

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