Nitrate-Nitrogen Concentrations in the Northern Guam Lens and Potential Nitrogen Sources

By

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WATER AND ENVIRONMENTAL RESEARCH INSTITUTE OF THE WESTERN PACIFIC
UNIVERSITY OF GUAM

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ABSTRACT

Nitrate-nitrogen concentrations in the Northern Guam Lens (NGL) were studied using nitrate-nitrogen data from 147 water wells. Data spanning from January 1978 through December 2000 indicated that concentrations had not neared the United States Environmental Protection Agency's Safe Drinking Water maximum contaminant level of 10 mg/l. However, 39 wells had increasing nitrate-nitrogen trends while nine wells had decreasing trends based on linear regression. Twenty-two wells had maximum nitrate-nitrogen levels between 4 and 4.99 mg/l while six wells had maximum concentrations over 5 mg/l. The Mangilao Subbasin had the highest number of wells with statistically increasing nitrate-nitrogen concentrations. Potential nitrogen sources in northern Guam were identified through aerial and terrestrial investigation. These sources include sewer lines, septic tank/leaching field systems, golf courses, farms, piggeries, fish farms, chicken farms, pastures, and ponding basins.

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1.0 INTRODUCTION

Nitrate-nitrogen (NO_3-N) is a naturally occurring form of inorganic nitrogen that is found in fertilizers and organic matter but is also produced from the breakdown of organic matter and fecal material. At concentrations over 10 mg/l, NO_3-N can cause methemoglobinemia or "blue-baby syndrome", a blood disorder that most commonly affects infants. Methemoglobinemia decreases the oxygen supply to cells and tissues, resulting in convulsions and death in extreme cases. Because of this, the United States Environmental Protection Agency (USEPA) set the NO_3-N Safe Drinking Water (SDW) maximum contaminant level (MCL) at 10 mg/l. The SDW standards also require that a parameter's monitoring frequency be increased if 50% of its MCL is reached (USEPA, 2000). However, Guam Environmental Protection Agency's (GEPA) *1992 Revised Guam Water Quality Standards* indicates that Guam's ambient groundwater NO_3-N concentration can be as high as 5 mg/l. The naturally high nitrate-nitrogen content of the Northern Guam Lens (NGL), Guam's major source of drinking water, has prompted a study of groundwater nitrate-nitrogen levels and potential sources.

2.0 PROJECT OBJECTIVES AND SCOPE

The purpose of this study is to provide managers, regulators, and lawmakers with information on: (1) where NGL well nitrate-nitrogen concentrations are increasing or are already relatively high and (2) possible anthropogenic sources of nitrate-nitrogen or forms of nitrogen that may be converted to nitrate-nitrogen. Study results are to be used to support management or regulatory practices aimed at halting groundwater nitrate-nitrogen concentration increases and therefore preventing concentrations from nearing or exceeding the SDW standard of 10 mg/l. The maintenance of groundwater NO_3-N levels will insure the Northern Guam Lens's continued use as a safe source of drinking water.

The study area begins at the contact between the northern limestone plateau and southern volcanic highlands, and ends at the northern tip of Andersen Air Force Base (Figure 1). Nitrate-nitrogen concentrations were collected from production wells and golf course monitoring wells in the study area.

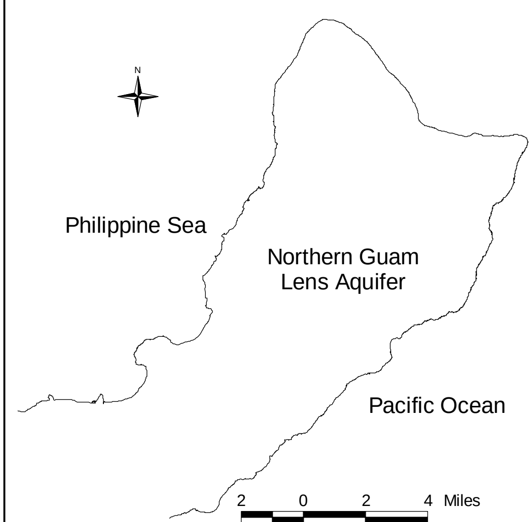

Figure 1. The Northern Guam Lens Aquifer.

3.0 THE NITROGEN CYCLE

3.1 Nitrogen compounds

Inorganic nitrogen forms include nitrogen gas (N_2), nitrite ion (NO_2^-), nitrate ion (NO_3^-), ammonia (NH_3), and ammonium ion (NH_4^+). Organic nitrogen is found in proteins, amino acids, humic compounds, and amines (Canter, 1997). The transformations from one nitrogen form to another depend on redox potential, pH, and other environmental conditions (Canter, 1997; Follett, 1989). A general subsurface nitrogen cycle is diagrammed in Figure 2.

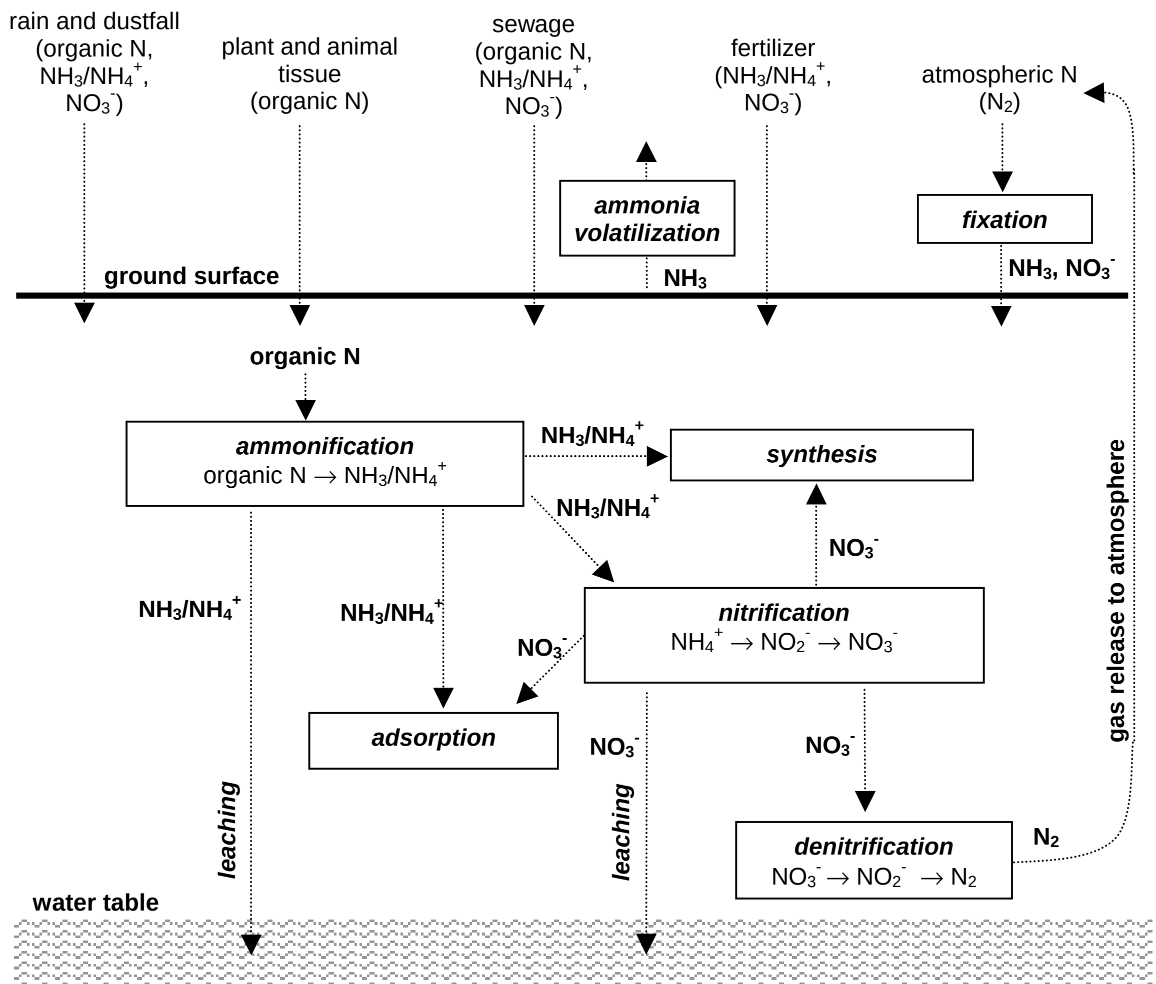

Figure 2. Nitrogen cycle in the subsurface environment. (Adapted from Figure 1-3. The nitrogen cycle in soil and groundwater. USEPA, 1993.)

3.2 Nitrogen sources

3.2.1 Natural sources

Nitrogen and nitrogen compounds originating from dustfall can enter the subsurface and become part of that environment's nitrogen cycle. Additionally, atmospheric nitrogen can be fixed and contribute to the subsurface nitrogen content. Tangantangan, *Leucaena leucocephala*, and other local legumes may contribute to groundwater nitrogen loading (Mink, 1991), though local studies on tangantangan nitrogen fixation rates have not been published.

3.2.2 Plant and animal tissue

Organic sources of nitrogen include decomposing plant and animal matter from developed and undeveloped (jungle) areas, animal husbandry waste, and human waste. Organic nitrogen from decomposing plant and animal matter can enter the subsurface environment at the source or be carried by runoff flow to low-lying areas such as ponding basins or closed contour depressions, where flow entering the ground is concentrated. Local urban runoff nitrate-nitrogen levels have been reported as high as 4.56 mg/l (Zolan, Clayshulte, Winter, Marsh, and Young, 1978).

Animal husbandry is fairly common on Guam. It is not unusual for a household to raise pigs and chickens, though commercial operations (including piggeries, a chicken farm, and fish farms) do exist. A ton of fresh pig manure can contain 12 lb of total nitrogen and 7 lb of ammonium (Zublena, Barker, Parker, and Stanislaw, 1993).

Domestic sewage is about 60% ammonium and 40% organic nitrogen (USEPA, 1993). Septic tanks can produce effluent with a concentration of 20 to 55 mg/l of ammonia and under 1 mg/l as nitrate (Canter, 1997). Although ammonium is not a SDW standard, it can be converted to nitrate through the process of nitrification.

3.2.3 Fertilizers

Fertilizers are utilized by golf courses as well as commercial and private farms. Although golf course fertilizer application is reported to GEPA, farm application of fertilizer is not currently being reported to government agencies.

3.3 Nitrogen transformations

Nitrogen transformation mechanisms include fixation, ammonification, nitrification, denitrification, synthesis, and ammonia volatilization:

- fixation: nitrogen gas is transformed to organic nitrogen compounds, nitrate, or ammonium
- ammonification: organic nitrogen is transformed to the ammonium form
- nitrification: the biological oxidation of ammonium ions to nitrite and then to nitrate
- denitrification: the biological reduction of nitrate to nitrite and then to nitrogen gas
- synthesis: ammonium or nitrate forms are taken up by plants to form protein
- ammonia volatilization: the conversion of ammonia to gaseous form

A basic understanding of the nitrogen cycle is important, as subsurface nutrient cycling of nitrogen compounds, rather than direct nitrate-nitrogen loading from sources seems to be responsible for nitrate-nitrogen concentrations in carbonate aquifers (Kreitler and Browning, 1983). Local studies support the application of this theory to the NGL aquifer (Zolan et al., 1978; Matson, 1991).

4.0 METHODS

The study was conducted in three stages. For the first stage, nitrate-nitrogen data were collected for 147 wells (140 production wells and 7 monitoring wells), listed in Table 1, from January 1978 through December 2000. Guam Waterworks Authority (GWA), GEPA, the Air Force, the Navy, and private companies own the wells. The data were used to construct databases in monthly intervals. Statistics including average, standard deviation, minimum, and maximum values were calculated. Data were linearly regressed using the Excel© spreadsheet program. The calculated correlation coefficients (r_{calc}) were compared to critical values (r_{crit}) at an alpha value of 0.05. Critical correlation coefficients were obtained from Zarr (1984, Table B.16: *critical values of the correlation coefficient, r*). Equations with r_{calc} equaling or exceeding r_{crit} values were considered significant. Sample data sets that had significant linear regression equations where the sample slope differed from zero were considered to have either increasing or decreasing trends, based on the sign of the sample slope. Wells that did not have significant regression equations were analyzed based on average and maximum nitrate-nitrogen values from the 5-year periods from 1986 through 1990, 1991 through 1995, and 1996 through 2000.

Table 1. Water wells, well type, and owner. "P" indicates a production well and "M" indicates a monitoring well.

Well	Type	Owner	Well	Type	Owner
HGC-3	P	Alte Guam Golf Resort	F-6	P	Guam Waterworks Authority
F-19	P	EarthTech	F-7	P	Guam Waterworks Authority
F-20	P	EarthTech	F-8	P	Guam Waterworks Authority
D-25	P	EarthTech	F-9	P	Guam Waterworks Authority
D-26	P	EarthTech	F-10	P	Guam Waterworks Authority
D-27	P	EarthTech	F-11	P	Guam Waterworks Authority
D-28	P	EarthTech	F-12	P	Guam Waterworks Authority
Y-18	P	EarthTech	F-13	P	Guam Waterworks Authority
Y-19	P	EarthTech	F-15	P	Guam Waterworks Authority
Y-20	P	EarthTech	F-16	P	Guam Waterworks Authority
FM-1	P	Foremost Foods, Inc.	F-17	P	Guam Waterworks Authority
MG-1	M	Guam Int'l. Country Club	F-18	P	Guam Waterworks Authority
MG-2	M	Guam Int'l. Country Club	GH-501	P	Guam Waterworks Authority
MG-3	M	Guam Int'l. Country Club	H-1	P	Guam Waterworks Authority
M-GD	M	Guam Int'l. Country Club	HGC-2	P	Guam Waterworks Authority
A-1	P	Guam Waterworks Authority	M-1	P	Guam Waterworks Authority
A-2	P	Guam Waterworks Authority	M-2	P	Guam Waterworks Authority
A-3	P	Guam Waterworks Authority	M-3	P	Guam Waterworks Authority
A-4	P	Guam Waterworks Authority	M-4	P	Guam Waterworks Authority
A-5	P	Guam Waterworks Authority	M-5	P	Guam Waterworks Authority
A-6	P	Guam Waterworks Authority	M-6	P	Guam Waterworks Authority
A-7	P	Guam Waterworks Authority	M-7	P	Guam Waterworks Authority
A-8	P	Guam Waterworks Authority	M-8	P	Guam Waterworks Authority
A-9	P	Guam Waterworks Authority	M-9	P	Guam Waterworks Authority
A-10	P	Guam Waterworks Authority	M-12	P	Guam Waterworks Authority
A-11	P	Guam Waterworks Authority	M-14	P	Guam Waterworks Authority
A-12	P	Guam Waterworks Authority	M-15	P	Guam Waterworks Authority
A-13	P	Guam Waterworks Authority	M-16B	P	Guam Waterworks Authority
A-14	P	Guam Waterworks Authority	M-17A	P	Guam Waterworks Authority
A-15	P	Guam Waterworks Authority	M-17B	P	Guam Waterworks Authority
A-17	P	Guam Waterworks Authority	M-18	P	Guam Waterworks Authority
A-18	P	Guam Waterworks Authority	M-20A	P	Guam Waterworks Authority
A-19	P	Guam Waterworks Authority	M-21	P	Guam Waterworks Authority
A-21	P	Guam Waterworks Authority	NAS-1	P	Guam Waterworks Authority
A-23	P	Guam Waterworks Authority	Y-1	P	Guam Waterworks Authority
A-25	P	Guam Waterworks Authority	Y-2	P	Guam Waterworks Authority
A-26	P	Guam Waterworks Authority	Y-3	P	Guam Waterworks Authority
A-28	P	Guam Waterworks Authority	Y-4	P	Guam Waterworks Authority
A-29	P	Guam Waterworks Authority	Y-4A	P	Guam Waterworks Authority
A-30	P	Guam Waterworks Authority	Y-5	P	Guam Waterworks Authority
A-31	P	Guam Waterworks Authority	Y-6	P	Guam Waterworks Authority
A-32	P	Guam Waterworks Authority	Y-7	P	Guam Waterworks Authority
AG-1	P	Guam Waterworks Authority	Y-9	P	Guam Waterworks Authority
AG-2	P	Guam Waterworks Authority	Y-10	P	Guam Waterworks Authority
D-1	P	Guam Waterworks Authority	Y-12	P	Guam Waterworks Authority
D-2	P	Guam Waterworks Authority	Y-14	P	Guam Waterworks Authority

(continued)

Table 1 (continued)

Well	Type	Owner	Well	Type	Owner
D-3	P	Guam Waterworks Authority	Y-15	P	Guam Waterworks Authority
D-4	P	Guam Waterworks Authority	MGC-1	P	Mangilao Golf Course
D-5	P	Guam Waterworks Authority	MGC-2	P	Mangilao Golf Course
D-6	P	Guam Waterworks Authority	MGC-3	P	Mangilao Golf Course
D-7	P	Guam Waterworks Authority	MGC-4	P	Mangilao Golf Course
D-8	P	Guam Waterworks Authority	MGC MW-1	M	Mangilao Golf Course
D-9	P	Guam Waterworks Authority	MGC MW-2	M	Mangilao Golf Course
D-10	P	Guam Waterworks Authority	MGC MW-3	M	Mangilao Golf Course
D-11	P	Guam Waterworks Authority	MW-1	P	United States Air Force
D-12	P	Guam Waterworks Authority	MW-2	P	United States Air Force
D-13	P	Guam Waterworks Authority	MW-3	P	United States Air Force
D-14	P	Guam Waterworks Authority	MW-5	P	United States Air Force
D-15	P	Guam Waterworks Authority	MW-6	P	United States Air Force
D-16	P	Guam Waterworks Authority	MW-7	P	United States Air Force
D-17	P	Guam Waterworks Authority	MW-8	P	United States Air Force
D-18	P	Guam Waterworks Authority	NRMC-1	P	United States Navy
D-19	P	Guam Waterworks Authority	NRMC-2	P	United States Navy
D-20	P	Guam Waterworks Authority	NRMC-3	P	United States Navy
D-21	P	Guam Waterworks Authority	NCS-A	P	United States Navy
D-22A	P	Guam Waterworks Authority	NCS-B	P	United States Navy
D-24	P	Guam Waterworks Authority	NCS-2	P	United States Navy
EX-5A	P	Guam Waterworks Authority	NCS-3	P	United States Navy
EX-11	P	Guam Waterworks Authority	NCS-4	P	United States Navy
F-1	P	Guam Waterworks Authority	NCS-5	P	United States Navy
F-2	P	Guam Waterworks Authority	NCS-7	P	United States Navy
F-3	P	Guam Waterworks Authority	NCS-8	P	United States Navy
F-4	P	Guam Waterworks Authority	NCS-9A	P	United States Navy
F-5	P	Guam Waterworks Authority			

Next, maps were constructed using the ArcView GIS© (geographic information system) program. Wells with high or changing nitrate-nitrogen levels were mapped in Figure 3 with subbasins revised from CDM's (1982) original delineations by McDonald (2001) based on updated volcanic contours (Vann, 2000). Additional maps showing well locations relative to groundwater flow paths (based on updated volcanic contours) were used to identify areas where up-gradient land-use activities may potentially contribute to high or rising well nitrate-nitrogen levels.

The final step of the project required an investigation of land-use activities in areas of concern. The Department of Agriculture Natural Resource Conservation Service, University of Guam Cooperative Extension Service, and GEPA provided locations of known farms, piggeries, cattle ranches, and chicken farms. Terrestrial (automobile) and aerial (helicopter) reconnaissance of northern Guam was done to identify unregulated or otherwise unknown land uses that may potentially contribute to groundwater nitrate concentrations. The location of sanitary sewer lines and residences with septic tank/leaching field systems were identified in another Water and Environmental Research Institute (WERI) project (Heitz and Khosrowpanah, in progress), which was also funded by a United States Environmental Protection Agency grant. This project identified houses further than 1000m (328.1 ft) from sewer lines as probably having leaching field/septic tank systems. The location of all potential nitrogen sources were placed in GIS© coverages based on Bureau of Planning 1994 orthophotos, which were mapped in the Guam grid feet system.

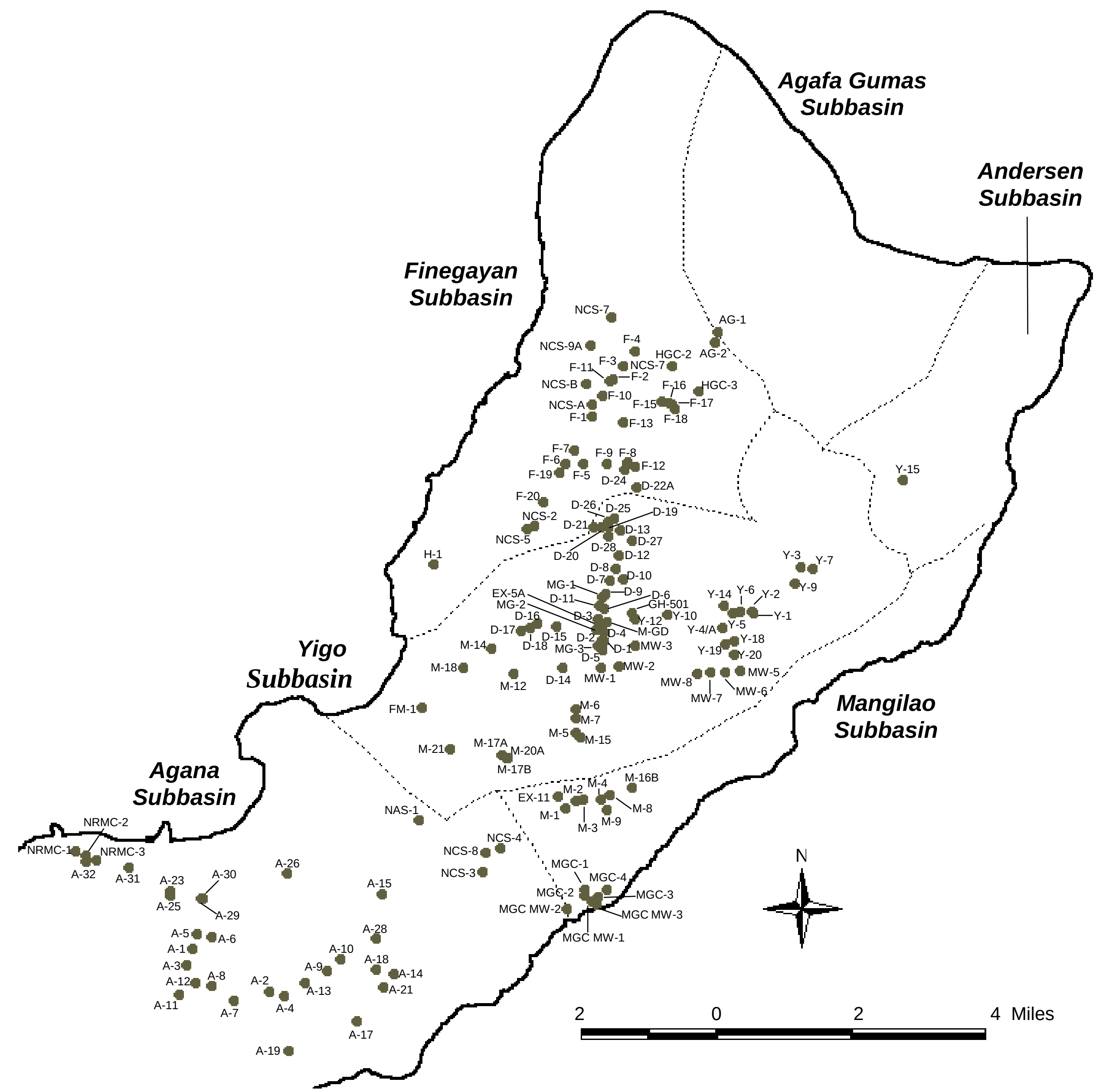

Figure 3. Map of production wells, monitoring wells, and subbasins. Subbasins were revised from CDM (1982) by McDonald (2001) based on updated basement contours (Vann, 2000).

5.0 Results

5.1 Nitrate-nitrogen statistics and trends

Of the 147 wells in the study, 48 had significant regression results at an alpha level of 0.05. Thirty-nine of these wells had increasing trends while the remaining 9 wells had decreasing trends (Table 2). Data records from January 1978 to December 2000 were analyzed.

Table 2. Wells with significant linear regression results at an alpha level of 0.05. "P" indicates a production well and "M" indicates a monitoring well. "r_{calc}" indicates the calculated correlation coefficient and "r_{crit}" refers to the critical correlation coefficient.

Well	Type	Regression Equation	Degrees of Freedom	r_{calc}	r_{crit}
M-GD	M	y = -0.0177x + 2.1552	19	0.548	0.433
A-1	P	y = 0.0053x + 1.0922	32	0.421	0.339
A-4	P	y = 0.0087x + 1.7232	31	0.673	0.344
A-5	P	y = -0.0042x + 2.3198	33	0.439	0.334
A-6	P	y = -0.0045x + 2.3654	33	0.450	0.334
A-23	P	y = -0.0099x + 3.9628	34	0.468	0.329
A-25	P	y = -0.009x + 4.4299	34	0.494	0.329
A-28	P	y = 0.0033x + 1.6157	32	0.361	0.339
A-31	P	y = -0.0044x + 2.8434	25	0.408	0.381
D-6	P	y = 0.0043x + 1.1129	30	0.588	0.349
D-7	P	y = 0.0032x + 1.2293	31	0.422	0.344
D-17	P	y = 0.0101x + 1.3804	34	0.776	0.329
D-19	P	y = 0.0048x + 1.0819	31	0.509	0.344
D-20	P	y = 0.0057x + 1.1843	32	0.475	0.339
D-21	P	y = 0.0093x + 1.7506	32	0.584	0.339
EX-11	P	y = 0.016x + 1.3149	29	0.872	0.355
F-1	P	y = 0.0043x + 0.8413	30	0.665	0.349
F-2	P	y = 0.0017x + 1.0105	30	0.420	0.349
F-3	P	y = 0.004x + 0.9462	30	0.654	0.349
F-4	P	y = -0.0022x + 0.9539	28	0.367	0.361
F-5	P	y = 0.0103x + 1.7139	34	0.793	0.329
F-6	P	y = 0.0085x + 1.2946	31	0.603	0.344
F-7	P	y = 0.0061x + 2.4602	31	0.638	0.344
F-8	P	y = 0.0111x + 1.6234	31	0.786	0.344
F-9	P	y = 0.0097x + 1.35	30	0.808	0.349
F-10	P	y = 0.005x + 1.135	29	0.675	0.355
F-11	P	y = 0.0023x + 0.882	30	0.534	0.349
F-12	P	y = 0.0122x + 2.0865	21	0.556	0.413
F-13	P	y = 0.0347x + 2.3978	8	0.751	0.632
FM-1	P	y = 0.0066x + 2.1882	6	0.716	0.707
GH-501	P	y = 0.0056x + 1.5308	31	0.518	0.344
HGC-2	P	y = -0.004x + 0.7711	14	0.497	0.497
M-1	P	y = 0.0107x + 1.0844	33	0.863	0.334
M-2	P	y = 0.0109x + 1.191	33	0.730	0.334
M-3	P	y = 0.0154x + 1.1759	33	0.907	0.334
M-4	P	y = 0.02x + 1.3423	34	0.900	0.329
M-8	P	y = 0.0138x + 1.4738	33	0.832	0.334
M-9	P	y = 0.0135x + 1.3147	32	0.879	0.339

(continued)

Table 2 (continued)

Well	Type	Regression Equation	Degrees of Freedom	r_{calc}	r_{crit}
M-14	P	y = 0.0117x + 2.0851	34	0.739	0.329
M-15	P	y = 0.0088x + 1.1646	33	0.687	0.334
M-16B	P	y = 0.013x + 1.6885	26	0.800	0.374
M-17B	P	y = 0.0028x + 2.0357	24	0.451	0.388
MGC-4	P	y = 0.0114x + 1.4159	68	0.616	0.235
NCS-A	P	y = 0.0033x + 1.6461	1	0.9999	0.9970
NCS-2	P	y = 0.0115x + 1.508	3	0.8898	0.878
Y-4	P	y = -0.018x + 3.4535	10	0.600	0.576
Y-4A	P	y = 0.01x + 2.4795	5	0.810	0.755
Y-5	P	y = 0.0073x + 2.0837	31	0.529	0.344

Nitrate-nitrogen linear trends are mapped with average concentrations of each well's entire sampling record in Figure 4. (Raw nitrate-nitrogen data are listed in Appendix A while statistics for the wells' available sampling records are listed in Appendix B.) With the exception of two wells, average nitrate-nitrogen concentrations from 1978 to 2000 were below 4 mg/l. MGC-1 (in the Mangilao Subbasin) had an average concentration of 4.18 mg/l, while NCS-4 (in the Agana Subbasin) had a mean level of 20.9 mg/l. NCS-4's extreme value was the only available nitrate-nitrogen concentration for this well, and this sample was taken for fiscal year 1993. NCS-3, the well closest in proximity to NCS-4, was sampled at the same time and reported a nitrate-nitrogen level of 0.35 mg/l. In the late 1990s, neighboring wells NCS-3 and NCS-8 had nitrate-nitrogen levels less than 2 mg/l. Thus, NCS-4's concentration may be anomalous (due to extreme localization of a nitrogen source) or due to sampling or laboratory error.

Average values describe a data set's central tendency, but the nature of nitrate-nitrogen's acute health effects requires scrutiny of maximum concentrations. Figure 5 displays maximum nitrate-nitrogen levels and linear trends, both calculated using each well's full sampling records. Twenty-eight wells had maximum levels greater than or equal to 4 mg/l. Twenty-two of these wells had maximum concentrations between 4 and 4.99 mg/l, while the remaining six wells had maximum concentrations over 5 mg/l. These wells are discussed by subbasin in subsequent sections.

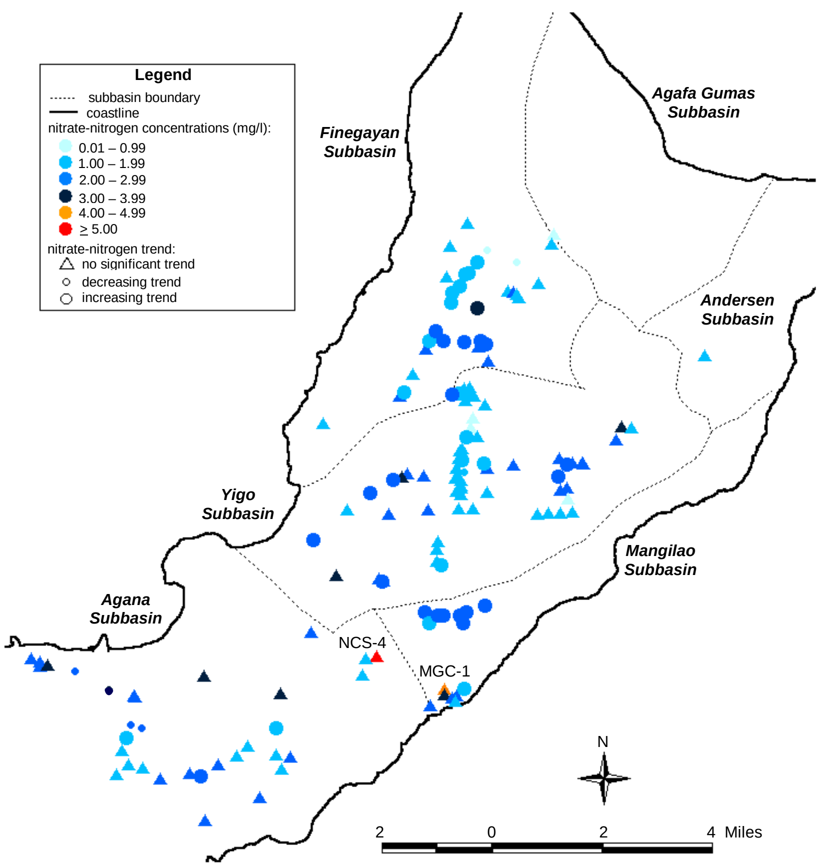

Figure 4. Average nitrate-nitrogen concentrations and linear trends (at an alpha value of 0.05) calculated from each well's full sampling record. Wells with concentrations greater than or equal to 4 mg/l are identified.

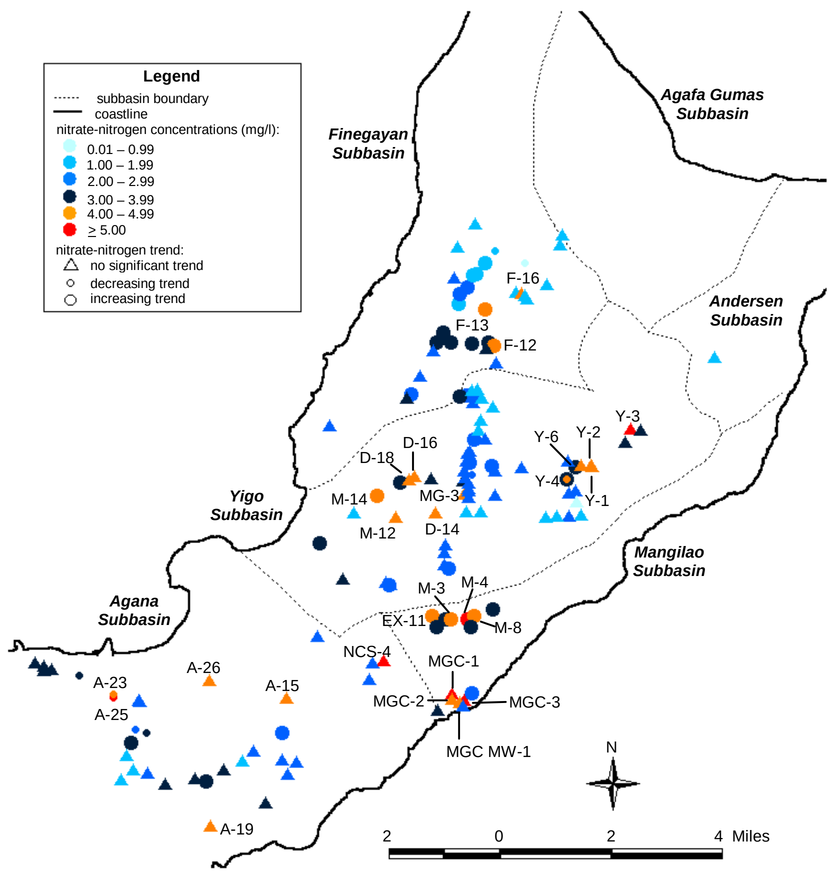

Figure 5. Maximum nitrate-nitrogen concentrations and linear trends (at an alpha value of 0.05) calculated from each well's full sampling record. Wells with concentrations greater than or equal to 4 mg/l are identified.

In addition to statistics and trends over a well's entire sampling record, temporal changes in nitrate-nitrogen concentrations were calculated in 5-year intervals (1986 to 1990, 1991 to 1995, and 1996 to 2000). Table 3 contains the number of wells with average and maximum concentrations in fixed concentration intervals during the three 5-year periods. Figures 6 through 11 map the same data. The number of water wells increased in each 5-year period. However, the number of wells with average and maximum concentrations greater than or equal to 4 mg/l was lowest in the 5-year period from 1991 to 1995 (with the exception of well NCS-4). Well nitrate-nitrogen statistics are discussed in detail, by subbasin, in subsequent sections.

Table 3. The number of water wells with average and maximum nitrate-nitrogen concentrations in specific intervals during the periods from 1986 to 1990, 1991 to 1995, and 1996 to 2000. Wells with concentrations over 4.00 mg/l are identified in italics.

	average concentration (mg/l)			maximum concentration (mg/l)		
time period / concentration (mg/l)	1986-1990	1991-1995	1996-2000	1986-1990	1991-1995	1996-2000
0.01 - 0.99	**7**	**8**	**9**	**1**	**5**	**5**
1.00 - 1.99	**52**	**56**	**49**	**31**	**35**	**30**
2.00 - 2.99	**29**	**45**	**49**	**40**	**39**	**51**
3.00 - 3.99	**7**	**6**	**25**	**12**	**29**	**33**
4.00 - 4.99	**2** *A-25* *A-26*	**1** *MGC-1*	**3** *A-16* *M-4* *MGC-1*	**11** *A-15* *A-23* *A-26* *D-14* *D-16* *D-18* *M-12* *Y-1* *Y-2* *Y-4* *Y-6*	**8** *A-15* *A-19* *A-23* *A-25* *MG-3* *MGC-1* *MGC-2* *MGC MW-1*	**13** *A-15* *A-25* *A-26* *D-14* *EX-11* *F-12* *F-13* *F-16* *M-3* *M-8* *M-14* *MGC-2* *MGC MW-1*
≥5.00	**0**	**1** *NCS-4*	**0**	**2** *A-25* *Y-3*	**1** *NCS-4*	**3** *M-4* *MGC-1* *MGC-3*
number of wells sampled	**97**	**117**	**135**	**97**	**117**	**135**

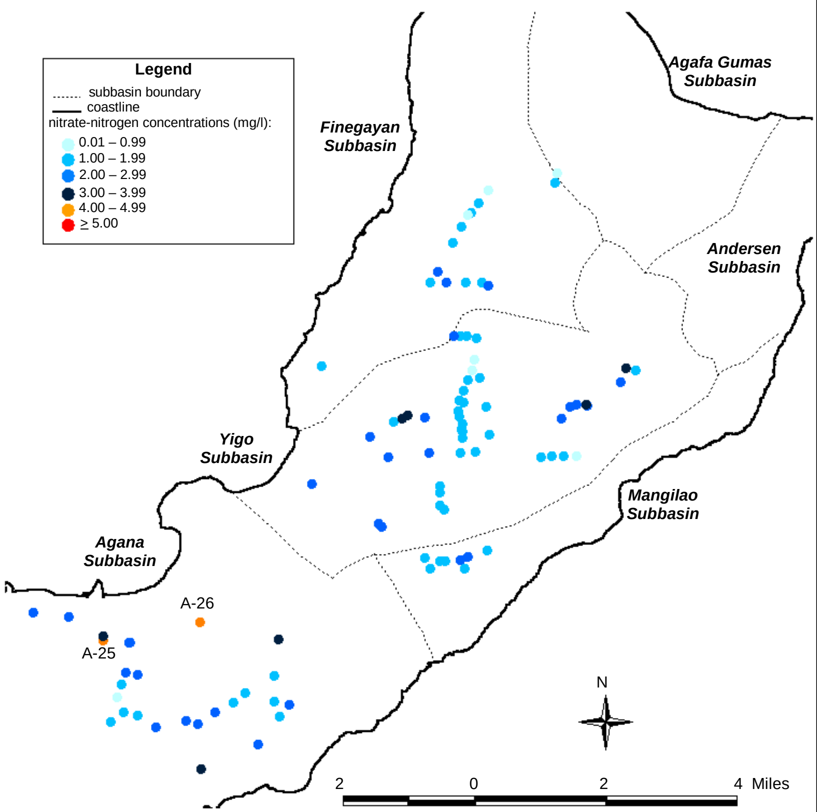

Figure 6. Average nitrate-nitrogen concentrations for the period from 1986-1990. Wells with concentrations greater than or equal to 4 mg/l are identified.

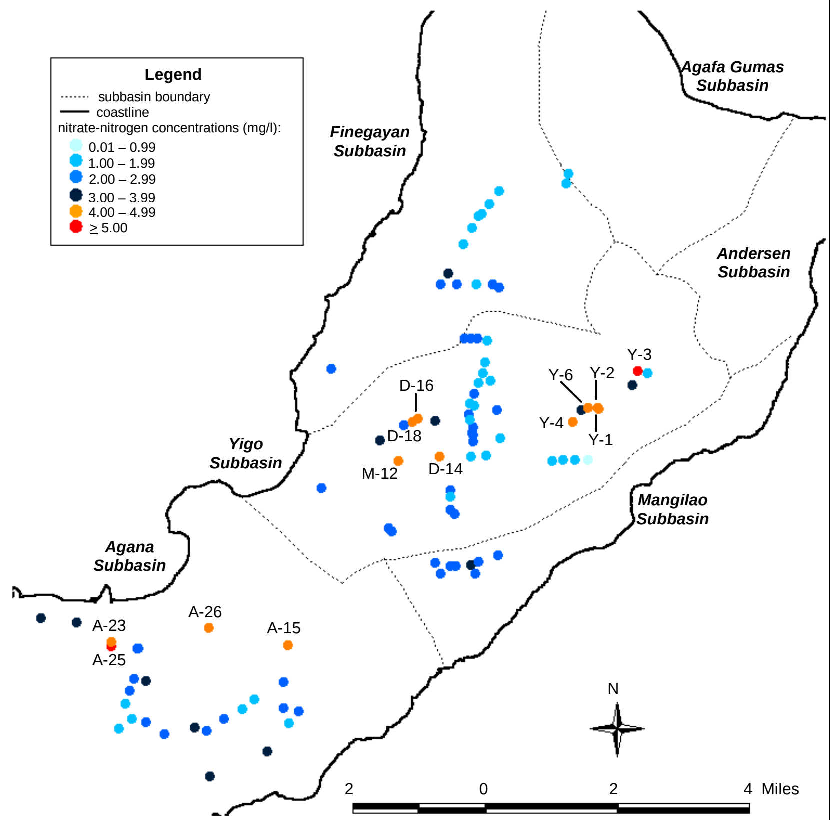

Figure 7. Maximum nitrate-nitrogen concentrations for the period from 1986-1990. Wells with concentrations greater than or equal to 4 mg/l are identified.

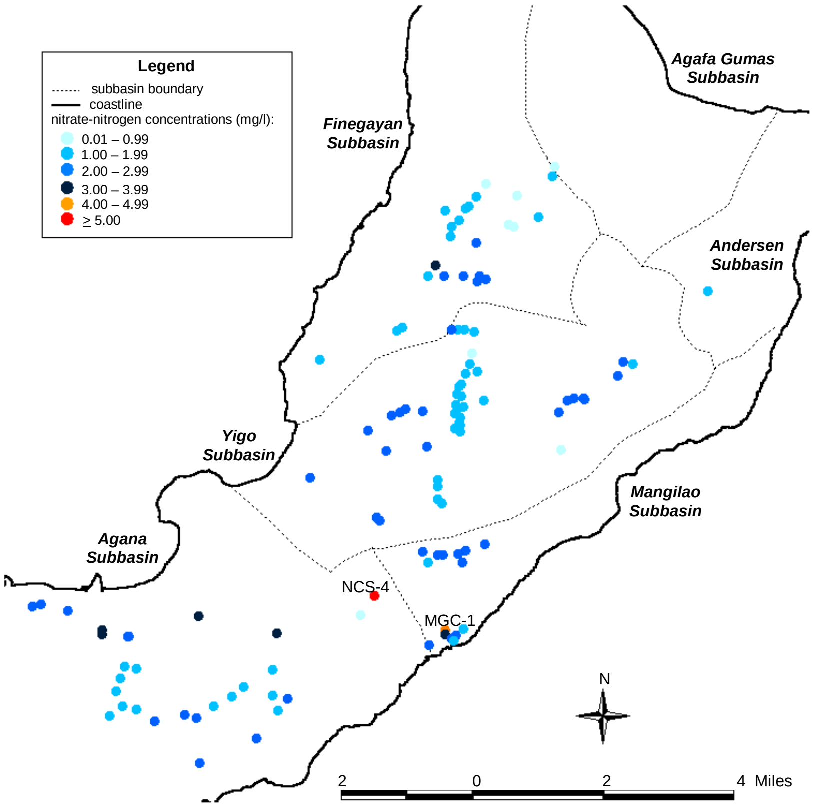

Figure 8. Average nitrate-nitrogen concentrations for the period from 1991 to 1995. Wells with concentrations greater than or equal to 4 mg/l are identified.

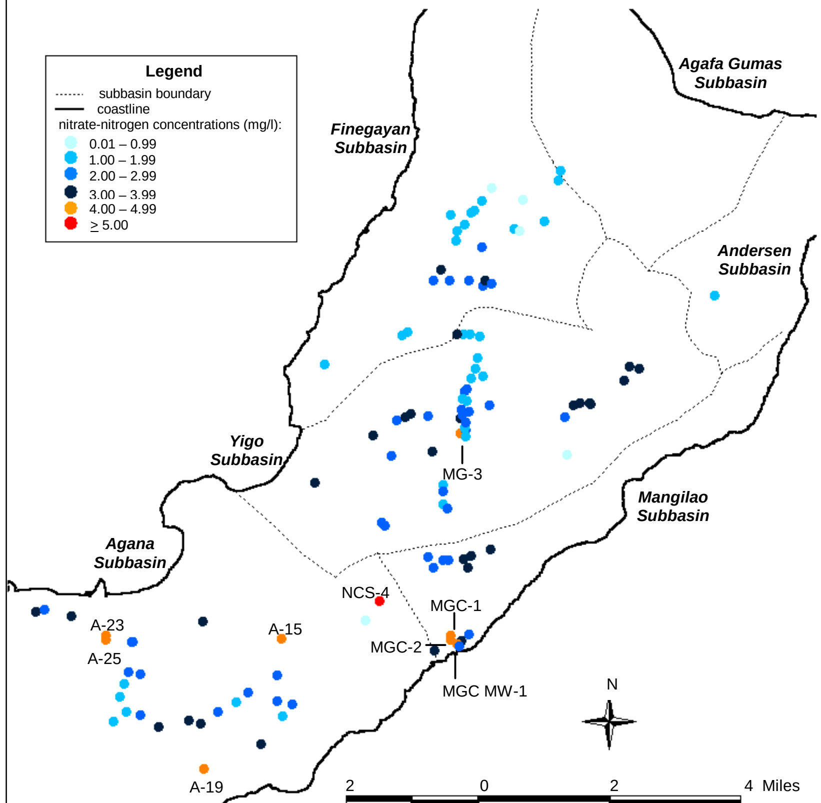

Figure 9. Maximum nitrate-nitrogen concentrations for the period from 1991 to 1995. Wells with concentrations greater than or equal to 4 mg/l are identified.

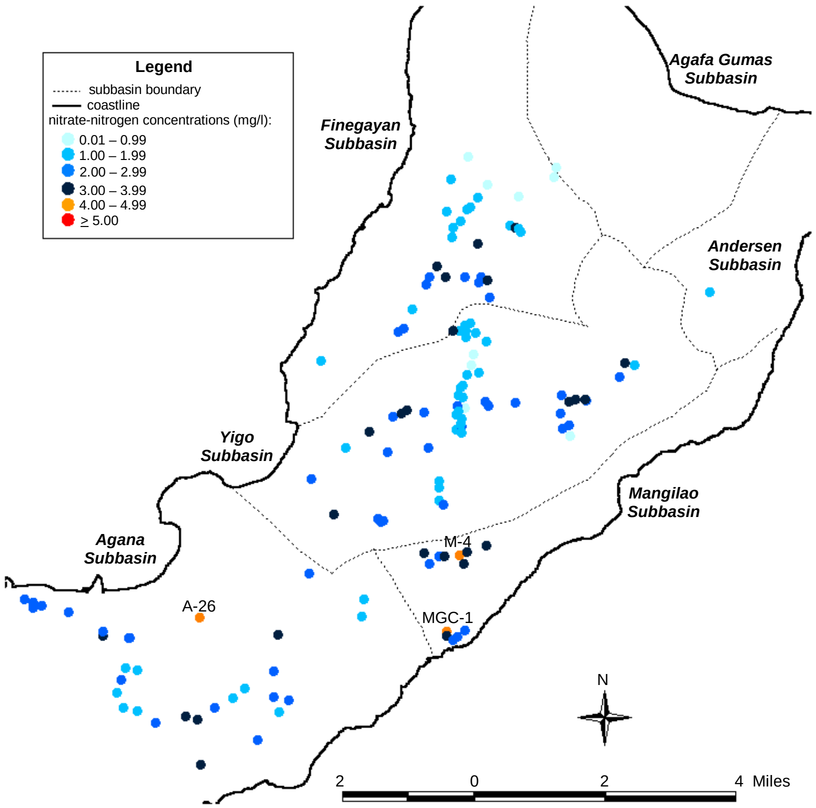

Figure 10. Average nitrate-nitrogen concentrations for the period from 1996 to 2000. Wells with concentrations greater than or equal to 4 mg/l are identified.

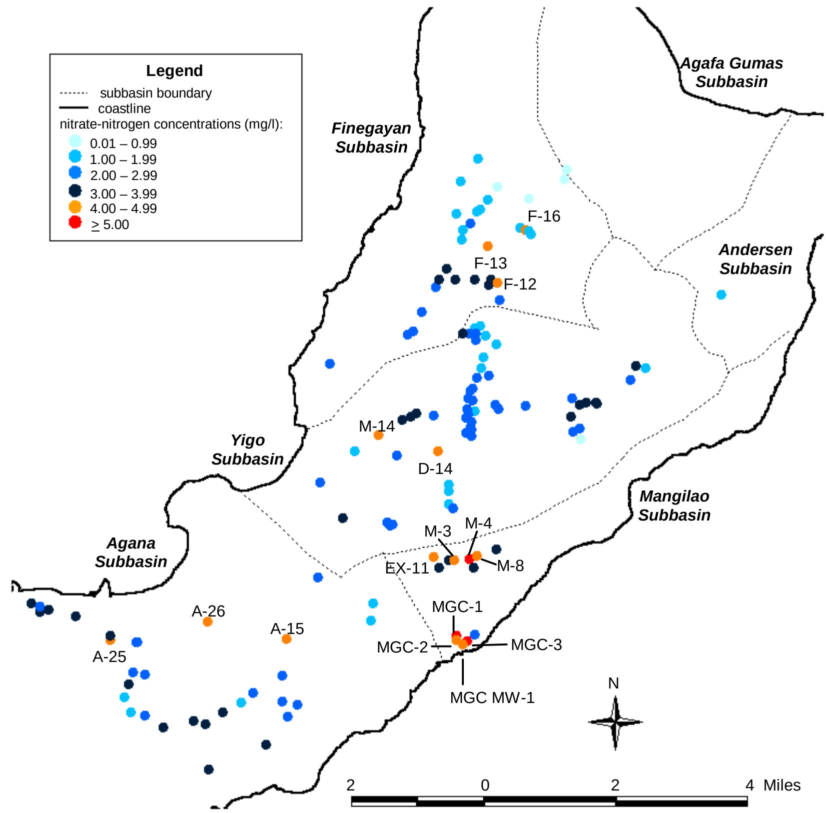

Figure 11. Maximum nitrate-nitrogen concentrations for the period from 1996 to 2000. Wells with concentrations greater than or equal to 4 mg/l are identified.

5.2 Nitrate-nitrogen concentrations by subbasin

5.2.1 Agafa Gumas and Andersen Subbasins

The two wells in the Agafa Gumas and Andersen Subbasins (AG-1 and Y-15) have maintained nitrate-nitrogen concentrations less than 2.99 mg/l, on average, and show no significant linear trend. As listed in Table 4, AG-1's average and maximum nitrate-nitrogen concentrations decreased from the 1991-1995 period to the 1996-2000 period. However, Y-15's 5-year average and maximum concentrations both increased from the 1991-1995 period to the 1996-2000 period.

Table 4. Full-record linear trends and average and maximum nitrate nitrogen concentrations over 5-year periods for Agafa Gumas and Andersen Subbasin wells. Blank entries indicate that the linear trend was not significant at an alpha level of 0.05 or that data were unavailable for a given time period.

		average concentration (mg/l)			maximum concentration (mg/l)		
well	linear trend	1986-1990	1991-1995	1996-2000	1986-1990	1991-1995	1996-2000
AG-1		0.92	0.96	0.44	1.12	1.13	0.68
Y-15			1.22	1.45		1.22	1.86

↑: statistically increasing nitrate-nitrogen concentrations over the entire period of record
↓: statistically increasing nitrate-nitrogen concentrations over the entire period of record
no arrow sign indicates that nitrate-nitrogen concentrations did not exhibit a significant linear trend over the entire period of record

5.2.2 Yigo Subbasin

Full-record average nitrate-nitrogen concentrations at Yigo Subbasin's 65 wells ranged from 1 to 3.99 mg/l (see Figure 4). As listed in Table 5, 13 wells (D-6, D-7, D-17, D-19, D-20, D-21, FM-1, GH-501, M-14, M-15, M-17B, Y-4A, and Y-5) had increasing trends while 2 wells (MG-D and Y-4) had decreasing trends. Interestingly, Y-4 had a decreasing trend while Y-4A had an increasing trend. Y-4A replaced Y-4 in 1994 and was drilled a few feet away from Y-4.

Table 5. Full-record linear trends and average and maximum nitrate nitrogen concentrations over 5-year periods for Yigo Subbasin wells. Blank entries indicate that the linear trend was not significant at an alpha level of 0.05 or that data were unavailable for a given time period.

		average concentration (mg/l)			maximum concentration (mg/l)		
well	linear trend	1986-1990	1991-1995	1996-2000	1986-1990	1991-1995	1996-2000
D-1		1.84	1.62	2.01	2.87	2.16	2.20
D-2		1.73	1.60	1.97	2.05	1.99	2.30
D-3		1.65	1.70	2.21	2.21	2.13	2.68
D-4		1.72	1.67	1.88	2.19	2.12	2.20
D-5		1.55	1.32	1.51	2.23	1.77	2.20
D-6	↑	1.29	1.43	1.87	1.66	1.76	2.40
D-7	↑	1.34	1.51	1.60	1.76	1.81	2.10
D-8		0.95	1.00	0.74	1.26	1.14	1.40
D-9		1.66	1.77	1.81	2.04	2.17	2.30
D-10		1.47	1.62	1.60	1.81	1.82	2.40
D-11		1.57	1.66	1.67	1.80	1.98	2.60
D-12		0.92	0.97	0.73	1.11	1.13	1.20
D-13		1.22	1.28	1.25	1.83	1.56	1.70
D-14		2.98	2.50	2.83	4.94	3.37	4.20
D-15		2.42	2.15	2.57	3.60	2.62	2.85

(continued)

Table 5 (continued)

		average concentration (mg/l)			maximum concentration (mg/l)		
well	linear trend	1986-1990	1991-1995	1996-2000	1986-1990	1991-1995	1996-2000
D-16		3.14	2.81	3.11	4.39	3.62	3.70
D-17	↑	1.75	2.16	2.97	2.14	2.97	3.80
D-18		3.11	2.86	3.33	4.80	3.31	3.60
D-19	↑	1.19	1.56	1.68	2.30	1.72	2.20
D-20	↑	1.35	1.70	1.97	2.96	1.99	2.50
D-21	↑	2.05	2.51	3.28	2.96	3.17	3.95
D-25				1.30			1.50
D-26				1.65			1.80
D-27				1.64			1.67
D-28				1.86			2.00
EX-5A		1.48	1.69	1.91	1.83	2.01	2.60
FM-1	↑	2.20	2.95	2.60	2.50	3.15	2.60
GH-501	↑	1.76	1.96	2.42	2.63	2.23	2.72
M-5		1.34	1.30	1.16	2.08	1.42	1.40
M-6		1.55	1.49	1.42	2.53	1.77	1.78
M-7		1.22	1.47	1.35	1.98	2.90	1.90
M-12		2.66	2.68	2.75	4.20	2.97	2.80
M-14	↑	2.53	2.95	3.95	3.86	3.31	4.20
M-15	↑	1.50	1.80	2.69	2.28	2.13	2.90
M-17A		2.07	2.03	2.19	2.18	2.55	2.30
M-17B	↑	2.14	2.09	2.40	2.35	2.53	2.50
M-18				1.49			1.50
M-20A				2.35			2.50
M-21				3.50			3.50
MG-1			1.08	1.33		2.14	2.46
MG-2			1.45	1.49		3.40	2.38
MG-3			1.57	1.60		4.90	2.35
M-GD	↓		1.79	0.94		2.30	1.87
MW-1		1.48			1.48		
MW-2		1.37			1.37		
MW-3		1.87			1.87		
MW-5		0.80			0.80		
MW-6		1.44	0.52		1.44	0.52	
MW-7		1.04			1.04		
MW-8		1.06			1.06		
Y-1		2.91	2.60	2.95	4.17	3.15	3.62
Y-2		3.07	2.76	3.22	4.34	3.23	3.88
Y-3		3.20	2.77	3.21	5.37	3.64	3.46
Y-4	↓	2.93	1.41		4.35	1.41	
Y-4A	↑		2.56	2.86		2.77	3.21
Y-5	↑	2.26	2.77	3.26	3.38	3.23	3.58
Y-6		2.94	2.98	3.12	4.61	3.68	3.70
Y-7		1.34	1.37	1.36	1.93	3.23	1.86
Y-9		2.07	2.25	2.30	3.02	3.01	2.34
Y-10				2.61			2.61
Y-12				2.08			2.38
Y-14				2.60			2.60

(continued)

Table 5 (continued)

		average concentration (mg/l)			maximum concentration (mg/l)		
well	linear trend	1986-1990	1991-1995	1996-2000	1986-1990	1991-1995	1996-2000
Y-18				2.10			2.10
Y-19				2.60			2.60
Y-20				0.90			0.90

↑: statistically increasing nitrate-nitrogen concentrations over the entire period of record
↓: statistically increasing nitrate-nitrogen concentrations over the entire period of record
no arrow sign indicates that nitrate-nitrogen concentrations did not exhibit a significant linear trend over the entire period of record

The remaining 50 wells did not have significant trends and their 5-year average and maximum concentrations generally fluctuate as a result of data variability. However, four wells (D-9, D-11, EX-5A, and MG-1) had both average and maximum values that increased in 5-year periods. D-3 and Y-6 had 5-year average concentrations that increased, while D-10 and D-12 had maximum levels that increased in the 5-year periods. Four wells (M-12, MG-2, MG-3, and Y-9) had average concentrations that increased, but maximum concentrations that decreased in the 5-year periods. M-6's 5-year average decreased. Y-3 had maximum 5-year levels that decreased. Two wells had average and maximum values that decreased in 5-year periods (M-5 and MW-6).

Maximum values in the Yigo Subbasin climbed as high as 5.37 mg/l (at well Y-3 in June 1987). Although a number of wells have statistically increasing nitrate-nitrogen trends, the maximum values reported during the period from 1986 to 1990 were the most extreme of the 5-year periods. Of current interest are wells with maximum values nearing 5 mg/l during the most recent time period (1996-2000). Wells D-14 and M-14 had maximum concentrations over 4 mg/l in the period from 1996 to 2000 (see Figure 11).

5.2.3 Finegayan Subbasin

Sixteen of the 32 wells in the Finegayan Subbasin had significant linear trends over their full nitrate-nitrogen record (see Table 6). Of these trends, fourteen were increasing (wells F-1, F-2, F-3, F-5, F-6, F-7, F-8, F-9, F-10, F-11, F-12, F-13, NCS-2, and NCS-A) while 2 were decreasing trends (wells F-4 and HGC-2). The remaining 16 wells in the subbasin had insignificant linear trend results.

Of the wells with insignificant linear trend results, four (D-24, F-15, F-16, and NCS-5) had average and maximum concentrations that increased in 5-year periods. Only one well with insignificant trend results, NCS-B, had decreasing 5-year average and maximum levels. Nitrate-nitrogen levels in the Finegayan Subbasin did not exceed 4 mg/l until the period from 1996 to 2000, with wells F-12, F-13, and F-16 (see Figure 11).

Table 6. Full-record linear trends and average and maximum nitrate nitrogen concentrations over 5-year periods for Finegayan Subbasin wells. Blank entries indicate that the linear trend was not significant at an alpha level of 0.05 or that data were unavailable for a given time period.

		average concentration (mg/l)			maximum concentration (mg/l)		
well	linear trend	1986-1990	1991-1995	1996-2000	1986-1990	1991-1995	1996-2000
AG-2		1.29	1.38	0.74	1.62	1.71	0.74
D-22A				2.20			2.20
D-24			2.23	2.31		2.23	3.00
F-1	↑	1.02	1.16	1.57	1.40	1.34	1.90
F-2	↑	1.08	1.16	1.15	1.39	1.40	1.42
F-3	↑	1.09	1.29	1.45	1.52	1.53	1.61

(continued)

Table 6 (continued)

well	linear trend	average concentration (mg/l)			maximum concentration (mg/l)		
		1986-1990	1991-1995	1996-2000	1986-1990	1991-1995	1996-2000
F-4	↓	0.91	0.76	0.49	1.33	0.87	0.80
F-5	↑	2.04	2.60	3.25	2.58	2.91	3.50
F-6	↑	1.62	1.98	2.46	2.31	2.70	3.00
F-7	↑	2.62	3.10	3.06	3.36	3.42	3.41
F-8	↑	1.97	2.69	2.95	2.58	3.08	3.72
F-9	↑	1.66	2.12	2.91	1.98	2.37	3.20
F-10	↑	1.29	1.60	1.71	1.75	1.96	2.03
F-11	↑	0.99	1.04	1.38	1.17	1.11	1.45
F-12	↑	2.41	2.40	3.45	2.69	2.86	4.06
F-13	↑		2.23	3.65		2.33	4.35
F-15			0.98	1.08		1.01	1.45
F-16			0.89	3.10		0.95	4.40
F-17				1.03			1.26
F-18				1.20			1.49
F-19				2.00			2.00
F-20				1.80			2.10
H-1		1.85	1.67	1.85	2.07	1.95	2.10
HGC-2	↓		0.68	0.28		0.82	0.69
HGC-3			1.25			1.27	
NCS-2	↑		1.54	2.20		1.58	2.30
NCS-5			1.81	2.23		1.81	2.70
NCS-7				0.93			1.00
NCS-9A				1.37			1.40
NCS-A	↑		1.65	1.90		1.65	1.90
NCS-B			1.50	1.40		1.50	1.40

↑: statistically increasing nitrate-nitrogen concentrations over the entire period of record
↓: statistically increasing nitrate-nitrogen concentrations over the entire period of record
no arrow sign indicates that nitrate-nitrogen concentrations did not exhibit a significant linear trend over the entire period of record

5.2.4 Mangilao Subbasin

The Mangilao Subbasin contains 15 wells, 9 of which had increasing linear trends over their complete nitrate-nitrogen record. These include all of the 8 GWA wells (EX-11, M-1, M-2, M-3, M-4, M-8, M-9, and M-16B) and MGC-4 (see Table 7). Of the six wells with insignificant trend results, 2 (MGC MW-1 and MGC-3) had increasing average and maximum 5-year levels. MGC-1's 5-year average levels decreased while the maximum values increased. MGC-2 had both average and maximum 5-year concentrations that decreased.

Table 7. Full-record linear trends and average and maximum nitrate nitrogen concentrations over 5-year periods for Mangilao Subbasin wells. Blank entries indicate that the linear trend was not significant at an alpha level of 0.05 or that data were unavailable for a given time period.

well	linear trend	average concentration (mg/l)			maximum concentration (mg/l)		
		1986-1990	1991-1995	1996-2000	1986-1990	1991-1995	1996-2000
EX-11	↑	1.91	2.58	3.74	2.50	2.88	4.70
M-1	↑	1.45	1.97	2.71	2.08	2.19	3.40

(continued)

Table 7 (continued)

well	linear trend	average concentration (mg/l) 1986-1990	average concentration (mg/l) 1991-1995	average concentration (mg/l) 1996-2000	maximum concentration (mg/l) 1986-1990	maximum concentration (mg/l) 1991-1995	maximum concentration (mg/l) 1996-2000
M-2	↑	1.50	2.15	2.83	2.54	2.49	3.30
M-3	↑	1.73	2.44	3.52	2.46	2.87	4.00
M-4	↑	2.11	2.92	4.32	3.60	3.59	5.00
M-8	↑	2.00	2.59	3.48	2.86	3.22	4.40
M-9	↑	1.83	2.35	3.36	2.67	3.01	3.90
M-16B	↑	1.96	2.45	3.53	2.35	3.06	3.53
MGC MW-1			2.29	2.42		4.00	4.26
MGC MW-2			2.35			3.47	
MGC MW-3			1.60			2.50	
MGC-1			4.23	4.13		4.90	5.73
MGC-2			3.92	3.83		4.85	4.84
MGC-3			2.13	2.98		3.80	20.00
MGC-4	↑		1.61	2.08		2.96	2.72

↑: statistically increasing nitrate-nitrogen concentrations over the entire period of record
↓: statistically increasing nitrate-nitrogen concentrations over the entire period of record
no arrow sign indicates that nitrate-nitrogen concentrations did not exhibit a significant linear trend over the entire period of record

Nitrate-nitrogen levels over 4 mg/l have been detected since the 1991-1995 period at wells MGC-1 and MGC-2. (see Figure 9). Mangilao Golf Course production and monitoring wells have spiked over 4 mg/l since 1991, with MGC-1 averaging over 4 mg/l from 1991 to 2000 (see Figures 8 and 10). The cluster of GWA wells also exhibited nitrate-nitrogen levels over 4 mg/l. EX-11, M-3, and M-8 had maximum levels between 4 and 4.99 mg/l, while M-4 spiked over 5 mg/l in the 5-year period from 1996 to 2000.

5.2.5 Agana Subbasin

Eight of the 34 wells in the Agana Subbasin had significant trend results. As noted in Table 8, three wells (A-1, A-4, and A-28) had increasing trends. Five wells (A-5, A-6, A-23, A-25, and A-31) had decreasing trends.

Table 8. Full-record linear trends and average and maximum nitrate nitrogen concentrations over 5-year periods for Agana Subbasin wells. Blank entries indicate that the linear trend was not significant at an alpha level of 0.05 or that data were unavailable for a given time period.

well	linear trend	average concentration (mg/l) 1986-1990	average concentration (mg/l) 1991-1995	average concentration (mg/l) 1996-2000	maximum concentration (mg/l) 1986-1990	maximum concentration (mg/l) 1991-1995	maximum concentration (mg/l) 1996-2000
A-1	↑	1.39	1.32	2.27	2.04	1.71	3.10
A-2		2.64	2.55	3.17	3.12	3.58	3.96
A-3		0.93	1.18	1.05	1.20	1.81	1.20
A-4	↑	2.08	2.35	3.14	2.87	3.05	3.66
A-5	↓	2.19	1.93	1.80	2.77	2.78	2.21
A-6	↓	2.23	1.94	1.82	3.03	2.99	2.52
A-7		2.43	2.53	2.58	2.87	3.34	3.14
A-8		1.84	1.83	1.72	2.28	2.37	2.00
A-9		1.38	1.32	1.10	1.58	1.92	1.70
A-10		1.48	1.60	1.96	1.91	2.28	2.90
A-11		1.12	1.18		1.57	1.77	
A-12		1.12	1.26	1.08	1.66	1.83	1.77

(continued)

Table 8 (continued)

		average concentration (mg/l)			maximum concentration (mg/l)		
well	linear trend	1986-1990	1991-1995	1996-2000	1986-1990	1991-1995	1996-2000
A-13		2.02	1.95	2.34	2.49	2.41	3.62
A-14		2.05	2.11	2.27	2.39	2.78	2.87
A-15		3.62	3.44	3.79	4.91	4.33	4.00
A-17		2.79	2.56	2.89	3.40	3.37	3.83
A-18		1.87	1.80	2.02	2.22	2.45	2.49
A-19		3.07	2.70	3.22	3.61	4.12	3.94
A-21		1.21	1.27	1.47	1.58	1.52	2.35
A-23	↓	3.64	3.06	2.64	4.69	4.06	3.62
A-25	↓	4.22	3.39	3.59	5.27	4.32	4.00
A-26		4.09	3.35	4.60	4.66	3.97	4.90
A-28	↑	1.73	1.89	2.11	2.04	2.21	2.94
A-29		2.58	2.20	2.17	2.58	2.69	2.52
A-30		2.82	2.48	2.55	2.92	2.99	2.94
A-31	↓	2.83	2.62	2.45	3.01	3.06	3.10
A-32		2.60	2.82	2.55	3.02	3.44	3.59
NAS-1				2.06			2.32
NCS-3			0.35	1.55		0.35	1.70
NCS-4			20.90			20.90	
NCS-8				1.47			1.70
NRMC-1				2.67			3.20
NRMC-2				2.40			2.50
NRMC-3			2.71	2.93		2.71	3.20

↑: statistically increasing nitrate-nitrogen concentrations over the entire period of record
↓: statistically increasing nitrate-nitrogen concentrations over the entire period of record
no arrow sign indicates that nitrate-nitrogen concentrations did not exhibit a significant linear trend over the entire period of record

The remaining 26 wells had insignificant trend results. Of these wells, five (A-10, A-11, A-14, NCS-3, and NRMC-3) had both average and maximum levels that increased in 5-year periods, though A-11 was shut down after 1995. A-7 and A-21 had increasing 5-year averages, while A-2, A-18, and A-32 had increasing 5-year maximum concentrations. A-8, A-9, and A-29 had decreasing 5-year averages while A-15 had decreasing 5-year maximum levels.

Wells A-15, A-23, A-25, and A-26 exhibited concentrations greater than or equal to 4 mg/l since 1986 (see Figures 7, 9, and 11). Although NCS-4's single nitrate-nitrogen level was reported at 20.9 mg/l, concentrations at nearby wells lead to the possibility that NCS-4's high level was due to extreme localization of a nitrogen source or due to sampling or laboratory error.

5.3 Areas of concern

Water well maximum concentrations over the full nitrate-nitrogen record were mapped over volcanic contours (Vann, 2000) to identify areas where surface activities could affect downgradient groundwater nitrate-nitrogen concentrations (Figure 12). Areas of concern were delineated to include the area from subbasin boundaries at a subbasin's highest volcanic basement elevations to the lowest volcanic elevations where wells with statistically rising nitrate-nitrogen concentrations or with maximum concentrations greater than or equal to 4 mg/l were located.

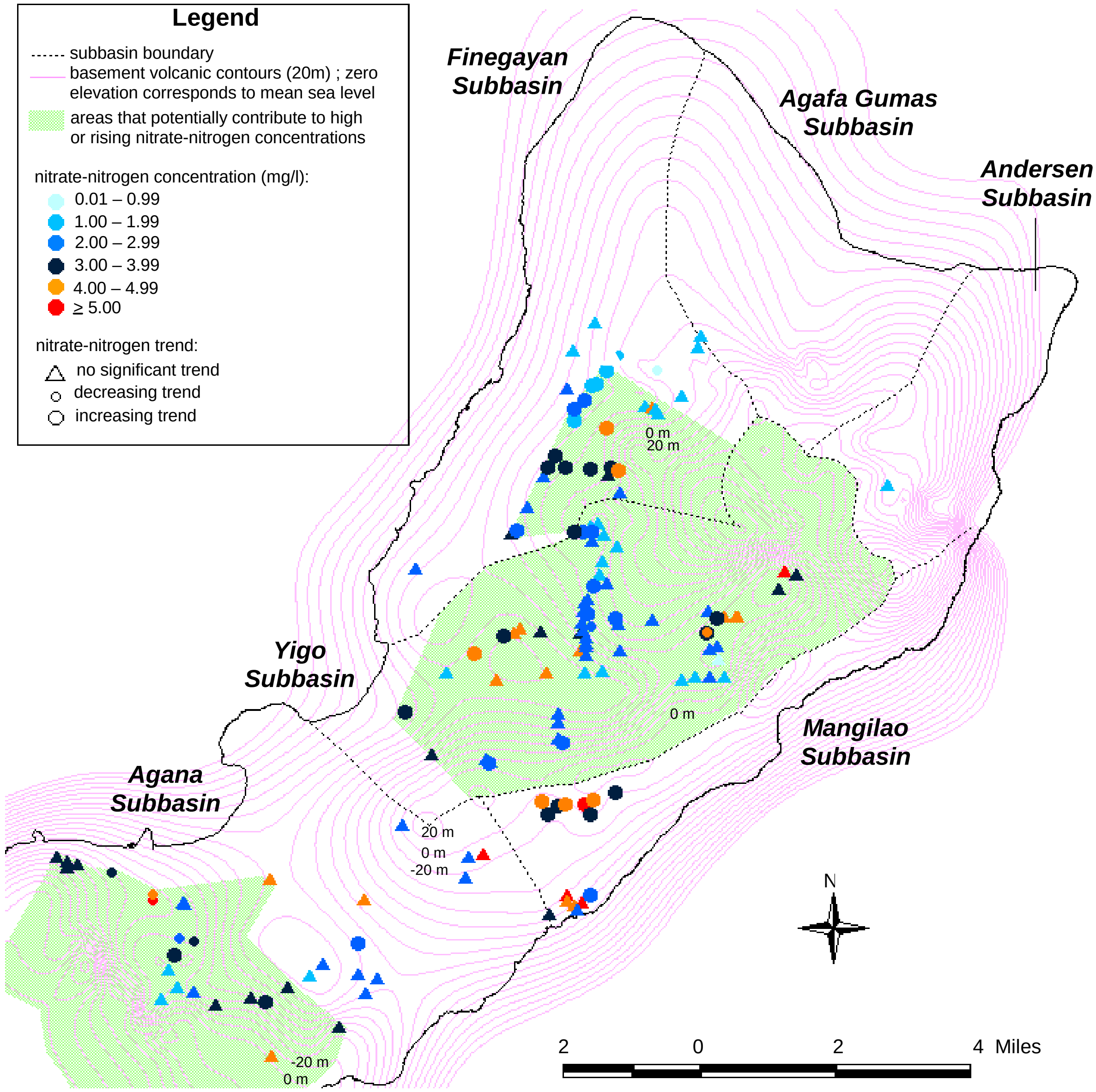

Figure 12. Map of areas where surface activities could influence downgradient groundwater nitrate-nitrogen concentrations. Concentrations shown are maximum levels over the wells' complete nitrate-nitrogen record.

5.4 Potential nitrogen sources

The locations of potential nitrogen sources were identified through aerial and terrestrial surveys of northern Guam. Approximately 15,500 septic tank/leaching field systems (Heitz and Khosrowpanah, in progress), sewer lines, 96 agricultural areas (farms), 21 piggeries, 1 chicken farm, 6 fish farms, 8 cattle pastures, 6 golf courses, and 81 ponding basins were identified. These potential nitrogen sources were mapped on 1994 Government of Guam Bureau of Planning orthophotos, as shown on Plate 1. Many households on Guam maintain personal gardens, ranches, and farm animals that were not discernible from the air or the road, therefore the number in each of these categories are minimum values. Small-sized nitrate sources would only be located by door-to-door surveys. As this study is a qualitative one, quantitative data (such as land area and the number of animals per farm) were not identified.

Dye-tracing and isotope testing would be required to determine hydraulic relationships between potential nitrogen sources and downgradient sites, such as water wells. However, groundwater flow paths, well locations, nitrate-nitrogen concentrations, and overland activities can be used to draw preliminary conclusions. An example of this is the cluster of GWA wells with rising nitrate-nitrogen concentrations in the Mangilao Subbasin where overland and upgradient land activities are primarily septic tank/leaching field systems with small-scale agriculture. The wells are located near the volcanic basement ridge, over volcanic highlands (see Figure 12), so there is a defined land area that can contribute to nitrate-nitrogen concentrations in the groundwater intercepted by these wells.

Investigation of nitrogen sources to wells located closer to the coast would be more difficult due to the potential for mixing of groundwater high in nitrates with groundwater low in nitrates (Howard, 1985), the influence of large rainfall events which transport nitrogen to the lens (Matson, 1991), and the hydraulic properties of the northern Guam aquifer. The aquifer contains numerous faults and closed contour depressions (sinkholes) that should be considered when studying groundwater flow. Closed contour depressions were catalogued (Taborosi, 2000) and are mapped in Figure 13.

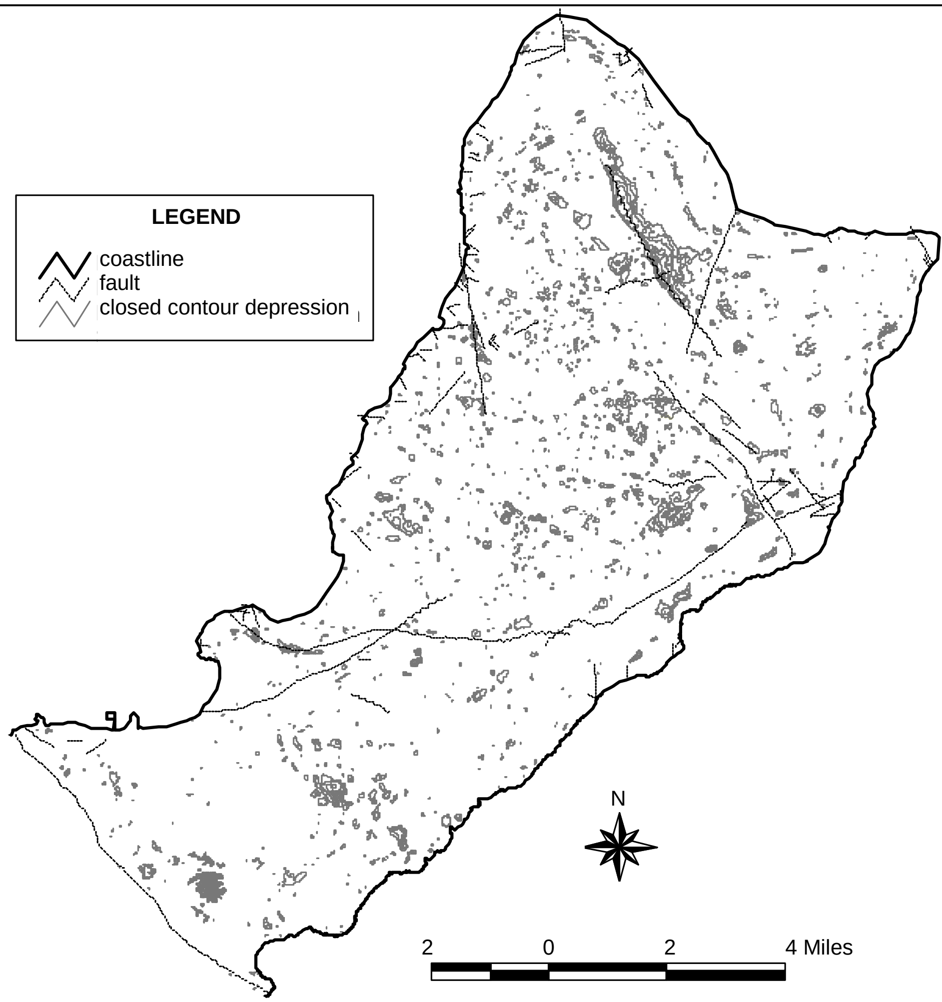

Figure 13. Northern Guam closed contour depressions and faults. (Adapted from Figure 7.1: Map of closed contour depressions in northern Guam. Taborosi, 2000.)

6.0 CONCLUSIONS AND RECOMMENDATIONS

Nitrate-nitrogen concentrations at water wells are below the Safe Drinking Water standard of 10 mg/l. However the acute effects of nitrate-nitrogen consumption on human health, primarily that of infants, requires action to prevent groundwater nitrate-nitrogen levels from rising to dangerous levels. It is critical that natural resource managers know the status of nitrate-nitrogen levels at water wells. Wells that have been identified as having positive (increasing) significant nitrate-nitrogen trends (Table 2), having increasing average and/or maximum concentrations in 5-year periods (Section 5.4), or having average and/or maximum levels greater than or equal to 4 mg/l should be closely monitored (Table 3). Areas of special concern should include the cluster of GWA wells and Mangilao Golf Course wells in the Mangilao Subbasin.

The inventory of potential nitrogen sources in northern Guam (Plate 1) should be maintained and updated. Data are available on ArcView GIS© coverages, copies of which are available from GEPA and WERI. Investigations linking potential nitrogen sources to water well nitrate-nitrogen concentrations would require dye-trace and isotope studies. Although nitrate-nitrogen is a naturally occurring groundwater constituent, additional loading by anthropogenic sources should be controlled by transferring septic tank/leaching field systems to sanitary sewer systems and by implementing agricultural best management practices.

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APPENDICES

Appendix A: Nitrate-nitrogen concentrations (mg/l).

	HGC-3	F-19	F-20	D-25	D-26	D-27	D-28	Y-18	Y-19	Y-20	FM-1	GICC MG-1	GICC MG-2	GICC MG-3	GICC M-GD	A-1	A-2	A-3	A-4
Jan-78																			
Feb-78																			
Mar-78																			
Apr-80																			
Feb-85																			
Mar-85																			
Mar-86																1.19	2.66	1.02	1.97
Jun-87											2.50					1.71	3.12	1.20	1.95
Dec-87																0.79	1.98	0.83	1.42
Feb-88																1.01	1.84	0.73	1.80
Mar-88																			
May-88																1.33	2.67	0.88	1.96
Jun-88											1.90								
Aug-88																1.38	2.70	0.79	1.91
Nov-88																0.80	2.10		1.62
Jan-89																1.34	2.73	0.92	2.04
May-89																1.44	2.80	0.81	2.06
Jul-89																1.58	2.88	0.81	2.87
Oct-89																1.75	2.79	0.81	2.52
Jan-90																1.55	2.76	1.07	2.18
Mar-90																			
Apr-90																1.49	3.00	1.09	2.31
Jun-90																1.43	2.69		2.17
Oct-90																2.04	2.92	1.15	2.46
Jan-91																1.21	2.78	1.51	
Apr-91																1.54	3.58	1.58	3.05
Jul-91																0.99	0.72	0.97	2.08
Oct-91																1.36	2.65	1.41	2.19
Apr-92																1.04	2.40	0.94	1.99
Aug-92												0.70	1.5	1.2					
Sep-92																			
Oct-92												1.20	1.5	1.2					
Nov-92																1.47	2.68	1.19	2.32
Nov-92																			
Dec-92																			
Jan-93																1.40	2.77	1.35	2.29
Jan-93																			
Feb-93																			
Mar-93											2.90								
Apr-93												0.78	1.7	1.4	2	1.71	2.73	1.15	2.49
May-93												0.20	0.45	0.4	0.62				
Jun-93	1.27											0.50	0.78	1.2					
Jul-93	1.25											0.83	1.7	1.7	2.1	1.38	2.69	1.81	
Aug-93	1.24																		
Sep-93												0.95	1.6	1.9	2				
Oct-93																			
Nov-93																			
Dec-93											2.70								
Jan-94												1.1	3.4	4.9	1.3				
Feb-94												1.00	1.4	1.4	2.1				
Mar-94												1.1	1.5	1.5	2.3				
Apr-94												1.1	1.5	1.5	2.1	0.65	1.27	0.98	1.19
May-94																			
Jun-94																			
Jul-94												1.07	1.29	1.29	1.85	1.22	2.73	1.15	2.43
Aug-94												2.14	1.44	1.45	2.11				
Sep-94												0.99	1.56	0.71	1.79				
Oct-94												1.07	1.3	1.45	1.38	1.63	2.81	0.96	2.60
Nov-94												1.28	1.13	1.45	1.51				
Dec-94												1	1.27	1.42	1.48				
Jan-95																			
Feb-95																			
Mar-95																			
Apr-95											2.90					1.48	2.75	0.76	2.52
May-95																			
Jun-95												1.203	1.194	0.973	2.08				
Jul-95																			
Sep-95												1.4	1.5	2	1.7				
Oct-95											3.15					1.39	2.90	1.02	2.61
Nov-95																1.38	2.79	0.86	2.77
Dec-95											3.10	1.95	1.31	2.3	1.95				
Jan-96																1.42	2.81	1.00	2.84
Feb-96												1	1.48	1.96	1.87				
Mar-96																			
Apr-96																			
May-96												0.95	1.25	1.94					
Jun-96																			
Jul-96																			
Aug-96												0.47	0.92	1.36					
Sep-96																	3.70		3.58
Oct-96																			
Nov-96												1.95	0.56	0.74	0.53				
Dec-96																			
Jan-97																			
Feb-97												0.95	0.92	1.05					
Mar-97																			
Apr-97																			
May-97											2.60	2.46	1.78	1.84					
Jun-97																			
Jul-97																3.1	2.7	1.2	2.64
Aug-97												1.4	0.46	0.45					
Sep-97																			
Oct-97																			2.96
Nov-97												1.57	1.91	1.72	0.6				
Dec-97																			
Feb-98												1.64	1.3	1.42		3.10	2.70	1.20	
Mar-98																			
Apr-98																			
May-98												1.62	2.38	1.76					
Jun-98																			
Aug-98												1.42	1.61	1.58					
Sep-98																			
Oct-98																			
Nov-98												1.72	1.62	1.9	0.75				
Dec-98																			
Feb-99												1.38	1.59	0.99					
Mar-99																			
Apr-99			1.5	1.1	1.8														
May-99												1.71	1.91	1.75					
Jun-99																			
Jul-99		2	2.1	1.5	1.5			2.1	2.6	0.9									
Aug-99												1.44	1.92	1.93					
Sep-99																			
Oct-99						1.6	2												
Nov-99												0.653	0.954	1.21					
Dec-99																			
Jan-00																			
Feb-00												1.15	1.85	1.93		1.46	3.96	0.81	3.66
Mar-00																			
May-00												1.06	1.81	2.12					
Jun-00																			
Aug-00												1.01	1.85	2.35					
Sep-00																			
Oct-00						1.67	1.71												
Nov-00												0.968	1.74	2.06					
Dec-00																			

Appendix A: Nitrate-nitrogen concentrations (mg/l).

	A-5	A-6	A-7	A-8	A-9	A-10	A-11	A-12	A-13	A-14	A-15	A-17	A-18	A-19	A-21	A-23	A-25	A-26	A-28
Jan-78																			
Feb-78																			
Mar-78																			
Apr-80																			
Feb-85																			
Mar-85																			
Mar-86	2.28	2.35	2.68	1.81	1.44	1.71	1.13	1.13	2.31	2.09	4.18	3.40	2.22	3.40	1.37	1.84	4.45		1.84
Jun-87	2.77	3.03	2.87	2.28	1.56	1.88	1.35	1.31	2.49	2.33	4.91	3.29	2.13	3.52	1.58	4.69	5.27	3.78	1.98
Dec-87	1.53	1.91	0.96	1.22	0.90	1.21	0.74	0.69	1.18	0.85	1.61	1.19	0.84	1.29	0.46	3.02	2.98	1.81	0.71
Feb-88	1.61	1.70	1.85	1.50	1.09	1.55	0.99	1.01	1.63	1.88	3.37	2.37	1.76	2.62	0.92	3.32	3.54	4.04	1.45
Mar-88																			
May-88	2.32	2.32	2.45	1.75	1.34	1.61	1.02	0.94	2.00	1.93	3.60	2.79	1.92	2.93	1.13	3.47	4.17	4.15	1.67
Jun-88																			
Aug-88	2.32	2.14	2.48	1.77	1.36	1.32	0.99	0.97	2.08	2.08	3.82	3.06	1.88	3.13	1.20	3.48	4.30	4.17	1.81
Nov-88	2.14	2.08	2.75	1.61		1.00	0.87	0.73	1.05	2.36	3.95	2.69	2.15	3.52	1.32	4.09	4.22	4.49	1.29
Jan-89	2.25	2.27	2.50	1.88	1.46	1.73	1.16	1.19	2.16	2.22	4.10	2.79	1.98	3.19	1.23	3.71	4.48	4.27	1.82
May-89	2.32	2.26	2.57	1.82	1.47	1.91	1.01	1.04	2.03	2.12	1.78	2.96	1.86	3.23	1.32	3.63	4.30	4.32	
Jul-89	2.72	2.33	2.77	1.97	1.49	0.11	1.10	1.10	2.02	2.39	3.86	3.19	2.14	3.38	1.38	4.61	4.71	4.66	2.04
Oct-89	1.99	1.94	2.31	1.96	1.34	1.77	1.01	1.11	2.22	2.16	3.72	2.75	1.19	3.17		3.75	4.13	4.29	1.84
Jan-90	2.03	2.29		1.91	1.42		1.37	1.36	2.33	2.05	3.79	2.71	1.88	2.59		4.01	3.95	4.12	1.84
Mar-90																			
Apr-90	2.28	2.35	2.68	1.99	1.49		1.40	1.40	2.47	2.12	4.11	2.86	2.02	3.36	1.23	4.34	4.28	4.49	1.97
Jun-90	2.28	2.23	2.60	1.91	1.38	1.69		1.18		2.21	3.55	2.79	1.98	3.05	1.29	3.46	4.13	4.06	2.00
Oct-90	2.02	2.21	2.56	2.18	1.58	1.79	1.57	1.66	2.25	2.01	3.88	2.98	2.14	3.61	1.33	3.22	4.39	4.58	1.89
Jan-91	1.93	2.08	2.90	1.95	1.37	1.78	1.60	1.57	2.12	2.33	3.63	2.55		3.20	1.18	3.81	4.32	3.96	1.99
Apr-91	2.78	2.99	3.34	2.37	1.78	2.28	1.77	1.83	2.41	2.78	4.33	3.37	2.45	4.12	1.52	4.06	4.10	2.90	2.21
Jul-91	2.10	2.12	2.66	1.91	1.35	1.62	1.21	1.16	2.34	2.27	3.77	2.70	1.88		1.23	3.57	4.06	3.50	2.10
Oct-91	1.93	1.87	2.57	1.93	1.28		1.21	1.25	2.19	2.20	3.85		2.00			3.43	3.80	3.91	1.95
Apr-92	1.85	1.93	2.57	1.82	1.41	1.61	1.18	1.29	1.95	2.23	3.55	2.49	1.82	2.96	1.49	3.62	3.78	3.78	1.90
Aug-92																			
Sep-92																			
Oct-92																			
Nov-92	1.89	1.74	2.71	2.05	1.26	1.73	1.25	1.26	2.18	2.05	3.57	2.66	1.83	3.06	1.36	3.78	3.75	3.84	2.04
Nov-92																			
Dec-92																			
Jan-93	1.91	2.16	2.52	2.07	1.22	1.74	1.41	1.42	2.10	2.04	3.35	2.68	1.89	3.01	1.26	3.65	3.66	3.54	1.90
Jan-93																			
Feb-93																			
Mar-93																			
Apr-93	2.22	2.27	2.81	1.99	1.50	2.04	1.36	1.33	2.23	2.32	2.62	2.73	2.05	2.94	1.31	3.43	3.82	3.68	2.03
May-93																			
Jun-93																			
Jul-93	2.02	1.92	2.46	2.05	1.29	1.69	1.06	1.08	1.95		3.60	2.45	1.77	2.71	1.35	3.17	3.80	3.40	1.92
Aug-93																			
Sep-93																			
Oct-93																			
Nov-93																			
Dec-93																			
Jan-94																			
Feb-94																			
Mar-94																			
Apr-94	0.95	0.93	1.28	0.44	0.57	0.79	0.46	0.48	0.68	1.00	1.49	1.38	0.86	1.05	0.59	1.05	1.69	1.65	1.02
May-94																			
Jun-94																			
Jul-94	2.05	1.78	2.39	2.07	1.47	0.73	1.11	1.46	1.96	2.54	3.90	2.76	1.88	2.74	1.41	2.98	3.39	3.36	1.95
Aug-94																			
Sep-94																			
Oct-94	1.92	1.64	2.49	2.00	1.92	1.90	1.17	1.14	1.84	2.10	3.63	2.53	1.86	2.70	1.23	3.35	3.36	3.79	2.00
Nov-94																			
Dec-94																			
Jan-95																			
Feb-95																			
Mar-95																			
Apr-95	2.00	1.94	2.43	1.91	1.17	1.62	1.01	1.05	1.88	2.05		2.60	1.75	2.76	1.40	2.88	2.91	3.72	2.01
May-95																			
Jun-95																			
Jul-95																			
Sep-95																			
Oct-95	1.91	2.00	2.38	1.89	1.21	1.73	1.07	1.28	2.06	2.08		2.52	1.73	0.94	1.35	1.05	1.21	1.32	1.80
Nov-95	1.46	1.70	2.47	1.02	0.97	1.19	0.90	1.25	1.32	1.55	3.44	2.46	1.38	2.85	1.08	2.03	3.17	3.97	1.54
Dec-95																			
Jan-96	1.85	1.87	2.55	1.92	0.84	1.37		1.33	1.83	1.90	3.42	2.29	1.77	2.83	0.83	2.82	3.13	3.83	1.89
Feb-96																			
Mar-96																			
Apr-96			2.60	2.00						2.20	3.60	2.80		2.90	1.40			4.30	2.10
May-96																			
Jun-96																			
Jul-96																			
Aug-96																			
Sep-96	2.13	1.89														3.41	3.62		
Oct-96																			
Nov-96																			
Dec-96																			
Jan-97																			
Feb-97																			
Mar-97																			
Apr-97																			
May-97																			
Jun-97																			
Jul-97	1.4	1.4	2.3	1.7	1.36	1.98		0.6	1.92	2.2	4	2.8	1.73		1.3	2	3.6	4.9	2.12
Aug-97																			
Sep-97																			
Oct-97				1.26	0.5	1.6			2		4	2.8	2.1			2	3.6	4.9	1.5
Nov-97																			
Dec-97																			
Feb-98	1.40	1.40	2.30	1.70				0.60		2.20	4.00	2.80				2.00	3.60	4.90	
Mar-98																			
Apr-98																			
May-98																			
Jun-98																			
Aug-98																			
Sep-98																			
Oct-98																			
Nov-98																			
Dec-98																			
Feb-99																			
Mar-99																			
Apr-99																			
May-99																			
Jun-99																			
Jul-99																			
Aug-99																			
Sep-99																			
Oct-99																			
Nov-99																			
Dec-99																			
Jan-00																			
Feb-00	2.21	2.52	3.14		1.7	2.9		1.77	3.62	2.87	3.7	3.83	2.49	3.94	2.35	3.62	4	4.76	2.94
Mar-00																			
May-00																			
Jun-00																			
Aug-00																			
Sep-00																			
Oct-00																			
Nov-00																			
Dec-00																			

Appendix A: Nitrate-nitrogen concentrations (mg/l).

	A-29	A-30	A-31	A-32	AG-1	AG-2	D-1	D-2	D-3	D-4	D-5	D-6	D-7	D-8	D-9	D-10	D-11	D-12	D-13
Jan-78																			
Feb-78																			
Mar-78																			
Apr-80																			
Feb-85																			
Mar-85																			
Mar-86					1.12	1.41	1.85	1.75	1.56	1.72	1.91	1.36	1.24	1.00	1.57	1.27	1.53	0.772	1.19
Jun-87					0.74	1.03	2.87	2.05	2.21	2.19	2.23	1.66	1.63	1.26	2.04	1.81	1.74	1.11	1.83
Dec-87					0.99	1.03	1.36	1.29	1.20	1.38	1.20	0.97	0.93	0.69	1.20	0.93	1.01	0.71	0.86
Feb-88					0.75	1.15	1.47	1.49	1.26	1.46	1.24	1.02	0.97	0.71	1.33	1.07	1.18	0.70	0.94
Mar-88																			
May-88					0.83	1.33	1.80	1.78	1.49	1.69	1.51	1.30	1.26	0.75	1.59	1.27	1.52	0.88	1.05
Jun-88																			
Aug-88					0.88	1.33	1.85	1.74	1.61	1.67	1.43	1.25	1.33	0.94	1.76	1.49	1.55	0.97	1.15
Nov-88					0.88	1.51	1.62		1.36	1.49	1.35	1.05	1.28	0.74		1.46	1.55	0.75	1.09
Jan-89					1.09	0.94	1.90	1.78	1.71	1.75	1.54	1.30	1.43	0.96	1.75	1.60	1.63	0.98	1.21
May-89						1.41	1.86	1.82	1.73	1.80	1.62	1.36	1.39	1.01	1.76	1.58	1.68	1.00	1.29
Jul-89			3.01		0.92	1.33	1.79	1.80	1.77	1.76		1.38	1.39	0.94	1.71	1.56	1.66	0.97	1.23
Oct-89			2.86				1.83	1.60	1.80	1.87	1.51	1.34	1.41	1.26	1.73		1.71	1.00	1.19
Jan-90			2.60		0.95	1.26	1.79	1.85	1.72	1.78	1.59	1.48	1.48	1.01	1.79	1.67	1.62	0.99	1.26
Mar-90																			
Apr-90		2.84	2.86	1.96	0.97	1.38	1.77	1.74	1.69	1.60	1.50	1.37	1.33	1.01	1.67	1.54	1.74	0.97	
Jun-90		2.69	2.90	2.82	0.96	1.31	1.79	1.68	1.69		1.55	1.25	1.31	0.97	1.72	1.56	1.62	0.97	1.30
Oct-90	2.58	2.92	2.72	3.02	0.94	1.62	2.06	1.88	2.01	1.96	1.45	1.23	1.76	1.01		1.77	1.80	1.07	1.49
Jan-91	2.24	2.26	2.71	2.45	0.97	1.42	1.67	1.73	1.81	1.83	1.59	1.26	1.42	0.98	1.83	1.63	1.58	1.03	1.12
Apr-91	2.69	2.99	3.06	3.13		1.71	2.16	1.99	2.13	2.12	1.77	1.57	1.68	1.09	2.17	1.80	1.91	1.13	1.56
Jul-91	2.44	2.75	2.89	2.94	1.06	1.45	1.68	1.62	1.76		1.48	1.32	1.37	0.92	1.79	1.54	1.51	0.92	1.15
Oct-91	2.40	2.52	2.75		1.02	1.41	1.69	1.60	1.63	1.66	1.32		1.38	0.95	1.70		1.42	0.89	1.11
Apr-92	2.16	2.44	2.52	2.96	0.98	1.48	1.66		1.74	1.79	1.41	1.32	1.54	0.98	1.86	1.67	1.63	0.95	1.35
Aug-92																			
Sep-92																			
Oct-92																			
Nov-92	2.49	2.51	2.81	2.64	1.13		1.74	1.81	1.88	1.81	1.39	1.28	1.56	1.07	1.92	1.58	1.89	1.00	1.34
Nov-92																			
Dec-92																			
Jan-93	2.21	2.57	2.81	3.28	1.10	1.57	1.87	1.71	1.97	1.90	1.45	1.50	1.60	1.07	1.93	1.68	1.97	1.12	1.35
Jan-93																			
Feb-93																			
Mar-93																			
Apr-93	2.25	2.54	2.84	3.44	1.02	1.45	1.72	1.66	1.93	1.74	1.33	1.50	1.65	1.06	1.93	1.69	1.85	0.94	1.18
May-93																			
Jun-93																			
Jul-93	2.22	2.56	3.04	3.30	0.97	1.37	1.66	1.67	1.93	1.65	1.24	1.40	1.56	1.02	1.80	1.67	1.81	0.88	1.30
Aug-93																			
Sep-93																			
Oct-93																			
Nov-93																			
Dec-93																			
Jan-94																			
Feb-94																			
Mar-94																			
Apr-94	1.07	1.33	1.32	1.27	0.67	0.83	0.77	0.82	0.72	0.55	0.74	0.76	0.47	0.68	0.78	0.76	0.40	0.57	1.16
May-94																			
Jun-94																			
Jul-94	2.63	2.65	2.62	2.92	1.01	1.36	1.66	1.51	0.60	1.83	1.32	1.70	1.73	1.14	1.76	1.67	1.98	1.07	1.30
Aug-94																			
Sep-94																			
Oct-94	2.07	2.49	2.53	2.64	0.88	1.32	1.47	1.54	1.86	1.65	1.23	1.76	1.81	1.08	1.75	1.82	1.85	0.97	1.37
Nov-94																			
Dec-94																			
Jan-95																			
Feb-95																			
Mar-95																			
Apr-95	2.02	2.65	2.59	2.89	0.75	1.16	1.46	1.45	1.80	1.47	1.10	1.42	1.64	0.93	1.72	1.70	1.62	1.12	1.23
May-95																			
Jun-95																			
Jul-95																			
Sep-95																			
Oct-95	2.14	2.51	2.42	2.75	0.96	1.40	1.57	1.59	1.81	1.63	1.29	1.69	1.70	1.14	1.77	1.78	1.85	0.99	1.39
Nov-95	2.04	2.44	2.40	2.84	0.98	1.40	1.58	1.69	1.89	1.71	1.13	1.52	1.61	0.85	1.82	1.75	1.67	0.99	1.25
Dec-95																			
Jan-96	2.11	2.50	2.37	2.84	0.68	0.74	1.83	1.40	1.65	1.55	0.86	1.62	1.41	0.68	2.02			0.71	1.02
Feb-96																			
Mar-96																			
Apr-96			2.60																
May-96																			
Jun-96																			
Jul-96																			
Aug-96																			
Sep-96	2.41	2.63																	
Oct-96																			1.55
Nov-96																			
Dec-96																			
Jan-97																			
Feb-97																			
Mar-97																			
Apr-97																			
May-97																			
Jun-97																			
Jul-97	2	2.4	2.2	2.1							1.6								
Aug-97																			
Sep-97																			
Oct-97	2	2.4	2.2	2.1	0.19		2.2	2.3	2.3	1.9	1.3	1.6	1.3	0.14	1.1	0.8	0.73	0.29	0.74
Nov-97																			
Dec-97																			
Feb-98	2.00	2.40	2.20	2.10							1.60								
Mar-98																			
Apr-98																			
May-98																			
Jun-98																			
Aug-98																			
Sep-98																			
Oct-98																			
Nov-98																			
Dec-98																			
Feb-99																			
Mar-99																			
Apr-99																			
May-99																			
Jun-99																			
Jul-99																			
Aug-99																			
Sep-99																			
Oct-99																			
Nov-99																			
Dec-99																			
Jan-00																			
Feb-00	2.52	2.94	3.1	3.59			2			2.2	2.2	2.4	2.1	1.4	2.3	2.4	2.6	1.2	1.7
Mar-00								2.21	2.68										
May-00																			
Jun-00																			
Aug-00																			
Sep-00																			
Oct-00																			
Nov-00																			
Dec-00																			

	D-14	D-15	D-16	D-17	D-18	D-19	D-20	D-21	D-22A	D-24	EX-5A	EX-11	F-1	F-2	F-3	F-4	F-5	F-6	F-7
Jan-78																			
Feb-78																			
Mar-78																			
Apr-80																			
Feb-85																			
Mar-85																			
Mar-86	3.17	2.51	3.30	1.71	3.19	1.05	1.17	1.69			1.71	1.79	1.11	1.10	1.11	0.931	1.85	1.62	2.37
Jun-87	4.94	3.60	4.39	1.89	4.80	2.30	2.96	2.96					0.75	0.85	0.83	0.67	1.66	1.31	2.17
Dec-87	2.17	1.78	2.23	1.17	2.36	0.69	0.80	1.36			1.28	0.80	0.62	0.85	0.56		1.52	1.17	2.07
Feb-88	2.42	2.04	2.50	1.36	2.68	0.83	0.95	1.67			1.48	1.52	0.78	0.89	0.89	0.70	1.70	1.34	2.18
Mar-88																			
May-88	2.70	2.24	2.94	1.79	2.94	0.99	1.02	1.86			1.60	1.83	0.91	1.07	1.03	0.77	1.93	1.62	2.62
Jun-88																			
Aug-88	2.87	2.39	3.13	1.87	2.91	1.13	1.23	1.90			0.005	1.77	0.94	1.11	1.09	0.91	2.12	1.35	2.65
Nov-88	2.79	2.20	3.22	1.56	2.77	1.09	1.07	1.69			1.10	2.15	0.63	0.75	0.62	0.63	1.38	0.93	2.00
Jan-89	2.98	2.40	3.19	1.84	3.27	1.24	1.32	1.99			1.65	2.09	1.00	1.14	1.17	0.93	2.13	1.65	2.71
May-89	2.97	2.43	3.23	1.95	3.11	1.21	1.35	2.02					1.17	1.17	1.22	0.98	2.35	1.79	2.92
Jul-89	2.95	2.32	3.12	1.90	3.09	1.20	1.25	1.95			1.83	2.25	1.12	1.14	1.20	1.30	1.77		
Oct-89	2.86	2.40	3.21	1.74	3.02	1.25	1.37	2.03			1.62	1.82	1.22	1.24	1.29	1.10	2.47	1.95	2.92
Jan-90	2.91	2.49	3.22	1.83	2.98	1.26	1.36	2.26			1.77	2.17	1.23	1.20	1.21	0.85	2.35	2.02	3.00
Mar-90																			
Apr-90	2.77	2.29		1.75	2.89	1.23	1.40	2.23			1.73	2.23	1.21	1.21	1.33	0.68	2.34		2.88
Jun-90	2.76	2.28	3.12	1.81	3.15		1.30	2.45			1.70		1.20	1.14	1.28	1.33	2.42	1.97	2.86
Oct-90	3.50	2.94		2.14	3.45	1.23	1.73	2.72			1.79	2.50	1.40	1.39	1.52	0.99	2.58	2.31	3.36
Jan-91	2.68	2.41	3.43	1.78	2.96	1.39	1.50	1.55			1.57	2.43	1.20	1.21	1.36	0.71	2.40	1.73	2.89
Apr-91	3.37	2.62	3.62	2.35	3.30	1.58	1.67	2.81			2.01	2.44	1.13	1.18	1.17	0.67	2.48	1.94	3.12
Jul-91	2.72	2.44	3.00	2.10	3.19	1.54	1.48	2.44			1.74	2.39		1.20	1.32	0.87	2.80	2.02	3.05
Oct-91	2.56	2.20	3.01	1.87	3.10	1.54	1.55	2.56			1.58	2.30	1.11	1.13	1.24	0.84	2.71	1.53	2.99
Apr-92	2.49	2.23	3.12	2.05	3.01	1.51	1.52	2.65			1.88	2.74	1.14	1.08	1.28	0.81	2.58	2.13	2.99
Aug-92																			
Sep-92																			
Oct-92																			
Nov-92	2.60	2.38	3.17	2.31	3.31	1.72	1.88	3.09				2.56	1.15	1.15	1.31	0.87	2.91	2.27	3.42
Nov-92																			
Dec-92																			
Jan-93	2.58	2.31	2.99	2.42	3.22	1.70	1.83	3.17			1.96	2.80	1.12	1.15	1.32	0.84	2.85	2.18	3.08
Jan-93																			
Feb-93																			
Mar-93																			
Apr-93	2.58	2.02	2.77	2.39	3.03	1.57	1.86	3.00			1.97	2.88	1.32	1.15	1.30	0.78	2.79	2.26	3.25
May-93																			
Jun-93																			
Jul-93	2.52	2.09	2.61	2.35	2.94	1.71	1.86	3.03			1.84	2.59	1.19	1.15	1.23	0.71	2.64	2.09	3.36
Aug-93																			
Sep-93																			
Oct-93																			
Nov-93																			
Dec-93																			
Jan-94																			
Feb-94																			
Mar-94																			
Apr-94	0.98	1.17	1.02	1.19	0.76	0.84	0.79	1.04			0.24		1.02	1.11	1.20	0.66	2.58	0.52	2.94
May-94																			
Jun-94																			
Jul-94	2.67	2.54	2.45	2.97	3.03	1.70	1.92	2.86			1.84	2.70	1.04	1.09	1.31	0.77	2.70	2.07	3.15
Aug-94																			
Sep-94																			
Oct-94	2.51	2.09	2.95	2.28	2.81	1.66	1.99	2.30			1.69	2.46	1.17	1.12	1.22	0.75	2.62	2.14	3.13
Nov-94																			
Dec-94																			
Jan-95																			
Feb-95																			
Mar-95																			
Apr-95	2.40	1.84	2.66	1.99	2.85	1.64	1.86	2.64			1.71	2.68	1.09	1.10	1.28	0.51	2.46	1.99	2.93
May-95																			
Jun-95																			
Jul-95																			
Sep-95																			
Oct-95	2.47	2.01	2.75	2.32	2.91	1.67	1.98	2.32			1.87	2.66	1.23	1.17	1.30		2.54	2.13	3.06
Nov-95	2.38	1.89	2.53	1.96	2.42	1.66	1.86	2.24		2.23	1.79	2.53	1.34	1.40	1.53	0.80	1.98	2.70	3.14
Dec-95																			
Jan-96	2.85	2.08	3.15	2.58	2.98	1.41	1.79	2.95		2.56	1.82	2.32	1.17	0.87	1.29	0.17	2.49	1.74	2.93
Feb-96																			
Mar-96																			
Apr-96	2.70																		
May-96																			
Jun-96																			
Jul-96																			
Aug-96																			
Sep-96																			
Oct-96		2.85	3.70	3.05	3.20	2.05	2.50	3.95									3.50		
Nov-96																			
Dec-96																			
Jan-97													1.90					1.54	3.28
Feb-97																			
Mar-97																			
Apr-97																			
May-97																			
Jun-97																			
Jul-97	4.2	2.6	2.9	2.8	3.4				2.2	2		3.9					3.5	3	
Aug-97																			
Sep-97																			
Oct-97	0.2	2.6	2.9	2.8	3.4	1.05	1.27	2.9	2.2	2	1.3	3.9					3.5	3	2.6
Nov-97																			
Dec-97																			
Feb-98	4.20	2.60	2.90	2.80	3.40				2.20	2.00		3.90					3.50	3.00	
Mar-98																			
Apr-98																			
May-98																			
Jun-98																			
Aug-98																			
Sep-98																			
Oct-98																			
Nov-98																			
Dec-98																			
Feb-99																			
Mar-99																			
Apr-99																			
May-99																			
Jun-99																			
Jul-99																			
Aug-99																			
Sep-99																			
Oct-99																			
Nov-99																			
Dec-99																			
Jan-00																			
Feb-00	2.8	2.7	3.1	3.8	3.6	2.2		3.3		3	2.6			1.42	1.61	0.8	3.03		3.41
Mar-00							2.32					4.7	1.63						
May-00																			
Jun-00																			
Aug-00																			
Sep-00																			
Oct-00																			
Nov-00																			
Dec-00																			

	F-8	F-9	F-10	F-11	F-12	F-13	F-15	F-16	F-17	F-18	GH-501	H-1	HGC-2	M-1	M-2	M-3	M-4	M-5	M-6
Jan-78																			
Feb-78																			
Mar-78																			
Apr-80																			
Feb-85																			
Mar-85																			
Mar-86	1.60	1.52	1.21	1.05							1.75			1.31	1.45	1.43	1.56	1.46	1.60
Jun-87	1.34	1.34	1.05	0.75								1.54		2.08	2.54	2.46	2.71	2.08	2.53
Dec-87	1.30	1.26	0.93	0.68							1.30			0.56	0.65	0.68	0.70	0.56	0.69
Feb-88	1.44	1.44	1.03	0.79							1.43	1.56		1.10	1.05	1.15	1.30	1.04	1.31
Mar-88																			
May-88	1.89	1.71	1.28	0.97							1.71	1.88		1.07	1.27	1.41	1.83	1.20	1.42
Jun-88																			
Aug-88	2.02	1.82	1.39	1.06								1.73		1.44		1.54	1.86	1.36	1.58
Nov-88		1.36	0.80	0.60							1.05	1.82		1.56	1.72	1.98	2.29	1.48	1.57
Jan-89	2.05	1.85	1.54	1.09							1.85	1.94		1.49	1.52	1.90	2.07	1.38	1.67
May-89	2.31	1.92	1.54	1.15							2.63	1.87		1.50	1.46	1.69	2.05	1.35	1.57
Jul-89	2.07	1.75		1.10							1.84	1.97		1.60	1.49	1.72	3.60	1.35	1.55
Oct-89	2.28	1.98		1.14							1.67	1.80		1.45	1.53	1.61	1.90	1.24	
Jan-90	2.27		1.08	1.15							1.83	2.02		1.56	1.50	1.81	2.42	1.33	1.56
Mar-90																			
Apr-90	2.46 or 2.1	1.93	1.55	1.05	2.13						1.81	1.95		1.66	1.74	2.08	2.50	1.38	
Jun-90	2.40		1.60	1.06							1.86	1.88		1.88	1.87	2.19	2.47	1.34	
Oct-90	2.58		1.75	1.17	2.69						2.09	2.07		1.56	1.20	2.25	2.41	1.52	
Jan-91	2.52	1.99	1.57	1.11	2.56							1.95	0.82	1.77	2.14	2.11	2.47	1.34	
Apr-91	2.25	2.06	1.50	0.97	2.52						2.07	1.89		1.70	1.95	2.41	2.47	1.42	
Jul-91	2.38	2.16	1.74	1.09	2.44						2.00	1.74	0.70	1.90	2.30	2.02	2.63	1.40	
Oct-91	2.49	2.10	1.69	1.04	2.48						2.00	1.87		1.86	2.12	2.15	2.49	1.31	1.44
Apr-92	2.46	2.11	1.52	0.98	2.40						2.03	1.77	0.75	2.05	2.31	2.34	2.74	1.40	1.62
Aug-92																			
Sep-92																			
Oct-92																			
Nov-92	2.83	2.32	1.62	1.05	2.57						2.10	1.73	0.75	2.02	2.44	2.57	2.69	1.35	1.68
Nov-92																			
Dec-92																			
Jan-93	2.69	2.18	1.65	1.04	2.75						2.12	1.75	0.76	2.05	2.38	2.42	2.73	1.42	1.77
Jan-93																			
Feb-93																			
Mar-93																			
Apr-93	2.85	2.19	1.56	1.02	2.40						2.23	1.73	0.66	2.14	2.45	2.39	2.69	1.27	1.64
May-93																			
Jun-93																			
Jul-93	2.64	2.00	1.32	1.02	2.19						1.98	1.63	0.62	2.05	2.49	2.56	3.01	1.25	1.36
Aug-93																			
Sep-93																			
Oct-93																			
Nov-93																			
Dec-93																			
Jan-94																			
Feb-94																			
Mar-94																			
Apr-94	2.99	2.37	1.39	1.04	0.30						0.40	0.68	0.81	1.90	2.00	2.55	3.22	1.21	0.73
May-94																			
Jun-94																			
Jul-94	2.62	2.31	1.70	1.04	2.58						2.21	1.60	0.63	1.94	2.37	2.63	2.96	1.29	1.61
Aug-94																			
Sep-94																			
Oct-94	2.81	2.32	1.59	1.01	2.77						2.02	1.66	0.56	1.97	1.78	2.30	3.28	1.23	1.51
Nov-94																			
Dec-94																			
Jan-95																			
Feb-95																			
Mar-95																			
Apr-95	2.73	1.31	1.96	0.96	2.44	2.23	0.94	0.78			2.01	1.68	0.47	2.03	1.83	2.76	3.57	1.18	1.47
May-95																			
Jun-95																			
Jul-95																			
Sep-95																			
Oct-95	2.97	2.20	1.56	1.05	2.86	2.33	1.01	0.95			2.10	1.70	0.62	2.02	1.79	2.54	3.59	1.24	1.51
Nov-95	3.08	2.14	1.62	1.11	2.79	2.12	0.99	0.94			2.17	1.69	0.67	2.19	1.86	2.87	3.33	1.19	1.59
Dec-95																			
Jan-96	3.40	2.13	1.40	1.30	3.41	2.70	0.54				2.18	1.50	0.02	2.65	1.71	3.09	3.92	1.39	1.78
Feb-96																			
Mar-96																			
Apr-96			1.70						1.20	1.30	2.40	1.80							
May-96																			
Jun-96																			
Jul-96																			
Aug-96																			
Sep-96						2.90									2.69		4.08		
Oct-96					3.65	4.35													
Nov-96																			
Dec-96																			
Jan-97	2.8.						1.24	0.94											
Feb-97																			
Mar-97																			
Apr-97																			
May-97																			
Jun-97																			
Jul-97		3.2			3.2	3.9		4.4	0.9	1	2.4			2.50	3.10	3.50	4.30	1.00	1.20
Aug-97																			
Sep-97																			
Oct-97	1.73	3.2			3.2	3.9		4.4	0.9		2.4		0.14	2.5	3.1	3.5	4.3	1	1.2
Nov-97																			
Dec-97																			
Feb-98		3.20			3.20	3.90		4.40	0.90	1.00	2.40			2.50	3.10	3.50	4.30	1.00	1.20
Mar-98																			
Apr-98																			
May-98																			
Jun-98																			
Aug-98																			
Sep-98																			
Oct-98																			
Nov-98																			
Dec-98																			
Feb-99																			
Mar-99																			
Apr-99																			
May-99																			
Jun-99																			
Jul-99																			
Aug-99																			
Sep-99																			
Oct-99																			
Nov-99																			
Dec-99																			
Jan-00																			
Feb-00	3.72	2.84	2.03	1.45	4.06	3.87	1.45	1.34	1.26	1.49		2.1							
Mar-00											2.72	2	0.69	3.4	3.3	4	5	1.4	1.7
May-00																			
Jun-00																			
Aug-00																			
Sep-00																			
Oct-00																			
Nov-00																			
Dec-00																			

Appendix A: Nitrate-nitrogen concentrations (mg/l).

	M-7	M-8	M-9	M-12	M-14	M-15	M-16B	M-17A	M-17B	M-18	M-20A	M-21	NAS-1	Y-1	Y-2	Y-3	Y-4	Y-4A	Y-5
Jan-78																			
Feb-78																			
Mar-78																			
Apr-80																			
Feb-85																			
Mar-85																			
Mar-86	1.37	1.86	1.72	2.56	2.33	1.41								2.91	2.98	3.38	2.76		2.19
Jun-87	1.98	2.86	2.67	4.20	3.86	2.28								4.17	4.34	5.37	4.35		3.38
Dec-87	0.50	0.71	1.00	1.45	0.98	0.58	0.79							2.10	2.06	2.29			1.34
Feb-88	0.86	1.43	1.24	2.07	1.96	1.10	1.53							2.41	2.62	2.59	2.33		1.83
Mar-88																			
May-88	1.06	1.75	1.47	2.32	2.19	1.34	1.81							2.86	3.09	3.33	2.98		1.65
Jun-88																			
Aug-88	1.16	1.90	1.68	2.63	2.50	1.25	1.99							2.99	3.10	3.20	3.00		2.20
Nov-88	1.31	2.34	2.10	3.03	2.79	1.66	2.35							1.94	2.35	1.58	2.02		1.80
Jan-89	1.28		1.92	2.58	2.76	1.57	2.12							3.19	3.18	3.19	2.93		2.55
May-89	1.24	2.19	1.77	2.64	2.33	1.46	2.00							3.26	3.34	3.45	3.10		1.89
Jul-89	1.35	1.83		2.77	2.70	1.47	2.06	2.01	2.09					3.06	3.28	3.40	2.95		2.34
Oct-89	1.16	2.02	1.85	2.42	2.33	1.41	1.94	1.92	2.09					2.81	3.07		2.86		2.27
Jan-90	1.23	2.34	2.05	2.67	2.66	1.53	2.30	2.09	2.07					3.13	3.23	3.02	2.91		2.46
Mar-90																			
Apr-90	1.27	2.28		2.83	2.92	2.05	2.35	2.09	2.10					3.02	3.23	3.42			2.57
Jun-90	1.31	2.19	2.01	2.77	2.95	1.62	2.27	2.10	2.11					2.92	3.06	3.46			2.67
Oct-90		2.33	2.27	3.03	2.64	1.78		2.18	2.35					2.92	3.07	3.17			2.80
Jan-91	1.25	2.28	2.03	2.61	2.94	1.68	2.40	1.94	1.93					3.15	2.88	2.86			2.83
Apr-91	1.07	2.07	1.87	2.79	2.97	1.55	2.15	2.55	2.53					3.00	3.23	3.64			3.23
Jul-91	1.37	2.10	2.07	2.97	2.94	1.90	2.27	2.13	2.13					2.70	3.02	3.45			2.94
Oct-91	1.33	2.27	2.13	2.68	2.58	1.61	2.01	2.04	2.06					2.62	2.92	1.61			2.65
Apr-92	1.40	2.28	2.28	2.84	3.04	1.90	2.21	2.08	2.02					2.56	2.81	3.30			2.80
Aug-92																			
Sep-92																			
Oct-92																			
Nov-92	1.44	2.88	2.29	2.77	2.22	1.97	2.41	2.03						2.82	2.93	2.82			2.82
Nov-92																			
Dec-92																			
Jan-93	1.49	2.47	2.34	2.75	3.22	2.05	2.61	2.08	2.12					2.75	2.90	2.71			2.82
Jan-93																			
Feb-93																			
Mar-93																			
Apr-93	1.42	2.23	2.08	2.55	3.04	2.11	2.32	1.98	2.06					2.53	2.31	2.24			3.03
May-93																			
Jun-93																			
Jul-93	1.45	2.34	2.13	2.46	2.90	2.13	2.27	1.93	1.99					2.56	2.62	2.89			2.90
Aug-93																			
Sep-93																			
Oct-93																			
Nov-93																			
Dec-93																			
Jan-94																			
Feb-94																			
Mar-94																			
Apr-94	1.45	2.99	2.32	2.64	2.91	0.72	2.30	1.91	1.96					1.14	1.38	1.34	1.41		1.53
May-94																			
Jun-94																			
Jul-94	1.44	2.69	2.42		2.86	1.95	2.40	1.91	2.02					2.56	2.76	3.04			2.91
Aug-94																			
Sep-94																			
Oct-94	1.30	2.87	2.67	2.56	3.09	1.79	2.63	1.84	1.99					2.73	3.04	2.56		2.59	2.83
Nov-94																			
Dec-94																			
Jan-95																			
Feb-95																			
Mar-95																			
Apr-95	2.90	3.07	2.85		3.20	1.90	2.77	1.83	1.95					2.58	2.85	3.05		2.52	2.68
May-95																			
Jun-95																			
Jul-95																			
Sep-95																			
Oct-95	1.32	3.12	2.77	2.54	3.10	1.79	3.06	1.89	2.03					2.82	3.02	3.12		2.77	2.84
Nov-95	1.35	3.22	3.01	2.66	3.31	1.94	2.96	2.33	2.53					2.43	2.70	2.88		2.35	2.69
Dec-95																			
Jan-96	0.96	3.88	3.20	2.57	4.00	2.25	3.53	2.18	1.97					1.71	2.66	3.46		2.51	3.58
Feb-96																			
Mar-96																			
Apr-96				2.80	3.80			2.10	2.50										
May-96																			
Jun-96																			
Jul-96																			
Aug-96																			
Sep-96		3.28	3.45									3.50							
Oct-96																			
Nov-96																			
Dec-96																			
Jan-97																			
Feb-97																			
Mar-97																			
Apr-97										1.50									
May-97																			
Jun-97																			
Jul-97	1.30	3.10	3.20	2.80	3.90	2.90			2.50	1.48									
Aug-97																			
Sep-97																			
Oct-97	1.3	3.1	3.2	2.8	3.9	2.9			2.5		2.2			3.62	3.11	3.09		2.85	3.07
Nov-97																			
Dec-97																			
Feb-98	1.30	3.10	3.20	2.80	3.90	2.90			2.50										
Mar-98																			
Apr-98																			
May-98																			
Jun-98																			
Aug-98																			
Sep-98																			
Oct-98																			
Nov-98																			
Dec-98													1.8						
Feb-99																			
Mar-99																			
Apr-99																			
May-99																			
Jun-99																			
Jul-99																			
Aug-99																			
Sep-99																			
Oct-99																			
Nov-99																			
Dec-99																			
Jan-00																			
Feb-00													2.32						
Mar-00	1.9	4.4	3.9		4.2	2.5		2.3	2.4		2.5			3.51	3.88	3.09		3.21	3.13
May-00																			
Jun-00																			
Aug-00																			
Sep-00																			
Oct-00																			
Nov-00																			
Dec-00																			

	Y-6	Y-7	Y-9	Y-10	Y-12	Y-14	Y-15	MGC-1	MGC-2	MGC-3	MGC-4	MGC MW1	MGC MW-2	MGC MW-3	MW-1	MW-2	MW-3	MW-5	MW-6
Jan-78																1.7			
Feb-78																			
Mar-78															1.3		1.7	0.8	2.2
Apr-80																1.9			1.8
Feb-85																1.4			
Mar-85															1.4		2	1.4	1.3
Mar-86	3.02																		
Jun-87	4.61	1.93																	
Dec-87	2.05	1.09																	
Feb-88	2.33	1.12	0.00																
Mar-88															1.48				1.44
May-88	2.55	1.13	1.62																
Jun-88																			
Aug-88	2.95	0.91	1.66																
Nov-88	2.16	0.98	1.60																
Jan-89	3.30	1.55	2.23																
May-89	3.12	1.52	2.24																
Jul-89	3.01	1.43	2.13																
Oct-89	2.46	1.29	2.47																
Jan-90	3.03	1.62	3.02																
Mar-90																1.37	1.87	0.8	
Apr-90	3.27	1.27	2.95																
Jun-90	3.29	1.25	2.37																
Oct-90		1.65	2.56																
Jan-91	2.82	1.20	2.75																0.52
Apr-91	3.62	1.38	2.81																
Jul-91	1.35	3.23	2.27																
Oct-91	3.04	1.26	2.57																
Apr-92	3.39	1.21	2.59																
Aug-92																			
Sep-92																			
Oct-92																			
Nov-92	3.26	1.31	2.74																
Nov-92																			
Dec-92																			
Jan-93	3.68	1.13	3.01																
Jan-93																			
Feb-93								4.48	4.85	1.82	1.12								
Mar-93								4.26	4.74	2.08	1.38	3.47	3.47	0.41					
Apr-93	3.61	1.06	2.11					4.32	4.3	1.21	0.98								
May-93								4.03	4.12	1.67	1.26								
Jun-93								4.9	4.5	1.7	1.3		1.7	1.5					
Jul-93	3.52	1.16	1.94					3.13	3.24	1.86	1.01								
Aug-93								4.61	4.28	1.87	1.37								
Sep-93								4.06	4.04	1.77	1.32	1.21	2.5	1.79					
Oct-93								4.08	3.98	1.93	1.36								
Nov-93								4.46			1.46								
Dec-93								4.16		1.9	1.47	2.43	2.28	1.72					
Jan-94								4.58		2.14	1.58								
Feb-94								3.93		1.88	1.46								
Mar-94								3.42	3.1	1.75	1.2	1.88	1.88	1.78					
Apr-94	0.67	0.89	1.02					3.28	4.34	2.29	1.5								
May-94								4.01	4.46	2.15	1.41								
Jun-94								4.22	4.17	2.3	1.53	2.3	2.87	1.55					
Jul-94	3.31	1.33	1.90					4.64	4.36		1.62								
Aug-94									0.97	2.07	1.48								
Sep-94								4.31	4.01		1.65	2.22	3.32	1.6					
Oct-94	3.07	1.46	1.94					3.94	3.93		1.75								
Nov-94								4.41	4.15		1.67								
Dec-94								4.68	4.18		1.75	2.84	2.38	1.66					
Jan-95								4.05	3.72	2.79	1.93								
Feb-95								4.35	4.06	3.8	2.96								
Mar-95								4.1	3.99	2.37	1.84	1.74	2.14	1.56					
Apr-95	3.07	1.05	1.78					4.85	4.52	2.54	2.11								
May-95								4.41	4.15	2.3	1.7								
Jun-95								4.39	4.03	2.47	1.64	2.09	2.13	1.77					
Jul-95								3.79	3.49	2.22	1.89								
Sep-95									2.22	1.29		1.06	1.21	1.34					
Oct-95	3.26	1.56	2.27					4.62	4.45	2.9	2.14								
Nov-95	2.98	1.25	2.07				1.22	4.24	3.83	2.53	1.9								
Dec-95								4.69	3.34		2.31	4	2.35	2.5					
Jan-96	2.55	1.63	2.25				0.88	4.96		2.53	2.23								
Feb-96								5		3.04	2.54								
Mar-96								3.06		2.24	1.62	2.53							
Apr-96					2.10		1.60	5.05		2.8	2.34								
May-96								3.46	3.95	2.22	2.02								
Jun-96								5.73	4.44	3.29	2.72	1.63							
Jul-96								4.06	4.33	2.65	1.97								
Aug-96								4.34	4.14	2.75	1.85								
Sep-96								3.97	3.97	2.75	1.85	4.26							
Oct-96								4.71	4.53	3.04	1.8								
Nov-96								5.13	4.82	3.23	2.04								
Dec-96								3.49	3.83	2.56	1.66	1.4							
Jan-97								3.27	2.51	3.31	2.61								
Feb-97								4.81	4.14	2.5	1.97								
Mar-97								2.75	1.74	1.37	1.17	2.16							
Apr-97								4.68	3.89	1.52	1.26								
May-97								4.06	3.71	2.07	2.02								
Jun-97								3.81	3.43	2.03	2.04	2.11							
Jul-97						2.6		4.45	3.88	1.84	2.23								
Aug-97																			
Sep-97								1.56	4.69	2.25	1.82	3.03							
Oct-97	3.12	0.58			1.76			4.08	3.83	2.16	1.88								
Nov-97								3.59	3.22	2.44	2								
Dec-97												2.29							
Feb-98									3.79	2.04	2.06								
Mar-98								4.35	3.3		2.23	2.05							
Apr-98								4.23	3.74		2.49								
May-98								4.47	4.11	2.31	2.42								
Jun-98								4.25	4.37		2.64	1.8							
Aug-98																			
Sep-98								2.43	2.53		1.42	1.61							
Oct-98																			
Nov-98																			
Dec-98								4.75	4.35	2.6	2.45	2.67							
Feb-99																			
Mar-99								4.31	3.94	20	2.33	2.86							
Apr-99																			
May-99										1.96									
Jun-99								5.05	4.84	2.44	2.21	2.41							
Jul-99																			
Aug-99																			
Sep-99								5.22	4.75	2.51	2.32	2.81							
Oct-99																			
Nov-99																			
Dec-99								3.19	2.31	1.41	1.26	1.86							
Jan-00																			
Feb-00																			
Mar-00	3.7	1.86	2.34	2.61	2.38		1.86	3.34	3.3	2.47	2.49	2.4							
May-00																			
Jun-00								5.07	4.71		2.51	2.55							
Aug-00																			
Sep-00								5.01	4.46		2.4	3.08							
Oct-00																			
Nov-00																			
Dec-00								2.87	2.76		2.24	2.91							

	MW-7	MW-8	NRMC-1	NRMC-2	NRMC-3	NCS-A*	NCS-B*	NCS-2*	NCS-3*	NCS-4*	NCS-5	NCS-7	NCS-8	NCS-9A
Jan-78														
Feb-78														
Mar-78	1.7	1.3												
Apr-80														
Feb-85														
Mar-85		1												
Mar-86														
Jun-87														
Dec-87														
Feb-88														
Mar-88	1.04													
May-88														
Jun-88														
Aug-88														
Nov-88														
Jan-89														
May-89														
Jul-89														
Oct-89														
Jan-90														
Mar-90		1.06												
Apr-90														
Jun-90														
Oct-90														
Jan-91														
Apr-91														
Jul-91														
Oct-91														
Apr-92														
Aug-92														
Sep-92														
Oct-92														
Nov-92														
Nov-92														
Dec-92														
Jan-93														
Jan-93														
Feb-93														
Mar-93						1.65	1.5	1.5	0.35	20.9				
Apr-93														
May-93														
Jun-93														
Jul-93														
Aug-93														
Sep-93														
Oct-93														
Nov-93														
Dec-93														
Jan-94														
Feb-94														
Mar-94														
Apr-94														
May-94														
Jun-94														
Jul-94														
Aug-94														
Sep-94														
Oct-94														
Nov-94														
Dec-94					2.71			1.58			1.81			
Jan-95														
Feb-95														
Mar-95														
Apr-95														
May-95														
Jun-95														
Jul-95														
Sep-95														
Oct-95														
Nov-95														
Dec-95														
Jan-96														
Feb-96														
Mar-96			3.2	2.5	3.1			2.2			1.9	1	1.7	1.4
Apr-96														
May-96														
Jun-96														
Jul-96														
Aug-96														
Sep-96														
Oct-96														
Nov-96														
Dec-96														
Jan-97														
Feb-97														
Mar-97			2.4	2.2	2.5			2.1	1.4		2.1	0.88	1.2	1.3
Apr-97														
May-97														
Jun-97														
Jul-97														
Aug-97														
Sep-97														
Oct-97														
Nov-97														
Dec-97														
Feb-98														
Mar-98														
Apr-98														
May-98														
Jun-98														
Aug-98														
Sep-98													.	
Oct-98														
Nov-98														
Dec-98														
Feb-99														
Mar-99														
Apr-99														
May-99														
Jun-99														
Jul-99			2.4	2.5	3.2	1.9	1.4	2.3	1.7		2.7	0.9	1.5	1.4
Aug-99														
Sep-99														
Oct-99														
Nov-99														
Dec-99														
Jan-00														
Feb-00														
Mar-00														
May-00														
Jun-00														
Aug-00														
Sep-00														
Oct-00														
Nov-00														
Dec-00														

* result for FY 1993 date set at March 1993 for regression calculations

Appendix B: Nitrate-nitrogen concentration statistics (mg/l).

well	count	average	st. dev.	maximum	minimum	range	median	mode
HGC-3	3	1.25	0.02	1.27	1.24	0.03	1.25	#N/A
F-19	1	2.00	#DIV/0!	2.00	2.00	0.00	2.00	#N/A
F-20	2	1.80	0.42	2.10	1.50	0.60	1.80	#N/A
D-25	2	1.30	0.28	1.50	1.10	0.40	1.30	#N/A
D-26	2	1.65	0.21	1.80	1.50	0.30	1.65	#N/A
D-27	2	1.64	0.05	1.67	1.60	0.07	1.64	#N/A
D-28	2	1.86	0.21	2.00	1.71	0.29	1.86	#N/A
Y-18	1	2.10	#DIV/0!	2.10	2.10	0.00	2.10	#N/A
Y-19	1	2.60	#DIV/0!	2.60	2.60	0.00	2.60	#N/A
Y-20	1	0.90	#DIV/0!	0.90	0.90	0.00	0.90	#N/A
FM-1	8	2.72	0.40	3.15	1.90	1.25	2.80	2.90
GICC MG-1	40	1.20	0.46	2.46	0.20	2.26	1.10	0.95
GICC MG-2	40	1.47	0.52	3.40	0.45	2.95	1.50	1.50
GICC MG-3	40	1.59	0.71	4.90	0.40	4.50	1.48	1.20
GICC M-GD	21	1.62	0.56	2.30	0.53	1.77	1.85	2.10
A-1	34	1.46	0.50	3.10	0.65	2.45	1.41	1.38
A-2	35	2.68	0.58	3.96	0.72	3.24	2.73	2.70
A-3	32	1.06	0.26	1.81	0.73	1.08	1.01	0.81
A-4	33	2.35	0.54	3.66	1.19	2.47	2.31	#N/A
A-5	35	2.02	0.38	2.78	0.95	1.83	2.02	2.28
A-6	35	2.04	0.40	3.03	0.93	2.10	2.08	2.35
A-7	34	2.50	0.44	3.34	0.96	2.38	2.56	2.57
A-8	35	1.82	0.36	2.37	0.44	1.93	1.91	1.91
A-9	33	1.32	0.30	1.92	0.50	1.42	1.36	1.34
A-10	31	1.60	0.50	2.90	0.11	2.79	1.69	1.73
A-11	29	1.15	0.27	1.77	0.46	1.31	1.13	1.01
A-12	34	1.18	0.31	1.83	0.48	1.35	1.19	1.25
A-13	33	2.02	0.50	3.62	0.68	2.94	2.06	2.00
A-14	34	2.11	0.38	2.87	0.85	2.02	2.14	2.20
A-15	34	3.58	0.72	4.91	1.49	3.42	3.71	3.60
A-17	35	2.71	0.48	3.83	1.19	2.64	2.75	2.80
A-18	33	1.86	0.36	2.49	0.84	1.65	1.88	1.88
A-19	31	2.93	0.71	4.12	0.94	3.18	3.01	3.52
A-21	31	1.27	0.32	2.35	0.46	1.89	1.31	1.23
A-23	36	3.23	0.88	4.69	1.05	3.64	3.45	2.00
A-25	36	3.77	0.76	5.27	1.21	4.06	3.81	3.60
A-26	35	3.86	0.85	4.90	1.32	3.58	3.97	4.90
A-28	34	1.85	0.37	2.94	0.71	2.23	1.91	1.84
A-29	22	2.21	0.34	2.69	1.07	1.62	2.22	2.00
A-30	24	2.54	0.32	2.99	1.33	1.66	2.53	2.40
A-31	27	2.63	0.37	3.10	1.32	1.78	2.71	2.20
A-32	22	2.73	0.55	3.59	1.27	2.32	2.84	2.10
AG-1	29	0.91	0.19	1.13	0.19	0.94	0.96	0.88
AG-2	29	1.31	0.22	1.71	0.74	0.97	1.37	1.41
D-1	33	1.76	0.32	2.87	0.77	2.10	1.77	1.79
D-2	31	1.70	0.27	2.30	0.82	1.48	1.71	1.78
D-3	33	1.72	0.39	2.68	0.60	2.08	1.76	1.80
D-4	31	1.71	0.29	2.20	0.55	1.65	1.74	1.83
D-5	34	1.44	0.30	2.23	0.74	1.49	1.44	1.24
D-6	32	1.40	0.29	2.40	0.76	1.64	1.37	1.36
D-7	33	1.44	0.29	2.10	0.47	1.63	1.42	1.33
D-8	33	0.95	0.22	1.40	0.14	1.26	0.98	1.01
D-9	31	1.73	0.30	2.30	0.78	1.52	1.76	1.76
D-10	30	1.55	0.33	2.40	0.76	1.64	1.62	1.67
D-11	32	1.62	0.38	2.60	0.40	2.20	1.65	1.62
D-12	33	0.93	0.18	1.20	0.29	0.91	0.97	0.97
D-13	33	1.25	0.22	1.83	0.74	1.09	1.23	1.30
D-14	36	2.76	0.78	4.94	0.20	4.74	2.71	2.70
D-15	36	2.33	0.39	3.60	1.17	2.43	2.35	2.60
D-16	34	2.99	0.53	4.39	1.02	3.37	3.06	3.12
D-17	36	2.12	0.54	3.80	1.17	2.63	1.98	2.80
D-18	36	3.04	0.55	4.80	0.76	4.04	3.03	3.40
D-19	33	1.42	0.38	2.30	0.69	1.61	1.41	1.05
D-20	34	1.58	0.47	2.96	0.79	2.17	1.51	1.86
D-21	34	2.40	0.63	3.95	1.04	2.91	2.38	1.69
D-22A	3	2.20	0.00	2.20	2.20	0.00	2.20	2.20
D-24	6	2.30	0.41	3.00	2.00	1.00	2.12	2.00
EX-5A	30	1.62	0.49	2.60	0.01	2.60	1.72	1.71
EX-11	31	2.51	0.76	4.70	0.80	3.90	2.44	3.90
F-1	32	1.13	0.25	1.90	0.62	1.28	1.15	1.17
F-2	32	1.12	0.15	1.42	0.75	0.67	1.14	1.15
F-3	32	1.21	0.22	1.61	0.56	1.05	1.26	1.28
F-4	30	0.81	0.22	1.33	0.17	1.16	0.80	0.67
F-5	36	2.48	0.54	3.50	1.38	2.12	2.49	3.50

"#DIV/0!" And "#N/A" indicates that the statistic could not be calculated

Appendix B: Nitrate-nitrogen concentration statistics (mg/l).

well	count	average	st. dev.	maximum	minimum	range	median	mode
F-6	33	1.91	0.56	3.00	0.52	2.48	1.97	3.00
F-7	33	2.89	0.38	3.42	2.00	1.42	2.94	2.92
F-8	31	2.41	0.57	3.72	1.30	2.42	2.46	#N/A
F-9	32	2.07	0.51	3.20	1.26	1.94	2.08	3.20
F-10	31	1.48	0.28	2.03	0.80	1.23	1.55	1.39
F-11	32	1.03	0.16	1.45	0.60	0.85	1.05	1.05
F-12	23	2.68	0.70	4.06	0.30	3.76	2.58	3.20
F-13	10	3.22	0.85	4.35	2.12	2.23	3.39	3.90
F-15	6	1.03	0.31	1.45	0.54	0.91	1.00	#N/A
F-16	8	2.27	1.77	4.40	0.78	3.62	1.15	4.40
F-17	5	1.03	0.18	1.26	0.90	0.36	0.90	0.90
F-18	4	1.20	0.24	1.49	1.00	0.49	1.15	1.00
GH-501	33	1.96	0.45	2.72	0.40	2.32	2.02	2.40
H-1	32	1.77	0.25	2.10	0.68	1.42	1.79	1.73
HGC-2	16	0.60	0.22	0.82	0.02	0.80	0.67	0.75
M-1	35	1.86	0.51	3.40	0.56	2.84	1.90	1.56
M-2	35	2.01	0.62	3.30	0.65	2.65	1.87	3.10
M-3	35	2.29	0.70	4.00	0.68	3.32	2.30	3.50
M-4	36	2.82	0.93	5.00	0.70	4.30	2.69	2.47
M-5	35	1.30	0.23	2.08	0.56	1.52	1.34	1.35
M-6	28	1.50	0.33	2.53	0.69	1.84	1.57	1.20
M-7	34	1.35	0.37	2.90	0.50	2.40	1.31	1.30
M-8	35	2.51	0.69	4.40	0.71	3.69	2.34	2.34
M-9	34	2.33	0.65	3.90	1.00	2.90	2.20	3.20
M-12	33	2.68	0.40	4.20	1.45	2.75	2.67	2.80
M-14	36	2.94	0.66	4.20	0.98	3.22	2.93	2.33
M-15	35	1.80	0.53	2.90	0.58	2.32	1.79	1.90
M-16B	28	2.28	0.49	3.53	0.79	2.74	2.29	2.27
M-17A	24	2.06	0.17	2.55	1.83	0.72	2.06	2.09
M-17B	26	2.17	0.22	2.53	1.93	0.60	2.09	2.50
M-18	2	1.49	0.01	1.50	1.48	0.02	1.49	#N/A
M-20A	2	2.35	0.21	2.50	2.20	0.30	2.35	#N/A
M-21	1	3.50	#DIV/0!	3.50	3.50	0.00	3.50	#N/A
NAS-1	2	2.06	0.37	2.32	1.80	0.52	2.06	#N/A
Y-1	33	2.77	0.55	4.17	1.14	3.03	2.82	2.56
Y-2	33	2.94	0.50	4.34	1.38	2.96	3.02	3.23
Y-3	32	3.00	0.72	5.37	1.34	4.03	3.09	3.45
Y-4	12	2.80	0.70	4.35	1.41	2.94	2.92	#N/A
Y-4A	7	2.69	0.29	3.21	2.35	0.86	2.59	#N/A
Y-5	33	2.58	0.54	3.58	1.34	2.24	2.69	2.80
Y-6	32	2.97	0.72	4.61	0.67	3.94	3.07	2.55
Y-7	32	1.35	0.45	3.23	0.58	2.65	1.27	1.13
Y-9	29	2.18	0.63	3.02	0.00	3.02	2.25	2.27
Y-10	1	2.61	#DIV/0!	2.61	2.61	0.00	2.61	#N/A
Y-12	3	2.08	0.31	2.38	1.76	0.62	2.10	#N/A
Y-14	1	2.60	#DIV/0!	2.60	2.60	0.00	2.60	#N/A
Y-15	4	1.39	0.43	1.86	0.88	0.98	1.41	#N/A
MGC-1	68	4.18	0.72	5.73	1.56	4.17	4.29	4.06
MGC-2	63	3.87	0.77	4.85	0.97	3.88	4.03	3.83
MGC-3	58	2.59	2.39	20.00	1.21	18.79	2.27	2.30
MGC-4	70	1.86	0.46	2.96	0.98	1.98	1.85	1.26
MGC MW1	31	2.38	0.73	4.26	1.06	3.20	2.30	#N/A
MGC MW-2	12	2.35	0.64	3.47	1.21	2.26	2.32	#N/A
MGC MW-3	12	1.60	0.47	2.50	0.41	2.09	1.63	#N/A
MW-1	3	1.39	0.09	1.48	1.30	0.18	1.40	#N/A
MW-2	4	1.59	0.25	1.90	1.37	0.53	1.55	#N/A
MW-3	3	1.86	0.15	2.00	1.70	0.30	1.87	#N/A
MW-5	3	1.00	0.35	1.40	0.80	0.60	0.80	0.80
MW-6	5	1.45	0.63	2.20	0.52	1.68	1.44	#N/A
MW-7	2	1.37	0.47	1.70	1.04	0.66	1.37	#N/A
MW-8	3	1.12	0.16	1.30	1.00	0.30	1.06	#N/A
NRMC-1	3	2.67	0.46	3.20	2.40	0.80	2.40	2.40
NRMC-2	3	2.40	0.17	2.50	2.20	0.30	2.50	2.50
NRMC-3	4	2.88	0.33	3.20	2.50	0.70	2.91	#N/A
NCS-A	2	1.78	0.18	1.90	1.65	0.25	1.78	#N/A
NCS-B	2	1.45	0.07	1.50	1.40	0.10	1.45	#N/A
NCS-2	5	1.94	0.37	2.30	1.50	0.80	2.10	#N/A
NCS-3	3	1.15	0.71	1.70	0.35	1.35	1.40	#N/A
NCS-4	1	20.90	#DIV/0!	20.90	20.90	0.00	20.90	#N/A
NCS-5	4	2.13	0.40	2.70	1.81	0.89	2.00	#N/A
NCS-7	3	0.93	0.06	1.00	0.88	0.12	0.90	#N/A
NCS-8	3	1.47	0.25	1.70	1.20	0.50	1.50	#N/A
NCS-9A	3	1.37	0.06	1.40	1.30	0.10	1.40	1.40

"#DIV/0!" And "#N/A" indicates that the statistic could not be calculated

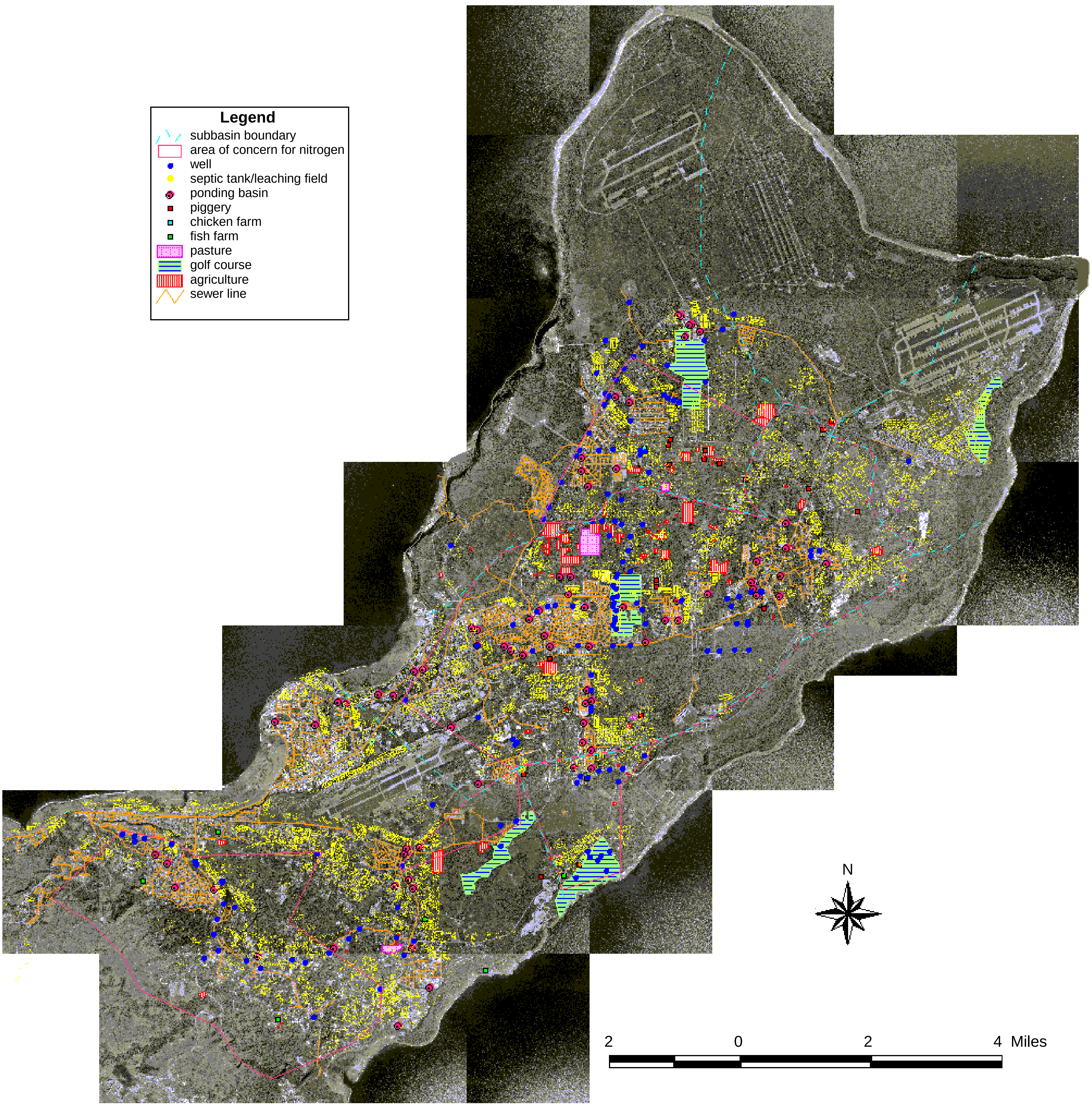

Plate 1. Potential nitrogen sources in Northern Guam (shown on 1994 Government of Guam Bureau of Planning orthophotos).