

Contents

Contents.....	ii
Definition of Selected Terms.....	xv
Executive Summary.....	1
Investigation Purpose.....	1
Geography, Climate and Land Use.....	1
Geologic Framework.....	2
Geologic History.....	2
Ground Water Occurrence.....	3
Ground Water Temperatures.....	4
Hydraulic Properties of Basalt and Basin Fill.....	4
Ground Water Flow.....	4
Influences Upon Ground Water Elevations.....	5
Ground Water Response to Development.....	6
Ground Water Drawdown Calculations.....	7
Conclusions.....	8
Introduction.....	11
Problem Statement.....	11
Investigation Purpose.....	13
Statutory Authority to Conduct an Investigation.....	13
Project Wells.....	14
Well Identification and Location.....	16
Well Identification.....	16
Locations.....	16
Acknowledgements.....	18
Geography and Climate.....	19
Location.....	19
Physical Geography.....	19
Climate.....	21
Land Ownership and Use.....	24
Ground Water Development History.....	27
Well Drilling History.....	27
Ground Water Irrigation Rights.....	28
ADR Ground Water Irrigation Rights.....	32
Ground Water Response to Development.....	33
Geologic Framework.....	37
Introduction.....	37
Physiographic Province.....	37
Stratigraphy.....	38
Development of Stratigraphic Understanding.....	38
Current Stratigraphic Understanding.....	40

Geologic Structure.....	42
Exposed Structure.....	42
Buried Structure.....	44
Age of Sub-basin Structures.....	45
Sub-basin Geologic History.....	45
Hydrogeology.....	47
Previous Investigations.....	47
Ground Water in the Major Stratigraphic Units.....	49
General Stratigraphy and Ground Water Occurrence.....	49
Ground Water in Basalt.....	49
Ground Water in Sedimentary Deposits.....	52
Ground Water Level Data Collection.....	56
Ground Water Response to Stress.....	58
Precipitation, Barometric Pressure, and Earth Tides.....	58
Canal Leakage.....	62
River Stage.....	63
Irrigation.....	64
Ground Water Use.....	65
Relationship Between Ground Water in Basalt and in Sedimentary Deposits.....	67
Relationship Between Ground Water and the Lost River.....	71
Introduction.....	71
Seepage Run Method to Quantify a Ground Water and River Relationship.....	71
Lost River Seepage Run Conducted by OWRD.....	72
Bonanza Big Springs Historical Discharge.....	78
Ground Water Sub-Areas.....	78
Introduction.....	78
South Langell Valley Sub-Area.....	81
Lorella Sub-Area.....	82
Bonanza Sub-Area.....	87
Swan Lake Valley to Poe Valley Sub-Area.....	89
Horizontal Ground Water Flow.....	94
Introduction.....	94
General Sub-Basin Flow.....	95
South Langell Valley Sub-Area.....	96
Lorella Sub-Area.....	98
Bonanza Sub-Area.....	100
Swan Lake Valley to Poe Valley Sub-Area.....	102
Vertical Ground Water Flow.....	104
Introduction.....	104
South Langell Valley Sub-Area.....	105
Lorella Sub-Area.....	105
Bonanza Sub-Area.....	110
Swan Lake Valley to Poe Valley Sub-Area.....	111
Summary.....	113

Aquifer Properties.....	115
Introduction.....	115
Effective Transmissivity and Storage Coefficient.....	118
Aquifer Tests Conducted.....	119
South Langell Valley Sub-Area Test.....	119
Lorella Sub-Area Tests.....	123
Bonanza Sub-Area Tests.....	129
Swan Lake Valley to Poe Valley Sub-Area Test.....	133
Aquifer Properties Conclusion.....	137
Potential Ground Water Drawdowns Related to ADR Ground Water Permits...	138
Introduction.....	138
Method Used for Estimating Potential Ground Water Drawdowns.....	138
South Langell Valley Sub-Area.....	141
Lorella Sub-Area.....	145
Bonanza Sub-Area.....	148
Swan Lake Valley to Poe Valley Sub-Area.....	156
Summary of Drawdown Calculations.....	159
Investigation Conclusions.....	162
General Technical Conclusions.....	162
Ground Water Response to Development.....	164
Potential Impact Upon the Lost River and Bonanza Big Springs.....	165
References Cited.....	168

Figures

Figure 1. Project wells used for the eastern Lost River sub-basin ground water investigation.....	14
Figure 2. Illustration of the public land survey system.....	17
Figure 3. Ground water investigation location.....	19
Figure 4. Geography of the eastern Lost River sub-basin.....	20
Figure 5. Total precipitation and cumulative departure from average by water year at Klamath Falls from 1921 to 2000.....	22
Figure 6. Monthly maximum, minimum, and average precipitation at Klamath Falls from 1921 to 2000.....	23
Figure 7. Daily maximum, minimum, and average temperatures averaged by month for Klamath Falls from 1971 to 2000.....	23

Figure 8.	Areas enclosed by the boundaries of irrigation districts relying upon U.S. Bureau of Reclamation Klamath Project surface water.....	25
Figure 9.	Areas where irrigation independent of the Klamath Project water can occur under existing Oregon surface water and ground water rights.....	26
Figure 10.	Cumulative number of water wells constructed in eastern Lost River sub-basin from 1950 to mid 2002.....	27
Figure 11.	Cumulative number of applications for the ground water rights for the eastern Lost River sub-basin valid in 2002.....	29
Figure 12.	Distribution of eastern Lost River sub-basin acreage related to primary ground water rights valid for irrigation in 2002.....	30
Figure 13.	Distribution of eastern Lost River sub-basin acreage related to supplemental ground water rights valid for irrigation in 2002.....	31
Figure 14.	Distribution of existing or proposed wells related to the ground water rights valid for irrigation in the eastern Lost River sub-basin in 2002.....	32
Figure 15.	Distribution of eastern Lost River sub-basin acreage and wells related to ADR permits for primary or supplemental ground water use for irrigation.....	33
Figure 16.	Hydrograph of ground water levels measurements at state observation well 288 (well KLAM 13427).....	34
Figure 17.	Hydrograph of ground water level measurements at state observation well 288 (KLAM 13427) with graph of cumulative departure from average precipitation by water year at Klamath Falls.....	35
Figure 18.	Hydrograph of ground water levels measurements at state observation well 292 (well KLAM 14731).....	36
Figure 19.	Areas of geologic mapping in or near the eastern Lost River sub-basin from the mid 1990s through 2001.....	41
Figure 20.	Faults mapped in or near the eastern Lost River sub-basin.....	43
Figure 21.	Reported well yield at 199 wells obtaining ground water from basalt within or adjacent to east Lost River sub-basin valleys.....	51

Figure 22.	Calculated specific capacity at 115 wells obtaining ground water from basalt within or adjacent to east Lost River sub-basin valleys.....	51
Figure 23.	Reported water temperature for ground water in basalt at 157 wells within or adjacent to east Lost River sub-basin valleys.....	52
Figure 24.	Reported well yield for sediment at 44 ground water wells Within or adjacent to east Lost River sub-basin valleys.....	54
Figure 25.	Calculated specific capacity at 7 sediment ground water wells within or adjacent to east Lost River sub-basin valleys.....	55
Figure 26.	Reported water temperature for ground water in sediment at 24 wells within or adjacent to east Lost River sub-basin valleys.....	55
Figure 27.	Location of the investigation ground water level measurement wells.....	57
Figure 28.	Graph of ground water levels measurements at state observation well 288 (well KLAM 13427) and cumulative departure from average precipitation by water year at Klamath Falls from 1950 to 2000.....	58
Figure 29.	Hydrograph of OWRD south Langell Valley aquifer test ground water level measurements at well KLAM 10641 showing pumping and barometric pressure influences.....	60
Figure 30.	Graph of barometric pressure during OWRD south Langell Valley aquifer test.....	60
Figure 31.	Hydrograph of OWRD south Langell Valley aquifer test ground water level measurements at well KLAM 10641 with barometric pressure influences removed.....	61
Figure 32.	Hydrograph of OWRD Lorella aquifer test ground water level measurements at well KLAM 10362 and graph of the ocean tide at Coos Bay.....	61
Figure 33.	Hydrograph of OWRD ground water level measurements at well KLAM 13582 showing a canal leakage influence.....	62
Figure 34.	Hydrograph of OWRD measurements of the ground water level at well KLAM 50318 and the Lost River at Bonanza Big Springs Park.....	63

Figure 35.	Hydrograph of OWRD ground water level measurements at well KLAM 10813 showing irrigation influence.....	64
Figure 36.	Hydrograph of OWRD ground water level measurements at well KLAM 10814 showing no irrigation influence.....	65
Figure 37.	Hydrograph of OWRD ground water level measurements at well KLAM 10641 showing ground water use influence in basalt.....	66
Figure 38.	Hydrograph of OWRD ground water level measurements at well KLAM 14871 showing ground water use influence in basin fill.....	66
Figure 39.	Hydrograph of OWRD ground water level measurements at well KLAM 10699 showing ground water use influence superimposed upon canal leakage influence.....	67
Figure 40.	Hydrograph of ground water level measurements at sediment well KLAM 11473 and basalt well KLAM 13456 showing an efficient (direct) hydraulic connection.....	68
Figure 41.	Hydrograph of ground water level measurements at sediment well KLAM 10159 and basalt well KLAM 51131 showing an inefficient hydraulic connection.....	69
Figure 42.	Hydrograph of ground water level measurements at sediment well KLAM 11569 and basalt well KLAM 12369 showing perched ground water.....	70
Figure 43.	Lost River flow measurement sites for December 1997 seepage run.....	73
Figure 44.	Lost River flow in December 1997.....	76
Figure 45.	Lost River specific electrical conductance in December 1997.....	76
Figure 46.	Lost River elevation variability above Bonanza Big Springs during five-day December 1997 seepage run.....	77
Figure 47.	Bonanza Big Springs Discharge and cumulative departure from average of water year precipitation at Klamath Falls.....	78
Figure 48.	Eastern Lost River sub-basin sub-areas with associated wells and approximate boundaries.....	79

Figure 49.	Representative hydrographs for the four sub-areas in the eastern Lost River sub-basin.....	80
Figure 50.	South Langell Valley sub-area wells and approximate north boundary location.....	81
Figure 51.	Hydrograph of ground water in basalt at 4 wells and basin fill sedimentary deposits at 1 well in the south Langell Valley sub-area.....	82
Figure 52.	Lorella sub-area wells and approximate north and south boundary locations.....	83
Figure 53.	Hydrograph of ground water in basalt and basin fill in the Lorella sub-area.....	84
Figure 54.	Extreme example of ground water in basalt in the Lorella sub-area responding strongly to ground water pumping.....	85
Figure 55.	Hydrograph of ground water in different basalt water bearing zones at a double completion well in the Lorella sub-area.....	85
Figure 56.	Lorella sub-area wells separated into 9 compartments.....	86
Figure 57.	Bonanza sub-area wells and approximate boundary locations.....	87
Figure 58.	Hydrograph of ground water in basalt and basin fill in the Bonanza sub-area.....	88
Figure 59.	Swan Lake Valley to Poe Valley sub-area wells and approximate boundary locations.....	89
Figure 60.	Hydrograph of ground water in basalt and basin fill in the Swan Lake Valley to Poe Valley sub-area.....	90
Figure 61.	Swan Lake Valley to Poe Valley sub-area wells separated into the central portion and 3 adjoining compartments.....	91
Figure 62.	Normalized hydrograph of ground water in basalt at and basin fill in the central portion of the Swan Lake Valley to Poe Valley sub-area.....	92
Figure 63.	Example ground water hydrograph for the north Swan Lake Valley compartment of the Swan Lake Valley to Poe Valley sub-area.....	93

Figure 64.	Example ground water hydrograph for the south Poe Valley compartment of the Swan Lake Valley to Poe Valley sub-area.....	94
Figure 65.	Comparison of south Langell Valley ground water from basalt level at well KLAM 10641 and Kilgore Spring water level in 2001.....	97
Figure 66.	Well water temperature versus well depth at well KLAM 10362 in the Lorella sub-area.....	107
Figure 67.	Well water temperature versus well depth at well KLAM 52096 in the Lorella sub-area.....	108
Figure 68.	Hydrograph of ground water level measurements at KLAM 52204 and KLAM 52096 double completion well in the Lorella sub-area.....	110
Figure 69.	Comparison of ground water elevations in Pine Flat sediment and basalt.....	112
Figure 70.	Well water temperature versus well depth at well KLAM 51131 in the Swan Lake to Poe Valley sub-area.....	114
Figure 71.	Linear graph of idealized ground water level at an observation well responding to pumping and shut off at a neighboring well....	115
Figure 72.	Semi-log graph of idealized ground water level at an observation well responding to pumping and shut off at a neighboring well.....	116
Figure 73.	Semi-log graph of idealized ground water level at an observation well responding to pumping at a neighboring well and a no-flow boundary influence.....	117
Figure 74.	Semi-log graph of idealized ground water level at an observation well responding to pumping at a neighboring well and a recharge boundary influence.....	118
Figure 75.	Location of wells used for the OWRD 1999 aquifer test in south Langell Valley.....	120
Figure 76.	Location of wells used for the OWRD 1999 aquifer test in the Lorella Sub-area.....	124

Figure 77.	Location of wells used for the OWRD 1999 aquifer test in north Poe Valley within the Swan Lake Valley to Poe Valley sub-area.....	134
Figure 78.	Location of south Langell Valley sub-area wells subject to ADR permit conditions	142
Figure 79.	Location of Lorella sub-area wells subject to ADR permit conditions.....	146
Figure 80.	Location of Bonanza sub-area wells subject to ADR permit Conditions.....	149
Figure 81.	Location of Swan Lake Valley to Poe Valley sub-area wells subject to ADR permit conditions.....	156

Tables

Table 1.	Summary of 32 applications received from 1991 to 1993 to appropriate ground water in the Langell, Yonna, and Poe Valleys for supplemental and primary irrigation use.....	11
Table 2.	Investigation data derived from 239 project wells and 18 other wells in the eastern Lost River sub-basin.....	15
Table 3.	Summary of ground water temperature, well yield, and specific capacity on water well reports for 205 eastern Lost River sub-basin basalt wells.....	50
Table 4.	Summary of ground water temperature, well yield, and specific capacity on water well reports for 48 eastern Lost River sub-basin wells producing from or penetrating through sediments overlying basalt.....	53
Table 5.	Type of water level measurements conducted at 205 wells for the eastern Lost River sub-basin ground water investigation.....	56
Table 6.	Summary of December 1997 Lost River seepage run.....	75
Table 7.	General information related to wells used for the OWRD 1999 aquifer test in the south Langell Valley sub-area.....	119
Table 8.	Summary of estimated south Langell Valley basalt transmissivity and storage coefficient values using OWRD 1999 aquifer test data adjusted for barometric pressure changes.....	122

Table 9.	General information related to wells used for the OWRD 1999 aquifer test in the Lorella sub-area.....	124
Table 10.	Summary of transmissivity and storage coefficient values estimated for canal-influenced basalt in the Lorella northeast compartment, Lorella sub-area using OWRD 1999 aquifer test data adjusted for barometric pressure changes.....	127
Table 11.	Summary of transmissivity and storage coefficient values reported by CH2MHill (1994) for canal-influenced basalt in the Bryant Mountain to Dead Indian Hill terrace middle compartment, Lorella sub-area.....	128
Table 12.	Summary of transmissivity and storage coefficient values for the Bonanza sub-area basalt water bearing zones hydraulically connected to Bonanza Big Springs as reported by the U.S. Geological Survey and CH2MHill	130
Table 13.	Summary of transmissivity values for the Bonanza Sub-area deep basalt water bearing zones reported by CH2MHill (1994 and 2002).....	131
Table 14.	General information related to wells used for the OWRD 1999 aquifer test in northern Poe Valley, Swan Lake Valley to Poe Valley sub-area.....	134
Table 15.	Summary of estimated basalt transmissivity and storage coefficient values for basalt in the central portion of the Swan Lake Valley to Poe Valley sub-area using OWRD 1999 north Poe Valley aquifer test data.....	135
Table 16.	Summary of effective basalt transmissivity and storage coefficient values for the eastern Lost River sub-basin.....	137
Table 17.	Summary of calculated potential drawdowns at the Lost River caused by exercising ADR permits in the south Langell Valley sub-area.....	143
Table 18.	Summary of calculated potential drawdowns at Kilgore Springs caused by exercising ADR permits in the south Langell Valley sub-area.....	144
Table 19.	Summary of calculated potential drawdowns at the Lost River caused by exercising ADR ground water permits in the Lorella sub-area.....	147

Table 20. Summary of calculated potential drawdowns at the Lost River caused by exercising ADR permits in the Bonanza sub-area.....	150
Table 21. Summary of calculated potential drawdowns at Bonanza Big Springs caused by exercising ADR permits in the Bonanza sub-area.....	153
Table 22. Summary of calculated potential drawdowns at the Lost River caused by exercising ADR permits in the Swan Lake Valley to Poe Valley sub-area.....	157
Table 23. Summary of calculated potential drawdowns at west Poe Valley springs caused by exercising ADR permits in the Swan Lake Valley to Poe Valley sub-area.....	158

Plates

Plate 1 Geography of the eastern Lost River sub-basin
Plate 2. Eastern Lost River sub-basin project wells
Plate 3 Top of basalt below basin fill sedimentary deposits in the eastern Lost River sub-basin.
Plate 4 Eastern Lost River sub-basin potentiometric map, basalt ground water elevations in March 1999
Plate 5 Lorella sub-area potentiometric map, canal influenced basalt ground water elevations in March 1999

Appendices

Appendix 1 Permitted supplemental and primary irrigation water use related to 32 applications received from 1991 to 1993 to appropriate ground water in the Langell, Yonna, and Poe Valleys
Appendix 2 Project Wells
Appendix 3 Klamath Falls precipitation in inches from 1921 to 2000
Appendix 4 Klamath Falls average daily maximum, minimum, and average temperatures by month in degrees Fahrenheit from 1971 to 2000

- Appendix 5** Number of water wells constructed for different uses by location as noted on water well report
- Appendix 6** State Observation Well Hydrographs
- Appendix 7** Summary of Stratigraphic Units Identified in the Eastern Lost River Sub-basin by 1974 to 2004 Investigations
- Appendix 8** Correlation of geologic units identified by previous investigators from 1974 to 2004 and as generalized by this study
- Appendix 9** Geologic Cross Sections
- Appendix 10** Hypotheses for Sub-basin Stratigraphy and Structural Development
- Appendix 11** Hydrogeologic Information found on or derived from water well reports
- Appendix 12** Project Recorder and Monthly Well Hydrographs
- Appendix 13** Ground Water Elevation Measurements
- Appendix 14** Land Elevation for Each Project Well Site
- Appendix 15** Hydrographs comparing water level fluctuations in basalt and basin fill sedimentary deposits
- Appendix 16** Project Surface Water Sites
- Appendix 17** Lost River Seepage Run Data
- Appendix 18** Lost River Seepage Run Conductivity Analysis
- Appendix 19** USGS Lost River Seepage Run Data
- Appendix 20** Bonanza Big Springs historical discharge measurements
- Appendix 21** South Langell Valley 1999 OWRD aquifer test graphs
- Appendix 22** South Langell Valley 1999 OWRD aquifer test, pumping well data (KLAM 10495)

- Appendix 23** South Langell Valley 1999 OWRD aquifer test, observation well data (KLAM 10641)
- Appendix 24** South Langell Valley 1999 OWRD aquifer test, observation well data (KLAM 15129)
- Appendix 25** South Langell Valley 1999 OWRD aquifer test, observation well data (domestic sedimentary well)
- Appendix 26** South Langell Valley 1999 OWRD aquifer test, discharge data
- Appendix 27** Lorella 1999 OWRD aquifer test graphs
- Appendix 28** Lorella 1999 OWRD aquifer test, observation well data (KLAM 10554)
- Appendix 29** Lorella 1999 OWRD aquifer test, observation well data (KLAM 52204)
- Appendix 30** Lorella 1999 OWRD aquifer test, observation well data (KLAM 52096)
- Appendix 31** Lorella 1999 OWRD aquifer test, observation well data (KLAM 10362)
- Appendix 32**--Lorella 1999 OWRD aquifer test, observation well data (KLAM 10364)
- Appendix 33** Lorella 1999 OWRD aquifer test, discharge data
- Appendix 34** North Poe Valley 1999 OWRD aquifer test graphs
- Appendix 35**--North Poe Valley 1999 OWRD aquifer test, pumping well data (KLAM 10292)
- Appendix 36** North Poe Valley 1999 OWRD aquifer test, observation well data (KLAM 10252)
- Appendix 37** North Poe Valley 1999 OWRD aquifer test, observation well data (KLAM 51131)
- Appendix 38** North Poe Valley 1999 OWRD aquifer test, discharge data

Appendix 39 Ground water drawdown calculated for South Langell Valley sub-area ADR ground water permits

Appendix 40 Ground water drawdown calculated for Lorella sub-area ADR ground water permits

Appendix 41 Ground water drawdown calculated for Bonanza sub-area ADR ground water permits

Appendix 42 Ground water drawdown calculated for Swan Lake Valley to Poe Valley sub-area ADR ground water permits

Definition of Selected Terms

Acre-foot: The volume required to cover 1 acre to a depth of 1 foot. This volume equals 43,560 cubic feet or 325,851 gallons.

Aquifer: A body of rock and/or sediments that will yield water in a usable quantity to a well or spring.

Alluvium: Clay, silt, sand, gravel or similar material deposited by running water.

Andesite: A fine grained, gray to grayish black volcanic rock, typically containing the minerals plagioclase, augite, biotite, or hornblende.

Barometric Efficiency: A ratio of the water level change in a well to the inverse barometric pressure change (converted to feet of water).

Basalt: A very fine grained, dark gray to black volcanic rock. The minerals it contains (pyroxene, plagioclase, olivine) are relatively high in iron and magnesium.

Confined Aquifer: An aquifer bounded above and below by material of distinctly lower permeability than the aquifer itself. Ground water in the aquifer is under sufficient pressure to rise above the level at which it is encountered by a well. The water in a well may or may not rise above land surface.

Earth Tide: The rising and falling of the earth crust in response to the same forces that produce ocean tides. During high (maximum) tides, the crust dilates which reduces pressure on ground water and causes water in a well to drop (generally less than 0.10 foot). During low tide, the crust relaxes which increases pressure on ground water and causes water in a well to rise.

Effective Transmissivity and Storage Coefficient: This investigation used the Theis equation to calculate the potential ground water drawdown at the Lost River and at springs due to pumping at individual wells. The actual drawdown is related to the pumping rate, the hydraulic properties of the geologic units (transmissivity and storage coefficient), and boundary influences. The Theis equation does not include boundary influences. That can lead to incorrect drawdown calculations, too much or too little depending upon the boundary influence. This investigation indirectly added boundary influences by using an effective transmissivity and storage coefficient for the actual values in the Theis equation calculations. The effective values are the actual values adjusted to include boundary influences. They were obtained by iteratively using an aquifer test derived storage coefficient and a range of aquifer test derived transmissivities in Theis equation calculations. The values that best reproduced observed drawdown and/or recovery at different locations were used.

Excessively Declining Water Levels as defined in Oregon Administrative Rule OAR 690-08-001 (6) means any ongoing lowering of the water level in a ground water reservoir or part thereof which: (a) precludes, or could preclude, the perpetual use of the reservoir; or (b) represents an average downward trend of three or more feet per year for at least 10 years; or (c) represents, over a five year period, an average annual lowering of the water level by 1% or more of the initial saturated thickness as determined by observation or investigation in the affected area; or (d) results in water quality deterioration.

Fault: A fracture or zone of fractures in the earth's crust along which there has been displacement of one side relative to the other.

Geologic Structure: A general term for features created by movement, bending, tilting, or breaking of rock layers or units.

Hydraulic Conductivity: A measure of the capacity of rock and/or sediment to transmit water. It is expressed as the rate (volume/time) at which water moves through a unit area of an aquifer under a unit hydraulic gradient. Its value depends upon the physical properties of the water and the aquifer. Larger values means water can move more easily.

Hydraulic Gradient: A measure of the slope of the potentiometric surface. It is the change in total head per unit distance measured in the direction of steepest change. This gradient drives ground water flow.

$$\text{Hydraulic Gradient} = \frac{(\text{Total Head at Point A}) - (\text{Total Head at Point B})}{\text{Distance Between A and B}}$$

Lithology: The description of rocks on the basis of color, mineral composition, and grain size.

Palagonite: Basaltic glass weathered to a yellow or orange mineral.

Paleomagnetism: The intensity and direction of residual magnetization in ancient rocks. The magnetic particles in the rock were oriented by the earth's magnetic field as it existed when the rock was formed.

Phenocryst: A crystal conspicuously larger than most crystals in the rock.

Phyric (porphyritic): A basalt rock texture in which larger crystals (phenocrysts) are set in a matrix of finer grained crystals and glass (groundmass).

Pillow Lava: Lobes of lava stacked one upon another resembling a pile of bed pillows. They are formed by lava flowing into water.

Pillow-Palagonite (Pillow Breccia): Pillow lava surrounded by yellow or orange minerals formed as the pillow lava weathers.

Potentiometric Surface: A surface that represents the total head in an aquifer. It is defined by the elevation at which water stands in cased wells that penetrate the aquifer. A water table is a particular potentiometric surface for unconfined ground water.

Saturated: The condition in which the pores and/or fractures in rock and/or sediment are filled with water.

Sediment: Solid fragmental material that settled down from a state of suspension in wind, water, or ice, was chemically precipitated from solution, or was secreted by organisms. The settling process forms layers.

Specific Capacity: The yield (rate of discharge) from a pumped well divided by the water level drawdown in the well due to the pumping. It is often expressed as gallons per minute per foot of drawdown (gpm/ft).

Speicfic Yield (Unconfined Storativity): The volume of water released from or added to storage in a unit prism of an unconfined aquifer per unit change in the water table. Water released is due to dewatering of aquifer pore spaces and water added is due to filling of aquifer pore spaces.

$$\text{Specific Yield} = \frac{\text{(volume of water released)(aquifer thickness)}}{\text{(aquifer volume with unit base)(unit decline of water table)}}$$

Storage Coefficient (Storativity): The volume of water released from or added to storage in a unit prism of a confined aquifer per unit change in total head. Water released is due to compaction of the aquifer and expansion of water when pressure is relieved. Water added is due to expansion of the aquifer and compaction of the water associated with an increase of pressure.

$$\text{Storage Coefficient} = \frac{(\text{volume of water released})(\text{aquifer thickness})}{(\text{aquifer volume with unit base})(\text{unit decline of total head})}$$

Stratigraphy: The branch of geology which treats the formation, composition, sequence, and correlation of rock layers.

Total Head: Total Head = Elevation Head + Pressure Head

Elevation Head = the elevation of a point of interest in an aquifer relative to some reference measuring point (i.e. sea level).

Pressure Head = the water column height that can be supported by the pressure at the point of interest in the aquifer.

Transmissivity: A measure indicating how easily water can move through an aquifer. The rate at which water is transmitted through a unit width of aquifer under a unit hydraulic gradient.

$$\text{Transmissivity} = (\text{hydraulic conductivity})(\text{aquifer thickness})$$

Tuffaceous: A rock containing up to 50 percent volcanic ash.

Unconfined Aquifer Water Table Aquifer): An aquifer in which a water table forms the upper ground water surface.

Volcanic Breccia (agglomerate): A rock composed of angular volcanic fragments (larger than 64 mm) set in finer volcanic material.

Volcaniclastic: A rock composed of volcanic fragments.

Water Table: The upper ground water surface in an unconfined aquifer where the pressure of the water in the porous medium equals atmospheric pressure.