The Establishment of a Long-term Citizens Groundwater Monitoring Program for the North Fork of the Shenandoah River Watershed

Year Three

1996

A cooperative effort by
The Friends of the North Fork of the Shenandoah River,
The Lord Fairfax Planning District,
and the
EPA Region 3 Groundwater Office

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FRIENDS OF THE NORTH FORK OF THE SHENANDOAH RIVER

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EXECUTIVE SUMMARY

A 1993 Virginia Department of Conservation and Recreation (DCR) report assessed the highest possible ranking for nonpoint source pollution (NPS) priority to the watershed of the North Fork of the Shenandoah River. A cooperative effort by Friends of the North Fork Shenandoah River (FNFSR), local government, and the U.S. Environmental Protection Agency (USEPA) was undertaken in the summer of 1994 to set up a long-term citizens groundwater monitoring program for the watershed to assist in the identification and control of NPS and other contamination problems. The main objectives of the program were to: 1) initiate a benchmark of groundwater quality, 2) identify specific contaminants, and 3) monitor long-term groundwater quality trends.

The second year (1995) of the Citizens Groundwater Monitoring Program (CGMP) for the North Fork of the Shenandoah River Watershed emphasized testing of groundwater samples for acidity/alkalinity (pH), and the presence of total and fecal coliforms, viruses, atrazine and metolachlor (herbicides), nitrate-nitrogen and phosphate. Chromium, manganese, and lead, metals commonly associated with sewage (biosolids), were added to the program as the application of biosolids to farmland in Shenandoah County is common.

Sampling for the third year of the program was conducted in August and September 1996. Twenty-four wells were once again selected to represent as many different regions, topographies, and land uses as possible within the boundaries of Shenandoah County. As before, wells selected varied in depth, age, flow, (gallons/minute, GPM), construction, and usage.

In 1996, thirteen samples (54.2%) were negative for both total and fecal coliforms while eight samples (33.3%) were positive for total coliforms but negative for fecal coliforms. Three samples (12.5%) were positive for both total and fecal coliforms, and of these, two samples (8.3%) were also positive for fecal streptococci.

Six samples (25%) contained aluminum in concentrations ranging from 0.008 milligrams/liter (mg/L) to 0.044 mg/L. Hexavalent chromium was found in concentrations of 0.01 mg/L to 0.02 mg/L in thirteen samples (54.2%) which are less than the USEPA Maximum Contaminant Level (MCL) of 0.1 mg/L. Twenty-one samples (87.5%) contained copper in concentrations ranging from 1.7 microgram/liter (ug/L) to 356.0 ug/L; the current USEPA Secondary MCL for copper is 1 mg/L (or 1000 ug/L) which all 21 samples fell below. Lead concentrations ranging from 1 ug/L to 9 ug/L were found in five samples (20.8%). These values were all below the USEPA MCL of 0.015 mg/L (or 15 ug/L) lead.

Manganese was found in all 24 samples (100%) ranging in concentrations of 0.10 mg/L to 0.73 mg/L which all fall above the USEPA Secondary MCL of 0.05 mg/L. Seventeen samples (70.8%) tested positive for nitrate-nitrogen with concentrations ranging

between 0.1 mg/L and 5.8 mg/L which fall well below the USEPA MCL for nitrate-nitrogen of 10.0 mg/L. Eighteen samples (75%) were found to contain phosphate in concentrations ranging from 0.01 mg/L to 1.97 mg/L. Acidity/alkalinity (pH) readings were between 6.1 and 8.1.

Atrazine was determined to be in concentrations ranging between 0.05 ug/L and 0.55 ug/L in ten samples (41.7%). The current USEPA MCL for atrazine is 3.0 ug/L. Twenty-two samples (91.7%) tested positive for metolachlor with concentrations ranging from 0.06 ug/L to 0.58 ug/L; currently there exists no USEPA MCL for metolachlor. The assays used for these herbicides have minimum and maximum detection limits of 0.05 ug/L and 5.0 ug/L, respectively, so it is impossible to prove any samples were actually negative for either. Results can only be presented as less than the minimum detection level of 0.05 ug/L. All 24 samples were determined to contain at least 0.05 ug/L of atrazine, metolachlor, or both herbicides.

It is strongly recommended to have these assays performed again during the 1997 sampling to search for similarities and differences in the results which could enable possible contamination sources to be identified and corrected. Establishing a winter sampling would also yield important data as the groundwater table rises to its highest level of the year during the winter months. This would enable the FNFSR database to be expanded to include two sets of data for each well each year and would thereby allow for seasonal comparisons to be evaluated as well.

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I. INTRODUCTION

A. SETTING

Most of the watershed of the North Fork of the Shenandoah River is located in Shenandoah County, Virginia. Shenandoah County is located in the northwest section of the Shenandoah Valley and is bounded by the Allegheny Mountains, with Massanutten Mountain to the northeast and east, and Shenandoah Mountain and Great North Mountain to the northwest. Blessed with an abundance of natural springs, streams, and the North Fork of the Shenandoah River, the area has drawn settlers since the mid-1600s. It is an area of exceptional beauty. The Indians called the sparkling Shenandoah River the "Daughter of the Stars" and the valley was known as "The Valley of the Daughter of the Stars."

Woodstock, the seat of Shenandoah County, was founded in 1752. Shenandoah County consists of 512 square miles with the North Fork of the Shenandoah River flowing north through the county for approximately ninety miles. Eighty-seven miles of the North Fork's tributaries are designated trout waters. The famous seven horseshoe bends of the North Fork, a tourist attraction, are to the east of the town of Woodstock and visible from Woodstock Tower. The North Fork of the Shenandoah River joins the South Fork of the Shenandoah River at the town of Front Royal to make the Shenandoah River. The Shenandoah River continues

flowing north to its confluence with the Potomac River at Harpers Ferry, West Virginia, with the Potomac flowing southeast to enter the Chesapeake Bay.

B. BACKGROUND

In 1986 a comprehensive study of water demands in the North Fork of the Shenandoah River Subarea was completed by the Virginia State Water Control Board. The subarea is drained by the North Fork of the Shenandoah River and its major tributaries that include Stoney Creek, Smith Creek, Passage Creek and Cedar Creek. The subarea includes minor portions of the counties of Rockingham, Page, Warren, and Frederick. Identified items that posed potential detrimental effects on future water quantity and quality in the subarea included: agriculture and irrigation practices, unaccounted water, rural expansion, lack of emergency water sources for towns, and lack of environmental flow-by constraints.

In 1988 the Virginia Water Project, Inc. delivered to Shenandoah County a DRASTIC report with groundwater pollution potential maps. The DRASTIC methodology was developed by the National Water Well Association (NWWA) under contract to the USEPA using seven parameters to evaluate groundwater pollution potential: Depth to water table, net Recharge, Aquifer media, Soils, Topography, Impact of vadose zone, and hydraulic Conductivity. The Shenandoah County DRASTIC report, with its multicolored format, graphically demonstrates high groundwater contamination potential for Shenandoah County because of its

abundance of clay soil types, carbonated rock, shallow soils, Karst topography, and population and industrial growth.

A 1993 Virginia, Nonpoint Source Pollution Watershed Assessment Report by the Department of Conservation and Recreation (DCR) highlighted the North Fork of the Shenandoah River watershed as having an extremely high potential for nonpoint source pollution (NPS) from agricultural operations. The Holman Creek area, in the North Fork watershed, was identified as one of the highest rated areas in the state for overall agricultural pollution potential. The Shenandoah Valley region, because of its high priority ratings for animal nutrient loading and agricultural land loadings, is now targeted by the DCR for conservation programs and priority funding for nutrient management and other agricultural NPS programs.

A 1993 sampling of groundwater and surface water sites in Shenandoah County by the United States Geological Survey (USGS) indicated the presence of a significant number of pesticides including: simazine, prometon, metolachlor, atrazine, and tebuthiuron.

Previous county well test projects conducted by the Friends of the North Fork Shenandoah River (FNFSR), in cooperation with the Student Training Environmental Program (STEP) of Virginia Polytechnic Institute and State University (VPI&SU), revealed fecal coliform and nitrate levels in excess of federal drinking water standards (Thurmond 1991, Arpad and Morneau 1993). The 1993 USGS study, concentrated in the magisterial districts of Lee

and Ashby (Holman Creek area), indicated that approximately twenty-five percent (25%) of the sample sites had fecal coliform or nitrate-nitrogen levels above established USEPA Maximum Contaminant Levels (MCL).

C. OBJECTIVES

The main objectives for The Establishment of a Long-term Citizens Groundwater Monitoring Program for the North Fork of the Shenandoah River Watershed are to provide high quality groundwater data which can be used to: 1) establish a benchmark of current groundwater quality, 2) identify specific contaminants, and 3) monitor long-term groundwater quantity and quality trends in the North Fork of the Shenandoah River Watershed. Such actions will allow the identification of contaminants that pose health risks to the citizens of Shenandoah County and environmental risks to the North Fork of the Shenandoah River, its tributaries, and ultimately, the Chesapeake Bay.

II. METHODS AND PROCEDURES

A. SITE SELECTION

In order to provide a county-wide geographical sampling of the watershed, a broad criterium of four wells from each of the six magisterial districts was selected. Then at least one well in each magisterial district was chosen from the current USEPA STORET System, a nationwide database of sampling sites and their associated water quality data.[1] Additional monitoring wells were selected to vary in depth, age, flow, construction and usage. Wells ranged in age from a new (less than one year old) drilled well to an old (more than 100 years old) dug well and ranged in use from private farm and subdivision wells to commercial wells for public use and meat-packing operations. Selected wells were located in regions of the magisterial district with different topographies and land uses. Also, many of the selected wells were near watercourses.

Well information and data gained through two previous FNFSR well testing projects in addition to STORET data and STORET TAG sheets were used to identify wells within the selection criteria. Owners of those wells were notified about the proposed groundwater monitoring program and asked for their potential

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[1] STORET (STO-storage; RET-retrieval) is a database of Sampling Sites and their associated water quality data. It was begun in 1964 by the USEPA and is currently undergoing a revised management system which will be called STORET X.

long-term participation in such a program. Candidate wells were plotted on the Shenandoah County map to ensure broad watershed representation, and final selection of primary wells and alternate wells occurred after location by the Global Positioning System (GPS) team and initial site survey.

Each year several of the original selected wells are dropped from the program at the owners' requests. Change in ownership of the property seems to be the leading cause for this. Alternate wells have been placed into the program to keep the number of sampling locations at four per magisterial district, however the GPS team has not determined locations of alternate wells added in 1996. These will be determined during the 1997 sampling.

B. SITE LOCATION

As the groundwater monitoring program was anticipated to be a long-term project, accurate site location (in latitude and longitude) was paramount. Positioning of each site in the Geographical Information System (GIS) data bases would allow creation of various GIS overlays which could be utilized to depict current transportation networks, watercourses, land use patterns, and other pertinent demographic information.

The 24 original well sites were located in Shenandoah County and mapped using Global Positioning System (GPS) technology. Locational data were collected over a three day period in August, 1994, using a Trimble Navigational Pathfinder Professional Positioning System Unit borrowed from the U.S. Forest Service (USFS), George Washington National Forest (GWNF), Lee Ranger

District. One hundred Latitute/Longitude positions were collected from a configuration of four satellites at each site. The satellite data was then downloaded and differentially corrected at the Lee Ranger District Office using Trimble's PFinder software and base station data collected from the USFS, GWNF, GPS Base Station at Harrisonburg VA. Accuracy levels for the corrected Latitude/Longitude positions of the wellheads are expected to be within one to three meters with uncorrected positions within nine to 12 meters.

C. SAMPLING METHODS

All samples for chemical and herbicidal testing were collected by Tracey S. DiPaola during August and September 1996. Samples for microbiological testing were collected by either Dr. Charles Hagedorn, VPI&SU, or Tracey S. DiPaola in September 1996.

Five plastic laboratory sample bottles were used for each site; two acid-washed bottles were used for aluminum, copper, manganese, and phosphate screenings; two bottles were used for chromium, lead, nitrate-nitrogen, atrazine, and metolachlor assays; and one bottle was used for all microbiological testing. Procedural guidelines used for sample containers and sample preservation were from the 1992 "EPA RCRA Groundwater Monitoring Draft Technical Guidance", Standard Methods for the Examination of Water and Wastewater, 18th Ed., and Hach Water Analysis Handbook, 2nd Ed. Bottle labeling included the well identification number with this identifier verified before the start of each sampling. Samples were taken, in most cases, from

an outside hydrant or spigot and immediately placed on ice until they could be stored at 4°C.

Water was allowed to run at each selected site until it reached its coldest temperature, and timed to ensure purging of standing water in the well pipe. The purging procedure was used to ensure samples collected from the well are representative of the in-situ groundwater quality. Well volumes were determined and calculated by using Pennsylvania Department of Environmental Resources methodology (Appendix A).

After the calculated time, the water was turned off and the sample spigot was rinsed with a wash bottle. The designated wash bottle was thoroughly rinsed with water from the sample well then allowed to fill with water to overflowing. The spigot nozzle was then submerged in the wash bottle and washed thoroughly. The sample bottles and their caps were rinsed under the spigot, filled to overflowing, and capped. Sample bottles were placed in an ice chest for transport.

A field/laboratory worksheet was used to record the well identification number, date and time of sampling, site characteristics, existing weather conditions, and other pertinent comments. In 1994, a photo was taken of each well site during the time of sampling to show the general characteristics of each site.

D. ANALYTICAL METHODS

All microbiological assays were performed by Dr. Charles Hagedorn in his laboratory at VPI&SU, Blacksburg, VA. All chemical and herbicidal tests were performed by Tracey DiPaola at the FNFSR office, Woodstock VA.

1. Microbiological Assays

a. Coliforms - Presence-absence tests were performed using the Colilert procedure, a five tube test based on the Most Probable Number (MPN). Tests positive for total coliforms but negative for fecal coliforms were confirmed by membrane filtration on eosin methylene blue (EMB) agar.

b. Fecal Coliforms - Samples positive for fecal coliforms in the Colilert procedure were then evaluated for bacterial densities by the membrane-filtration (MF) method with mFC agar, method 9222D Fecal Coliform Membrane Filter Procedure, Standard Methods for the Examinaton of Water and Wastewater, 18th Ed., American Public Health Association, 1992. Coliform densities were calculated with Section 9222B.6 methodology.

c. Fecal Streptococci - Tests were performed by the membrane filtration procedure, with mEnterococcus agar, Section 9230 A, B, and C methodology.

2. Chemical Assays

a. Aluminum - Concentrations ranging from 0 to 0.220 milligrams/l (mg/L) were determined using the Eriochrome Cyanine R Method with a Hach DR/2000 spectrophotometer at a wavelength of 535 nm. Eriochrome cyanine R combines with aluminum in a sample

to produce an orange-red color, the intensity of which is proportional to the aluminum concentration.

b. Chromium, hexavalent - Concentrations ranging from 0 to 0.60 mg/L Cr^{6+} were determined using the 1,5-Diphenylcarbohydrazide Method (powder pillows) with a Hach DR/2000 spectrophotometer at a wavelength of 540 nm. Hexavalent chromium is determined by the 1,5-diphenylcarbohydrazide method using a single dry powder formulation called ChromaVer 3 Chromium Reagent which contains an acidic buffer combined with 1,5-diphenylcarbohydrazide which reacts to give a purple color when hexavalent chromium is present.

c. Copper - Concentrations ranging from 0 to 210.0 micrograms/liter (ug/L) were determined using the Porphyrin Method with a Hach DR/2000 spectrophotometer at a wavelength of 425 nm. The porphyrin indicator forms an intense, yellow complex with any free copper present in the sample.

d. Lead - Concentrations ranging from 0 to 150 ug/L were determined using the Lead Trak ^{R} Fast Column Extraction Method with a Hach DR/2000 spectrophotometer at a wavelength of 477 nm. Acid soluble lead, as Pb^{2+}, is first concentrated on a fast column extractor and then eluted from the extractor and determined colorimetrically with an indicator.

e. Manganese - Concentrations ranging from 0 to 20.0 mg/L were determined using the Periodate Oxidation Method with a Hach DR/2000 spectrophotometer at a wavelength of 525 nm. Manganese in the sample is oxidized to the purple permanganate state by

sodium periodate, after buffering the sample with citrate. The purple color is directly proportional to the manganese concentration.

f. Nitrate-nitrogen - Concentrations ranging from 0 to 30.0 mg/L NO_3^--N were determined using the Cadmium Reduction Method (powder pillows) with a Hach DR/2000 spectrophotometer at a wavelength of 500 nm. Cadmium metal reduces nitrates present in the sample to nitrite. The nitrite ion reacts in an acidic medium with sulfanilic acid to form an intermediate diazonium salt which couples to gentisic acid to form an amber-colored product.

g. Phosphorous, reactive (orthophosphate) - Concentrations ranging from 0 to 2.50 mg/L PO_4^{3-} were determined using the PhosVer 3 (Ascorbic Acid) Method (powder pillows) with a Hach DR/2000 spectrophotometer at a wavelength of 890 nm. Orthophosphate reacts with molybdate in an acid medium to produce a phosphomolybdate complex. Ascorbic acid then reduces the complex, giving an intense molybdenum blue color.

h. Acidity/Alkalinity (pH) - The degree of acidity or alkalinity of a sample was determined using either a Hach pH Pocket Pal Tester or an Orion Research Ionalyzer/model 399A. Each meter was calibrated before use with a Standard Buffer Solution of 7.0 +/- 0.2. All values were expressed to the nearest one-tenth.

3. Herbicide Assays

a. Atrazine - Concentrations ranging from 0.05 to 5.0 ug/L were determined using the Ohmicron Atrazine RaPID Assay^R with a Hach DR/2000 spectrophotometer to produce absorbance values. Results

from calibrators are plotted on provided graph paper and used to determine final concentrations of the enzyme-linked immunosorbent assay (ELISA).

b. Metolachlor - Concentrations ranging from 0.05 to 5.0 ug/L were determined using the Ohmicron Metolachlor RaPID Assay^{R} with a Hach DR/2000 spectrophotometer to produce absorbance values. Results from calibrators are plotted on provided graph paper and used to determine final concentrations of the enzyme-linked immunosorbent assay (ELISA).

III. RESULTS AND DISCUSSION

A. Microbiological Assays

1. Total and Fecal Coliforms

In 1996, thirteen samples were negative for both total and fecal coliforms. Based on EPA standards, these would be given a designation as "potable water." Thirteen were also negative for both total and fecal coliforms in the 5/95 sampling, and 12 were negative for both in the 8/94 sampling.

Eight samples in 1996 were positive for total coliforms but negative for fecal coliforms (compared to 8 in the 5/95 sampling and 5 in the 8/94 samping). The colilert most-probable-number procedure was then used to obtain a number for total (but not fecal) coliforms. These results for total coliforms per 100 m/L are

Sample	Average number	Statistical range
SD005	<22	0 to 60
SA004	9.2	1.6 to 29.4
SS002	5.1	0.5 to 19.2
SS005	<22	0 to 60
SM001	5.1	0.5 to 19.2
SM006	9.2	1.6 to 29.4
SL003	<22	0 to 60
SL004	5.1	0.5 to 19.2

No action need be taken by property owners at this time, but they will be informed, and should consider having their water tested periodically to see if fecal coliforms appear. Of these eight, two were also positive for total coliforms in 1995 (SD005 and SA004), three were negative in 1995 (SM001, SM006, and SL004),

one new location was positive this year (SL003), and two were only positive for totals this year but were positive for both totals and fecals in 1995 (SS002 and SS005).

Three samples in 1996 were positive for both total and fecal coliforms. Three samples were positive in 5/95 and seven samples were positive in 8/94. All three are below the action point (EPA standard of 0 fecals per 100 mL). Property owners should sample their water more frequently (once every three months), and treat if fecals continue to be found. Persons living at SL001, SJ003, and SA003 should not consume water without boiling the water or using other means of sterilization. That water should be retested within a month. If the numbers of fecal coliforms is reduced to zero, then the fecal coliforms were probably washed into the well by Hurricane Fran.

2. Fecal Streptococci

Two samples were positive for fecal streptococci in 1996. Both of these samples (SJ003 and SL001) were also positive for fecal and total coliforms. No action need be taken based on the presence of fecal streptococci, as these organisms are not a suitable indicator of fecal pollution. The recovered isolates will be used in further tests that may enable the source of the pollution to be identified.

3. Results of Selected Individual Samples

Of six new sites added in 1996, only one (SL003) was positive, and just for total coliforms.

One location (SA003) has been positive for total and fecal coliforms for all three years of monitoring. The well and water supply at this location should be inspected.

Two locations (SJ003 and SL001) were positive for total and fecal coliforms in 1994, negative for both in 1995, and now are positive again for both in 1996. SL001 exceeded the EPA limit in 1994 as well as 1996.

4. Summary Comparing 8/94, 5/95, and 9/96 Samplings

All samplings are very similar where total and fecal coliforms are concerned (12 in 8/94, 11 in 5/95 and 9/96). The sample results for 9/96 are generally very similar to those of 5/95. The 1996 results may be related to a dilution effect caused by the hurricane that occurred two weeks prior to the sampling. The 1994 results are higher for fecal coliforms because three of the locations that were positive for fecals withdrew after 1994. Subtracting these three provides a total of 4 for 1994, very similar to 1995, and 1996 (3 each).

	Total Coliforms	Fecal Coliforms	Viruses	Fecal Streptococci
8/94	12	7	29	Not done
5/95	11	3	10	Not done
9/96	11	3	Not done	2

Groundwater is usually considered to move in the subsurface environment very slowly, and to change only over extended periods of time. The similarity of the 1994-1996 results support this generalization, as even a catastrophic surface event like

Hurricane Fran had little impact on fecal pollution in groundwater based on the wells that were sampled.

B. Chemical Assays

1. Aluminum

Aluminum was added to the 1996 assays based on a recommendation from the 1995 report to expand the program to include more metals indigenous to sewage and agricultural biosolids. Six samples (25%) contained aluminum in concentrations ranging from 0.008 to 0.044 mg/L. Currently there exists no USEPA MCL for this metal. Two of the samples containing aluminum were from the Ashby District, two from Johnston, one from Lee and one from Stonewall District. These results do not follow any noticeable trends based on wellhead locations, however, it would be worthwhile to test again for this metal in future samplings.

2. Chromium

Hexavalent chromium was assayed once again this year even though all 1995 samples were negative for this ion. Thirteen samples (54.2%) were found to contain chromium in concentrations of either 0.01 or 0.02 mg/L. The current USEPA MCL for chromium is 0.1 mg/L, so none of the samples tested contained over the MCL. It would be prudent to continue assaying for this ion in future samplings to determine if the chromium level is increasing in the groundwater of Shenandoah County. All four samples from Lee District contained chromium as did three from Ashby, three from Madison, and one each in Davis, Johnston, and Stonewall.

3. Copper

Copper, as aluminum, was added to the 1996 assays based on the 1995 recommendation to add metals indigenous to sewage and biosolids. Twenty-one samples (87.5%) contained copper in concentrations ranging from 1.7 to 356.0 ug/L. The current USEPA Secondary MCL for copper is 1 mg/L or 1000 ug/L, therefore, all 21 samples do fall below this standard. Copper was found in all samples from Ashby, Madison and Stonewall Districts and in three of the samples from each of the districts of Davis, Johnston, and Lee. Eight samples (33.3%) contained between 5 and 10 ug/L, three samples (12.5%) contained between 13 and 16 ug/L, and four samples (16.7%) contained concentrations of copper between 29 and 36 ug/L. The highest concentrations found were 243.5 ug/L for 94SA004 and 356.0 ug/L for 94SS001. Samples 94SA004 and 94SS001 are from water supplies serving older residences which possibly contain older plumbing systems from which copper may be leaching.

4. Lead

Lead was again included in the 1996 assays as a total of ten samples (41.7%) were positive for lead in the 1995 testing. Five samples (20.8%) tested positive for lead, three of which were also found to contain lead in the 1995 assay. These samples were 94SA004, 94SJ002, and 94SS001. Sample 94SA004 went from 1 ug/L in 1995 to 9 ug/L in 1996, while sample 94SJ002 stayed at 1 ug/L in both assays and sample 94SS001 decreased from 8 ug/L to 1 ug/L over the two years. One sample 94SJ005 tested positive this year for 1 ug/L lead after testing negative last year. Well 96SA005,

added this year as a replacement, was sampled and found to contain a lead concentration of 6 ug/L.

Three of the wells which tested positive for lead in 1995 subsequently have resigned from the CGMP for 1996, so comparisons are not possible for those water supplies. The remaining four lead-positive samples from 1995 all tested negative for lead this year. Three of these decreased from 1 ug/L to 0 ug/L while one sample 94SS004, decreased from 83 ug/L to 0 ug/L.

As the current USEPA MCL for lead is 0.015 mg/L or 15 ug/L, all samples which tested positive for lead in both 1995 and 1996 were below this standard except for 94SS004 at 83 ug/L in 1995. As stated above this water supply now tests at 0 ug/L lead.

5. Manganese

All 24 samples (100%) were found to contain concentrations of manganese ranging from 0.10 mg/L to 0.73 mg/L. In 1995, 79 percent of the samples contained manganese with 74 percent of these at concentrations below 0.5 mg/L. In 1996 18 samples (75%) had concentrations below 0.5 mg/L and 6 samples (25%) between 0.50 and 0.73 mg/L manganese. The current USEPA Secondary MCL for manganese is 0.05 mg/L. All manganese-positive samples in both 1995 and 1996 were found to have concentrations greater than this standard.

Of the 18 samples which can be compared directly between the 1995 and 1996 assays, nine were found to have increased in manganese concentrations ranging from 0.1 to 0.6 mg/L increase, with the largest change found in sample 94SJ002 which tested

negative in 1995 and then was found to have a concentration of 0.6 mg/L in 1996. Four samples decreased in concentration levels by a range of 0.1 to 0.2 mg/L decrease and five samples were found to have the same concentrations of manganese in both 1995 and 1996.

6. Nitrate-nitrogen

Seventeen samples (70.8%) had concentrations of nitrate-nitrogen ranging between 0.1 mg/L and 5.8 mg/L. The current USEPA MCL for nitrate-nitrogen is 10 mg/L which none of the samples exceeded. Of these samples six (25%) had concentrations below 1.0 mg/L, seven (29.2%) had concentrations ranging from 1.0 to 5.0 mg/L, and four (16.7%) had concentrations ranging from 5.1 mg/L and 5.8 mg/L nitrate-nitrogen.

In 1995, 21 of the 23 samples collected contained concentrations of nitrate-nitrogen. Of those 21 samples, ten had concentrations below 1.0 mg/L, eight had concentrations ranging from 1.0 to 5.0 mg/L, two had concentrations ranging from 5.1 mg/L to 10 mg/L and one sample, 94SL002, had a concentration of 35.8 mg/L nitrate-nitrogen (above USEPA MCL).

Nitrate-nitrogen was the only chemical assay included in the 1994 CGMP so therefore this is the only chemical assay for which three years of data has been collected. In 1994 23 of the 24 samples collected contained concentrations of nitrate-nitrogen. Of these 23 samples 15 had concentrations below 1.0 mg/L, four had concentrations between 1.0 and 5.0 mg/L and four had concentrations between 5.1 and 10 mg/L nitrate-nitrogen.

Of the eighteen sites that have been sampled in 1994, 1995 and 1996, fifteen have had concentrations which each year have continued to be either less than 1.0 mg/L or between 1.1 mg/L and 5.0 mg/L or greater than 5.0 mg/L. Eleven of these sites have always tested at less than 1.0 mg/L, one site at between 1.0 and 5.0 mg/L and two sites at greater than 5.0 mg/L nitrate-nitrogen. Sample 94SL004 decreased from 5.49 mg/L in 1994 to 0.1 in 1995 and then increased to 5.0 mg/L in 1996. Sample 94SA004 has increased from 0.08 mg/L to 0.1 mg/L to 5.1 mg/L over the three-year period. Sample 94SS004 increased from 2.75 mg/L in 1994 to 8.8 mg/L in 1995 and then decreased to 5.8 mg/L in 1996.

In the districts of Davis, Johnston, Madison, and Stonewall nitrate-nitrogen concentrations increased from 1994 to 1995 and decreased from 1995 to 1996 at the 11 sites sampled over the past three years. In Lee District one of three sample sites followed this trend as well. Future samplings may show this trend to be related to weather or seasonal influences.

7. Phosphate

Eighteen samples (75%) were found to contain phosphate concentrations ranging from 0.01 mg/L to 1.97 mg/L. Sixteen of these had concentrations of less than 0.10 mg/L, one sample contained 0.17 mg/L and one sample, 94SM001, contained 1.97 mg/L. Currently there exists no USEPA MCL for phosphates. All four samples from Madison District, three samples each from Ashby, Davis, Johnston, and Stonewall, and two samples from Lee District contained phosphate.

In 1995, 22 samples of 23 collected contained phosphate. Four of those samples contained less than 0.1 mg/L phosphate, sixteen contained between 0.1 and 1.0 mg/L, while two samples 94SD005 and 94SM002 contained 1.44 mg/L and 2.56 mg/L phosphate, respectively. Sample 94SD005 fell to 0.05 mg/L this year and 94SM002 resigned from the CGMP in 1996.

8. Acidity/Alkalinity (pH)

All pH readings were between 6.1 and 8.1. In 1995 they varied between 6.5 and 8.5, which is normal for Shenandoah County.

C. Herbicide Assays

1. Atrazine

Ten samples (41.7%) had concentrations of the herbicide, atrazine, ranging from 0.05 ug/L to 0.55 ug/L. The detection limit of this assay is 0.05 ug/L and eight samples (33.3%) indicated concentrations of near this amount but less than this amount. The remaining six samples (25%) are actually labeled with concentrations below the detection level (BDL) of 0.05 ug/L. As this assay determines concentrations of 0.05 to 5.0 ug/L, it is impossible to prove a concentration of 0 ug/L atrazine. It is only possible to determine the concentration is below 0.05 ug/L.

All four samples in Davis District had atrazine present, as well as three samples in Madison, and one sample positive in each of Ashby, Lee, and Stonewall Districts. Only Johnston had all four samples test below the detection limit of 0.05 ug/L.

In 1995, 11 samples (45.8%) had concentrations of atrazine above 0.05 ug/L but all were equal to or below 0.3. The remaining thirteen samples (54.2%) indicated levels of atrazine below the minimal detection limit of 0.05 ug/L. The current USEPA MCL for atrazine is 3.0 ug/L; all samples positive for atrazine in 1995 and 1996 fell below this concentration standard.

2. Metolachlor

Twenty-two samples (91.7%) tested positive for metolachlor with concentrations ranging from 0.06 ug/L to 0.58 ug/L. As with the atrazine, the metolachlor assay can detect from 0.05 to 5.0 ug/L of the herbicide. Of the twenty-two samples, five (20.8%) had concentrations of 0.06 ug/L to 0.1, eleven (45.8%) had concentrations greater than 0.1 to 0.3, and six (25%) had concentrations of greater than 0.3. Samples 95SM006 and 94SS004 had the highest concentrations of the sampling, both showing 0.58 ug/L metolachlor. The only samples that were found to contain less than 0.05 ug/L metolachlor were 94SM005 and 94SD005.

In 1995, six samples (25%) contained metolachlor in concentrations from 0.05 to 0.09 ug/L. Of these six sampling sites, two dropped out of the program, however, the remaining four samples that were metolachlor-positive in 1995 increased in contamination levels in 1996. Currently there exists no USEPA MCL for this herbicide.

D. TABLES AND FIGURES (Pages 24-43)

Table 1. GIS Locations for CGMP Water Wells Sampled in August and September 1996.

Well Name	Latitude Degrees	Latitude Minutes	Latitude Seconds	Longitude Degrees	Longitude Minutes	Longitude Seconds
94SL001	38	38	26.826	78	38	50.748
94SL002	38	40	12.967	78	40	22.336
94SL003	*	*	*	*	*	*
94SL004	38	43	20.131	78	43	39.994
94SA001	38	47	41.890	78	49	15.916
94SA003	38	47	58.286	78	40	0.538
94SA004	38	51	27.119	78	44	20.173
96SA005	*	*	*	*	*	*
94SM001	38	49	5.154	78	32	17.092
94SM005	*	*	*	*	*	*
95SM006	38	52	30.001	78	39	5.015
96SM007	*	*	*	*	*	*
94SJ002	38	52	55.763	78	27	29.050
94SJ003	38	55	0.142	78	25	22.798
94SJ005	38	55	39.000	78	22	30.000
96SJ006	*	*	*	*	*	*
94SS001	39	0	0.569	78	30	52.850
94SS002	38	56	52.740	78	30	52.807
94SS004	38	55	23.499	78	29	17.668
94SS005	38	54	35.666	78	31	29.243
94SD002	38	57	6.500	78	22	45.163
94SD004	38	56	48.638	78	22	55.388
94SD005	38	56	33.332	78	24	10.522
96SD006	*	*	*	*	*	*

* not yet determined.

Table 2. GIS Locations for CGMP Water Wells Sampled in May 1995.

Mag. District	Well Name	Latitude			Longitude		
		Degrees	Minutes	Seconds	Degrees	Minutes	Seconds
Ashby	SA001	38	47	41.890	78	49	15.916
	SA002	38	50	15.901	78	42	1.330
	SA003	38	47	58.286	78	40	0.538
	SA004	38	51	27.119	78	44	20.173
Davis	SD002	38	57	6.500	78	22	45.163
	SD003	38	56	44.268	78	23	30.175
	SD004	38	56	48.638	78	22	55.388
	SD005	38	56	33.332	78	24	10.522
Johnston	SJ001	38	50	42.636	78	25	29.075
	SJ002	38	52	55.763	78	27	29.050
	SJ003	38	55	0.142	78	25	22.798
	SJ005	38	55	39.000	78	22	30.000
Lee	SL001	38	38	26.826	78	38	50.748
	SL002	38	40	12.967	78	40	22.336
	SL004	38	43	20.131	78	43	39.994
	SL005	38	45	31.224	78	50	29.211
Madison	SM001	38	49	5.154	78	32	17.092
	SM002	38	50	50.160	78	31	54.325
	SM004	38	52	40.236	78	41	10.003
	SM006	38	52	30.001	78	39	5.015
Stonewall	SS001	39	0	0.569	78	30	52.850
	SS002	38	56	52.740	78	30	52.807
	SS004	38	55	23.499	78	29	17.668
	SS005	38	54	35.666	78	31	29.243

Table 4. Results of Several Microbiological Assays Performed on Water Samples Collected from CGMP Wells September 1996.

Sample #	Presence/Absence Coliform Test* Total	Presence/Absence Coliform Test* Fecal	Fecal Coliforms ** Cells/100ml	Fecal Streptococci*** Cells/100ml
94SL001	+	+	<10	14
94SL002	—	—	—	—
94SL003	+	—	—	—
94SL004	+	—	—	—
94SA001	—	—	—	—
94SA003	+	+	<1	—
94SA004	+	—	—	—
96SA005	—	—	—	—
94SM001	+	—	—	—
94SM005	—	—	—	—
95SM006	+	—	—	—
96SM007	—	—	—	—
94SJ002	—	—	—	—
94SJ003	+	+	<1	12
94SJ005	—	—	—	—
96SJ006	—	—	—	—
94SS001	—	—	—	—
94SS002	+	—	—	—
94SS004	—	—	—	—
94SS005	+	—	—	—
94SD002	—	—	—	—
94SD004	—	—	—	—
94SD005	+	—	—	—
96SD006	—	—	—	—

* Presence-absence test conducted by the Colilert procedure. Tests positive for total coliforms but negative for fecal coliforms were confirmed by membrane filtration on eosin methylene blue agar (EMB)

** Fecal coliform test performed by the membrane filtration procedure, with mFC agar.

*** Fecal streptococci test performed by the membrane filtration procedure, with mEnterococcus agar.

Table 5. Results of Several Microbiological Assays Performed on Water Samples Collected from CGMP Wells May 1995.

Sample #	Presence/Absence Coliform Test* Total	Presence/Absence Coliform Test* Fecal	Fecal Coliforms ** Cells/100ml	Coliphage Virus Test *** Particles/100ml
94-SA-001	+	—	—	—
94-SA002	+	—	—	35.0
94-SA003	+	+	<1	1.0
94-SA004	+	—	—	—
94-SD002	—	—	—	16.0
94-SD003	+	—	—	—
94-SD004	+	—	—	—
94-SD005	+	—	—	—
94-SJ001	—	—	—	—
94-SJ002	—	—	—	2.4
94-SJ003	—	—	—	22.0
94-SJ005	—	—	—	—
94-SL001	—	—	—	0.8
94-SL002	—	—	—	—
94-SL004	—	—	—	—
94-SL005	—	—	—	0.8
94-SM001	—	—	—	0.2
94-SM002	+	—	—	—
94-SM004	+	—	—	—
95-SM006	—	—	—	—
94-SS001	—	—	—	—
94-SS002	+	+	<1	0.8
94-SS004	—	—	—	—
94-SS005	+	+	<1	—

* Presence-absence test conducted by the Colilert procedure. Tests positive for total coliforms but negative for fecal coliforms were confirmed by membrane filtration on eosin methylene blue agar (EMB)

** Fecal coliform test performed by the membrane filtration procedure, with mFC agar.

*** Coliphage test performed by the single layer agar overlay assay.

Table 7. Results of Several Chemical Assays Performed on Water Samples Collected from CGMP Wells in August and September 1996.

Sample #	pH	Al mg/l	Cr^{6+} mg/l	Cu µg/l	Pb µg/l	Mn mg/l	NO_3^--N mg/L	PO_4^{3-} mg/L
94SL001	7.4	0	0.02	0	0	0.1022	0.3	0.05
94SL002	7.2	0	0.01	4.2	0	0.1000	5.3	0.00
94SL003	7.6	0.014	0.01	3.2	0	0.5130	3.0	0.02
94SL004	7.4	0	0.01	4.1	0	0.3978	5.0	0.00
94SA001	7.6	0	0.02	15.1	0	0.2300	0	0.00
94SA003	7.4	0	0.01	3.0	0	0.1060	5.3	0.03
94SA004	6.1	0.027	0	243.5	9	0.2340	5.1	0.01
96SA005	7.9	0.008	0.01	3.2	6	0.2300	1.5	0.09
94SM001	6.7	0	0	9.7	0	0.6144	0	1.97
94SM005	6.9	0	0.01	13.2	0	0.4312	1.8	0.03
95SM006	6.9	0	0.01	4.5	0	0.2080	0.1	0.03
96SM007	6.9	0	0.01	15.2	0	0.2304	2.9	0.03
94SJ002	8.1	0.014	0	29.8	1	0.5800	0.3	0.00
94SJ003	6.9	0	0.02	35.2	0	0.5320	0	0.03
94SJ005	7.6	0	0	0	1	0.2200	0.4	0.01
96SJ006		0.015	0	9.5	0	0.4080	0	0.08
94SS001	7.0	0.044	0	356.0	1	0.3270	0	0.04
94SS002	6.8	0	0	8.8	0	0.3384	2.0	0.17
94SS004	6.9	0	0.01	6.3	0	0.5000	5.8	0.00
94SS005	7.0	0	0	4.1	0	0.2004	1.7	0.05
94SD002	7.3	0	0	31.7	0	0.1094	0.3	0.01
94SD004	7.5	0	0.01	29.6	0	0.2016	0.5	0.03
94SD005	6.7	0	0	1.7	0	0.7336	0	0.05
96SD006	7.3	0	0	0	0	0.1020	0	0.00

Table 8. Results of Several Chemical Assays Performed on Water Samples Collected from CGMP Wells in May 1995.

Sample #	pH	Cr mg/L	Pb µg/L	Mn mg/L	NO_3^--N mg/L	PO_4^{3-} mg/L
94-SA-001	7.5	0.00	0.00	0.2	0.00	0.15
94-SA002	*	*	*	*	*	*
94-SA003	7.3	0.00	0.00	0.1	6.70	0.26
94-SA004	7.3	0.00	1.00	0.4	0.10	0.17
94-SD002	7.4	0.00	0.00	0.1	0.70	0.07
94-SD003	7.9	0.00	34.00	0.6	1.20	0.00
94-SD004	7.3	0.00	0.00	0.3	0.70	0.07
94-SD005	6.9	0.00	1.00	0.8	0.70	1.44
94-SJ001	7.4	0.00	1.00	1.1	1.00	0.09
94-SJ002	7.6	0.00	1.00	0.0	1.00	0.35
94-SJ003	6.5	0.00	0.00	0.3	0.60	0.49
94-SJ005	7.4	0.00	0.00	0.1	0.90	0.08
94-SL001	7.3	0.00	1.00	0.2	0.00	0.28
94-SL002	7.4	0.00	0.00	0.0	35.80	0.19
94-SL004	7.1	0.00	1.00	0.4	0.10	0.17
94-SL005	8.5	0.00	1.00	0.5	1.10	0.44
94-SM001	6.8	0.00	0.00	0.2	0.40	0.32
94-SM002	7.1	0.00	0.00	0.0	3.70	2.56
94-SM004	7.0	0.00	0.00	0.0	3.20	0.20
95-SM006	7.2	0.00	0.00	0.2	0.70	0.13
94-SS001	7.2	0.00	8.00	0.1	0.80	0.84
94-SS002	7.2	0.00	0.00	0.0	2.80	0.47
94-SS004	7.5	0.00	83.00	0.1	8.80	0.20
94-SS005	7.0	0.00	0.00	0.1	2.80	0.37

* Well not accessible due to sale of property

Table 9. Results of a Nitrate-Nitrogen Assay Performed on Water Samples Collected from CGMP Wells in August 1994.

Mag. District	Well Name	Nitrate-Nitrogen (mg/L)
Ashby	SA001	0.02
	SA002	0.10
	SA003	6.78
	SA004	0.08
Davis	SD002	0.03
	SD003	0.18
	SD004	0.02
	SD005	0.02
Johnston	SJ001	0.02
	SJ002	0.07
	SJ003	0.10
	SJ005	0.06
Lee	SL001	0.03
	SL002	8.88
	SL004	5.49
	SL005	0.00
Madison	SM001	0.02
	SM002	8.40
	SM003	0.02
	SM004	3.14
Stonewall	SS001	0.30
	SS002	2.70
	SS004	2.75
	SS005	2.26

Table 10. Results of Two Herbicidal Assays Performed on Water Samples Collected from CGMP Wells in late August and September 1996.

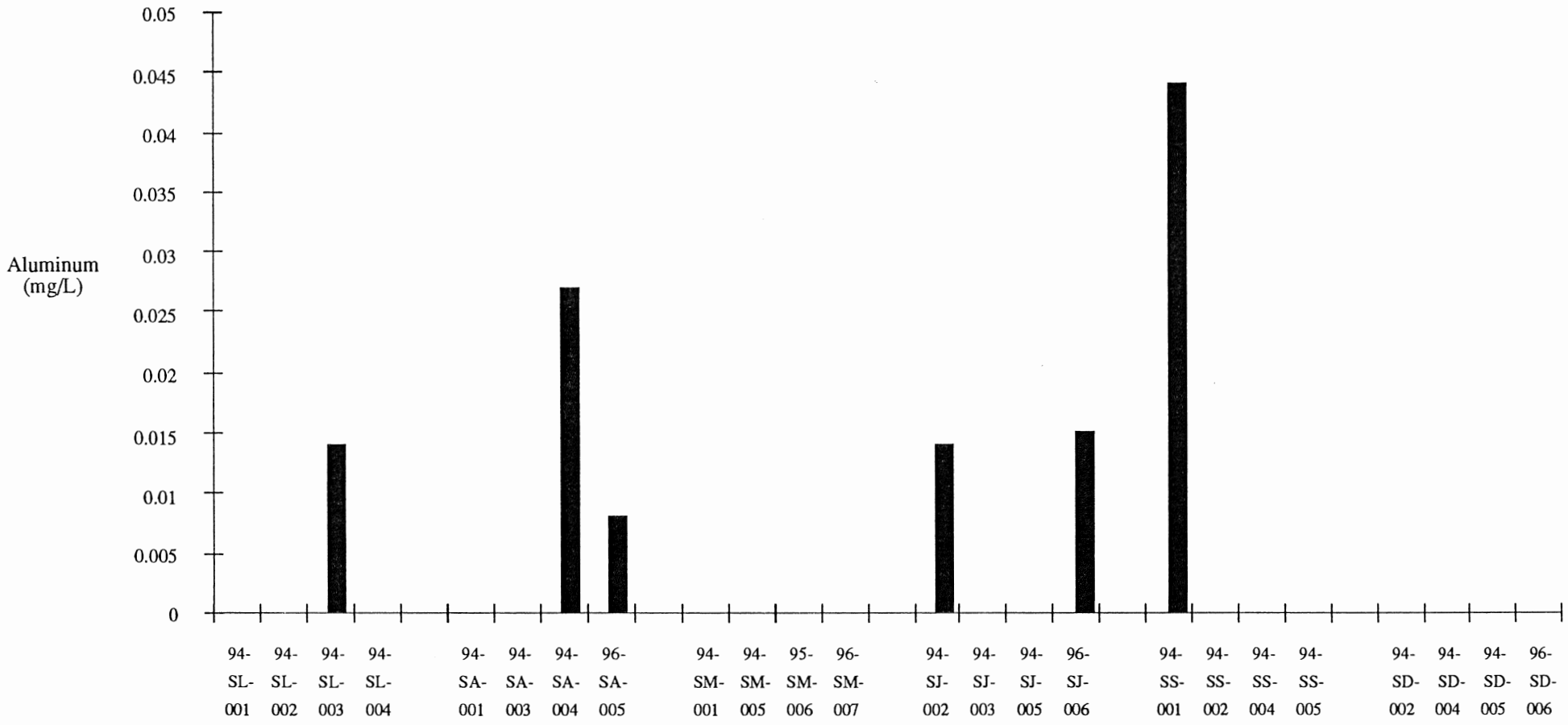
Sample #	Metolachlor µg/L	Atrazine µg/L
94SL001	0.160	<0.05
94SL002	0.140	0.12
94SL003	0.240	<0.05
94SL004	0.075	BDL*
94SA001	0.070	BDL
94SA003	0.360	0.08
94SA004	0.220	<0.05
96SA005	0.150	BDL
94SM001	0.165	BDL
94SM005	< 0.05	0.05
95SM006	0.580	0.06
96SM007	0.140	0.22
94SJ002	0.350	BDL
94SJ003	0.105	BDL
94SJ005	0.220	<0.05
96SJ006	0.090	<0.05
94SS001	0.330	<0.05
94SS002	0.280	<0.05
94SS004	0.580	0.55
94SS005	0.280	<0.05
94SD002	0.060	0.13
94SD004	0.080	0.08
94SD005	<0.05	0.08
96SD006	0.340	0.05

* BDL = Below Detection Level of 0.05 µg/L.

Table 11. Results of Two Herbicidal Assays Performed on Water Samples Collected from CGMP Wells in May 1995.

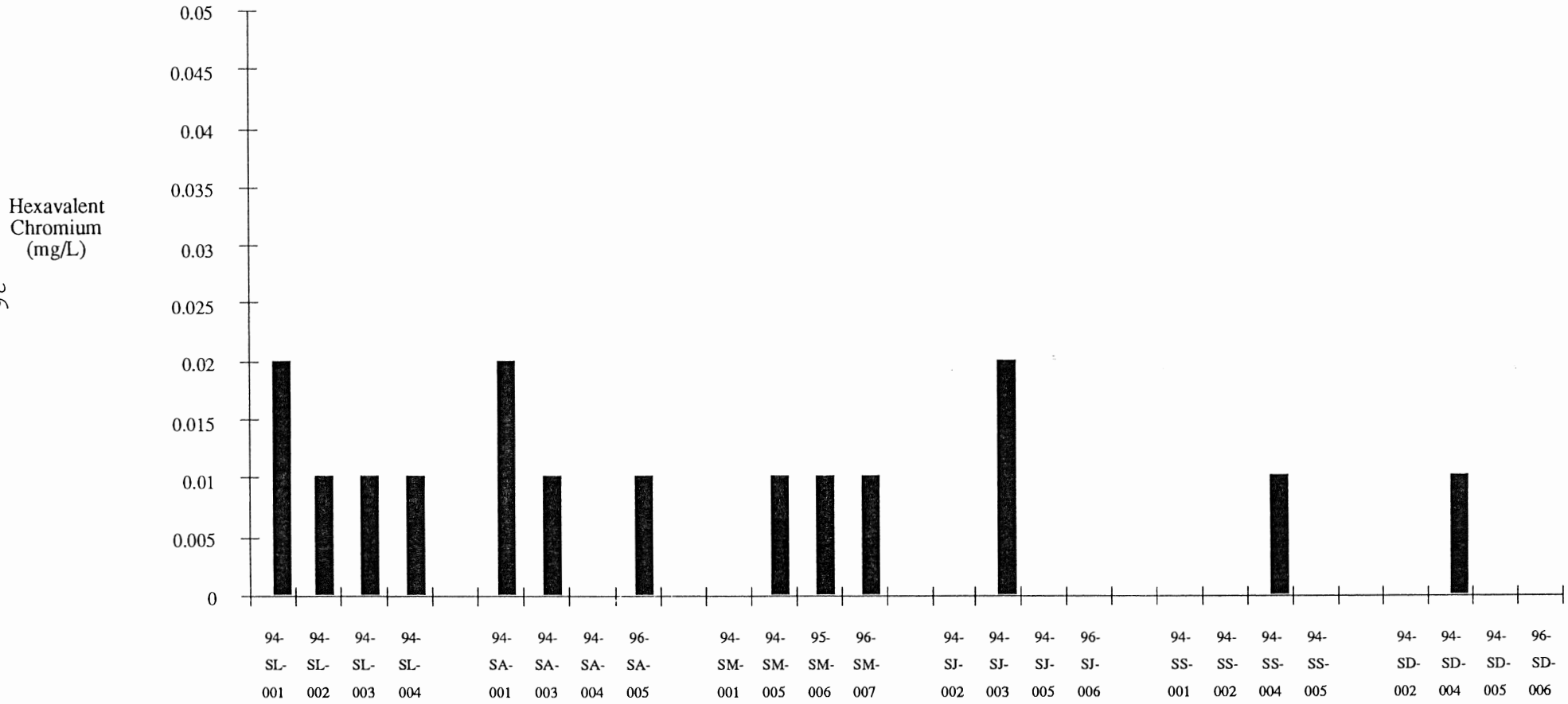
Sample #	Metolachlor µg/L	Atrazine µg/L
94-SA-001	0.02	0.25
94-SA002	0.09	0.00
94-SA003	0.07	0.16
94-SA004	0.07	0.00
94-SD002	0.00	0.00
94-SD003	0.02	0.01
94-SD004	0.03	0.00
94-SD005	0.02	0.00
94-SJ001	0.03	0.05
94-SJ002	0.02	0.06
94-SJ003	0.04	0.00
94-SJ005	0.04	0.00
94-SL001	0.03	0.12
94-SL002	0.08	0.00
94-SL004	0.01	0.05
94-SL005	0.02	0.00
94-SM001	0.02	0.05
94-SM002	0.05	0.16
94-SM004	0.04	0.03
95-SM006	0.05	0.18
94-SS001	0.03	0.05
94-SS002	0.00	0.30
94-SS004	0.03	0.00
94-SS005	0.00	0.00

Figure 1. Aluminum concentrations of water from CGMP wells sampled in August and September 1996.*



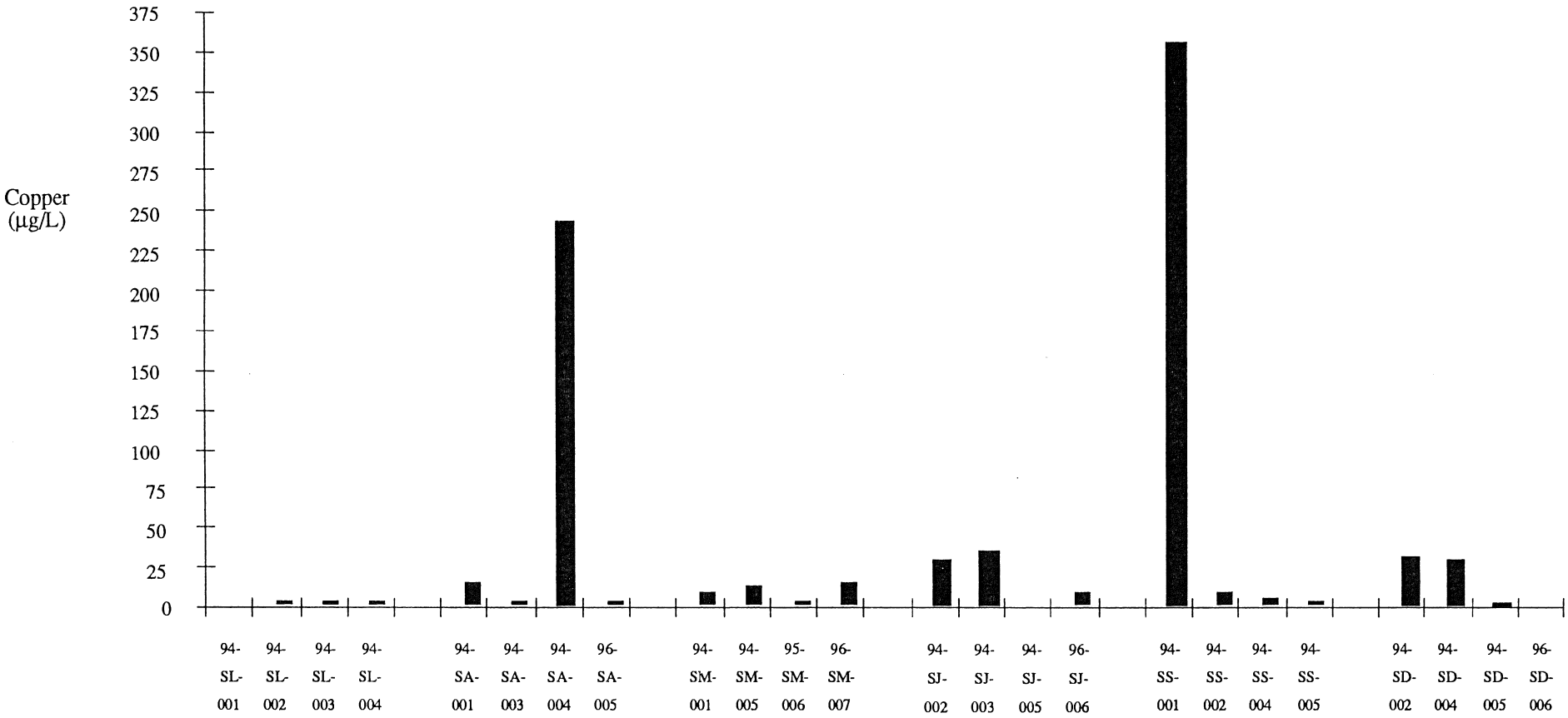
* There currently exists no U.S. EPA designated Maximum Contaminant Level (MCL) for Aluminum.

Figure 2. Chromium, hexavalent, (Cr^{6+}) concentrations of water from CGMP wells sampled in August and September 1996.*



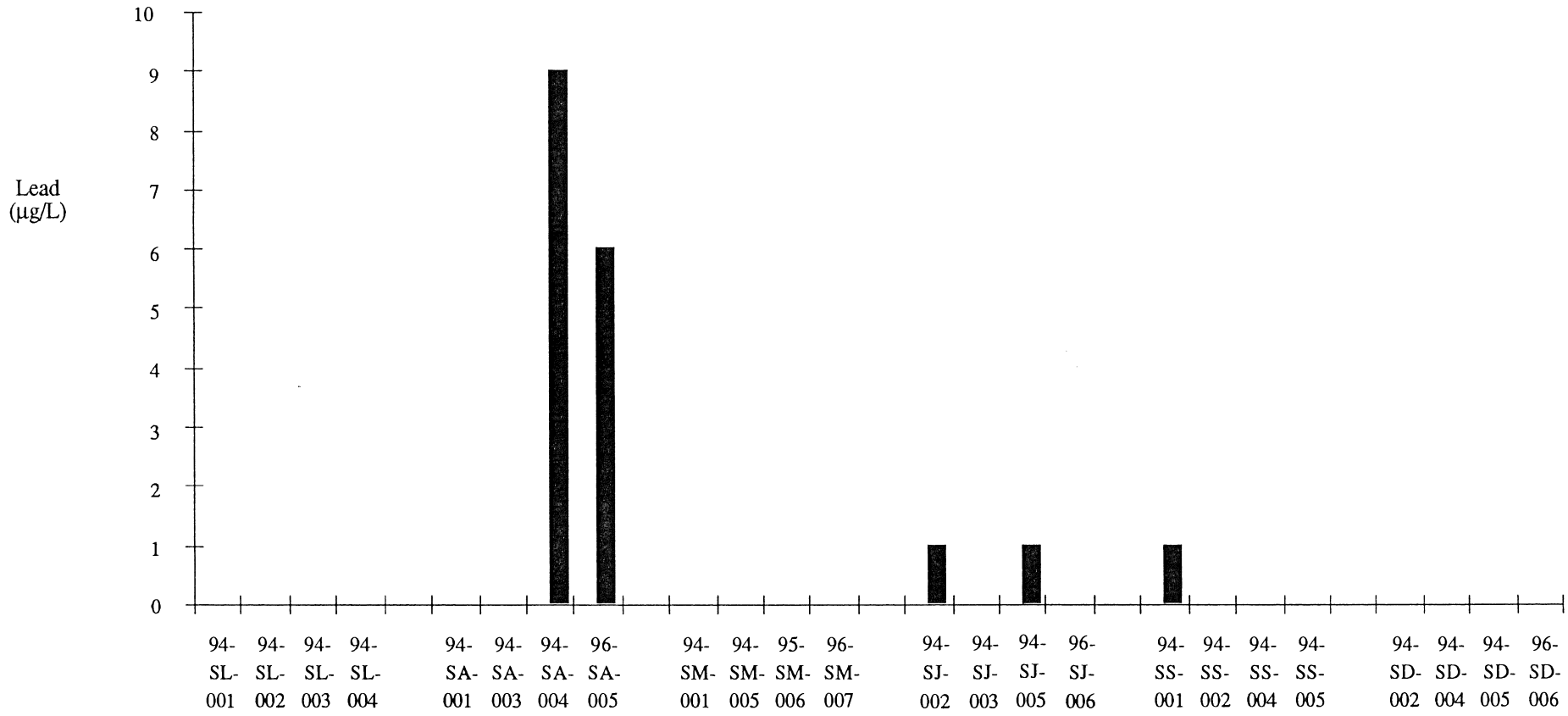
* The current U.S. EPA designated Maximum Contaminant Level is 0.1 mg/L for Chromium.

Figure 3. Copper concentrations of water from CGMP wells sampled in August and September 1996.*



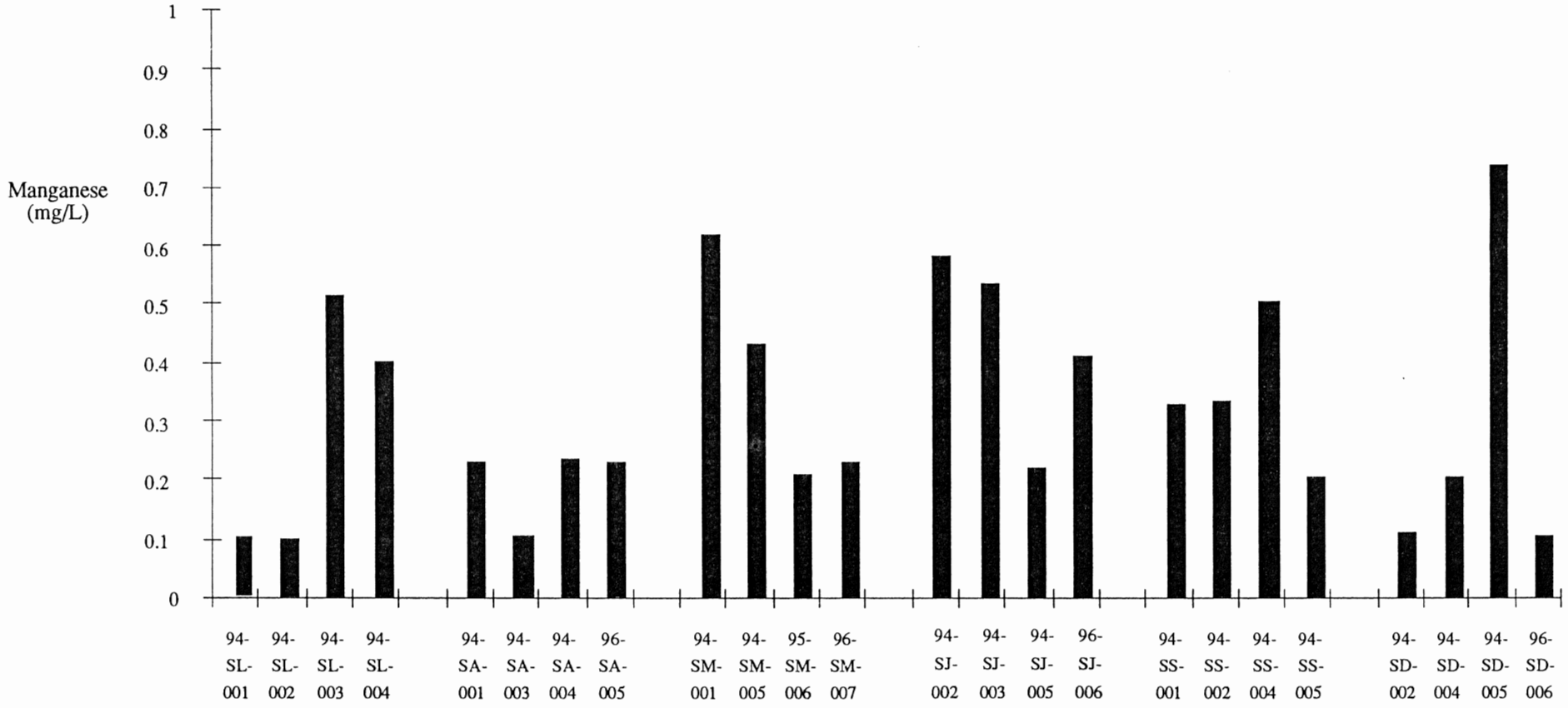
* The current U.S. EPA designated Secondary Maximum Contaminant Level is 1 mg/L (1000 µg/L) for Copper.

Figure 4. Lead concentrations of water from CGMP wells sampled in August and September 1996.*



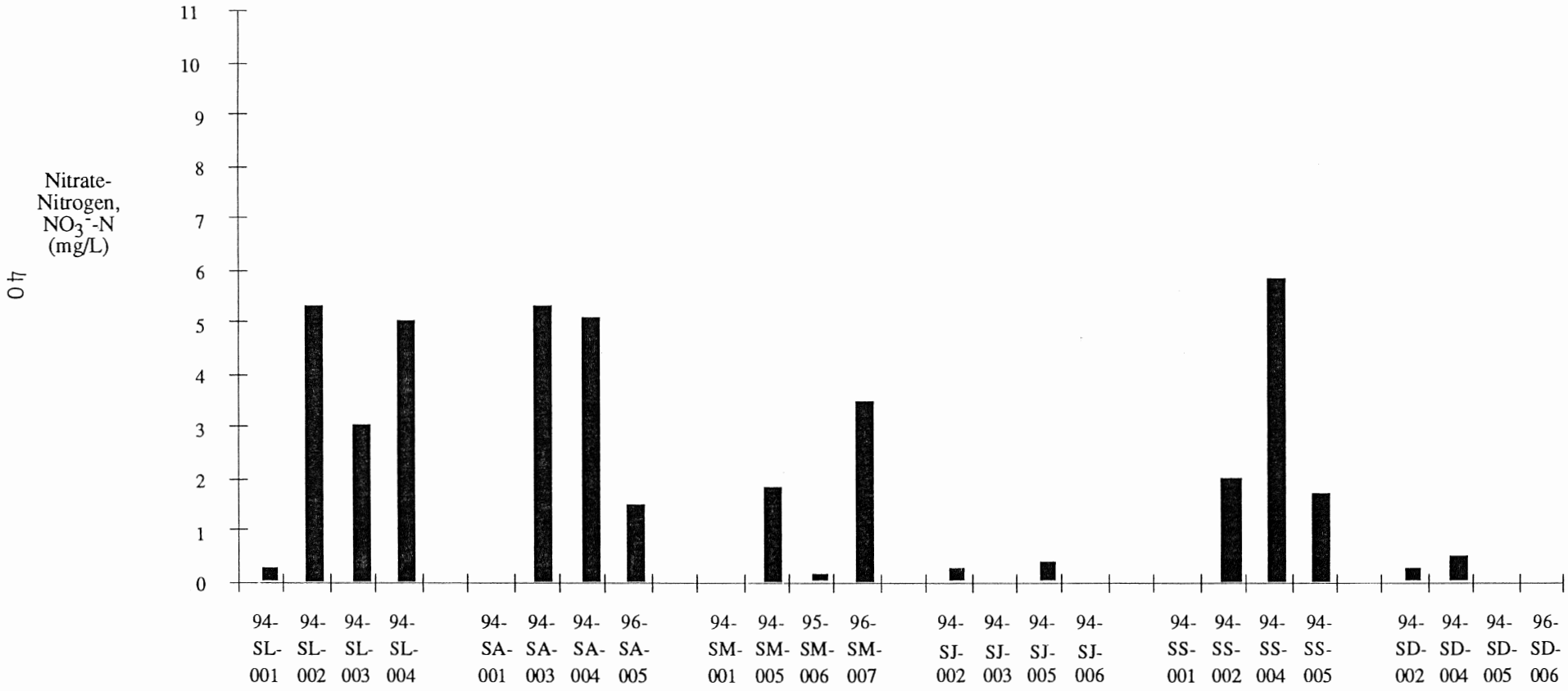
* The current U.S. EPA designated Maximum Contaminant Level is 0.015 mg/L (15 µg/L) for lead.

Figure 5. Manganese concentrations of water from CGMP wells sampled in August and September 1996.*



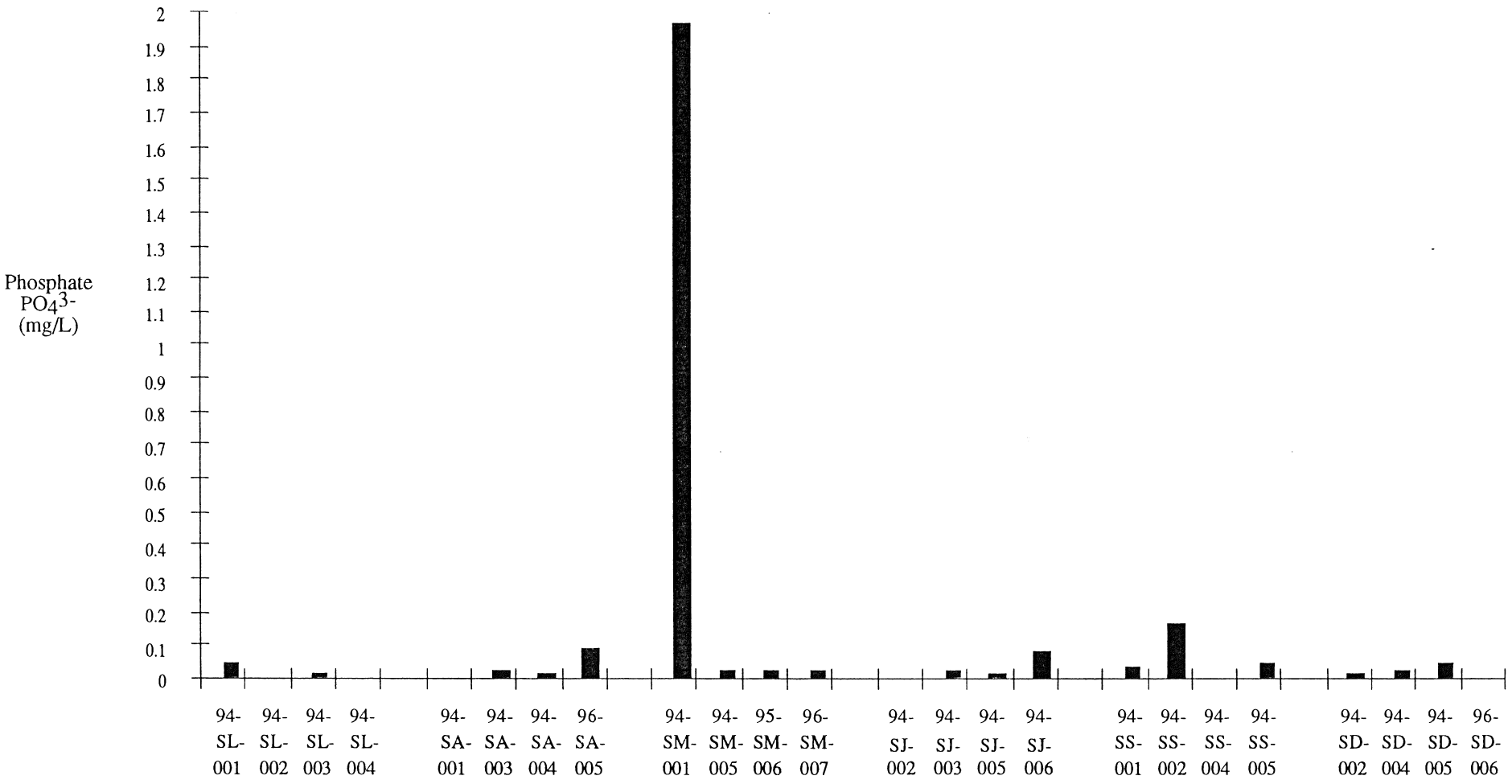
* The current U.S. EPA designated Secondary Maximum Contaminant Level is 0.05 mg/L for Manganese.

Figure 6. Nitrate-Nitrogen concentrations of water from CGMP wells sampled in August and September 1996.*



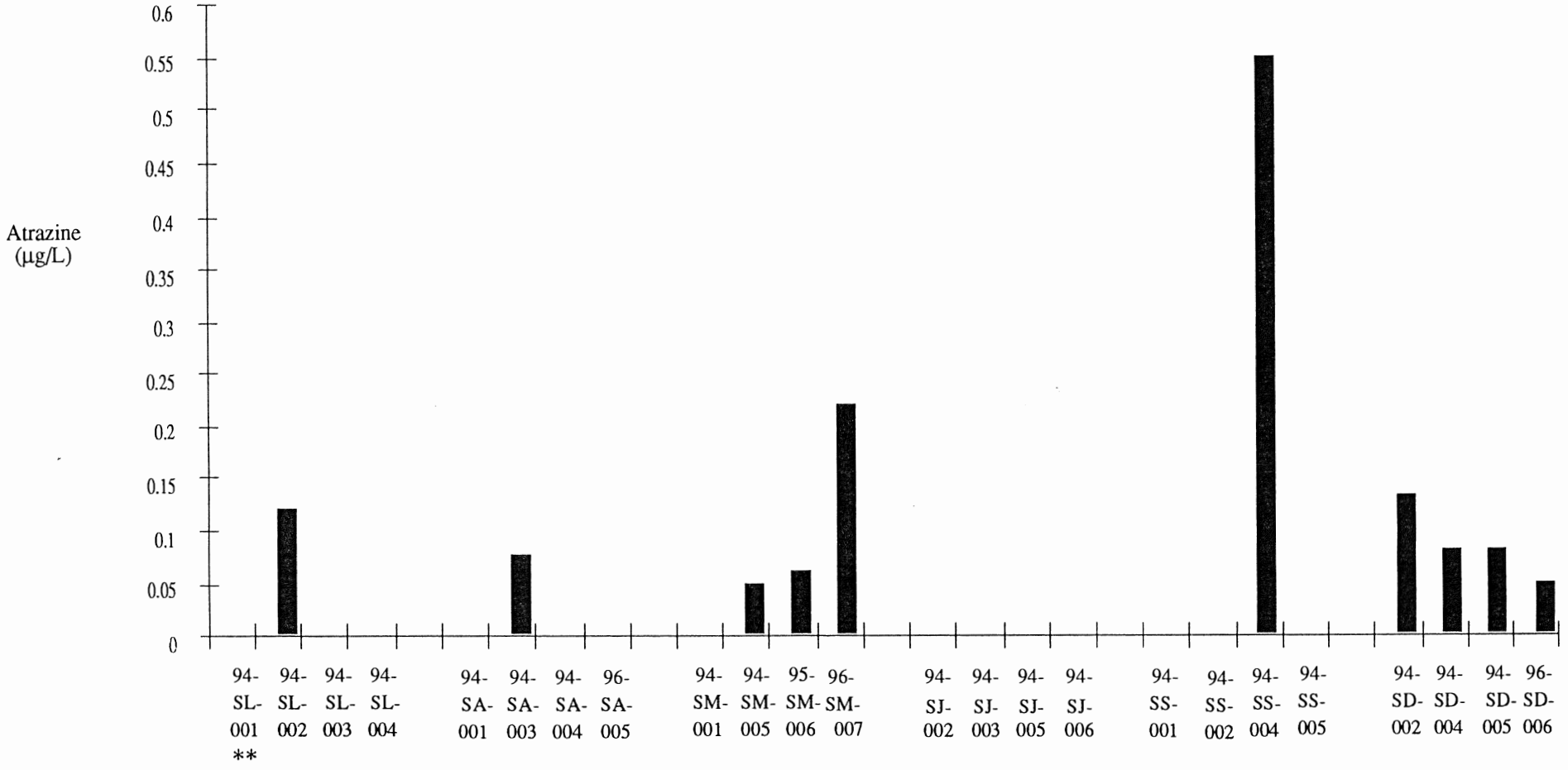
* The current U.S. EPA designated Maximum Contaminant Level is 10 mg/L for Nitrate as Nitrogen.

Figure 7. Phosphorus, reactive, concentrations of water from CGMP wells sampled in August and September 1996.*



* There currently exists no U.S. EPA designated Maximum Contaminant Level for Phosphate.

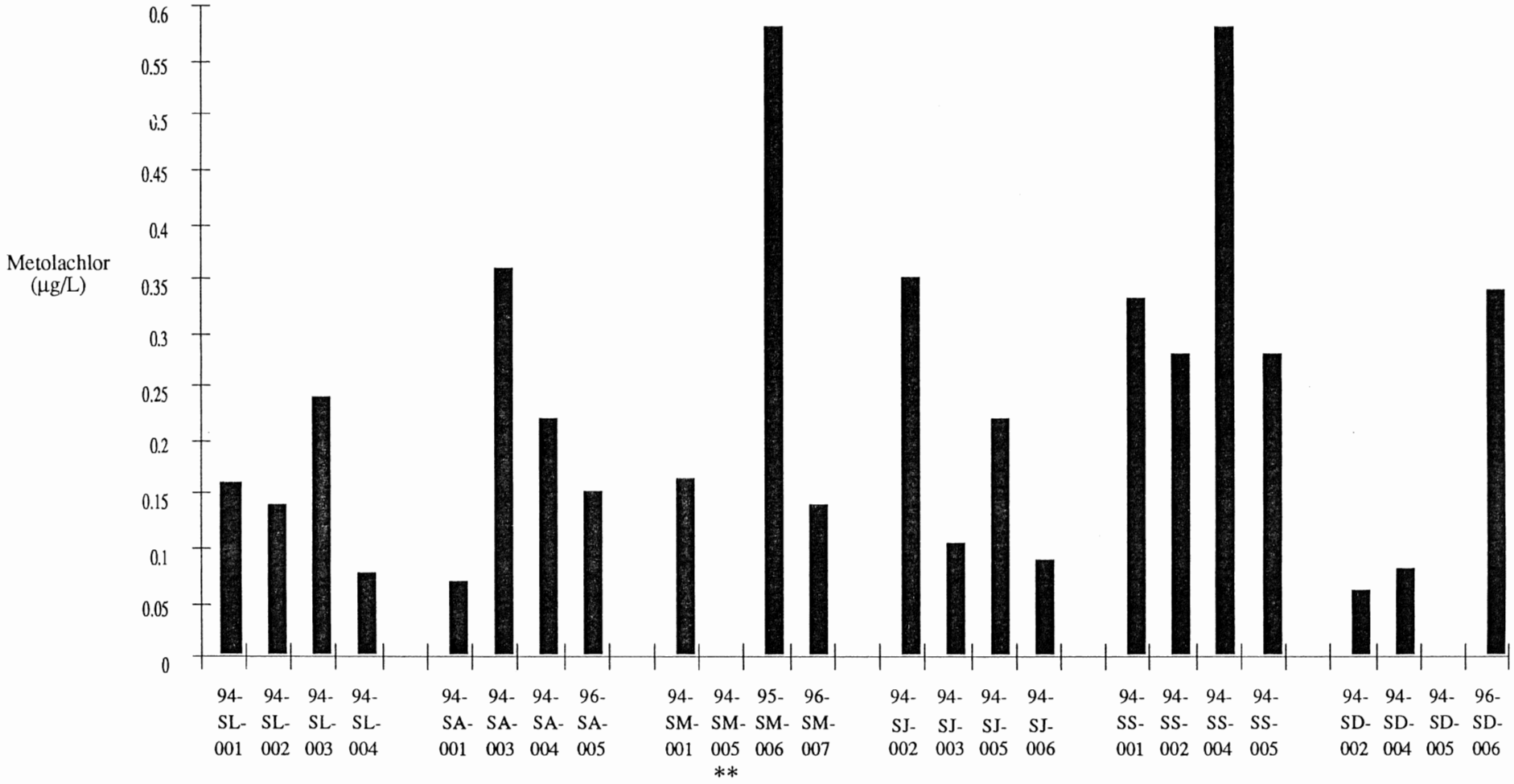
Figure 8. Atrazine concentrations of water from CGMP wells sampled in August and September 1996.*



* The current U.S. EPA designated Maximum Contaminant Level (MCL) is 3.0 µg/L for Atrazine.

** Samples found to have concentrations of <0.05 µg/L were left blank.

Figure 9. Metolachlor concentrations of water from CGMP wells sampled in August and September 1996.*



* There currently exists no US EPA designated Maximum Contaminant Level (MCL) for Metolachlor.

** Samples found to have concentrations of <0.05 µg/L were left blank.

IV. CONCLUSIONS

In the 1988 DRASTIC report by the National Water Well Association (NWWA) and the United States Environmental Protection Agency (USEPA), Shenandoah County, Virginia, is shown to have an extremely high pollution potential due to its Karst topography. The Citizens Groundwater Monitoring Program (CGMP), developed by the Friends of the North Fork Shenandoah River (FNFSR) and funded by the USEPA, has sampled selected water wells in 1994, 1995 and 1996.

In 1994, 1995, and 1996 microbiological assays indicated 46 percent of collected samples each year were contaminated with coliform bacteria. The 1995 chemical assays indicated that 17 percent of the samples collected were from water sources with contaminate levels that raised health concerns. In 1996, no wells tested exceeded USEPA Maximum Contamination Levels (MCL) for chromium, copper, lead, or nitrate, however, all wells tested over the USEPA Secondary MCL for manganese.

In 1995, 92 percent of sampled wells had some level of herbicidal contamination. In 1996 all 24 wells (100%) tested positive for either atrazine, metolachlor, or both herbicides.

Results from these three years of sampling water wells in Shenandoah County do indicate groundwater contamination has occurred at some level and that the contamination levels over the three samplings appear to be very similar. Contaminants move through groundwater in seasonal plumes and one summer sampling

each year may be providing misleading results. Adding a winter sampling when groundwater levels are at their highest and microbial activity (that consumes nitrates, phosphates, coliforms, etc.) is at its seasonal low point would perhaps present much different contaminant levels and trends than the data collected during the past three summer samplings.

V. RECOMMENDATIONS

The CGMP should be expanded to include more metals indigenous to sewage and agricultural biosolids such as cadmium, mercury, and nickel, that could identify possible leaching of biosolid applications from farmland into the groundwater. One or more herbicidal assays might also be added to the CGMP. Due to the Karst topography found in Shenandoah County concern exists about interaction between surface and groundwaters. It is also recommended that the program at some time incorporate testing for automobile oil in the well water samples collected.

It is highly recommended that several samplings (at least two) be arranged per year to monitor the selected wells through seasonal weather changes. Microbiological, chemical, and herbicidal assays should be run for a period of several years to document the degree of contamination present throughout the county, however other assays may be added to broaden the database. Extra testing does include increased financial and technical support which may overextend the granted budget. Quality assays that allow the database to be built slowly most likely will provide better long-term information.

VI. REFERENCES

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APPENDIX A

Well Purging Procedure

To purge a well, one must remove the standing water in the well (well volume). The standing water in the well is the water between the water surface and the bottom of the well. Well volumes can be calculated by using the following conversion chart.

Nominal Well Diameter (inches)	Approximate Gallons per foot
2	0.164
3	0.367
4	0.653
6	1.468
8	2.610
10	4.078
12	5.872

Once the diameter of the well has been determined and the length of the water column, the approximate number of gallons of water required for purging (5 times) can be determined e.g., a well with a 4" diameter and a 20' column of water (purged 5 times) would require:

(5 X 20' X 0.653 = 65.3)

or the removal of approximately 65 gallons of water.

Reference: Department of Environmental Resources, PA.