MBMG 455

Ground-Water Evaluation
Florence, Montana

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Introduction

Location

Florence, Montana, is located on the western side of the Bitterroot valley in Ravalli County (figure 1). Situated about 30 miles north of Hamilton, the county seat, and 20 miles south of Missoula, the community within the original Florence town site (T. 16 N., R. 20 W., parts of sections 11 and 14) has a population of approximately 250 residents (Sass, 1998), served by about 150 wells. Many residents are retired, and many more commute to Missoula for work.

The project area extends beyond the original town site and includes T. 10 N., R. 20 W, sections 2, 3, 10, 11, 14, and 15. Approximately 400 wells are included in the ground-water data base established for the project. Based on a ratio of 1.7 residents per well for the town site, the population within the project area is estimated to be 670.

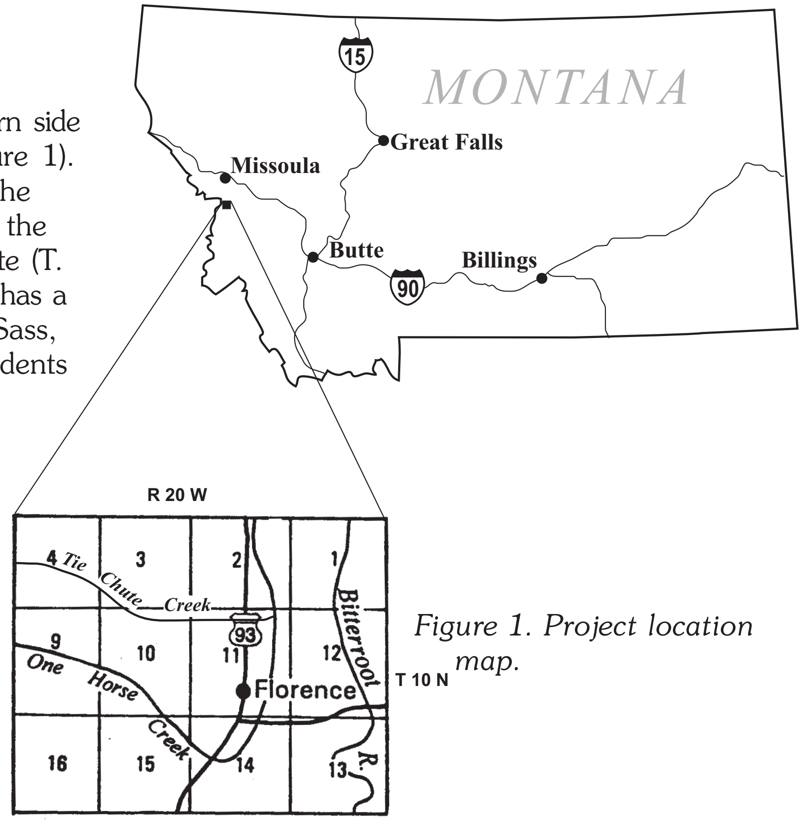

Figure 1. Project location map.

Physiography and Climate

Florence (elevation 3,280 feet) is located at the base of the Bitterroot Mountains on a terrace 20–40 feet above the valley floor. Natural vegetation consists of evergreens, grasses, and shrubs. The project area is drained by Tie Chute and One Horse creeks, tributaries to the Bitterroot River.

Climatic data for Stevensville, Montana, about 10 miles south of Florence, are summarized in table 1. Mean annual precipitation at Stevensville is approximately 12.5 in., about 40 percent of which occurs as snowfall during the winter months.

Reasons for Evaluation

Rapid population growth in the Florence area and the associated proliferation of individual wells and septic tanks has raised concerns about ground-water supply and quality. Sediment underlying Florence is a potential conduit for contaminant migration to ground and surface water. Florence does not have a community water-supply or sewage-treatment system. Many residents are concerned that ground water supplying individual wells may become contaminated by septic tank effluent and that additional ground-water pumping may deplete the available supply.

Data accessed from the Montana Bureau of Mines and Geology (MBMG) Ground-Water Information Center (GWIC) data base (1998) indicate that there were approximately 62 wells in the Florence area in 1970. Approximately 172 wells were drilled during the 1970s, 135 wells during the 1980s, and an estimated 200 wells in the 1990s; septic system installations follow a similar trend (figure 2). Ground-water conditions were evaluated to determine current aquifer status and its vulnerability to increasing numbers of septic systems, with future development.

Table 1. Period of record monthly climate summary–Stevensville, Montana (247894).

Period of Record: 8/23/1911 to 4/30/1998

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average max. temp. (°F)	33	40	49	59	68	75	85	83	72	59	43	34	58.3
Average min. temp. (°F)	15	19	25	31	37	44	47	45	38	31	23	17	30.9
Average total precipitation (in.)	1.1	0.9	0.8	0.8	1.5	1.6	0.9	0.9	1.1	0.9	1.1	1.1	12.5
Average total snowfall (in.)	12	9.9	6.8	1.6	0.5	0	0	0	0	1	6.6	11	48.8
Average snow depth (in.)	3	2	1	0	0	0	0	0	0	0	1	2	1

McCurdy, G.D., 1998, Western Regional Climate Center, http://www.wrcc.dri.edu/.

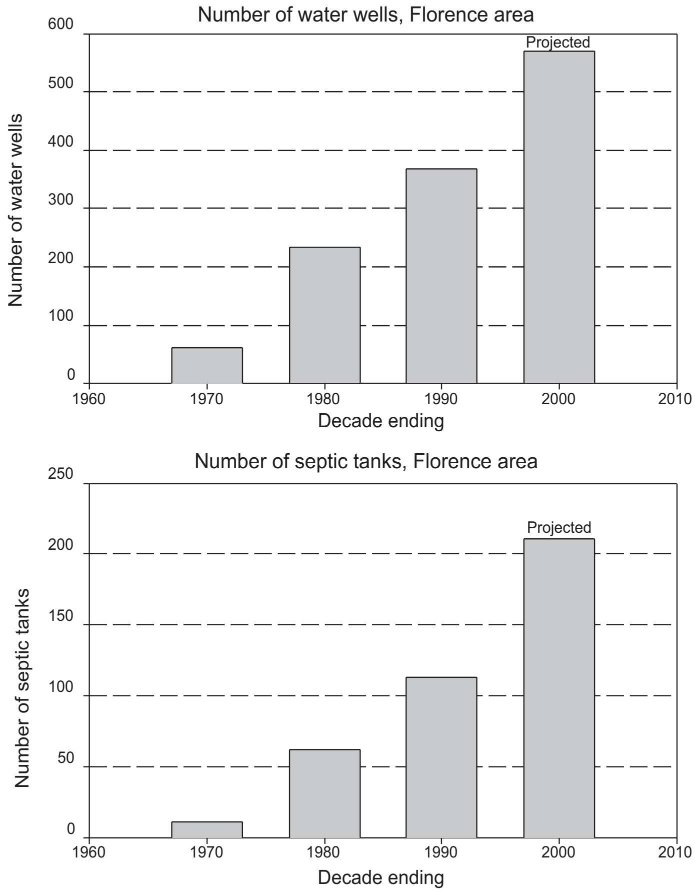

Figure 2. New wells and septic systems, Florence.

Data Review and Investigation Methods

Existing geological and hydrological reports of the Florence area were reviewed for information pertinent to this study. Ground- and surface-water data (location, source, and water quality, levels, and lithology) in the GWIC data base (1998) were accessed and are included, with a description of field methods, in a supplemental report: MBMG 397 (Norbeck and McDonald, 2000).

Surface-Water Resources

Surface-water resources near Florence include the Bitterroot River, approximately one mile east of town, and two tributaries: Tie Chute and One Horse creeks, which flow eastward out of the Bitterroot Mountains north and south of town, respectively. Both creeks are perennial, and portions of their flow are diverted for irrigation west of town. In addition to irrigation, surface-water resources near Florence are utilized for recreation, primarily fishing.

Discharge rates for the Bitterroot River at Florence were monitored during the last quarter of 1966 and are presented in figure 3, along with data collected at Missoula between 1989 and 1997 (U.S. Geological Survey [USGS], 1999). Analytical data for a sample collected in 1955 from the Bitterroot River at Florence (table 2) indicates that the water was dominated by calcium and bicarbonate (table 2, figure 4).

Water in Tie Chute and One Horse creeks is dominated by calcium and bicarbonate ions (figure 4, plate 1). Total dissolved solids (TDS) concentrations range from 35 to 65 mg/L, with an arithmetic mean of 44.1 mg/L. Total dissolved solids in Tie Chute Creek increase downstream from 35 to 37 mg/L (figure 5) as discharge decreases from 1.0 to 0.2 cfs. In One Horse Creek, TDS decrease in the downstream direction (figure 6) as discharge increases from 0.5 to 5.3 cfs and then decreases to 0.3 cfs. At the farthest downstream site, water was almost stagnant and exhibited a brown color. Increasing TDS in the downstream direction is typical for most Montana streams. The reason for the TDS decrease downstream in One Horse Creek water samples is unknown. Neither nitrate nor phosphate were detected in samples from either creek.

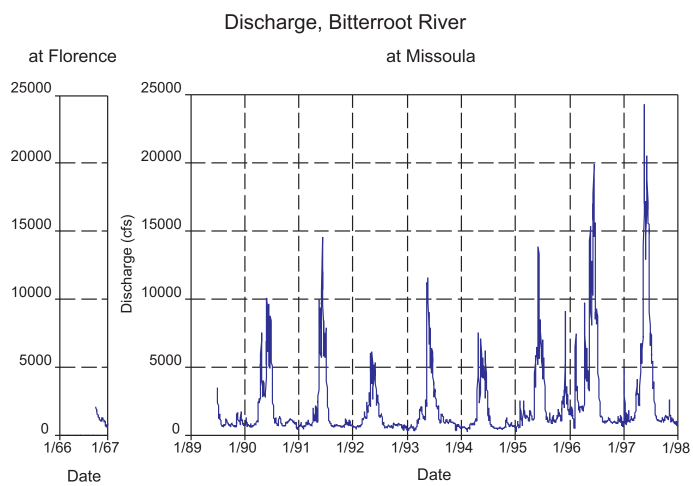

Figure 3. Surface-water flow for the Bitterroot River at Florence and Missoula.

Table 2. Water-quality data, Bitterroot River at Florence 10/12/1955.

Total dissolved solids, mg/L	95	Hardness as $CaCO_3$	65
Specific conductance, micromhos/cm	154	Sodium adsorption ratio	0.4
pH	7.4	Temperature, °C	11
Calcium (Ca), mg/L	20	Bicarbonate (HCO_3) mg/L	89
Magnesium (Mg), mg/L	3.7	Carbonate (CO_3), mg/L	0
Sodium (Na), mg/L	6.6	Chloride (Cl), mg/L	1.5
Potassium (K), mg/L	2.0	Sulfate (SO_4), mg/L	2.1
Iron (Fe), mg/L	0	Nitrate (NO_3), mg/L	0.4
Silica (SiO_2), mg/L	15	Fluoride (F), mg/L	0.1
Boron (B), mg/L	0.04		

McMurtrey and others, 1972

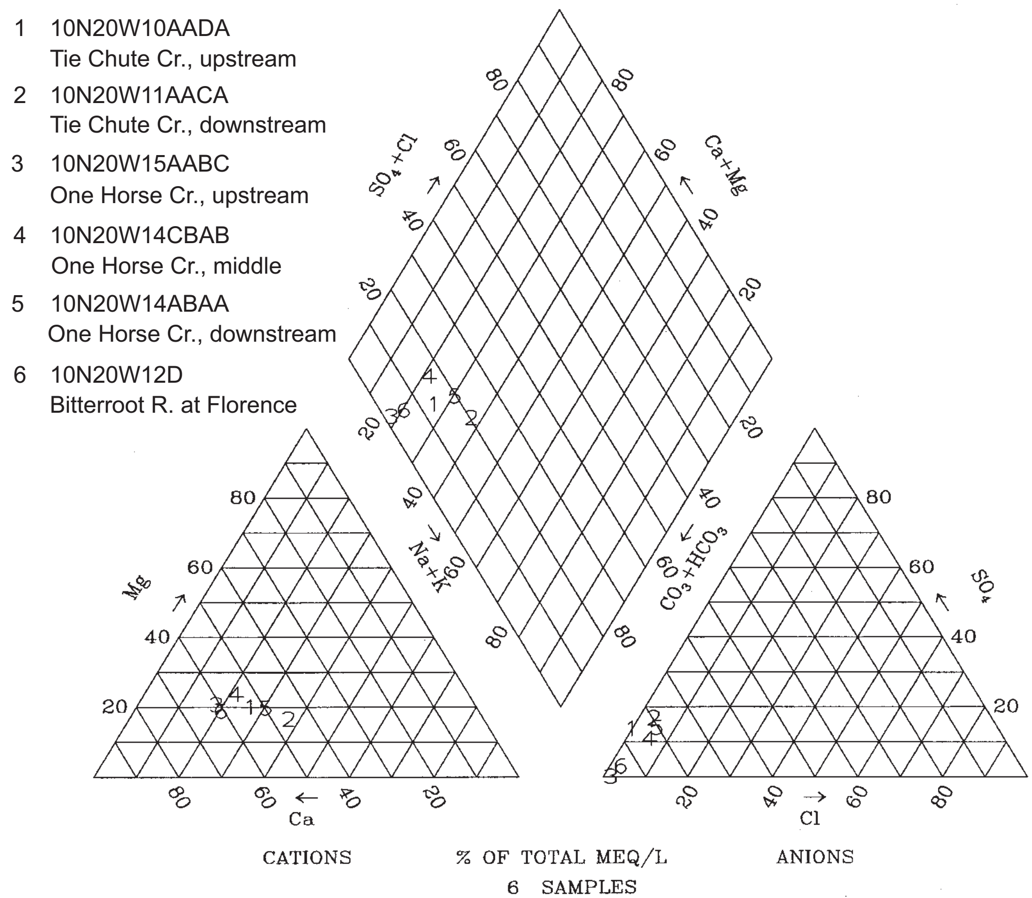

Figure 4. Ionic percentages in surface-water samples.

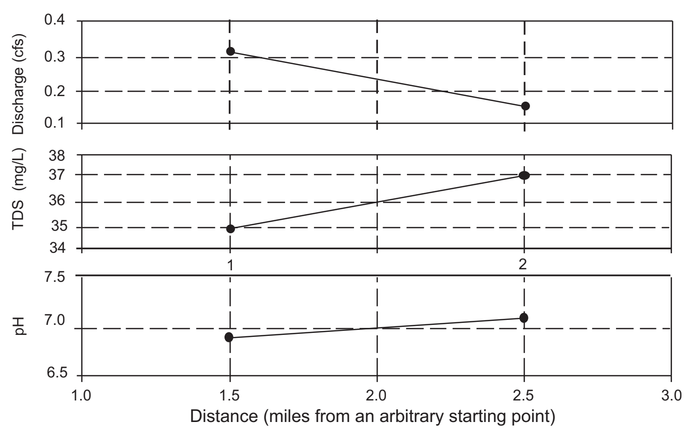

Figure 5. Tie Chute Creek discharge, TDS, and pH versus distance downstream (sample numbers refer to figure 4).

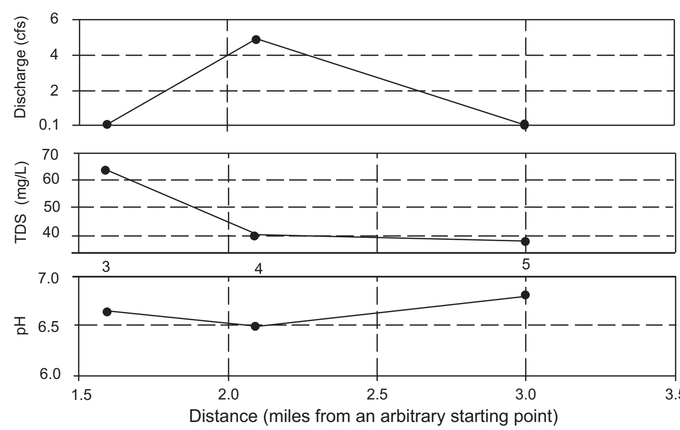

Figure 6. One Horse Creek discharge, TDS, and pH versus distance downstream (sample numbers refer to figure 4).

Hydrogeology

Geology

The geology of the Florence study area (figures 7, 8) is characterized by thick deposits of Tertiary and Quaternary valley fill overlying Middle Proterozoic to Eocene bedrock. Several investigators have described the geology in this area, including Ross (1952), McMurtry and others (1972), Noble and others (1982), and Lonn and Sears (1997). The work of Lonn and Sears (1997) provides the most comprehensive description of the surficial geology surrounding the study area and is the basis for the following summary.

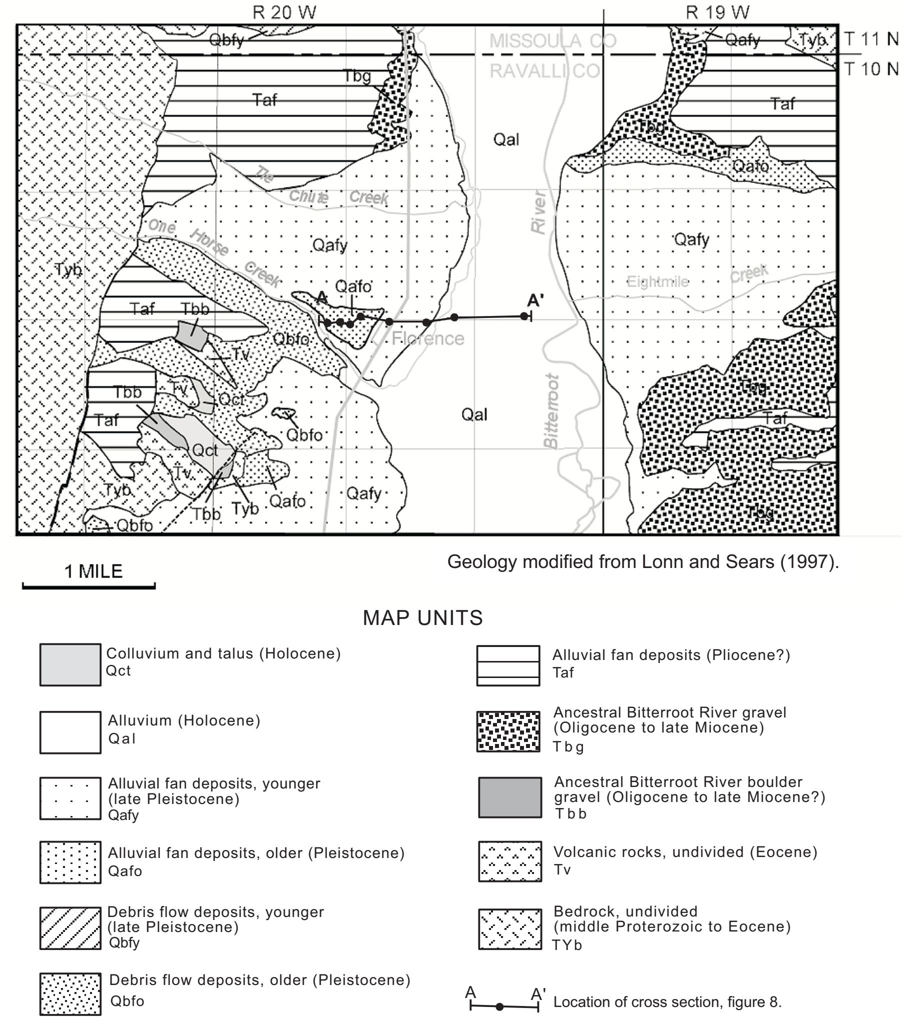

Figure 7. Florence area geologic map.

Bedrock is exposed at higher elevations in the mountains that border the Bitterroot valley. The Sapphire Mountains to the east are underlain by Proterozoic sedimentary rock of the Belt Supergroup and, to a lesser extent, Cretaceous intrusive and associated metamorphic rock. The Bitterroot Mountains to the west are underlain predominately by Cretaceous intrusive rock and associated metamorphosed, Proterozoic sedimentary rock. Early Tertiary volcanic rock occurs locally along the edge of the mountains (McMurtrey and others, 1972).

Unconsolidated to partially consolidated Tertiary deposits overlie bedrock throughout the valley and are best exposed on the broad terraces that flank the Bitterroot River. In the Florence area, these deposits are differentiated into those derived from the ancestral Bitterroot River and those formed as alluvial fans (Lonn and Sears, 1997). The ancestral Bitterroot River deposits (Oligocene to Late Miocene) consist of well-sorted, well-rounded, well-stratified sand, pebbles, and cobbles, with interbedded, light-tan clay and silt. A boulder-dominated facies is present southwest of Florence and forms flat surfaces that overly bedrock at higher elevations. The alluvial fan deposits (Pleistocene?) form gently sloping terraces, perched 200 feet above the valley floor. These deposits consist of poorly sorted, moderately stratified boulders and cobbles in a sandy silt matrix, with abundant interbedded, massive, micaceous silt layers. The Tertiary alluvial-fan deposits generally occur as interfluvial remnants separated by younger Quaternary fan and outwash-terrace deposits.

Quaternary deposits mantle Tertiary sediment in most of the study area (figure 8); they include fan and outwash-terrace deposits, flood-plain alluvium, older boulder fans, and minor colluvium. The fan and outwash-terrace deposits lie 5–25 feet above the valley floor and consist of well-rounded, unweathered cobbles and boulders in a matrix of sand and gravel. These deposits average 40 feet thick and are differentiated into older (Pleistocene) and younger (Late Pleistocene) units (Lonn and Sears, 1997). The younger fans lie between and below the dissected remnants of older fans and underlie much of the study area, including the town of Florence. Older (Pleistocene) boulder fans, deposited by debris flows, are present southwest of Florence and consist of huge angular boulders up to 10 feet across in a poorly sorted matrix of gravel, sand, and silt. Minor Holocene colluvium and talus are present on the steeper slopes and consist of unconsolidated, unsorted, locally derived accumulations of angular boulders, cobbles, pebbles, sand, and silt.

East of Florence, the valley floor is underlain by approximately 40 feet of Quaternary (Holocene) alluvial and flood-plain deposits. These deposits consist of well-rounded, well-sorted gravel and sand, with minor silt and clay. Clast lithologies represent rock types of the entire drainage basin and were derived from reworked Tertiary and Pleistocene deposits. The Quaternary alluvium overlies approximately 2,000 feet of Tertiary valley fill (Noble and others, 1982).

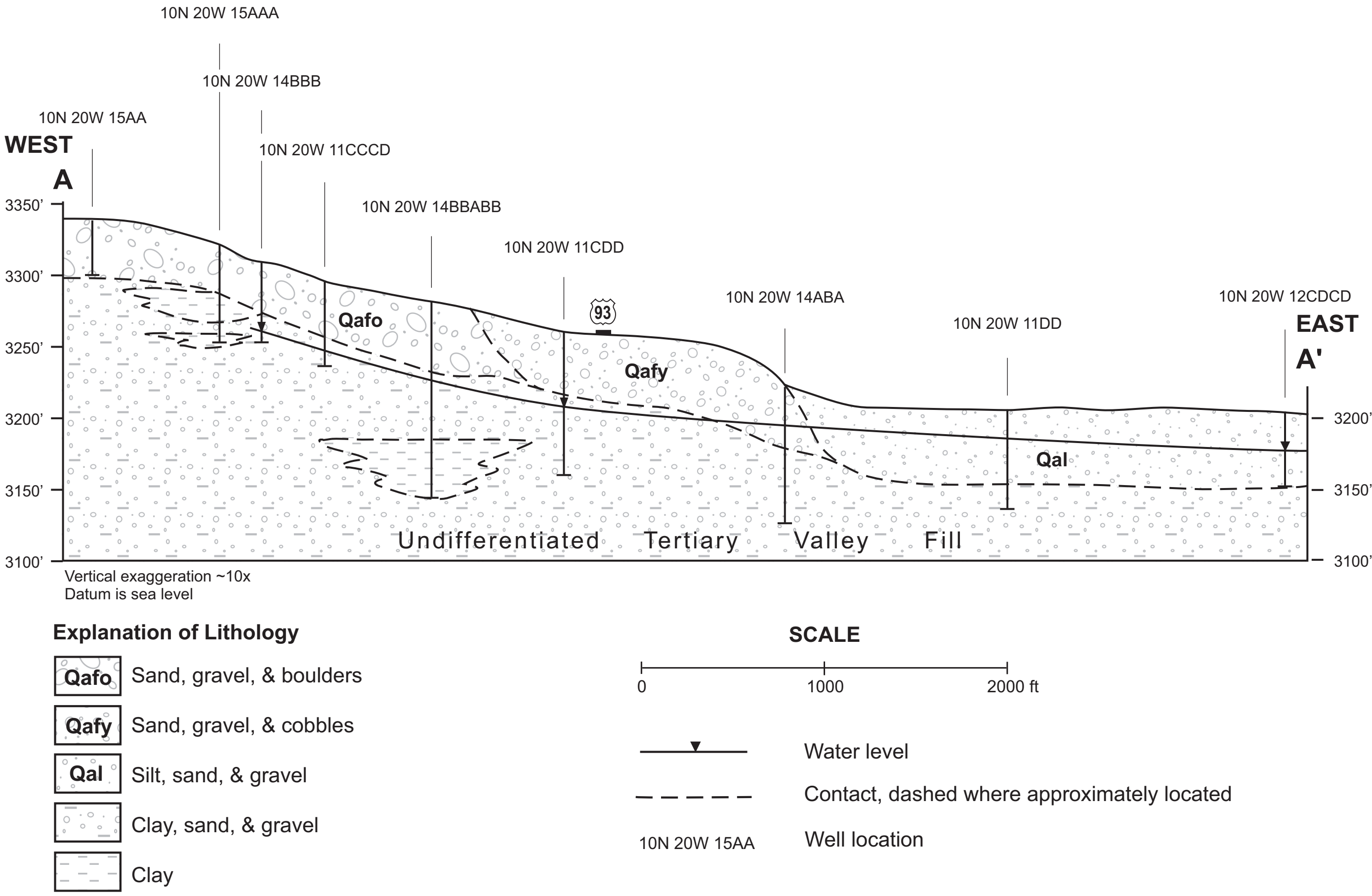

Figure 8. Generalized geologic cross section of Florence area; trace and map units shown on figure 7.

Ground-Water Flow

Drillers' logs include numerous water-discharge and water-level drawdown reports that are difficult to evaluate because of the various techniques used. For this evaluation, short-duration, single-well pumping tests, conducted during site visits, were used to estimate aquifer properties for the wells in table 3 using Jacob and Theis techniques. Transmissivity and hydraulic-conductivity values are measures of the ease with which ground water will flow. The values found for the Florence area (table 3) are consistent with those occurring in unconsolidated sediment throughout Montana. Commonly in such aquifers, the shallowest beds are the most conductive and transmissive. For the Florence area, there are weak trends of decreasing conductivity and transmissivity with depth (figure 9), which is consistent with conditions in other areas.

Ground water near Florence is recharged by infiltration from streams, ditches, and applied irrigation water as well as direct precipitation infiltration. Ground water discharges to wells, springs, streams, and to the atmosphere via evaporation from free water bodies fed by ground water and plant transpiration.

Ground-water flow patterns (plate 2), based on measured well-water levels and perennial stream elevations, are generally from west to east toward the Bitterroot River. Plate 2 suggests that recharge occurs in topographically high areas, with discharge occurring to streams, wetlands, and the Bitterroot River flood plain. Precise areas or locales of ground-water discharge to streams are difficult to determine because of complex subsurface conditions.

Stream gain or loss measurements (table 4) gave various results. Seepage measurements (plate 1, table 4) indicate that One Horse Creek lost water to ground water (recharge) at 10N20W15AABCB, gained from ground water at 10N20W14CBABB, and lost at 10N20W14ABAAA. At 10N20W14CBABB, where the creek was gaining, the stream flow was highest, and at 10N20W14ABAAA where the creek was losing, the stream flow was lowest. Tie Chute Creek was in equilibrium with ground water at 10N20W11BBCBC and was gaining at 10N20W11AAABC. The stream flow decrease may be partly caused by irrigation diversions between the two measurement sites.

Ground-Water Use

Most wells draw water from unconsolidated sedimentary deposits. A few wells on the western edge of the project area penetrate igneous and metamorphic bedrock. Yields for wells in and near Florence range from a measured pumping rate of one gallon per minute (gpm) to a reported 200 gpm, with an arithmetic mean of 23.4 gpm. Well depths range from 9 to 580 feet, with a mean of 73 feet, and depth-to-water ranges from above ground (flowing) to 150 feet below surface, with a mean depth of 30 feet. At most locations within the project area, water-bearing sand and gravel deposits are found at relatively shallow depths (less than 100 feet).

Ground water near Florence is used mostly for domestic supplies, including lawn and garden sprinkling, stock water, and limited irrigation. Usage by category (based on the number of wells in each category as determined from GWIC data as of August 1998) for the study area is tabulated below:

Use	*Percent*
Domestic	82.8
Unknown or Unused	9.8
Irrigation	2.4
Stock Water	0.9
Public Supply	1.7
Other	2.4

Ground-Water Quality

Table 5 summarizes water quality for the Florence area and gives minimum, median, and maximum values for parameters and constituents along with applicable drinking-water standards.

Ground water near Florence is dominated by calcium and bicarbonate ions (figure 10, plate 1), although some samples have almost as much sodium as calcium. Total dissolved solids (calculated) range from 23 to 544 mg/L, with a median value of 71 mg/L. A sample collected during drilling from well 10N20W11CDCD is a calcium-chloride water, but later samples are calcium-bicarbonate water. The initial sample may have been affected by drilling additives. A 270-feet-deep well completed in granite (10N20W15ACBB) produced sodium-bicarbonate water, with the highest concentrations seen during this study of fluoride, arsenic, boron, and bromide ions. The source of these ions may be the granitic bedrock; no other possible source could be found.

Trace element concentrations are low, typically below detection. Fluoride ranges from below detection in most samples to a high of 7.12 mg/L in well 10N20W15ACBB, with a median value of <0.05 mg/L.

With the exception of barium, copper, and zinc, metals concentrations were usually below detection. Barium

Table 3. Aquifer test data.

Well	Test Date	Pump Test Duration (minutes)	Pumping Rate (gpm)	Trans-missivity (T) (ft^2/day)	Storativity (S)	Hydraulic Conductivity (K) (ft/day)
10N20W02AAAABD	11-Jun-96	36	13.2	570		17
10N20W02ABAABA	10-Jun-96	30	6.0	2,500		72
10N20W02BADDAD	11-Jun-96	60	9.5	1,700		63
10N20W02BBAABA	10-Jun-96	30	4.9	3.9	0.2	0.06
10N20W02DBACBD	12-Jun-96	29	10.0	300	0.1	7.0
10N20W10AADDBC	21-Aug-96	44	8.2	710		19
10N20W11ADCACC	15-Jul-96	17	12.8	7,500		1,150
10N20W11BACADD	15-Jul-96	50	8.6	57	0.02	0.7
10N20W11BCBBDD	15-Jul-96	50	6.7	420		6.0
10N20W11BCDACD	22-Nov-96	42	13.3	160	0.01	6.0
10N20W11CBCBCA	15-Jul-96	20	4.0	120	0.07	3.0
10N20W11DBCCA	17-Jul-96	10	6.0	42	0.05	2.0
10N20W11DCBCBB	16-Jul-96	75	6.7	1,300		32
10N20W14ABCBCB	22-Nov-96	28	14.3	480		21
10N20W14BAAABC	20-Aug-96	44	7.5	770		28
10N20W14BACAAB	22-May-97	60	12.0	5,000		190
10N20W14BACBDB	21-Nov-96	60	1.0	13,300		290
10N20W14BBBBAA	17-Jul-96	24	12.0	1,200		61
10N20W14BBDDCC	22-Nov-96	41	11.8	2,060		46
10N20W14CBDCDD	20-Aug-96	25	12.0	3,400		140
10N20W15AABACB	21-Aug-96	25	13.2	300		
		Log-normal Means =		600	0.05	19

Table 4. Seepage rates.

Site	Location	Date	Gain/Loss	Seepage Rate* $ft^3/day/ft^2$	Stream Discharge (cfs)
One Horse Creek	10N20W15AABCB	08/21/97	0.2 mL loss	-0.000003	0.5
One Horse Creek	10N20W14CBABB	08/20/97	7.2 mL gain	0.00038	5.3
One Horse Creek	10N20W14ABAAA	08/21/97	64.3 mL loss	-0.00083	0.3
Tie Chute Creek	10N20W11BBCBC	10/17/97	0	0	1
Tie Chute Creek	10N20W11AAABC	08/20/97	8.9 mL gain	0.00011	0.3

* A positive seepage rate (cubic feet of water/day/square foot of seepage face [$ft^3/day/ft^2$]) indicates ground-water discharge (gaining stream), a negative seepage rate indicates ground-water recharge (losing stream).

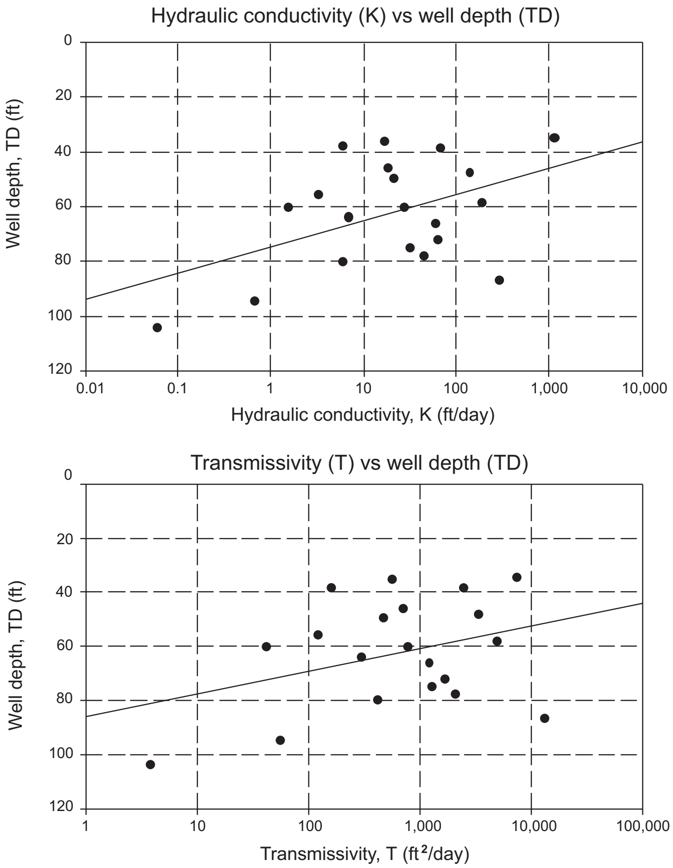

Figure 9. Relation between aquifer properties and well depth.

ranged from below detection to 117 micrograms per Liter (µg/L) in well 10N20W15DBBD, with a median concentration of 17 µg/L. Copper ranged from below detection to 117 µg/L in well 10N20W10CACC, with a median concentration of 31 µg/L. Zinc concentrations ranged from below detection to 304 µg/L in well 10N20W14BCDC, with a median concentration of 23 µg/L.

Constituents that exceeded maximum contaminant levels (MCL) for inorganic chemicals include 7.9 µg/L beryllium in well 10N20W14BACCBA (MCL, 4 µg/L), 547 µg/L chromium in well 10N20W14BCABCA (MCL, 100 µg/L), and 7.1 mg/L fluoride in well 10N20W15ACBBCC (secondary MCL, 2 mg/L).

Nitrate in Ground Water

Peavy and others (1980) report that septic tank effluent typically contains the ranges of constituents shown in table 6. Phosphate was not detected in Florence area ground water; nitrate and chloride concentrations are plotted on plate 3.

Most of the nitrogen released by septic tanks is ammonia and organic nitrogen (Madison and Brunett, 1984). Ammonia is converted to nitrate as follows:

$$H_4^+ + O_2 \xrightarrow[\text{bacteria}]{\text{nitrosomonas}} NO_2^- + O_2 \xrightarrow[\text{bacteria}]{\text{nitrobacter}} NO_3$$

Nitrate is soluble and highly mobile under aerobic conditions, but under anaerobic conditions, it undergoes denitrification according to the following:

$$NO_3^- + \text{organic carbon} \longrightarrow NO_2^- + \text{organic carbon} \longrightarrow N_2 + CO_2 + H_2O$$

In ground water near Florence, nitrate concentrations range from below instrument detection (0.05–0.25 mg/L, depending on sample preservation) to 8.3 mg/L, with a median value of 0.61 mg/L (figure 11). Madison and Brunett (1984) suggested that nitrate-nitrogen concentrations greater than 3 mg/L may be indicative of anthropogenic sources, such as feedlots, fertilizer, and septic tanks. Of these possible sources, septic tanks are a primary concern at Florence. As shown on the probability plot for nitrate (figure 12), only three samples exceed 3 mg/L: 3.03 mg/L in well 10N20W14BACC, 5.50 mg/L in well 10N20W14BACA, and 8.30 mg/L in well 10N20W11ADCA. These samples are denoted by boxes in figures 12, 13, and 14. The first two wells are in, or downgradient of, the original Florence town site (plate 3); the third is downgradient of the Florence-Carlton School, a restaurant, a trailer court, and several homes. Although nitrate values in these wells are anomalously high, the concentrations are still below the U.S. Environmental Protection Agency (USEPA) primary drinking-water standard of 10 mg/L (USEPA, 1982).

Peavy and others (1980) report that many researchers have used a correlation between nitrate and chloride ions to differentiate between animal waste (including human) and fertilizer pollution of ground-water supplies. Both are mobile in the subsurface environment and are found in septic tank effluent, but chloride is not a component of fertilizer. The plot of chloride versus nitrate (figure 13) exhibits a positive correlation between these two ions, suggesting contamination of ground water by septic tank effluent or animal waste. The regression line excludes the two highest chloride values.

Probability plots of nitrate and chloride concentrations in Florence ground water (figures 12, 14) also suggest contamination. A log-normal distribution is expected for any given population; whereas on these plots, two populations are evident. The lower line on each plot represents natural ionic concentrations, and the higher concentrations of the upper lines represent human impacts or geologic conditions in the case of high chloride concentrations.

Table 5. Minimum, median, and maximum values for ground-water parameters and constituents.

Property or constituent and reporting unit	Number of analyses/ number of detections	Minimum	Median	Maximum	USEPA drinking water standard or health advisory
Ground-Water Parameters					
TDS calculated (mg/L)	63/63	22.89	71	543.91	500 (SMCL)
Field SC (μmhos/cm)	63/63	28.8	94	897	—
Field pH	63/59	5.65	6	8.6	6.5–8.5 (SMCL)
Hardness as $CaCO_3$ (mg/L)	63/63	7.57	31	168.84	—
Alkalinity as $CaCO_3$ (mg/L)	63/63	7	33	408.94	—
Water temperature (°C)	63/59	5.1	11	20	—
Major Ions (mg/L)					
Ca	63/63	2.345	9	47.31	—
Mg	63/63	0.417	2	12.32	—
Na	63/63	1.735	5	162.5	—
K	63/63	0.4	1	10.7	—
Fe	63/34	<0.003	0	0.45	0.3 (SMCL)
Mn	63/28	<0.001	<0.004	0.19	50 (SMCL)
SiO_2	63/63	10.4	25	55.4	—
HCO_3	63/63	8.54	40	498.6	---
Cl	63/59	<0.05	2	73.4	250 (SMCL)
SO_4	63/56	<1	4	71.9	250 (SMCL)
NO_3	63/52	<0.05	1	8.3	10 (MCL)
F	37/17	<0.05	<0.05	7.12	2 (SMCL)
PO_4	60/2	<0.05	<0.05	0.2	—
Trace Elements (μg/L)					
Aluminum, Al	57/1	<15	<30	73.2	50–200 (MCL)
Antimony, Sb	57/0	<2	<2	<10	6.0 (MCL)
Arsenic, As	59/3	<1	<1	5.7	50 (MCL)
Barium, Ba	59/59	3.3	17	117	2,000 (MCL)
Beryllium, Be	58/2	<2	<2	7.9	4.0 (MCL)
Boron, B	59/1	<30	<30	251	—
Bromide, Br	59/1	<25	<25	167	—
Cadmium, Cd	59/0	<2	<2	<2	5.0 (MCL)
Chromium, Cr	59/15	<2	<2	546.7	100 (MCL)
Cobalt, Co	59/1	<2	<2	2.5	—
Copper, Cu	59/36	<2	31	117	1,300 (action level)
Lead, Pb	59/2	<2	<2	3.3	15 (action level)
Lithium, Li	59/2	<5	<10	193	—
Molybdenum, Mo	59/0	<10	<10	<20	—
Nickel, Ni	59/11	<2	<2	4.8	100 (MCL)
Nitrate, NO_2 as N	29/13	<0.05	<0.05	2.7	1,000 (MCL)
Selenium, Se	59/0	<1	<1	1.1	50 (MCL)
Silver, Ag	59/2	<1	<1	503	100 (AQ)
Strontium, Sr	59/59	22	22	19	—
Titanium, Ti	59/4	<10	<10	41	—
Vanadium, V	59/2	<5	<5	304	—
Zinc, Zn	59/51	<2	<2	<20	5,000 (AQ)
Zirconium, Zr	59/0	<5	<5		—

(—., no data; <, less than; μmhos/cm, micromhos per centimeter at 25° C; mg/L, milligrams per Liter; USEPA, U.S. Environmental Protection Agency; MCL, maximum contaminant level; SMCL, secondary maximum contaminant level; AQ, Standard based on aesthetic quality and not a health standard)

No other explanation is known because there is little fertilizer use (lawn and garden fertilization is thought to be minimal) in the area, and the highest nitrate values occur downgradient of likely anthropogenic sources.

Circled points on figures 12, 13, and 14 denote the three samples with the highest chloride concentrations: 73.4 and 36.1 mg/L at 10N20W11CDCD, and 26.7 mg/L at 10N20W15ACBBCC. Only two points are circled on figures 12 and 13 because nitrate was not detected in the sample from well 10N20W15ACBBCC. Although figure 14 shows two distributions, the anomalous concentrations may represent geologic conditions rather than pollution. The three highest chloride concentrations were found in two wells that are 342 feet and 270 feet deep and probably completed in Tertiary sediment.

Points in the squares on figures 12, 13, and 14 denote the three samples with the highest nitrate concentrations: 8.3 mg/L at 10N20W11ADCACC, 5.5 mg/L at 10N20W14BACAAB, and 3.03 mg/L at 10N20W14BACCBA. The first two wells are 35 feet and 59 feet deep and are probably completed in Quaternary sediment. The depth of the third well is unknown.

Total dissolved solids, calcium, magnesium, sodium, sulfate, bicarbonate, and chloride concentrations tend to increase with depth (figure 15a–g). This increase may be caused by solution of aquifer minerals as ground water moves through the subsurface. Nitrate concentrations seem to decrease with depth (figure 15h), a finding that is consistent with a shallow source such as septic-system effluent.

Tritium in Ground Water

Tritium, a radioactive isotope of hydrogen, with a half-life of 12.43 years, is commonly used for identification of modern ground-water recharge. It occurs naturally, but atmospheric testing of thermonuclear devices between 1951 and 1980 greatly increased levels in precipitation around the globe (Clark and Fritz, 1997). To determine relative ground-water ages in the Florence area, tritium levels were analyzed in 35 samples from 30 locations (table 7, plate 4). The highest tritium concentrations appear to be clustered in two areas: south of Tie Chute Creek in section 11 and along One Horse Creek in sections 14 and 15. Examination of lithologic logs suggests that shallow sediment (0–40 feet) contains less clay in these locations than elsewhere in the project area, a condition that would allow faster infiltration of precipitation and snow melt. All other sites had concentrations less than 10 tritium units. Tritium was not detected in samples from wells 10N20W10ADCC and 10N20W10DCAA; both are deeper than 100 feet. Information published by Hendry (1988) suggests that concentrations greater than 10 may represent water ages less than 30 years (correlates with areas of coarser, shallow sediment in the study area). Concentrations between 2 and 10 may represent ages less than 45 years, and concentrations below detection may represent ages greater than 60 years. Therefore, Florence ground water is generally less than 45 years old; the two wells with undetectable tritium levels suggest that the deep ground water is more than 60 years old.

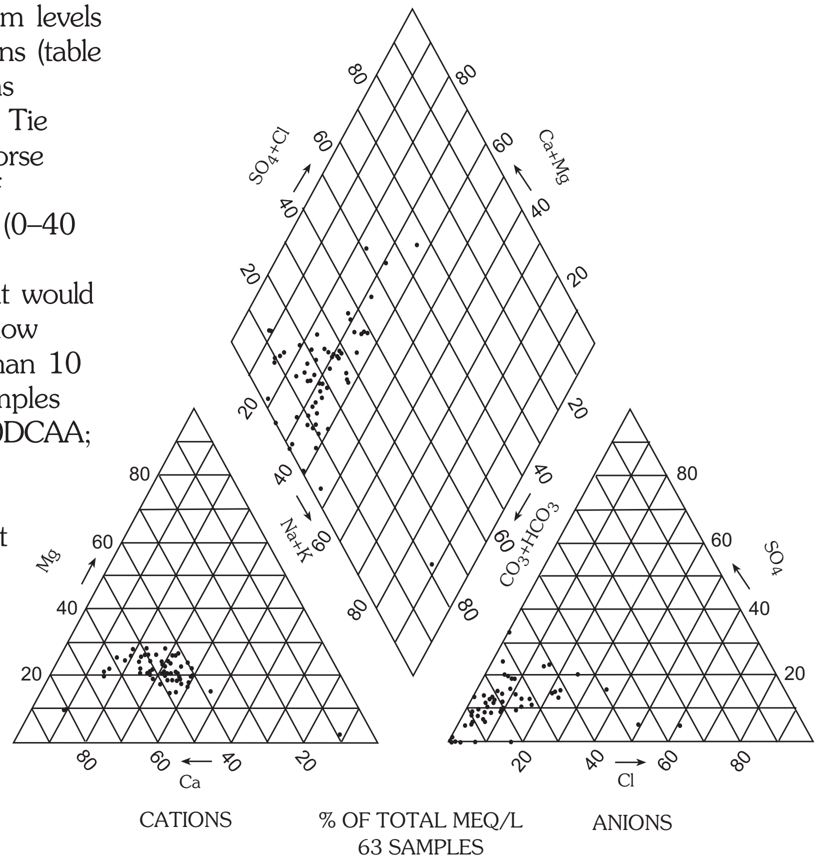

Figure 10. Ionic percentages in ground-water samples.

Aquifer Vulnerability

Two hundred seventeen septic-system locations in and around Florence are shown on plate 5. Septic tank information from Ravalli County files and the site inventory are listed in appendix F of MBMG 397 (Norbeck and McDonald, 2000). The heaviest current development is concentrated west and north of town in sections 2, 3, and 10. Development in these areas, particularly in section 10, may eventually cause degradation of ground water beneath Florence. As previously mentioned, nitrate data suggest that ground water is being degraded by septic tank effluent, although no values currently exceed drinking-water standards.

If the processes of nitrification/denitrification are ignored, the theoretical nitrate loading (increase in nitrate concentration) caused by septic-tank effluent can be calculated for the flow paths (numbered 1 to 4 from north to south) that are defined by flow direction arrows shown on plate 2. Information needed for this calculation includes the amount of nitrate that a septic tank releases to ground water, aquifer transmissivity, and the hydraulic gradient. Ver Hey and Woessner (1987) report 8.3 and 8.7 kg/yr of nitrogen reaching ground water under two systems in the Missoula area. An average of 8.5 kg/yr, along with a log-normal mean transmissivity of 603 feet^2/day (table 3), septic tank densities from plate 5, and gradients from plate 2, were used in the nitrate loading calculations summarized in table 8.

The calculated nitrate-loading values in table 8 are estimates based on limited data and ignore the processes of nitrification and denitrification, but calculated nitrate concentrations (row 8, table 8) generally agree with average concentrations (row 9, table 8) for the flow paths on plate 1. A calculated average nitrate loading for the entire project area at current development levels is about 0.5 mg/L.

Row 14, table 8, estimates the number of additional septic tanks that could be installed before the drinking-water standard of 10 mg/L for nitrate is exceeded. These estimates are subject to errors in

Table 6. Typical septic tank effluent characteristics.

Constituent (mg/L)	Range	Mean
Total phosphates (PO_4 as P)	6.25–30.0	11.6
Nitrate as N	0.0–0.1	0.026
Chlorides	37.0–101.0	53.0

the many assumptions used to develop them; however, they illustrate that continued development in the Florence area has the potential to increase nitrate concentrations in ground water moving toward the Bitterroot River flood plain. Although processes such as denitrification will reduce nitrate concentrations somewhat, continued development may cause exceedences of drinking-water standards in the future.

Conclusions

The ground water under Florence is found in unconsolidated Quaternary and Tertiary sediment deposited by the ancestral Bitterroot River and its tributaries. Sediment includes silt, sand, gravel, cobbles, and boulders. Aquifer tests (table 3) indicate that per-meabilities range from low, 0.6 feet/day, to moderate, 1,150 feet/day. Well

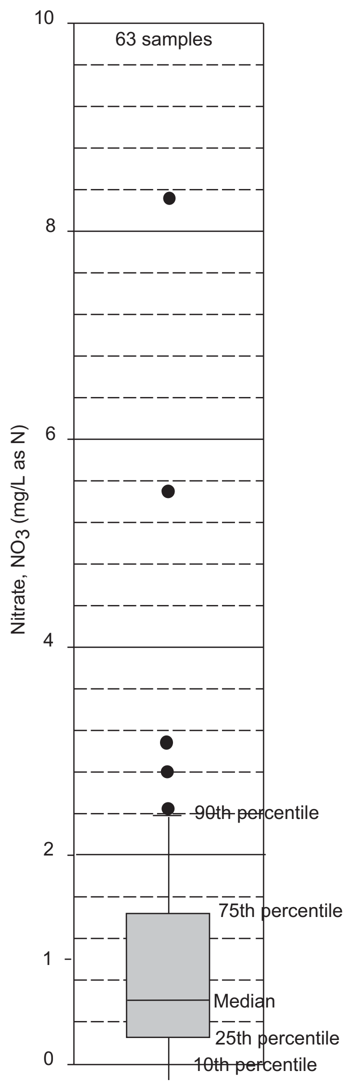

Figure 11. Nitrate concentrations in Florence ground water.

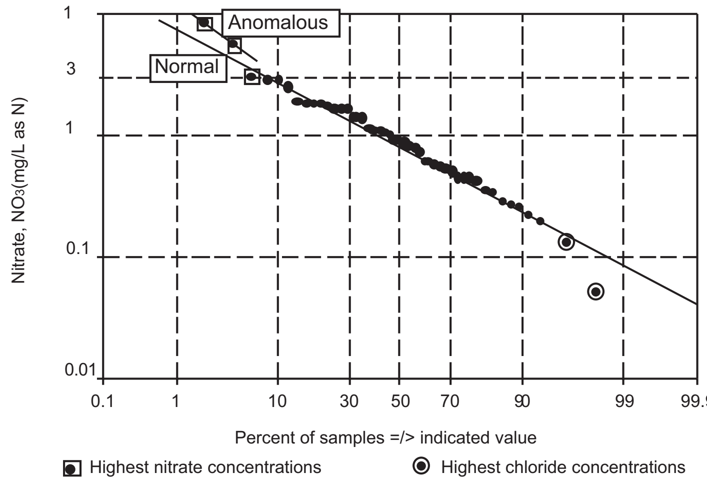

Figure 12. Probability plot, nitrate in Florence ground water.

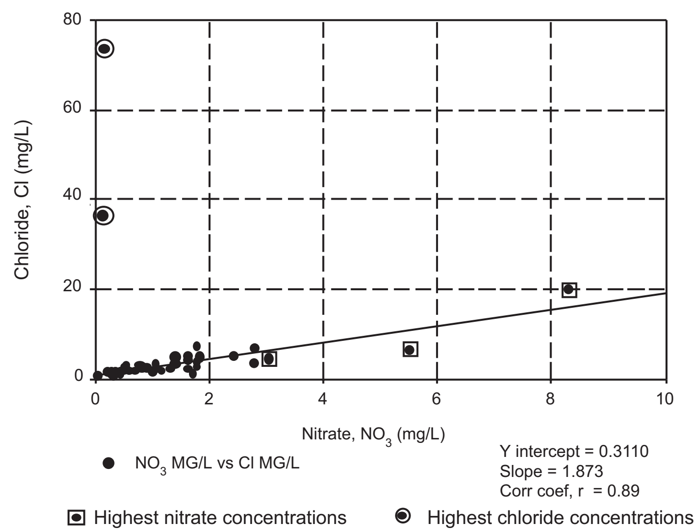

Figure 13. Chloride versus nitrate in Florence ground water.

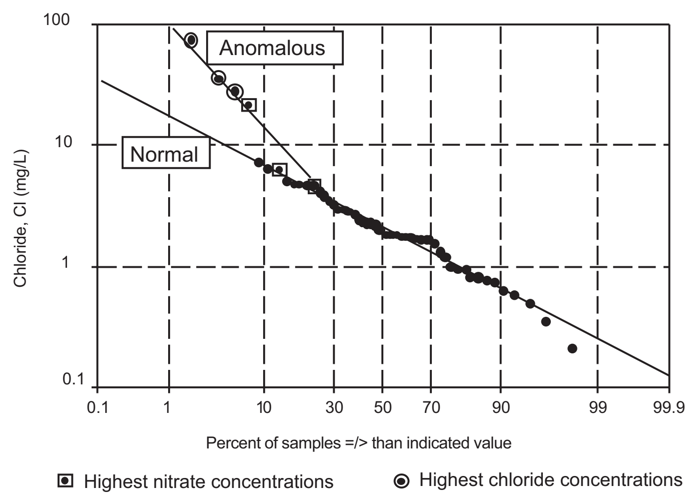

Figure 14. Probability plot, chloride in Florence ground water.

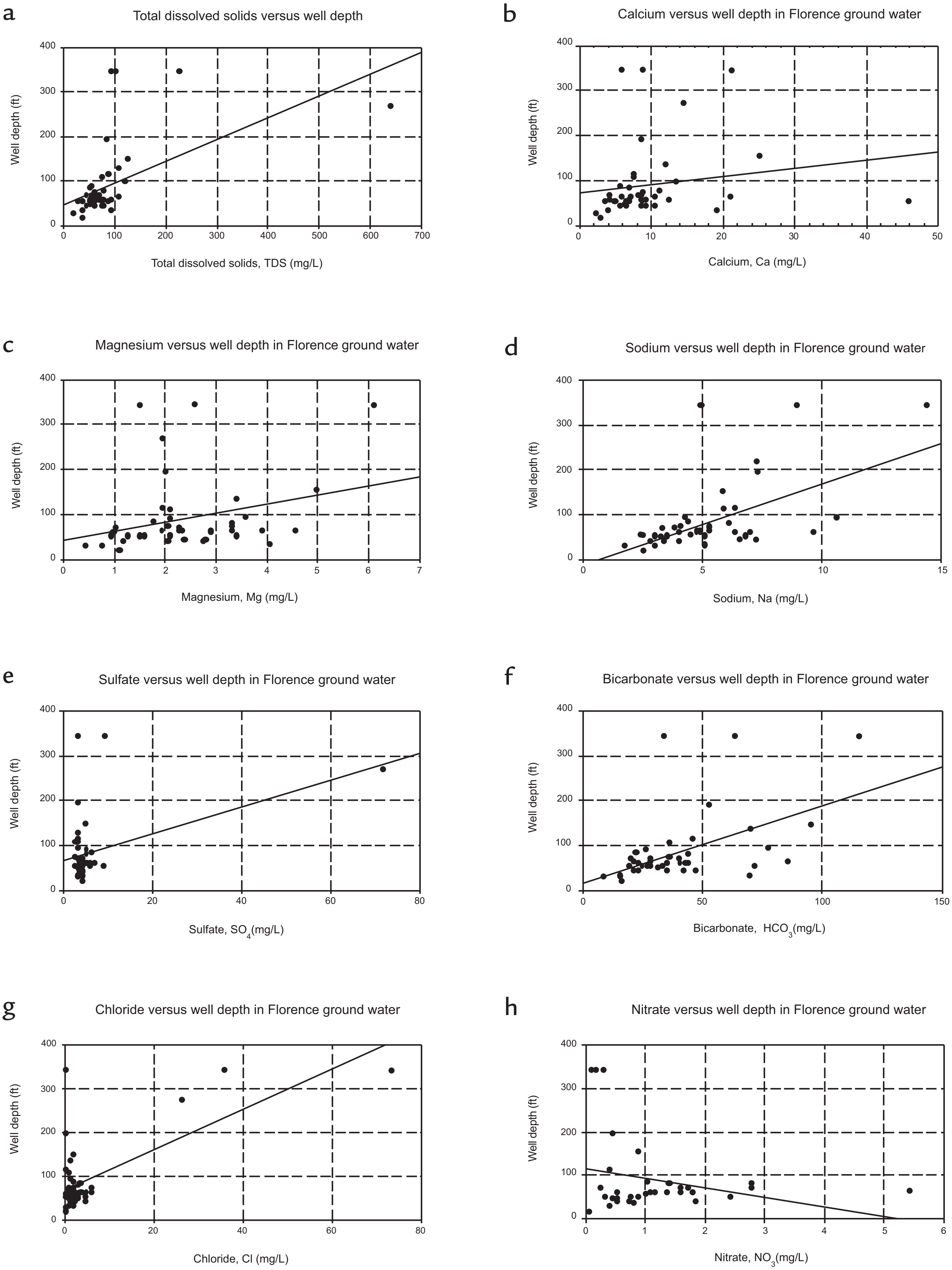

Figure 15. Ion concentrations versus well depth.

Table 7. Tritium in Florence area ground water.

Location	Lab QW Number	Site Number	Sample Date	Tritium Units	Error +/-
10N20W02CDBABC	98Q0858	M:63933	29-Mar-98	3.9	0.4
10N20W02DBACBD	98Q0855	M:124587	30-Mar-98	6.8	0.6
10N20W03DADDCC	98Q0872	M:63950	29-Mar-98	3.3	0.4
10N20W10ADCB	98Q0861	M:123152	30-Mar-98	7.4	0.6
10N20W10ADCC	98Q0856	M:157453	16-Apr-98	<0.8	0.2
10N20W10BADDD	98Q0868	M:139841	31-Mar-98	7.8	0.6
10N20W10BADDD		M:139841	DUP	7.4	0.6
10N20W10BBDB	98Q0857	M:63977	30-Mar-98	7.8	0.6
10N20W10BBDB		M:63977	DUP	8	0.6
10N20W10CACC	98Q0865	M:63988	28-Mar-98	8.8	0.7
10N20W10DCAA	98Q0905	M:166832	2-May-98	<0.8	0.5
10N20W11ABADBC	98Q0867	M:123569	28-Mar-98	7.6	0.6
10N20W11ACCBA	98Q0909	M:64025	4-May-98	22.6	1.7
10N20W11ACCBA		M:64025	DUP	24.3	1.8
10N20W11ACCBAD	98Q0910	M:130921	1-May-98	21.1	1.6
10N20W11BADCDD	98Q0864	M:136269	28-Mar-98	7.5	0.6
10N20W11BCADA	98Q0853	M:160354	29-Mar-98	20.3	1.4
10N20W11BDADD		M:166833	8-Apr-98	11.3	0.8
10N20W11BDADD	98Q0898	M:166833	1-May-98	16.4	1.3
10N20W11CBCBC	98Q0866	M:136423	29-Mar-98	11	0.8
10N20W11CBDAA	98Q0900	M:166835	2-May-98	11.3	1
10N20W11CBDCA	98Q0863	M:147580	28-Mar-98	9.5	0.7
10N20W11DBAB	98Q0469	M:163262	9-Feb-98	15.9	1.1
10N20W11DBDAC	98Q0904	M:166834	3-May-98	16.3	1.3
10N20W14ABCAC	98Q0869	M:166186	29-Mar-98	7	0.6
10N20W14ABCAC		M:166186	DUP	7.8	0.6
10N20W14BACBAC	98Q0903	M:64178	2-May-98	10.5	0.9
10N20W14BADBB	98Q0907	M:160812	1-May-98	10.6	1
10N20W14BADBB		M:160812	DUP	11.1	0.9
10N20W14CBCDA	98Q0902	M:121919	2-May-98	10.5	0.9
10N20W14CCDAA	98Q0899	M:64163	2-May-98	11.7	1
10N20W15ACADBD	98Q0859	M:166188	31-Mar-98	11.9	0.9
10N20W15ACBBCC	98Q0906	M:64209	3-May-98	8.4	0.8
10N20W15DBAADB	98Q0854	M:64208	30-Mar-98	7.2	0.6
10N20W15DBBD	09Q0908	M:130928	1-May-98	11.3	1

yields are typically adequate for domestic use and range from 1 to 200 gpm.

Most samples represent a calcium-bicarbonate water, with TDS concentrations less than 100 mg/L; however, a few samples had TDS concentrations greater than 100 mg/L. Ground water supplying most Florence area wells is relatively young, less than 45 years old.

Data analysis for nitrate and chloride in Florence ground water suggests that ground water is being degraded by septic tank effluent, although drinking-water standards were not exceeded in any sampled wells to date. Additional development may result in nitrate concentrations exceeding the primary drinking-water standard of 10 mg/L at some time in the future.

A monitoring well network is recommended to detect problems before they become critical and to assist in future growth planning. Suggested general locations are shown on figure 16. The three westernmost sites (along the Florence-Carlton Loop) are downgradient of areas currently being developed and upgradient of Florence. These sites would detect degradation of ground water under the Florence County Water and Sewer District. The three eastern sites (along the railroad tracks) are downgradient of Florence and would detect potential degradation of ground water discharging to the Bitterroot River. Existing wells that can be sampled from a tap at the wellhead or at an outside hydrant prior to treatment, storage, or filtration are recommended. Nitrate concentrations may vary seasonally in shallow aquifers; therefore, sampling for nitrate and chloride should be conducted at least quarterly until seasonality is determined. Options to mitigate future ground-water contamination include a community water system and/or a community waste-treatment system. A community water system would provide residents the option to connect to a reliable, safe water supply but would not prevent further contamination of ground water because it would not address contamination from individual septic systems. The water system would have to be located and designed so that future Florence-area growth would not impair supply. Community waste treatment would eliminate septic-system effluent from property that uses the system, thereby preventing, or at least slowing, further contamination of Florence-area ground water.

Acknowledgements

This study was funded under the Renewable Resource Grant and Loan Program administered by the Montana Department of Natural Resources and Conservation. The Florence County Water and Sewer District and Judy Sass of the Midwest Assistance Program provided valuable support and assistance throughout the project.

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Table 8. Calculated nitrate loading for Florence ground water.

Row #		Flow path #1	Flow path #2	Flow path #3	Flow path #4
1	Log-normal mean transmissivity, T ($meters^2$/day)	22	40	17	22
2	Flow path width, W (meters)	2,179	853	777	1,113
3	Hydraulic gradient, I (meters/meter)	0.042	0.033	0.038	0.042
4	Q = T x W x I (L/yr), (row 1 x row 2 x row 3 x 1,000L/$meters^3$ x 365 day/year)	$7.25x10^8$	$4.05x10^8$	$1.81x10^8$	$3.70x10^8$
5	Estimated increase in nitrate concentration in ground water/septic tank (mg/L/tank), (8,500,000 mg/yr/tank*/row 4)	0.012	0.020	0.045	0.023
6	Number of existing septic tanks	65	74	7	59
7	Estimated nitrate load due to existing septic systems (mg/yr), (row 6 x 8,500,000 mg/yr/tank)	$5.53x10^8$	$6.29x10^8$	$6.38x10^8$	$5.02x10^8$
8	Calculated current nitrate concentration (mg/L)	0.8	1.6	3.5	1.4
9	Actual current nitrate concentrations (mg/L)	0.7	1.3	6.6	1.1
10	Difference between current nitrate concentration and EPA standard of 10 mg/L	9.3	8.7	3.4	8.9
11	Calculated number of additional septic tanks that might be installed before nitrate in ground water exceeds 10 mg/L, (row 10/row 5)	793	415	72	388
12	Total number of septic tanks under maximum development (nitrate in ground water <10 mg/L), (row 11 + row 6 ± ~50%)	400–1300	200–800	50–250	200–700
13	Flow path area (acres)	1,135	33	397	517
14	Septic tank density under maximum development (tanks/acre), (row 13/row 12)	2.6–0.9	1.4–0.5	5.4–1.8	2.3–0.8

*NO_3 from septic tanks = 8,500,000 mg/yr/tank (VerHey and Woessner, 1987)

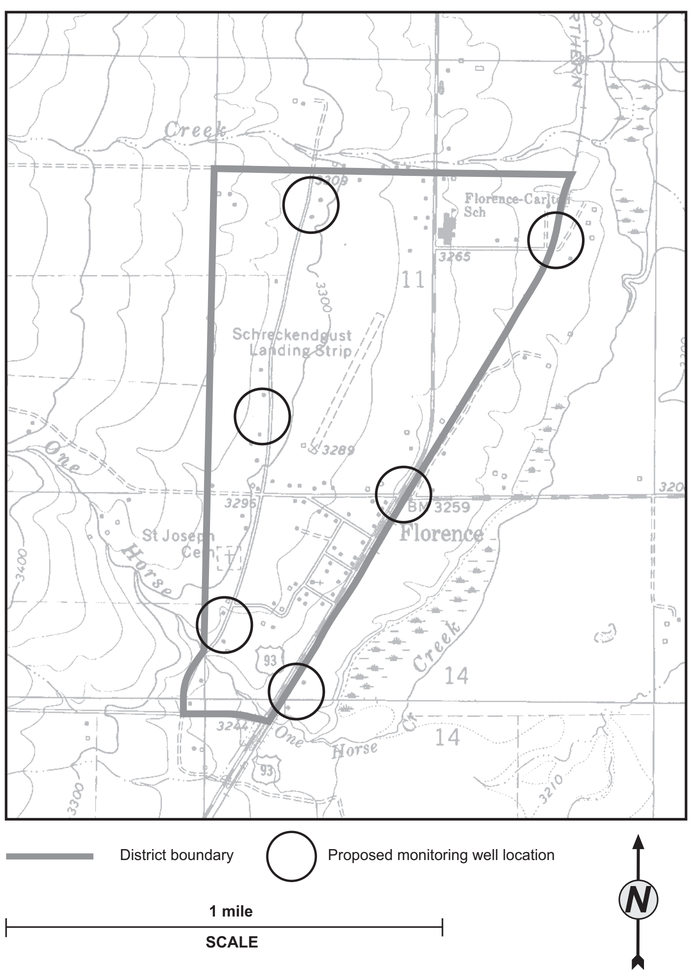

Figure 16. Suggested monitoring well locations.

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Appendix A
Data-Point Numbering System

Explanation

The system of numbering data points in this report is based on the U.S. Bureau of Land Management system of public lands subdivision. The project lies within the Montana Principal Meridian system: data point numbers are ascribed that identify specific locations within the system. The first two digits and following letter of a data point number indicates the township north of the baseline; the next two digits and letter, the range west of the Principal Meridian; and the fifth and sixth digits, the section in which the data point is located (figure A-1). The letters A, B, C, and D, following the section number, locate the point within the section. The first letter denotes the 160-acre tract; the second, the 40-acre tract; the third, the 10-acre tract; the fourth, the 2.5-acre tract; and so on out to as small a tract as can be identified for a particular data point (up to six tracts for this project). The letters are assigned counterclockwise, beginning in the northeast quadrant. If two or more data-points are located in the same tract, numbers are added as suffixes. It is important to note that the order of quarter-tract designations is exactly reversed from that commonly used by surveyors; here the order begins with the largest quarter and progresses to the smallest. Thus in figure 4, the designation 02N03W16ABDA identifies the first data point in the NE¼SE¼NW¼NE¼ of section 16, Township 2 North, Range 3 West.

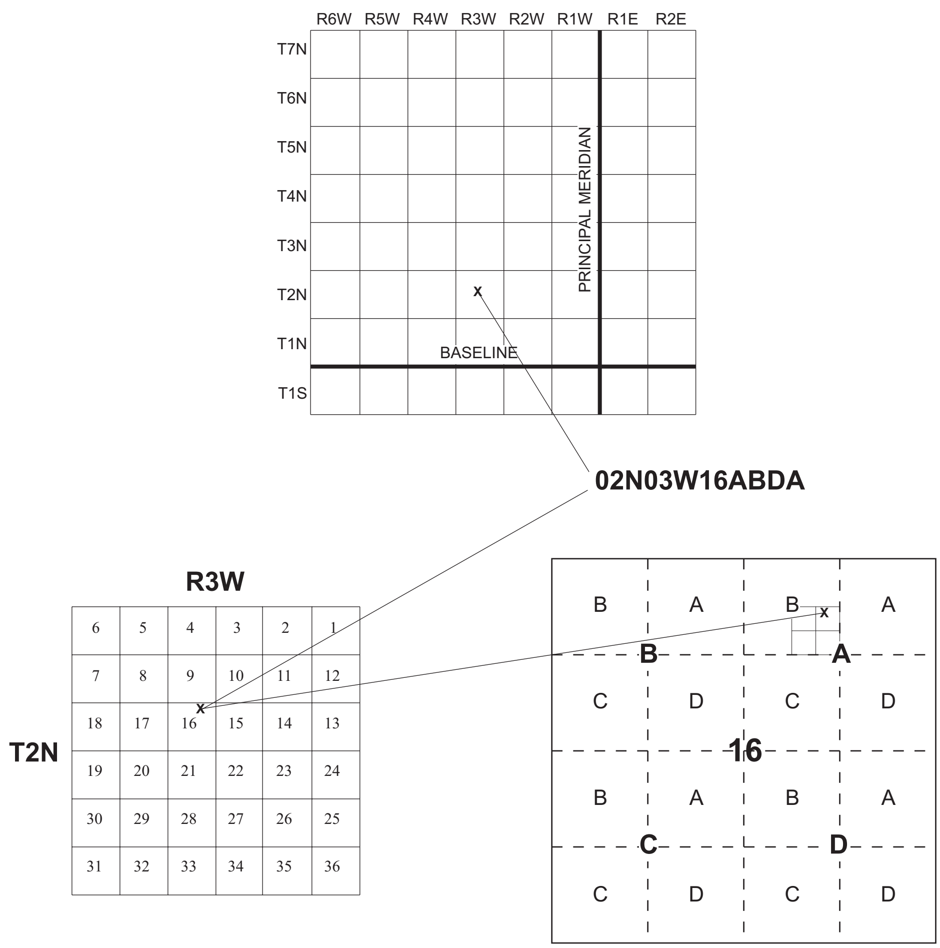


Figure A-1. Data-point numbering system.

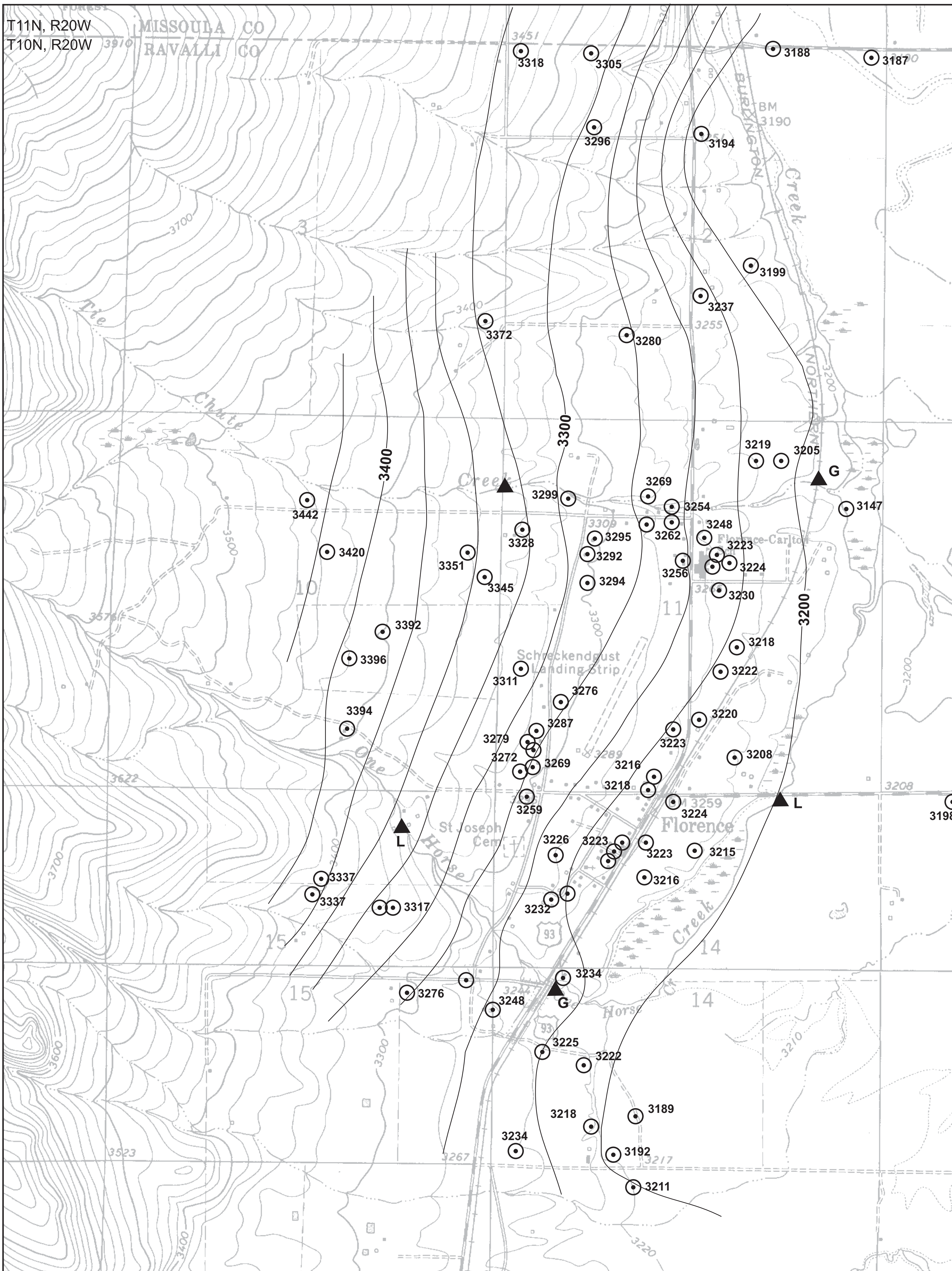


Plate 1. Ground-water levels, Florence

Water-level contour interval = 25 feet

3337 Well with water-level elevation

Seepage measurement site
G = gaining stream
L = losing stream

Ground-water flow direction

N

1 mile

SCALE

Base from USGS 7.5' Florence and Stevensville topographic maps

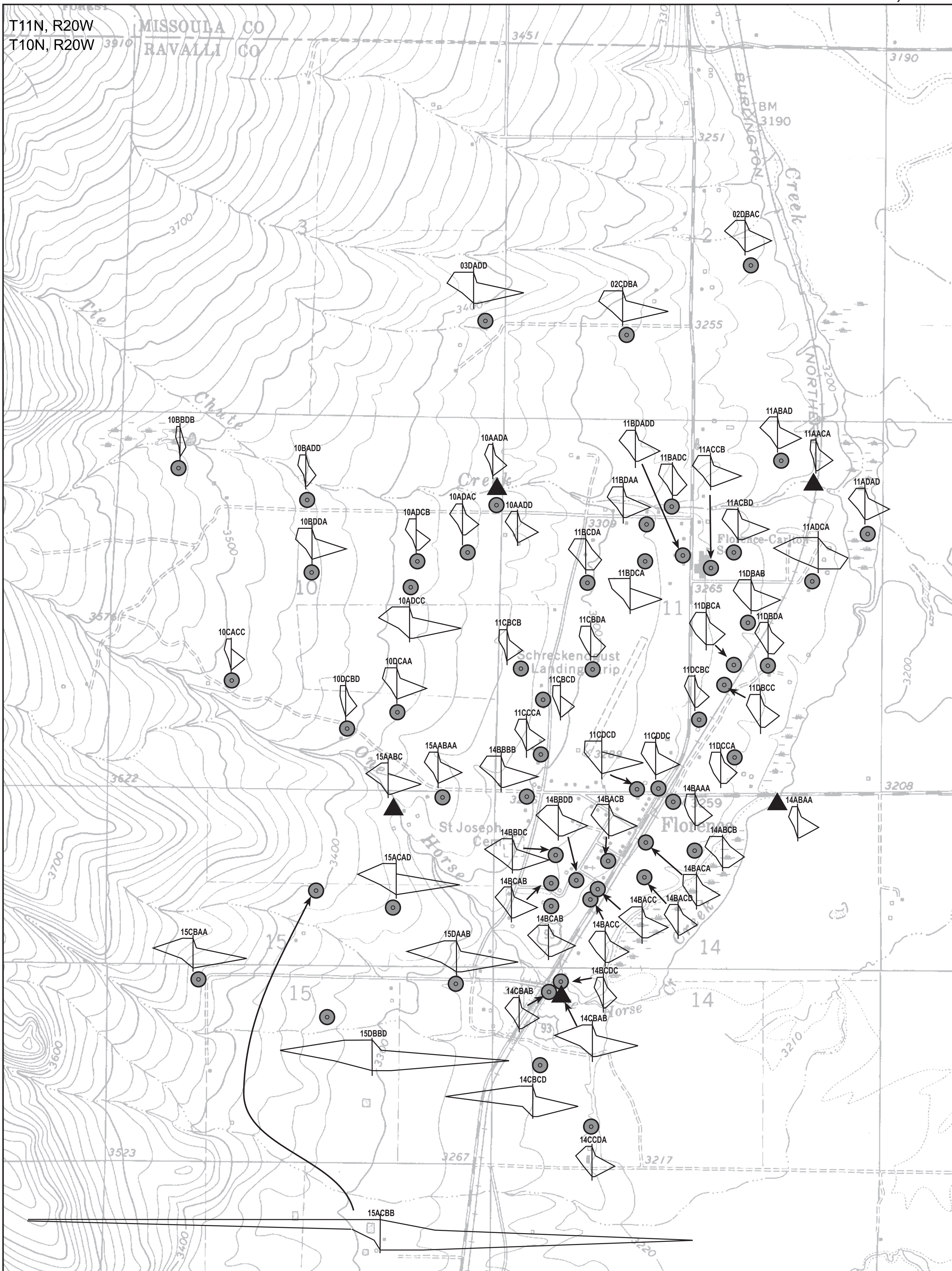
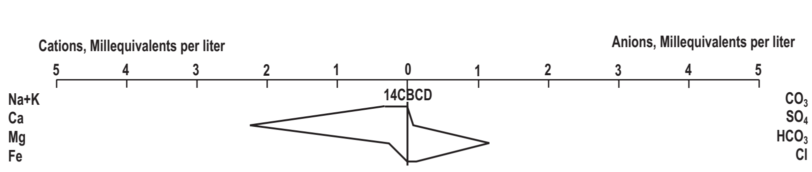


Plate 2. Generalized water quality, Florence



Water well

Seepage measurement site

1 mile

SCALE

Base from USGS 7.5' Florence and Stevensville topographic maps

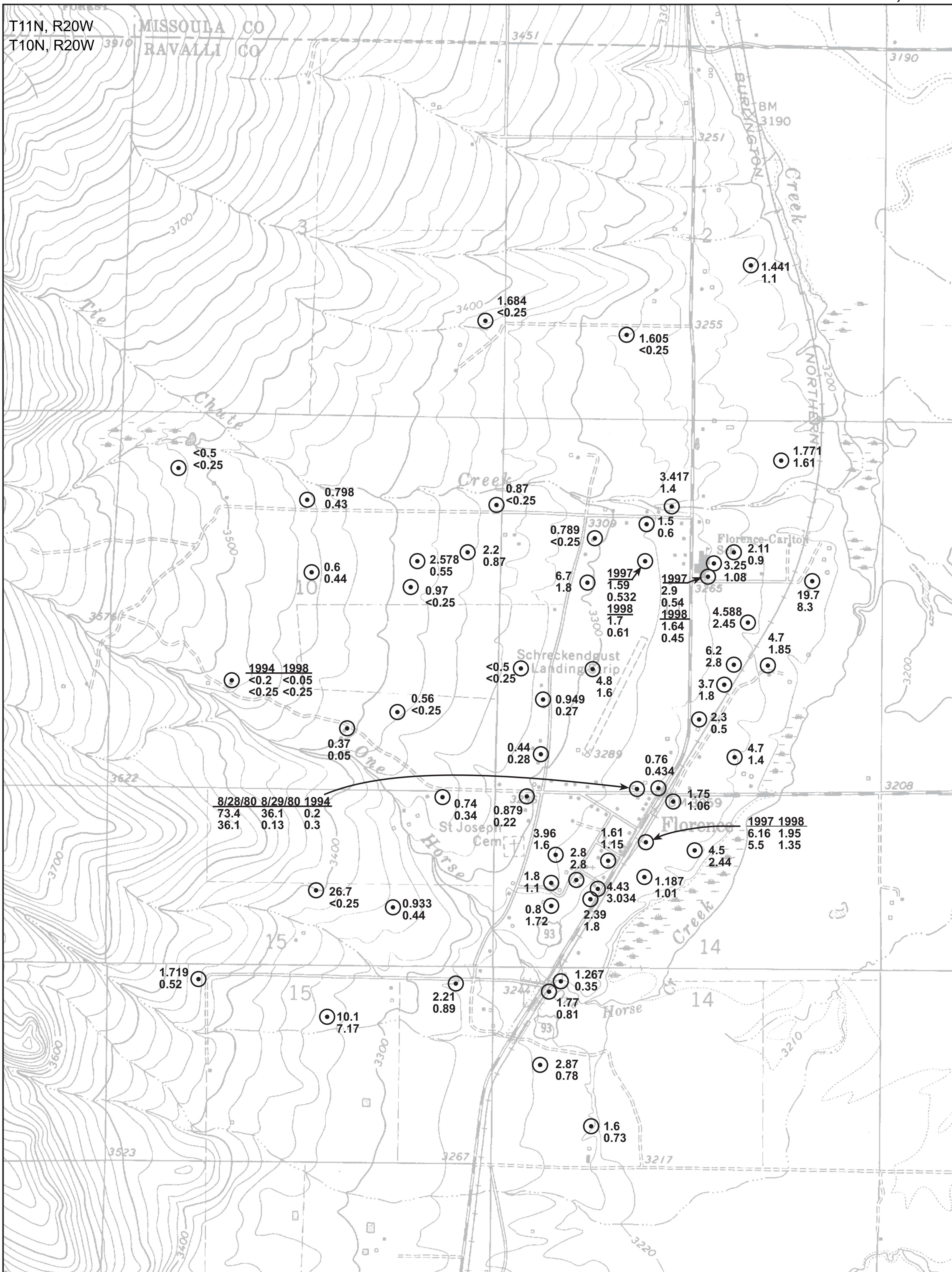


Plate 3. Chloride and nitrate concentrations in ground water, Florence

4.43
3.03 Water well, chloride (mg/L)
nitrate as N (mg/L)

N

1 mile

SCALE

Base from USGS 7.5' Florence and Stevensville topographic maps

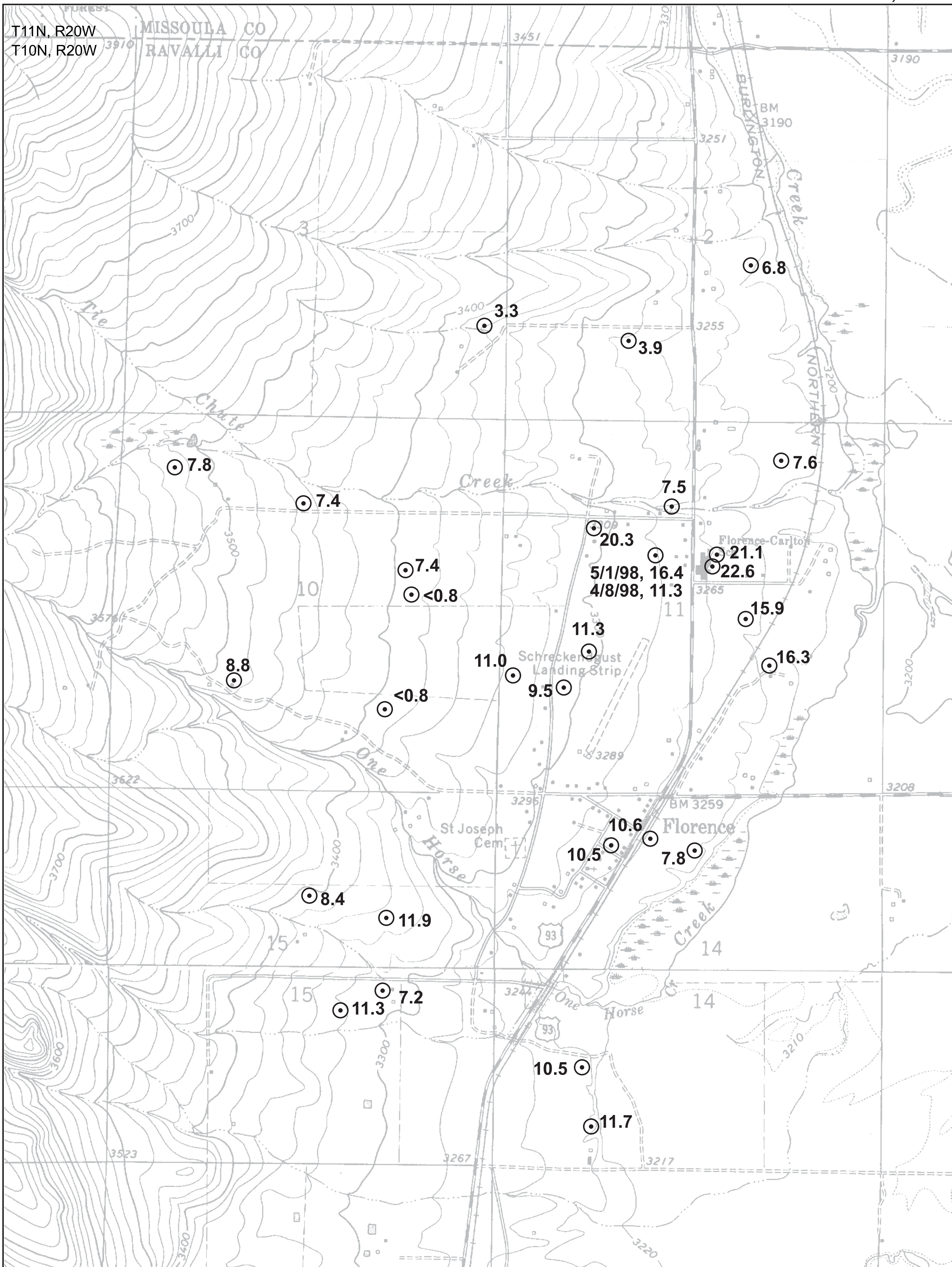


Plate 4. Tritium concentrations in ground water, Florence

7.4 Water well, tritium concentration in Tritium Units

Dates of collection are listed on wells with more than one sample.

1 mile

SCALE

Base from USGS 7.5' Florence and Stevensville topographic maps

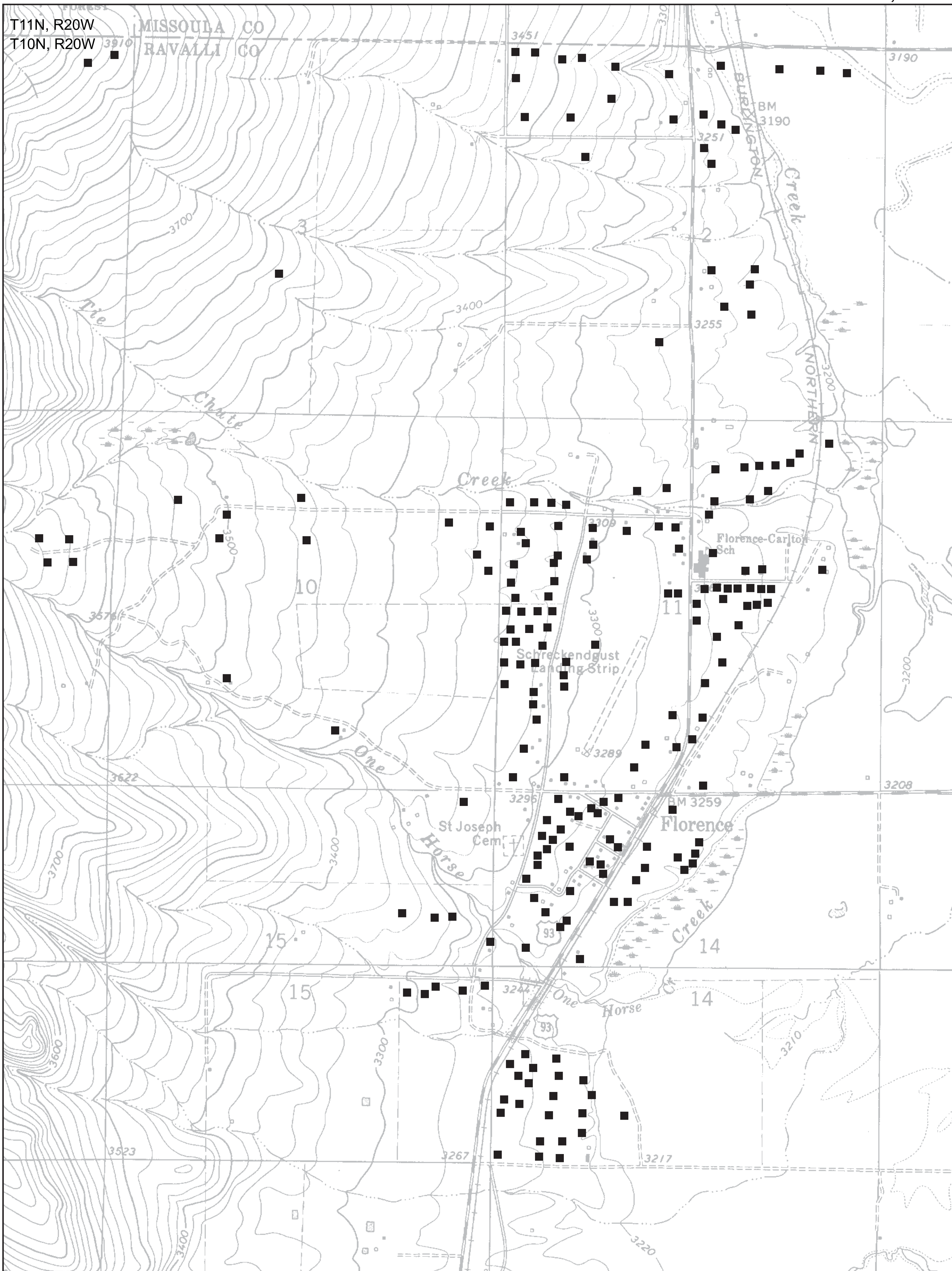


Plate 5. Septic system locations, Florence

■ Septic system

N

1 mile

SCALE

Base from USGS 7.5' Florence and Stevensville topographic maps