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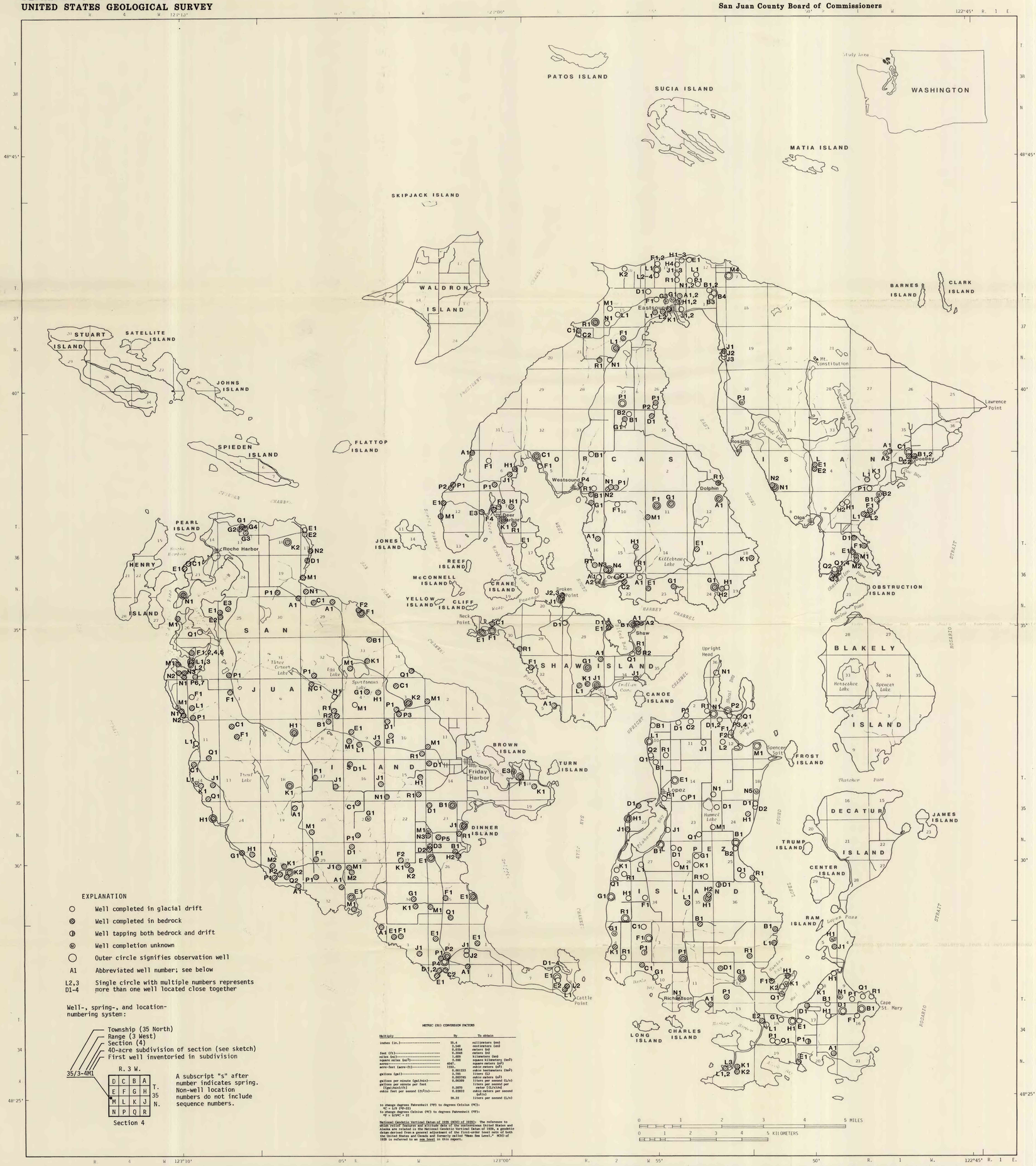

Base from U.S. Geological Survey
Orcas Island, Richardson 1:62,500, 1957;
Sucia Island, 1973, Stuart Island, 1953;
Waldron Island, 1954, Roche Harbor, 1954,
Friday Harbor, 1954, False Bay, 1:24,000, 1954.

OCCURRENCE, QUALITY, AND USE OF GROUND WATER IN ORCAS, SAN JUAN, LOPEZ, AND SHAW ISLANDS, SAN JUAN COUNTY, WASHINGTON

Ground-Water Conditions in San Juan County, Washington

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ABSTRACT

Ground water, which supplies most of San Juan County's water needs, occurs in both bedrock and glacial drift. Water in the bedrock occurs in fractures in the otherwise dense, poorly permeable rock. Deposits of sand and gravel in the glacial drift provide the highest yields to wells drilled into unconsolidated materials. Specific capacities of bedrock wells are typically low, and those of glacial-drift wells are considerably higher.

Ground water is high in dissolved solids and hardness; 29 of 56 wells sampled had water classified as very hard. Sixteen percent of the 171 ground-water wells tested for indicator bacteria had positive counts of one or more of these bacteria: total coliform, fecal coliform, fecal streptococcus. Nine percent of the 279 wells sampled for chloride in September 1981, appear to be affected by seawater intrusion. All of these wells are located within a mile of the coast; 60 percent of these wells are on Lopez Island.

In 1980 an estimated total of 220 million gallons of ground water was withdrawn for all uses. Ninety percent of all ground-water use is for domestic and public supply purposes. Heavy pumpage on northern and southern Lopez Island correlates with areas having high chloride concentrations.

PURPOSE AND SCOPE

The ever-increasing popularity of the islands of San Juan County as a residential and marine-oriented recreational area has increased the demand for water--especially for domestic use. The islands are mostly underlain by bedrock of poor permeability and thin deposits of glacial drift, resulting in a limited ground-water supply. In addition, surface-water supplies are limited on three of the four major islands included in this report.

Thus, a need exists for reliable information concerning the broad aspects of ground-water quality and availability in the county. The San Juan County Board of Commissioners requested that the U.S. Geological Survey collect and interpret data that would provide a basis for land-use planning and development decisions. The study had two major objectives: (1) define on an areal basis the present quality of ground water in the four major islands--Orcas, San Juan, Lopez, and Shaw; and (2) define, to the extent available data allow, the nature and hydrologic characteristics of the unconsolidated deposits on these islands, and define the flow system within these deposits. In addition, ground-water pumpage distribution and rates were to be determined and evaluated in relation to seawater intrusion.

The report has been designed in a format that will provide basic information to groups that are responsible for the planning and administration of water resources in the county, and to individuals as a guide in evaluating local ground-water conditions. There are 12 sheets that present information on the following topics:

Sheet No.	Title
1	Ground-water conditions in San Juan County, Washington
2	Generalized geology and geohydrologic conditions
3	Known thickness of glacial drift
4	Ground-water flow system/well depths
5	Specific capacities of wells
6	Geochemistry of ground water, June 1981
7	Chloride concentrations and seawater intrusion in aquifers
8	Seasonal and long-term changes in chloride concentrations
9	Occurrence of indicator bacteria in ground water
10	Location of major ground-water withdrawals by water-use category for 1980
11	Estimated ground-water use in 1980
12	Comparison of 1980 estimated ground-water use with allocations of water-rights certificates

LOCATION AND EXTENT OF THE AREA

San Juan County is located in the northwestern part of Washington State between the mainland of Washington and Vancouver Island, British Columbia. The total area of the county is approximately 265 square miles (mi^2), with 172 mi^2 of actual land area. Although more than 400 islands are visible at low tide, the four largest islands--Orcas, San Juan, Lopez, and Shaw--account for more than 85 percent of the county's land area, and are the subject of this report.

ACKNOWLEDGEMENTS

The cooperation of many well drillers, well owners, and tenants who supplied information and allowed access to the wells is gratefully acknowledged. Well records and miscellaneous well data were also made available through the Washington State Departments of Ecology and of Social and Health Services, by county resident and professional engineer Stephen Braun, and by Dr. William Wallace of San Diego State University. Special thanks are extended to the Agricultural Stabilization and Conservation Service Committee for San Juan County and to Cooperative Extension Service agent Lee Campbell for their assistance in providing water-use data related to stock and ranching.

PREVIOUS STUDIES

The first significant study and mapping of the geology of the San Juan Islands was done by McLellan (1927). Subsequent geologic mapping of parts of the islands has been done by contributors to a report on the geology and water resources of the islands by the Washington Department of Ecology (1975). A brief discussion of the principal aquifers and well yields in the islands is included in a statewide summary by Molenaar, Walters, and Grimstad (1980). A study of seawater intrusion in coastal Washington (Dion and Sumioka, 1982) includes analysis of dissolved chloride in wells drilled within 1 mile of the coast in the islands. Soils of the islands have been surveyed by the U.S. Soil Conservation Service (1962).

Detailed studies have been made of the ground-water resources of the East Sound basin, Orcas Island, by Washburn (1954), Grimstad (1973), Noble (1974), ARC Engineers (1978), Carr (1979), and Dow and Carr (1980). The results of these studies have been used in the preparation of this report. Studies have also been done to determine availability of ground-water supplies at English and American Camps on San Juan Island by Cline (1969, 1971) and at Mackaye Harbor on Lopez Island by Wildrick (1980).

METHODS OF INVESTIGATION

Records of about 800 wells were compiled and reviewed. Approximately 300 of these wells selected for field visits, beginning in April 1981. Selections were based on several criteria: (1) well use; (2) depth; (3) geographic location; (4) geologic framework; (5) reported yield; (6) existing water-quality data; and (7) permission from the owner/tenant to include the well in this study. The wells were visited in April and September 1981 to measure depth to water and to collect a water sample for analysis of chloride concentration and specific conductance. From the well inventory, an observation-well network of 59 wells was selected for monthly measurements of these same parameters. In June 1981, the 59 wells were also sampled for analysis of a more complete suite of chemical constituents. In August 1981, 171 sites were sampled for the presence of bacteria, which could be used as indicators of possible pollution from such sources as septic systems, dumps, or feedlot and farmland runoff.

Available data on geologic and hydrologic features important to ground-water occurrence were examined. These included rock types and structures outlined in a report by the Washington Department of Ecology (1975). Also evaluated were lineaments (sheet 2) that were defined and mapped from aerial photographs and topographic maps for possible correlation with ground-water occurrence and spring zones, and water chemistry. Questionnaires were sent to approximately 120 water-system managers and numerous phone calls were made to determine rates and distribution of ground-water pumpage during 1980.

Each sheet presents in detail the method of data collection and analysis applicable to its topic.

CLIMATE, TOPOGRAPHY AND DRAINAGE

The topographic setting and mild climate of San Juan County have made this area one of the most scenic and outstanding recreation attractions in the Pacific Northwest. The surrounding marine waters and breezes from the Pacific Ocean provide for mild temperatures throughout most of the year.

The individual islands vary in the ruggedness of their topography. Orcas Island has the greatest relief, with land-surface altitude ranging from sea level to 2,409 feet (the summit of Mount Constitution on Orcas Island). Seven of the eight peaks in the study area that rise to over 1,000 feet are on Orcas Island; the eighth is on San Juan Island. Most of the intermontane valleys and lowland areas on Shaw and San Juan Islands have a low, rolling landscape. Lopez Island is, for the most part, flat or gently rolling, its highest point being Lopez Hill at an altitude of 535 feet.

The topography of the area reflects the processes of glacial erosion and deposition. The ice came from the north; its passage is marked by major waterways, such as San Juan Channel, West Sound, East Sound, and Lopez Sound, oriented generally parallel to the direction of ice movement. Bedrock at higher elevations was carved, scraped, and rounded, while low-lying areas were mantled with unconsolidated glacial deposits of clay, silt, sand, gravel, boulders, and till.

Situated in the "rain shadow" of the Olympic Mountains to the southwest, the San Juan Islands receive considerably less precipitation than do other areas of western Washington. Mean annual precipitation ranges from less than 20 inches in the southern part of the county to about 30 inches in the northern part.

Surface-water runoff from the San Juan Islands is low compared with most other areas in western Washington. Most of the streams on the islands have intermittent flow directly related to precipitation; they usually go dry by June and do not begin to flow again until late October or November. The only perennial streams of significant size are Cold and Cascade Creeks on the slopes of Mt. Constitution on Orcas Island. Cold Creek heads in a large spring in bedrock, and Cascade Creek has its source at Mountain Lake, the largest freshwater body in the islands. Lakes, reservoirs, and manmade ponds occur throughout the islands and are locally an important source of water for drinking, irrigation, and ranching needs.

SUMMARY OF PRINCIPAL FINDINGS

Principal findings of the 1981 ground-water study, as described on sheets 2 through 12, are summarized in the following paragraphs.

Ground water, which supplies most of the county's water needs, occurs in two rock types--bedrock and glacial drift. Specific capacities of wells show great local variations for both rock types; however, specific capacities of bedrock wells are typically low, and those of glacial-drift wells are considerably higher. Most bedrock wells have heads within 20 or 30 feet of land surface, even though the water-yielding fracture zones may be much deeper. Glacial-drift wells, particularly in the broad drift area of Lopez Island, have water-level altitudes that are generally within 10 feet of sea level, regardless of the land-surface altitude. Over three-quarters of the wells in the study area are finished at altitudes below sea level, the deepest wells being along the coast. Because of both depth and location, these wells have a high potential for seawater intrusion.

Ground water is high in dissolved solids and hardness; half the wells sampled had water classified as very hard (more than 180 mg/L expressed as $CaCO_3$). Only one water sample did not meet the State primary drinking standards--a well on Orcas Island that was high in fluoride. Secondary standards were exceeded for iron, manganese, chloride, and dissolved solids--29 of 56 samples analyzed exceeded one or more of these standards. Nine percent of the 279 wells sampled for chloride in September appeared to be affected by seawater intrusion. Most (75 percent) of these wells are located within 1/4 mile of the shoreline. Sixteen percent of the 171 wells tested for indicator bacteria showed contamination. These wells were distributed throughout the study area, but occurred most frequently on Orcas Island.

In 1980 an estimated total of 220 million gallons of ground water was withdrawn for all uses. Heavy pumping on northern and southern parts of Lopez Island correlates with areas of high chloride concentrations, suggesting that seawater intrusion has occurred in response to large ground-water withdrawals in those areas. In many coastal areas where seawater intrusion is apparent, however, large ground-water withdrawals are not evident. This suggests that heavy pumping rates not always prerequisites for the occurrence of seawater intrusion. A comparison of Washington Department of Ecology water-rights allocations with estimated 1980 pumpage rates indicates that 83 percent of existing water rights are currently not being used.

MANAGEMENT CONSIDERATIONS

The data presented on sheets 2 through 12 describe current ground-water conditions and serve as a base to which future water-quality conditions can be compared. Continued efforts are needed to collect water-quality and pumpage data in order to detect any changes in ground-water conditions as follows:

1. Detailed evaluations are needed of hydrogeologic conditions and aquifer characteristics that control the movement of the freshwater/seawater interface. This could be accomplished by constructing of freshwater-seawater models representing conditions at selected cross sections through the unconsolidated sediments of Lopez and southern San Juan Islands;
2. Continued monitoring of selected wells for chloride concentrations is needed, using the information gained in this study for the judicious selection of an observation-well network. Sampling of selected nonpumping wells at coastal and inland locations would be a useful addition to the observation network. Year-round sampling and analysis would provide information on seasonal recharge characteristics;
3. An assessment of the effects of intrusion-control measures that could be implemented in glacial drift materials, such as altering pumpage rates/distribution, augmenting fresh ground-water recharge, and (or) developing the means to maintain a freshwater mound along the coast to prevent encroachment of seawater inland is needed (see sheet 7);
4. Evaluation of hydrologic conditions, sources of wastes, well construction, and aquifer characteristics is needed in order to access those factors that increase the susceptibility of wells to bacterial degradation;
5. Sanitary water quality should be monitored on a continuous basis. The scope of such a monitoring program would be county-wide, but with an emphasis on sampling a greater number of wells on Orcas Island, where bacterial contamination is most prevalent. Such a monitoring program would provide early warning of potentially more serious problems and aid in developing criteria for a more effective management of sanitary quality; and
6. Continued efforts are needed to identify and estimate major withdrawals to update pumpage data and monitor impacts of increased water use, especially water level and chloride changes. Particular attention should be given to areas on the islands with high densities of water systems, high pumpage rates, and (or) ground water known to be high in chloride concentration.

GLOSSARY

Anicline - loss in solution that are negative in charge, such as chloride, bicarbonate, and sulfate.
Aquifer - a formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs.
Artesian - a well deriving its water from a confined aquifer (water is held under pressure by overlying rock materials having distinctly lower permeability). The water level in an artesian well stands above the top of the aquifer (and it taps; if the water level stands above land surface, the well is a flowing artesian well.
Background - defined for this study as the natural levels of chloride found in fresh ground water that is not contaminated by saltwater.
Bedrock, consolidated rock - dense, hard rock in which individual grains are firmly cemented together by heat and pressure.
Cations - ions in solution that are positive in charge, such as calcium, magnesium, sodium and potassium.
Coliform bacteria - a group of bacteria found in the intestinal tracts of mammals. Although relatively harmless themselves, they are used to indicate water that contains disease-producing bacteria and viruses and, therefore, can be used as indicators of pollution.
Commingled - the mixing of water from different aquifers such as in a flowing artesian, storm, or public water supply.
Confined aquifer - an aquifer in which water is under pressure greater than atmospheric pressure and is held in the bottom of a rock type of distinctly lower permeability than that of the aquifer. Also called an artesian aquifer.
Discharge - rate of flow at a given instant in terms of volume per unit of time--for example, gallons per minute.
Dissolved solids - for this investigation, summation of all major dissolved constituents remained in a water sample after it has been filtered through a 0.45 micrometer (0.00000 Washington) filter.
Domestic water use - water used by single-family residences principally for drinking, cooking, washing, and sanitary purposes.
Drawdown - lowering of water level in a well as a result of pumping from the well.
Evapotranspiration - the combined processes of evaporation and transpiration.
Fault - a fracture or fracture zone in a rock mass, along which there has been displacement of the two sides relative to one another parallel to the fracture.
Fracture - break in rocks due to intense folding, faulting, compaction, or other stresses.
Glacial drift - unconsolidated (unlayered) material deposited by glaciers, by glacial meltwater streams, or in glacial lakes.
Hardness - a measure of principally calcium and magnesium ions dissolved in water. It is usually reported as an equivalent concentration of calcium carbonate ($CaCO_3$).
Igneous rock - rock formed by solidification from a molten or partially molten state.
Indicator bacteria - for this investigation, water was tested for the occurrence of two groups of bacteria - coliform and fecal streptococci. The presence of these bacteria in water supplies indicates that contamination is occurring from some source such as septic tanks, landfills, and (or) livestock.
Industrial water use - water used in a factory that manufactures, processes, or prepares a product. Also includes the sanitary facilities, irrigation of grounds, cooling, or operation of one units.
Infiltration - the flow or movement of water through the soil into the ground.
Intermontane - literally, "between mountains."
Irrigation water use - water used for watering of farm crops, school grounds, golf courses, cemeteries.
Joint - fracture or parting that abruptly interrupts the physical continuity of a rock mass.
Lineament - a set of aligned topographic features that may denote underlying structures, such as faults or fractures in bedrock.
Mean - an average of all the values in a sample set.
Median - the middle value in a distribution, above and below which lie an equal number of values.
Metamorphic rock - rock that has been formed from pre-existing rocks by metamorphosis, chemical, and (or) structural change, in response to pronounced changes of pressure, chemical environment, and increases in temperature.
Ninety-five percent level of confidence - level of probability that a given value will be exceeded only 5 percent of the time out of 20, the calculated sample mean will approximate the population mean.
Percolation - movement of water through the interstices of rock or soil.
Permeability - measure of the relative ease with which a rock material can transmit liquid under a potential gradient. It is a property of the rock material dependent upon the shape and size of its pores.
Public-supply water use - water used for two or more household; commercial, industrial, or agricultural purposes, water districts, or municipalities.
Primary water-quality standards - maximum permissible level of a contaminant in water delivered to any user of a public water system of the national or state primary drinking water regulations as established by the Washington State Board of Health for selected physical properties and inorganic chemical constituents. Concentrations in excess of these maximum contaminant levels are considered to be a health risk and a violation if these waters are used for domestic use.
Recharge - the process by which water is added to an aquifer; the quantity of water that is added to the aquifer.
Recreation water use - for this investigation, water used for swimming and other recreation.
Relatively flushed - saline ground-water that occurs either because of incomplete flushing of salty water from ancient seawater intrusions or because it is true connate water (salty water stored in the aquifer since its deposition).
Secondary water-quality standards - recommended maximum levels established by the Washington State Board of Health for selected physical properties and inorganic constituents in drinking water; these levels relate to odor, appearance, and aesthetic qualities of the water supply.
Sedimentation - the process of the accumulation, compaction, and consolidation of sediment.
Specific capacity - rate of discharge of water from a well divided by the corresponding drawdown of the well, usually expressed in gallons per minute per foot of drawdown.
Specific conductance - measure of the capacity of water to transmit an electric current, usually given in micromhos per centimeter at 25° Celsius, indicative of concentration of dissolved solids.
Static water level - for this investigation, the water level of a well that is not being affected by withdrawal of ground water.
Stock water use - water used for livestock.
Stratigraphy - the study of the sequences of geology related to time. Stratigraphic sequence, and correlation of rock units.
Till - the part of glacial drift deposited directly by a glacier; an unsorted (nonlayered) mixture usually of cobbles, pebbles, and gravel in a matrix of clay, silt, and fine sand.
Transmissivity - the rate at which water is transmitted through a unit width of an aquifer under a unit hydraulic gradient.
Unconfined aquifer - an aquifer whose upper boundary is the water table.
Water table - the surface in a ground-water body at which the water pressure is atmospheric.
Water-table contour - imaginary line joining points of equal altitude on the water table.

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