Seawater Intrusion

1.0 Introduction

Saltwater intrusion is the movement of saline water into a freshwater aquifer. Where the source of this saline water is marine water, this process is known as seawater intrusion. The marine / saline waters of the Puget Sound surround Island County and as a result, all of the aquifers in the county that extend below sea level are at risk for seawater intrusion. The high mineral content (primarily salts) of marine waters causes these waters to be unsuitable for many uses, including human consumption. Thus if intrusion problems become extreme, they can render an aquifer and any wells that are completed in that aquifer unusable for most purposes.

As a result of the above concerns, Island County has historically taken a leading role in understanding and protecting its groundwater resources. The adoption of the Island County / Washington State Department of Health - Salt Water Intrusion Policy in 1989 represented a significant step toward this goal of protecting our aquifers. Fifteen years later, limitations of this policy have become evident, and significant new scientific information has become available. This topic paper provides an overview of current science and regulations, explores management options, and makes recommendations for future resource protection efforts.

1.1 Groundwater and Seawater Intrusion

When an aquifer is in hydraulic connection with saline / marine waters such as the Puget Sound, portions of the aquifer may contain saltwater while other portions contain fresh water. Freshwater is slightly less dense (lighter) than saltwater, and as a result tends to float on top of the saltwater when both fluids are present in an aquifer. There is a relationship based on the density difference between saltwater and freshwater that can be used to estimate the depth to saltwater based on the thickness of the freshwater zone above sea level. The relationship is known as the Ghyben-Herzberg relation (Figure 1). The boundary between the freshwater and the saltwater zones is not sharp but instead is a gradual change over a finite distance, and is known as the zone of diffusion or the zone of mixing.

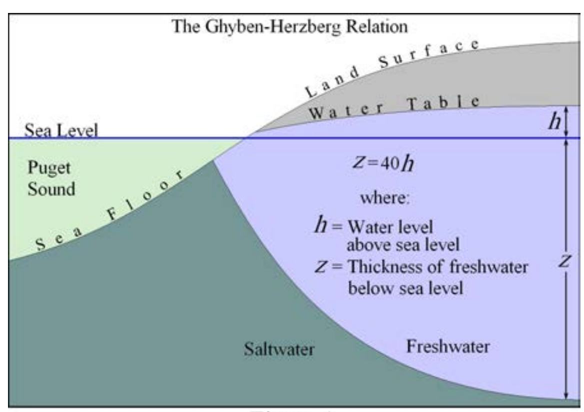


Figure 1.

In Island County, all of our groundwater originates as recharge from precipitation. This recharge creates a pressure distribution within our aquifers that tends to be highest in the center of the islands, lowering as you approach the shorelines. The pressure distribution leads to a flow in the aquifers that is vertically downward near the center of the islands, then flowing radially outward toward the shore (Figure 2).

Two mixing processes (diffusion and dispersion) continuously move saltwater into the freshwater zone. Flow in the freshwater zone sweeps this mixed-

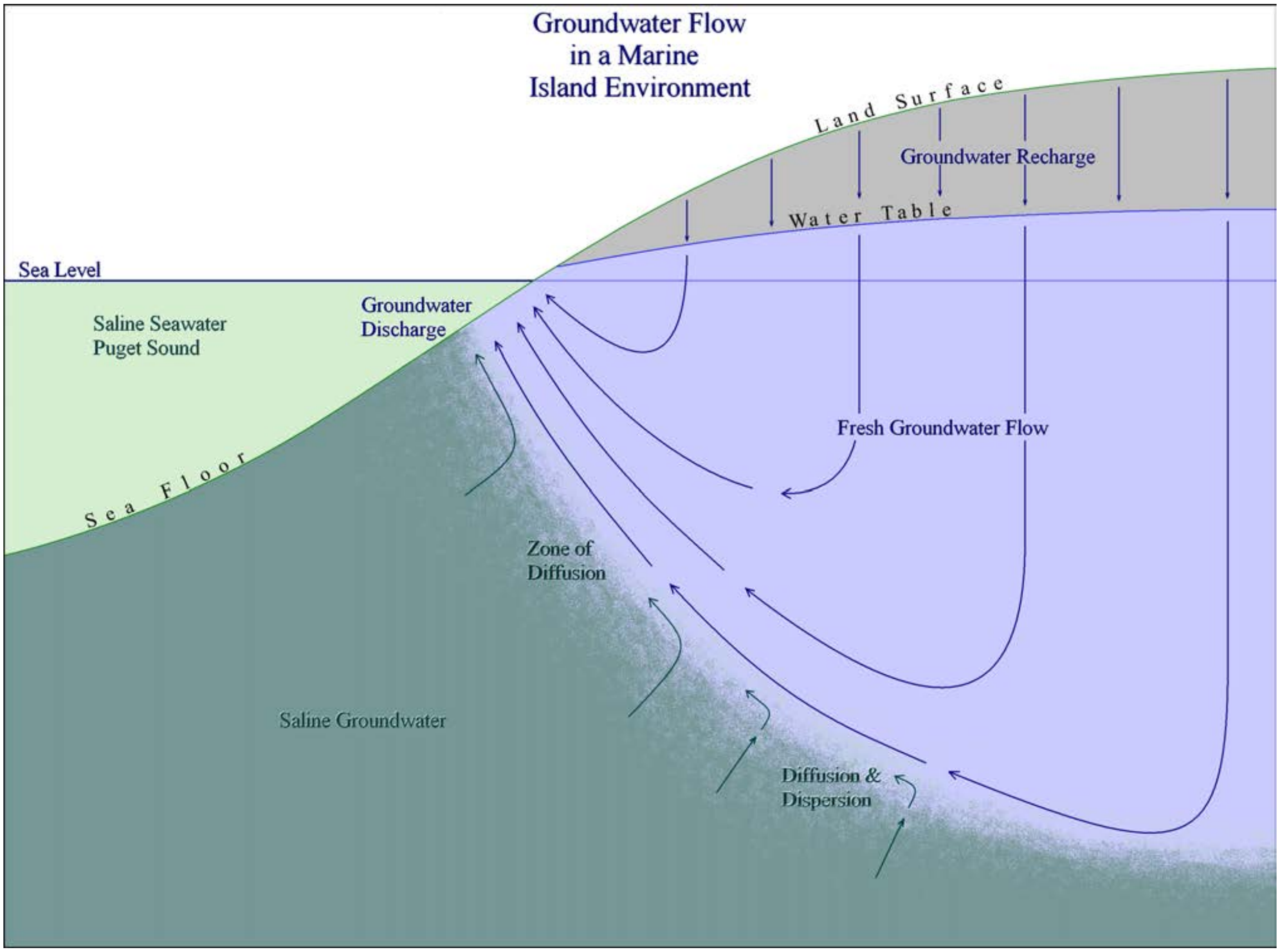


Figure 2.

brackish water toward the shoreline where it discharges at submarine seeps. The processes of recharge, flow, mixing, and discharge all work in unison to hold the interface position in a roughly stationary position. A change to one or more of these processes can result in a change in the position of the interface, an inland movement of the interface boundary known as lateral intrusion.

When a well is pumped, water levels in the vicinity of the well are lowered, creating a drawdown cone (Figure 3). If a saltwater zone exists in the aquifer beneath the well, the saltwater will rise up toward the well screen. This rising up of saltwater is known as upconing and is the second type of seawater intrusion.

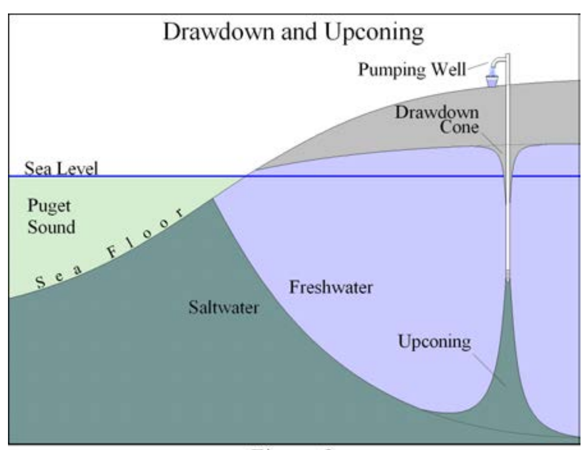


Figure 3.

The previous figures describe various characteristics of groundwater in coastal marine environments, from the perspective of a single aquifer. In reality the groundwater system in Island County is made up of multiple layers of unconsolidated sand and gravel, capable of supplying water to wells (aquifers). These aquifers are interbedded with lower permeability layers of silt and clay (aquitards) that pass water more slowly.

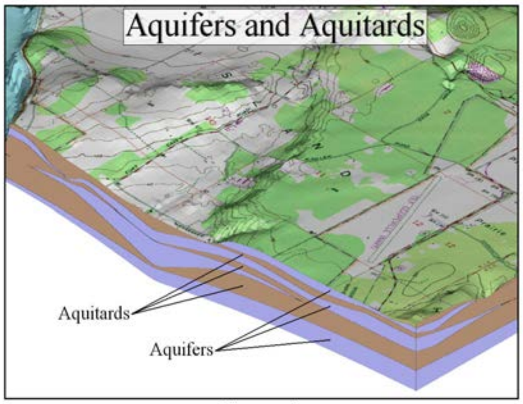


Figure 4.

Aquifers and aquitards in Island County vary spatially in both thickness and elevation, Figure 4. In any given area of the county, there may be several aquifers present, and each aquifer will have different hydraulic characteristics (recharge, pressure, capacity etc) and susceptibility to seawater intrusion. Even within a single aquifer, the hydraulic characteristics can vary significantly from one location to another. It is this variability and complexity of our groundwater system that makes the question of 'How much water is there?' so difficult to answer. As a result, water resource planning and management efforts have primarily relied on review of water use proposals on an individual basis. The scope and detail of the project review has relied on a triggering mechanism known as the Island County Saltwater Intrusion Policy.

2.0 Current Saltwater Intrusion Policy

In 1989 the Island County Health Department, in conjunction with the Washington State Department of Health, adopted the Island County Saltwater Intrusion Policy. The primary function of the policy is to trigger additional review (of potential for seawater intrusion) of new or expanding public water systems in areas where seawater intrusion appears to be occurring. The goal of this policy is to protect public water supplies from seawater intrusion.

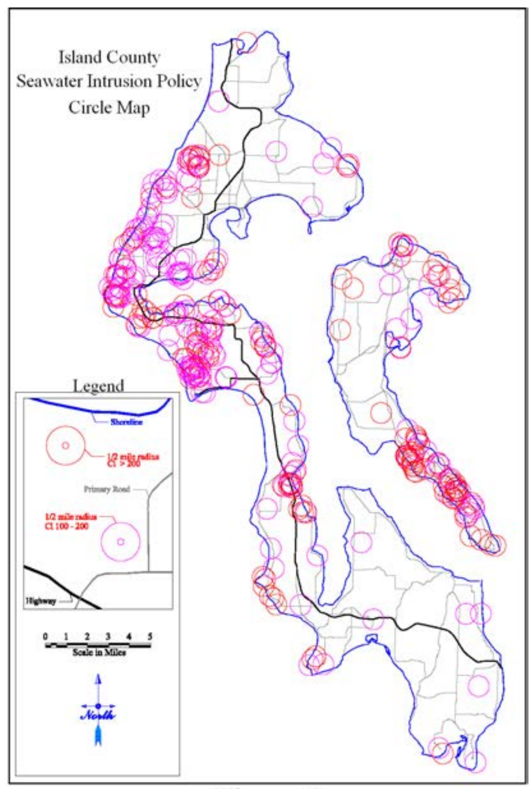


Figure 5.

The policy utilizes chloride concentrations in wells as its indicator of seawater intrusion and defines 'risk zones', drawing ½ mile circles around wells with elevated chloride concentrations. An area where all wells within ½ mile have chloride concentrations less than 100 milligrams per liter (mg/l) is considered 'low risk'. An area where one or more wells have chlorides between 100 and 200 mg/l is considered 'medium risk', and an area with one or more wells with chloride concentrations greater than 200 mg/l is considered 'high risk'. Drawing ½ mile circles around wells with elevated chloride concentrations yields the map shown in Figure 5 known as the Circle Map.

Inspection of Figure 5 shows a pattern where the majority of the ½ mile circles fall along the shoreline, which makes sense in light of the conceptual model shown in Figure 2 with the freshwater lens having a maximum thickness near the center of the island, thinning approaching the shorelines. However there are exceptions to this pattern, where isolated circles, and even clusters of circles fall away from the shorelines toward the island interiors. This discrepancy suggests a problem, either in the conceptual model of groundwater flow and seawater intrusion in an island environment, or with the use of chloride concentrations as the indicator of seawater intrusion.

2.1 Limitations of the Current Saltwater Intrusion Policy

Over ten years of experience in the application of the Saltwater Intrusion Policy has shed light on some limitations of the policy. The first limitation is the fact that there are other sources of chloride in the environment other than seawater intrusion. Non-intrusion chloride sources include: connate (very-old) groundwater, septic system effluent, very hard groundwater, windblown sea spray, and recharge from irrigation, agricultural practices, and well disinfection. Chloride from any of these sources can result in elevated levels of chloride concentrations in an aquifer, triggering the Saltwater Intrusion Policy when in fact the aquifer is not intruded. This erroneous interpretation of data is known as a false positive, where a test identifies a problem that does not in fact exist.

Figure 6 displays a chloride circle map for a portion of Central Whidbey Island. Although some of the circles bordering the shoreline on the map probably represent elevated chlorides due to seawater intrusion, it is believed that the majority of the inland circles are caused by something other than seawater intrusion; in this part of Whidbey Island, very hard groundwater appears to be to the source.

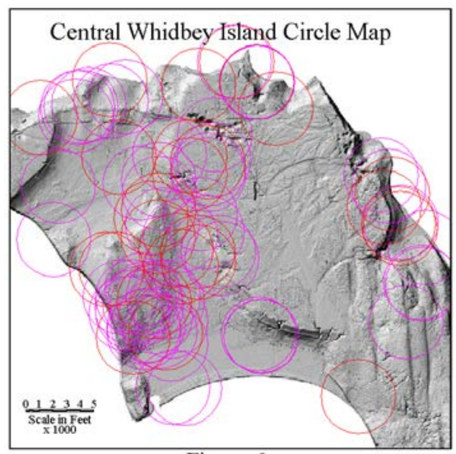


Figure 6.

Various chemical analysis tools have been utilized in an attempt to differentiate between chlorides caused by seawater intrusion and other sources, however no tool has been found that can differentiate all of these sources. In some cases, such as windblown sea spray, an aquifer may be impacted by seawater that is entering the aquifer from above. Chemically this may be indistinguishable from seawater entering laterally, but this movement of seawater into the aquifer has nothing to do with over-drafting the aquifer and classical seawater intrusion. The ambiguity of chloride source can result in incorrectly classifying a proposal as having risk for seawater intrusion, potentially costing significant time and financial costs for both the applicants and the permitting agencies. Denial of applications based on apparent risk for intrusion that is non-existent is also possible.

False positives are one potential problem for the Saltwater Intrusion Policy; a second involves the opposite effect, a false negative. False negatives occur when a test indicates that a problem does not exist, when in fact it does. In the overview of groundwater and seawater intrusion presented earlier in this paper, the mechanisms that influence the location and movement of the saltwater interface were discussed. The processes of groundwater recharge, flow, mixing, and discharge all combine to hold the interface position in a roughly stationary position. A change to any of these processes will result in a change in the position of the interface. However, the change in interface position following a change to the flow regime is not instantaneous, but instead the interface can take a significant amount of time to come into a new equilibrium position.

One of the principal tools used in evaluating proposed groundwater withdrawals is an aquifer test, where a well is pumped for a period of time and the aquifer's response (drawdown) to this pumping is monitored. Analysis of how an aquifer responds to pumping yields numeric values that quantify the hydraulic characteristics of the aquifer, primarily hydraulic transmissivity and storativity. These aquifer parameters can then be utilized to estimate how the aquifer will respond to pumping over longer periods of time.

In areas where seawater intrusion is a concern, water samples are typically collected during the test and sent to a laboratory for analysis of substances related to seawater intrusion. Since most of the 'other sources' of chlorides tend to be persistent, significant rises in chloride concentration during an aquifer test can generally be attributed to seawater intrusion. If no variation in chloride concentration occurs during a test, it is tempting to assume that seawater intrusion is not, and will not become a problem. However, a lack of change in chemistry during an aquifer test does not prove that intrusion (caused by the proposed withdrawal) will not occur at some later time. It is quite possible that the interface was at some distance from the well at the beginning of the test, and moved toward the well during the test, but did not reach the well screen, and as a result no change in chemistry was detected. Once the well is put into full time use, the interface may continue to move inland resulting in seawater intrusion.

Using chemistry as a tool to evaluate risk for seawater intrusion may show intrusion is occurring (excluding the problems with false positives discussed previously), but it cannot evaluate if intrusion is likely to occur in the future. In essence, chemistry is a not a predictive tool - it cannot predict that intrusion will occur in the future. Instead, chemistry is a reactive tool, capable only of reacting to intrusion once it begins to occur, and in some cases too late to prevent significant degradation of groundwater quality.

The use of a reactive rather than a predictive test for intrusion risk results in a lack of confidence in the water resource. Areas of the circle map that are currently ranked as low risk (no circles) have no information beyond the fact that intrusion has not occurred to date. This map gives no indication of whether or not there is either an ample supply of water or if intrusion is about to begin. This leaves the public and water resource managers in a state of constant uncertainty. Ultimately we need a tool that can assess the adequacy of our aquifers, and differentiate between those aquifers that have ample fresh water quantity and those that are only marginal.

3.0 Water Level Elevations and Seawater Intrusion

Earlier in this paper, the factors that influence the position and movement of the saltwater interface within an aquifer were discussed. Primary among those factors is the pressure in the freshwater zone relative to sea level, known as the Ghyben-Herzberg Relation. In order to prevent seawater from entering a freshwater aquifer, adequate freshwater pressure must be maintained. An aquifer's susceptibility for seawater intrusion can be evaluated by measuring the distribution of water level elevations. Thus the relationship between an aquifer's water level elevation and its susceptibility to seawater intrusion can be utilized as a planning and resource management tool. If employed in the same manner as the current Seawater Intrusion Policy, as a method of flagging a proposal for more detailed review, it may overcome virtually all of the policy's current limitations.

An aquifer that has water level elevations (pressure) significantly above sea level is not at risk for seawater intrusion, while an aquifer that has near sea level water levels is at risk. A more sophisticated analysis would be required to answer the question of whether or not the low-pressure aquifer would actually intrude due to a proposed withdrawal, but the risk for intrusion is definitely present. If aquifer water level elevations can be accurately determined, incorrectly identifying an area as being at risk for intrusion (false positives) should not occur.

The ability to accurately predict whether or not a proposed withdrawal will induce seawater intrusion into an aquifer varies with the complexity of the aquifer system, and how well the aquifer system is understood. However, predicting the long-term impact of a proposed withdrawal on the water level elevations in an aquifer is relatively simple, and thus it would be unlikely that a proposal would be ranked as having no risk of intrusion (false negative) where risk actually exists. Thus using aquifer water level elevations coupled with aquifer testing and some type of drawdown calculations provides a predictive tool for evaluating risk for future intrusion.

Finally, in areas where aquifers have substantial pressure above sea level, the public and water resource managers can be assured that unless this pressure is reduced, the aquifers are not at risk for intrusion. Similarly if an aquifer does not have significant pressure, but intrusion has not yet occurred, planning and management tools can be employed to help alleviate problems before they occur.

4.0 Phase II Assessment

The primary goal of the Watershed Planning Phase II Assessment is to quantify the water resources within a water resource inventory area (WRIA). For many WRIAs the primary resource is a river system, and quantification of the resource is relatively straightforward, involving collection of flow data from that system. In WRIA 6 (Island County) our primary water resource is contained in multiple discontinuous aquifers, with variable connection to recharge areas and the saline waters of the Puget Sound. The complexity of our groundwater system makes it virtually impossible to accurately quantify of the resource as a whole. As a result, the WRIA 6 planning unit opted to make the primary focus of its Phase II Assessment the evaluation of risk for seawater intrusion, utilizing water level elevations as the assessment tool.

In order to determine the water level elevation in an aquifer, two measurements are required. First a depth to water measurement is taken, finding the distance between the measuring point (typically the top of the well casing) and the water level. In order to convert this depth to water measurement into an elevation, the elevation of the measuring point must be determined. The depth to water is then subtracted from the measuring point elevation to find the water level elevation.

Determination of the elevation of the measuring point has traditionally been accomplished through the use of a differential level loop survey from the nearest vertical benchmark(s) to the well. Although traditional surveying can provide accurate elevation data, in many cases the time and costs associated with this method make it impractical. Recent advances in survey-grade GPS (Global Positioning System) technology have resulted in devices that are capable of determining the elevation of a location in a fraction of the time required for traditional surveying methods.

4.1 Phase II Data Collection

In order to evaluate the effectiveness of water level elevation as a tool for assessing seawater intrusion risk, water level elevation data from both intruded and non-intruded areas of the county was needed. To fulfill this need, data was collected from nearly 400 wells across the county, or roughly two wells per square mile. For each well utilized in the study, depth to water measurements were collected, and where possible a computerized data logger was installed in the wells to evaluate water level variations over time. In addition a water sample was collected from each well, and sent to a state-certified laboratory for major ion analysis.

Through a grant provided by the Washington State Department of Ecology, Island County was able to purchase a global positioning system (GPS) consisting of three survey-grade receivers and associated hardware. Two of these receivers were set up as permanent base stations to provide post-processing data, and the third was utilized as a roving unit to collect measuring point elevation data from each well utilized in the study.

Volunteers willing to let the county collect data from private and public water system wells were solicited via newspaper articles and direct mailings. In selecting wells for use in the study, we attempted to achieve an even distribution spatially at approximately two wells per square mile. Since we hoped to measure static (non-pumping) water levels, preference was given to wells with fewer homes connected. Preference was also given to wells completed (screened) below sea level. In any given area, if more than one aquifer was present, we attempted to collect data from the two most frequently utilized below sea level aquifers.

Over 730 wells were volunteered, of which field crews visited more than 470. Not all wells that were visited by our field crews could be utilized in our study. Wells that did not have access for measuring depth to water, or wells that did not have the ability to provide an untreated water sample were dropped from our study, resulting in a total of 379 wells from which all necessary data was successfully collected. Water level and chemistry data was collected from the study wells during the summers of 2001 and 2002; surveying of measuring point elevations was conducted from the spring of 2003 through the spring of 2004.

Aquifers can be influenced by tidal fluctuations in adjoining marine waters, resulting in variations in both water level and chemistry. Generally, wells that are affected by seawater intrusion and that are tidally influenced tend to exhibit higher chloride concentrations and water levels during higher tides. In an attempt to collect consistent data, wells that fell within ½ mile of the marine shoreline were monitored (water sampling and depth to water measurements) during a +6 foot or higher tide stage.

4.2 Phase II Data Analysis

The primary goals of the Phase II Assessment were to evaluate the use of water level elevation data as a tool for determining seawater intrusion risk, and to provide water level elevation data on a countywide basis to provide a new view of intrusion susceptibility. Evaluation of water level elevation data as a seawater intrusion tool can be approached in several ways. One method involves comparing intrusion (or lack thereof) from the perspective of water chemistry to the water level elevation data. As discussed earlier, there are several problems associated with the use of chemistry for evaluation of seawater intrusion. These problems complicate the use of chemistry as a tool for validation of the water level elevation methodology for seawater intrusion analysis.

Several different methods were utilized in our analysis of the chemistry data. The most simple of these methods was simply comparing chloride concentrations to water level elevations as shown in Figure 7. One problem with this analysis is the significant number of ‘false positives’ where there

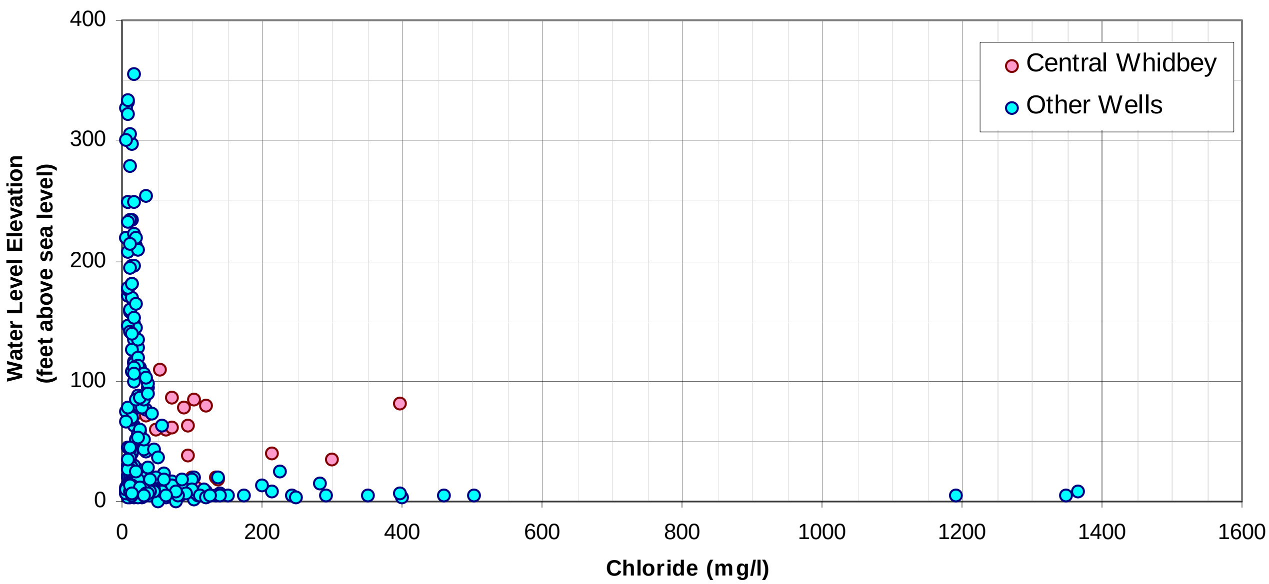


Figure 7.

are elevated chlorides that are not due to seawater intrusion. One area of known false positives for chloride data is Central Whidbey Island. These wells are impacted by very hard groundwater, which results in elevated chloride concentrations that do not appear to be caused by conventional seawater intrusion. Figure 7 differentiates the wells in Central Whidbey from all other wells as shown in the legend. With the exception of the data from Central Whidbey, the plot displays the expected results, with elevated chloride concentrations occurring with lower water level elevations.

Another type of analysis that has application to seawater intrusion is a piper diagram, where chemical sample results are plotted based on the relative proportion major ions (Figure 8). For each water sample, a point is plotted in the lower left triangle based on the proportions of positively charged ions (cations), and a second point is plotted in the lower right triangle based on the proportions of negatively charged ions (anions). These two points are then extrapolated up into the upper diamond to place a third point.

In general, fresh groundwater samples will land near the area labeled as 'fresh' in the upper diamond, while pure seawater will plot near the 'sea' label. Water that results from conservative mixing (mixing without ionic exchange reactions) between freshwater and seawater would plot along the line labeled 'mixing'. When mixing occurs in the presence of aquifer materials, ion exchange reactions often occur between the groundwater and the aquifer material, which alter the chemical composition of the water. This change in chemical composition results in a deviation from the conservative mixing line on the piper diagram, moving the point upward into the upper portion of the diamond during intrusion, and downward toward the lower portion of the diamond during freshening. Using this method, it is possible to deduce not only if a water sample is impacted by intrusion, but also if the intrusion was getting worse (intrusion exchange) or better (freshening exchange) at the time the sample was taken.

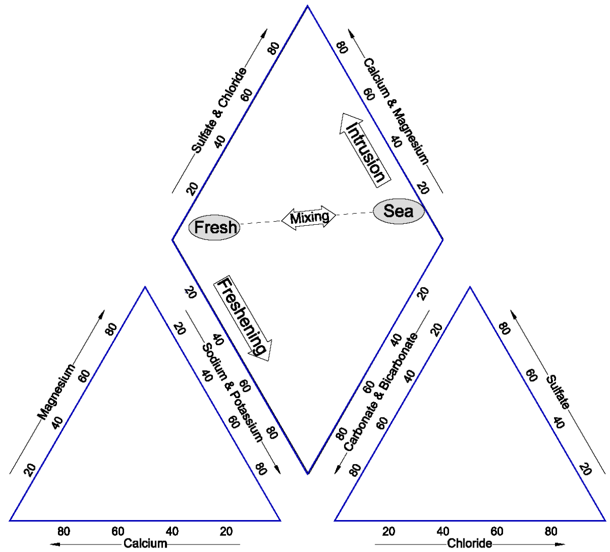


Figure 8.

Figure 9 is a piper diagram plotting the chemistry data from all of the wells utilized in the Phase 2 assessment. The color of the each data point in the upper diamond reflects the elevation of the bottom of the well as shown in the legend. The radius of each upper diamond data point reflects the total dissolved solids (TDS) for that sample, with larger circles having greater quantities of dissolved minerals. A program was developed that automatically evaluates the sample results, assigning each sample a code indicating where it lands on the diagram as shown in Figure 9. The samples collected as part of the Phase II Assessment were processed using the above methodology to evaluate the ion balance of each, and then these results were grouped and the average water level elevation (in feet above MSL) for each grouping was evaluated.

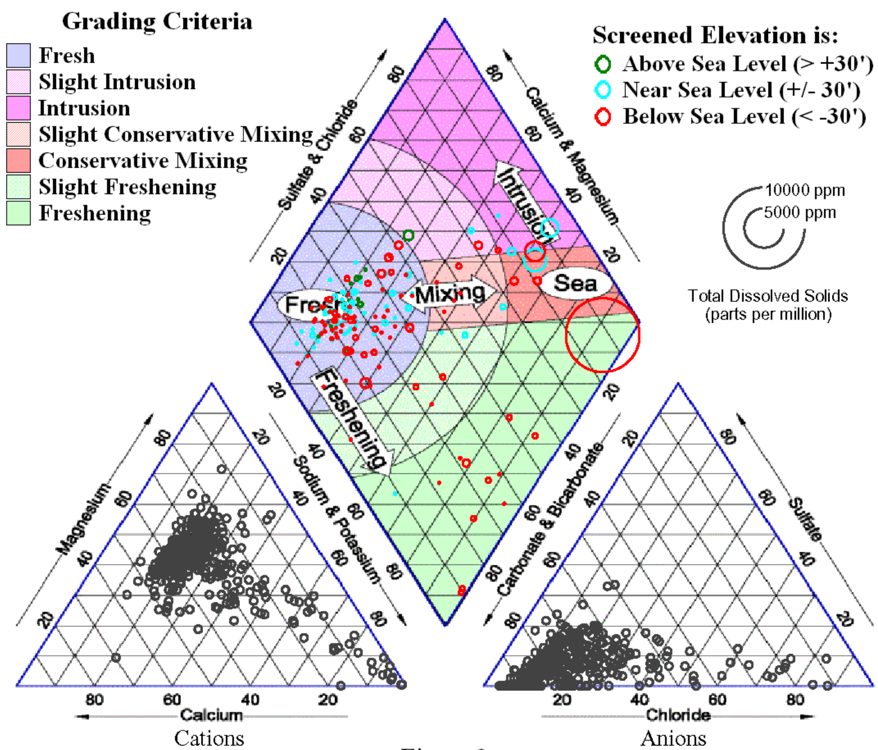


Figure 9.

The results of this evaluation are presented in Table 1. This analysis was performed on data that excluded wells that are completed above sea level and those wells in Central Whidbey where anomalous chemistry is known to occur.

Another diagnostic tool used to analyze chemical sampling results as they relate to seawater intrusion is to evaluate the ratio of chloride to electrical conductivity. This analysis is especially suited for evaluating areas where extremely hard groundwater results in elevated chloride concentrations. The concept behind this tool is that electrical conductivity is directly related to the overall quantities of dissolved solids. For any given concentration of chloride, one would expect a much higher conductivity value if the chlorides were the result of very hard water due to the presence of other dissolved constituents.

	Water Level Elevation (ft MSL)		
Piper Diagram Analysis	**Avg**	**Min**	**Max**
Normal Groundwater	16.0	-29.3	139.3
Slight Freshening Exchange	18.1	5.1	44.4
Freshening Exchange	34.0	6.5	300.7
Slight Conservative Mixing	5.5	2.0	7.5
Conservative Mixing	4.6	3.9	5.4
Slight Intrusion Exchange	6.2	5.7	6.6
Intrusion Exchange	5.7	3.1	8.6

Table 1.

Figure 10 is a chloride vs. conductivity plot displaying the samples taken during the Phase II Assessment; sample points are color-coded based on the water level elevations as shown in the legend.

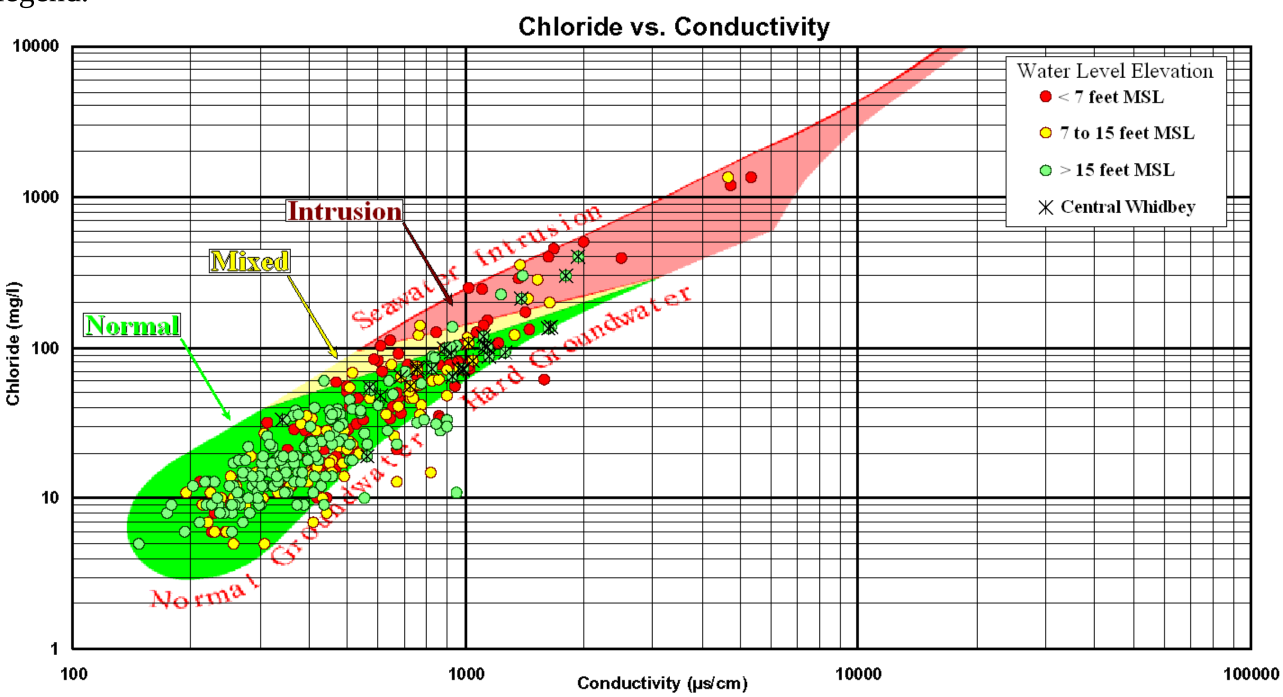


Figure 10.

Table 2 summarizes the results of this analysis, grouping results by the diagnostic technique presented in Figure 10, and comparing those results with average water level elevations for each group of results. This analysis was performed on data that excluded wells that are completed above sea level and those wells in Central Whidbey where anomalous chemistry is known to occur.

Chloride vs. Conductivity	Water Level Elevation (ft MSL) Avg	Min	Max
Normal (green)	16.2	-29.2	300.7
Mixed (yellow)	7.9	2.0	19.7
Seawater Intrusion (red)	8.4	3.1	24.

Table 2.

Another method for evaluating water level elevation as a tool for seawater intrusion risk assessment is to compare water level elevation data to the conceptual model for groundwater flow in a marine island environment as discussed earlier. The conceptual model predicts that water level elevations should be highest near the center of the island, with water levels dropping toward the shoreline. The conceptual model also predicts that if seawater intrusion was to occur in an area, it would occur first along the shoreline, moving inland as the situation worsens.

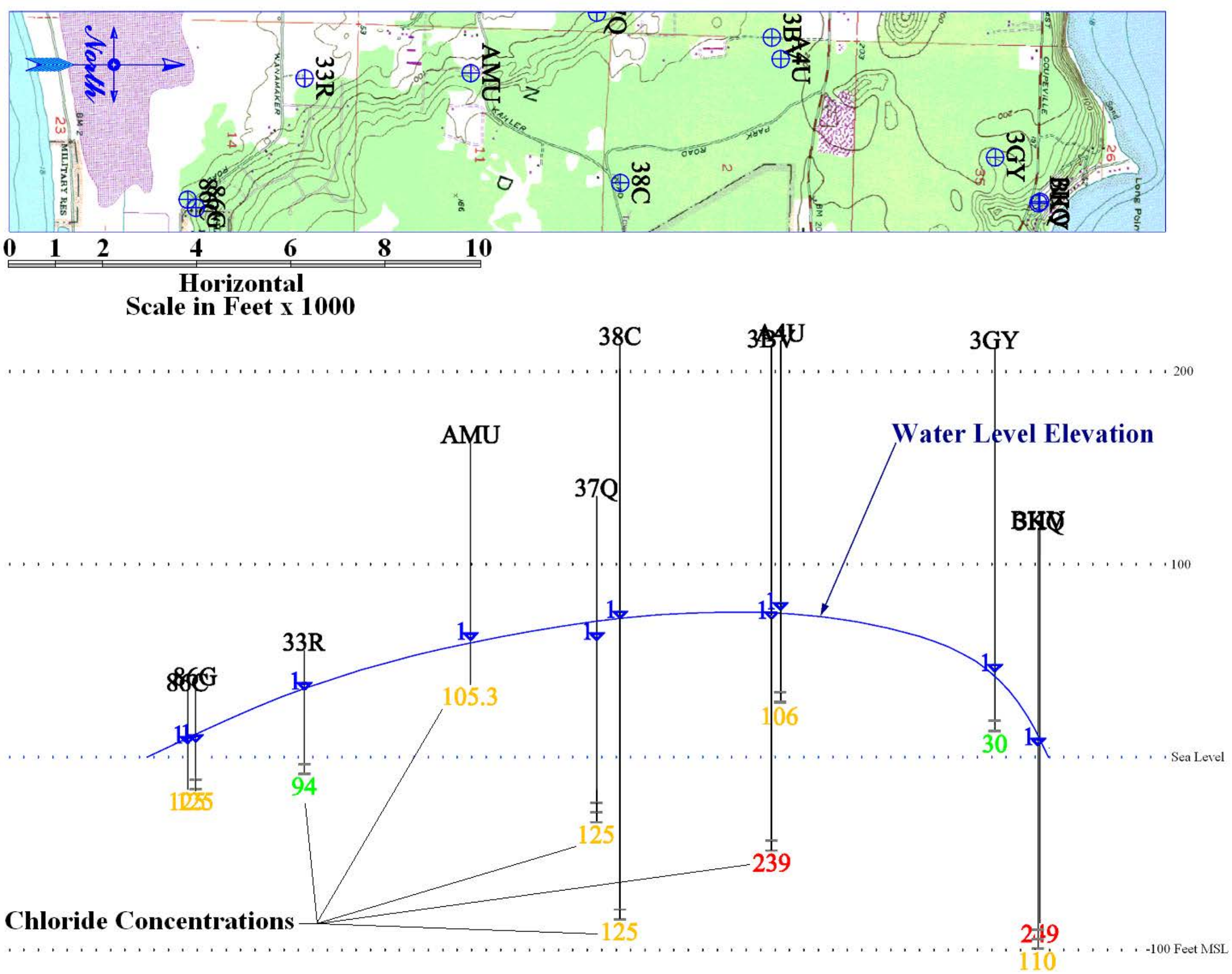


Figure 11.

Figure 11 displays a section of Central Whidbey, with a map of Phase II well locations, and a vertical 'stick' diagram of well stratigraphy including elevations of the water table at each well represented by the blue triangles. The diagram shows that the water level elevation data is in good agreement with the conceptual model. Also shown at the base of each well in the stick diagram is the chloride concentration from that well. The elevated chloride concentrations in wells near the center of the island, including wells that are completed (screened) significantly above sea level (such as wells AMU and A4U), represent the anomalous chemistry found in Central Whidbey wells discussed previously. Previous analysis of Central Whidbey that utilized chemistry as the primary analysis tool correctly identified those wells that were completed above sea level as being non-intrusion sources. However, those wells that were completed below sea level remained somewhat in question. Using water level elevation data provides clear differentiation between those wells that are impacted by intrusion and those that are not (false positives).

One final analysis was performed on the data collected during the Phase II Assessment. This analysis involved review of all available data including the various chemical analysis described above, water level elevation, and when available, historical chemistry data for analysis of variations in chemistry over time. Also included in this review was data from other nearby wells that appear to be completed in the same aquifer. For each well in the study, a determination was made based on all available data as to the likelihood that the well was suffering from the impacts of seawater intrusion. Wells were grouped into one of three categories as follows:

Summary Analysis	# of Wells
No Indications of Intrusion	242
Inconclusive Indications of Intrusion	101
Positive Indicators for Intrusion	36

This analysis is used for two purposes: in study results discussions with each volunteer / participant in the Phase II Assessment, and in the statistical evaluation of water level elevation data presented in Section 5.1.

Figure 12 presents a countywide view of the Phase II Assessment wells, grouped by water level elevations. With a few exceptions on North Whidbey (which will be discussed later in this paper), the elevation data closely conforms to the conceptual model. Virtually all the red, orange and yellow data points (lower water level elevations) are located along the shorelines, while the green and cyan data (higher water level elevations) are located inland. Lower elevation data are almost always clustered in groups, indicating that these areas have reduced water level elevations.

Water level elevation data can be used to identify ‘false positives’ in chemistry data, and in addition it can be used to identify ‘false negatives’. Several shoreline areas on South Whidbey and Western Camano have relatively low water level elevations (red and orange data points), but as of now have not experienced any chemical indications of intrusion. These areas can be interpreted as being at risk for intrusion, although intrusion has not yet begun to occur. Larger project proposals in these low water level elevation areas should be evaluated from the perspective of seawater intrusion. Chloride data alone would not have provided this advance warning of pending intrusion problems, but instead could only react after intrusion actually begins to occur.

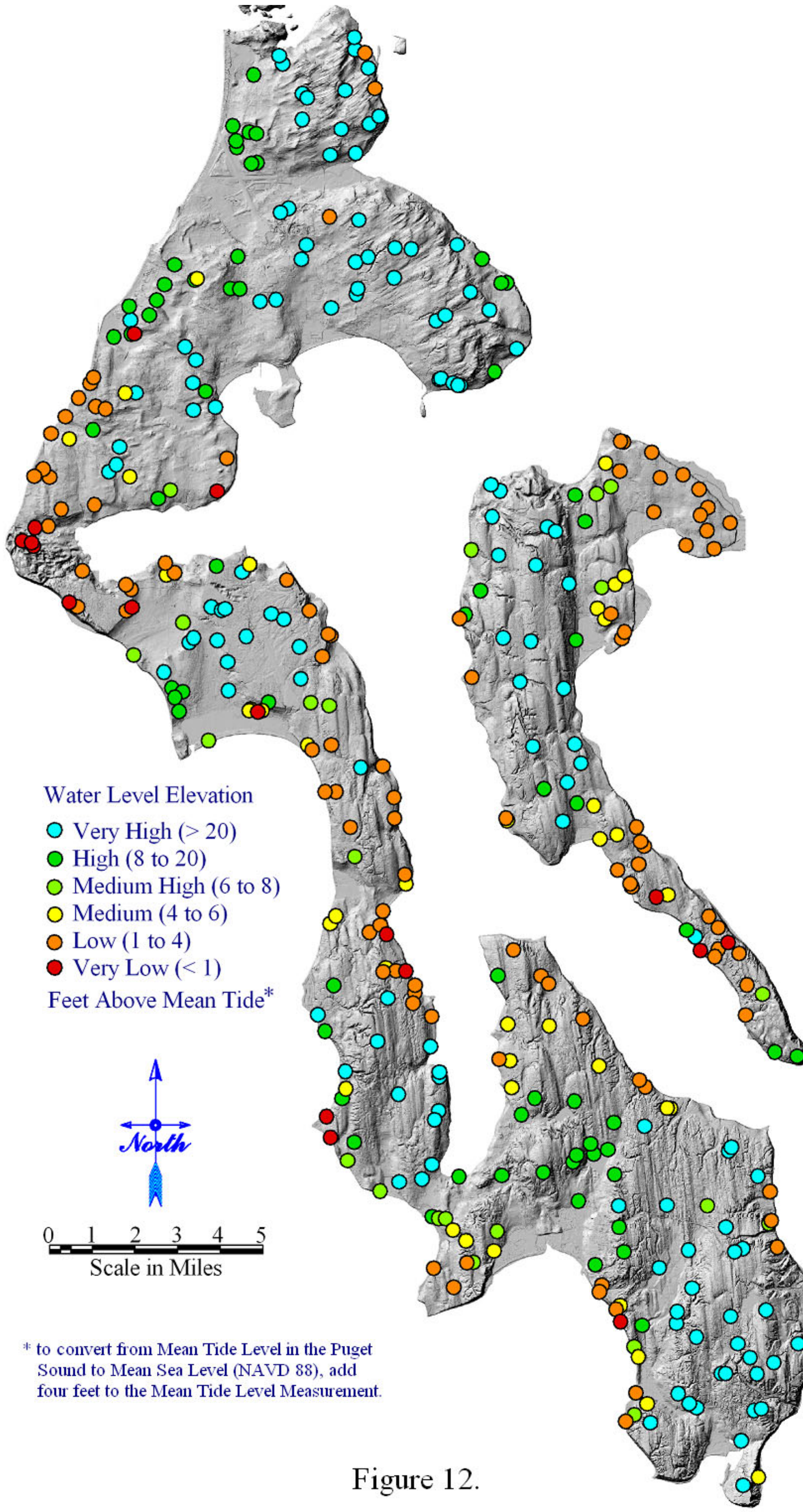

Water Level Elevation
Very High (> 20)
High (8 to 20)
Medium High (6 to 8)
Medium (4 to 6)
Low (1 to 4)
Very Low (< 1)
Feet Above Mean Tide*
North
0 1 2 3 4 5
Scale in Miles
* to convert from Mean Tide Level in the Puget Sound to Mean Sea Level (NAVD 88), add four feet to the Mean Tide Level Measurement.

Figure 12.

An additional benefit of using water level elevation as a tool for evaluating seawater intrusion risk is the ability to define areas where intrusion is unlikely to be an issue in the foreseeable future. Areas in Figure 12 with cyan data points have water level elevations more than twenty feet above mean tide. These areas are unlikely to suffer from intrusion, even when substantial withdrawals and drawdown occur.

In many cases, water level elevations can be pulled significantly below sea level at a pumping well and yet not induce seawater intrusion, as long as the water level elevations in the aquifer rise high enough between the pumping well and the submarine aquifer outcrop to prevent saltwater from entering into the aquifer.

This situation creates what is known as a 'false interface' and is illustrated in Figure 13. The drawdown cone at the pumping well extends below sea level, which causes the Ghyben-Herzberg predicted interface position to move upward to the well screen. Water level elevations are significantly above sea level in the aquifer between the well and the shoreline (A), resulting in the predicted interface position falling significantly below the bottom of the aquifer (B), and preventing the movement of saltwater to beneath the well, which prevents seawater intrusion at the well.

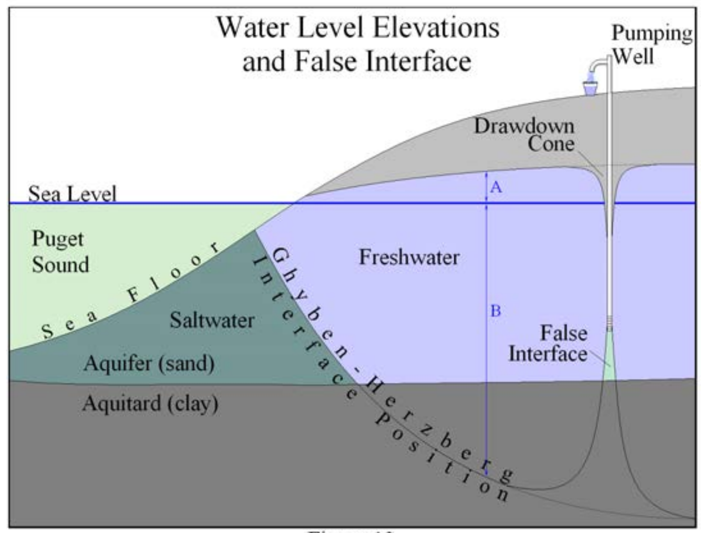


Figure 13.

The important factor in preventing seawater intrusion is not the water level at the pumping well, but instead it is the water level in the area between the well and the shoreline. If water levels in an aquifer are lowered, reducing the pressure above sea level (A), the predicted interface position at (B) will rise until a critical level is reached where the base of the interface rises up to the base of the aquifer. Once the critical rise has been reached, intrusion of the pumping well will occur rather rapidly. Once water level elevations are lowered below the critical level and the seawater interface moves into the base of the aquifer beneath a pumping well, the strategies for mitigation change. From that point forward, attempts to control rather than prevent intrusion are required. Measures such as relocating wells, reducing pumping rates, and raising well intakes (screens) are typically employed.

There is one additional conclusion can be drawn from examination of the water level elevation study results: risk for intrusion is highest near the shoreline, and decreases as you move inland. In some cases, wells currently showing signs of intrusion may exhibit intrusion problems even if they were the only wells completed in that particular aquifer. In these cases, the problem is not so much one of over-drafting the aquifer, but rather one of poor selection of well location. These wells were initially installed into the zone of diffusion, and thus experienced elevated chlorides from the day they were installed.

Figure 14 presents an example of this situation, with an aquifer with high freshwater flow discharging a substantial amount of water to the Puget Sound. Some of this freshwater discharge could be utilized as a water source, if the resultant movement of the interface could be tolerated. Two wells are shown in Figure 14: a shoreline well with its well screen positioned at the base of the aquifer and an inland well with an elevated screen. As in the previous example, pumping of the inland well, even at a substantial rate, will not result in intrusion of the inland well. In contrast, the shoreline well will suffer from intrusion, even when pumped at a relatively low rate. Depending on the specific aquifer conditions and the distance of the second (inland) well, pumping of that well may induce drawdown on the shoreline well. Such drawdown would result in a worsening of intrusion problems for the shoreline well. Although the aquifer has significant capacity for additional withdrawals, the poor placement and subsequent intrusion of the shoreline well would be interpreted as a degradation of water quality, resulting in limiting future withdrawals from this aquifer in the immediate area. In fact, given the above-described scenario, the Washington Department of Ecology (DOE) would not approve a water right application for the inland well, based on the degradation of water quality it would cause on the shoreline well.

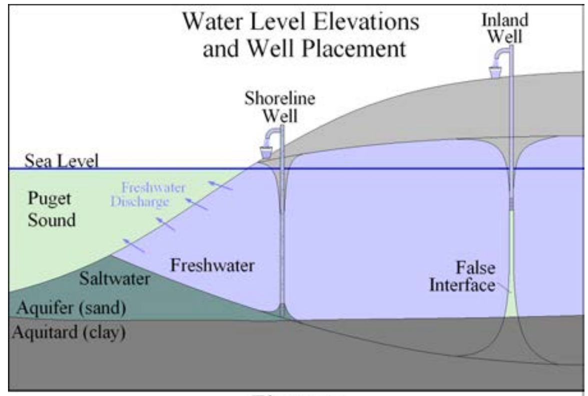


Figure 14.

A loss of capacity can occur in aquifers that are not subject to seawater intrusion, where well construction can pose a limitation on the ability to utilize the resource. Take for example a well being constructed to supply water for a particular purpose; the well is drilled into a one hundred foot thick, highly productive aquifer. Due to the aquifer's high productivity, it is only necessary to drill twenty feet into the aquifer in order to achieve the desired well production rate and the well is completed at that depth. Years later several new wells are completed for other purposes, and these withdrawals result in a lowering of the water table in the aquifer, and a reduction in the production capacity of the existing well. In this situation, the aquifer is capable of supplying additional water to new wells, but in so doing these withdrawals would impair the ability of the existing well to produce water. Under these circumstances, DOE would require that the existing well fully penetrate the aquifer, or in other words, the existing well owner could only claim an impairment if his well was screened at the base of the aquifer, allowing for full utilization of the resource.

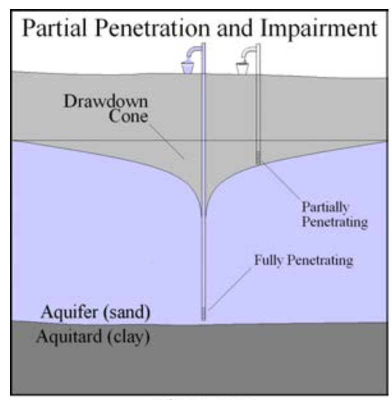


Figure 15.

Seawater intrusion can be viewed as an inverted version of the partially penetrating well construction situation described above. An aquifer that could otherwise produce a significant quantity of water could be rendered useless due to "intrusion", caused by poor well placement and construction (too close to the shore, and/or too deep). If maximizing the use of groundwater resources is a desired goal, then a solution to this problem, similar to the fully penetrating solution described above, will need to be devised and implemented.

Groundwater in Island County is too limited to waste due to poor well design and placement. Long-term strategies for resource management in a marine island environment need to include the concept of placing the points of withdrawal away from the shoreline, toward the center of the island where the risk for intrusion is less. Existing shoreline wells could be converted to observation wells, for monitoring the position of the interface to insure that it is not moving inland further than desired.

5.0 Seawater Intrusion Policy - Revision Options

The proposed Seawater Intrusion Policy is made up of three principal components as follows:

1. **Suggested Triggering Mechanism**: A criterion for evaluating where the policy should or should not apply. Chloride concentrations and water level elevations are examples of potential triggering mechanisms.

2. **Applicability**: A criterion for evaluating what type of projects should be reviewed under the policy. Adding connections or creating new public water systems, drilling of new wells, and subdivision of land are examples of actions that could be reviewed for potential to cause / exacerbate intrusion problems.

3. **Implications**: A set of actions that result from triggering review of a project for which the policy applies. Testing, monitoring, hydrogeologic analysis, and phased development are some possible implications when an applicable proposal is flagged via the triggering mechanism.

For each of these components, there exists a wide range of possible methods and implementation options. It is not possible in the context of this paper to discuss and review all of these potential options, so instead these discussions have taken place within meetings of the WRAC's groundwater subcommittee, and this paper reflects the resulting recommendations.

To be effective, any policy needs to be easily understood and implemented. The simpler the regulation, the more likely it is to accomplish its goals. The current Seawater Intrusion Policy has a relatively complex implementation matrix with a total of 12 categories, with 14 options that can be required, potentially required, or recommended within each category. Recently, the Washington State Department of Health (DOH) has re-assessed its role in implementing the Seawater Intrusion Policy. DOH found that it has little legal authority to regulate public water systems based on resource protection issues, and as a result DOH no longer utilizes the 100 and 200 mg/l chloride triggering system, but instead relies on the 250 mg/l secondary MCL as a threshold for triggering management options. This has resulted in a situation where smaller Group B water systems (overseen by Island County Health) undergo more strenuous seawater intrusion testing / review than the larger Group A systems (overseen by DOH). In addition, discussions with DOH have revealed that even the 250 threshold currently utilized may not be enforced in the future. A new/revised Seawater Intrusion Policy needs to provide a rational and consistent approach for proposal review.

Ultimately, the selection of trigger levels, applicability, and implications needs to balance the burden on applicants and regulators (costs involved with evaluating proposals for potential intrusion impacts) against some measure of the cost of having an aquifer intruded to any given level. Lower trigger values, wider applicability and more significant implications may increase costs for applicants and regulators, but will provide greater protection for groundwater resources. Conversely, higher trigger thresholds, more restricted applicability, and milder implications result in lower cost but provide less protection and may result in more severe intrusion problems prior to triggering regulatory protection measures.

5.1 Suggested Triggering Mechanisms

One goal of the Phase II Assessment was to evaluate the possibility of using water level elevation as a tool for assessing seawater intrusion risk. Data collected during the Phase II Assessment indicate that there are areas in Island County where water level elevations are low, but as of yet the wells in these areas have not suffered from chemical impacts of intrusion such as rising chloride concentrations. It is possible that additional small withdrawals can be obtained in these areas without causing intrusion, and so these areas could be treated differently from areas where water levels are low and chemical impacts have occurred.

The proposed triggering mechanism combines water level elevation data with chemistry data. Low risk areas would be defined as those areas with high water level elevations, regardless of chemistry. Under this triggering criterion, the false positive problems described earlier (where elevated chlorides result from process other than seawater intrusion) would be defined as low risk as long as the water level elevations in the area were above the triggering threshold. Medium risk areas would be those areas where water elevations fall below some triggering threshold, while high risk would be defined as areas with lower water level elevations and elevated chloride concentrations. A new category, very high risk, will be defined where water levels are low and chloride concentrations reach a more severe level.

The chloride concentration trigger levels (100 and 200 mg/l) utilized by the current policy to define medium and high-risk areas were likely selected (on the high side) with the issues related to false positives and non-intrusion sources in mind. Using water level elevation as the initial screening criteria may reduce or eliminate these problems, enabling the use of a more conservative (lower) threshold chloride concentration (trigger). Alternatively, selecting a relatively high trigger level such as 250 mg/l would provide consistency with current DOH guidelines and the EPA secondary MCL for chloride. One could argue that any selected trigger level will - in the long run - be met or exceeded in many coastal areas / aquifers since certain types of development will continue to occur without regard for intrusion while concentrations fall below the selected trigger level. (see Section 6.0)

One option for defining a trigger value for chloride would be to couple the trigger to health risks presented by intrusion. The U.S. EPA is responsible for setting maximum contaminant levels (MCL) for drinking water, with primary MCL values representing health risk standards, while secondary MCL's are esthetic (taste, odor, color etc.) standards. The EPA has set a secondary MCL for chloride at 250 mg/l based on taste thresholds. Although the EPA considers sodium a primary (health risk) contaminant, they have not set an MCL for sodium, but rather have issued a recommended level of 20 mg/l for those consumers who may be restricted for daily sodium intake. Using water quality data from sampling marine waters around Island County, the ratio of chloride to sodium in these waters is approximately 1.8 mg/l of chloride for every mg/l of sodium. Using this ratio to extrapolate the chloride concentration that would accompany 20 mg/l of sodium yields a concentration of 36 mg/l chloride. Despite the logical link to health effects, a chloride trigger level as low as 36 mg/l would only be feasible if it makes sense from the perspective of groundwater chloride concentrations in groundwater that is not impacted by seawater intrusion.

A second analysis was performed to assess Island County groundwater chloride concentrations. This analysis utilized all chloride and conductivity sampling data on file, first filtered to include only those water samples that appear to be normal groundwater (not intruded) based on chloride vs. conductivity ratios (see Figure 10), wells that are completed below sea level, and excluding Central Whidbey wells. The mean chloride concentration in these water samples was 38.8 mg/l with a standard deviation of 30.6. Adding two times the standard deviation to the mean value yields the statistical value below which 97.5% of all samples will fall, which calculates to be 100.0 mg/l.

An idealized graphical representation of this concept is presented as a frequency of occurrence plot in Figure 16. The horizontal axis displays chloride concentrations while the vertical axis displays the frequency of occurrence, with higher points on the curve representing concentrations that occur more frequently. The peak of the curve represents the mean or average chloride concentration (38.8 mg/l), and moving two standard deviations to the right defines the value (100 mg/l) below which 97.5% of all samples will fall (hatched area).

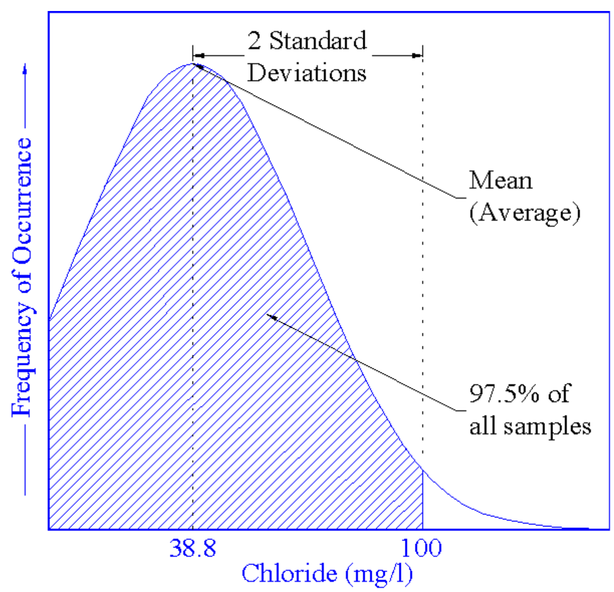


Figure 16

The mean chloride concentration in Island County (38.8 mg/l for non-intruded wells) is very near the trigger level derived using the sodium health based chloride criteria (36 mg/l). As a result this trigger cannot be utilized since its use would identify nearly half of all non-intruded wells as exceeding this value. However, the chloride concentration analysis does provide a possible trigger, the chloride concentration for which the vast majority of wells that are not suffering from intrusion would fall below. Selecting a value of 100 mg/l would provide a fairly conservative triggering mechanism, yet have relatively few false positives. This value also has the advantage of having been utilized by the current policy and thus has some level of public acceptance.
A water level elevation triggering value also needs to be selected in order to incorporate this tool into the seawater intrusion policy. Data pertaining to water level elevations and intrusion levels are available from the Phase II assessment. In this case, elevations lower than the trigger level will be interpreted as having risk for intrusion, so the evaluation will target maximum water level elevations

in wells that are known to be intruded. Using the methodology outlined above, the mean water level elevation in wells classified as having positive indicators for intrusion (see page 12, lines 10 - 25) is 5.6 feet above mean sea level (MSL, NAVD 88) with a standard deviation of 1.4 feet. Adding two times the standard deviation to the mean yields a value of 8.4 feet MSL, below which 97.5% of the water level elevations for intruded wells would fall.

It should be noted that the mean sea level datum does not equal mean tide level in the Puget Sound. The National Geodetic Survey (NGS) maintains tidal benchmarks around the Puget Sound, and these benchmarks have information relating to various vertical datum including NAVD 88 and the mean tide levels. The mean tide level in the Puget Sound varies spatially, but typically in the area of Island County the mean tide level is at just over four feet on NAVD 88. Thus the 5.6 feet level identified in the previous paragraph equates to just over 2 feet above the mean tide level.

Using the criteria defined above, the new Seawater Intrusion Policy would be defined as follows:

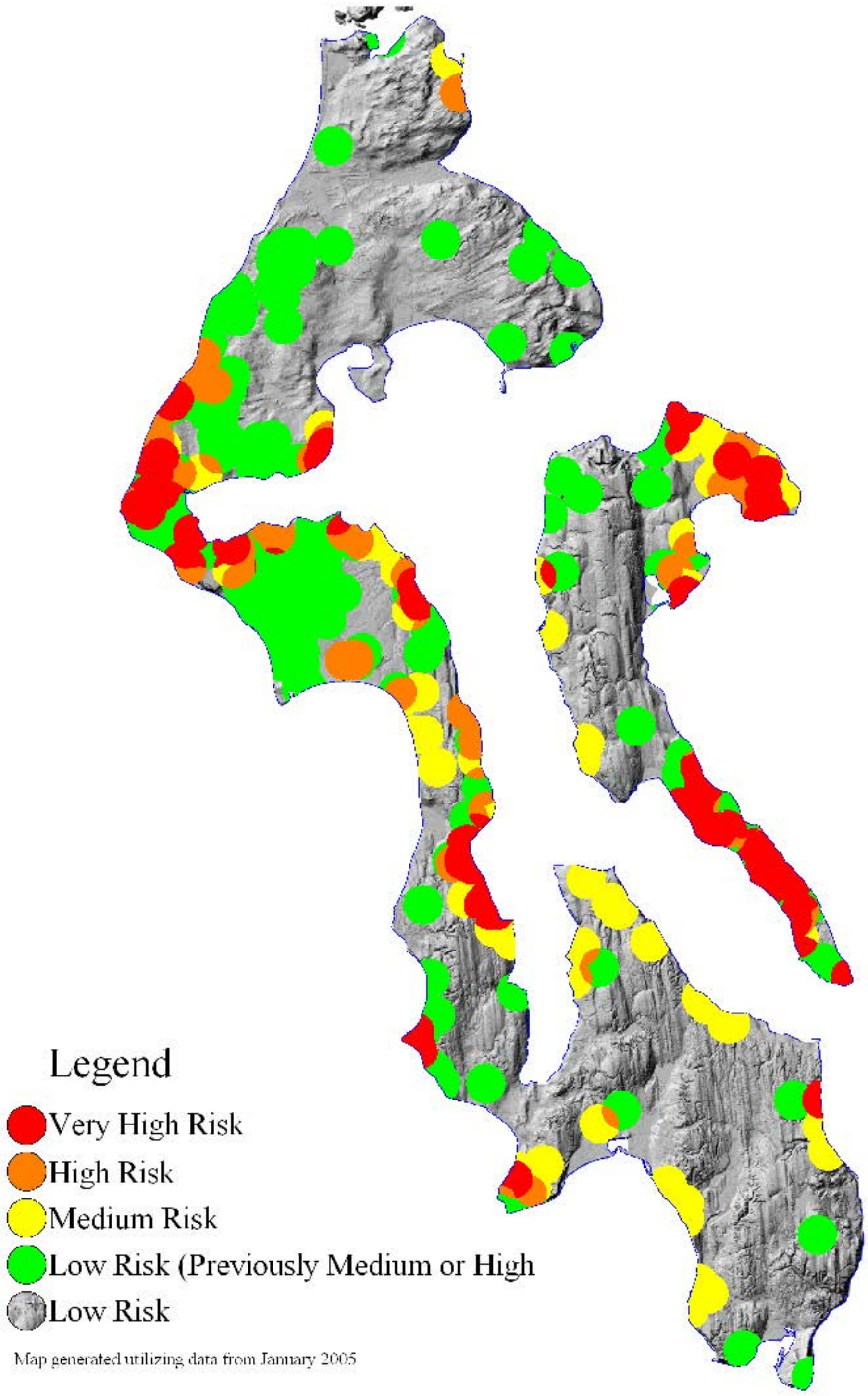
Risk Category	Water Level Elevation [1]	Chloride Concentration [2]
Low	Greater than 8.4	Any [3]
Medium	Less than or Equal to 8.4	Less than 100
High	Less than or Equal to 8.4	Between 100 and 250
Very High	Less than or Equal to 8.4	Greater than 250

Table 3.

[1] Water Level Elevation in feet above Mean Sea Level (MSL) NAVD 88. +4 feet MSL = 0 feet relative to Mean Tide Level in the Puget Sound. For example, 8.4 feet MSL = 4.4 feet above Mean Tide Level.
[2] Chloride Concentration in Milligrams per Liter (mg/l)
[3] Where water level elevations are greater than 8.4 feet, chloride concentrations are irrelevant

The current Seawater Intrusion Policy defines risk areas by placing ½ mile radius circles around wells with elevated chloride concentrations; utilizing circles has worked reasonably well and is easily implemented. The new policy would maintain this strategy, utilizing ½ mile circles around wells with low water level elevations, and wells with elevated chloride concentrations. The combined overlay of the chloride and water level elevation maps will be used to define risk areas.

A preliminary map generated using the above criteria is presented in Figure 17. Of particular interest on this map are the green and yellow areas. Green areas are areas with elevated chloride concentrations but high water level elevations, previously described as ‘false positives’, such as Central Whidbey Island south of Coupeville. Yellow areas represent areas with low water level elevations, but without elevated chlorides; these areas are considered to be ‘false negatives’ or



Revised Seawater Intrusion Policy 'Circle Map'
Utilizing Water Level Elevation and Chloride Data
Figure 17.

areas where intrusion risk is present but intrusion has yet to be identified based upon existing data.

It should be noted that ICHD currently has significantly more chloride data available than water level elevation data. In particular, certain areas of the county have no water level data but do have chloride data. If the chloride concentrations in these areas are elevated (but there is no water level data), then these areas are mapped as green or low risk. Without water level information it is uncertain if these areas are truly represented as low, medium or high risk. Water level data elevation must be collected in these areas to determine what risk category should actually apply. Examples of where this problem is likely occurring are portions of the panhandle on Camano Island, and in the kettles region west of Penn Cove on Whidbey Island.

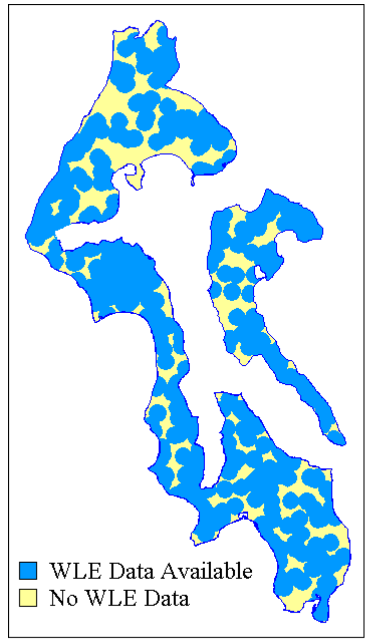


Figure 18

A lack of water level elevation data occurs most frequently in areas where larger public water systems are present, such as within the service area for the City of Oak Harbor, and in the area of NAS Whidbey Island. A map showing water level elevation data coverage is presented in Figure 18. The need for additional water level elevation data to fill these information gaps is discussed in Section 5.3.

5.2 Applicability

Based on the factors influencing seawater intrusion presented in Section 1.1, it is clear that once an aquifer reaches a critically low water level elevation, any groundwater withdrawal has the ability to induce intrusion. Areas that have water level elevations above this minimum (low risk in Table 3) are not at risk for intrusion, and so proposals within these areas would not be subjected to review for seawater intrusion.

Medium risk areas as defined in Table 3 have low water level elevations, but have yet to experience any groundwater quality (chlorides are below 100 mg/l) impacts. Proposals that withdraw relatively smaller volumes of water have a lower potential for impact, and therefore do not pose as high a risk to a marginally adequate aquifer as larger proposed withdrawals. As such, smaller proposals that would potentially add 6 or less equivalent residential units (ERU) would be allowed to occur in a medium risk area, but those proposals that would include more than six connections would be subject to review. Exempted proposals include subdivisions of up to six lots, addition of up to six connection approvals to an existing water system, or creation of a new water system with up to six connections. Note that the above description defines the expansion of a water system, which entails the addition of new connection approvals (either within or outside of the systems defined service area), not the putting to use of previously approved but currently unused connections. It is anticipated that in most cases, connecting to systems that are growing into previously approved connections will occur on a house-by-house basis, and will generally occur at a relatively low rate.

High-risk areas as defined in Table 3 have low water level elevations and have chloride impacts between 100 and 250 milligrams per liter. In this situation, even smaller (6 ERU's or less) proposals can potentially push the aquifer into significant deterioration due to seawater intrusion.

In high-risk areas, any proposal that would add more than 1 ERU, which includes subdivision of land, creation of any new public water system, and expansion or infilling of public water systems would be subject to review. In addition, individual wells on parcels of less than 1.5 acres in size would also be reviewed in high-risk areas.

Very high-risk areas are defined as having low water level elevations, and chloride concentrations in excess of 250 milligrams per liter in the source of water that is used for the proposal. In this situation, the well has reached a significant level of contamination, and the potability of the water begins to come into question. Water systems with chloride concentrations greater than 250 milligrams per liter would be placed on moratorium (no new connections allowed) until the situation can be remedied or mitigated. Individual wells on parcels less than five acres in size will also be subject to review.

Chloride concentrations in wells that are impacted by seawater intrusion typically peak during the late summer and drop off during the winter months. In most cases, this is not due to changes in recharge to the aquifers, because the travel time (the time it takes a raindrop to move down through the overlying stratigraphy to recharge an aquifer) is on the order of years. The annual rise and fall of chloride concentrations is actually caused by the increase in pumping associated with lawn watering and other seasonal water use. For this reason, a drop in chloride concentration associated with seasonal variation will not, on its own, be considered a mitigation of seawater intrusion.

The applicability of the policy as defined above primarily targets the subdivision of land, and creation or expansion of water systems (including individual wells under certain circumstances). All of these actions involve the use of additional groundwater resources associated with growth, or the addition of new buildings and/or residents within the county. It is acknowledged, however, that existing water users within an area suffering from seawater can contribute to intrusion problems, and that placing the burden of finding and implementing remedies solely on those systems that are expanding may not be equitable. For example, two existing adjacent public water systems may have wells completed in the same aquifer. If this aquifer begins to suffer from seawater intrusion, and one of the systems desires to add new connections, that system could be required to find and implement mitigation measures to avoid further intrusion. If the other system has no plans to expand, currently no mitigation would be required even if the system operated in a manner that exacerbated the problem.

Ideally, measures to mitigate seawater intrusion would be enacted by all users of the impacted resource, regardless of whether or not growth is occurring in an area. In reality, state and local governments have limited legal authority to regulate groundwater withdrawals unless they are either applying for a permit (such as a development permit) or they are in violation of state water law (conservation, beneficial use, etc.). As such, voluntary participation in mitigation efforts should be encouraged, and strategies for long-term regulatory mechanisms should be investigated. This investigation must take into account the legal mechanisms and limitations associated with a more holistic groundwater management effort that identifies existing management tools and the relationship between State Water Law and Groundwater Degradation.

5.3 Implications

It is proposed that public water systems (3 or more connections) that have sources (wells) that fall within medium, high, or very high risk areas would be required to collect water samples from these sources in April and August of each year, and submit those samples to a state certified laboratory for chloride and conductivity analysis. Water level elevation data would be collected from all potentially regulated projects other than individual wells. (See Figure 19.)

Proposed projects that fall within risk areas as defined in Section 5.1, and meet the applicability criteria defined in Section 5.2, will be evaluated to determine if the proposed withdrawal will negatively impact the aquifer by inducing or worsening seawater intrusion. In most cases this evaluation will require the collection and analysis of data pertaining to the well and the aquifer in which the well is completed (screened).

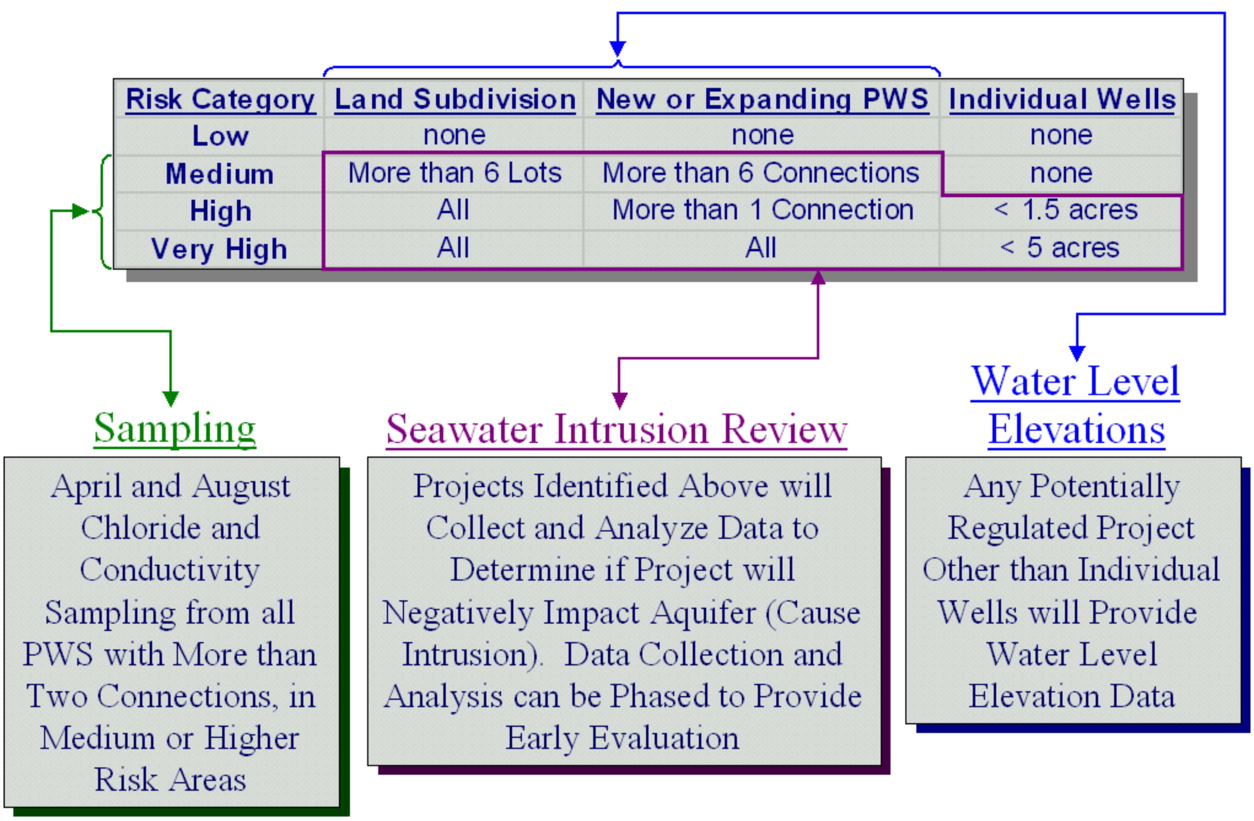


Figure 19.

It is worth noting that implementation of the current Seawater Intrusion Policy has changed substantially since the policy was initially developed. When the policy was initially adopted, Island County Health did not have a professional hydrogeologist on staff to assist in evaluating projects. As a result, all applicable projects that were found to be at risk (medium or high risk as defined by the current policy) were required to supply a full hydrogeologic assessment of their project. Now that the department has hydrogeologic expertise, projects that fall under review can be screened for the applicability of the policy to the specific project. Smaller quantities of initial data can be collected at a greatly reduced cost and an initial determination can be made as to the need for additional data based on the preliminary results. This can result in a significant savings for some applicants, while allowing other applicants to make informed decisions on whether or not to pursue the additional data collection (with the associated costs) given the results of the preliminary testing, or perhaps to evaluate other more promising courses of action. This methodology of phased review and staged data collection (and incremental costs associated with this data) is expected to continue regardless of any potential modifications to the triggering requirements.

If a proposed project were determined to be at risk based on the preliminary data, aquifer testing and analysis would be required to determine the hydraulic characteristics of the aquifer. The results of this testing will be used to evaluate the long-term impacts the proposed withdrawal will have on the aquifer and nearby wells. The aquifer testing and impact prediction analysis would result in a hydrogeologic report; a hydrogeologist licensed in the State of Washington should prepare this report and oversee the aquifer testing and analysis. The specific details of data collection and analysis requirements will be determined on a case-by-case basis. Costs associated with data collection and analysis will be borne by the applicant.

6.0 Options

Option #1 No Action

The no-action option relies on the continued use of the current (chloride based) seawater intrusion policy. This option has both benefits and drawbacks; the primary benefit is ease of implementation. The drawbacks associated with this option relate to the shortcomings of the current seawater intrusion policy discussed earlier in this paper. These are the false positives (elevated chlorides identifying areas as being at risk for intrusion where no risk exists) and false negatives (the failure to identify risk until after intrusion occurs). This option has low additional cost and moderate to low effectiveness.

Option #2 Seawater Intrusion Policy Modification

This option involves modification of the Seawater Intrusion Policy to include the use of water level elevation as described in Section 5 of this paper. As with the no-action option, modification of the Seawater Intrusion Policy has both advantages and disadvantages. The primary drawback for this strategy is the increased cost to the applicant. Although depth to water measurements are relatively easy and inexpensive to obtain, the surveying of measuring point elevations will result in additional expense. Advantages to modifying the Seawater Intrusion Policy far outweigh the disadvantages, and include the elimination of false positives (flagging of proposals for risk where in fact none exists) and of false negatives (flagging of proposals that present risk that were previously missed). Modifying the Seawater Intrusion Policy will provide security for those systems that are not at risk for intrusion, and give direction to those seeking a more adequate water supply.

The current Seawater Intrusion Policy was approved and adopted by agreement between the Health Services Director for the Island County Health Department and the Manager of State Department of Health, Northwest Region, Drinking Water Operations. Modifications to policy could be accomplished through several approaches, each having distinct advantages and disadvantages. These options include the development of a new joint policy, the development of an Island County policy, adoption of a Resolution by the Board of Island County Commissioners, or the inclusion of the review criteria into Island County Code. This option is anticipated to have moderate cost and high effectiveness.

Option #3 Monitoring Network Modification

Island County Health currently operates a long-term groundwater-monitoring network. This network is meant to provide data for analysis of long-term trends in groundwater quality and quantity. The network is composed of individual and group domestic water supply wells. At the time that the network was developed, chloride concentration was selected as the tool for evaluating seawater intrusion trends. Water level elevation will provide an earlier warning of pending intrusion problems for aquifers that occur below sea level, and also provide warning of dewatering (lowering of water levels) in above sea level / perched aquifers.

Because the current network utilizes water supply wells as its monitoring points, small-scale trends (on the order of fractions of a foot per year) are virtually impossible to detect. This is because the wells are almost always in a state of recovery from some pumping prior to monitoring. For example, if a well had been pumped an hour prior to monitoring, it may have recovered to with a 10^{th} of a foot of static, but if it had been pumped 15 minutes prior to monitoring it may be one half foot below static. Dedicated monitoring wells located some distance from larger water supply wells would always be static since they would not be pumped other than for sampling. As a result, they would provide much higher quality data pertaining to seasonal and long-term water level changes.

Water quality data (chloride concentrations) collected from wells that are subject to intrusion is highly dependant on the timing and duration of pumping prior to sampling. Thus a water supply well could be sampled twice during a 24-hour period, and different chloride values may be obtained depending on how much the well had been in use prior to the arrival of the sampling staff. Dedicated monitoring wells would not suffer from this problem, since the wells would not be in use prior to sampling and the values obtained would be much more consistent and comparable. Using a network of dedicated monitoring wells, the quality of data obtained from the network would be significantly improved, with detection of trends in water level or chemistry at a much earlier point / lower level. Early detection of trends in water level and / or chemistry is a critical element of a successful groundwater resource management program. This option is considered high cost and high effectiveness.

Option #4 Uniform Application of Seawater Intrusion Review

Regardless of how the current Seawater Intrusion Policy is modified to include water level elevation data, the resultant policy/resolution/code should be applied uniformly to all water system developments, including those currently outside the purview of the Island County Health Department (i.e. Group A Systems). Island County, along with DOH and DOE, needs to formally address how the seawater intrusion protection strategy will be applied to developing Group A water systems. ICHD currently reviews individual wells, smaller water systems (2 to 14 connections/Group B), and land subdivision proposals. ICHD review of these projects from the perspective of seawater intrusion is expected to continue in the future. DOH provides oversight of larger (Group A) public water systems, while the DOE provides oversight of the water resources of the state including the review of water right permit applications. DOH has recently re-assessed its partner role in implementing the Seawater Intrusion Policy. DOH has determined that it has legal authority to regulate public water systems based on public health issues only (i.e. not on any resource protection issue basis).

Most Group A water systems in Island County are required to obtain a water right permit from DOE. When the aquifer proposed for use is at risk for seawater intrusion, DOE generally applies provisions relative to seawater intrusion, including monitoring requirements. In the event of rising chloride concentrations, the provisions allow DOE to require mitigation / corrective action. If mitigation measures are not successful in controlling the increasing chloride concentrations, DOE has the ability to freeze the system at the current stage of development. Some older water right permits may not contain specific provisions related to seawater intrusion. In these cases DOE still has the ability to provide resource oversight based on the water quality / anti-degradation policy (WAC 173-200-030).

The proposed mechanism for review of Group A water systems involves utilizing DOE's technical staff and regulatory authority to provide oversight of Group A water systems when review is triggered by the seawater intrusion policy. Three agencies would be involved in this process; Island County Health would maintain the policy maps (circle maps) that identify risk areas; DOH would utilize these maps to evaluate what water system actions would result in a need for seawater intrusion review; and, when triggered, DOE would provide the technical resource review. The details of this arrangement would be outlined within an interagency agreement or Memorandum of Understanding between the three agencies and should be explored further during the implementation of the watershed plan.. Prior to the initiation of such an agreement it is imperative to fully understand the legal basis of applying limitations on withdrawals as they pertain to existing water rights. This option is anticipated to have low cost and high effectiveness.

Option #5 Future Policy Recommendations

As Island County aquifers are recharged annually by rainfall, it is important to manage withdrawals so that they do not exceed sustainable yields. To support this goal, Island County should develop valid and verifiable thresholds, using chloride levels and water levels above sea level, as indicators that water withdrawals are exceeding recharge, which reflects a depletion of fresh or potable water supplies from county aquifers.

To reverse such possible depletion, Island County should pursue the development of incentives and regulations which, in applying to all freshwater withdrawals within an area where the freshwater within an aquifer is being depleted, would implement water use reductions to both prevent further depletion and return the aquifer to a maintainable water balance. Due to legal and administrative hurdles, this option is not feasible at the current time. However the WRAC recognizes the need for such policies and recommends that strategies to overcome these hurdles be pursued.

7.0 Conclusions

Island County has historically taken a leading role in understanding and protecting its groundwater resources, particularly in the area of seawater intrusion. The adoption of the Seawater Intrusion Policy in 1989 represented a significant step toward this goal of protecting our aquifers. This topic paper attempts to provide an overview of current science and regulations, and makes recommendations for future resource protection efforts. Specifically this paper provides recommendations for updating the Seawater Intrusion Policy to incorporate additional analysis tools, and to simplify and streamline the use of the policy. These changes result in a tool that overcomes many of the problems associated with the current policy. Both the current policy and the proposed policy revisions define a screening tool used to evaluate risk for seawater intrusion and trigger additional review where needed. Neither the current policy nor the proposed policy revisions are meant to draw conclusions regarding the likelihood of seawater intrusion posed by any particular proposal.

As in the case of the 1989 seawater intrusion policy, science, technology, regulatory and political issues continuously change through time. The recommendations of this paper should not be taken as static and final, but only one step in a long-term strategy of adaptive management, critical to the protection of our water resources into the future.