PRELIMINARY HYDROGEOLOGY OF THE CASCADE AREA, VALLEY COUNTY, IDAHO

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By

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INTRODUCTION

The Cascade area has experienced increased population growth during the last several years which will likely continue through the foreseeable future. Consequently an increase will result in the demand for clean water supplies and for environmentally acceptable repositories of effluent. This study of the region surrounding Cascade (Figure 1) was undertaken at the request of the Idaho Department of Environmental Quality in order to provide hydrogeological data that will enhance their ability to efficiently manage these increased demands. To this end, we have compiled and reviewed existing geologic and hydrogeological data where available, and have provided new data where possible to fill gaps. Past studies have focused on glacial deposits (Othberg, 1987), faulting (Anderson, 1934; Giorgis et al, 2004), hydrothermal potential (Wilson, 1976), mapping of crystalline rocks of the Idaho batholith (Lund, et al, 1999), and engineering reports describing local hydrogeology near new developments. These studies, however, do not tell the complete

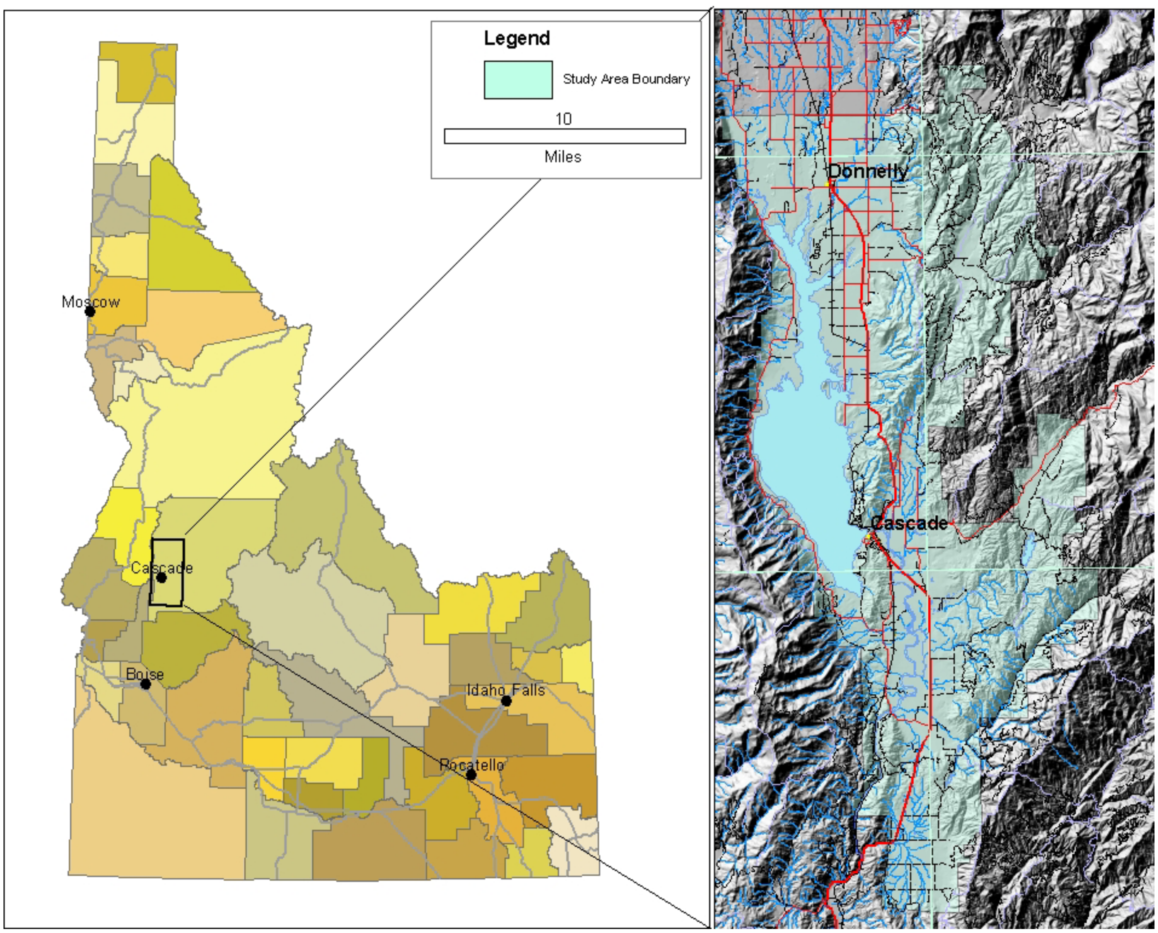

Figure 1, Location map of the Cascade study area, Valley County, Idaho story of the complex hydrogeology of this area, and this study falls short as well. Only sparsely distributed hydrogeologic data are available for much of the terrain in the study area, and no comprehensive geologic maps have been published. We attempted to synthesize all available data in the most meaningful and accurate way possible, but may have extrapolated these data beyond the limits that some researchers will find acceptable. Our conclusions should therefore be viewed as preliminary. The reader of this work should know that a full understanding of the hydrogeology must await information that fills the fragmentary and incomplete database.

The primary access point to data as part of this study resides in the digital geologic map, support files, and the Access database. The digital geologic map, portrayed graphically in Plate 1 shows lithologic information on surface and at depth; well logs, hydrologic data, and structural information are accessible via hot links on the digital map and in the Access database. This report provides an overview of these data. A CD containing the digital geologic map, support files and Access database accompanies this report.

Purpose

This study was designed to provide hydrogeologic information that will assist the Idaho Department of Environmental Quality (IDEQ) in evaluating water supply and septic disposal issues in the Cascade area. IDEQ utilizes a nutrient-pathogen evaluation nitrogen mass-balance spreadsheet that calculates lot size based on recharge, gradient and hydraulic conductivity estimates. The spreadsheet utilizes a mass balance approach documented by Bauman (1985). Our study provides estimates of much of the required spreadsheet input data for each of the geological units that occur in the study area.

Objectives

Our objective in completing this study was to provide basic hydrogeologic descriptions of the many lithologic units in the Cascade area and to provide insight relative to water supply and septic disposal issues. The descriptions include the distribution of surficial litho-geologic units and subsurface units, as well as the hydrogeologic characteristics of each unit. We chose to present these data in association with a digital geologic map in a GIS that will allow insertion of new data as they become available.

Methods of Study

Creation of a bibliography of past geologic and hydrogeologic work initiated our studies. The REFERENCES CITED AND PARTIAL BIBLIOGRAPHY section of this report summarizes results from this literature search. Our study area, shown in Figure 1, includes all of Round Valley and the southern and central part of Long Valley; it does not include the northern portion of Long Valley where Quaternary glacial processes had a greater influence on the distribution of basin-filling sediments.

Surface Geology

We compiled available geologic mapping from public sources (Wilson, 1976; Lund et al, 1999; Othberg, 1987). The digital geologic map (on CD and Plate 1) uses this information as well as a comprehensive interpretation from aerial photography from photos provided by Boise National Forest, and from field analysis of outcrops.

We collected fracture and joint data from 85 granitic rock outcrops located throughout the study area. Fractures are defined by the American Geological Institute as breaks in rocks that may or may not show displacement across the broken zone whereas joints are a special type of fracture that shows no indication of displacement. Fractures that show displacement have a higher probability of containing fine-grained material such as clay. Both fractures and joints will influence the direction and rate of ground water flow. Data generated from our structural study were analyzed using equal-area stereonet projections and are presented both graphically and as raw data in the GIS database. Graphical stereonet projections of raw data from each location are hot linked to the geologic map. The collection of these structural data provided an opportunity to field check the lithologic units interpreted by air photo analysis.

Subsurface Geology

Water well logs acquired from the Idaho Department of Water Resources (IDWR) were used to determine and describe subsurface lithologies. Scanned images of the well logs were georeferenced and attached by hot links to the geologic map to provide easy access to these data. Defining an accurate location of the drill holes that these logs represent is an inherent problem. We attempted to locate the wells that we utilized by using Map Quest (www.mapquest.com/), so most are located relatively accurately. Well locations shown on Plate 1 that do not have hot-linked logs have not been checked and were located randomly within the quarter-quarter section recorded on the log. Geophysical data, where available, were used to provide additional subsurface geometries (Bradford et al, 2004; Liberty et al, 2003).

Hydrogeology

Well logs on file with IDWR were used to infer the potentiometric surface. The wells were projected onto 10 M DEMs to obtain well head elevations. The depth to static water was then subtracted from the well head elevation to obtain elevation of the static water table. The potentiometric surface map was produced by kriging the elevation of the static water table. Although the water table changes with time, introducing noise into the potentiometric surface data, kriging tends to smooth these data producing reasonable maps.

We collected available data from hydraulic tests conducted in the study area. We also examined well logs for interpretable tests. Interpretable tests include data regarding pumping rate, pumping time, drawdown, and well completion information. These tests along with the subsurface geology data were then used to infer hydraulic conductivity for the various geologic units.

GEOLOGIC ANALYSIS

The Cascade area lies along the western margin of the Idaho Batholith, a region of Cretaceous and Tertiary-age granitic rocks. Mid-Tertiary basaltic lava flows of the Columbia River Group lie above the granites (Manduca, 1993; Schmidt, 1964; Fitzgerald, 1982). Our study area lies within a Tertiary-age fault-bound depression within the granitic terrain. It forms a unique hydrogeological entity, the Cascade basin, which includes Round Valley in the south, Long Valley to the north, and several smaller peripheral basins to the east (Figure 1). Based on the stratigraphic and structural juxtaposition of Cretaceous granitic rocks with Columbia River basalt, and overlying Tertiary sedimentary basin infill, we infer that the Cascade basin began developing in mid Tertiary time. Recent seismic activity centered near Cascade indicates that the basin is still forming (http://www.bhs.idaho.gov/local/counties/valley.htm).

The geologic map (on CD and Plate 1) shows the type of rocks or sediments exposed at surface. Our database and the digital map include the type of strata that occurs below surface and an average depth to those strata. This interpreted vertical stratigraphy is based on lithologies shown in well logs, on exposures of older strata along basin margins, and on geophysics where available. The following section discusses these rock types from old to young.

Lithology

Crystalline Rocks Of The Idaho Batholith

Granitic rocks of the Cretaceous Idaho batholith form the bedrock substrate throughout the Cascade Basin. Numerous separate intrusions representing a spectrum of compositional and textural varieties were mapped by Lund et al (1997, 1999), Wilson (1976), Manduca (1993), Schmidt (1964), and were confirmed by our work. The suite of granitic rocks includes granodiorite, tonalite, quartz monzonite, and true granite. We combined these individual crystalline rock types (Kib, Plate 1) into one unit because they show hydrologically similar properties. The rock types, distribution, and descriptions from the original mappers can be accessed from within our digital map.

Tertiary Strata

Tcrb

Basaltic lavas of the Columbia River Basalt group occur as erosional remnants above the granitic rocks (Figure 2). They lie within some of the basins and on higher surrounding ground. The unit consists of massive olivine basalt lavas and contains locally interbedded lacustrine sediments. The lavas generally contain abundant polygonal cooling joints. Weathering of exposures, particularly along joint surfaces, has resulted in well-developed clay-rich spheroidal weathering rinds. This process tends to fill fractures with hydro-expandable montmorillonite clay. The extensive weathering of the near-surface lava has resulted in a capping of low hydraulic conductivity material on the top of the basalt unit. It forms subdued outcrops flanked by thick, reddish montmorillonite-rich clay soil.

Figure 2; Exposure of Columbia River basalt lava in road metal quarry; located south of Donnelly in Section 2, T15N R3E. Note drill holes in center of photo; they were probably drilled to acquire paleomagnetic data.

Ts

Undifferentiated Tertiary sedimentary strata occur below, within and above the Columbia River Basalt sequence (Tcrb, Plate 1). They consist of consolidated and commonly lithified clay-rich fluvio-lacustrine beds. These strata, where exposed at surface, weather to very clay-rich soil and generally do not form outcrops. This unit was identified at surface by the presence of distinct terrace-shaped land forms recognized on aerial photographs and confirmed by clay-rich road cuts. Subsurface occurrences were identified by the presence of thick clay-rich beds in drill logs. The unit includes historic names such as the Payette and Latah formations. Modern-day landforms have no apparent bearing on the shape of older Tertiary units such as Ts and Tcrb.

TQs

Late Tertiary (?), Pliocene (?) and early Quaternary fluvio-lacustrine deposits consisting of clay-rich gravel occur interlaye red with silty lacustrine beds (Figure 3). The unit was identified by the presence of strongly dissected terrace deposits. This is the oldest unit that accumulated in sedimentary basins that are still present today, such as Long and Round valleys. These strata probably accumulated during the incipient stages of development of these structural bedrock depressions.

Figure 3; Road cut exposure of dissected terrace gravel in Section 33, T16N R4E.

Quaternary and recent sediments

Qf

Geologically recent flood plain deposits form unit Qf. They consist of unconsolidated clay, silt, sand, and locally, gravel that accumulated in flooding events during which water left normally active channels. The Unit was defined from aerial photos that show geomorphic evidence of fluvial activity such as truncated meander scars. Field inspection showed that the unit consists primarily of clay and silt beds with interspersed sand and occasional gravel beds. Individual beds do not show planimetric or vertical continuity.

Qal

Undifferentiated Quaternary surficial deposits of unconsolidated clay, silt, sand, and gravel deposits form unit Qal. They show no evidence of recent sedimentation on aerial photographs but conversely show no evidence of active dissection. The unit includes gravel deposits that fill structural basins, glacial outwash, and pre-recent fluvio-lacustrine deposits.

Qaf

Quaternary and recent cone-shaped alluvial fan deposits occur as unconsolidated material that accumulated at the mouths of high-gradient streams during flash-floods. The material forming these deposits is generally unexposed, but exposures indicate that it consists of unsorted accumulations of coarse gravel in a clay, silt, and sand matrix. The unit was defined geomorphically from aerial photo interpretation and field evaluation.

Qfg

Quaternary-age fan-gravel deposits occur as unconsolidated material that accumulated along range-fronts and commonly along fault scarps such as the west side of Long Valley. The unit consists of unsorted and unlithified material with size fractions that range from clay to boulders tens of meters in diameter. Accumulations likely formed from mass-gravity deposits along the base of West Mountain. The horizontal and vertical distribution of this unit is highly unpredictable.

Qls

Quaternary landslide deposits formed from mass-gravity failure of steep slopes, primarily along fault scarps. The unit consists of unconsolidated coarse to very coarse material in a clay, silt, and sand matrix. Individual slides were identified by their distinctive morphology from aerial photos. Their position along fault scarps suggests that the slope failures may have been seismically induced.

Qg

Quaternary glacial outwash deposits accumulated along range fronts below areas of alpine glaciation and consist of unconsolidated clay, silt, sand, and gravel. The unit occurs as a mantle on older Quaternary and Tertiary deposits, and shows active dissection by modern-day streams. Mapping by Othberg (1987) delineates these surficial deposits in detail; some of the more extensive deposits were compiled on Plate 1 from his mapping.

Structure

Structural Architecture of the Cascade Basin

Tertiary basins like those in the Basin and Range province of Nevada generally contain numerous internal basins, and complex stratigraphy. They generally take millions of years to form and show complex patterns of development dictated in part by changes through time of regional stress fields. As stress fields change some faults cease to move while others form or reactivate.

The stratigraphy revealed by well logs and the shapes of basins shown by mapping and air photo analysis in the Cascade area show strong similarities to the Nevada-style basins. The Cascade basin contains a number of internal fault-controlled sub-basins separated by granitic horst blocks. The ridge of granite separating the valley occupied by Cascade Reservoir from Long Valley East of Cascade is such a horst block (Plate 1). The most visible internal basins include Round Valley, Little Valley, and Scott Valley (Plate 1). Each of the internal basins contains a unique type of infill; the specific type depends primarily on how vertically extensive the basin is and subordinately on its longevity. The deepest and earliest-formed sub-basins displaced Columbia River basalts and protected them from erosion. Sub-basins such as Long Valley near Donnelly have preserved sections of Columbia River basalt and an overlying section of Tertiary-age sedimentary infill. The more recently formed sub-basins such as Round Valley contain Tertiary-age sedimentary infill but no lavas, presumably because they were eroded away prior to basin formation.

Fault-Set Orientations

Past mapping and our field evaluation of the Cascade basin show that normal faults define the most prominent type of structure. The faults form three primary sets based on strike orientation; a north-south trending set, a west-northwest set and a northeasterly trending set (Plate 1). Crosscutting relationships and fault truncation patterns suggest that the west-northwest and the northeast sets generally predate the north-south faults. These three fault sets worked in concert to form the margins of the Tertiary basins. Fractures in granitic rocks generally parallel these fault orientations, which indicates that they were caused in part by formation of the faults.

Structural Fabric Analysis

The hydraulic conductivity of granitic rocks is controlled by weathering near surface and by fracturing at greater depths. We felt, therefore, that an understanding of the regional orientation of fracture patterns would enhance our understanding of ground water flow directions in these crystalline rocks. We measured the orientations of fracture patterns in 85 outcrops distributed throughout the study area. Our goal was to measure fractures in outcrops dispersed evenly throughout the study area but we found a paucity of outcrops in the central part. Plate 1 shows locations of data points from our analysis; the raw structural data are available in the database, and as southern hemispheric graphical representations hot linked to the data points on the digital map. The stereonet images are also on the CD.

Our analysis of fractures and other structural fabrics revealed three primary types; variably open fractures, aplite filled veins, and a strong, pervasively crushed mineral fabric including fault-gouge-filled shears. Graphical representations of these data are shown in Figure 4A - D. Variably open fractures (Figure 4A) have the greatest potential of controlling ground water flow, and these fractures show a diversity of orientations throughout the area studied. Rose diagrams (Figure 4A; Appendix 1) are the best tool to show populations of planar fabrics, such as fractures. They are circular histograms that show concentrations of strike orientations. The other types of fabrics (Figures 4B and C) are much less permeable. Figure 4D shows a contoured stereonet representation of all data combined.

When viewed globally all measured structures show a random pattern (Figure 4D). Geographic subsets of their orientations, expressed in rose diagrams, show more consistent patterns. Our geometric analysis shows that fractures and joints form three primary sets that mimic the orientations of mapped normal faults (Plate 1). We have geographically referenced rose diagrams to the digital map to show the compass bearing of fracture populations throughout the study area. These graphics, subset by township tiers, show this sub-region consistency (Plate 1; Appendix 1).

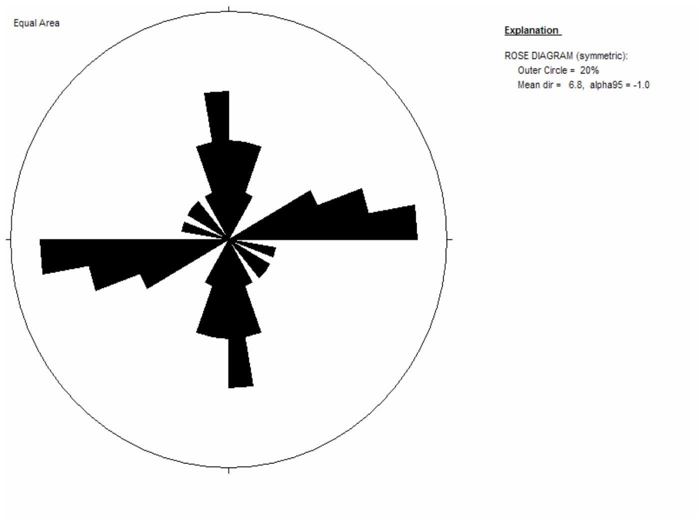

Figure 4A; Representative rose diagram showing the strike orientations of some fractures and joint populations measured in the Cascade study area. The rose "pedals" shows the concentration of compass bearings of strike; the outer circle represents a 20 percent

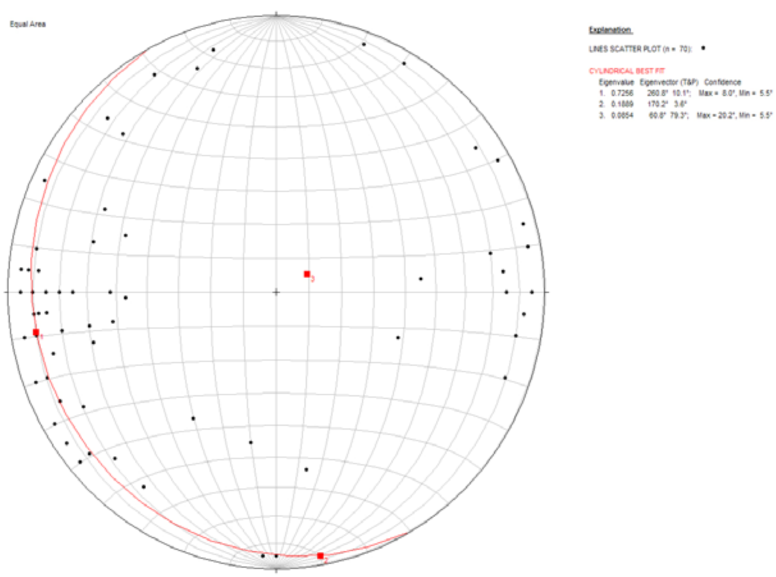

Figure 4B; Stereonet representation from the crushed mineral fabric visible throughout much of the Cascade area.

The diagrams shown in figures 4A - D are graphical representations of planar fabrics. Rose diagrams (Figure 4A) show only the distribution of strike in a planar-fabric population whereas a stereonet (figures 4B – D) shows both strike and dip.

Ground water in an unsaturated medium travels vertically downward under gravitational force. Therefore in an unsaturated fracture-controlled aquifer, such as granitic rock, ground water will preferentially follow the dip of a fracture. Ground water in a saturated medium generally has a stronger horizontal component to flow direction, so will preferentially travel along the strike of fractures in the down-gradient direction. The utility of these diagrams, therefore, depends on whether the ground water being evaluated saturates the aquifer. If an aquifer is unsaturated stereonet diagrams show information useful to flow direction. These types of diagrams are hot-linked on the map to each outcrop that we evaluated. The diagrams show each plane that was measured and the bearing and plunge of a line that represents the geometric average line of intersection of all planes at that location. The compass bearing of dip of a given plane will approximate the ground water flow direction along that fracture. These diagrams should only be used in an unsaturated, fracture-controlled medium.

In a saturated, fracture-controlled medium, such as crystalline rocks, rose diagrams show data pertinent to flow direction. In the saturated part of a fracture-controlled aquifer ground water preferentially flows along the strike of fractures in a down-gradient direction. Therefore the patterns shown by the rose diagrams indicate this preferential flow direction when used in conjunction with the water-table map. The rose diagrams show both possibilities of compass strike orientation, so the water table map would indicate which of these two orientations water would flow along. When two or more orientations are present, which is generally the case; the direction of ground water flow will probably be a function of fracture opening, concentration and an average of their orientations. Also, when two primary orientations are present, as in the case of much of the study area, ground water will probably flow better along the fracture set that lies closer to the ground water gradient direction than one that lies closer to normal.

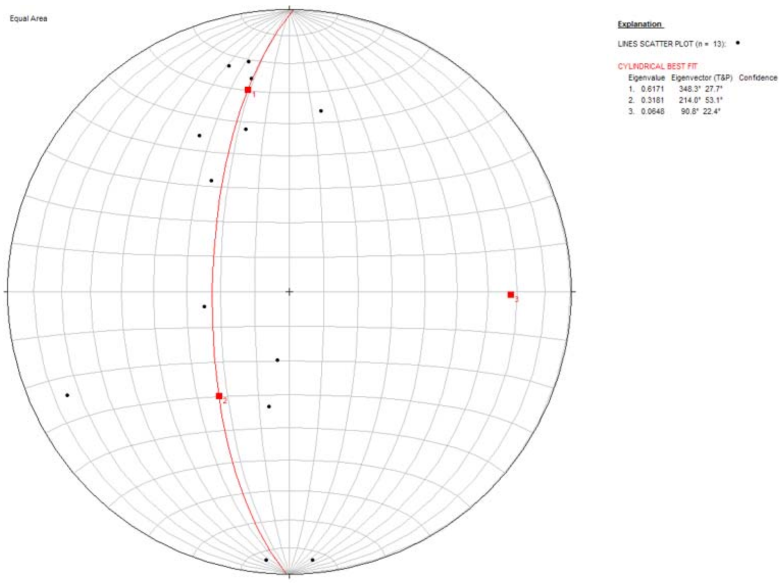

Figure 4C; Stereonet representation of aplite-filled fractures.

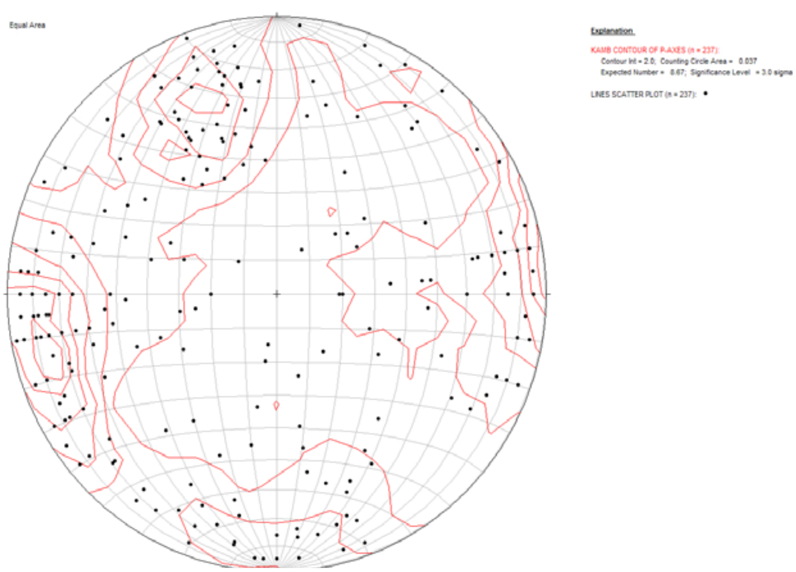

Figure 4D; Stereonet representation of all fabric types measured; red contours represent 2 percent increments of data concentration.

Hydrothermal Alteration

The Cascade region is a known hydrothermal area demonstrated by thermal wells and numerous hot springs (Wilson et al, 1976). Though study of this resource is beyond the scope of this project, residual effects of past thermal activity impacts ground water recharge and flow; interaction of thermal water with adjacent rock in conduits alters some original rock-forming minerals to clay. Elevated levels of clay, particularly hydro-expandable montmorillonite negatively impacts recharge and flow of ground water.

Geometry of Hydrothermal Alteration Systems

Hydrothermal systems that occur at surface do so by utilizing plumbing systems such as fractures and faults that allow the thermal water to travel rapidly to surface before cooling. Hydrothermally altered areas tend to weather and generally do not form outcrops. Our study recognized several areas where increased alteration occurs at the intersections of north-south trending faults with northeasterly or northwesterly trending structures. Wilson and others (1976) recognized 11 fault controlled hot springs within 12 miles of Cascade.

Zones of greater fracture density commonly envelop faults. We observed this in several areas of the Cascade basin where increased fracture concentrations occur in proximity to mapped faults. The road cuts along state highway 55 a few miles north of Cascade expose perhaps the best example of clay altered granitic rocks with strong fracturing that occurs along a major northeast-trending fault zone (Plate 1). The northerly projection of this fault system, in sections 13, 14, 22, 23, 24, 35, and 36, T15N R3E, is an area where a northeast-trending fault intersects at least two large west-northwest fault sets. Exposures of altered granitic rocks in the state park (section 35), active hot springs in section 13, and the low-lying terrain throughout these sections suggest that this entire area has been hydrothermally altered. Well logs and rock exposures indicate that altered granitic bedrock occur at a very shallow level throughout this area, so ground water recharge and flow will be limited by clay concentrations in fractures (Figure 5). The digital map can show the distribution of the terrain with shallow crystalline bedrock by configuring the symbology display parameters to use the SUBSTR_1 field.

The Cascade basin has numerous other aerially extensive clay-rich areas that probably formed from past hydrothermal activity. Road cuts within the community of Cascade indicate that this is such an area. Altered granitic terrain exposed in road cuts document other similar areas, including the Warm Lake highway north and northwest of Horse thief reservoir, the Gold Fork hot springs area, and the low hills centered in sections 9, 10, 16, 17, 20 and 21, T12N R4E. It is difficult to access how much of the alluvial covered terrain in the valley floors has been clay altered.

Figure 5: Photograph of hydrothermally altered and iron stained fractures in crystalline rocks of the Idaho Batholith; Taken one mile north of Gold fork hot spring.

HYDROGEOLOGIC ANALYSIS

This section provides an overview of the hydrogeology of the study area. In a regional sense, precipitation acts as the ultimate source for all recharge. In the Cascade area most of the precipitation recharging the ground water system originates in the mountains as snow during the winter. In the spring, the accumulated snow melts. Because spring temperatures tend to be cool and plants are just emerging, evapotransporation rates are small, allowing a high percentage of the infiltrating water to recharge the aquifers. Water recharged from snowmelt within the mountains tends to flow through shallow ground water flow systems to discharge either as small springs, as gaining reaches of small streams or as ground water flow into the aquifers that underlie the valley floor. Water recharged from snowmelt on the valley floor tends to directly enter the shallow ground water system in the valley. Ultimately, the ground water within valley flow systems discharges either as evapotranspiration or to the North Fork of the Payette River in Gaining reaches.

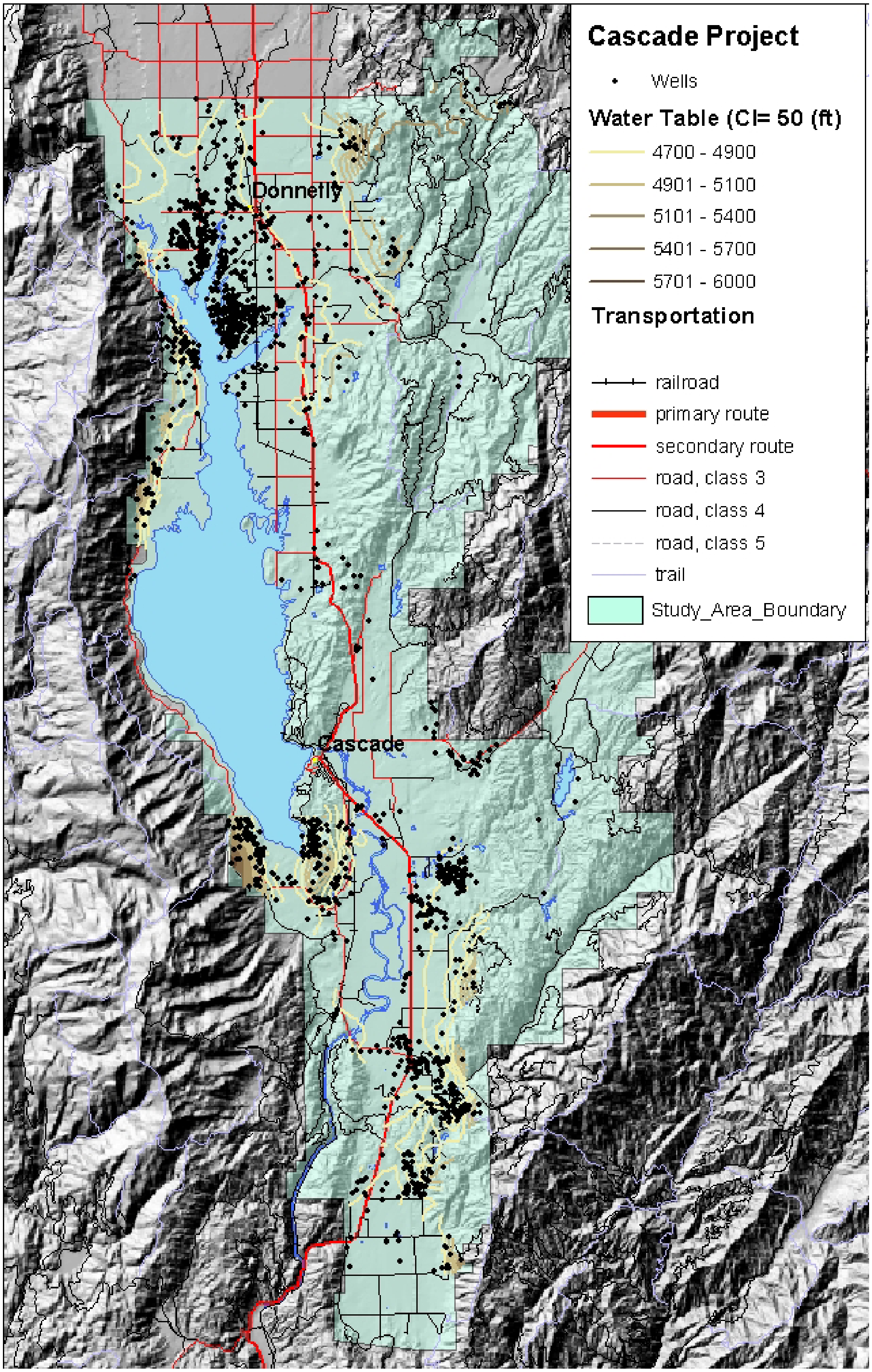

Figure 6. Potentiometric map.

The remainder of this report will discuss ground water flow systems, septic disposal issues, input parameters for the IDEQ spreadsheet, and conclude with an analysis of uncertainties in predictions from the spreadsheet. The ground water flow system section begins with a regional flow system discussion followed by an analysis of flow within the granitic rocks, the Tertiary sediments, and the Quaternary sediments.

Regional ground water flow system

The potentiometric surface map in Figure 6 was constructed using data gleaned from well logs on file with the IDWR. This water level data is collected by the drillers after they finish drilling each well, thus data from different years, seasons and depths are all included in the one data set. This sort of data set contains significant noise because of water level trends, seasonal fluctuations and vertical gradients. Although this data contains a fair amount of noise, it reveals many relevant characteristics of the regional flow system. The regional flow system is recharged in the mountains and discharges in lakes, rivers, and streams in the valleys as well as by evapotranspiration.

Round Valley, near the southern end of the study area is a closed structural basin with no surface water outlet. Since there are no evaporate deposits or saline seeps in the basin, an outlet for the ground water must exist. Perhaps the water exits along the southeastern most faults bounding Round Valley; alternatively the water may exit to the west or south west, toward the Payette River.

Ground Water Flow Systems In Granitic Rocks

The exposed granitic rocks tend to support ridges and hill tops, and thus receive higher precipitation rates than the other areas. All of the granitic outcrops we located consisted of heavily weathered material. This material tends to contain high percentages of clays. We think that this material would tend to inhibit infiltration. Thus, we think infiltration rates are modest in the granitic terrains, and most of the infiltration that does take place in the granitic rocks, probably takes place in less altered areas. The infiltrating water will follow fractures moving generally vertically down to the water table. Once it contacts the regional aquifer, the ground water works its way through the fractures towards the valley.

The necessity of following the fracture system tends to skew the flow direction toward that of the dominant fracture system. We collected data to help identify the direction of this skewing (anisotropy). This information was presented in the structural fabric analysis section above.

Ground Water Flow Systems In Older Quaternary And Tertiary Sediments

These sediments fill Long Valley and Round Valley at depth, thus the transition from fracture flow ground water flow in the granite to porous media flow in the sediments occurs along the edge of the valleys. This transition will generally result in a slowing in ground water velocity due to an orders of magnitude increase in porosity and more modest increase in hydraulic conductivity. The transition will also result in a change from fracture induced anisotropy to a host rock that probably does not impose significant anisotropy at depth.

Because these sediments are much older than the more recent Quaternary sediments, some digenetic changes have taken place. Such changes generally include weathering feldspars into clays, and cementation. These processes tend to reduce both porosity and hydraulic conductivity.

Ground Water Flow Systems In The Younger Quaternary Sediments

Ground water flow takes place within the younger Quaternary sediments in areas where the water table is close to the surface, such as in Round Valley and in Long Valley near the north end of the study area. Also recharge in the valleys takes place through the younger Quaternary sediments and discharge into lakes, rivers, and streams also takes place through the younger Quaternary sediments.

Analysis of the well logs we obtained from IDWR indicates that the younger Quaternary sediments are not usually used as aquifers; only 434 wells out of the 1440 we examined are less than 50 ft deep. Perhaps this is because the younger Quaternary sediments are considered vulnerable to contamination, or perhaps these sediments have limited storage capacity, or possibly these sediments tend not to yield adequate water to wells. Whatever the reason, these sediments do not tend to be the aquifer of choice in the Cascade area.

Only 25% (365/1440) of the wells we located for the Cascade area are less than 50 ft deep. 16% (59/379) of the wells completed in granitic rocks are less than 100 ft deep. Perhaps most wells are deeper than 50 ft because deeper wells tend to yield more water or have more available drawdown. In any case, the shallow, near surface material (be it crystalline or alluvial) is rarely used as a source of water in the Cascade area.

Septic disposal issues

A septic system consists of an underground tank and associated drain field. Typically the inlet is on one side of the tank and the outlet to the drain field is on the other side. Household waste enters on one side and processed waste exits toward the drain filed on the other side. Usually the tank is divided into two compartments. The first compartment is where the solids settle out forming a layer of sludge. Incoming waste forces the more clarified material as well as material less dense than water into the second chamber. Microorganisms digest the material in both chambers of the tank anaerobiclly (in the absence of oxygen). The incoming waste also forces some of the material from the second compartment out to the leach filed. Ideally constant use keeps the leach field perpetually wet. The persistent moisture allows a microbial mat to develop. This matt acts as the final filter metabolizing any leftover nutrients. If the soil is too permeable the it will not retain enough moisture to allow development of a healthy mat, on the other hand, if the soil is not permeable enough to allow the effluent escape rapidly enough, the area will be saturated.

The principal contaminants of concern from private septic systems include pathogenic microorganisms, nitrate, and synthetic organic molecules included in household chemicals such as solvents, cleaners, degreasers and pesticides. In a well-designed system the pathogenic microorganisms have to compete with the organisms in the mat. If the soil is too permeable allowing moisture to move away from the drain field quickly, a mat will not develop, allowing the pathogens to escape. A well-designed system with a healthy mat will also serve to metabolize any nitrate escaping the tank. The fate of synthetic organic molecules is quite variable. The environment in the septic tank and drain field mat is quite hostile, but frequently exotic microbial communities are required to completely degrade many of these chemicals.

When septic effluent leaves a drain field and mat, it migrates down through the vadose zone toward the potentiometric surface. In porous granular media this migration tends to involve more or less vertical percolation. In fractured rock the effluent must follow the fractures, moving along the surface of the rock or along sub-horizontal fractures until a sub-vertical fracture is encountered allowing access to the water table.

Once at the water table, the effluent will move with the ground water, generally staying at or near the potentiometric surface. In porous granular media fluid slowly weaves between the grains of earth material in the down-gradient direction. In fractured rock the effluent must follow the fractures, moving through a maze of high-angle and low-angle faults and fractures in the general down-gradient direction.

Effluent transport parameters

The IDEQ spreadsheet program requires estimates of water table gradient, hydraulic conductivity, and recharge. Gradient determines the direction in which the ground water will move. Hydraulic conductivity is a measure of how easily water can move through the earth material. Recharge adds water to the ground water system, additional water will serve to dilute any effluent plume. The program uses this information to calculate the potential for a proposed development to exceed a target nitrate level.

Gradient

The potentiometric surface map in Figure 6 shows the elevation of the water table. The potentiometric surface in this figure is trimmed to show contours only in areas where the data density is high enough to produce reasonable results. This map shows water moving from the mountains toward the valleys. Near the north end of Cascade Reservoir east of Donnelly the map shows the potentiometric surface dipping steeply toward the valley floor. South and west of Donnelly the map shows the potentiometric surface dipping steeply from West Mountain toward Cascade Reservoir. South of Cascade along the ridge between Long Valley and Round Valley the potentiometric surface slopes north toward Long Valley and south toward Round Valley.

The hydraulic gradient map in Figure 7 provides an estimate of the ground water gradient. The warmer colors on the map indicate steeper gradients. Note that the gradients tend to become steeper near the contact between the granitic rocks and the alluvial sediments. In most instances these are fault contacts as well as rather abrupt changes in hydraulic conductivity and porosity. The gradient map does not explicitly indicate the direction of ground water flow; this must be obtained from the potentiometric surface map in Figure 6.

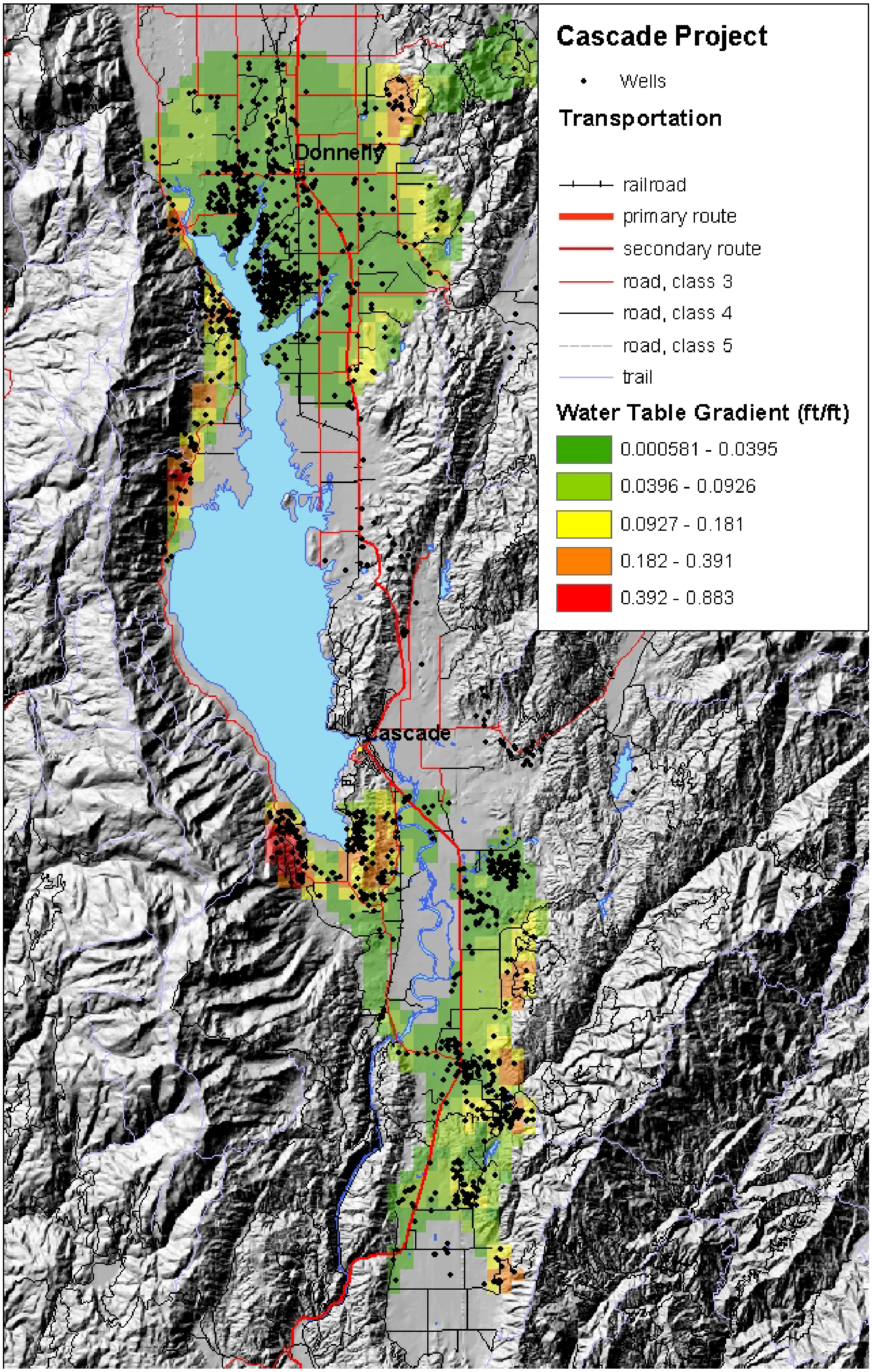

Figure 7. Hydraulic gradient map.

Porosity

Field work did not uncover any road cuts in unconsolidated sediments below the root zone. The project budget did not include drilling costs, so no samples of unconsolidated sediments were collected for laboratory analysis. In the absence of measured values, tables of characteristic values from various sources are provided (Tables 1 through 3).

Table 1. Porosity ranges from Driscoll, F.G., (1986).

Unconsolidated material	Porosity (%)
clay	45-55
silt	35-50
sand	25-40
sand & gravel	10-35
glacial till	10-25

Table 2. Porosity ranges from Fetter, C.W., (1994).

Sediments	Porosity (%)
well-sorted sand or gravel	25-50
sand & gravel	20-35
glacial till	10-20
silt	35-50
clay	33-60

Table 3. Porosity values from Todd, D.K., (1980).

Geologic Material	Representative Porosity
gravel, coarse	28
gravel, medium	32
gravel, fine	34
sand, coarse	39
sand, medium	39
sand, fine	43
silt	46
clay	42

Outcrops of the Idaho Batholith provided information that can be used to infer effective porosity. The fracture density and the aperture of the fractures on an outcrop can provide an estimate of effective porosity. Figure 8 contains porosity estimates based on observations collected at granitic rock outcrops. (number of fractures x aperture)/(length of outcrop normal to fracture pattern). These estimates apply to un-weathered or modestly weathered granite, porosity estimates for unconsolidated sediments should be used for the more heavily weathered granite. Other sources (http://www.stonecaretechniques.com/6_m.htm, http://gsa.confex.com/gsa/2001ESP/finalprogram/abstract_7550.htm, and http://www.mininglife.com/Miner/general/rock_porosity.htm) indicate that representative porosity for granite ranges from 0.4 to 1.5 %. These values are higher than most of our estimates, however, our estimates ignore intercrystalline porosity, and thus are more of an estimate of effective porosity (pore space through which water moves), which should be lower than total porosity.

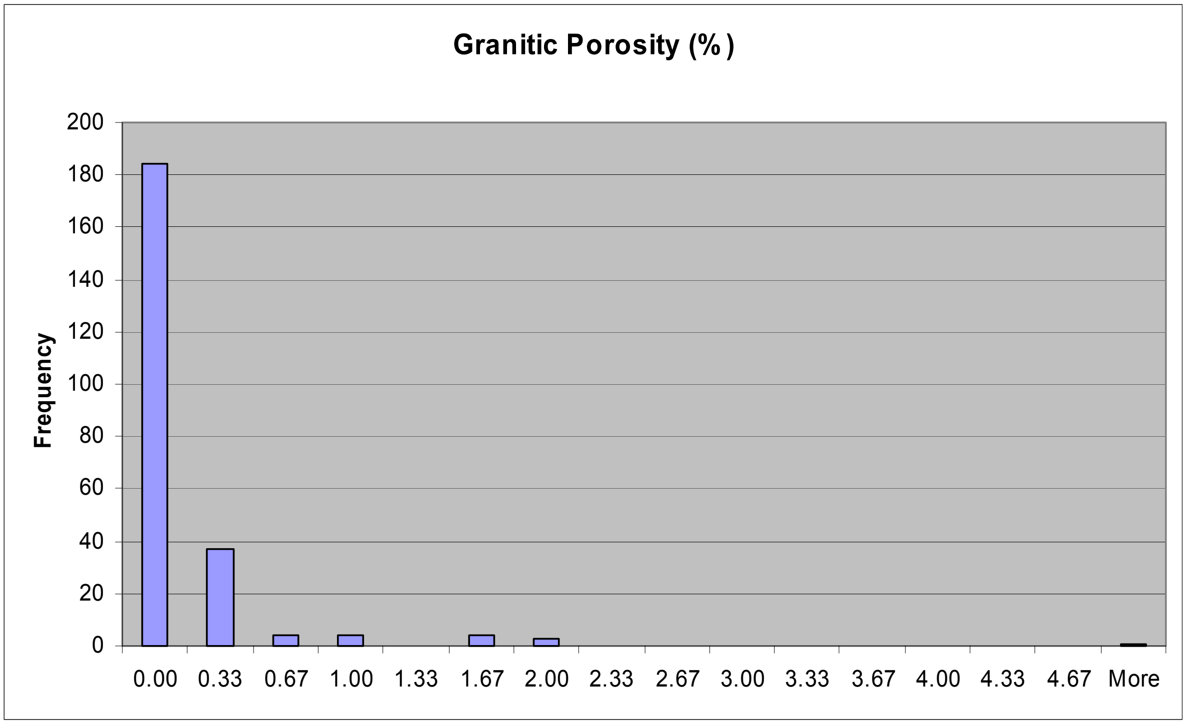

Figure 8. Granitic porosity estimated based on outcrop observations.

Hydraulic Conductivity

Several techniques exist for estimating aquifer hydraulic conductivity, these include controlled field aquifer tests, laboratory analysis of undisturbed field samples, driller conducted specific capacity tests and ranges of values from the literature. The controlled field aquifer tests are expensive, but provide more reliable estimates of the aquifers ability to store and transmit water than the other techniques. The laboratory experiments provide accurate estimates, but the volume of material tested is small, and therefore generally not as representative as a field test. Driller conducted specific capacity tests generally suffer because drillers do not collect as much data, nor do they collect it as carefully as a trained scientist or technician, however, the tests are field experiments and represent larger volumes of the aquifer than laboratory tests. Estimates from the scientific literature provide expected ranges, but may not be representative of any specific field site. We were able to locate three tests conducted by engineering firms and 31 specific capacity tests conducted by drillers in the study area. These tests and their associated hydraulic conductivity estimates are presented in Table 4.

Figure 9 shows the locations of wells with interpretable data. The transmissivity values obtained from wells listing "driller" as the source for the hydraulic conductivity value in Table 4 were calculated using data on the IDWR drilling reports and equation 1 from Driscol (1986):

Equation 1

$$T = \frac{Q}{s} \bullet 264 \bullet \log\left(\frac{0.3Tt}{r^2 S}\right)$$

where

s = drawdown (ft)

Q = discharge (gpm)

T = transmissivity (gpd/ft)

t = time (day)

r = well radius (ft)

S = aquifer storage

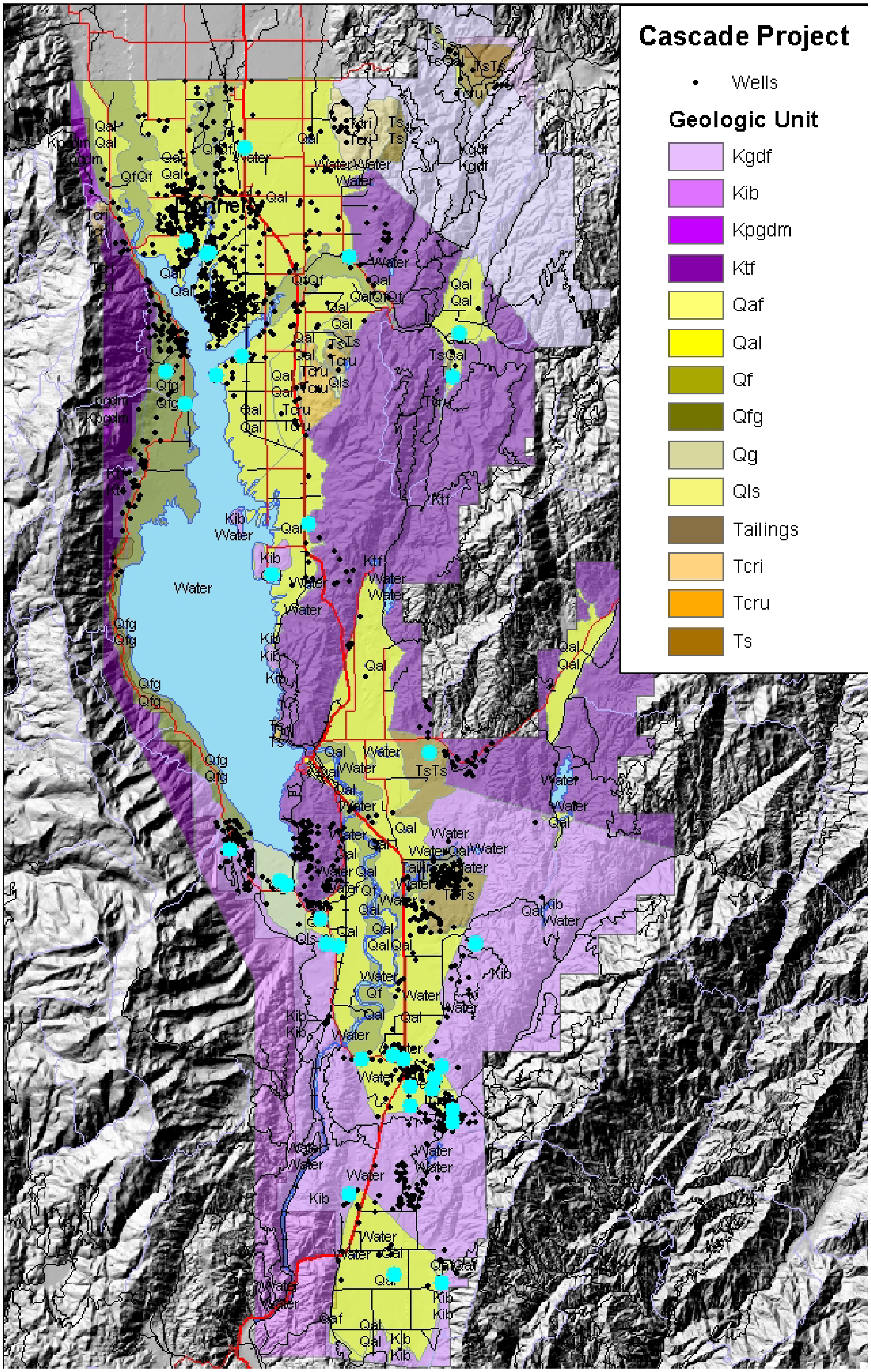

Figure 9. Location of wells with controlled aquifer tests and driller conducted specific capacity tests.

To use Equation one, the drilling report must contain specific capacity data including drawdown, discharge, and pumping time. Most drilling reports in the Cascade area did not contain all of the required information.

This equation can not be solved explicitly because transmissivity is on both sides of the equal sign. The equation must be solved by iterating to a solution. Equation one was used to calculate the transmissivity values for wells in Table 4 listing "driller" as the source. Transmissivity was obtained from engineering reports for all other wells.

Table 4. Wells with tests used to infer aquifer hydraulic conductivity. Tests where driller is identified as the source were specific capacity tests.

Owner	Source	Material	Open Interval	Well Depth	Casing Diameter (in)	Yield gpm	Drawdown (ft)	Thickness (ft)	Transmissivity (ft^2/d)	Hydraulic Conductivity (ft/d)	Aquifer
Welsh	Driller	Granite	300-400	400	4.5	2	400	100	1	0.01	Kib
Roper	Driller	Granite	24-164	164	8.0	2	134	134	2	0.02	Kib
Gestrin	Driller	Granite	50-99	100	8.0	6	90	49	10	0.2	Kib
Vail	Driller	Granite	115-138	140	4.0	10	80	23	10	0.4	Kib
Ogburn	Driller	Granite	75-90	105	8.0	10	90	15	20	1	Kib
Ratzlaff	Driller	Granite	190-250	250	4.5	50	100	60	100	2	Kib
Logan	Driller	Granite	60-80	80	6.0	9	50	20	40	2	Kib
Blm	Driller	Granite	75-95	100	6.0	15	60	20	60	3	Kib
Rice	Driller	Granite	127-137	137	8.0	10	45	10	40	4	Kib
Bennett	Driller	Granite	102	102	6.0	2	102	1	4	4	Kib
Kinnison	Driller	Granite	60-70	70	6.0	50	25	10	500	50	Kib
Bilbao	Driller	Gravel	62-68	74	6.0	12	25	6	50	8	Qal
Gatnk	Driller	Gravel	61-65	70	6.0	40	4	4	1000	200	Qal
Tamarack	Hydrologic	Gravel	302-411	560	6.0	600	121	80	800	10	Qfg
Tamarack	Hydrologic	Gravel	145-230	385	8.0	400	27	40	3000	70	Qfg
Harala	Driller	Basalt	57-61	65	6.0	4	0.0	4	80000	20000	Tcru
Martenes	Driller	Gravel	168-172	172	6.0	3.5	80	4	5	1	TQs
Healy	Driller	Gravel	65-85	90	6.0	20	40	20	60	3	TQs
Pancheri	Driller	Sand	168-305	305	12.0	200	110	62	200	3	TQs
Hollistar	Driller	Gravel	40-55	58	6.0	15	20	15	90	6	TQs
Herrick	Driller	Gravel	52-67	67	6.0	30	35	15	100	7	TQs
Carroll	Driller	Gravel	48-58	60	6.0	25	40	10	100	10	TQs
Mansell	Driller	Gravel	40-50	50	6.0	35	20	10	500	50	TQs
Wanner	Driller	Sand	200-205	206	4.5	24	15	5	300	60	TQs
Bracke	Driller	Gravel	69-84	85	8.0	45	5	15	1000	70	TQs
Ellis	Driller	Gravel	31-35	40	6.0	20	8	4	300	80	TQs
Justice	Driller	Sand	15-20	25	6.0	25	9	5	400	80	TQs
Kossler	Driller	Gravel	90-94	100	6.0	30	10	4	400	100	TQs
Campbell	Driller	Sand	72	72	6.0	25	22	1	100	100	TQs
Cascade	Driller	Sand	237-385	398	10.0	750	23	50	5000	100	TQs
Kossler	Driller	Gravel	90-94	100	6.0	30	10	4	400	100	TQs
Arroheadpt	Scanlian	Gravel	190-240	420	8.0	500	26	50	7000	100	TQs
Island	Driller	Sand	108-236	394	10.0	600	60	36	20000	600	TQs
Tomlinson	Driller	Sand	39-42	48	6.0	20	40	3	50	20	Ts

Based on the well location and the lithological data presented in the drilling report, the aquifer was assigned to one of the geologic units presented in the geologic map in Plate 1 Summary statistics for the various geologic units with interpretable well test information are presented in Table 5. The summary statistics are attached to the attribute table for the geologic map shape file forming new shape files. Table 5 is joined to the Surf_Lith column in shape file HcondSur, Table 5 is joined to the Substr_1 column in shape file Hcond2, and Table 5 is joined to the Substr_2 column in shape file Hcond3. Figure 10 shows the median hydraulic conductivity (ft/d) observed for the surficial geological unit. Figure 11 shows the median hydraulic conductivity (ft/d) for the second geologic unit. Figure 12 shows the median hydraulic conductivity (ft/d) for the third geologic unit. To use these data, one could click on the identify button in ArcView and then click on the appropriate map layer and examine the summary statistics. Knowing the depth to the water table, one could use the observed data to provide estimates of hydraulic conductivity for input into the spreadsheet model.

Table 5. Range of results by geologic unit.

Lithology	Min(ft/d)	Max(ft/d)	Mean(ft/d)	Median(ft/d)	Mode(ft/d)	No Tests
Kib	0.010	50	6	2	4	11
Qal	8	200	100	100	NA	2
Qfg	10	70	40	40	NA	2
Tcru	20000	20000	20000	20000	NA	1
TQs	1	600	80	70	100	17
Ts	20	20	20	20	NA	1

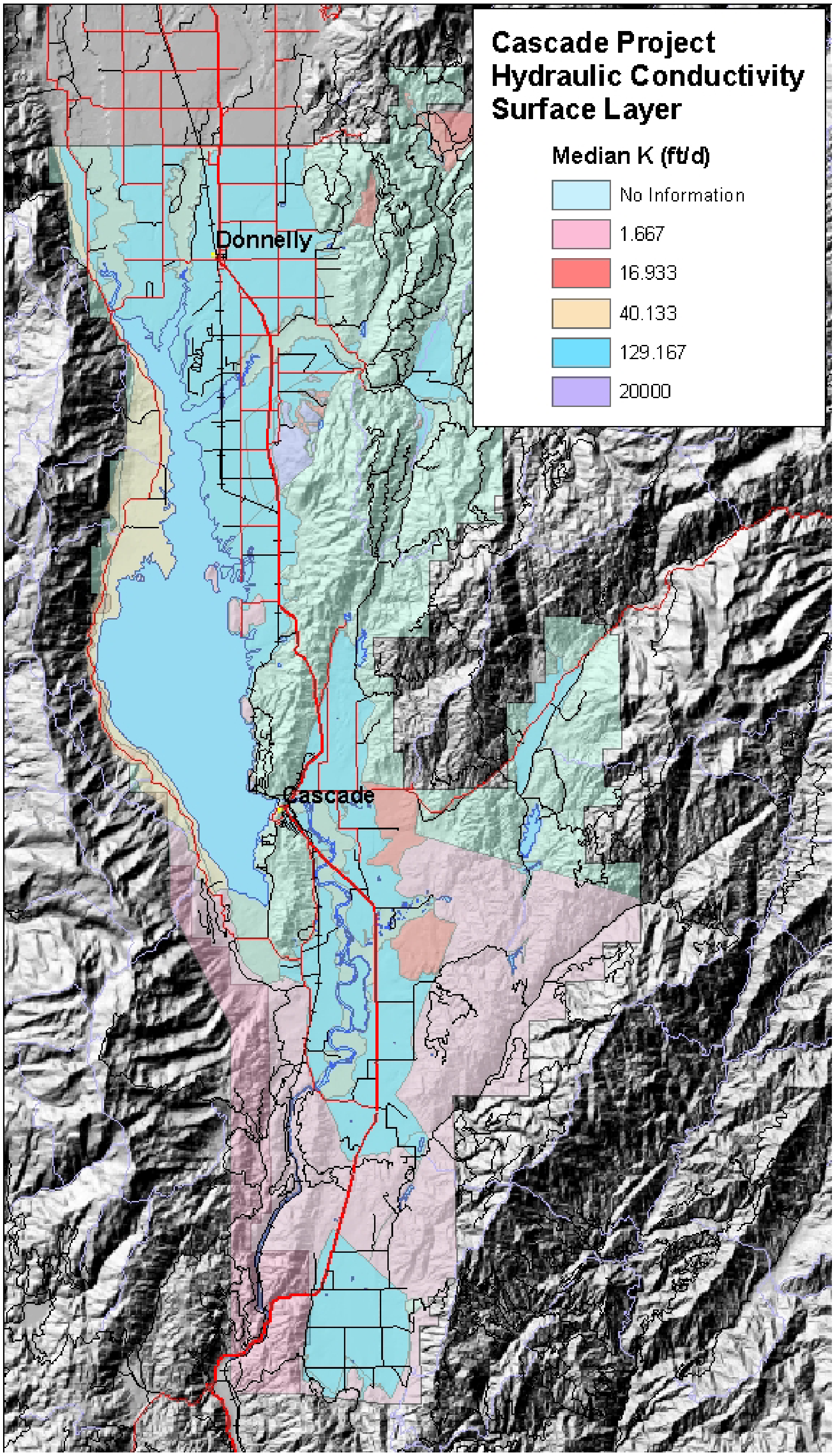

Figure 10. Median hydraulic conductivity of the surficial layer.

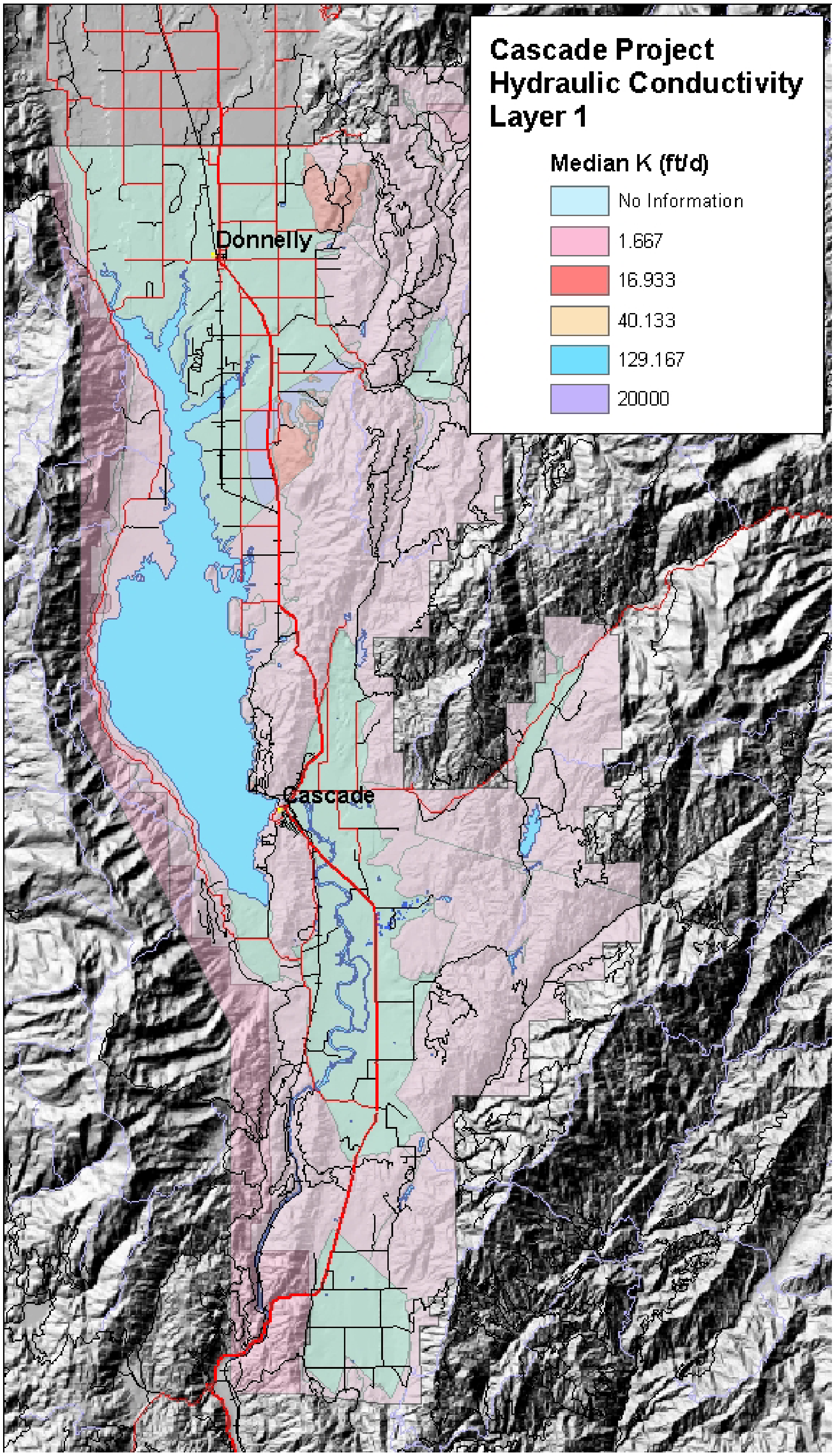

Figure 11. Hydraulic conductivity of geologic unit one.

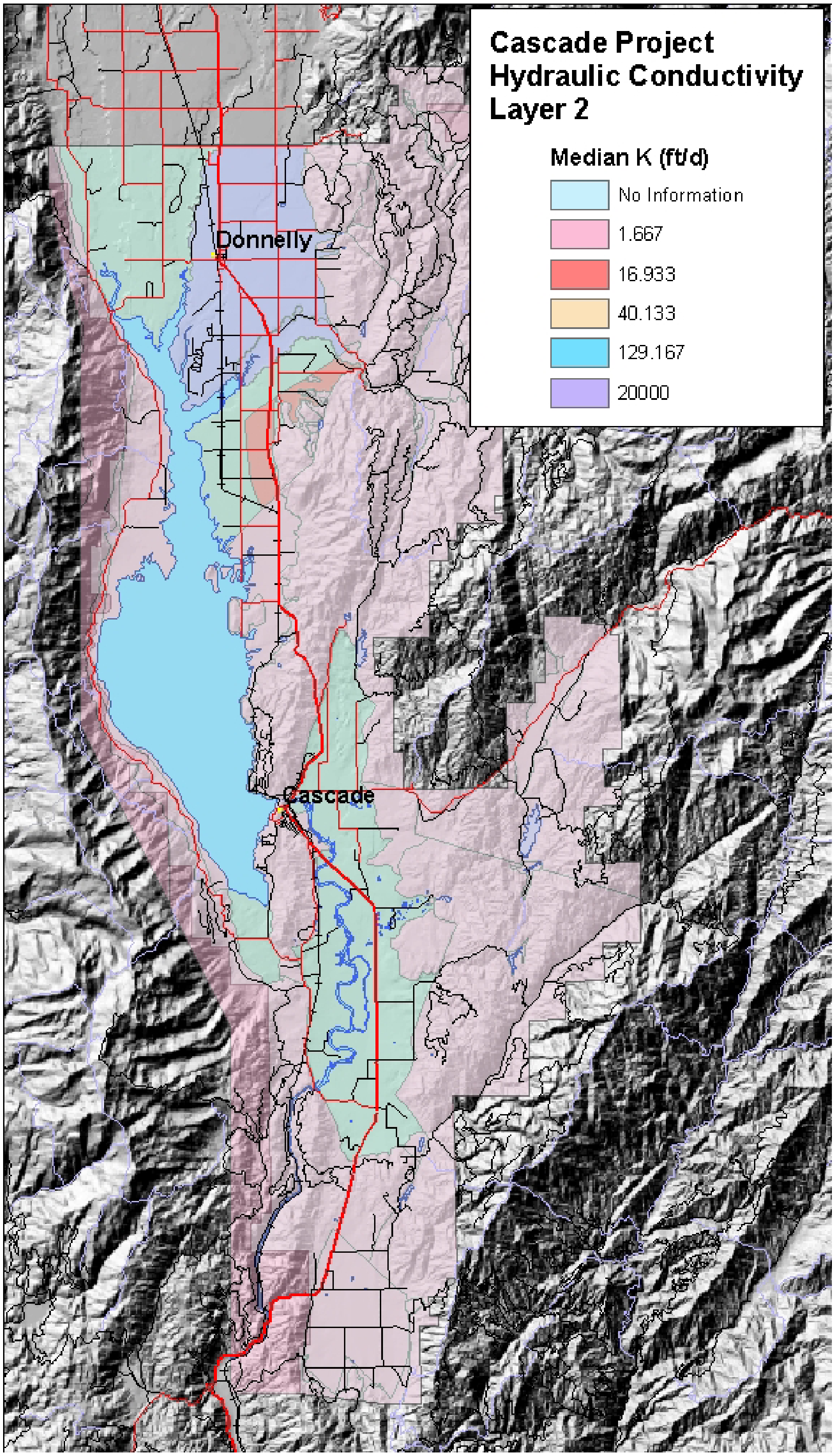

Figure 12. Hydraulic conductivity of geologic unit two.

In areas without adequate information, the applicant can obtain onsite information for the relevant parameters in the spreadsheet program. This might entail installing wells to conduct aquifer tests and determine the gradient.

General error analysis

The input parameters for the IDEQ mass-balance spreadsheet include aquifer hydraulic conductivity and gradient. This model will be applied to specific field sites in the Cascade area. The potential error in estimating gradient while using the program, in areas where enough data exist to supply an estimate will probably be low, while the error in estimating hydraulic conductivity is probably high. The hydraulic conductivity error probably is high because the natural variability of hydraulic conductivity is high, and because there are errors in the original estimates.

Although the hydraulic gradient was estimated using noisy data as mentioned before, the errors introduced in using these values will probably be small. The map looks consistent with the hydrogeologic conceptual. Also, the map was produced using kriging, and kriging is a robust contouring technique.

Natural variability for hydraulic conductivity is high in both fractured rock and unconsolidated material. For example, it is not uncommon to find hydraulic conductivity varying over several orders of magnitude at ground water contamination sites. Thus, the likely errors encountered in applying hydraulic conductivity estimates at a location remote from any estimation point regardless of the geologic unit, will be high.

GIS DATABASE

Description

The GIS database contains the geologic and hydrogeologic data collected during this study. It resides in two locations, in an Access database, and as tables associated with ArcView shp files.

Digital map

The digital map show the various lithologies exposed at surface. Our interpretation of subsurface lithologies at any given location can be acquired with the information tool in ArcView by clicking on the desired location.

Well logs

We have hot linked some of the well logs that we used to acquire subsurface geologic and hydrogeologic data. These well logs were obtained from IDWR and they were used to infer geologic units with depth, the elevation of the potentiometric surface, and, where sufficient data exists, estimate hydraulic conductivity. The information contained in the

IDWR logs is not usually recorded by scientists or trained technicians using rigorous quality control techniques. As such, this information should be viewed with some suspicion. However, it does represent as dense a data set as we could assemble given the scope of this project.

Structural data and outcrop photos

The raw structural data collected during this study and photos of outcrops reside in the Access database and in Appendix 1. These data are shown graphically in equal area projections, also in Appendix 1. Rose diagrams showing our interpretations of structural domains are hot linked to the digital map and are also included in Appendix 1.

Effluent transport parameters

The digital map contains summary statistics describing the hydraulic conductivity distribution for the geologic units with adequate hydraulic testing data. This information can be viewed with the information tool in ArcView by clicking on the desired location.

The gradient map shows the change in hydraulic head with respect to change in distance. This information is presented in Figure 7 and in the digital map. Simply click on the desired location using the information tool to extract the gradient.

CONCLUSIONS

Geology

Our compilation of historical geologic studies and our field work shows that the Cascade area is underlain by crystalline rocks of the Idaho Batholith. The Cascade basin is a structurally controlled feature that includes several nested, interior basins. The interior basins started forming in mid-Tertiary time, and continue to develop today. Depth to bedrock analyses from drill logs and geophysical data show that the basins are asymmetric with their west sides generally deeper than the eastern sides. Plate 1 shows the geometry of lithologic units exposed at surface; the digital geologic map contains information about the type of and depth to lithologies that occur below surface. The interpretations of subsurface geology were derived from water well logs and geophysical studies. Plate 1 also shows locations of wells recorded with the Idaho Department of Water Resources.

Basin-filling strata include basaltic lavas of the Columbia River Group, clay-rich lacustrine beds, unconsolidated Quaternary alluvium, and recent floodplain deposits. Surface exposures of the basaltic lavas show clay-rich weathering rinds. The Tertiary strata have been partially lithified, a process that generally decreases porosity and permeability.

Hydrogeology

The purpose of this investigation was to provide information that would help populate a model used by IDEQ to estimate lot size for developments. This work provides a digital gradient map that can be interrogated using the ArcView information tool to provide estimates of gradient anywhere with adequate data density. Summary statistics describing the hydraulic conductivity distribution for the various geologic units can also be accessed using the ArcView information tool. Tables 1 through 3 and Figure 8 provide estimates of porosity for several different types of geologic material.

Poorly sealed wells present an avenue through which the effluent can migrate deeper into the aquifer. When a well is pumping, it generates a vertical gradient, and a poorly sealed contact between the casing and borehole wall presents a convenient path to a deeper segment of the aquifer. Generally the annular space will only be sealed if the water table is within 18 ft of land surface. About 39% (567/1440) of the wells in the Cascade area are located in areas where the water table is within 18 ft of land surface. If one assumes that the effluent will make a plume about 10 ft thick, then the seal must extend at least 10 ft below the water table. Only about 12% (171/1440) of the wells in the Cascade area meet those criteria. Thus about 88% of the wells in the Cascade area are not adequately protected from any contaminant that may reside at or near the water table.

To minimize the risk of septic impacts on aquifers and water wells in the Cascade area IDEQ could impose special drilling requirements in this area. We suggest a minimum seal of 100 ft in granitic rocks and a minimum of a 50 ft seal in unconsolidated material. We also suggest requiring overdrilling the well and installing a seal consisting of a cement and bentonite mix through a tremie pipe from the bottom up.

PROPOSED FUTURE WORK

Although we know that anisotropy exists in the granitic rocks and what direction the flow paths will be diverted, we do not know the magnitude. Tracer tests would resolve this. In several instances, tracer tests are being conducted at developments on the granitic rocks in the form of septic effluent leaving developments. Perhaps an exhaustive sampling of wells in and around a few developments would serve to quantify anisotropy.

This study extended from Round Valley to just north of Donnelly. A logical course of action would entail extending the study north to McCall. This would capture more wells with interpretable aquifer tests. Unless the geology is carefully interpreted, the tests can not be added to the data base because they may not be assigned to the appropriate geologic unit.

Recharge, an input parameter to the IDEQ spreadsheet model, was not investigated during this study. A study to estimate recharge in the Cascade area would probably serve to significantly reduce predictive uncertainty. One possible avenue to investigate involves the use of environmental tracers to estimate aquifer recharge. An interesting offshoot from this study could be to examine the environmental tracer concentration above and below a development, and thereby estimate the impact of the development on recharge.

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APPENDIX 1

CD containing database, shape files, digital copy of report, geologic map, AutoCAD dwg files, and HPGL2 plot files of geologic map.