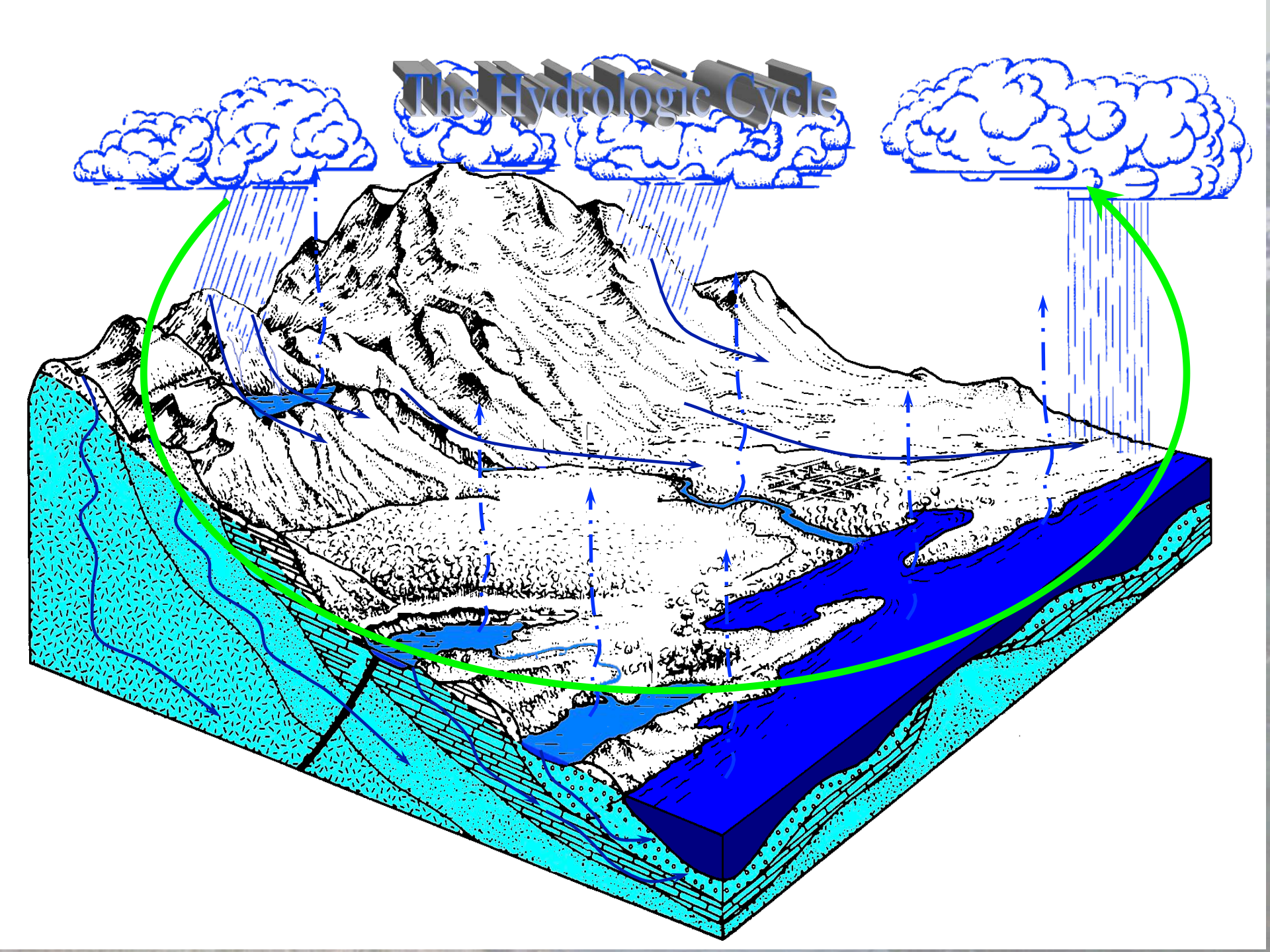
Island County Hydrogeology

Camano Island Aquifers
Your Groundwater

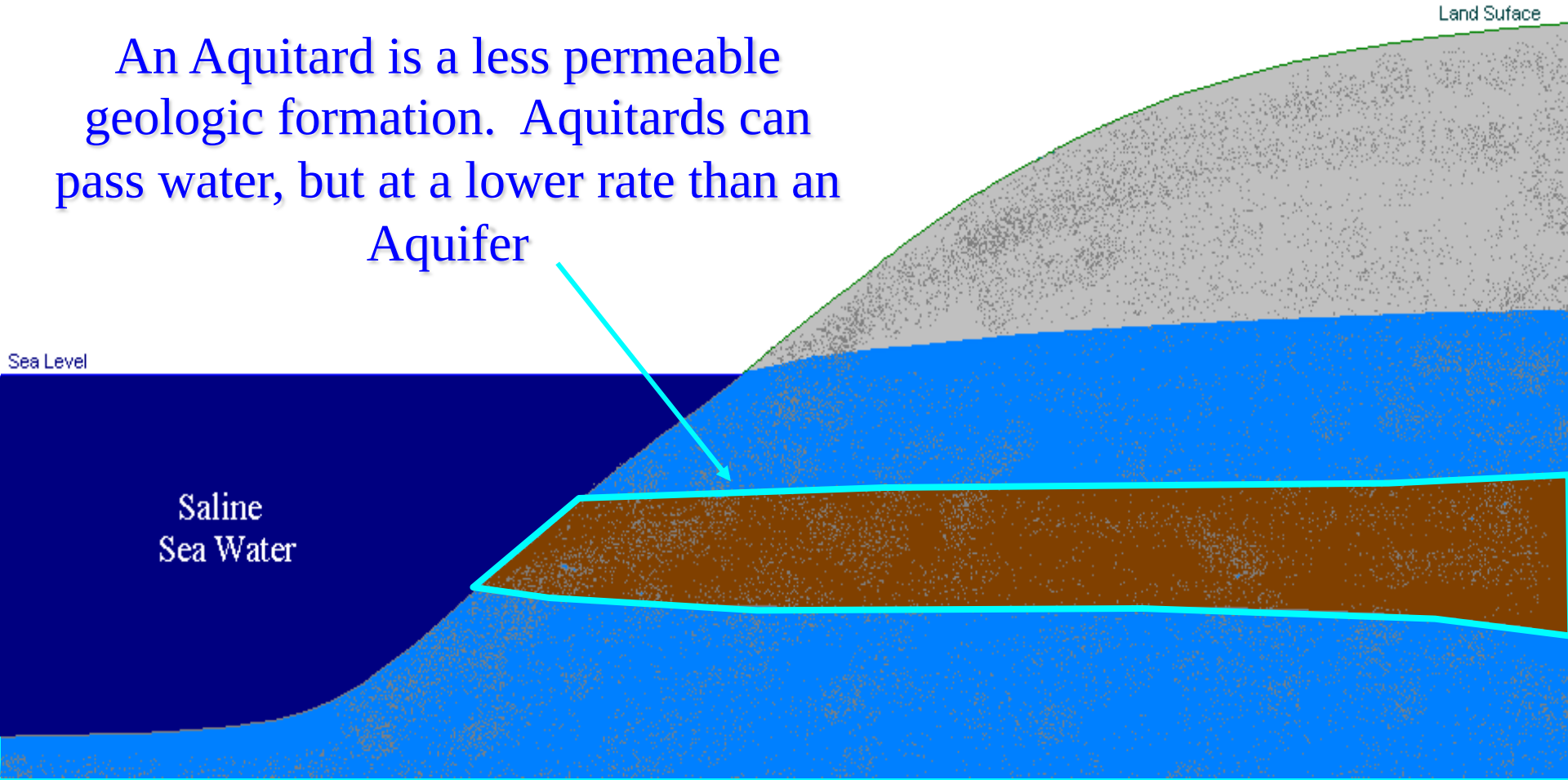
Doug Kelly
Hydrogeologist
Island County Public Health

ISLAND COUNTY PUBLIC HEALTH
ALWAYS WORKING FOR SAFER AND HEALTHIER COMMUNITIES

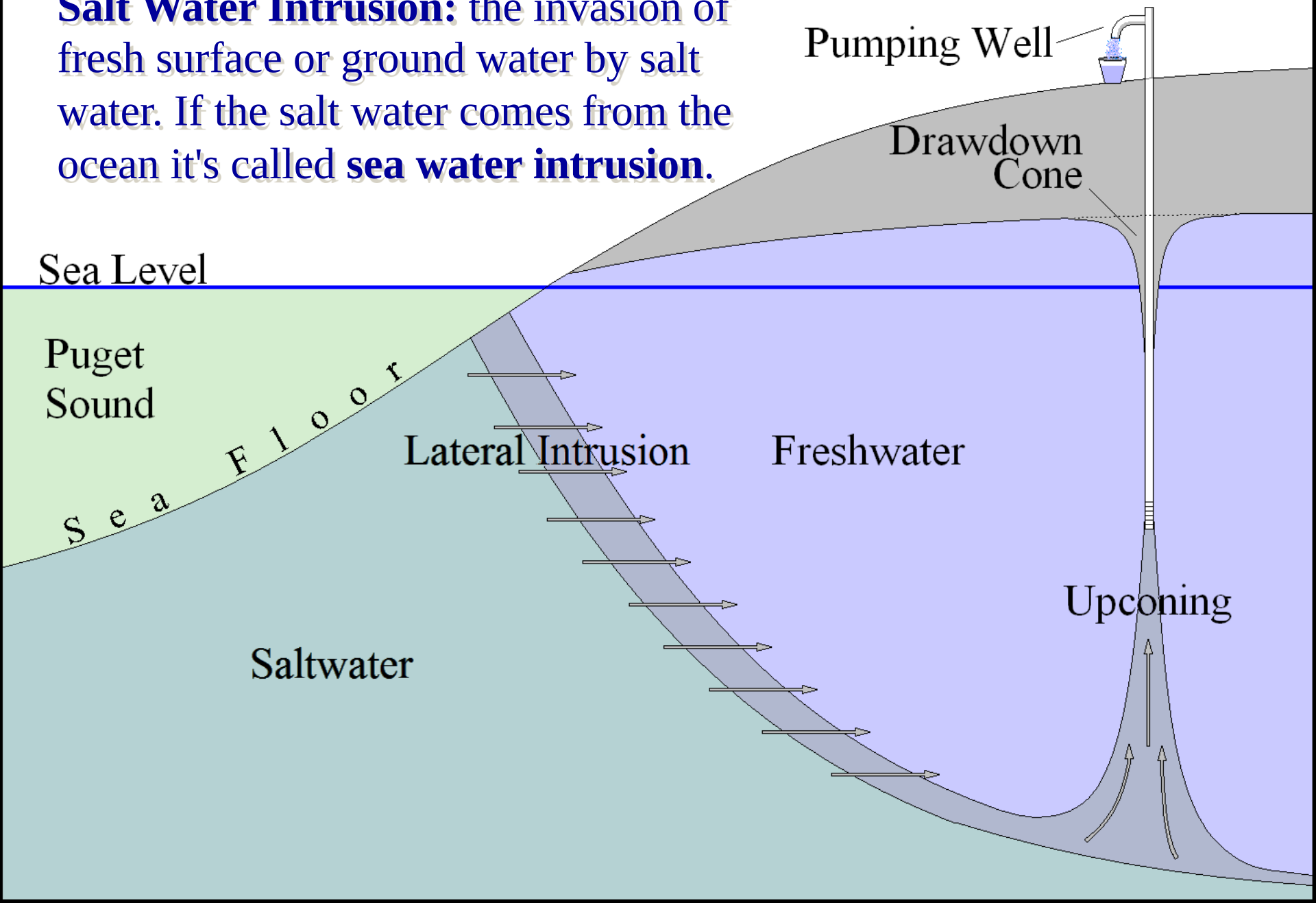

The Hydrologic Cycle

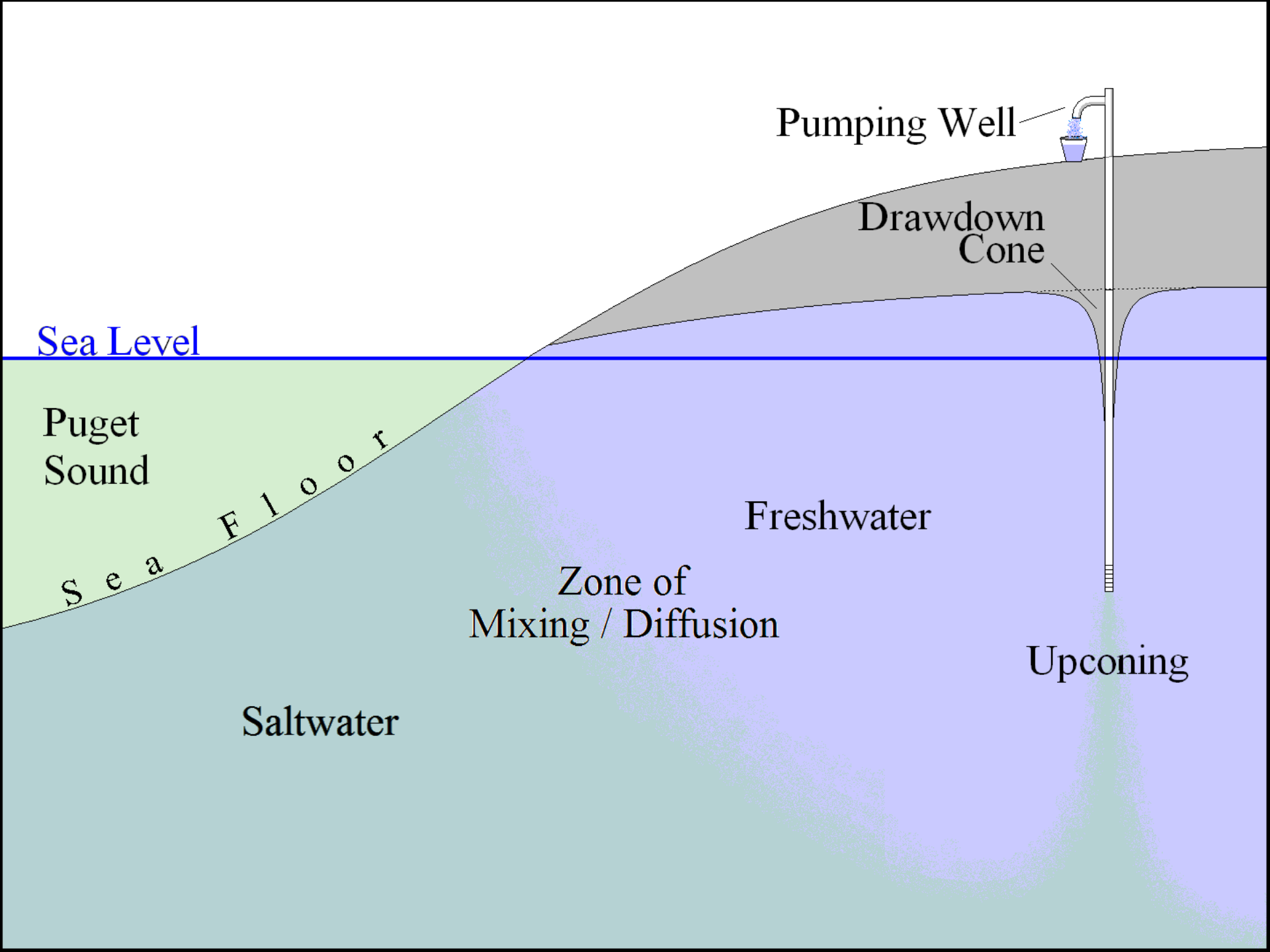
Definitions

An Aquitard is a less permeable geologic formation. Aquitards can pass water, but at a lower rate than an Aquifer

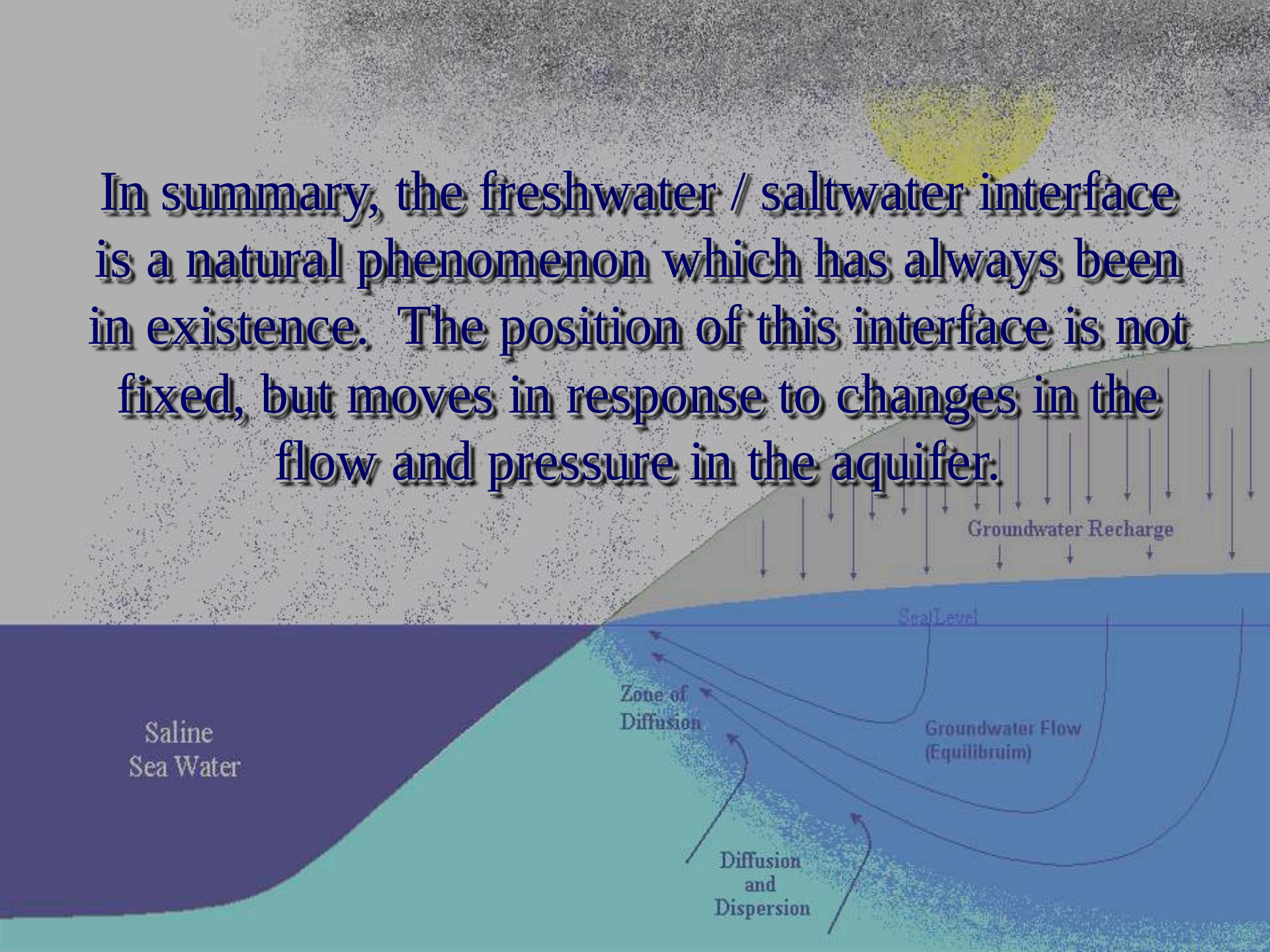


Salt Water Intrusion: the invasion of fresh surface or ground water by salt water. If the salt water comes from the ocean it's called **sea water intrusion**.

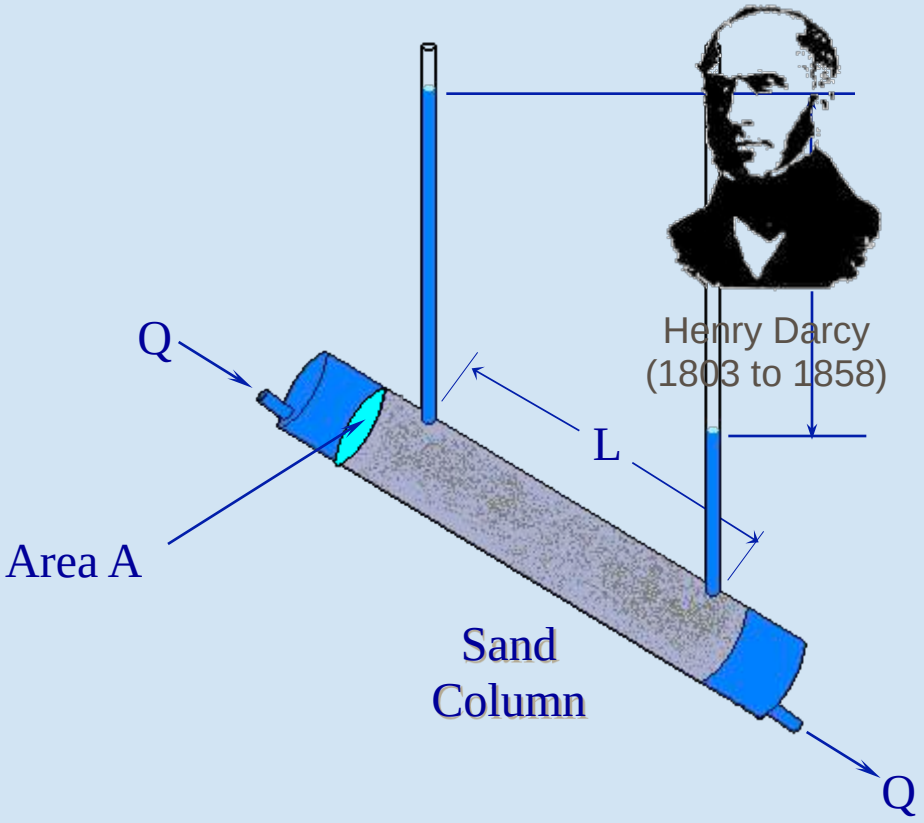



Pumping Well
Drawdown Cone
Sea Level
Puget Sound
Sea Floor
Freshwater
Zone of Mixing / Diffusion
Upconing
Saltwater

In summary, the freshwater / saltwater interface is a natural phenomenon which has always been in existence. The position of this interface is not fixed, but moves in response to changes in the flow and pressure in the aquifer.



Darcy's Law for Flow Through Porous Media



Henry Darcy
(1803 to 1858)

$$Q = -KA\frac{h}{L}$$

Where:
Q = Flow Rate
A = Cross-Sectional Area
h = Pressure Differential
L = Length
K = Hydraulic Conductivity

Darcy's Law and Hydraulic Conductivity

Darcy's Law

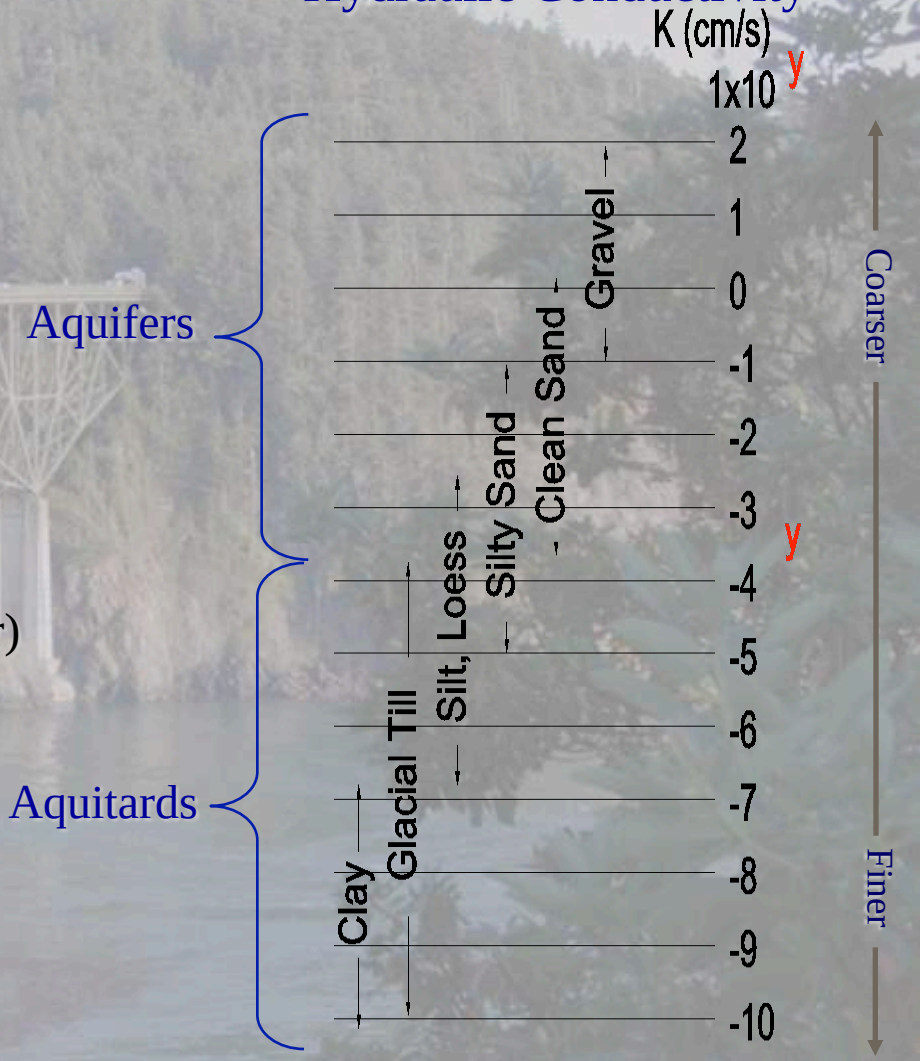
$$Q = -KA\frac{h}{L}$$

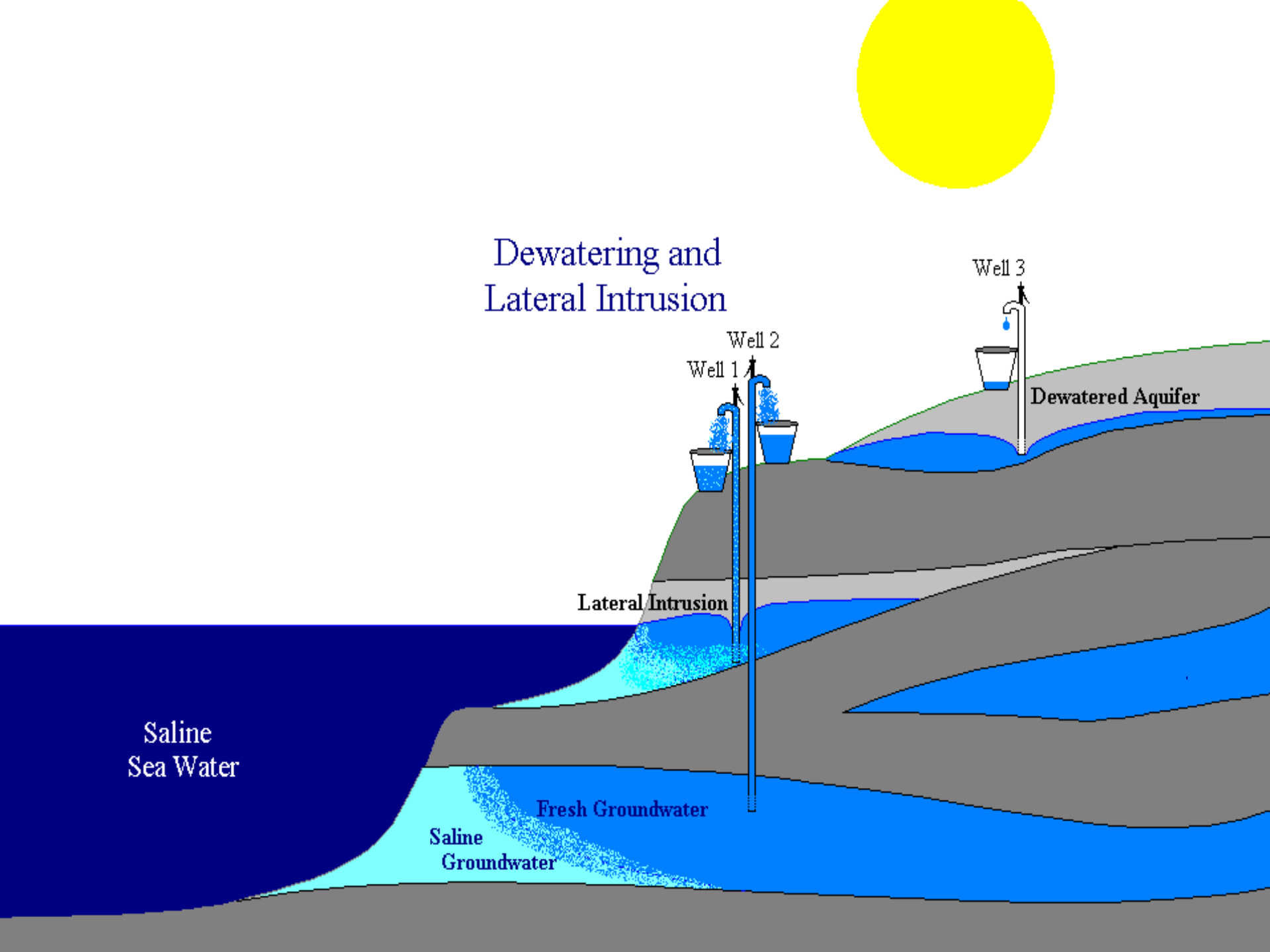
Hydraulic Conductivity **(K)** of a geologic formation depends on a number of factors including:

- Grain Size (coarser is better)
- Grain Shape (smooth is better)
- Grain Size Distribution (well sorted is better)
- Porosity (more is better)

Hydraulic Conductivity has dimensions of length per unit time such as Centimeters per Second or Feet per Day.

Some Examples of Hydraulic Conductivity




Dewatering and
Lateral Intrusion
Well 3
Well 2
Well 1
Dewatered Aquifer
Lateral Intrusion
Saline
Sea Water
Fresh Groundwater
Saline
Groundwater

Modes of Glacial Deposition

Sub-glacial / Ice Contacts Deposits

- Little or no sorting
- Highly compacted by overlying ice
- Produces glacial till or hardpan

Meltwater / Outwash Deposits

- Sorted
- Little or no compaction
- Produces Sand, Gravel, Silt and Clay

Geologic History – Island County Washington

Erathem	System	Series	GEOLOGIC CLIMATE UNITS		STRATIGRAPHIC UNITS		AQUIFERS AND CONFINING UNITS
CENOZOIC	QUATERNARY	PLEISTOCENE	Fraser Glaciation	Everson Interstade	Glaciomarine Drift of Everson Age		12,500 Years Ago
					Partridge Gravel Easterbrook (1968)		Aquifer E
				Vashon Stade	VASHON DRIFT	Till and Associated Drift of Vashon Age	Confining Unit E
						Esperance Sand Member	Aquifer D
			Olympia Interglaciation		Quadra Formation (Canadian usage)		27,000 Years Ago
			Possession Glaciation		Possession Drift		Confining Unit D
			Whidbey Interglaciation		Whidbey Formation		>40,000 Years Ago Aquifer C Confining Unit C
			Double Bluff Glaciation		Double Bluff Drift		?

Island County
Water Resource Management Efforts

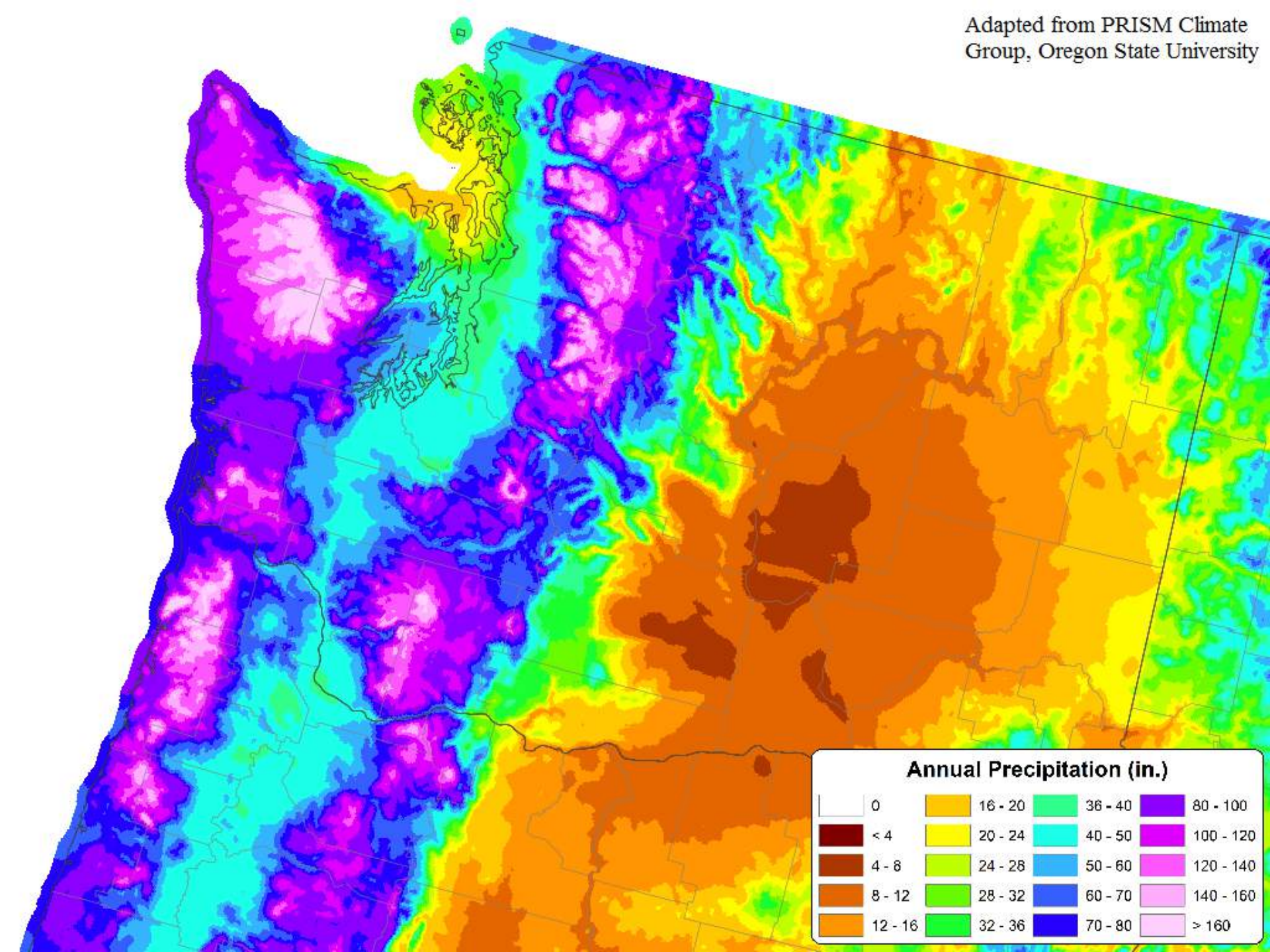
- 1979-83 USGS Water Resource Study
- 1982 EPA Sole Source Aquifer Designation
- 1985 Critical Water Supply Service Area
- 1989 DOH / ICHD Saltwater Intrusion Policy
- 1990 Coordinated Water System Plan
- 1990 MOU – Island County / DOE – Water Resource Planning, Management and Permitting
- 1990 ICC 13.03A Water System & Fireflow Requirements
- 1990 ICC 8.09 POTABLE WATER SOURCE AND SUPPLY
- 1991 Groundwater Management Plan
- 1995 Nitrate Study
- 1996 Island County Hydrogeologist
- 1997-2003 USGS Recharge Study
- 2001-2006 HB-2514 Watershed Planning (Phases I, II, III and IV)
- 2005 ICC 8.09.97 Critical Aquifer Recharge Area (CARA) Protection
- 2005 ICC 8.09.99 Seawater Intrusion Protection

Washington State Department of Health
Island County Health Department
Salt Water Intrusion Policy (Adopted 1989)

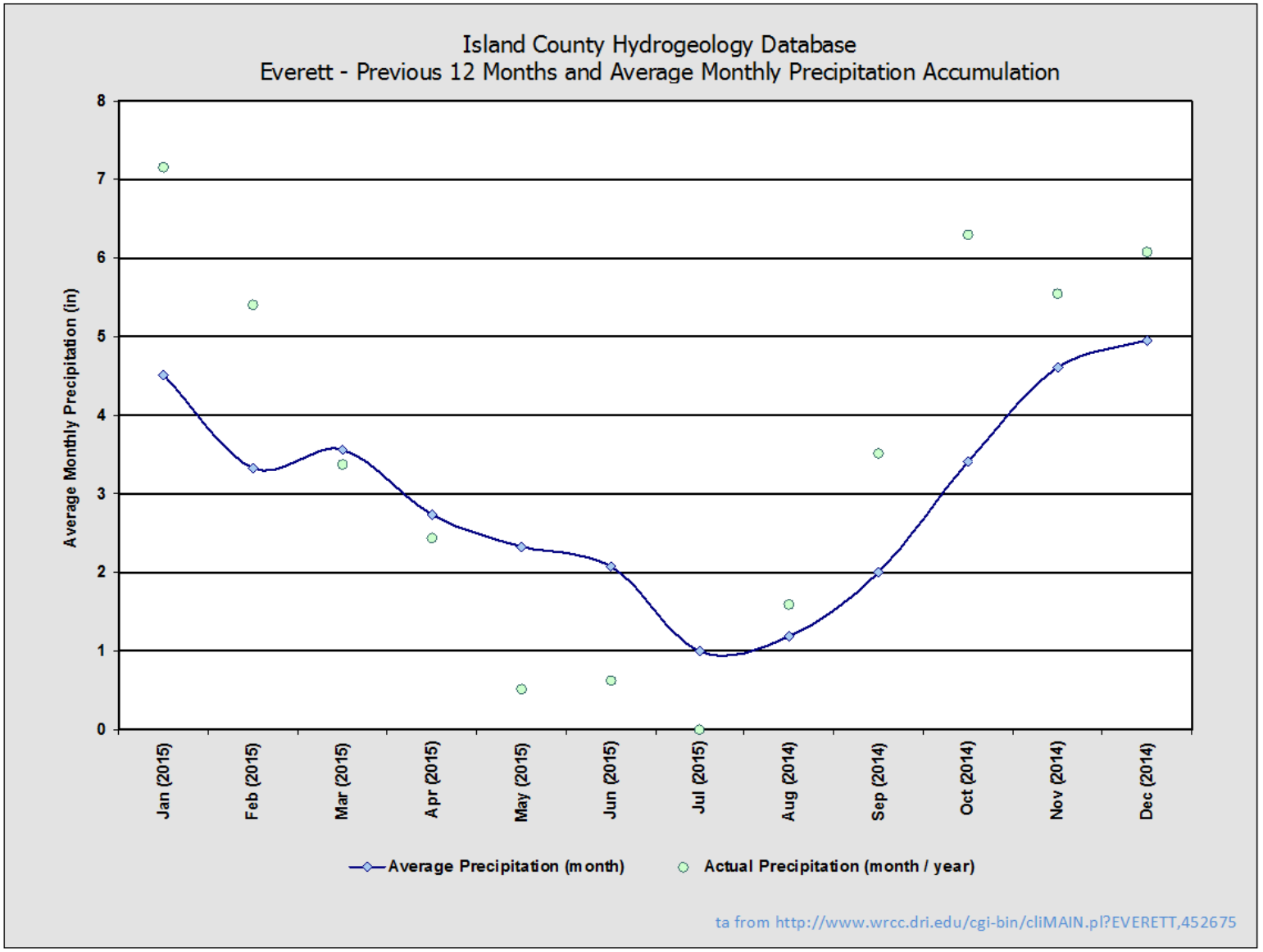
- Based on Chloride Concentration in Wells
- Created "Risk Zones"

Risk Category	Chloride (mg/L)
Low	< 100
Medium	100-200
High	> 200

- Utilized a 1/2 Mile Radius Around "Impacted" Wells
- Applied to Expansion / Development of Public Water Systems
- Applied to Subdivision of Land Through Anti-Degradation
- Modified in 2002 to Apply to Individual Wells on Parcels Less than 1.5 Acres in Size

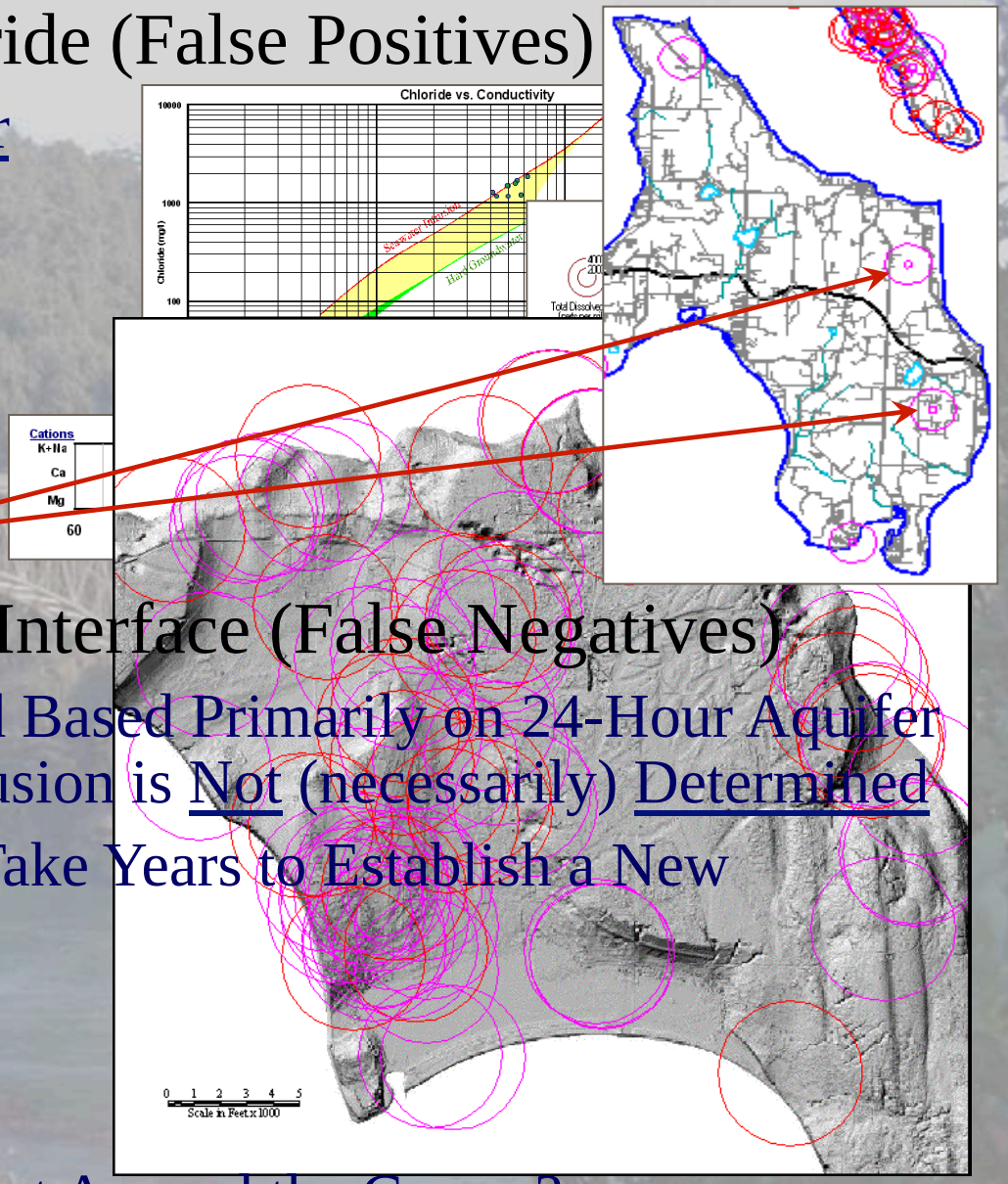

Adapted from PRISM Climate Group, Oregon State University
Annual Precipitation (in.)
0
< 4
4 - 8
8 - 12
12 - 16
16 - 20
20 - 24
24 - 28
28 - 32
32 - 36
36 - 40
40 - 50
50 - 60
60 - 70
70 - 80
80 - 100
100 - 120
120 - 140
140 - 160
> 160

2015 Drought

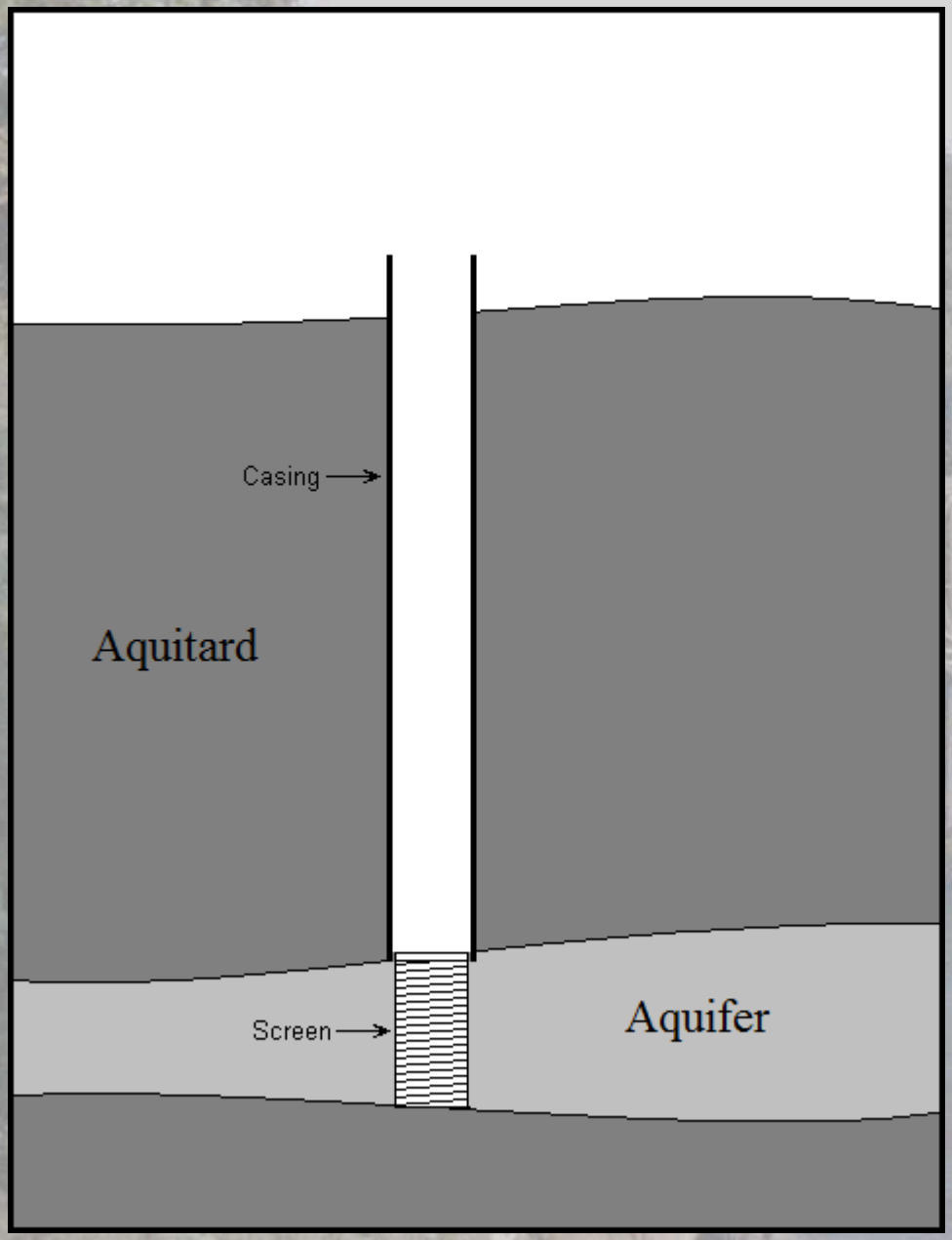


Problems with Chloride as an Indicator

- Other Sources of Chloride (False Positives)
  - Very Hard Groundwater
  - Septic Systems
  - Connate (Old) Waters
  - Windblown Sea Spray
  - Irrigation Recharge
  - Well Disinfection
- Transient Response of Interface (False Negatives)
  - Proposals are Evaluated Based Primarily on 24-Hour Aquifer Tests, Potential for Intrusion is Not (necessarily) Determined
  - Lateral Intrusion May Take Years to Establish a New Equilibrium Position
  - Lack of Prediction
- Lack of Confidence
  - Is Intrusion Looming Just Around the Corner?



Well Construction



Objectives

- Place a well screen in the aquifer.
- The screen allows water into the well, while holding back the aquifer material (sand / gravel).
- Install a well casing, to allow access for a pump etc.

Well Construction

Process

- Advance the casing until a suitable aquifer is penetrated.
- Place a well screen within the casing, adjacent to the aquifer.
- Pull the casing back, to expose the well screen to the aquifer formation.

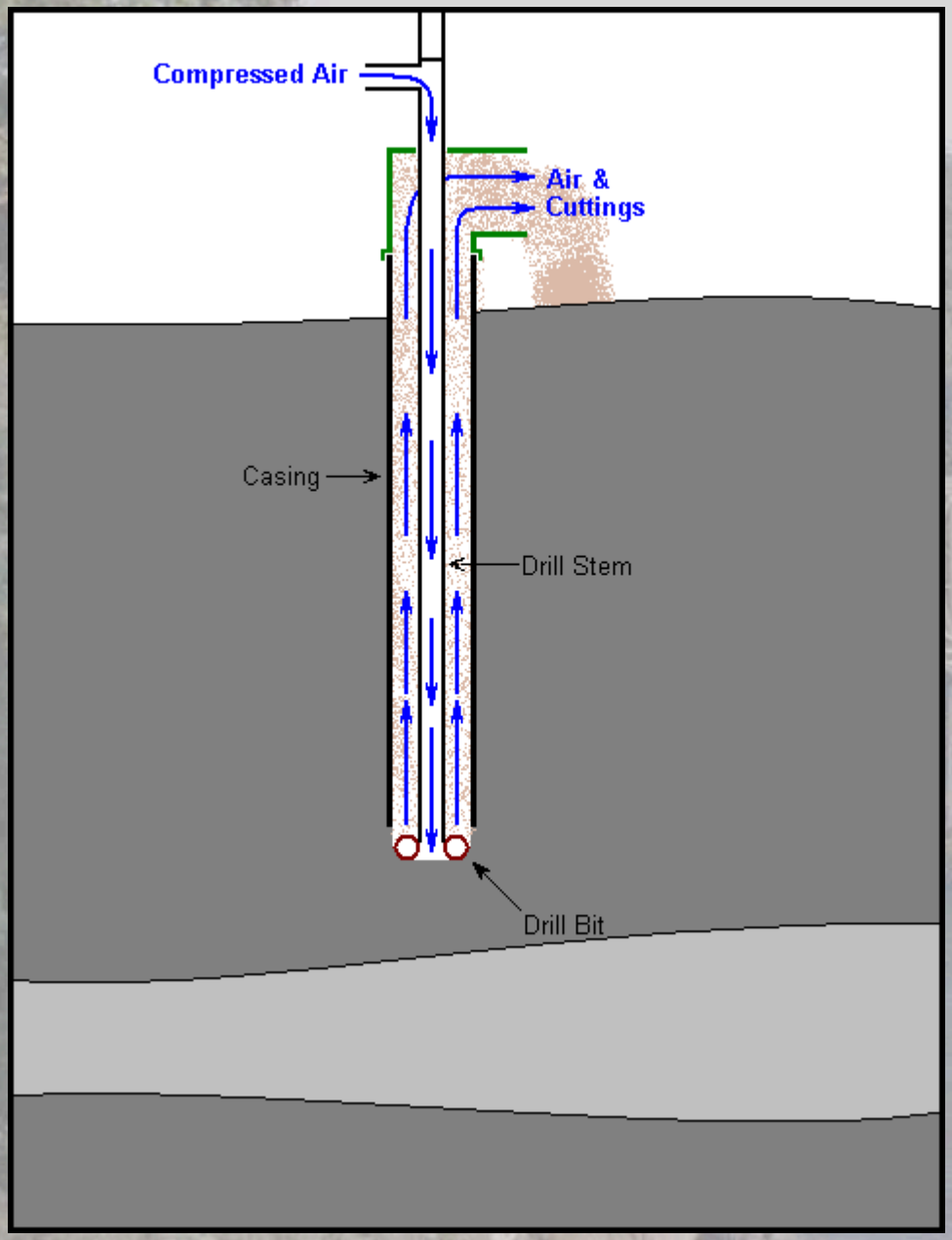
Well Construction

Drill Rigs

- Two types of drill rigs are typically used for drilling small domestic supply wells in our area:

1. Cable Tool
2. Air Rotary

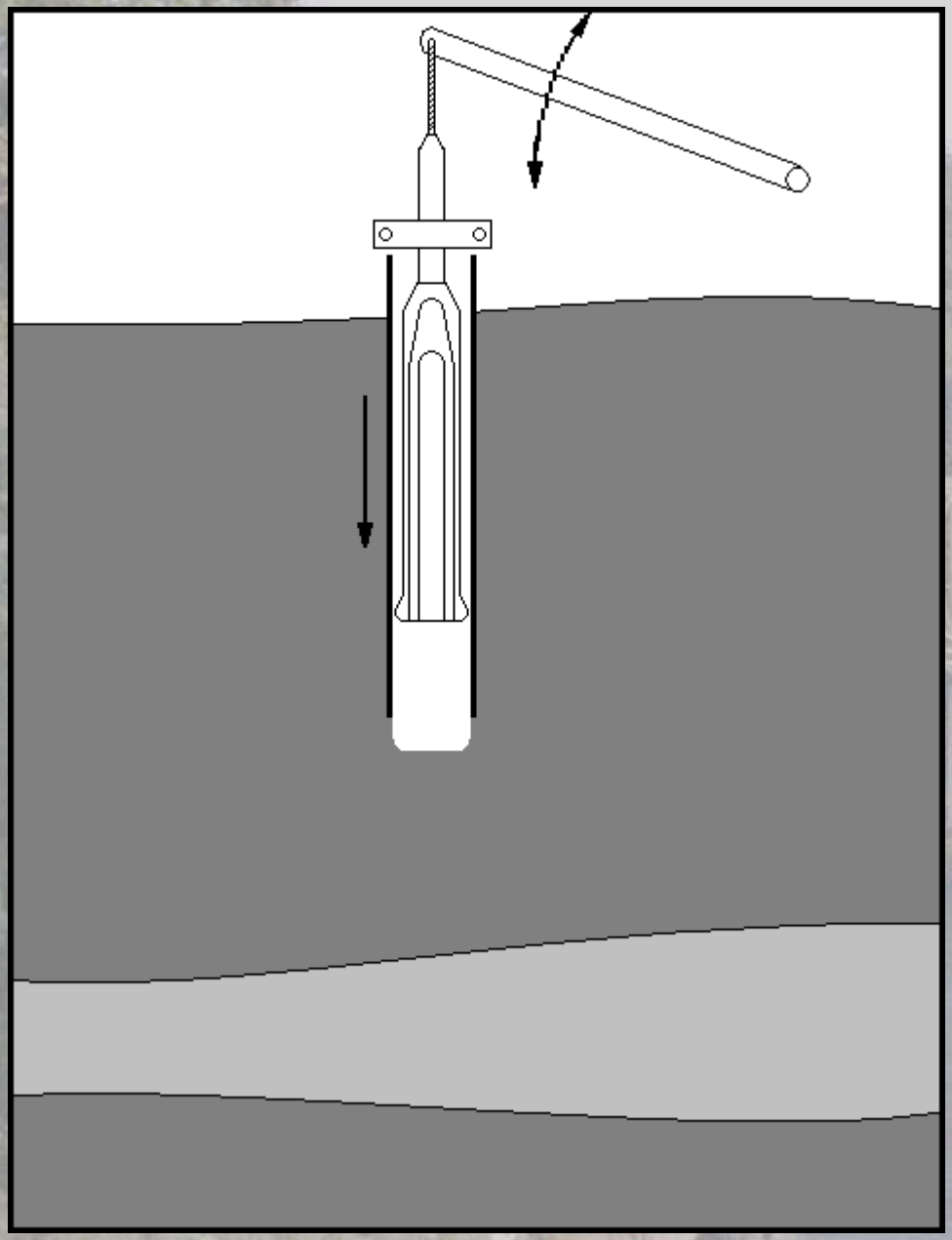
Well Construction



Air Rotary

- Formation is ground up by a spinning drill bit attached to the drill rig by the drill stem.
- Cuttings are removed by highly pressurized air.
- Casing is advanced simultaneously with drilling.

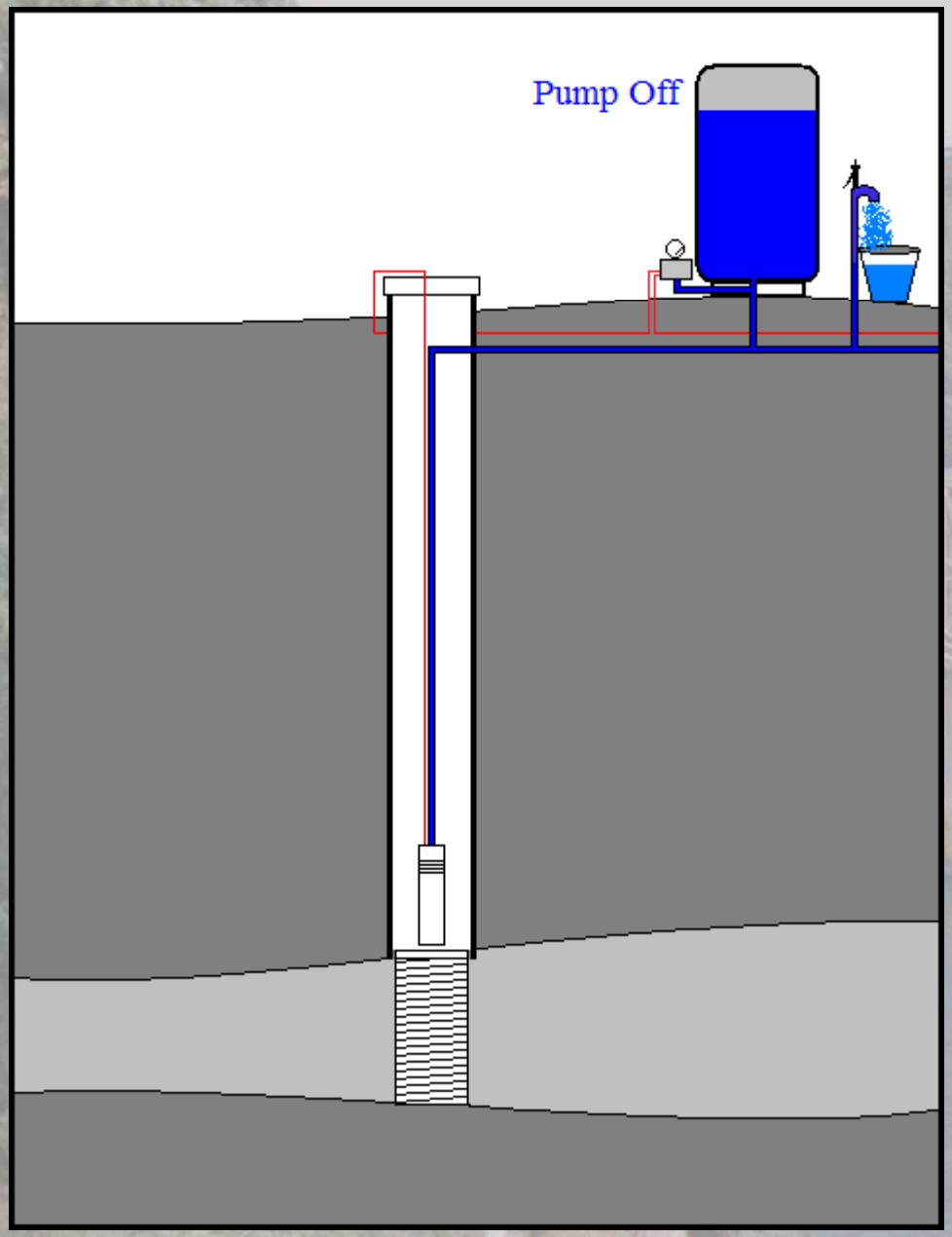
Well Construction



Cable Tool

- The formation is ground up by raising and lowering a heavy drill bit (on a cable)
- Cuttings are removed by a bucket with a flap valve at the bottom known as a bailer
- Casing is advanced by attaching a flange to the bit, and pounding the casing downward.

Well Construction



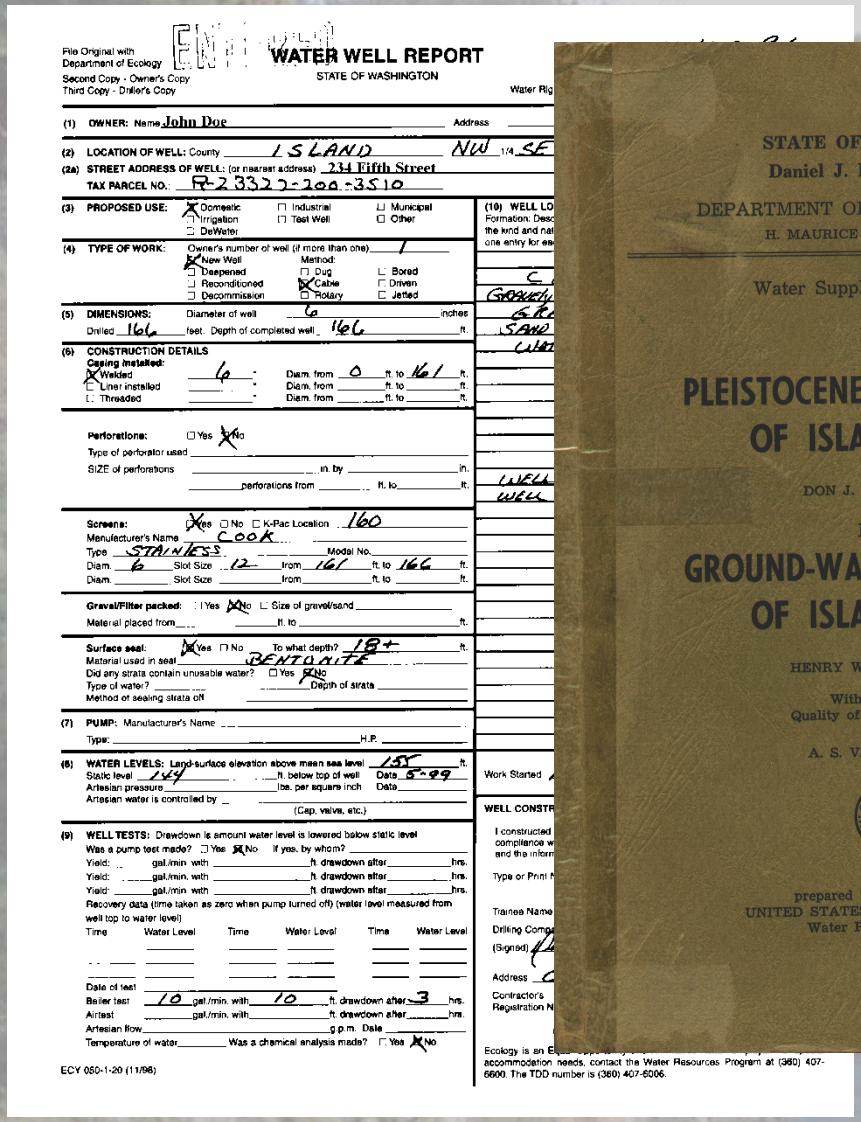
Additional Components

1. Well Pump
2. Electrical Wiring
3. Riser/Drop Pipe & Waterline
4. Well Cap
5. Alternate Riser Configuration:

   Pitless Adapter
6. Pressure Tank
7. Pump Control Circuit

Data Sources

Water Well Report



File Original with Department of Ecology
Second Copy - Owner's Copy
Third Copy - Driller's Copy

WATER WELL REPORT
STATE OF WASHINGTON

(1) OWNER: Name John Doe Address

(2) LOCATION OF WELL: County ISLAND NW 1/4 SE

(2a) STREET ADDRESS OF WELL: (or nearest address) 234 Fifth Street

TAX PARCEL NO. R-23322-200-3510

(3) PROPOSED USE: ☒ Domestic ☐ Industrial ☐ Municipal ☐ Irrigation ☐ Test Well ☐ Other ☐ DeWater

(4) TYPE OF WORK: Owner's number of well (if more than one) 1
☒ New Well ☐ Deepened ☐ Reconditioned ☐ Decommission
Method: ☐ Dug ☒ Cable ☐ Rotary ☐ Bored ☐ Driven ☐ Jetted

(5) DIMENSIONS: Diameter of well 6 inches
Drilled 166 feet. Depth of completed well 166 ft.

(6) CONSTRUCTION DETAILS
Casing installed: ☒ Welded 6" Diam. from 0 ft. to 161 ft.
☐ Liner installed " Diam. from ft. to ft.
☐ Threaded " Diam. from ft. to ft.

Perforations: ☐ Yes ☒ No
Type of perforator used
SIZE of perforations in. by in.
perforations from ft. to ft.

Screens: ☒ Yes ☐ No ☐ K-Pac Location 160
Manufacturer's Name COOK
Type STAINLESS Model No.
Diam. 6 Slot Size 12 from 161 ft. to 166 ft.
Diam. Slot Size from ft. to ft.

Gravel/Filter packed: ☐ Yes ☒ No ☐ Size of gravel/sand
Material placed from ft. to ft.

Surface seal: ☒ Yes ☐ No To what depth? 18+ ft.
Material used in seal BENTONITE
Did any strata contain unusable water? ☐ Yes ☒ No
Type of water? Depth of strata
Method of sealing strata off

(7) PUMP: Manufacturer's Name
Type: H.P.

(8) WATER LEVELS: Land-surface elevation above mean sea level 155 ft.
Static level 149 ft. below top of well Date 5-99
Artesian pressure lbs. per square inch Date
Artesian water is controlled by (Cap, valve, etc.)

(9) WELL TESTS: Drawdown is amount water level is lowered below static level
Was a pump test made? ☐ Yes ☒ No If yes, by whom?
Yield: gal./min. with ft. drawdown after hrs.
Yield: gal./min. with ft. drawdown after hrs.
Yield: gal./min. with ft. drawdown after hrs.
Recovery data (time taken as zero when pump turned off) (water level measured from well top to water level)

Time	Water Level	Time	Water Level	Time	Water Level

Date of test
Bailer test 10 gal./min. with 10 ft. drawdown after 3 hrs.
Airtest gal./min. with ft. drawdown after hrs.
Artesian flow g.p.m. Date
Temperature of water Was a chemical analysis made? ☐ Yes ☒ No

(10) WELL LO
Formation: Desc
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C
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WELL
WELL

Work Started
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and the inform
Type or Print N
Trainee Name
Driling Compa
(Signed)
Address
Contractor's Registration N

Ecology is an E
accommodation needs, contact the Water Resources Program at (360) 407-6600. The TDD number is (360) 407-6006.

ECY 050-1-20 (11/96)

STATE OF WASHINGTON
Daniel J. Evans, Governor
DEPARTMENT OF WATER RESOURCES
H. MAURICE AHLQUIST, Director

Water Supply Bulletin No. 25

Part I

PLEISTOCENE STRATIGRAPHY OF ISLAND COUNTY

By
DON J. EASTERBROOK
and

Part II

GROUND-WATER RESOURCES OF ISLAND COUNTY

By
HENRY W. ANDERSON, JR.

With a section on
Quality of the Ground Water
By
A. S. VAN DENBURGH

Part II
prepared in cooperation with
UNITED STATES GEOLOGICAL SURVEY
Water Resources Division
1968

Groundwater Chemical Analysis

Analytical/Environmental Services

onsulting, Inc (360)757-1400 - FAX (360)757-1402
gton, WA 98233

Reference: 95-0583
Project: Goodhue-Nims Water System

RMATION FOR INORGANIC CHEMICAL ANALYSIS

Analyte		*MCL	Result	UNITS	SRL	Complies
mony	Sb	0.006	<0.005	mg/L	0.005	Yes
nic	As	0.050	<0.01	mg/L	0.01	Yes
um	Ba	2.00	<0.1	mg/L	0.1	Yes
llium	Be	0.004	<0.002	mg/L	0.002	Yes
mium	Cd	0.005	<0.002	mg/L	0.002	Yes
mium	Cr	0.10	<0.01	mg/L	0.01	Yes
per	Cu	1.3*	<0.02	mg/L	0.02	Yes
	Fe	0.30	6.25	mg/L	0.05	No
	Pb	0.015*	0.008	mg/L	0.002	Yes
ganese	Mn	0.050	0.15	mg/L	0.01	No
cury	Hg	0.0020	<0.0005	mg/L	0.0005	Yes
el	Ni	0.10	<0.04	mg/L	0.04	Yes
nium	Se	0.050	0.012	mg/L	0.005	Yes
er	Ag	0.050	<0.010	mg/L	0.01	Yes
um	Na		14.0	mg/L	1.0	
llium	Tl	0.002	<0.001	mg/L	0.001	Yes
	Zn	5.00	2.78	mg/L	0.05	Yes
ness			218	mg CaCO3/L	10	
ific Conductance		700	495	uS	10	Yes
idity		1.0	0.9	NTU	0.1	Yes
r		15	>5	CU	5	Yes
ride	Cl	250	<20	mg/L	20	Yes
nide	CN	0.20	<0.10	mg/L	0.10	Yes
ride	F	2.0	<0.5	mg/L	0.5	Yes
te-N	NO3-N	10.0	1.2	mg/L	0.5	Yes
e-N	NO2-N	1.0	<0.5	mg/L	0.5	Yes
ate	SO4	250	31	mg/L	10	Yes
Dissolved Solids		500	NA	mg/L	150	

oratory Comments:

M.P. mp

Laboratory Supervisor:

Date of Report: 4/20/95

MCL - Maximum Contamination Level. Federal Action Levels are 0.015 mg/L for Lead and 1.3 mg/L for Copper
SRL - Specified Reporting Limit; NA - Not Analyzed; < - "less than"

Data Storage and Analysis

- Microsoft Access Databases
- Graphical Analysis Tools
- OLE Link to Mapping, Geo-Statistics and Groundwater Flow Modeling
- Electronic Data Transmission

WATER RESOURCE MANAGEMENT PLAN

Washington State Department of Ecology funded Island County to develop a Water Resource Management Plan, which was adopted by the Board of Island County Commissioners on June 20, 2005. A series of Topic Papers were drafted by the Island County Water Resource Advisory Committee. These Topic Papers were the basis of the Water Resource Management Plan, and can be found in Appendix F or Table B below.

After completion of the Water Resource Management Plan, Washington State Department of Ecology funded Island County to develop the Water Resource Detailed Implementation Plan. This working document was approved by the Water Resource Advisory Committee in December of 2006, and outlines specific watershed related projects.

Table A - Water Resource Management Plan		
Cover Page	BICC Resolution	Table of Contents
Acknowledgements	Water Resource Plan	CARA Map
Appendix A	Appendix B	Appendix C
Appendix D	Appendix E	Appendix F
Appendix G	Appendix H	Appendix I
Appendix J	Appendix K	Appendix L
Table B - Topic Papers		
Seawater Intrusion	Groundwater Recharge	Water Rights
Exempt Wells	Streamflow and Aquatic Habitat	Water System Coordination
Water Supply Alternatives	Rainwater Catchment	Conservation
Data Collection and Management	Education and Outreach	

WRAC Topic Paper Topics

- Conservation
- Arsenic
- Education and Outreach
- Data Collection and Management
- Water Rights
- Water Supply Alternatives
- Rainwater Catchment
- Exempt Wells
- Streamflows and Aquatic Habitat
- Water System Coordination
- Seawater Intrusion
- Groundwater Recharge

Groundwater Recharge

- **Quantity:** Maintaining adequate groundwater recharge rates through decreasing the impacts of surface modifications

- **Quality:** Managing surface contaminants to reduce the risk of percolation down into groundwater supplies

Groundwater Recharge / Quantity

Human activities can significantly reduce recharge rates. Percolation rates can be maintained/encouraged through using Low Impact Development (LID) methods such as:

- Limiting the surface area of hard/impervious paved surfaces
- Managing roof runoff and minimizing roof size, where possible
- Retaining surface water runoff in cisterns or other catchments
- Keeping native vegetation on-site, minimize grading / compaction

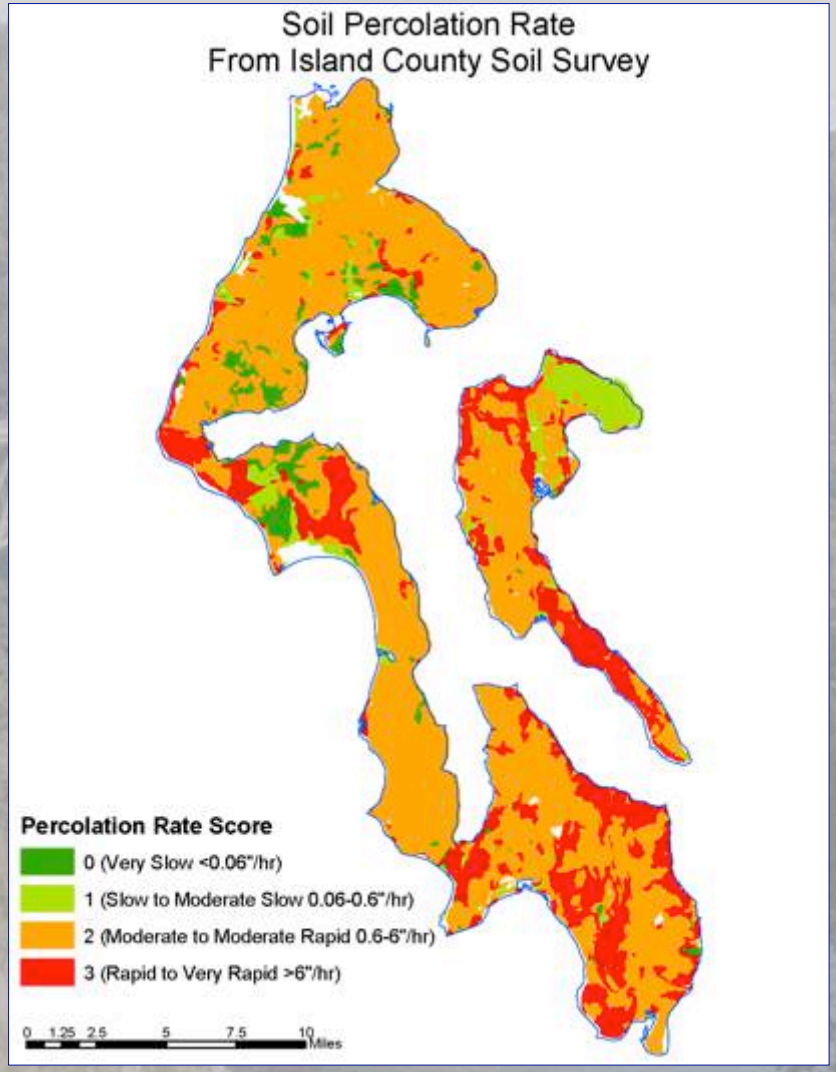
These LID methods can mitigate the effects of hard/ impervious surfaces, allowing retained or collected rainwater to percolate into the ground on-site instead of running off to Puget Sound

Groundwater Recharge / Quality

- Road Runoff
- Septic Systems
- Agriculture (Nutrients and Chemicals
- Residential Lawn Chemicals
- ~~Seawater Intrusion~~

Some aquifers have higher susceptibility to surficial contamination than others.

Critical Aquifer Recharge Areas (CARA)



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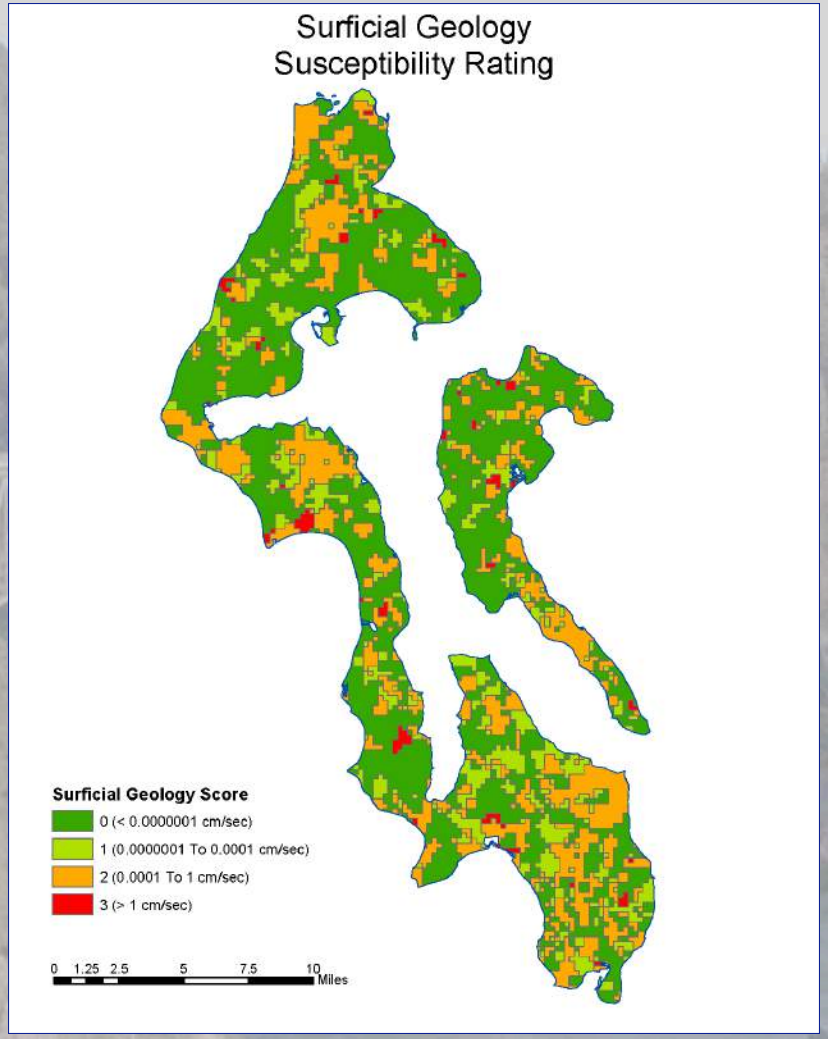

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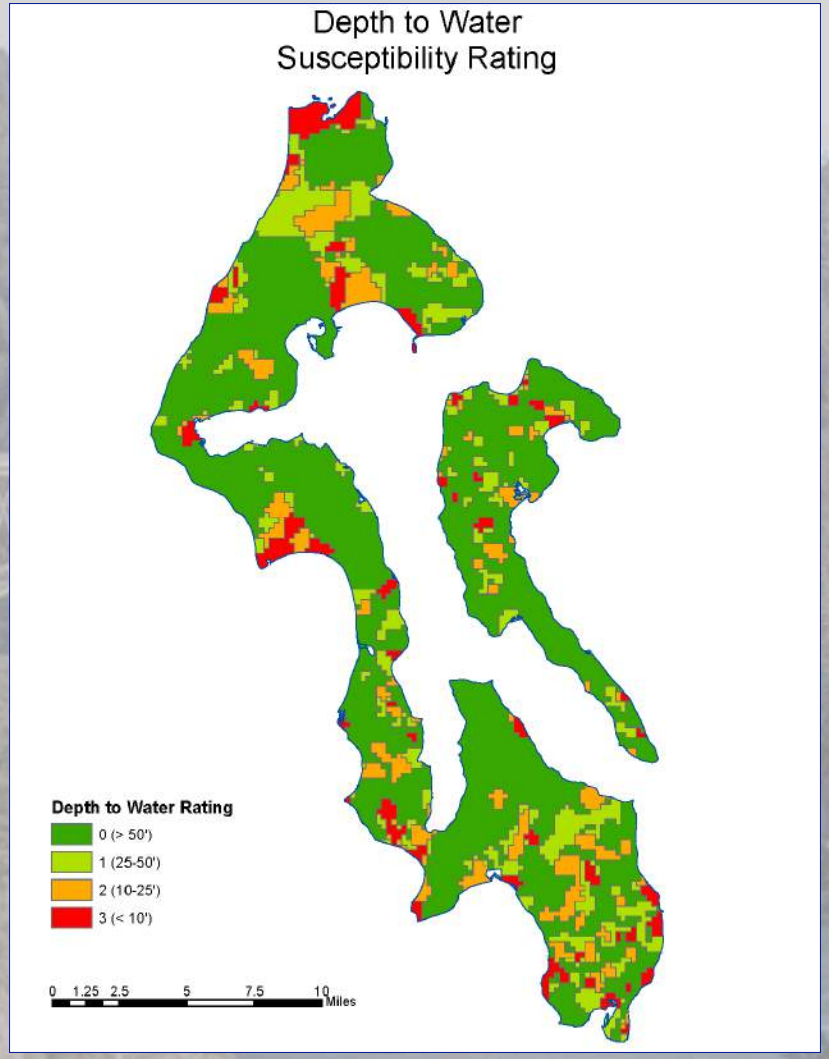

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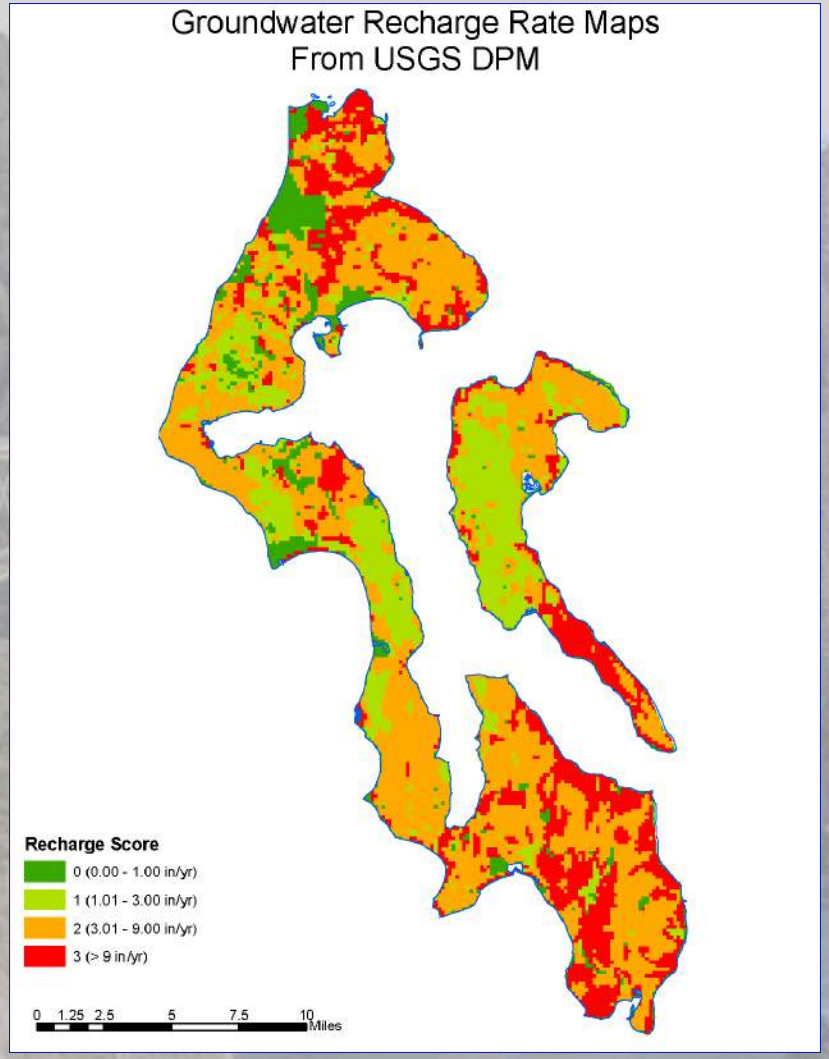

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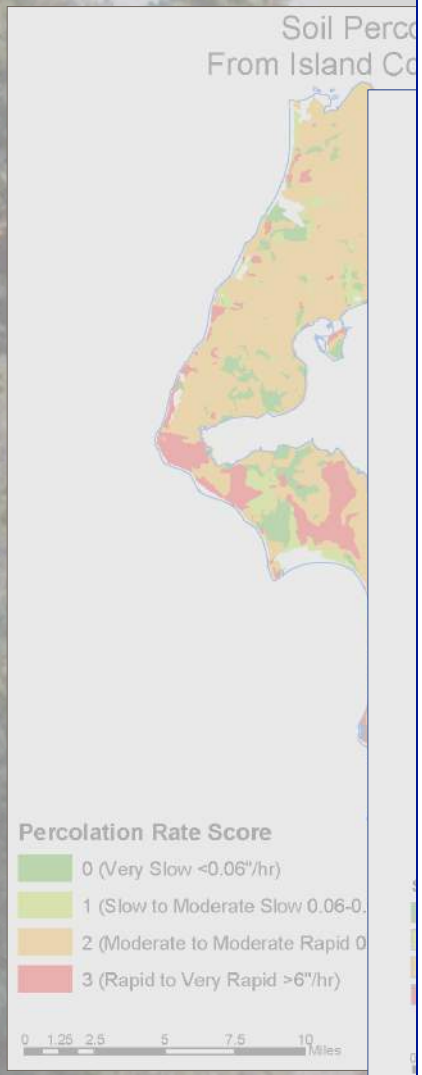
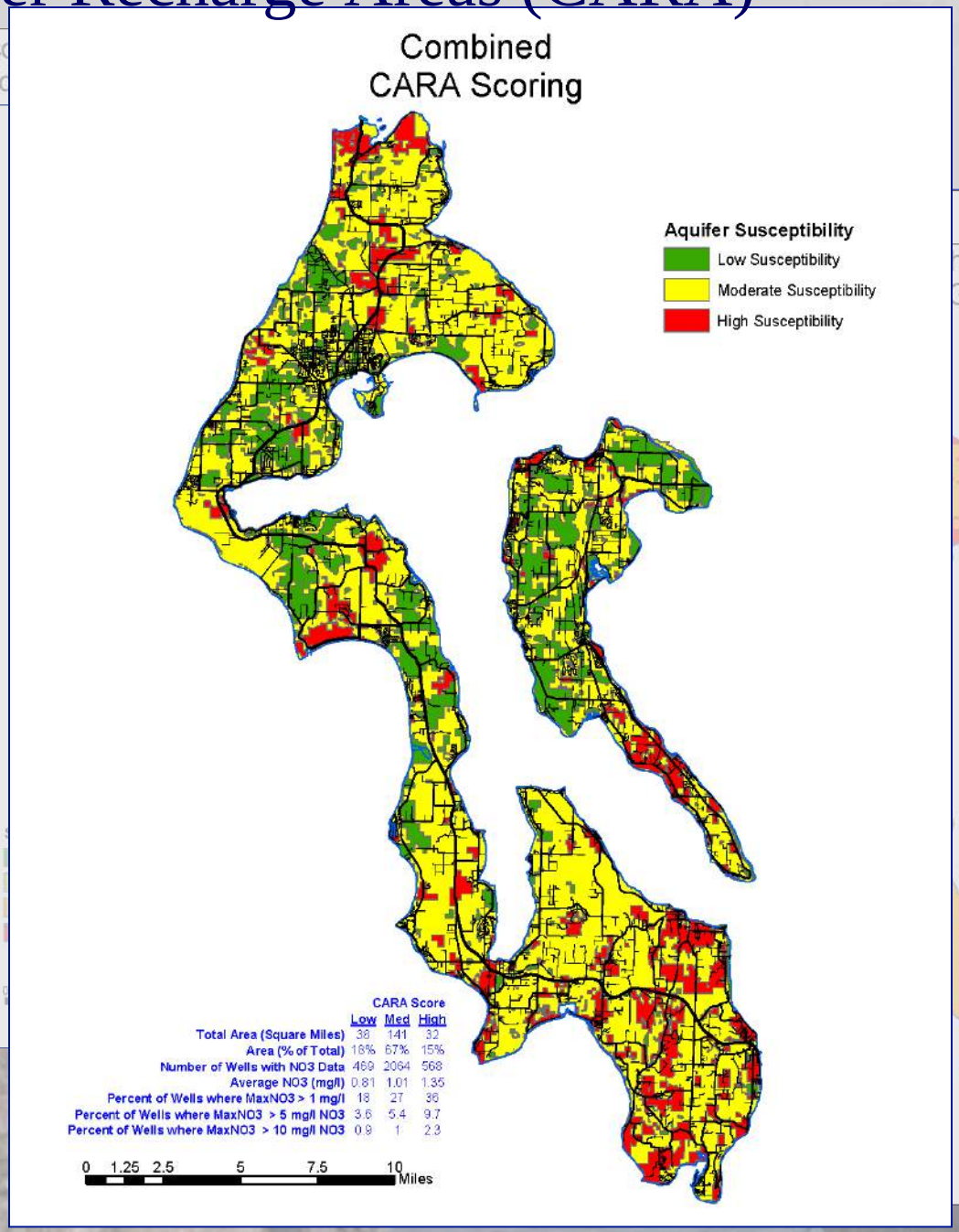
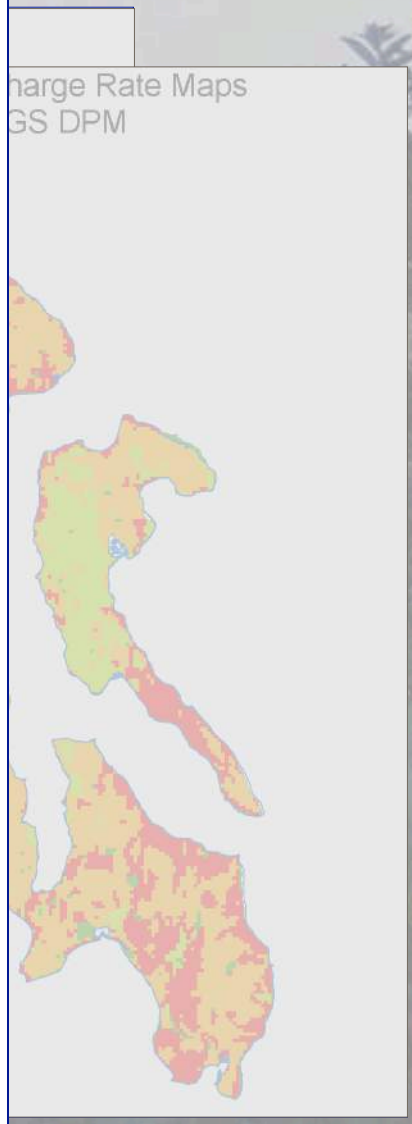
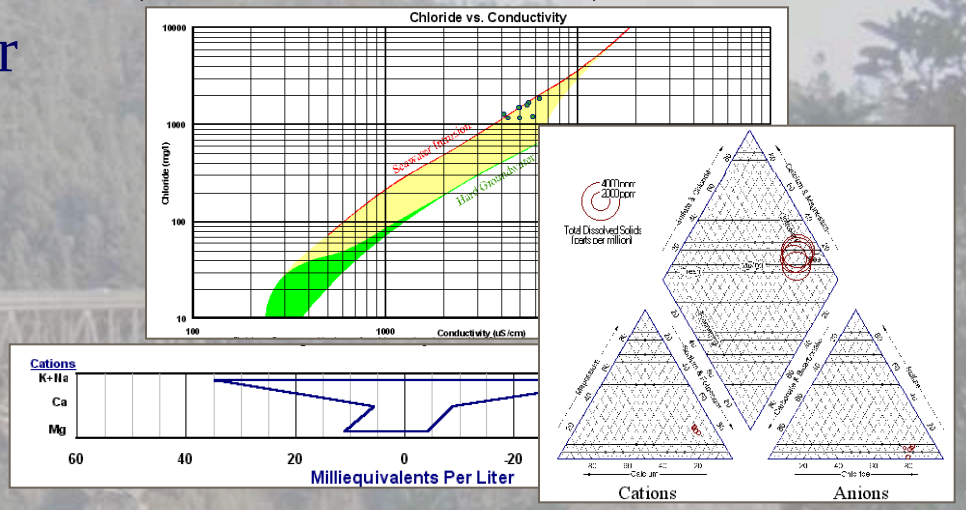






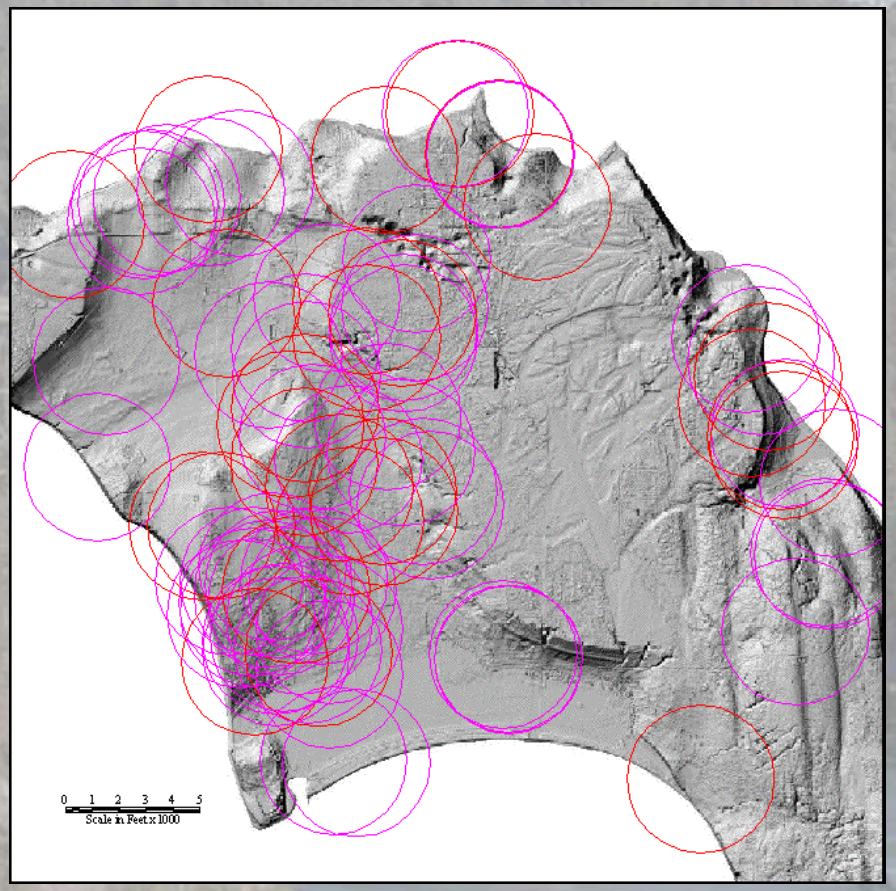
Seawater Intrusion

- Other Sources of Chloride (False Positives)
  - Very Hard Groundwater
  - Septic Systems
  - Connate (Old) Waters
  - Windblown Sea Spray
  - Irrigation Recharge
  - Well Disinfection



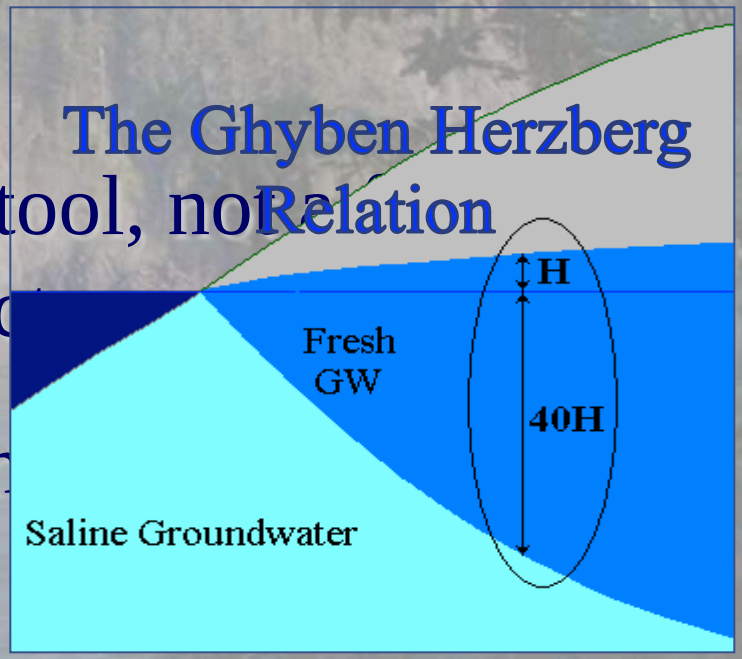
- Transient Response of Interface (False Negatives)
  - Lateral Intrusion May Take Years to Establish a New Equilibrium Position
- Lack of Prediction
- Lack of Confidence

Limitations of the Saltwater Intrusion Policy



Water Level Elevation and Seawater Intrusion

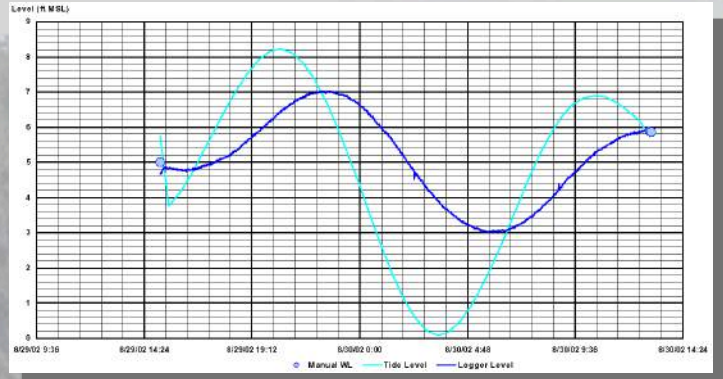
- Adequate aquifer pressure (above sea level) can prevent seawater intrusion
- Water level elevation can be used to assess risk for intrusion
- Create a screening / flagging tool, not
evaluation of any given proje
- Additional data collection / an
evaluate specific projects

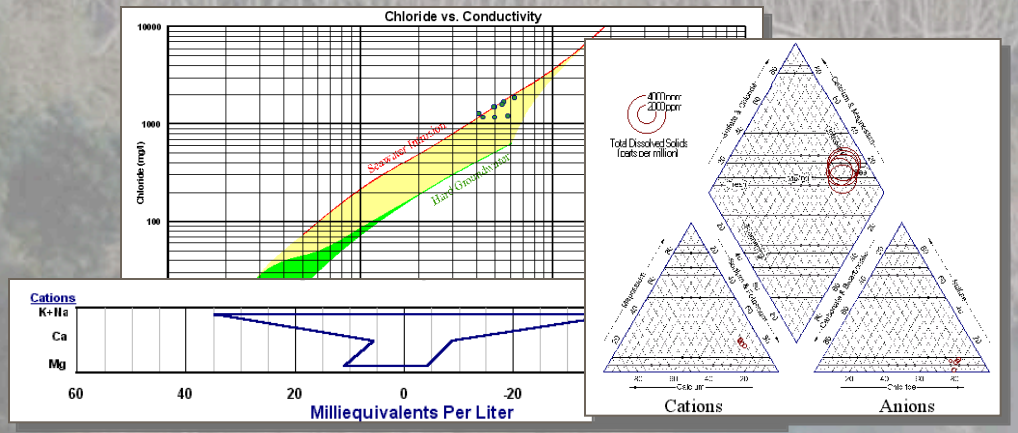


Phase II Assessment

- Data Collected from Nearly 400 Wells / 2 per Mile^2
- Depth to Water Measurements
- Computerized Data Loggers
- Water Sample → Laboratory

  Major Ion Analysis

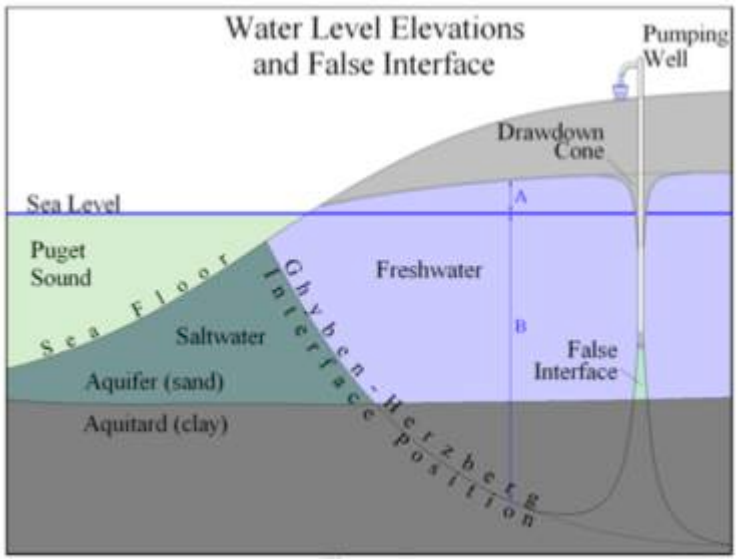


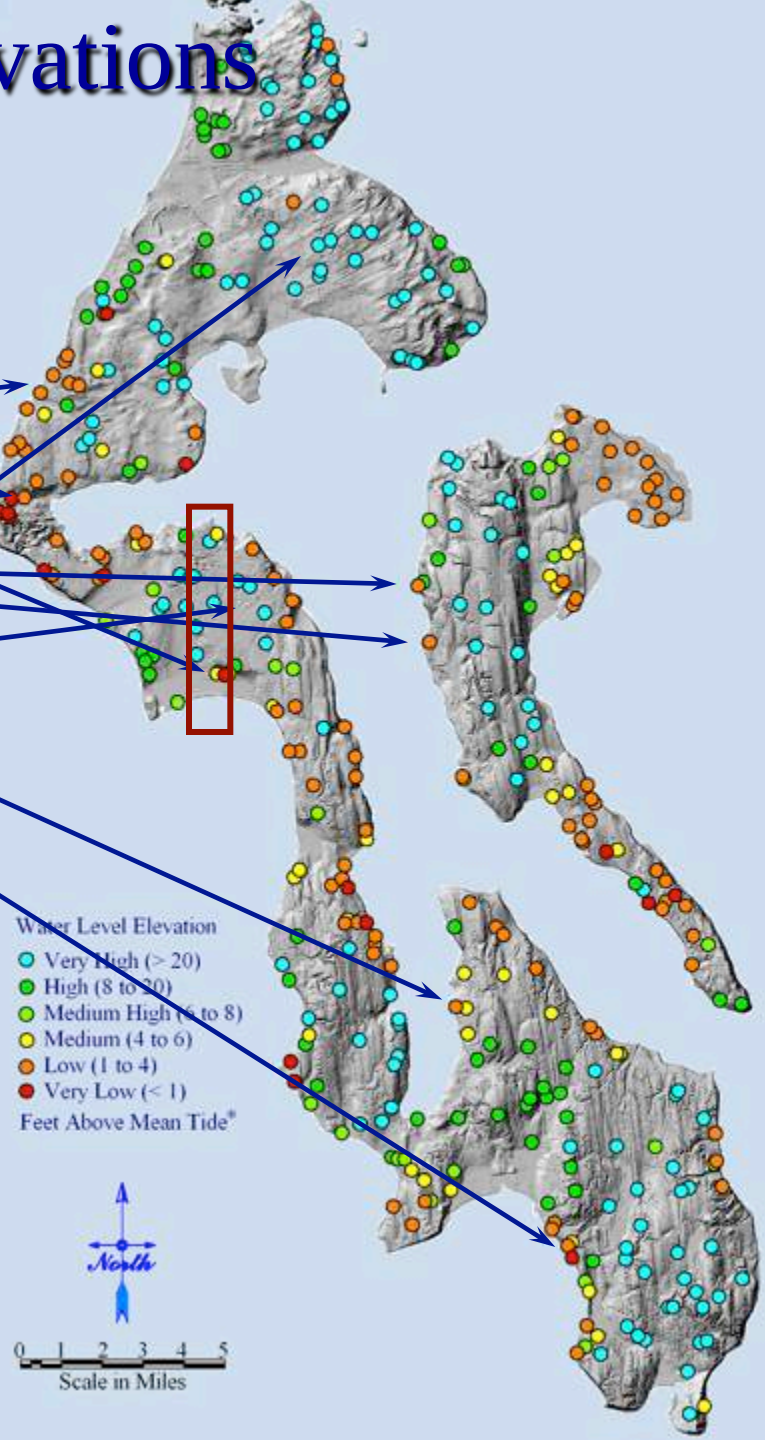


- Survey Grade GPS to Determine Measuring Point Elevations

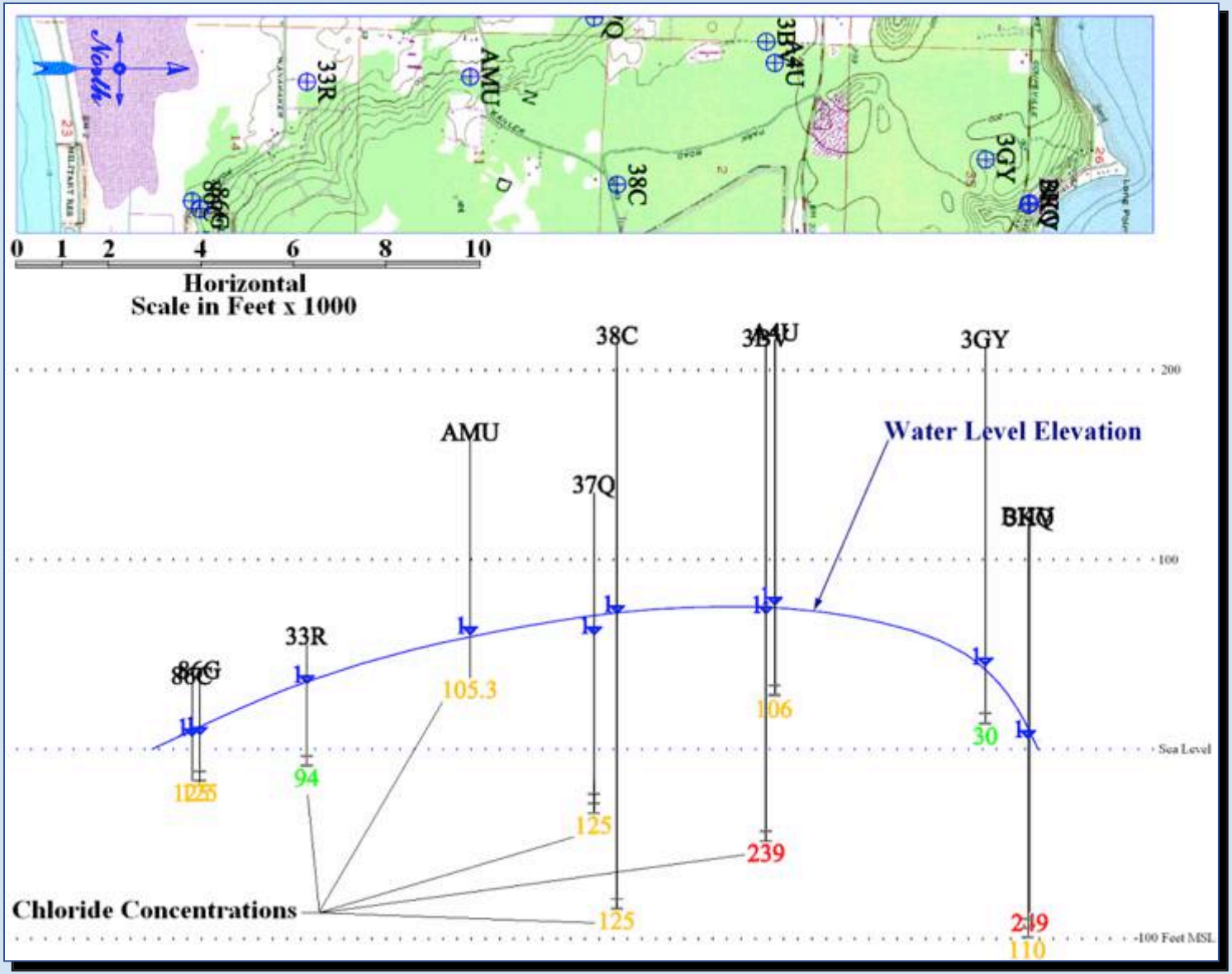
Water Level Elevations

- Low Water Level Elevation Near Shorelines
- Low WLE Clustered
- False Negatives
- High WLE / Confidence
- Confidence?

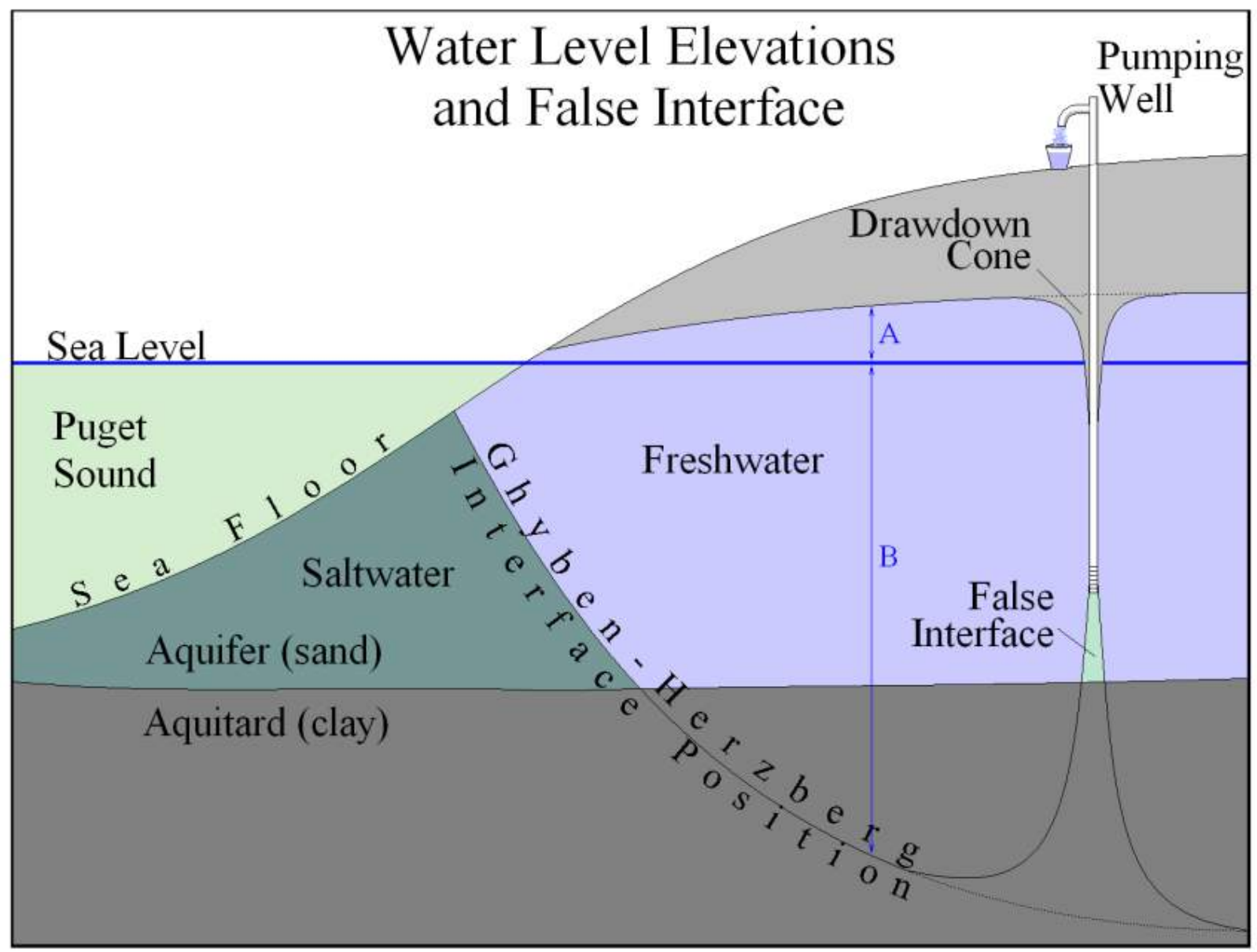




Water Level Elevations



Water Level Elevations



Island County
Revised Seawater Intrusion
Risk Rating

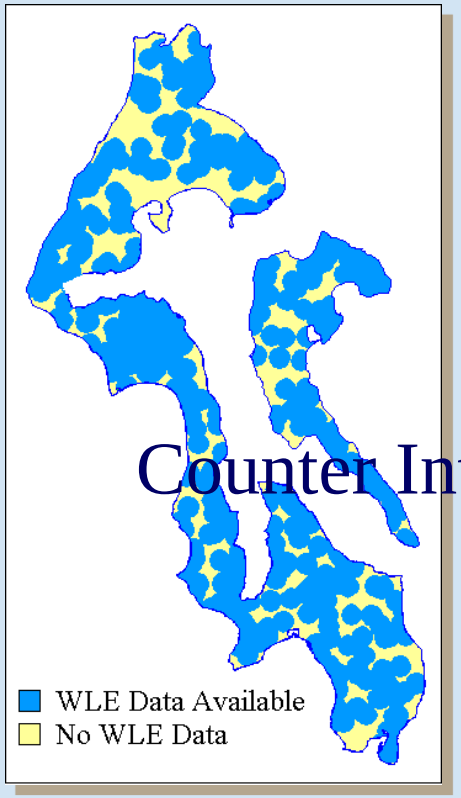
Risk Category	Water Level Elevation [1]	Chloride Concentration [2]
Low	Greater than 8.4	Any
Medium	Less than or Equal to 8.4	Less than 100
High	Less than or Equal to 8.4	Between 100 and 250
Very High	Less than or Equal to 8.4	Greater than 250

[1] Water Level Elevation in feet above Mean Sea Level (NAVD 88).
[2] Chloride Concentration in Milligrams per Liter

Continue Use of ½ Mile Radius Circles Around
Both Low-WLE and Elevated Chloride Wells

The New Circle Map

False Positives



Counter Intuitive?

False Negatives

Legend

- Very High Risk
- High Risk
- Medium Risk
- Low Risk (Previously Medium or High
- Low Risk

Map generated utilizing data from January 2005

Application to Land Use Proposals

Risk Category	Land Subdivision	New or Expanding PWS	Individual Wells
Low	none	none	none
Medium	More than 6 Lots	More than 6 Connections	none
High	All	More than 1 Connection	< 1.5 acres
Very High	All	All	< 5 acres

Sampling

April and August Chloride and Conductivity Sampling from all PWS with More than Two Connections, in Medium or Higher Risk Areas

Seawater Intrusion Review

Projects Identified Above will Collect and Analyze Data to Determine if Project will Negatively Impact Aquifer (Cause Intrusion). Data Collection and Analysis can be Phased to Provide Early Evaluation

Water Level Elevations

Any Potentially Regulated Project Other than Individual Wells will Provide Water Level Elevation Data

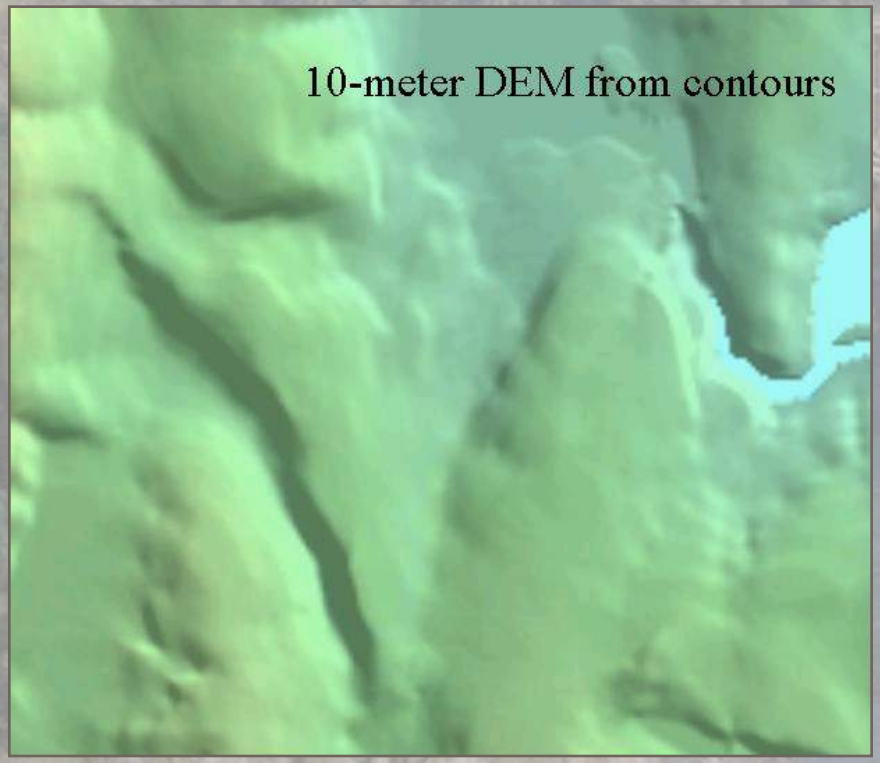
Codified

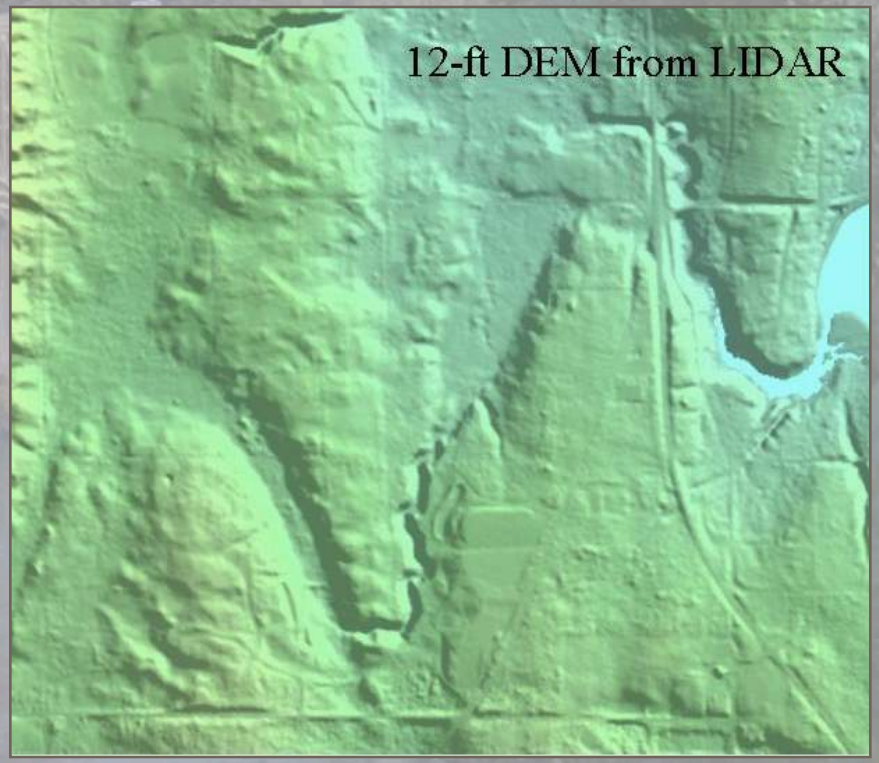
I.C.C. Chapter 8.09.099
Potable Water Source and Supply
Modified to Include New
Seawater Intrusion Protection Strategy

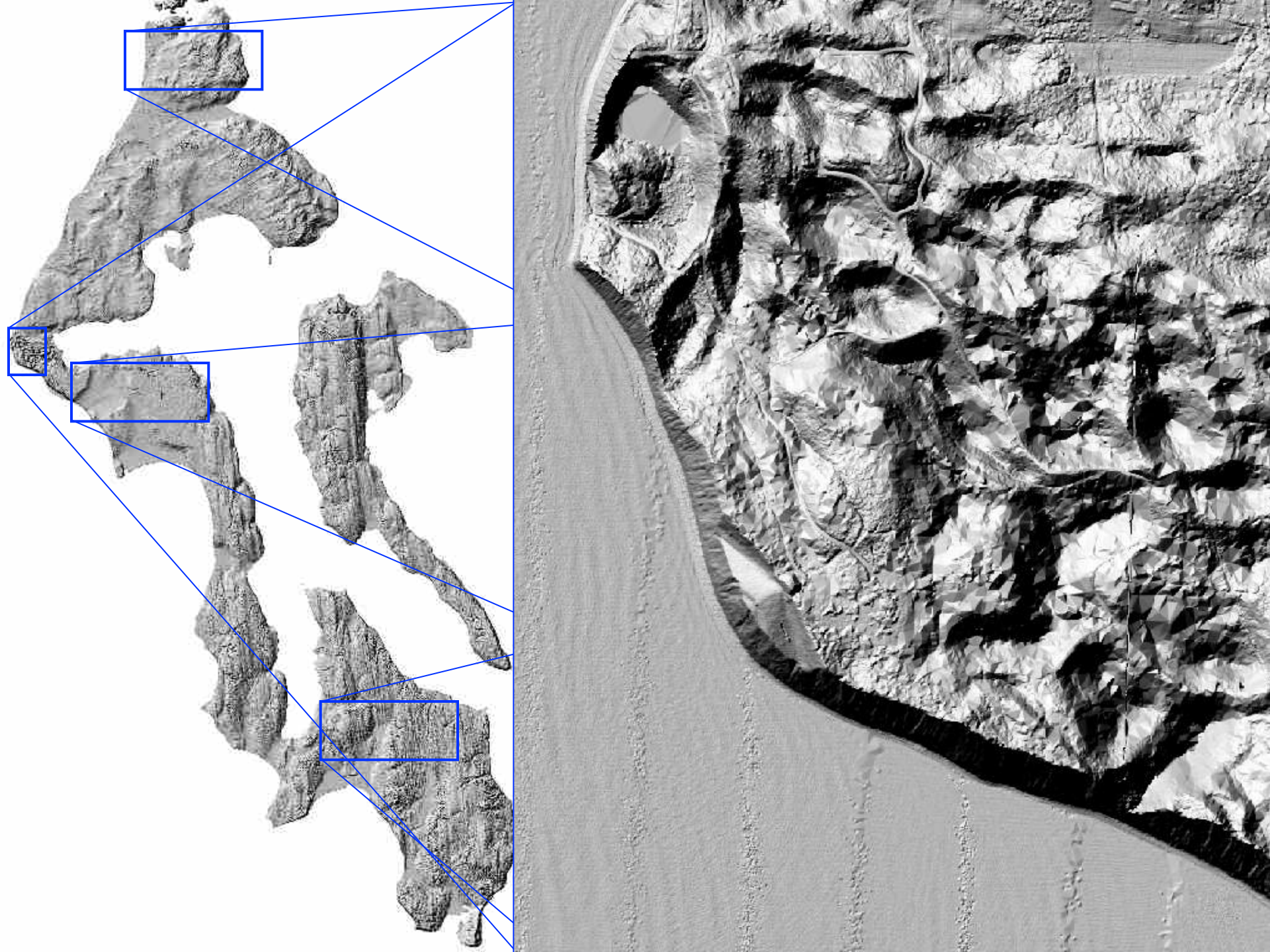
Effective June 21, 2005

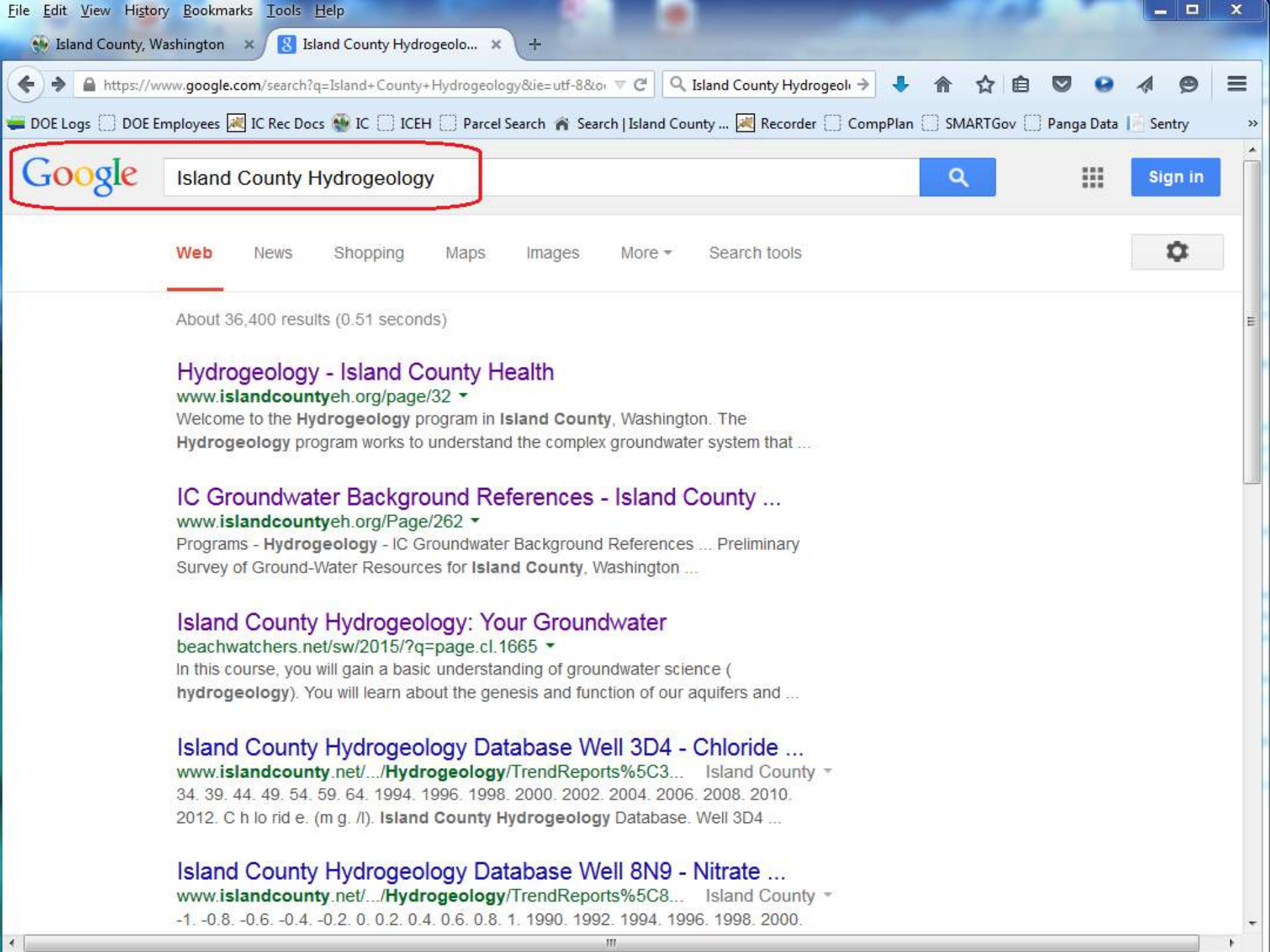
LIDAR

LIDAR (**LI**ght **D**istance **A**nd **R**anging) is a relatively new technology that employs an airborne scanning laser rangefinder to produce accurate topographic surveys of unparalleled detail.





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Google
Island County Hydrogeology
Sign in
Web
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Maps
Images
More
Search tools
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Hydrogeology - Island County Health
www.islandcountyeh.org/page/32
Welcome to the Hydrogeology program in Island County, Washington. The Hydrogeology program works to understand the complex groundwater system that ...
IC Groundwater Background References - Island County ...
www.islandcountyeh.org/Page/262
Programs - Hydrogeology - IC Groundwater Background References ... Preliminary Survey of Ground-Water Resources for Island County, Washington ...
Island County Hydrogeology: Your Groundwater
beachwatchers.net/sw/2015/?q=page.cl.1665
In this course, you will gain a basic understanding of groundwater science (hydrogeology). You will learn about the genesis and function of our aquifers and ...
Island County Hydrogeology Database Well 3D4 - Chloride ...
www.islandcounty.net/.../Hydrogeology/TrendReports%5C3... Island County
34. 39. 44. 49. 54. 59. 64. 1994. 1996. 1998. 2000. 2002. 2004. 2006. 2008. 2010. 2012. C h lo rid e. (m g. /l). Island County Hydrogeology Database. Well 3D4 ...
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Contact Information

Douglas J. Kelly L.G., L.HG

Island County Environmental Health

(360) 679-7885

From Camano: 629-4522

D.Kelly@co.island.wa.us