
**WATER QUALITY EVALUATION FOR THE
NORTH DAKOTA NATIONAL GUARD CAMP
GRAFTON (SOUTH UNIT),
EDDY COUNTY, NORTH DAKOTA:
1996 SAMPLING**

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EXECUTIVE SUMMARY

This report presents the data, results, and interpretations from an evaluation of ground-water and surface-water quality on the North Dakota National Guard (NDNG) Camp Grafton (South Unit) (labeled CGS in this report) in Eddy County, North Dakota, based on water samples taken in the fall of 1996. The 1996 study is part of an ongoing periodic evaluation of water quality on the CGS facility, which began in 1986. In 1986 wells for sampling basic water quality were placed by Comesky (1989). Basic water chemistry, trace elements were sampled in 1987. Some pesticide samples were also taken from surface waters in 1987. In 1991 water samples for basic water chemistry and trace elements were again taken from the wells placed by Comesky. An additional sample plan for detection of organic contaminants from pesticides, munitions and explosives, and petroleum residues was designed in 1992. Wells specifically designed for sampling organic contaminants in use areas were placed and sampled in 1992 and 1993 (Schuh 1994). Additional water samples for pesticides were taken from Lake Coe and South Washington Lake in 1994, and 1995. In September of 1996 a complete set of water samples was taken from the CGS Reserve. This Executive Summary presents the principle findings and recommendations of the 1996 sampling. A complete report on the 1996 study follows.

Inorganic Water Quality

In September of 1996 water samples were taken from 37 monitoring wells, at 18 sites, for measurement of background water chemistry and trace elements. Water samples were also taken from two surface-water sites, including a spring (148-63-2DA) and a reservoir near the M-60 machine-gun range (149-62-31C). Results indicate that there is no significant anthropogenic (caused by human use) impact on the basic water chemistry or trace elements in the Cherry Lake aquifer or in surface waters.

* Background water chemistry in the Cherry Lake aquifer varies from low TDS (total dissolved solids) of less than 200 mg/L to brackish water having TDS as high as 5,000 TDS. Principle dissolved salts vary from calcium bicarbonate, to predominantly sodium sulfatic water. In some cases, chloride concentrations are as high as 1,000 mg/L. Shallower water is usually the freshest, having lowest TDS and sulfate concentrations. Deeply buried aquifer subunits have higher dissolved solids, sodium, and sulfate.

* Nitrate concentrations in surface waters and ground-water at CGS are below levels of toxicological concern, based on an EPA Maximum Contaminant Level (EPA-MCL) of 44 mg/L. Of all water samples taken in 1996, the median nitrate concentration is 1 mg/L. The maximum

concentration is 7 mg/L. Most of the higher nitrate concentrations are in shallower wells. Since fertilizer is not used on the CGS Reserve the most probable nitrate source is manure from cattle grazed on the land. Trends in nitrate concentration since 1987 are variable, but from 1991 through 1996 the overall trend is toward lower nitrate concentrations. South Washington Lake has low nitrate concentrations. However, presence of manure along the lake border and strong algal blooms indicate that substantial nitrate influx is likely, and that nitrate is biologically consumed.

* Trace elements, including barium, lead, selenium, and mercury were not detected in significant quantities in 1996 or in previous samplings in 1986, and 1991-1993.

* Arsenic concentrations are relatively high in waters sampled on CGS. In some wells and in some surface water samples, arsenic concentrations exceed levels of toxicological concern (EPA-MCL is 50 µg/L). Arsenic concentrations have been relatively consistent over time, but vary over the area of the facility. Concentrations are at levels of toxicological concern in South Washington Lake. They are high in Lake Coe, and in the area of the CGS supply wells. Concentrations may also be high in the area of the M-60 machine-gun range. Arsenic concentrations are almost certainly natural in origin, and have not been caused by human use. However, certain uses that concentrate salts, such as use of reverse osmosis systems or boiling the water, may cause concentration of arsenic. Care is needed in disposal of reverse osmosis filtrate waters, or in consumptive use of boiled water.

Munititions and Explosives

In September of 1996 eleven water samples were taken from 9 sites, including five well sites, one spring (148-63-2DA) and one reservoir (149-62-2DA) for fourteen organic compounds used in munititions and explosives. Samples were taken from watersheds fed by the major munititions and demolitions training areas.

* Results indicated no detections of any of the compounds tested.

Petroleum Hydrocarbons

In September of 1996 nine water samples were taken from nine sites, including one from South Washington Lake, two from Lake Coe, and six from two wells on each of three sites, for measurement of total petroleum hydrocarbon (TPH) as gasoline and as fuel oil (including diesel fuel). Chosen sites were in watersheds near, or fed by areas used for vehicle staging, such as the Engineering Training Site, or common bivouac areas.

* Results indicated no detections of TPH as gasoline or fuel oil in any of the water samples.

Pesticides

In September of 1996 fourteen water samples were taken from eight sites for determination of pesticide concentrations. Samples included one from South Washington Lake, two from Lake Coe, one from a spring (149-63-13BDA), and ten samples from two wells on each of five well sites. Sites were chosen in watersheds near or downstream of areas where herbicides (picloram and 2,4-D) are used for leafy spurge control, or insecticide (chlorpyrifos) is used for mosquito control. Samples were tested for chlorpyrifos and picloram.

* Results indicated no detections of chlorpyrifos in any of the water samples. Picloram was not detected in any of the well samples or in the spring sample. Picloram was detected at low concentration (about 0.1 µg/L) in Lake Coe and South Washington Lake. Previous annual samples since 1993 have indicated that this concentration of picloram is consistently present. Detected presence is several orders of magnitude below EPA-MCL (500 µg/L).

Recommendations resulting from conclusions of the 1996 sample study include the following.

1. Picloram concentrations have been demonstrated to be consistent in Lake Coe and South Washington Lake. It is recommend that repeat pesticide sampling for picloram in the lakes every other year. instead of every year.
2. Supply wells located south of HWY 15 at (T149 R63 Section 35A) should be sampled for water chemistry and for trace elements. Supply wells should be sampled annually for determination of arsenic concentration. If supply wells are located on the M60 training site, or other nearby firing ranges, they should also be sampled for determination of arsenic concentrations.
3. During water purification training using reverse osmosis, filtrate should be analyzed for arsenic concentration. If filtrate has high arsenic, care should be taken in disposal. Sufficient filtered water to dilute the filtrate should be returned to the original source to offset the concentrated arsenic. Appropriate procedures for disposal of high arsenic filtrate should be established.

4. The use of the well-house area (T149N R63W Section 35A) as a staging area for storage of herbicide and for mixing pesticides should be reviewed for well-protection safety. Overflow from filling sprayers may contaminate wells. Also I would suggest storing pesticides away from the well site.
5. CGS land and water use should be reviewed, and sampled again for water quality in 2001.
6. Many of the barbed wire enclosures protecting the wells are badly damaged, and will not effectively protect the wells from breakage in the future. Barbed wire at all well sites should be inspected and repaired as soon as possible.
7. The PVC protective cover for WS-2 well 13103 (Site 1, 149-062-28CCC1) should be extended three or four inches.
8. The elevations of the measuring points (tops) of all wells should be surveyed.

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INTRODUCTION

In 1992 a water quality monitoring plan for the North Dakota National Guard Camp Grafton South (CGS) facility in Eddy County, North Dakota, was submitted to the North Dakota National Guard (Schuh 1992). The plan was designed to consider existing geologic and hydrologic information, current and future use patterns of the facility, objectives and goals of protection - including the sensitivity of resources to be protected, and the limitations of funding and resources available for implementing the plan. An attempt was also made to consider training objectives and resource conservation in a balanced manner, and to maximize the information obtainable from limited field data.

The initial sampling plan was laid out in two phases. Phase I consisted of the selection of appropriate surface-water sites and the construction of appropriate observation wells for monitoring munitions and explosives residues, petroleum residues, and pesticide contamination. Phase I also included base-line water samples for appropriate contaminants and for basic water quality and trace elements on each of the selected sites. Phase I was implemented in 1992 and 1993. In 1994 a report was published describing the monitoring well network, the water sample collection plan, and results of the base-line samples taken for each of the potential contaminant groups sampled at CGS. (Schuh 1994). Included in the 1994 publication were:

1. well and sampling locations;
2. well completion information, including lithologies, materials, construction methods, development, and cleaning procedures;
3. sampling procedures, including well purging methods, sampling methods, and sample-handling methods and procedures;
4. baseline data for basic water chemistry and trace elements from each newly constructed sample well;
5. data for water quality and trace elements measured in wells constructed before Phase I; and
6. a brief analysis and interpretation of results.

Phase II consisted of a plan for ongoing periodic assessment of water quality at CGS. The provisions of the initial Phase II plan were designed to be flexible and to allow for modification as understanding of area hydrology and its effect on water quality increases. Periodic sampling and assessment of CGS water quality were to be accomplished through periodic (three to six year interval) reevaluation of use of CGS and potential water contamination resulting from use patterns.

Summary of Results and Recommendations From the 1994 Sampling and Assessment

The following conclusions were reached in a previous ground-water quality study at CGS (Schuh 1994). Basic water quality of the Cherry Lake aquifer is of low to average total dissolved solids (TDS < 800), near-neutral pH, and low to slightly high sodium adsorption ratio (SAR). Shallow ground water is usually of the calcium bicarbonate type, while deeper aquifer units are frequently of the sodium sulfate type. There was no significant lead, mercury, selenium, or cadmium in any of the wells sampled. However, arsenic was present in most samples, and in some of the deeper aquifer units approached and even exceed EPA-MCL. Natural lakes were very high in TDS, sulfate, chloride, and sodium, with pH above 9 and very high SAR. There was no significant lead, mercury, selenium, or cadmium in any of the samples. However, arsenic approached or exceeded EPA-MCL in most samples. Nitrates were low in both surface and ground water. There were no indications of anthropogenic degradation of basic water quality on the reserve.

Of the wells sampled in 1992 and 1993 there was only one pesticide detection. Dimethoate was detected at a level just below the EPA Lifetime Health Advisory Level in one well near Lake Coe. However, dimethoate was never deliberately sprayed on CGS land. The well site of the detection was within the spray drift zone of aerially sprayed picloram during drilling and construction of the well. Dimethoate residual in the picloram spray is a likely source. The dimethoate detection does not indicate a likely case of environmental contamination from routine facility use and care. There were no detections of picloram, malathion, chlorpyrifos, or any other pesticides used on the reserve in any of the well or spring samples.

There were detections of picloram (at low levels) in Lake Coe and South Washington Lake in August of 1993. Because picloram was not detected in 1986, and because of the exceptionally heavy rainfall in 1993 it was suspected that these detections were a result of exceptional runoff. It is unlikely that contaminants entered Lake Coe or South Washington Lake through ground water.

There were no indications of total petroleum hydrocarbons (gasoline or fuel oil) in any of the samples taken from ground water in August of 1993.

There were no detections of munitions and explosives residues (HMX, RDX, Nitrobenzene, tetryl, 1,3-dinitrobenzene, 2,4,6-TNT, 2,4-DNT, and 2,6-DNT) in any of the water samples taken in the fall of 1992.

The following recommendations were offered as a result of conclusions from the 1994 report (Schuh 1994).

1. South Washington Lake and Lake Coe should be sampled at least once per year to determine if contamination with pesticides during spraying for leafy spurge is causing a serious or long-term problem. This should continue until detection levels remain below detection limits for at least three years. Other surface water samples may also be considered for annual pesticide sampling. Pesticide samples from other designated wells should be taken as planned for the three year resampling schedule laid out in PHASE II of the initial proposal.

2. Well 13102 on site 6 should be sampled for dimethoate again in early 1994. If any detections are made, the entire site (wells 13101 and 13102) should be sampled at least once per year until no further detections are found.

3. Selected basic water chemistry, trace element, TPH, pesticide, and munitions and explosives residue samples should be taken again in 1996, and on a three year rotating schedule as described under Phase II above.

4. All wells drilled in 1992 should be surveyed for measuring point elevation by the North Dakota National Guard.

5. All wells drilled in 1992 should be fitted with locked caps on the 4-inch protective covers by the North Dakota National guard.

6. After the next sampling period (1996), the North Dakota National Guard may wish to consider a comparative analysis and report on trends in water quality from 1986 to 1994.

In 1996 the use of the CGS facility was again evaluated, and a water-quality sampling plan was designed to monitor potential contamination from current land use practices . In September of 1996 water samples were taken from wells and surface waters at CGS. The purpose of this report is to evaluate the progress in accomplishing previous recommendations resulting from the 1994 assessment, and to evaluate the apparent water quality status of CGS water resources based on the most recent (1996) sample results, and

to evaluate some trends in the chemical composition of water samples taken over the ten-year period from 1986 through 1996.

LOCATION AND NUMBERING SYSTEM

The location and numbering system used in this report is based on the public land classification system used by the U.S. Bureau of Land Management. The system is illustrated in Figure 1. The first number denotes the township north of a base line, the second number denotes the range west of the fifth principal meridian, and the third number denotes the section in which the well or test hole is located. The letters A, B, C, and D designate, respectively, the northeast, northwest, southwest, and southeast quarter section, quarter-quarter section, and quarter-quarter-quarter section (10-acre tract). For example, well 149-063-4ADD is located in the SE 1/4 SE 1/4 NE 1/4 Sec. 4, T. 149 N., R. 63 W. Consecutive terminal numerals are added if more than one well or test hole is located within a 10 acre tract.

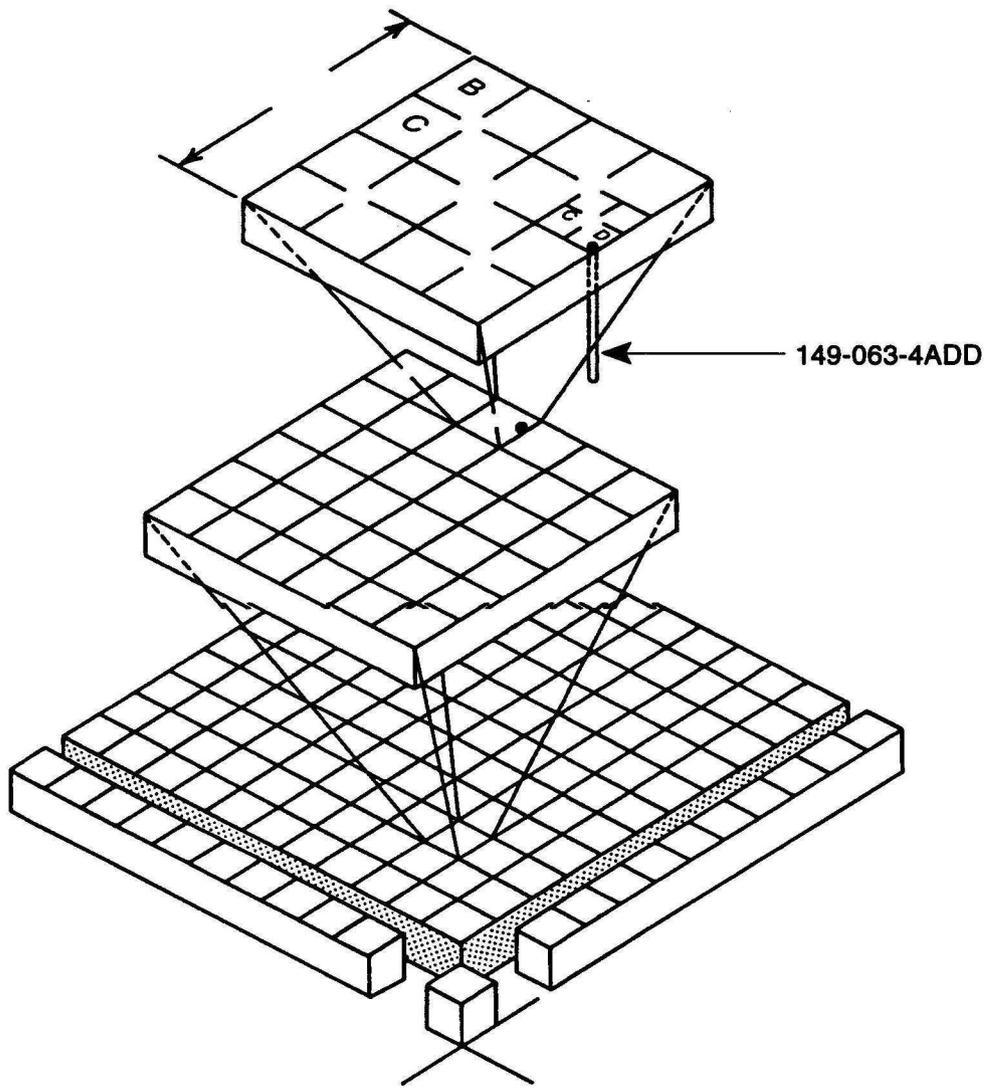


Figure 1. Map location and numbering system used in this report (from U.S. Bureau of Land Management).

CLIMATE, GEOLOGY, AND HYDROLOGY

CGS is located in Eddy County in East Central North Dakota (Figure 2). The facility occupies portions of four townships, Lake Washington (T149N R63W), Colvin (T149N R62W), Paradise (T148N R62W), and Cherry Lake (T148N R62W). CGS lands are approximately bisected by State Highway 15 which runs East-West.

Climate

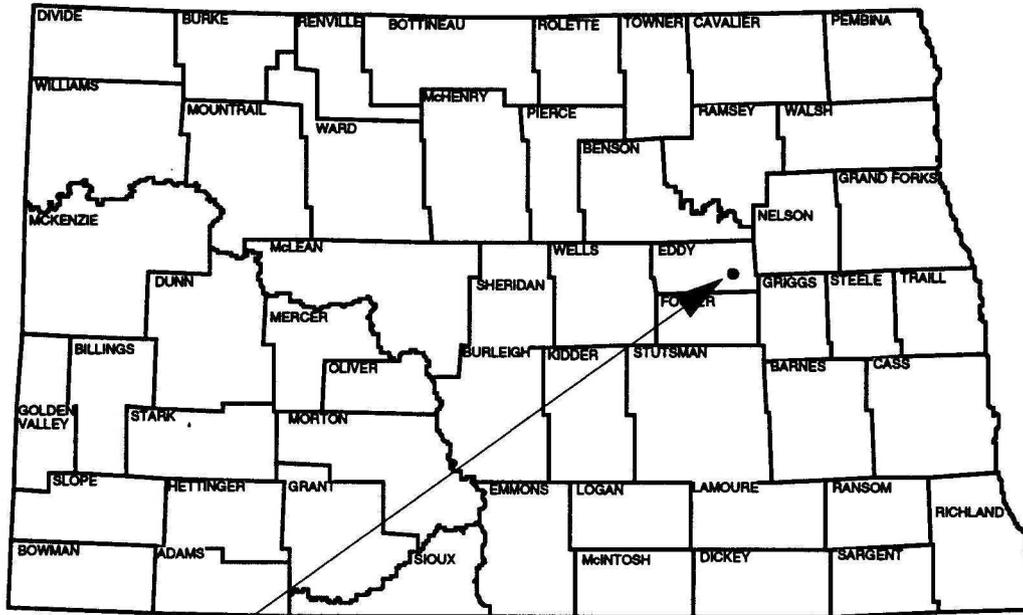
The Climate of Eddy County North Dakota is continental, having cold winters and hot summers. The onset of cold weather usually begins in early November. The frost usually leaves the soil in mid April. The moisture regime is borderline between semi-arid and sub-humid, with a long term average precipitation of about 48 cm (19 inches).

Geologic and Hydrologic Setting

The general geological setting of Camp Grafton South has been described by Bluemle (1965), and by Comeskey (1989). Local geology and its relation to water resources on the CGS facility and the sampling plan were discussed in detail by Schuh (1994). In general, the surficial geology of the CGS facility consist of uplands which are composed of glacial drift which comprise subunits of the McHenry End Moraine, and lowlands, or drainage basins, which drain toward the Sheyenne River about five miles north of CGS. A simple schematic of the relationship between moraine uplands and lowland basins is shown on Figure 3.

There are three distinct subunits of the McHenry End Moraine on the CGS facility (called moraine units 1, 2, and 3 in this report). The largest subunit (moraine unit 1) extends from the southern through the northern boundary on the east side of the facility, and separates the drainage into two principal basins. On the east side, all drainage flows northeastward toward the Sheyenne River through the Colvin Creek basin. On the west side of moraine unit 1, all drainage flows toward the Sheyenne River through the Lake Coe and South Washington Lake basin. The other two subunits of the McHenry End Moraine on the CGS facility (moraine units 2 and 3) are oriented north to south, and are located entirely in the southern half of the facility. Neither extends north of HWY 15. These two moraine subunits serve to divide the southern portion of the Lake Coe and South Washington Lake basin into three subbasins. Most drainage through the Lake Coe and South Washington Lake basin originates from the eastern two of these subbasins. Between moraine unit 1 and moraine unit 2 water flows northward to Lake Coe through a series of small lakes and

NORTH DAKOTA

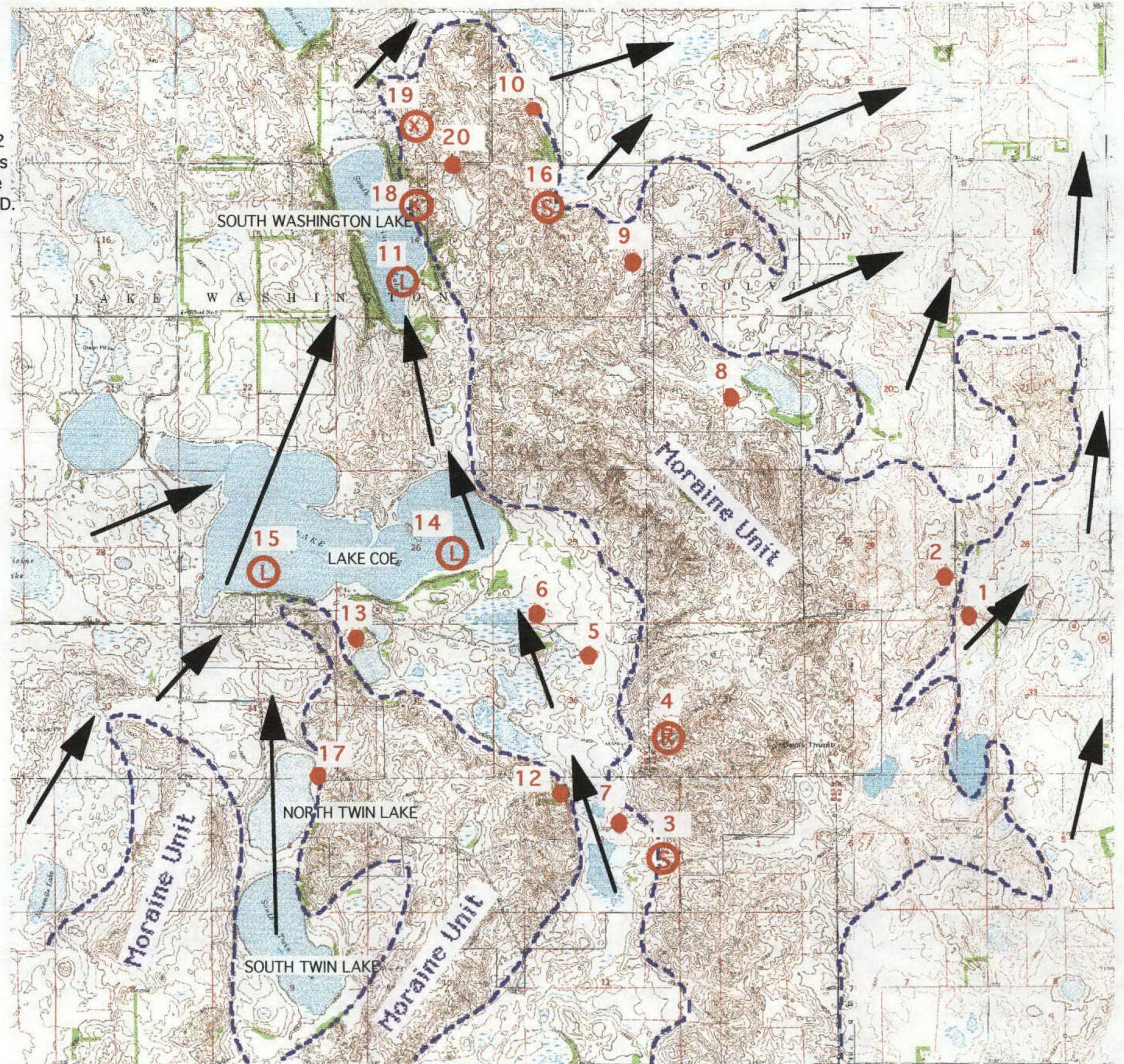


CAMP
GRAFTON
SOUTH

Figure 2. Location of the Camp Grafton (South Unit) training facility.

Figure 3. Schematic diagram of placement of WS-2 sample-well sites and surface-water sampling sites in relation to moraine subunits, and drainage to the Sheyenne River on the CGS facility, Eddy County, ND.

- LEGEND**
- Lake Sample (L in a circle)
 - Reservoir Sample (R in a circle)
 - Spring Sample (S in a circle)
 - Well Site (red dot)
 - Planned / Not Implemented (X in a circle)
 - Moraine Boundaries (dashed blue line)
 - Flow Direction (black arrow)



littoral areas. Between moraine unit 2 and moraine unit 3, water flows northward to Lake Coe through North and South Twin Lakes. Drainage from uplands to lowlands occurs through a series of coulees.

The principle ground-water resource underlying the CGS facility is the Cherry Lake aquifer. Trapp (1966B) and Comeskey (1989) described Cherry Lake aquifer system as composed of two confined units, separated by 20 to 40 feet of glacial till. The surface of the deepest (and least aerially extensive) unit is located approximately between 126 and 182 feet below land surface. Both Trapp (1996B) and Comesky (1989) have noted that the two confined units may be interconnected in some areas. However, drilling and exploration to date have not succeeded in documenting connections. There is some recent piezometric evidence that shallower confined aquifer units are not connected to deeper confined units at some locations, notably at Sites 17 near North Twin Lake and Site 6 located in the littoral area southeast of Lake Coe (Fig. 3). At these locations deeper aquifer units were subjected to substantial increases in artesian pressure (to the point of becoming flowing wells) following large rains in 1993. Shallower confined aquifer units at the same location exhibited much less extensive increases in piezometric pressure. These observations indicate that some areas of the deeper aquifer unit may be directly connected to recharge areas in the uplands, while being locally insulated from extensive interaction with overlying aquifer units or surface lakes. Conversely, in these examples surficial and shallow confined aquifer components do not appear to be strongly and directly affected by upland recharge, but rather appear to have piezometric responses more characteristic of water levels in nearby lakes.

In addition to the two confined units of the Cherry Lake aquifer, Comesky (1989) identified a surficial unconfined unit. The surficial unit consists of a sand mantle overlying the glacial till confining the lower units. In many areas, however, this mantle is not saturated. Comesky also described the presence of some coarse deposits within the glacial drift that are apparently locally isolated and not connected with the larger aquifer units.

Comeskey (1989) has described recharge as occurring through closed depressional areas on the McHenry Moraine. The local flow system from the Moraine is described as occurring easterly and westerly toward the dividing lowlands. Numerous springs flow out from the moraine at lower elevations in coulees and near lowlands and littoral areas. Springs may be exposures of contacts between surface sands and the underlying till, or they may consist of exposures of deeper buried units.

The lake system has been described as a window on the water table, and has been used to describe a general regional flow system northward to the Sheyenne River. Water table

maps (Trapp 1966A), which may or may not be related to piezometric levels in the underlying aquifers, indicate that overall regional ground-water flow at the water table is toward the Sheyenne River through the Washington lakes chain, and through the Colvin Creek lowland.

There is a very slight water table gradient southeastward toward the Johnson Lake aquifer, and some water movement may occur in that direction. Flow from Cherry Lake is indicated to be southward toward the Juanita Lake aquifer and the James River. Generally, however, CGS land is too far north to affect the southward drainage system. Also water-table gradients toward the Johnson Lake Aquifer are small. All indications from current information are that most ground water and surface water moves on a regional scale northward to the Sheyenne River through the Lake Coe /Washington Lake chain (and subunits), and through the Colvin Creek basin.

Readers are also referred to Comesky (1986) and Trapp (1966B) for in depth studies of the Cherry Lake aquifer. In addition, Schuh (1989) described the relationship between local geology and hydrology and land use practices and potential risk of ground-water contamination.

OBJECTIVES AND PRIORITIES

Objectives and priorities for the CGS water quality sampling plan were discussed in detail by Schuh (1994). In brief, priorities in designing the plan were:

Priority 1: protection of ground-water and surface-water exterior to CGS. The primary focus is on detection of contaminants migrating to regional rather than local flow systems, before they can substantially effect the regional resource.

Priority 2: protection of the wildlife, such as migratory waterfowl, that inhabit the lakes and wetlands of CGS.

Priority 3: protection of the local fresh-water supply.

Monitoring Plan Criteria

Factors considered in the water quality monitoring plan included (1) the nature of local and regional surface drainage, (2) the nature of local and regional ground-water flow, (4) the disposition and use of water by others near the military reservation, (4) the sensitivity of specific water uses on and near the reservation to specific contaminants, and (5) land use patterns on the military reservation. Consideration also given to the desirability of having all major use areas of the reserve given sample representation.

SELECTION OF SAMPLING POINTS AND MONITORING WELLS

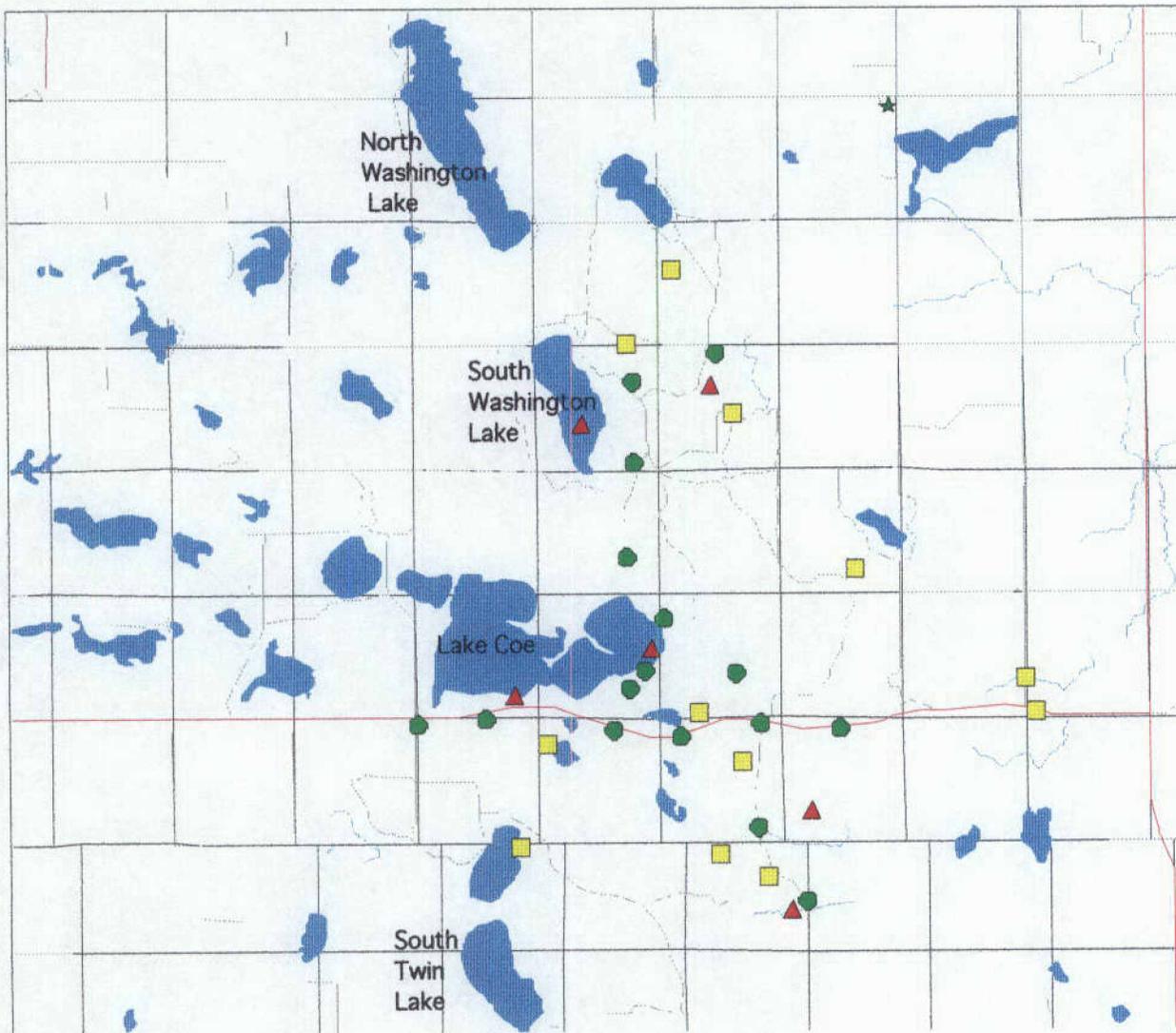
Water samples are taken from three basic sources on CGS. The three sample sources include two sets of sampling and monitoring wells, and a number of surface water sources that include two lakes, two springs, and one reservoir.

Well Set 1 (WS-1)

The first well set (labeled Well Set 1, or WS-1) was placed by Comesky (1989), in mapping the Cherry Lake aquifer on CGS. This well set consists of 25 wells placed in nests of one to four wells at a total of 12 sites. Well placement was non biased with respect to CGS use patterns, geology, and topography. Wells were placed at approximately evenly spaced intervals along two transects, one north to south, and the other east to west. Well construction was of 2-inch and 1.25 inch polyvinyl chloride (PVC) casing, and joints were bonded using solvent-weld cement containing methyl-ethyl ketone. WS-1 wells are protected from cattle by barbed wire fences, but they do not have a protective cover, nor are they locked and secured. Placement of these wells limits their usefulness for sampling contaminants from targeted land uses. Construction methods and security limitations also limit their usefulness for sampling organic contaminants (Parker et al. 1990, Sykes et al. 1986). However, both construction and placement methods render the WS-1 wells best suited for sampling background inorganic water chemistry. In addition, these wells have the longest sampling record for basic water chemistry (dating to 1987). WS-1 wells are used for ongoing sampling of basic water chemistry and for piezometric readings. They may also be used for supplemental sampling of organic contaminants if needed for investigation of specific problems. Locations of WS-1 wells are summarized on Table 1, and illustrated on Figure 4. Detailed hydrologic setting of well nests, lithologic logs for WS-1 wells,

Table 1. List and locations of 1993 proposed sampling sites for the CGS training facility as presented in the initial plan proposal. L indicates a lake sampling site, R indicates a reservoir sampling site, S indicates a natural spring sampling site, and W indicates a well sampling site. WS-1 designates wells placed by Comesky (1989). WS-2 designates wells placed by Schuh (1994). All WS well nests were to be sampled only in the shallowest well.

Well Set	Site	SWC Well No.	Township N	Range W	Section	Location	water source	Mun.	TPH	piclor am	chlor-pyrifos	Basic	Trace
WS-1		12024A	148	63	1	CBBC1	W					x	x
WS-1		12024B	148	63	1	CBBC2	W					x	x
WS-1		12024C	148	63	1	CBBC3	W					x	x
WS-1		12020A	149	63	14	DACD1	W					x	x
WS-1		12020B	148	63	14	DACD2	W					x	x
WS-1		12020C	148	63	14	DACD3	W					x	x
WS-1		12019A	149	63	23	ADBB1	W					x	x
WS-1		12019B	149	63	23	ADBB2	W					x	x
WS-1		12019C	149	63	23	ADBB3	W					x	x
WS-1		12017A	149	63	25	DBBC1	W					x	x
WS-1		12017B	149	63	25	DBBC2	W					x	x
WS-1		12017C	149	63	25	DBBC3	W					x	x
WS-1		12017D	149	63	25	DBBB4	W					x	x
WS-1		12025	149	63	26	DCA	W					x	x
WS-1		12012	149	63	27	DDDC1	W					x	x
WS-1		12015B	149	63	31	ABBC2	W					x	x
WS-1		12015C	149	63	31	ABBC3	W					x	x
WS-1		12026A	149	63	34	BBB1	W					x	x
WS-1		12026B	149	63	34	BBB2	W					x	x
WS-1		12011B	149	63	35	ABBD2	W					x	x
WS-1		12014A	149	63	36	AACB1	W					x	x
WS-1		12014B	149	63	36	AACB2	W					x	x
WS-1		12014C	149	63	36	AACB3	W					x	x
WS-1		12014D	149	63	36	AACB4	W					x	x
WS-1		12023A	149	63	36	DDBBC1	W					x	x
WS-1		12023B	149	63	36	DDBBC2	W					x	x
WS-1		12023C	149	63	36	DDBC3	W					x	x
WS-1		12021A	149	63		BAAB1	W					x	x
WS-2	1	13104	149	62	28	CCC2	W	x				x	x
WS-2	2	13105	149	62	29	DAD	W	x		x	x	x	x
WS-2	3	Spring	148	63	2	DA	S	x				x	x
WS-2	4	Reservoir	149	62	31	C	R	x				x	x
WS-2	5	13098	149	63	36	ACA2	W	x				x	x
WS-2	6	13102	149	63	25	CDC2	W	x		x	x	x	x
WS-2	7	13087	148	63	2	ACA2	W	x				x	x
WS-2	8	13091	149	62	19	DBD2	W		x	x	x	x	x
WS-2	9	13089	149	63	13	DAA2	W		x	x	x	x	x
WS-2	10	13093	149	63	12	CAC2	W		x	x	x	x	x
WS-2	11	S W Lake	149	63	14	CAC	L		x	x	x	x	x
WS-2	12	13085	148	63	2	BABC2	W		x	x	x	x	x
WS-2	13	13100	149	63	35	BCBA2	W		x	x	x	x	x
WS-2	14	Lake Coe	149	63	26	ADD	L		x	x	x	x	x
WS-2	15	Lake Coe	149	63	27	DDB	L		x	x	x	x	x
WS-2	16	Spring	149	63	13	BDA	S			x	x	x	x
WS-2	17	13096	148	63	4	ABA2	W			x	x	x	x
WS-2	18a		149	63	14	BAA	S			x	x	x	x
WS-2	18b)		149	63	14	BAA	S			x	x	x	x
WS-2	18c		149	63	14	BAA	S			x	x	x	x
WS-2	19		148	63	11	DDC	W			x	x	x	x
WS-2	20	13094	149	63	14	AAB	W			x	x	x	x



● Well Set 1 (WS-1) Sample Set (Comesky 1989) ▲ Surface-Water Sample Sites ■ Well Set 2 (WS-2) Sample Set (Schuh 1994)

Figure 4. Map of ground water and surface-water sampling sites used for monitoring water quality on Camp Grafton(South Unit) lands.

and initial water chemistry data from samples taken in 1987 are in Comesky (1989).

Well Set 2 (WS-2)

The second well set (labeled Well Set 2, or WS-2) was placed by Schuh (1994). This set consists of 23 wells placed in nests of one to three, at twelve sites. WS-2 sites were selected for coverage of drainage areas from areas of specific use within the CGS facility.

The WS-2 wells were placed primarily in the lower reaches of coulees feeding into the Colvin Creek and Lake Coe and South Washington Lake basins and their tributaries. The mouths of coulees were selected for two reasons. (1) The coulees are the major conduits of surface water runoff. For this reason, they are the logical points of concentration for contaminants draining from higher elevations. (2) Coulees are frequently the locations of springs, where till and overlying coarse units meet along the cuts or walls of the coulees. In some cases seepage faces are extensive and relatively permanent. In others they may flow only some of the time during wet years, or sporadically following particularly large rainfall events. When such springs are flowing, or when ground water is nearer the surface so that higher evaporation occurs, the flow lines for the local flow system of the moraine will bend toward the springs. This means that local ground water in the vicinity of springs should tend to receive any contaminant plumes from the upland recharge sites preferentially. Such monitoring points should provide optimal early warning and protection for both the regional ground-water flow system and the lake and littoral areas.

Well placement was also based on specific use of the watershed. Specific targeted uses included weapons and demolitions ranges, vehicle staging areas, bivouac areas, and pest control areas. To accommodate sampling for organic contaminants, well construction consisted of 2-inch PVC casing, with joints fastened using stainless steel screws, rather than solvent weld cement (Parker et al. 1990, Schuh et al. 1997, Sykes et al. 1986). Each well is secured by a 6-inch PVC cover (PC) with concrete at the base, and by a locking aluminum cap.

Placement, construction, and security make WS-2 wells most appropriate for sampling organic contaminants, and site-specific contaminants from munitions, pesticides, and petroleum spills on weapons and demolitions ranges, vehicular staging areas, bivouac sites, and pest control areas. Specific uses and locations for each well set were described in detail by Schuh (1994). A summary of samples taken from each well site in 1996 is shown on Table 2. Piezometric readings are avoided in these wells because of the desirability

Table 2. List and locations of proposed 1996-1997 sampling sites for the CGS training facility. L indicates a lake sampling site, R indicates a reservoir sampling site, S indicates a natural spring sampling site, and W indicates a well sampling site, WS-1 designates wells placed by Comesky (1989), and WS-2 designates wells placed by Schuh (1994).

Well Set	Site	SWC Well No.	Township N	Range W	Section	Location	water source	Mun.	TPH	picloram	chlor-pyrifos	Basic	Trace
WS-1		12024A	148	63	1	CBBC1	W					x	x
WS-1		12024B	148	63	1	CBBC2	W					x	x
WS-1		12024C	148	63	1	CBBC3	W					x	x
WS-1		12020A	149	63	14	DACD1	W					x	x
WS-1		12020B	148	63	14	DACD2	W					x	x
WS-1		12020C	148	63	14	DACD3	W					x	x
WS-1		12019A	149	63	23	ADBB1	W					x	x
WS-1		12019B	149	63	23	ADBB2	W					x	x
WS-1		12019C	149	63	23	ADBB3	W					x	x
WS-1		12017A	149	63	25	DBBC1	W					x	x
WS-1		12017B	149	63	25	DBBC2	W					x	x
WS-1		12017C	149	63	25	DBBC3	W					x	x
WS-1		12017D	149	63	25	DBBB4	W					x	x
WS-1		12025	149	63	26	DCA	W					x	x
WS-1		12012	149	63	27	DDDC1	W					x	x
WS-1		12015B	149	63	31	ABBC2	W					x	x
WS-1		12015C	149	63	31	ABBC3	W					x	x
WS-1		12026A	149	63	34	BBB1	W					x	x
WS-1		12026B	149	63	34	BBB2	W					x	x
WS-1		12011B	149	63	35	ABBD2	W					x	x
WS-1		12014A	149	63	36	AACB1	W					x	x
WS-1		12014B	149	63	36	AACB2	W					x	x
WS-1		12014C	149	63	36	AACB3	W					x	x
WS-1		12014D	149	63	36	AACB4	W					x	x
WS-1		12023A	149	63	36	DDBBC1	W					x	x
WS-1		12023B	149	63	36	DDBBC2	W					x	x
WS-1		12023C	149	63	36	DDBC3	W					x	x
WS-1		12021A	149	63	13	BAAB1	W					x	x
WS-2	1	13103	149	62	28	CCC1	W	x				x	x
WS-2	1	13104	149	62	28	CCC2	W	x				x	x
WS-2	2	13105	149	62	29	DAD	W	x				x	x
	3	Spring	148	63	2	DA	S	x				x	x
	4	Reservoir	149	62	31	C	R	x				x	x
WS-2	5	13097	149	63	36	ACA1	W	x				x	x
WS-2	5	13098	149	63	36	ACA2	W	x				x	x
WS-2	6	13101	149	63	25	CDC1	W	x				x	x
WS-2	6	13102	149	63	25	CDC2	W	x				x	x
WS-2	7	13086	148	63	2	ACA1	W	x				x	x
WS-2	7	13087	148	63	2	ACA2	W	x				x	x
WS-2	8	13090	149	62	19	DBD1	W		x	x	x		
WS-2	8	13091	149	62	19	DBD2	W						
WS-2	8	13106	149	62	19	DBD3	W		x	x	x		
WS-2	9	13088	149	63	13	DAA1	W		x	x	x		
WS-2	9	13089	149	63	13	DAA2	W		x	x	x		
WS-2	10	13092	149	63	12	CAC1	W		x	x	x		
WS-2	10	13093	149	63	12	CAC2	W		x	x	x		
	11	S W Lake	149	63	14	CAC	L		x	x	x		
WS-2	12	13084	148	63	2	BABC1	W						
WS-2	12	13085	148	63	2	BABC2	W						
WS-2	13	13099	149	63	35	BCBA1	W			x			
WS-2	13	13100	149	63	35	BCBA2	W			x			
	14	Lake Coe	149	63	26	ADD	L		x	x	x		
	15	Lake Coe	149	63	27	DDB	L		x	x	x		
	16	Spring	149	63	13	BDA	S			x	x		
WS-2	17	13095	148	63	4	ABA1	W			x			
WS-2	17	13096	148	63	4	ABA2	W			x			
WS-2	20	13094	149	63	14	AAB	W						

of avoiding surface contamination. WS-2 wells were sampled after their construction to provide baseline data in basic water chemistry and trace elements. However, they are not routinely used to monitor changes in basic water chemistry on the CGS facility. These samples are collected from WS-1 wells. WS-2 wells may be used or supplementary samples for basic water chemistry if needed for a specific investigative purpose. Locations of WS-2 wells are summarized on Table 2, and illustrated on Figure 4. Detailed hydrologic setting of well nests, lithologic logs for WS-2 wells, and initial water chemistry data from samples taken in 1992 and 1993 are in Schuh (1994).

Surface-Water Sampling Sites

There are five surface-water sampling sites. These include two springs, two sampling sites on Lake Coe, one sampling site on South Washington Lake, and one sampling site on a small reservoir located west of the M60 range. The two spring sites, and the three lake sites were sampled with the WS-1 well set in 1986. The reservoir was added with the 1993 sampling because of its position for collecting runoff from the M60 range (Fig. 5). Surface-water sampling locations are summarized on Table 2, and shown on Figures 3 and 4.

PREVIOUS SAMPLING RECOMMENDATIONS

Following water sampling and analysis in 1992 and 1993 six recommendations were made. These were listed above in the Introduction section. Recommendation #1, that Lake Coe and South Washington Lake be sampled at least once per year to determine if picloram contamination is an ephemeral or long-term condition, has been implemented. Samples for picloram were taken in 1994, 1995, and 1996 from each lake. Results indicated that trace levels of picloram were consistently present, and that background picloram is therefore a consistent outcome of current weed-control management on the CGS facility. Status of pesticide detections will be presented and discussed in greater detail later in this report. Recommendation #2, that dimethoate be resampled in WS-2 Well 13102 (Site 6) in early 1994 to determine whether the well was contaminated was implemented in June of 1994. Results indicated no further detections of dimethoate. The initial (fall 1993) detection was therefore either spurious or ephemeral. Recommendation #3, that sampling for each potential contaminant group be selectively repeated in 1996 was implemented and will comprise the discussion of most of this report. Recommendation #4, that all wells drilled

in 1992 be surveyed for measuring point elevation (MP) has not yet been implemented. Recommendation #5, that all wells drilled in 1992 be fitted with locking caps was completed by the North Dakota National Guard in 1995. However, WS-2 Well 13103 (Site 6, 149-062-28CCC1) was too long for the outside protective case, and the aluminum cap could not be closed without removing the inside cap, risking contamination of the well. This PC needs to be extended a few inches to allow for proper cap fit. Recommendation #6, that a comparative analysis of water chemistry data trends be considered following the 1996 sampling will be implemented as a part of this report.

CAMP GRAFTON SOUTH USE PATTERNS

In 1996 basic water chemistry and trace elements were measured in all of the WS-1 wells. Sampling from the WS-2 wells was designed to monitor potential contamination based on CGS use patterns. A summary of samples taken from each well and surface-water source is shown on Table 2. Sample results in this report will be discussed under categories 1. background water quality, 2. munitions and explosives, 3. pesticides, and 4. petroleum residues. CGS use patterns affecting water quality can be summarized as follows.

1. Agricultural use: most of the CGS facility is used for grazing during part or all of the year. The primary chemical parameter of concern would be nitrate. Nitrate is tested with basic water quality sampling on the WS-1 wells and selected WS-2 wells (Table 2). Weed control (primarily leafy spurge) is practiced throughout CGS. Herbicides used are picloram and 2,4-D.

2. Bivouac sites: common bivouac site locations are shown on Figure 5. Potential contaminants on bivouac sites include gasoline and diesel fuel (from vehicles staged on site), and insecticides used for mosquito control (usually malathion or chlorpyrifos). Previously, potential nitrate and bacterial contamination from latrines was possible. Current CGS practice (since about 1990) is to use portable lavatories, which should minimize future contamination. Tests for bivouac areas include TPH as gasoline, TPH as fuel oil (which includes diesel fuel), insecticides (chlorpyrifos and malathion), and nitrates from basic water chemistry analysis. Also, some trace metals may serve as

CAMP GRAFTON SOUTH

BIVOUAC SITES, TRAINING AREAS & RANGES

AREA NO.	AREA DESCRIPTION	GRID LOCATION
B-1-1	BIVOUAC SITE	NH 22658585
B-1-2	BIVOUAC SITE	NH 23108489
B-1-3	BIVOUAC SITE	NH 23808503
B-1-4	BIVOUAC SITE	NH 25558490
B-1-5	BIVOUAC SITE	NH 24958630
B-1-6	BIVOUAC SITE	NH 23368054
B-1-7	BIVOUAC SITE	NH 22908090
B-1-8	BIVOUAC SITE	NH 24148175
B-1-9	BIVOUAC SITE	NH 23758175
B-1-10	BIVOUAC SITE	NH 22908160
B-1-11	BIVOUAC SITE	NH 22158155
B-1-12	BIVOUAC SITE	NH 26558268
B-1-13	BIVOUAC SITE	NH 25057945
B-1-14	BIVOUAC SITE	NH 25358280
T-1-1	INDIRECT WEAPONS EMPL.	VIC NH 245845
T-1-2	DIRECT FIRE EMPLACEMENT	VIC NH 257825
T-1-3	TANK DITCH / BARRIER AREA	NH 251825 TO 257817
T-1-4	TIMBER TRESTLE BRIDGE SITE	VIC NH 247827
T-1-5	BAILEY BRIDGE SITE	VIC NH 246824
T-1-6	ENGINEER EQUIP. TRNG. SITE	VIC NH 252858
T-1-7	M4T6 BRIDGE SITE, DRY (NORTH)	VIC NH 256845
T-1-8	M4T6 BRIDGE SITE, DRY (SOUTH)	VIC NH 146826
R-1-1	M203, AT 4, MK 19 RANGE	NH 25757995
R-1-2	DEMOLITION RANGE	NH 25608025
R-1-3	MULTIPURPOSE MG RANGE	NH 28308130
R-1-4	MODIFIED RECORD FIRE RANGE	NH 28308020
R-1-5	KD RANGE (NOT CONSTRUCTED)	
R-1-6	25 METER ZERO RANGE	NH 28308055
R-1-7	COMBAT PISTOL RANGE	NH 28308060
R-1-8	MICLIC RANGE	NH 28308085

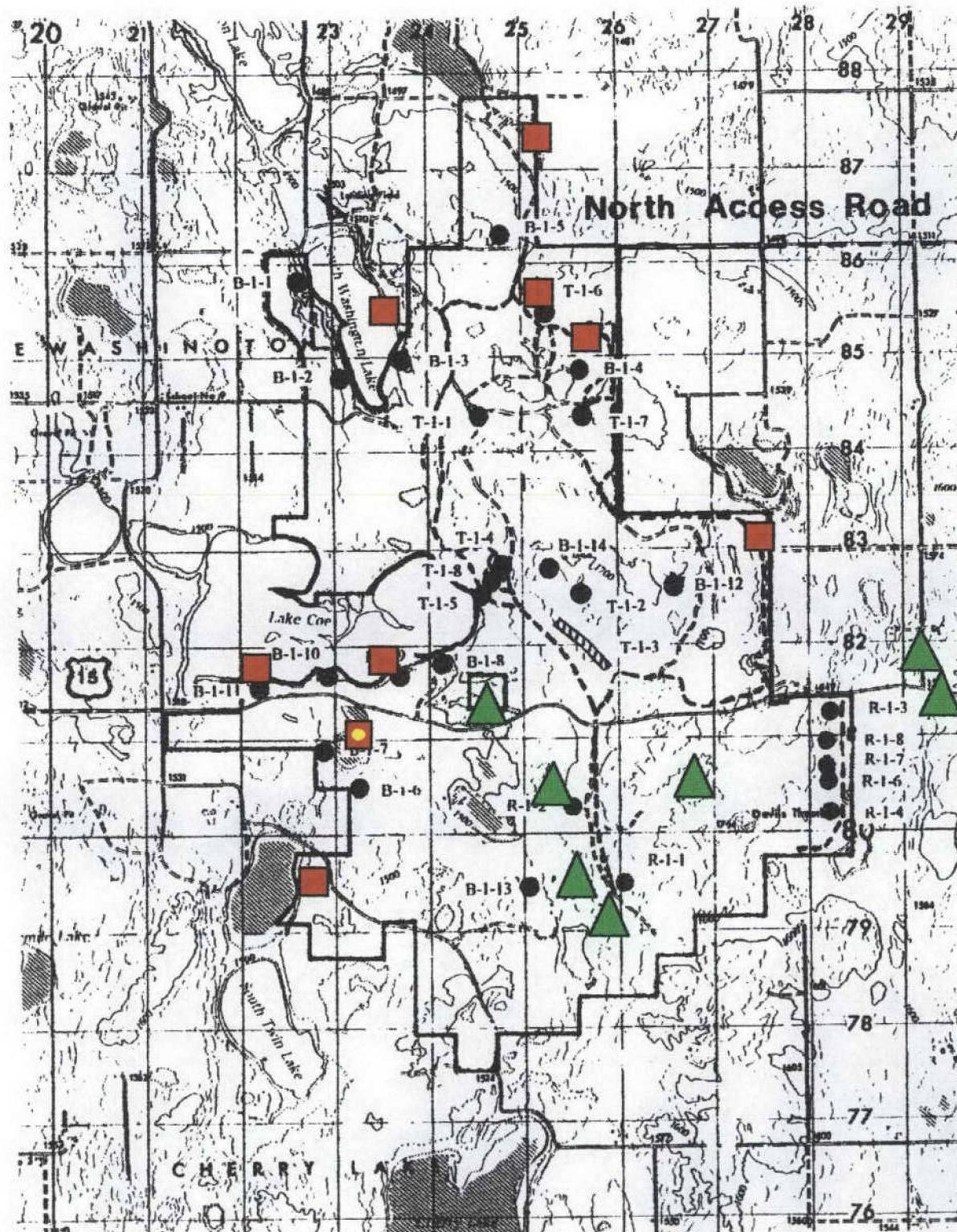


Figure 5. Sample sites for pesticide samples in relation to bivouac sites; and sample sites for explosives residue samples in relation to training areas involving demolitions and munitions training. ● indicates site with no TPH sample.

indicators of contamination from spills of used motor oils. Locations of pesticide, petroleum, basic water chemistry, and trace element samples are on Table 2.

3. Munitions and explosives use sites: most of these are located south of HWY 15. The demolitions range, located at T149N R63W Section 36DC has been in operation since 1993. The M60 range located at T149N R62W Section 32B was completed in 1993. The M203 range was completed in 1992; and the pistol range was completed in 1995.

SAMPLING AND LABORATORY METHODS

Sampling methods were designed for specific contaminants. Sampling procedures for low level detection of organic compounds, such as petroleum products, explosives residues, and pesticides, require "clean-clean" procedures, which involve high assurance against spurious contamination caused by field procedures. Because of their low concentrations, trace elements also require greater cleanliness in sampling. Basic water chemistry can usually be sampled using less stringent procedures, although even for the elements care is necessary to avoid contamination.

In the CGS monitoring plan, general water chemistry and trace elements were sampled using PVC bailers. They were taken from wells from which at least three well volumes had been purged using either air lift, or suction lift methods. Air-lift purging was used for wells having piezometric surface too deep for suction lift. A rubber compressor hose was field-cleaned by coiling it in a polyethylene tub, and scrubbing it with non-phosphate soap, and rinsing with distilled water. The tip was inserted in the well to a level at least 20 feet above the well screen. An air compressor was used to air lift the water. Suction lift was used on wells having piezometric surface near enough to the surface to support a water column (generally less than 20 feet). A 1-inch rigid polyethylene hose was washed with non-phosphate soap and stored in a polyethylene bag. The hose was inserted in the well, and water was pumped using a jet pump.

For organic contaminants, five well volumes were evacuated from the well to be sampled. Air lift was not used for these samples, because of concern over possible introduction of petroleum residues on a compressor hose. Clean-clean procedures were used. A polyethylene apron was placed on the soil around each well to be sampled, and weeds and brush were flattened. The well-cap was removed, and the inside and outside of the well were cleaned using non phosphate detergent and a clean-white disposable laboratory tissue.

Shallow wells were purged using the suction-lift procedure described above. Deeper wells were purged using a gas-squeeze pump. For petroleum samples the engine used for operating the gas-squeeze pump was moved as far downwind as possible from the sample well. Both the polyethylene hose of the suction pump and the gas squeeze pump were thoroughly cleaned with non phosphate detergent and distilled water before placement in the well.

After purging, water samples were taken using a disposable polyethylene bailer. An assistant washed the hands of the clean worker with detergent and water. The assistant then presented an opened package of disposable latex gloves to the clean worker, who removed them and put them on his hands. The assistant then opened the end of the disposable bailer package, without touching the bailer, and placed the still-covered body of the bailer under the arm of the clean worker. The assistant then removed a spool of nylon rope from a polyethylene bag, and without touching the rope presented the spool to the clean worker. The clean worker tied the rope to the bailer with gloved hand, and then placed the bailer down the well for sampling. About one well volume was bailed using the bailer, and the well was then sampled. The assistant opened caps of the bottles. Replicate bottles were partially filled from each full bailer. Bottles were filled to the top before capping. After completion the samples were placed in coolers with frozen "blue-ice". All samples were placed in a refrigerator at the Carrington Research Extension Center each evening after sampling. Sample bottles were transported to Bismarck and placed in a refrigerator before packing and sending to the laboratory using one-day express delivery.

One difference from this procedure was the sampling of TPH for gasoline and fuel oil on two sites (Site 8, and Site 9 near the Engineering Training Site). For deep wells on these sites, the gas-squeeze pump malfunctioned. Instead, the well was bailed for three well volumes using a six-foot length PVC bailer. The final sample was taken using a disposable polyethylene bailer.

General Water Chemistry and Trace Elements

General water chemistry [pH, total dissolved solids (TDS), hardness, specific conductivity, temperature, sodium adsorption ration (SAR), bicarbonate (HCO_3), potassium (K), sodium (Na), sulfate (SO_4),, nitrate (NO_3), chloride (Cl), fluoride (F), boron (B), silicate (SiO_2), iron (Fe), manganese (Mn), calcium (Ca), and magnesium (Mg.)]; and trace elements [arsenic (As), barium (Ba), mercury (Hg), lead (Pb), and selenium (Se)] were taken from each well in the fall of 1996. Previous samples taken in 1994 included cadmium (Cd)and zinc (Zn) as well. All samples were taken after purging

of at least three well volumes of water from the well. Samples were stored in 500 ml polyethylene bottles. All basic chemistry bottles were washed with well water before collecting the sample. Bottles used for water samples for trace metal analysis were washed with concentrated nitric acid, two distilled water washes, and one deionized water wash before use. In some samples, laboratory grade concentrated hydrochloric acid was used for wash. Trace element impurities in the hydrochloric acid were negligible. Samples for trace metal analysis were acidified in the field with 2 ml of concentrated nitric acid per 500 ml sample. Lab methods for general chemistry and trace elements were described previously by Shaver (1991). Nitrate measurements were made using an Orion ion-specific electrode, using an Orion conductivity meter.

Organic Compounds

TPH as gasoline, TPH as fuel oil, and pesticides chlorpyrifos, dimethoate, and picloram were analyzed by Minnesota Valley Testing Laboratory (New Ulm, MN). The laboratory method used for TPH as gasoline and fuel oil was Method 8015 in EPA-SW-846 (USEPA 1992). Chlorpyrifos and dimethoate were extracted using Method 3510 in EPA-SW-846, and were measured using Method 8081 in EPA-SW-846. Picloram was extracted and measured using Method 8150 described in EPA-SW-846. Methods for determining TPH and pesticides in previous sampling (1992 and 1993) were described by Schuh (1994).

Water samples taken in 1996 for determination of munitions and explosives were analyzed by DATA CHEM LABORATORIES (Salt Lake City, Utah). Target analytes included 2-Amino-4,6-Dinitrotoluene (2-Am-DNT), 4-amino-2,6-Dinitrotoluene (4-Am-DNT), 1,3-Dinitrobenzene (DNB), 2,4-Dinitrotoluene (2,4-DNT), 2,6-Dinitrotoluene (2,6-DNT), octahydro-1,3,5,7-tetranitro-1,3,5,7-Tetrazocine (HMX), Nitrobenzene, 2-Nitrotoluene, 3-Nitrotoluene, 4-Nitrotoluene, hexahydro-1,3,5-trinitro-1,3,5-Triazine 1,3,5-Trinitrobenzene (TNB), 2,4,6-Trinitrotoluene (TNT), and (RDX), methyl-2,4,6-TrinitrophenylNitramine (TETRYL). The laboratory procedure used was Method 8330 documented in EPA-SW-846 (USEPA 1992). Methods for initial munitions and explosives samples taken prior to 1996 are described in Schuh (1994). Water samples were packed in a cooler with blue-ice cooling elements, after a night of chilling in a refrigerator. However, laboratory measurements of ambient air temperature in the cooler at the time of delivery indicated that the temperature was above the 4^o C specification. This indicates that the number of cooling elements was inadequate. While such temperature drift is undesirable, it occurred gradually and over a relatively short period of transit. It is not

likely that results were significantly altered. However, the reader may adjust his interpretation of these data according to these facts.

RESULTS

As previously described, changes in basic water chemistry and trace elements are routinely measured using water samples from WS-1 wells. In addition, WS-2 wells used for sampling for potential contamination from munitions and explosives were also sampled for basic water chemistry and trace elements in 1996 because of potential elevated nitrates from ammonium nitrate, and potential lead contamination from projectiles. Samples were also taken for selected munitions and explosives, pesticides, and petroleum hydrocarbons. A summary of wells and surface waters sampled is shown on table 2.

Background Water Chemistry

Background water chemistry of the Cherry Lake aquifer varies. Total dissolved solids (TDS) varies from as low as 200 mg/L to as much as 2000 mg/L in well samples, and TDS in surface-water samples can be as high as 5,000 mg/L. pH varies from lows near 6, to high values near 9. Ground-water salts vary from predominantly calcium bicarbonate to predominantly sodium sulfatic water constituents. Chloride concentrations vary from negligible to more than 1,000 mg/L, depending on the individual well. Anionic composition of many deep water samples is a mixture of chloride, sulfate, and bicarbonate.

Basic water chemistry data for the WS-1 wells are summarized on Table 3. Historical data, as well as 1996 data, are also included. A historical summary of basic water chemistry data for the organic contaminant (WS-2) sampling wells is on Table 4. In general, highest specific conductance and TDS are in the deeper wells (screens placed more than 100 feet below land surface). Sodium contents are also highest in the deeper wells. Shallow wells commonly have a sodium adsorption ratio (SAR) of 2 or less. Several the deep wells have SAR values greater than ten, and some are as large as 35. Sulfate concentrations are positively correlated with sodium and negatively correlated with calcium (Fig. 6). Deeper wells are, in general, more sulfatic than shallower wells (Fig. 6). However, some are also high in chloride. Highest SAR and specific conductance values are in the deep wells of nests placed in the uplands east of South Washington Lake.

Although Comesky (1989) identified three main subunits of the Cherry Lake aquifer, the aquifer is heterogeneous. Some aquifer subunits may be interconnected, while

others may occur as isolated pockets within the glacial till. Temporal changes in water chemistry of some deep wells indicate that they are connected to other aquifer units, and can be freshened. For example, The deep well on Site 6 (Table 4) located in the littoral area southeast of Lake Coe changed from a specific conductance of 1041 $\mu\text{mho/cm}$ in October of 1992, to 471 $\mu\text{mho/cm}$ in September of 1996. Following large rains in 1993 this well was flowing, indicating a large change in piezometric pressure caused by recharge in the uplands. Thus, both changing piezometric pressure and water chemistry data indicate a deep well connected to the surface, and freshened by rainfall at some distance (more than one mile) from the well. Similar, but less marked decreases in specific conductance occurred for several deep wells, as shown by data on Tables 3 and 4. Differences in water chemistry between deep wells may be strongly related to their levels of isolation from other fresher bodies of water.

Most of the shallow wells have low SAR values, low specific conductance, and low TDS. The pH of most shallow wells is slightly acid to neutral (6.5 to 7.5). Predominant cations are calcium. Water from most shallow wells is of good quality for drinking. Water from springs is usually of good quality, and similar in chemistry to water samples taken from shallow wells.

Surface waters, and particularly Lake Coe and South Washington Lake, are windows on the water tables, and appear to function as evaporative sinks for waters moving slowly toward the Sheyenne River. Water in these lakes is brackish, having specific conductance ranging from 3,720 to 6,430 $\mu\text{mho/cm}$. Lake waters are high in sodium, having very large SAR values, and also in sulfate and bicarbonate.

Background Trace Elements

Background trace elements for WS-1 are shown on Table 5. In WS-1 wells, trace elements arsenic, mercury, lead, and selenium were measured in 1987, 1991, and 1996. In addition, barium was measured in 1991 and 1996, and cadmium and zinc were measured in 1991. For barium, cadmium, mercury, lead, selenium and zinc there were no detections at levels of toxicological concern in any of the samples. Most were non detections. There were also no trends of rising concentrations.

Background trace elements for were measured for all WS-2 wells in 1993 (Table 6) and for selected wells in 1996. Barium and lead were sampled in wells designated as indicators of contamination from munitions and explosives (Table 2), as possible indicators of residuals from projectiles and barium nitrate. Other trace metals were sampled from wells associated with some bivouac areas. There were no detections of barium, cadmium,

Table 3. Basic chemical properties of water samples taken from WS-1 wells (Comesky 1989) on the Camp Grafton South Military Reservation.

Location	Screened Interval (ft)	Date Sampled	(milligrams per liter)														Hardness CaCO ₃	as NCH	% Na	SAR	Spec Cond (µmho)	Temp (°C)	pH	
			SiO ₂	Fe	Mn	Ca	Mg	Na	K	HCO ₃	CO ₃	SO ₄	Cl	F	NO ₃	B								TDS
149-062-31ABBC2	162-167	09/11/96		0.15	0.21	42	11	61	8.9	332	0	37	4.2	0.3	0.1		329	150	0	45	2.2	493	7.9	
149-062-31ABBC2	162-167	10/23/91	29	0.02	0.2	42	12	65	9	325	0	36	4.4	0.3	0	0.26	358	150	0	46	2.3	563	5	8.44
149-062-31ABBC2	162-167	09/01/87	31	0.04	0.27	45	12	64	9.1	321	0	43	4	0.3	2.8	0.28	370	160	0	44	2.2	570	13	
149-062-31ABBC3	78-83	09/11/96		0.3	0.64	69	18	4.5	5.2	300	0	21	2.5	0.2	0.1		269	250	0	4	0.1	410	7.6	
149-062-31ABBC3	78-83	10/23/91	32	0.02	1.1	63	18	5.5	6.2	290	0	19	3	0.2	3.6	0.01	295	230	0	5	0.2	455	6	7.97
148-063-01CBBC2	151-156	09/11/96		0.04	0.79	38	11	82	7.5	344	0	44	6.7	0.2	0.1		359	140	0	54	3	509	8.1	
148-063-01CBBC2	151-156	10/23/91	30	0.02	0.68	37	11	80	9.1	341	0	42	7.3	0.3	0	0.3	386	140	0	54	2.9	583	6	8.03
148-063-01CBBC2	151-156	09/02/87	30	0.01	0.79	40	11	75	7.9	339	0	40	4.8	0.3	1.7	0.27	379	150	0	51	2.7	590	11	
48-063-02DA	0-0	09/04/96		0.05	0.29	74	21	5.5	3.5	337	0	16	0.3	0.2	0.3		287	270	0	4	0.1	424	13.3	
148-063-02DA	0-0	10/22/92	25	0.06	0.03	71	21	6	4	294	0	34	2.7	0.2	0	0.03	309	260	23	5	0.2	502	9	6.8
148-063-02DA	0-0	09/11/86	33	0.02	0.04	72	21	5.5	2.2	310	0	27	2.6	0.1	0	0.03	316	270	12	4	0.1	540	13	
148-063-11CCB	0-0	07/17/64	18	0.17		76	23	39	8.2	376	0	59	5.5	0.3	4.5	0	419	284	0	22	1		7.8	
149-062-31ABBC2	162-167	09/11/96		0.15	0.21	42	11	61	8.9	332	0	37	4.2	0.3	0.1		329	150	0	45	2.2	493	7.9	
149-062-31ABBC2	162-167	10/23/91	29	0.02	0.2	42	12	65	9	325	0	36	4.4	0.3	0	0.26	358	150	0	46	2.3	563	5	8.44
149-062-31ABBC2	162-167	09/01/87	31	0.04	0.27	45	12	64	9.1	321	0	43	4	0.3	2.8	0.28	370	160	0	44	2.2	570	13	
149-062-31ABBC3	78-83	09/11/96		0.3	0.64	69	18	4.5	5.2	300	0	21	2.5	0.2	0.1		269	250	0	4	0.1	410	7.6	
149-062-31ABBC3	78-83	10/23/91	32	0.02	1.1	63	18	5.5	6.2	290	0	19	3	0.2	3.6	0.01	295	230	0	5	0.2	455	6	7.97
149-063-13BAAB1	96-101	09/11/96		0.43	0.42	110	30	830	25	782	0	77	1100	0.3	17		2580	400	0	81	18	3060	7.9	
149-063-13BAAB1	96-101	10/23/91	26	0.03	0.44	110	30	820	20	755	0	79	1100	0.3	0.1	2.4	2560	400	0	81	18	4440	6	8.03
149-063-13BAAB1	96-101	09/01/87	25	0.02	0.22	64	18	470	17	633	0	140	490	0.4	5.5	1.2	1540	230	0	80	13	3710	12	
149-063-13BD	0-0	09/11/86	30	0.03	0.13	79	25	17	7	365	0	31	4.3	0.2	0.3	0.06	374	300	1	11	0.4	620	14	
149-063-14CA	0-0	09/11/86	1.4	0.04		15	60	1000	280	737	400	930	360	0.1	1	2.7	3410	280	0	77	26	5400	15	
149-063-14DACD1	212-217	09/11/96		0.01	0.17	9.3	4	490	10	782	0	330	140	0.7	2.3		1370	40	0	95	34	1858	8.3	
149-063-14DACD1	212-217	10/23/91	30	0.02	0.16	13	4	510	9.5	772	0	340	160	0.6	3.7	2	1450	49	0	95	32	2310	6	8.62
149-063-14DACD1	212-217	09/01/87	31	0.03	0.39	20	6	640	12	752	0	430	360	0.5	0.6	3.4	1870	75	0	94	32	3070	12	
149-063-14DACD2	151-156	09/11/96		0.05	0.18	11	4	310	9	693	0	190	19	0.6	0.2		885	44	0	92	20	1173	8.4	
149-063-14DACD2	151-156	10/23/91	29	0.02	0.17	15	3	320	7.9	671	0	190	23	0.6	1.8	1.3	923	50	0	92	20	1384	6	8.41
149-063-14DACD2	151-156	09/01/87	31	0.01	0.22	14	4	310	8.4	659	0	200	20	0.7	0.5	1.1	915	52	0	92	19	1460	12	
149-063-14DACD3	38-43	09/10/96		0.09	0.07	73	23	15	5.5	353	0	31	4.5	0.2	1.8		328	270	0	10	0.4	499	7.7	
149-063-14DACD3	38-43	10/23/91	29	0.08	0.07	70	23	15	5.8	335	0	35	5.6	0.2	1.4	0.05	350	270	0	11	0.4	567	6	8.04
149-063-14DACD3	38-43	09/01/87	32	0.01	0.06	73	23	18	6.8	341	0	35	3.9	0.2	2.4	0.06	362	280	0	12	0.5	580	12	
149-063-23ADBB1	218-223	09/11/96		0.12	0.42	41	9.5	70	6.5	337	0	23	18	0.2	0.2		335	140	0	50	2.6	491	8.5	
149-063-23ADBB1	218-223	10/23/91	28	0.11	0.41	44	11	67	6.3	331	0	23	16	0.2	4.3	0.14	363	160	0	47	2.3	569	6	8.3
149-063-23ADBB1	218-223	09/01/87	30	0.09	0.43	41	10	76	6.9	322	0	19	21	0.2	2.9	0.15	367	140	0	52	2.8	590	12	
149-063-23ADBB2	32-37	09/10/96		0.25	0.4	77	22	6	3.1	310	0	53	1.7	0.1	0.4		317	280	29	4	0.2	471	7.9	
149-063-23ADBB2	32-37	10/23/91	26	0.05	0.35	72	21	8	3.3	304	0	45	3.9	0.2	0.7	0.05	331	270	17	6	0.2	524	9	8.08
149-063-23ADBB2	32-37	09/01/87	28	0.21	0.44	74	21	6.5	3.6	298	0	40	1.6	0.2	0.4	0.04	323	270	27	5	0.2	515	11	
149-063-23ADBB3	7-12	09/10/96		1.7	1.3	80	18	3.5	1.4	315	0	19	2.7	0.1	14		297	270	16	3	0.1	462	10.9	
149-063-23ADBB3	7-12	10/23/91	27	0	0.05	82	20	3.5	1.2	331	0	9.9	3.4	0.2	24	0.03	334	290	16	3	0.1	537	10	8.08
149-063-23ADBB3	7-12	09/01/87	38	0.11	0.33	77	18	4	2.3	287	0	16	1	0.2	3.4	0.05	301	270	31	3	0.1	585	14	
149-063-25DBBC1	263-268	09/11/96		0.02	0.28	18	4.5	250	7.4	458	0	110	97	0.4	1.2		715	64	0	88	14	1008	8.8	
149-063-25DBBC1	263-268	10/24/91	27	0	0.24	18	4.5	250	8	454	0	100	96	0.4	0	0.71	729	64	0	88	14	1144	5	8.15
149-063-25DBBC1	263-268	09/01/87	30	0.01	0.24	19	4.5	240	7.5	444	0	100	99	0.4	0.6	0.65	721	66	0	87	13	1200	12	
149-063-25DBBC2	78-83	09/11/96		0.15	0.13	29	8.5	120	8.3	418	0	53	8.4	0.5	0.9		435	110	0	69	5	632	7.9	
149-063-25DBBC2	78-83	10/24/91	26	0.01	0.11	25	7.5	130	7.9	416	0	45	7.5	0.5	5.6	0.47	460	94	0	73	5.8	706	7	8.16
149-063-25DBBC2	78-83	09/02/87	22	0.01	0.15	26	7.5	160	14	376	0	150	4.1	0.5	3.1	0.55	573	96	0	75	7.1	860	11	
149-063-25DBBC3	51-56	09/10/96		0.08	0.25	66	19	5	4.3	293	0	26	3.7	0.2	0.6		269	240	3	4	0.1	411	9.4	
149-063-25DBBC3	51-56	10/24/91	24	0	0.03	62	17	6.5	3.9	264	0	23	4.8	0.2	2.4	0.03	274	220	8	6	0.2	457	9	7.84
149-063-25DBBC3	51-56	09/02/87	31	0.09	0.5	72	20	6	5.1	314	0	25	1	0.3	0.4	0.06	316	260	5	5	0.2	490	11	
149-063-25DBBC4	23-28	09/10/96		1.8	0.69	74	19	6	4.3	325	0	20	2.9	0.2	0.1		289	260	0	5	0.2	442	7.5	
149-063-25DBBC4	23-28	10/24/91	32	1.8	0.74	70	19	7	4.9	316	0	18	4	0.2	3	0.04	317	250	0	5	0.2	500	9	7.32
149-0																								

Table 3 (continued). Basic chemical properties of water samples taken from WS-1 wells (Comesky 1989) on the Camp Grafton South Military Reservation.

Location	Screened Interval (ft)	Date Sampled	(milligrams per liter)															Hardness CaCO ₃	as NCH	t Na	SAR	Spec Cond (µmho)	Temp (°C)	pH	
			SiO ₂	Fe	Mn	Ca	Mg	Na	K	HCO ₃	CO ₃	SO ₄	Cl	F	NO ₃	B	TDS								
149-063-26DA	0-0	09/11/86	7.9	0.14	0.01	15	40	1300	160	1230	200	980	540	0.1	1	3.7	3850	200	0	87	40	6000	15		
149-063-26DCA	38-43	09/12/96		1.4	0.31	87	58	83	14	500	0	230	20	0.2	0.4		740	460	46	28	1.7	880	7.9		
149-063-26DCA	38-43	10/24/91	27	0.49	0.28	73	53	82	14	476	0	190	14	0.3	0	0.21	688	400	10	30	1.8	996	7	7.87	
149-063-26DCA	38-43	09/01/87	28	0.61	0.34	71	46	83	12	444	0	170	14	0.3	2	0.26	647	370	2	32	1.9	975	11		
149-063-27CA	0-0	09/11/86	2.2	0.18	0.01	15	40	1400	180	1210	300	1100	580	0.2	0.1	4.8	4220	200	0	88	43	6400	14		
149-063-27DDDC2	158-163	09/11/96		0.02	1.1	57	15	65	8.6	308	0	94	41	0.3	0.2		434	200	0	40	2	725	7.7		
149-063-27DDDC2	158-163	11/19/91	28	0.01	1.1	53	15	64	9.2	299	0	89	15	0.3	1.2	0.31	423	190	0	40	2	638	7	7.53	
149-063-27DDDC2	158-163	09/01/87	10	0.15	0.24	29	8.5	2.5	14	161	0	61	1.8	0.1	1	0.07	207	110	0	4	0.1	241	13		
149-063-34BBB1	251-256	09/12/96		0.07	0.72	52	14	50	7.2	318	0	48	10	0.5	0.3		340	190	0	36	1.6	491	8		
149-063-34BBB1	251-256	11/19/91	30	0.01	0.73	49	15	59	7.7	328	0	47	13	0.5	0	0.2	384	180	0	40	1.9	595	7	7.05	
149-063-34BBB1	251-256	09/01/87	27	0.03	0.68	47	23	120	14	428	0	110	23	0.5	1	0.28	577	210	0	53	3.6				
149-063-34BBB2	27-32	09/12/96		0.01	0.33	75	24	18	3.5	305	0	63	5.5	0.2	17		357	290	36	12	0.5	486	7.4		
149-063-34BBB2	27-32	10/22/92	25	0.02	0.01	70	23	16	3.1	281	0	66	5.6	0.1	7.6	0	354	270	39	11	0.4				
149-063-34BBB2	27-32	10/24/91	25	0.01	0.04	71	23	18	3.6	289	0	72	8	0.2	5.1	0.05	368	270	35	12	0.5	566	6	7.95	
149-063-34BBB2	27-32	09/01/87	27	0.01	0.34	74	25	28	4.7	298	0	89	8.5	0.2	1	0.1	405	290	44	17	0.7	670	11		
149-063-35ABBD2	45-50	09/10/96		1.2	0.29	80	29	99	10	459	0	170	11	0.2	0.1		627	320	0	39	2.4	835	7.7		
149-063-35ABBD2	45-50	10/24/91	27	0.37	0.34	68	26	94	9.9	432	0	130	10	0.3	5.5	0.24	585	280	0	41	2.4	869	7	8.02	
149-063-35ABBD2	45-50	09/01/87	29	0.76	0.29	68	25	93	9.6	422	0	120	8.5	0.2	1.8	0.3	564	270	0	42	2.5	880	10		
149-063-36AACB2	181-186	09/11/96		0.02	1.1	64	13	140	9.5	467	0	110	33	0.2	0.2		601	210	0	58	4.2	804	8.4		
149-063-36AACB2	181-186	10/22/91	28	0.03	1	62	13	140	9	457	0	110	30	0.1	0.8	0.48	619	210	0	58	4.2	929	7	7.75	
149-063-36AACB2	181-186	09/02/87	31	0.03	1.1	63	13	140	9.8	452	0	110	32	0.2	2.7	0.5	626	210	0	58	4.2	950	10		
149-063-36AACB3	64-69	09/11/96		0.37	0.6	110	29	9	6.5	472	0	50	5.2	0.2	0.1		444	390	7	5	0.2	627	8.4		
149-063-36AACB3	64-69	10/22/91	29	0.23	0.61	120	32	11	7.4	486	0	55	5	0.1	0	0.04	499	430	33	5	0.2	763	8	7.41	
149-063-36AACB3	64-69	09/02/87	32	0.18	0.81	110	30	11	7.4	401	0	57	3	0.2	0.4	0.06	450	400	70	6	0.2	740	10		
149-063-36AACB4	24-29	09/10/96		0.01	0.02	82	23	4	2.8	342	0	27	4.1	0.2	12		323	300	19	3	0.1	481	7.6		
149-063-36AACB4	24-29	10/22/91	26	0.01	0.02	78	23	6	5.6	329	0	36	6	0.1	10	0.03	353	290	20	4	0.2	597	8	7.59	
149-063-36AACB4	24-29	09/02/87	29	0.02	0.03	79	23	5.5	3.5	305	0	29	2.9	0.2	3.2	0.03	325	290	42	4	0.1	540	12		
149-063-36BBD2	22-27	09/11/96		0.03	0.36	66	19	45	7.6	370	0	47	8.2	0.3	0.4		376	240	0	28	1.3	536	8.7		
149-063-36BBD2	22-27	10/24/91	30	0.01	0.34	60	19	49	7.7	358	0	42	8.9	0.3	0.2	0.19	394	230	0	31	1.4	620	9	7.96	
149-063-36BBD2	22-27	09/01/87	31	0.01	0.11	59	22	47	7.5	358	0	43	8	0.3	1	0.23	395	240	0	29	1.3	620	14		
149-063-36DDBC1	131-136	09/11/96		0.1	0.62	29	7	130	6.9	403	0	47	18	0.3	0.6		439	100	0	72	5.7	613	7.7		
149-063-36DDBC1	131-136	10/22/91	27	0.29	0.77	28	7	140	6.9	413	0	48	20	0.3	0	0.35	482	99	0	74	6.1	748	6	8.18	
149-063-36DDBC1	131-136	09/02/87	31	0.02	0.93	30	8	130	7.5	399	0	49	18	0.5	2	0.38	474	110	0	71	5.4	720	11		
149-063-36DDBC2	83-88	09/11/96		0.01	1.3	59	16	52	7.3	360	0	41	9.9	0.2	0.1		364	210	0	34	1.6	509	7.4		
149-063-36DDBC2	83-88	10/22/91	29	0.02	1.3	56	16	52	7.6	353	0	35	9.2	0.2	0.4	0.16	381	210	0	34	1.6	598	6	7.83	
149-063-36DDBC2	83-88	09/02/87	32	0.01	1.4	55	15	61	7.6	353	0	38	9.4	0.3	0.4	0.22	394	200	0	39	1.9	620	10		
149-063-36DDBC3	46-51	09/10/96		0.55	0.31	75	22	11	4.1	345	0	27	5.3	0.2	0.1		316	280	0	8	0.3	465	7.9		
149-063-36DDBC3	46-51	10/22/91	27	0.31	0.3	72	21	16	5.6	339	0	30	5.5	0.2	3.7	0.05	349	270	0	11	0.4	548	7	2	
149-063-36DDBC3	46-51	09/02/87	30	0.4	0.32	77	22	8	4.4	329	0	28	3.3	0.2	0.5	0.08	336	280	13	6	0.2	540	10		

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Table 4. Basic chemical properties of water samples taken from WS-2 wells (Schuh 1994) on the Camp Grafton South Military Reservation.

Site	Location	Screened Interval (ft)	Date Sampled	(milligrams per liter)															Hardness CaCO ₃	as NCH	% Na	SAR	Spec Cond (µmho)	Temp (°C)	pH		
				SiO ₂	Fe	Mn	Ca	Mg	Na	K	HCO ₃	CO ₃	SO ₄	Cl	F	NO ₃	B	TDS									
1	149-062-28CCC1	139-144	09/05/96		0.06	0.61	34	8	180	7.4	481	0	130	1.4	0.3	0.3		599	120	0	75	7.1	794	9.4			
1	149-062-28CCC1	139-144	10/21/92	25	0.06	0.55	32	8	180	8.8	482	0	130	6.1	0.3	2.9	0.58	631	110	0	76	7.5	958	8	7.26		
1	149-062-28CCC2	56-61	09/04/96		0.47	0.37	76	19	25	9.7	376	0	45	0.3	0.2	0.2		361	270	0	16	0.7	515	9.1	7.07		
1	149-062-28CCC2	56-61	10/21/92	30	0.3	0.4	78	20	27	10	372	0	49	3.5	0.2	4.3	0.15	406	280	0	17	0.7	661	8			
2	149-062-29DAD	50-55	09/04/96		0.13	0.52	84	22	11	7.8	368	0	49	0.2	0.2	0.2		356	300	0	7	0.3	527	8.5	7		
2	149-062-29DAD	50-55	10/21/92	33	0.1	0.52	88	24	12	7.3	365	0	54	1.7	0.2	2	0.11	403	320	20	7	0.3	608	10			
3	148-063-02DA	0-0	09/04/96		0.05	0.29	74	21	5.5	3.5	337	0	16	0.3	0.2	0.3		287	270	0	4	0.1	424	13.3			
3	148-063-02DA	0-0	10/22/92	25	0.06	0.03	71	21	6	4	294	0	34	2.7	0.2	0	0.03	309	260	23	5	0.2	502	9	6.8		
3	148-063-02DA	0-0	09/11/86	33	0.02	0.04	72	21	5.5	2.2	310	0	27	2.6	0.1	0	0.03	316	270	12	4	0.1	540	13			
4	148-062-31C	0-0	10/22/92	3	0.12	0.01	36	9.5	3.5	18	182	0	0.8	2.8	0.1	0.6	0.02	164	130	0	5	0.1	331	10	7.25		
5	149-063-36ACA1	41-48	09/03/96		0.19	0.34	60	15	22	6.4	305	0	26	0.2	0.2	0.1		280	210	0	18	0.7	427	7.6			
5	149-063-36ACA1	41-48	10/22/92	25	0.12	0.34	60	15	23	6.7	302	0	23	2.6	0.2	1.8	0.13	307	210	0	18	0.7	543	10	6.65		
5	149-063-36ACA2	21-27	09/03/96		0.92	0.61	65	16	7	3.8	300	0	16	0	0.2	0.2		258	230	0	6	0.2	425	7.2			
5	149-063-36ACA2	21-27	10/22/92	24	0.61	0.66	67	16	8	5.3	288	0	17	3.5	0.2	0	0.05	284	230	0	7	0.2	491	10	6.63		
6	149-063-25CDC1	110-115	09/05/96		0.23	0.42	75	24	10	4.3	366	0	23	1.2	0.2	0.1		318	290	0	7	0.3	471	12.4			
6	149-063-25CDC1	110-115	10/22/92	25	0.04	1.5	94	19	120	13	250	0	300	46	0.4	2.2	0.47	745	310	110	44	3	1041	10			
6	149-063-25CDC2	25-30	09/05/96		0.02	1.8	91	19	120	11	246	0	310	43	0.4	5		722	310	100	45	3	890	14.6			
6	149-063-25CDC2	25-30	10/22/92	25	0.27	0.46	77	25	11	4.3	359	0	22	3.1	0.2	0.1	0.06	345	300	2	7	0.3	579	10	6.58		
7	148-063-02ACA1	97-102	09/03/96		0.03	1.3	78	20	23	5.4	369	0	37	0.5	0.2	0.4		348	280	0	15	0.6	524	8.5			
7	148-063-02ACA1	97-102	10/22/92	25	0.02	1.3	83	21	23	5.1	371	0	37	3.8	0.2	1.1	0.12	384	290	0	14	0.6	623	8	6.42		
7	148-063-02ACA2	18-23	09/03/96		0.47	0.28	55	15	2	1.6	246	0	4.5	0.2	0.1	0.5		201	200	0	2	0.1	337	7.7			
7	148-063-02ACA2	18-23	10/22/92	26	0.23	0.37	53	15	2.5	1.6	236	0	4.5	2.2	0.1	0.8	0.03	222	190	1	3	0.1	464	10	6.6		
8	149-062-19DBD1	95-100	08/25/93	31	0.18	0.56	89	21	16	13	375	0	45	3.7	0.2	5.6	0.04	410	310	1	10	0.4	673	10	7.55		
8	149-062-19DBD3	43-48	08/25/93	40	0.04	0.71	69	18	8	7.8	311	0	23	4.7	0.2	1.1	0.09	326	250	0	6	0.2	1109	10	6.87		
9	149-063-13DAA1	95-100	08/25/93	59	0.04	0.07	13	4	300	8.9	716	0	150	8.4	0.7	5	1.7	904	49	0	92	19	1299	9	8.13		
9	149-063-13DAA2	30-35	08/25/93	28	0.02	0.02	83	31	9	4.5	383	0	35	6.2	0.2	1.2	0.05	387	330	21	5	0.2	776	11	7.69		
10	149-063-12CAC1	105-110	08/25/93	28	0.18	0.28	38	11	150	9.9	453	0	79	30	0.4	5.4	0.05	575	140	0	68	5.5	867	11	7.23		
10	149-063-12CAC2	45-50	08/25/93	26	0.14	0.48	78	23	13	5.1	346	0	27	2.7	0.2	1.3	0.73	348	290	6	9	0.3	581	12	6.35		
11	149-063-14DBB	0-0	08/24/93	32	0.03	0.01	20	35	630	200	778	100	710	260	0.1	1.1	0.06	2370	190	0	75	20	3720	26	9.05		
12	148-063-02BABC1	69-74	08/26/93	29	0.12	0.39	27	8.5	110	6.2	399	0	26	12	0.3	4.5	0.22	421	100	0	68	4.8	653	7	7.8		
12	148-063-02BABC2	12-17	08/26/93	26	0.02	0.04	110	35	9.5	3.2	450	0	65	7.1	0.1	5.7	0.04	484	420	50	5	0.2	746	8	7.56		
13	149-063-35BCBA2	23-28	08/24/93	26	0.71	0.79	84	27	19	4.7	364	0	60	7.7	0.2	0.9	0.08	410	320	22	11	0.5	629	14	7		
14	149-063-26ADD	0-0	08/24/93	9.7	0.05	0.01	20	33	900	120	1060	200	730	370	0.1	2	3.8	2910	190	0	85	28	3950	27	9.2		

Table 4 (continued). Basic chemical properties of water samples taken from WS-2 wells (Schuh 1994) on the Camp Grafton South Military Reservation.

Site	Location	Screened Interval (ft)	Date Sampled	(milligrams per liter)															Hardness CaCO ₃	as NCH	% Na	SAR	Spec Cond (µmho)	Temp (°C)	pH
				SiO ₂	Fe	Mn	Ca	Mg	Na	K	HCO ₃	CO ₃	SO ₄	Cl	F	NO ₃	B	TDS							
15	149-063-27DDB	0-0	08/24/93	9.4	0.13	0.01	20	35	1500	200	1510	400	1200	630	0.1	0	1.5	4740	190	0	88	47	6430	26	9.46
16	149-063-13BDA	0-0	09/11/86	30	0.03	0.13	79	25	17	7	365	0	31	4.3	0.2	0.3	0.06	374	300	1	11	0.4	620	14	
16	149-063-13BDA	0-0	09/05/96		0.04	0.17	76	25	13	6.4	366	0	32	0.9	0.3	0.2		290	0	9	0.3	483	16.3		
16	149-063-13BDA	0-0	08/25/93	34	0.09	1	90	30	15	4.8	428	0	22	2.9	0.2	0	0.07	411	350	0	8	0.3	660	18	7.22
17	148-063-04ABA2	25-30	08/26/93	26	0.43	0.68	81	25	46	4.6	369	0	94	11	0.1	1	0.09	472	310	3	24	1.1	718	11	7.47
Site s 18 and 19*		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
20	149-063-14AAB	17-22	08/25/93	29	1.9	0.58	88	30	12	3.9	409	0	24	7.6	0.2	2.3	0.06	401	340	8	7	0.3	633	11	7.06

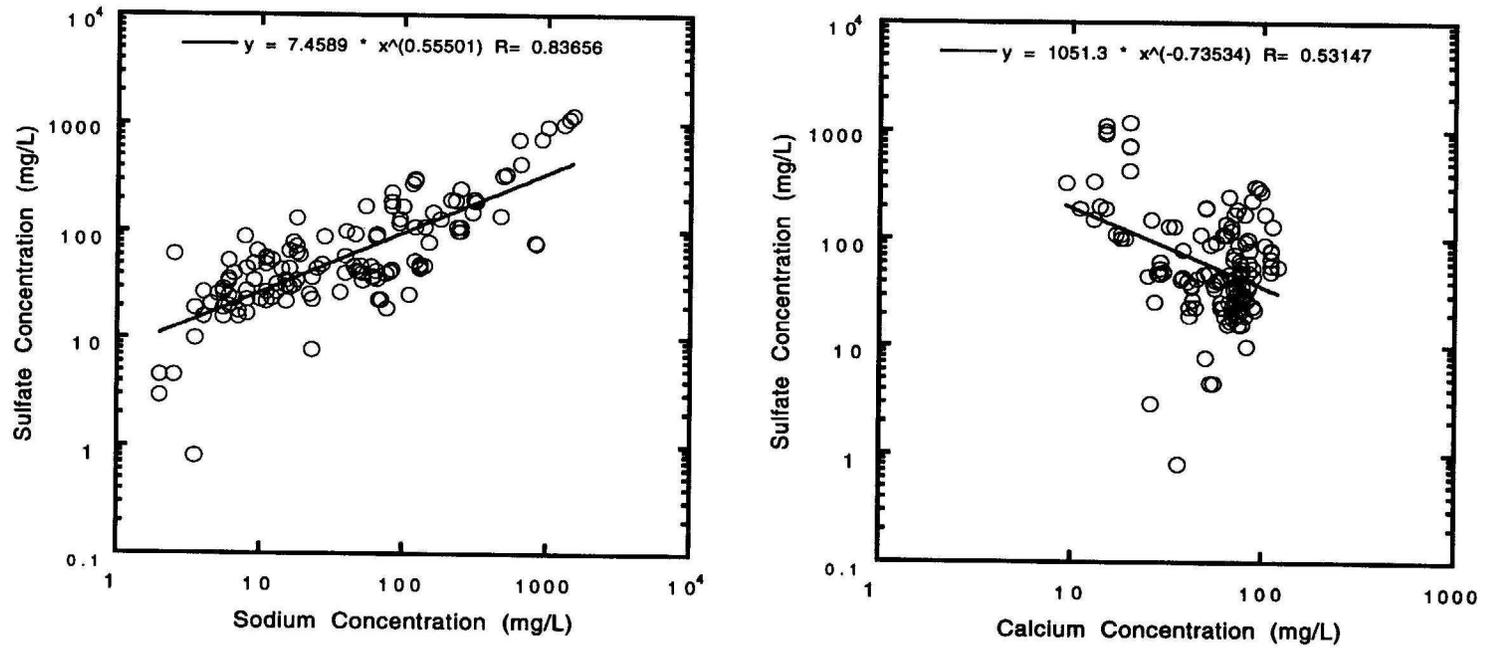


Figure 6. Sulfate concentration versus sodium and calcium concentrations for water samples taken from WS-1 wells in the Cherry Lake aquifer on the Camp Grafton South Military Reservation.

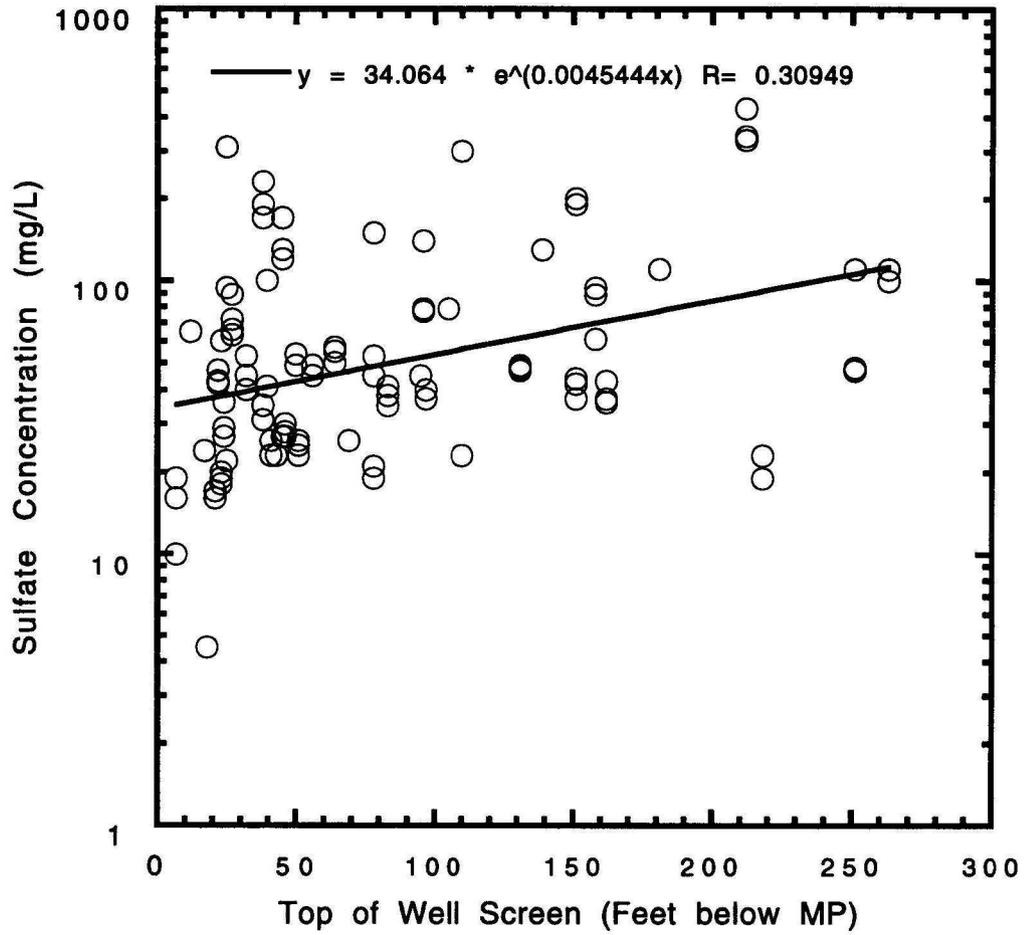


Figure 7. Sulfate concentration of water samples taken from WS-1 wells in the Cherry Lake aquifer at CGS, versus the depth to the top of the well screen.

Table 5. Barium (Ba), and trace element [arsenic (As), cadmium (Cd), mercury (Hg), lead (Pb), selenium (Se), and Zinc (Zn)] concentrations for water samples taken from WS-1 wells (Comesky 1989).

Location	Screened Interval (ft)	Date Sampled	(micrograms per liter)						
			As	Ba	Cd	Hg	Pb	Se	Zn
USEPA MCL (*MCLC)			50	1000	10	2	15	10	* 5000
14906231ABBC2	162-167	9/1/87	42	ns	ns	0	1	0	ns
14906231ABBC2	162-167	10/23/91	1	47	0	0	0	0	10
14906231ABBC2	162-167	9/11/96	47	47	ns	0	0	0	ns
14906231ABBC3	78-83	10/23/91	10	160	0	0	0	0	6
14906231ABBC3	78-83	9/11/96	10	120	ns	0	0	0	ns
148-063-01CBBC2	151-156	9/2/87	0	ns	ns	0	0	0	ns
148-063-01CBBC2	151-156	10/23/91	0	58	0	0	0	0	6
148-063-01CBBC2	151-156	9/11/96	0	59	ns	0	0	0	ns
149-063-13BAAB1	96-101	09/01/87	25	ns	ns	0	0	4	ns
149-063-13BAAB1	96-101	10/23/91	25	230	0.1	0	0	4	15
149-063-13BAAB1	96-101	9/11/96	36	160	ns	0	0	0	ns
149-063-14DACD1	212-217	09/01/87	6	ns	ns	0	0	0	ns
149-063-14DACD1	212-217	10/23/91	4	13	0	ns	1	ns	8
149-063-14DACD1	212-217	9/11/96	6	12	ns	0	0	0	ns
149-063-14DACD2	151-156	09/01/87	4	ns	ns	0	0	0	ns
149-063-14DACD2	151-156	10/23/91	4	21	0	0	0	0	29
149-063-14DACD2	151-156	9/11/96	4	20	ns	0	0	0	ns
149-063-14DACD3	38-43	09/01/87	8	ns	ns	0	0	0	ns
149-063-14DACD3	38-43	10/23/91	8	86	0	0	0	0	12
149-063-14DACD3	38-43	9/10/96	6	91	ns	0	0	2	ns
149-063-23ADBB1	218-223	09/01/87	3	ns	ns	0	0	0	ns
149-063-23ADBB1	218-223	10/23/91	3	170	0.1	0	0	0	5
149-063-23ADBB1	218-223	9/11/96	3	120	ns	0	0	0	ns
149-063-23ADBB2	32-37	09/01/87	2	ns	ns	0.1	1	1	ns
149-063-23ADBB2	32-37	10/23/91	2	170	0	0.1	1	1	7
149-063-23ADBB2	32-37	9/10/96	0	180	ns	0	0	0	ns
149-063-23ADBB3	7-12	09/01/87	1	ns	ns	0.1		2	ns
149-063-23ADBB3	7-12	10/23/91	1	50	0	0.1	1	3	6
149-063-23ADBB3	7-12	9/10/96	0	160	ns	0	0	1	ns
149-063-25DBBC1	263-268	09/01/87	1	ns	ns	0.2	0	0	ns
149-063-25DBBC1	263-268	10/24/91	2	26	0	0.1	1	0	14
149-063-25DBBC1	263-268	9/11/96	4	24	ns	0	0	0	ns
149-063-25DBBC2	78-83	09/02/87	13	ns	ns	0	0	0	ns
149-063-25DBBC2	78-83	10/24/91	19	38	0.4	0.1	0	0	11
149-063-25DBBC2	78-83	9/11/96	25	35	ns	0	0	0	ns
149-063-25DBBC3	51-56	09/02/87	6	ns	ns	0.3	0	0	ns
149-063-25DBBC3	51-56	10/24/91	3	85	0	0.1	0	0	9
149-063-25DBBC3	51-56	9/10/96	3	120	ns	0	0	0	ns

Table 5 (continued). Barium (Ba), and trace element [arsenic (As), cadmium (Cd), mercury (Hg), lead (Pb), selenium (Se), and Zinc (Zn)] concentrations for water samples taken from WS-1 wells (Comesky 1989).

Location	Screened Interval (ft)	Date Sampled	(micrograms per liter)						
			As	Ba	Cd	Hg	Pb	Se	Zn
149-063-25DBBC4	23-28	09/02/87	8	ns	ns	0	0	0	ns
149-063-25DBBC4	23-28	10/24/91	2	150	0	0.1	0	0	6
149-063-25DBBC4	23-28	9/10/96	3	190	ns	0	0	0	ns
149-063-26DCA	38-43	09/01/87	15	ns	ns	0.1	0	0	ns
149-063-26DCA	38-43	10/24/91	13	51	0	0.1	0	0	14
149-063-26DCA	38-43	9/12/96	19	38	ns	0.1	0	0	ns
149-063-27DDDC2	158-163	09/01/87	7	ns	ns	0.1	0	2	ns
149-063-27DDDC2	158-163	11/19/91	1	30	0.4	0	0	1	43
149-063-27DDDC2	158-163	9/11/96	1	16	ns	0	0	0	ns
149-063-34BBB1	251-256	09/01/87	2	ns	ns	0	0	0	ns
149-063-34BBB1	251-256	11/19/91	4	60	0.8	0	0	1	24
149-063-34BBB1	251-256	9/12/96	3	36	ns	0.1	0	0	ns
149-063-34BBB2	27-32	09/01/87	1	ns	ns	0	0	0	ns
149-063-34BBB2	27-32	10/24/91	1	39	0.1	0.1	0	2	5
149-063-34BBB2	27-32	9/12/96	1	33	ns	0	0	1	ns
149-063-35ABBD2	45-50	09/01/87	22	ns	ns	0	0	0	ns
149-063-35ABBD2	45-50	10/24/91	16	47	0.1	0.1	0	0	9
149-063-35ABBD2	45-50	9/10/96	20	44	ns	0	0	0	ns
149-063-36AACB2	181-186	09/02/87	1	ns	ns	0	0	1	ns
149-063-36AACB2	181-186	10/22/91	1	62	0	0	0	0	7
149-063-36AACB2	181-186	9/11/96	0	77	ns	0	0	0	ns
149-063-36AACB3	64-69	09/02/87	13	ns	ns	0.1	0	1	ns
149-063-36AACB3	64-69	10/22/91	11	210	0	0	0	0	13
149-063-36AACB3	64-69	9/11/96	8	260	ns	0	0	0	ns
149-063-36AACB4	24-29	09/02/87		ns	ns	0	0	1	ns
149-063-36AACB4	24-29	10/22/91	0	77	0.1	0	0	0	18
149-063-36AACB4	24-29	9/10/96	0	90	ns	0	0	0	ns
149-063-36BBDA2	22-27	09/01/87	20	ns	ns	0	0	0	ns
149-063-36BBDA2	22-27	10/24/91	12	62	0.1	0.1	0	0	9
149-063-36BBDA2	22-27	9/11/96	22	46	ns	0	0	0	ns
149-063-36DDBC1	131-136	09/02/87	1	ns	ns	0.2	0	0	ns
149-063-36DDBC1	131-136	10/22/91	2	62	0	0	0	0	5
149-063-36DDBC1	131-136	9/11/96	1	48	ns	0	0	0	ns
149-063-36DDBC2	83-88	09/02/87	1	ns	ns	0	0	0	ns
149-063-36DDBC2	83-88	10/22/91	1	66	0	0	0	0	6
149-063-36DDBC2	83-88	10/22/91	1	60	ns	0	0	0	ns
149-063-36DDBC3	46-51	09/02/87	11	ns	ns	0	0	0	ns
149-063-36DDBC3	46-51	10/22/91	9	100	0	0	0	0	12
149-063-36DDBC3	46-51	9/10/96	5	110	ns	0	0	0	ns

Table 6. Barium (Ba), and trace elements [arsenic (As), cadmium (Cd), mercury (Hg), lead (Pb), selenium (Se), and Zinc (Zn)] concentrations for WS-2 wells (Schuh 1994).

Site	Location	Screened Interval (ft)	Date Sampled	(micrograms per liter)						
				As	Ba	Cd	Hg	Pb	Se	Zn
1	149-062-28CCC1	139-144	10/21/92	4	ns	0	0	0	0	ns
1	149-062-28CCC1	139-144	09/05/96	4	13	ns	0	0	0	ns
1	149-062-28CCC2	56-61	10/21/92	52	ns	0	0	0	0	ns
1	149-062-28CCC2	56-61	09/04/96	47	53	ns	0	0	0	ns
2	149-062-29DAD	50-55	10/21/92	25	ns	0	0	0	0	ns
2	149-062-29DAD	50-55	09/04/96	26	97	ns	0	0	0	ns
3	148-063-02DA	0-0	09/11/86	1	ns	ns	0.1	1	1	ns
3	148-063-02DA	0-0	10/22/92	2	ns	0	0	0	0	ns
3	148-063-02DA	0-0	09/04/96	1	82	ns	0	0	0	ns
4	148-062-31C	0-0	10/22/92	2	ns	0	0	0	0	ns
4	148-062-31C	0-0	09/04/96	4	93	ns	0	0	0	ns
5	149-063-36ACA1	41-48	10/22/92	26	ns	0	0	0	0	ns
5	149-063-36ACA1	41-48	09/03/96	20	130	ns	0	0	0	ns
5	149-063-36ACA2	21-27	10/22/92	13	ns	0	0	0	0	ns
5	149-063-36ACA2	21-27	09/03/96	11	270	ns	0	0	0	ns
6	149-063-25CDC1	110-115	10/22/92	4	ns	0	0	0	0	ns
6	149-063-25CDC1	110-115	09/05/96	6	100	ns	0	0	0	ns
6	149-063-25CDC2	25-30	10/22/92	7	ns	0	0	0	0	ns
6	149-063-25CDC2	25-30	09/05/96	1	29	ns	0	0	0	ns
7	148-063-02ACA1	97-102	10/22/92	2	ns	0	0	0	0	ns
7	148-063-02ACA1	97-102	09/03/96	0	150	ns	0	0	0	ns
7	148-063-02ACA2	18-23	10/22/92	2	ns	0	0	0	0	ns
7	148-063-02ACA2	18-23	09/03/96	1	170	ns	0	0	0	ns
8	149-062-19DBD1	95-100	08/25/93	51	ns	0	0	0	0	ns
8	149-062-19DBD3	43-48	08/25/93	6	ns	0	0	0	0	ns
9	149-063-13DAA1	95-100	08/25/93	10	ns	0	0	0	0	ns
9	149-063-13DAA2	30-35	08/25/93	2	ns	0	0	0	0	ns
10	149-063-12CAC1	105-110	08/25/93	14	ns	0	0	0	0	ns
10	149-063-12CAC2	45-50	08/25/93	5	ns	0	0	0	0	ns

Table 6 (continued). Barium (Ba), and trace elements [arsenic (As), cadmium (Cd), mercury (Hg), lead (Pb), selenium (Se), and Zinc (Zn)] concentrations for WS-2 wells (Schuh 1994).

Site	Location	Screened Interval (ft)	Date Sampled	(micrograms per liter)						
				As	Ba	Cd	Hg	Pb	Se	Zn
11	149-063-14DBB	0-0	08/24/93	71	ns	0	0	0	0	ns
12	148-063-02BABC1	69-74	08/26/93	1	ns	0	0	0	0	ns
12	148-063-02BABC2	12-17	08/26/93	2	ns	0	0	1	0	ns
13	149-063-35BCBA1	23-28	08/24/93	2	ns	0	0	0	0	ns
13	149-063-35BCBA2	23-28	08/24/93	10	ns	0	0	0	0	ns
14	149-063-26ADD	0-0	08/24/93	10	ns	0	0	0	0	ns
15	149-063-27DDB	0-0	08/24/93	24	ns	0	0.1	1	0	ns
16	149-063-13BDA	0-0	9/11/86	2	ns	ns	0.1	1	0	ns
16	149-063-13BDA	0-0	8/25/93	2	ns	0	0	0	0	ns
16	149-063-13BDA	0-0	9/5/96	3	91	ns	0	0	0	ns
17	148-063-04ABA1	25-30	08/26/93	20	ns	0	0	0	0	ns
17	148-063-04ABA2	25-30	08/26/93	4	ns	0	0	0	0	ns
Sites 18 and 19*		-	-	-	-	-	-	-	-	-
20	149-063-14AAB	17-22	08/25/93	3	ns	0	0	0	0	ns

mercury, lead, or selenium levels of toxicological concern, or of rising trends in concentrations. Most were non detections.

Nitrate

Nitrate is one contaminant of potential concern. Nitrate has an EPA-MCL of 10 mg/L nitrate as N, or 44 mg/L nitrate. Possible nitrate sources are fertilizers and manure from cattle. A certain amount of nitrate can result from atmospheric fixation and from mineralization of soil organic matter. Small amounts of nitrate might be locally derived from ammonium nitrate and barium nitrate used in explosives. Moderate amounts of nitrate would be expected to be immobilized almost entirely within the grass vegetation on the CGS lands.

In general, nitrate concentrations in samples were low. The highest nitrate concentration measured since 1987 was 7.6 mg/L. However, the median nitrate concentration for all three sample years in the WS-1 wells (1987, 1992, and 1993) was close to 1 mg/L. Nitrate concentrations appeared to increase slightly in 1992, and then decreased by 1996 for most wells. Nitrate concentrations were variable, but there were a larger number of wells having higher nitrate concentrations at wells screened at less than 100 feet (Fig. 8). This indicates a likely surface source. Occasional nitrate concentrations above 1 - 3 mg/L may originate in manure from cattle pastured on the Reserve. However, detections at this level are below levels of toxicological concern, and appear to be ephemeral in nearly all cases. Nitrate concentrations measured in WS-2 wells are similar to those measured in the WS-1 wells. There is no evidence of ground-water contamination with nitrate occurring at levels of toxicological or environmental concern on the Camp Grafton Reserve under current uses and practices.

In surface-water samples, including South Washington Lake and Lake Coe, nitrate concentrations were low (Table 4). However, large amounts of manure were mixed with soil at the edge of South Washington Lake, and large amounts of algae were visible in the water. While dissolved oxygen was not measured, the biological oxidation demand on these lakes might be substantial.

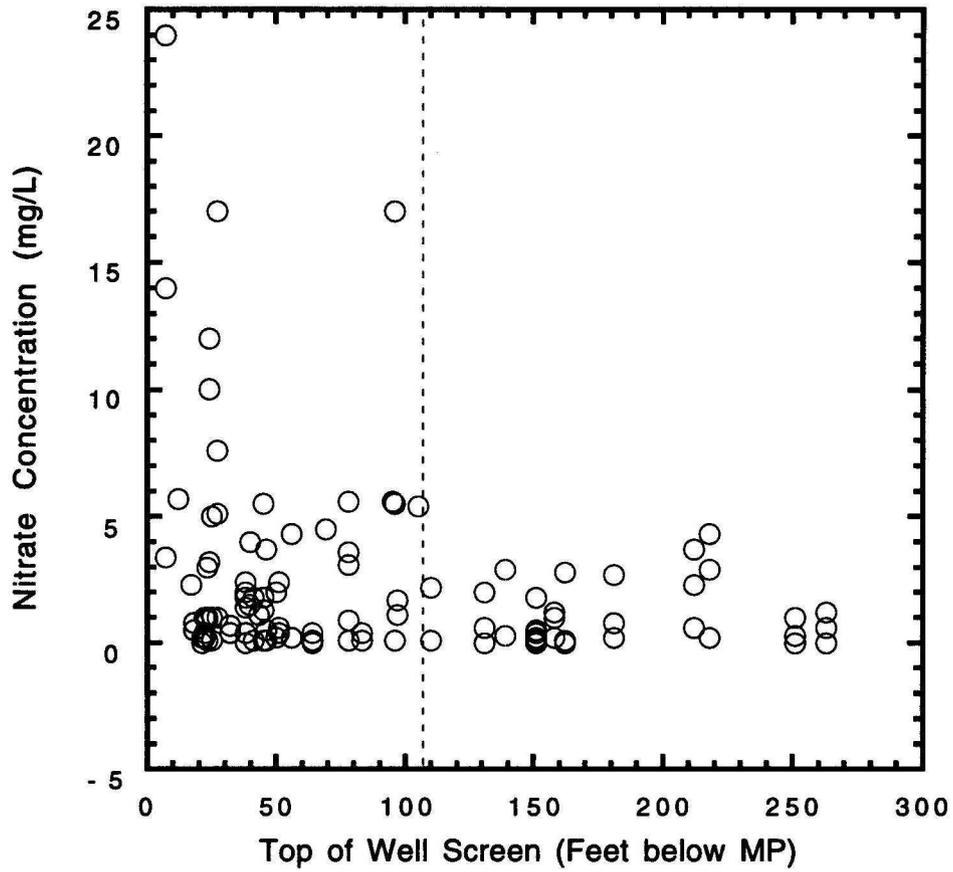


Figure 8. Nitrate concentration versus the depth of the well screen for WS-1 wells (Comesky 1989). Depth is measured from the measuring point, which is surveyed at the top of the well.

Arsenic

One trace element of concern in the Cherry Lake aquifer is arsenic. Arsenic is found in concentrations that approach and sometimes exceed EPA-MCL (50 µg/L) for drinking water in some of the wells, and in all of the lake samples tested. Arsenic concentrations in ground-water samples are highly variable, ranging from non detects to about 70 µg/L. Arsenic concentrations for WS-1 are shown on Table 5. Arsenic concentrations for selected WS-2 wells sampled in 1992, and later selected WS-2 wells are on Table 6. A probability distribution for both sets of data is shown on Figure 9. For both data sets, median values are similar (4.5 µg/L for WS-1, 5.5 for WS-2). There is a wide variation in arsenic concentrations, as indicated by a coefficient of variation (CV) of 120% on WS-1, and 130% on WS-2). There is a slight, but significant positive (P = 0.01) correlation between arsenic and sulfate concentrations. There also seems to be a relationship between variability of arsenic concentration and depth. The spread of data from WS-1 wells on Figure 9 indicates that the distribution of arsenic concentrations is uniform to a depth of about 160 feet. For wells deeper than 160 feet, concentrations appear to be more tightly grouped between 1 and 10 µg/L. This apparent change, however, may be a result of fewer wells and sample sets at the greater depths.

There are no indications of temporal change in arsenic concentration in any of the wells or lakes over ten years of sampling. Arsenic concentrations are natural, and have not been caused by CGS facility use. Large concentrations in lakes and in some wells have likely been caused by evaporative concentration. While high arsenic concentrations have not been caused by use, there are some uses the CGS facility that may be affected by arsenic. Two of these are (1) the water supply used for CGS; and (2) the operation of reverse osmosis (RO) equipment for training purposes using waters from Lake Coe, or South Washington Lake.

In 1988 two 5-inch diameter supply wells were drilled at a site just south of HWY 15 (149-63-35A). Well-screens were placed at depths of 26 to 34 feet, and 28 to 36 feet. Measured pumping capacities were 51 and 55 gpm. About 200 feet west of the supply wells (at 149-63-35ABBD2) a sample well (WS-1 set) was placed with screen at about 45 to 50 feet. Arsenic concentrations in this well varied from 16 to 22 mg/L (one third to half of the EPA-MCL). While these concentrations were below levels of

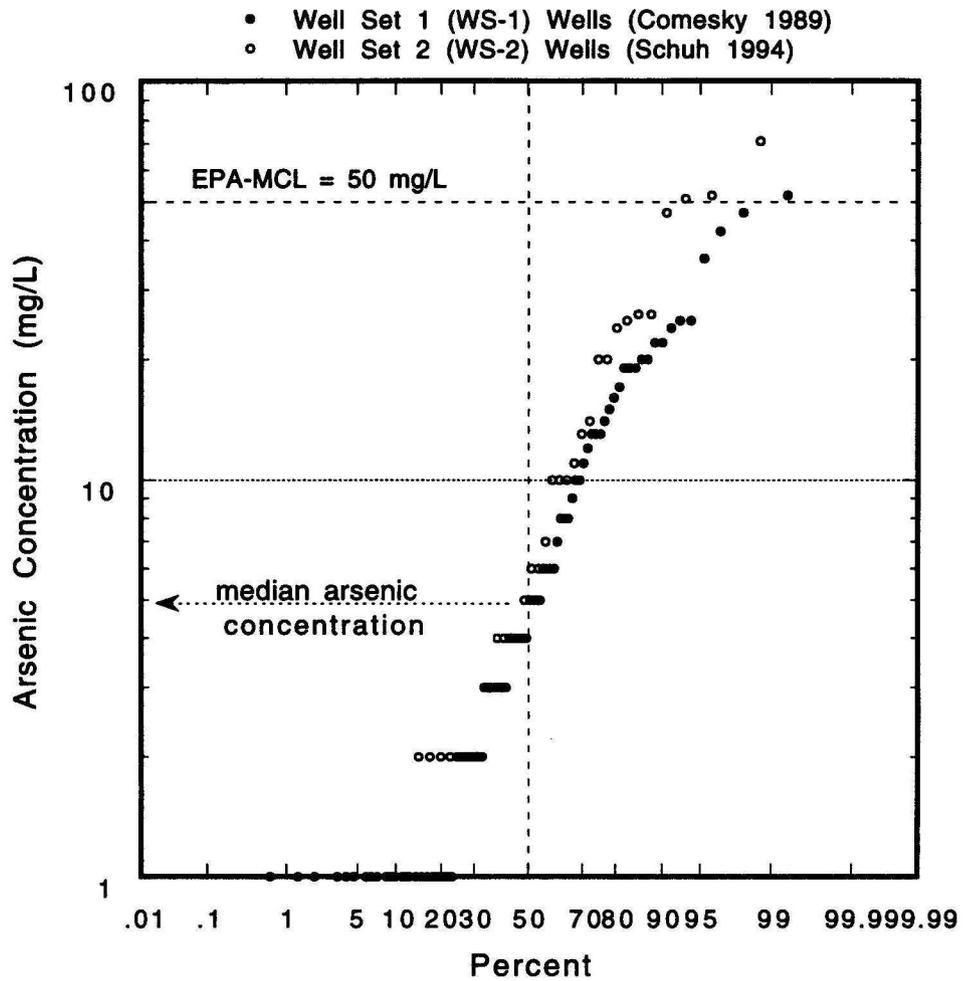


Figure 9. Probability distribution of arsenic concentrations measured in WS-1 and WS-2 wells in all samplings since 1987.

toxicological regulation, uses resulting in concentration of salts, such as evaporation or reverse osmosis application, could cause concentration of arsenic to levels above EPA regulatory standards.

Other well sites having high arsenic concentrations are shown on Tables 5 and 6. One well having a particularly high arsenic concentration is located at 149-62-31ABBC2, which is located just south of HWY 15, west of the M60 range, with a screened interval from 162 to 167 feet. Other SW-2 wells having high arsenic concentrations are shown on Table 6. The deep well (Site 1, 149-062-28CCC2) located about one-half mile east of the previously described (149-062-31ABBC2) well having high arsenic concentration has a similar high arsenic concentration, varying between 47 and 52 $\mu\text{g/L}$. This exceeds EPA MCL. A few hundred feet north of Site 1, the well placed at Site 2 (149-062-29DAD) also had a high arsenic concentration. Data on Tables 5 and 6 indicate that arsenic concentrations were high in the sections bordering the south side of HWY 15. These include T149N R63W Sections 35 and 36 and T 149N R63W Sections 29, 31, and 32. The area having potentially high arsenic concentrations would include the M60 range, the equipment storage site located in T149N-R63W Section 36, and the main well site T149N-R63W Section 35. Water supplies on each of these sites should be periodically tested for arsenic.

Two sample sites having large arsenic concentrations are Lake Coe, and South Washington Lake. The arsenic concentration in South Washington Lake is close to the EPA-MCL, while Lake Coe arsenic is about half of the EPA-MCL. Some caution is warranted in using these water sources for drinking water supplies. Care is also warranted in use of waters from these lakes for training using reverse osmosis equipment. A potential problem may be incurred in disposing of the filtrate from the osmosis. Filtrate waters removing arsenic would substantially concentrate arsenic. For example, some reverse osmosis systems might concentrate all of the arsenic in 20 percent of the water (a concentration factor of about 5). With a concentration factor of 5, water from Lake Coe would leave a filtrate having an arsenic concentration of about 125 $\mu\text{g/L}$, more than double the EPA-MCL. Water from South Washington Lake would leave a filtrate having a concentration of about 250 $\mu\text{g/L}$, or five times the EPA-MCL. Such filtrate waters should be disposed of with care. Release directly back into the lake would likely not cause a serious problem, particularly if the filtered water were replaced with it after training. Disposal of filtrate at any given soil site may cause local ground-water contamination. Handling procedures for RO filtrate from waters of Lake Coe and South Washington Lake should be considered by CGS administrators.

Munitions and Explosives

Almost all activities using live ammunition and explosives at CGS are concentrated in the plateau area of the eastern component McHenry End Moraine located on Sections 31 and 32 (T149N, R62W) and in the lowland of Section 36 (T149N, R63W). Facilities located within these bounds include a demolition range, a recoilless rifle range, a modified record fire range, an M-203 range, and an M-60 machine gun range as shown on Figure 5.

(1) The demolitions range is located on the south half of T149N R63W Section 36. Surface-water and ground-water draining from this area would flow northwestward to the Lake Coe and South Washington Lake basins, and from there toward the Sheyenne River. Wells sampled and tested for munitions and explosives from the demolitions range would include the nest placed at Site 5, a few hundred feet northwest of the demolitions range, and the nest placed at Site 6, in a wetland southeast of Lake Coe (Table 2, Figure 5).

(2) The M203 range is located in the northeast quarter of T148N R63W, Section 2. The M203 range has been constructed, but was not yet in use in 1996. Both ground-water and surface runoff from this area would flow westward to the wetland in the center of T148N R63W Section 2, and from there northward through the Lake Coe and South Washington Lake basins toward the Sheyenne river. Ground water from the M203 range may also discharge from the spring (148-063-02DA) located in the southeast quarter of T148N R63W Section 2.

Wells sampled and tested for munitions and explosives from the M203 range would include the nest placed at Site 7, located near the wetlands, just north of the road between the M203 range and the abandoned Pinkerton farm, and in a coulee that has extended westward from the area of the M203 range (Fig. 5); and the well nests at Sites 5 and 6 described above for the demolitions range, which lie with the general northward ground-water flow path from the M203 range. In addition, the spring located at T148N R63W Section 2 (Fig. 5) was also sampled and tested for residues from munitions and explosives, and for nitrate and lead.

(3) The western half of T149N R62W, Section 32 is occupied by several training sites, including an M60/.50 caliber machine gun training site, a pistol range, an M-16 zero range, and a modified record fire range. All of these facilities were in use in 1996. There is also a planned KD (known distance) range which is not yet in use. These training

facilities are located on a ridge that comprises a divide between the Colvin Creek drainage basin, and the Lake Coe and South Washington Lake drainage basin (Fig. 3). Depending on time, conditions, and specific location of contaminant use, both surface-water and ground-water flow could carry contaminants in either direction. A reservoir located in the southwest quarter of T149N R62W Section 31 collects water from the training area, and would be expected to trap contaminants.

Wells sampled for munitions and explosives from the training facilities in western T149N R62W Section 32 include nests of wells placed in Sites 5 and 6 on the side of the Lake Coe and South Washington Lake drainage. These are the same as described for the demolitions range in (1) above. In addition, a water sample was taken from the reservoir in southwest T149 R62 Section 31. On the eastern side of the training complex, surface-water and ground-water flow toward the Colvin Creek drainage basin is tested by sampling a well nest placed at Site 1 (149-062-28CCC1&1), and a single well placed at Site 2 (149-062-29DAD).

In 1992 water samples for residues of munitions and explosives were taken only from the shallow wells of each well nest. Because large increases in piezometric pressures in deeper wells in 1993 indicated a likely connection between deeper units of the Cherry Lake aquifer and recharge in the CGS uplands, deeper wells were also sampled on each of the sites in the fall of 1996. The only exception is Site 2, where there was only a single well.

Analyses for eight explosive compounds in samples taken in 1992, and fourteen in samples taken in 1996 were discussed in the Methods section above. Results are shown on Table 7. There were no detections of organic residues from explosives in any of the wells, springs, or surface water-bodies sampled in either year .

In addition to organic residues from explosives, elevated lead might indicate contamination from projectiles and from compounds like lead styphonate. In addition, high nitrate concentrations might serve as indicators of contamination from ammonium nitrate and barium nitrate. Of the six sites sampled for organic residues from explosives, including the reservoir and the spring, all had low nitrates (a fraction of a part per million), and nitrate concentrations in all wells had decreased since 1992 (Table 4). On the same six sites, there were no detections of lead in ground water (at 1 $\mu\text{g/L}$) except one detection in the reservoir in 1986 (Table 5), which was before construction of the M60 range.

Aside from samples taken from the six sites specifically designated to test for residues from munitions and explosives, additional information can be obtained from several of the WS-1 wells placed by Comesky (1989) for piezometric measurements and sampling for basic water quality. Five of the WS-1 well nests (12013, 12014, 12015, 12023, and

Table 7. Concentrations of munitions and explosives residues in WS-2 wells (Schuh 1994) designated for monitoring effects of demolitions and firing ranges.

Location	Well Number	Site No.	Date m/y	2-Amino-4-6-DNT µg/l	4-Amino-2,6-DNT µg/l	1,3-Dinitrobenzene µg/l	2,4-DNT µg/l	2,6-DNT µg/l	HMX µg/l	Nitrobenzene µg/l	2-Nitrotoluene µg/l	3-Nitrotoluene µg/l	4-Nitrotoluene µg/l	RDX µg/l	TETRYL µg/l	1,3,5-Trinitrobenzene µg/l	2,4,6-TNT µg/l
14906228CCC1	13103	1	9/96	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
14906228CCC2	13104	1	10/92 9/96	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
14906229DAD	13105	2	10/92 9/96	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
14806302DA	Spring	3	10/92 9/96	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
14906231C	Reservoir	4	10/92 9/96	ND	ND	ND	ND	ND	<5.33*	ND	ND	ND	ND	<4.16*	ND	<2.10*	ND
14906336ACA1	13097	5	9/96	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
14906336ACA2	13098	5	10/92 9/96	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
14906325CDC1	13102	6	10/92 9/96	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
14906325CDC2	13103	6	10/92 9/96	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1490602ACA1	13086	7	10/92 9/96	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
14806302ACA2	13087	7	10/92 9/96	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Det. Limit		10/92			0.458	0.397		0.533	0.682				0.416	0.631	0.210	0.426
	Det. Limit		9/96	0.058	0.11	0.088	0.11	0.17	0.072	0.19	0.21	0.30	0.20	0.23	0.25	0.066	0.21

* < sign indicates that higher detection limits were caused by laboratory interferences.

12024, located as shown on Figure 4), are located within the area of the demolitions and firing ranges. Nitrate concentrations of samples from all of these wells were at a fraction of a part per million, and had been trending downward since earlier samples in 1986 and 1993. The only exception was the shallow well at site 12024 (12024B, 148-063-01CBBC2) which had been increasing since 1986, and had a nitrate concentration of 12 mg/L. Nitrate concentrations from these wells are shown on Table 3. 12 mg/L is still below the EPA MCL for nitrate of 45 mg/L. Lead concentrations from each of these sites was also non detectable at (1 mg/L), and showed no increasing trend from 1987, through 1991 and 1996. The only well having a detection of lead at 1 mg/L was 12015B (149-063-31ABBC2) in 1996. Lead concentrations from these wells are shown on Table 6.

Water samples taken in the fall of 1996 from one spring, one reservoir, and seventeen wells with screens placed in strata representing all identified subunits of the Cherry Lake aquifer, at 9 sites within the drainage area of CGS lands used for training involving munitions and explosives show no indications of nitrate or lead contamination resulting from training activities. Many of the wells and surface-water sites were previously sampled in 1992 or 1993. Some were also sampled in 1987. The only apparent trend is that of decreasing nitrate concentrations in many of the wells. These data, along with non detections for explosives, show no indication of contamination of the Cherry Lake aquifer from training activities on the CGS facility involving munitions and explosives, as of the fall of 1996.

Pesticides

The two primary pesticide uses at CGS are leafy-spurge control, which uses a mixture of 2,4-D and picloram, and mosquito control in bivouac areas, for which either malathion or chlorpyrifos (Lorsban) are most frequently used.

Herbicide Contamination

The locations of spray applications vary. Leafy spurge is scattered throughout the CGS land, and spray strategies are used in conjunction with experiments testing other non chemical control measures, including grazing by goats and insects that feed on leafy spurge. Both ground and aerial application are used for herbicide application. Because of the windy conditions spray drift is a likely hazard using aerial application. Some common areas of herbicide application north of HWY 15 are in T149N R63W Sections 12, 14, and 15 on the northern border of the facility, and T149N R63W Section 30, particularly in the vicinity of a brushy draw called "Buck Hollow" in the northwest quarter section. South of HWY 15

one area of common application is the uplands east of North Twin Lake, including T149N R63W Section 35, and T148N R63W Sections 4 and 5.

After construction of wells for sampling organic chemicals, an initial pesticide screening was conducted in 1993 for 32 pesticides, including picloram, 2,4-D, malathion, and chlorpyrifos. Water samples from the Colvin Creek drainage basin (east of CGS) were taken from shallow wells on Sites 2 (east of the CGS facility), 8 (east of Buck Hollow), 9 (south of the Engineering Training Site), 10 (near the northern boundary of the camp, and 16 (a spring located northwest of the Engineering Training Site). Locations are given on Figure 4, Table 1, and Table 2). Water entering the South Washington Lake and Lake Coe drainage basin was sampled from shallow wells at Sites 12, 13, and 17, located east, north, and west of the southeastern moraine subunit, south of HWY 15; from the shallow well located at Site 6 located between the eastern and central moraine subunits south of HWY 15; from sample Sites 14 and 15 on Lake Coe; and from Site 11 on South Washington Lake. Locations are given on Figure 4, Table 1, and Table 2.

Results of 1993 herbicide tests are shown on Table 8. There were no detections of any of the herbicides tested, including picloram and 2,4-D, in any of the wells sampled or in the spring located at site 16. There were, however, trace concentrations of picloram in both South Washington Lake and Lake Coe. Because detections were only in the lakes, it most likely that picloram entered the lakes from runoff, or from direct spray drift. Contamination of the lakes through the ground-water system is very unlikely.

Because of the initial picloram detections, South Washington Lake and Lake Coe were sampled annually in the summers of 1994 and 1995, and again in the fall 1996. Results for all herbicide analysis following 1993 are on Table 9. Picloram concentrations remained at about a constant level throughout the four-year period over which samples were taken. It thus appears that under current weed management practices, surface waters on the CGS facility can be expected to maintain a background concentration of picloram at a fraction of a $\mu\text{g/L}$. These concentrations are not of toxicological concern. EPA-MCL for picloram is about 500 $\mu\text{g/L}$, or 2,500 to 5,000 times measured concentrations. Fish and wildlife susceptibility to picloram is also relatively low.

All sites sampled in 1993, with the exception of site 6 southeast of Lake Coe, and site 2 in the Colvin Creek basin were sampled again were in 1996. Following initial non detections for all herbicides other than picloram in 1993, well samples in 1996 were only tested for picloram. Because of piezometric evidence indicating that deeper units of the Cherry Lake aquifer were connected with surface recharge from the upland areas, deep wells were also sampled on each of the well sites. Results are shown on Table 8. Picloram was not

detected in any of the samples. From 1993 through 1996, there was no evidence of ground-water contamination with picloram at any of the sampled depths, under conditions caused by current weed-control practices on the CGS facility.

Water samples taken from 1993 through 1996 indicate that there is no evidence of herbicide contamination at any of the ground-water or spring sample locations. South Washington Lake and Lake Coe exhibited a consistent background presence of picloram at a fraction of a part per billion concentration throughout the sample period. All detections were below levels of current EPA regulatory concern.

Insecticide Contamination

Water samples from all of the wells sampled for herbicides were also screened for insecticides in 1993. The primary use for insecticides is mosquito control in bivouac areas. For this reason, sites sampled for insecticides are selected as indicators of potential contamination occurring near bivouac sites. Sample locations and results are shown on Table 3 and Figure 4. There were no detections of chlorpyrifos or malathion in any of the initial samples. There was one detection of dimethoate on Site 6 (Table 8). It is likely that the fall 1993 detection was caused either by residue in the spray tank of an aerial sprayer that had been spraying picloram about 2 miles northeast (and upwind) of site 6 at the time of well construction. Site 6 was resampled for dimethoate in June of 1994. Results indicated no detection. Wells selected to sample for insecticides in 1996 are shown on Table 2. Well Sites 13 and 17 south of HWY 15 were not sampled in 1996 because most bivouac areas south of HWY 15 are located within the safety fan of the M60 range, and use frequency has decreased. In 1996 all water samples were analyzed only for chlorpyrifos. Results (Table 9) indicated no detections of chlorpyrifos. Of insecticides commonly used for mosquito control near bivouac areas, none were detected in any of the water samples taken from surface-water, spring, or sample well sites from 1993 through 1996.

Total Petroleum Hydrocarbons (TPH)

One potential cause of ground-water contamination is spill or leakage of petroleum hydrocarbon compounds from vehicles at bivouac or training sites. During training, vehicles used in transport and supply are frequently staged at bivouac sites. If on-site filling is attempted, or if vehicles are damaged, gasoline, diesel fuel, lubricating oil, or hydraulic fluids could spill onto the topsoil, and eventually leach to ground water. Water samples were analyzed for TPH as gasoline, which is a test for petroleum hydrocarbons in the gasoline fraction; and TPH as fuel oil, which is a test for petroleum hydrocarbons in the

Table 8. Pesticide concentrations for initial (base-line) water samples taken in 1993 from WS-2 wells (Schuh 1994) in areas selected for monitoring herbicide and insecticide use. ND is a non detect at the specified Lab MDL.

SWC Well Number	13085	13090	13093	13094	13095	13096	13100	13102	13105	13106	SW Lake	Lake Coe	Lake Coe	Spring	Field Blank	Field Blank	Lab MDL
Sample Date	8/26/93	8/25/93	8/25/93	8/25/93	8/26/93	8/26/93	8/24/93	10/28/92 8/26/93*	10/28/92 8/26/93*	8/25/93	8/26/93	8/24/93	8/24/93	8/25/93	8/25/93	10/28/92	
Site Number	12	9	10	20	17-1	17-2	13	6	2	8	11	14	15	16			
Analyte	µg/	µg/	µg/	µg/	µg/	µg/	µg/	µg/	µg/	µg/							
alachlor	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.5							
atrazine	ND	ND	ND	ND	ND	ND	ND	ND	ND	1							
butylate	ND	ND	ND	ND	ND	ND	ND	ND	ND	1							
chloramben	ND	ND	ND	ND	ND	ND	ND	ND	NA	0.1							
chlorpyrifos	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.5							
cyanazine	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.5							
diallate	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.5							
dicamba	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.1							
dimethoate	ND	0.8	ND	ND	ND	ND	ND	ND	ND	ND	0.5						
EPTC	ND	ND	ND	ND	ND	ND	ND	ND	ND	1							
ethalfuralin	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.5							
fonofos	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.5							
linuron	ND	ND	ND	ND	ND	ND	ND	ND	ND	1							
malathion	ND	ND	ND	ND	ND	ND	ND	ND	ND	1							
metho	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.5							
parathion	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.5							
metolachlor	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.5							
metribuzin	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.5							
pendimethalin	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.5							
picloram	ND	ND	ND	0.4	0.2	0.2	ND	ND	NA	0.1							
phorate	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.5							
propachlor	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.5							
prometon	ND	ND	ND	ND	ND	ND	ND	ND	ND	1							
propazine	ND	ND	ND	ND	ND	ND	ND	ND	ND	1							
simazine	ND	ND	ND	ND	ND	ND	ND	ND	ND	1							
terbufos	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.5							
triallate	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.5							
triclopyr	ND	ND	ND	ND	ND	ND	ND	ND	NA	0.1							
trifluralin	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.5							
2,4-D	ND	ND	ND	ND	ND	ND	ND	ND	NA	0.5							
2,4-DB	ND	ND	ND	ND	ND	ND	ND	ND	NA	0.5							
2,4,5-T	ND	ND	ND	ND	ND	ND	ND	ND	NA	0.1							
2,4,5-TP	ND	ND	ND	ND	ND	ND	ND	ND	NA	0.1							

Table 9. Pesticide concentrations for water samples taken from WS-2 wells since 1993, in areas selected for monitoring herbicide and insecticide use, from Lake Coe, and from South Washington Lake. NS means no sample taken. ND is a non detect at the specified Lab MDL.

Analyte	Well Number	* 13088	* 13089	* 13090	* 13092	* 13093	* 13095	* 13096	* 13099	* 13100	13102	13106	SW Lake	Lake Coe	Lake Coe	Spring	Lab MDL
	Well Location	149-063-13DAA1	149-063-13DAA2	149-062-19DBD1	149-063-12CAC1	149-063-12CAC2	149-063-04ABA1	149-063-04ABA2	149-163-35BCBA1	149-163-35BCBA2	149-063-25CDC2	149-062-19DBD3	149-063-14CAC	149-063-26ADD	149-063-27ddb	149-063-13DBA	149-063-13DBA
	Site Number	9	9	8	10	10	17	17	13	13	6	8	11	14	15	16	16
Analyte	Date	Analyte Concentration in [µg/]															
chlorpyrifos	8-26-93	ns	ns	ND	ns	ND	ND	ND	ns	ND	ND	ND	ND	ND	ND	ND	0.5
	9-4-96	ns	ns	ND	ns	ns	ns	ns	ns	ns	ns	ns	ND	ND	ND	ND	0.5
	9-10-96	ND	ND	ns	ND	ND	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
dimethoate	8-26-93	ns	ns	ND	ns	ND	ND	ND	ns	ND	0.8	ND	ND	ND	ND	ND	<0.5
	6-23-94	ns	ns	ns	ns	ns	ns	ns	ns	ns	< 0.5	ns	ns	ns	ns	ns	ns
picloram	8-26-93	ns	ns	ND	ns	ND	ND	ND	ns	ND	ND	ND	0.4	0.2	0.2	ND	0.1
	6-23-94	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	0.2	0.2	0.2	ns	ns
	7-12-95	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	0.3	ns	0.1	ns	ns
	9-4-96	ns	ns	ND	ns	ns	ns	ns	ns	ns	ns	ns	ND	0.1	0.2	0.2	ND
	9-10-96	ND	ND	ns	ND	ND	ND	ND	ND	ND	ns	ns	ns	ns	ns	ns	ns

fuel oil fraction, and includes diesel fuel. These were treated as an index of site contamination from petroleum products.

In 1993 only shallow wells were sampled. During 1993 rising piezometric pressure in the lower confined units of the Cherry Lake aquifer indicated that recharge in the uplands of CGS did effect, and was connected to the deeper units of the aquifer. For this reason, some of the deep wells were also sampled in 1996. Results of all sampling are shown on Table 9.

Petroleum contamination from the Engineering Training Site, located in the north half of T149N R63W Section 30 was tested by sampling two wells at 149-063-13DAA (Site 9 on Figure 4, and Table 2). The shallowest well (149-063-13DAA2) was sampled in 1993 and 1996. The deeper well (149-063-13DAA1) was sampled in 1996 only. Results are shown on Table 9. Tests for TPH as gasoline and fuel oil indicated no detections for any of the samples. There is no evidence of petroleum contamination from the Engineering Training Site.

Commonly used bivouac sites in 1993 included the south shore of Lake Coe, the area southeast of South Washington Lake, the northern extremity of CGS in T149N R63W Section 12, the western extremity of the Reserve near an area commonly called "Buck Hollow" in T148N R63W Section 19, and the area of T149N R63W Section 35 south of HWY 15. Sample sites for TPH determination were selected for each of these areas.

In 1993 one sample was taken from the south portion of Lake Coe (Sample Site 14 ,Table 2; 149-063-26ADD). In 1996 two samples were taken. The additional sample was taken at Site 15 (149-063-27DDB). Locations of sample sites are shown on Figure 4. Results are on Table 9. There were no detections of TPH as gasoline or fuel oil in any of the samples.

One sample was taken from South Washington Lake in 1993 at 149-063-14CAC, and again in 1996 at the same location. WS-2 Site identification numbers are on Table 2. Locations of sample sites, are shown on Figure 4. Results of TPH tests are on Table 9. There were no detections of TPH as gasoline or fuel oil in any of the samples.

On the northern boundary of the Reserve, a water sample was taken from shallow well 149-063-12CAC2 in 1993. In 1996, water samples were taken from both the shallow well and from a deeper well at 149-063-12CAC1. WS-2 Site identification number (Site 10) and well-screen depths are on Table 2. Locations of sample sites, are shown on Figure 4. Results of TPH tests are on Table 9. There were no detections of TPH as gasoline or fuel oil in any of the water samples taken on Site 10.

On the western extremity of CGS, a water sample was taken from shallow well 149-062-19DBD3 in 1993. In 1996, water samples were taken from both the shallow well and from a deeper well at 149-062-19DBD1. WS-2 Site identification number (Site 8) and well-screen depths are on Table 2. Locations of sample sites, are shown on Figure 4. Results of TPH tests are on Table 9. There were no detections of TPH as gasoline or fuel oil in any of the water samples taken on Site 8.

In 1993 Water samples were taken to test for potential petroleum contamination south of HWY 15 from shallow wells 148-063-02BABC1 (WS-2 Site 12, north of the abandoned Pinkerton farm, Table 2 and Figure 4) and 149-063-35BCBA2 (WS-2 Site 13, on the border of a wetland south of HWY 15). Well-screen depths are on Table 2. Locations of sample sites, are shown on Figure 4. No TPH as gasoline or fuel oil were detected in 1993. After construction of the M60 machine-gun range in 1995 much of the area south of HWY 15 fell within the safety fan of the firing range. Bivouac south of HWY 15 is now limited. Wells 148-063-02BABC1 and 149-063-35BCBA2 were not sampled in 1996.

In summary, in five lake samples taken in 1993 and 1996, five shallow well water samples taken in 1993, three shallow well samples taken in 1996, and three deep well samples taken in 1996, there have been no detections of petroleum hydrocarbons as gasoline or fuel oil. **There is no evidence of ground-water or surface-water contamination from vehicle leakage on Camp Grafton (South Unit).**

Table 10. Concentrations of Total Petroleum Hydrocarbons (TPH) as gasoline and fuel oil (including diesel fuel) for WS-2 wells (Schuh 1994) used to monitor effects of vehicle use and staging areas. SW Lake* is South Washington Lake.

SWC Well Number	Sample Date	13084	13090	13106	13088	13089	13092	13093	13100	SW Lake*	Lake Coe	Lake Coe	Field DW blank	lab MDL
Sample Site Location		148-063-02BABC2	149-062-19DBD1	149-062-19DBD3	149-063-13DAA1	149-063-13DAA2	149-063-12CAC1	149-063-12CAC2	149-063-35BCBA2	149-063-14CAC	149-063-26ADD	149-063-27DDB		
WS-2 Well-Site Number (Table 2)		12	8	8	9	9	10	10	13	11	14	15	-	
TPH (gas) mg/l	Fall 1993	ND	-	ND	-	ND	-	ND	ND	ND	ND		ND	0.5
	Fall 1996	-	ND	ND	ND	ND	ND	ND	-	ND	ND	ND	-	0.1
TPH (fuel oil) mg/l	Fall 1993	ND	-	ND	-	ND	-	ND	ND	ND	ND		ND	1.0
	Fall 1996	-	ND	ND	ND	ND	ND	ND	-	ND	ND	ND	-	0.4

SUMMARY

Comesky (1989) identified three layers or subunits of the Cherry Lake aquifer underlying CGS. He observed that there was some question as to whether these units were connected. Piezometric evidence at some sites near North Twin Lake and Lake Coe indicates that the upper and lower units of the aquifer are locally unconnected. On these sites the shallow aquifer units reflect the levels of the nearby lakes, while the deeper units appear to respond piezometrically to recharge events in the uplands, and flow under artesian pressure following large recharge events. This means that while the deeper units may be locally unconnected with shallower aquifer units, they are, in some cases, connected to surface aquifer units in the uplands.

Water chemistry of the Cherry Lake aquifer underlying CGS varies from low TDS, less than 200 mg/L, to as high as 5,000 mg/L. Predominant dissolved salts vary from calcium bicarbonate, to predominantly sodium sulfatic water. In some cases, chloride concentrations are high (up to 1000 mg/L). Generally, shallow water is fresher and has less dissolved solids, sodium, and sulfate. Deeper buried aquifer subunits have higher dissolved solids, sodium, and sulfate.

Nitrate concentrations are below levels of toxicological concern, having a median value of about 1 mg/L, and a maximum value of 7 mg/L. EPA-MCL is 44 mg/L. Nitrate concentrations are highly variable, but most of the higher nitrate concentrations are in shallower wells, indicating likely influx from the surface. Since no fertilizers are applied on CGS land, the source of nitrate for wells having higher concentrations is likely manure from cattle grazed on CGS lands. Concentrations are low, however. There is no trend in data indicating that nitrate levels are increasing since 1987. Nitrate concentrations in 1996 appeared to be generally lower than those taken in the period from 1991 through 1993. Nitrate concentrations in surface waters, including South Washington Lake and Lake Coe, are low. However, some portions of the borders of these lakes have substantial amounts of manure mixed with soil, and the lakes themselves (particularly South Washington Lake) have large algae blooms, indicating likely influx and biological assimilation of nitrogen.

Trace elements, including barium, lead, selenium, and mercury were not detected in significant quantities in 1996 or in previous sampling in 1986 and 1991-1993. In previous sampling (1991-1993) cadmium and zinc were also not detected in significant quantities. There is no evidence of contamination from heavy metals.

Arsenic is present in ground water and surface water at levels of toxicological concern. Ground water samples for arsenic vary from non detects to as high as 70 µg/L.

EPA-MCL is 50 µg/L. Variability of arsenic concentration is large. Concentrations tend to be more variable (and higher) in water taken from wells with screens at less than 160 feet. In general, arsenic concentrations tend to be high south of HWY 15, and east of CGS. Arsenic concentrations are moderately high near the current water-supply wells for CGS, and may be high in the vicinity of the M60 range on the eastern part of the facility. A list of areas having relatively high arsenic is discussed in the text. Surface waters, which often serve as evaporative concentration sinks for arsenic, are also moderately high to high in arsenic. South Washington Lake is near, or above EPA-MCL for arsenic. There are no temporal trends indicating an increase or decrease in arsenic concentrations. High arsenic is natural, and is not caused by human activities. However, some caution may be warranted for water uses which result in concentration of salts, such as boiling or water purification through reverse osmosis units. Remaining concentrated arsenic in boiled water, or concentrated arsenic in the filtrate from reverse osmosis, could cause a problem if improperly used or improperly disposed of.

There is no evidence of the contamination from petroleum hydrocarbons as gasoline or fuel oil (including diesel fuel) in any of the ground water or surface water samples taken. This is consistent with previous samples taken in 1993. There is no evidence of pesticide presence in any of the ground water or spring samples. This includes a broad pesticide screening in 1992, and samples taken for chlorpyrifos and picloram in 1996. There is evidence of consistent presence of picloram at low concentrations in Lake Coe and South Washington Lake. Concentrations (about 0.1 µg/L) are 1/5000 of the EPA-MCL. Picloram is also known to have a low order of toxicity to wildlife and fish. Picloram concentrations thus appear to be of little environmental concern.

There is no evidence of the presence of contaminants in ground water, or in a surface-water reservoir near the M-60 Range, that might originate from use of munitions and explosives. This includes analysis for fourteen organic explosive compounds, nitrate, and lead. Previous water samples taken in 1992-1993 also indicated no detectable concentrations of organic explosive compounds, nitrate, or lead that might originate from use in weapons and demolitions training on the CGS facility.

RECOMMENDATIONS

1. Picloram concentrations have been demonstrated to be consistent in Lake Coe and South Washington Lake. It is recommended that repeat pesticide sampling for picloram in the lakes occur every other year instead of every year.
2. Water chemistry in supply wells located south of HWY 15 at (T149 R63 Section 35A) should be sampled for water chemistry and for trace elements. It is suggested that an annual sample for arsenic be taken from the supply wells. If supply wells are located on the M60 training site, or other nearby firing ranges, they should also be sampled for arsenic.
3. During water purification training using reverse osmosis, filtrate should be analyzed for arsenic concentration. If filtrate has high arsenic, care should be taken in disposal. Sufficient filtered water to dilute the filtrate should be returned to the original source to offset the concentrated arsenic. Appropriate procedures for disposal of high arsenic filtrate should be established.
4. The use of the well-house area (T149N R63W Section 35A) as a staging area for storage of herbicide and for mixing pesticides should be reviewed for well-protection safety. Overflow from filling tanks may contaminate wells. Also, it is suggested that pesticides be stored away from the well site.
5. CGS use should be reviewed and sampled again for water quality in 2001.
6. Many of the barbed wire enclosures protecting the wells are badly damaged, and will not effectively protect the wells from breakage in the future. Barbed wire at all well sites should be inspected and repaired as soon as possible.
7. The PVC protective cover for WS-2 well 13103 (Site 1, 149-062-28CCC1) should be extended three or four inches.
8. The elevations of the measuring points (tops) of all wells should be surveyed.

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