Chapter V
Impacts Assessment

To understand the impacts of climate change on agricultural land in the Snohomish and Stillaguamish River floodplains, the Snohomish Conservation District initiated technical studies on flooding, groundwater levels, saltwater intrusion, land subsidence and aggradation, and crop impacts. This chapter summarizes key findings of these technical studies. The full studies and online tools can be found on the Conservation District website at https://snohomishcd.org/ag-resilience.

The Take-Away: Flooding

Increases in the extent of flooding will put additional farmland at risk of inundation, particularly during more frequent storm events (such as the 2-year and 10-year floods). Tens of thousands of additional acres will be flooded on a 2-year event by mid-century and critical stage heights will be exceeded more frequently each year.

Flooding

Much of the most valuable and productive farmland in Puget Sound is located within floodplains, which provide nutrient rich soils and excellent growing conditions. While floodplains are important areas for agricultural production, the flooding associated with these areas also poses a risk to agriculture. Flood waters and debris can damage structures, fencing and equipment resulting in costly repairs and clean-up efforts. High energy flows cause erosion to banks resulting in loss of land. High waters pose a risk to livestock if not moved to higher ground. In addition, the standing water and associated drainage impacts can result in negative impacts to yields and delayed spring cultivation.

Climate change is expected to lead to more frequent and severe flooding as sea levels rise and as precipitation patterns and loss of snowpack shift toward more intense winter storm events.[1] In order to understand future flood hazard conditions in the Stillaguamish and Snohomish River floodplains, the Conservation District partnered with the University of Washington Climate Impacts Group (CIG) and Fathom to develop future flood hazard maps. CIG and Fathom used a regional flood frequency analysis from historical records of river flows to develop hydraulic models, and then used future climate change projections for the 2050s and 2080s to develop flooding simulations. The approach used is a pilot of a new and less expensive method of flood modeling. The resulting maps are at a coarse scale (10m) and are thus most appropriate for general risk assessment and planning purposes, not for site-level analysis.

Friend and Foe

"Hazel Blue Acres is nestled snugly between stretches of the Stillaguamish River near Silvana, WA. Here, rows of organic blueberries weather the floods and droughts of life on that powerful and changeable river."

Karen Wolden-Fuentes,
Hazel Blue Acres Farm, Photovoice 2017

Table V-1. Projected Extent of Flooding

	HISTORIC	2050s		2080s	
	ACRES	ACRES	PERCENT CHANGE	ACRES	PERCENT CHANGE
Stillaguamish River watershed					
2-year flood	9,095	38,575	324%	41,448	356%
10-year flood	37,642	54,288	44%	56,988	51%
100-year flood	65,281	66,527	2%	68,267	5%
Snohomish River watershed					
2-year flood	16,946	40,134	137%	45,511	169%
10-year flood	64,392	72,330	12%	76,111	18%
100-year flood	93,995	94,276	<1%	98,228	5%

Projected increases in discharge and flood stage will increase the amount of land inundated in a flood. The table above shows the acreage flooded and the percent change in area flooded for both watersheds given historic data (closest approximation of current conditions) as well as under projected flooding conditions for the 2050s and the 2080s (RCP 8.5 high emissions scenario).[2]

As shown in Table V-1, increases in the extent of flooding will put additional farmland at risk of inundation. In the Stillaguamish River watershed, current flooding extent for the 2-year flood (50% chance event) is projected to more than quadruple by the middle of the century, going from 9,095 acres inundated to 38,575 acres. In the Snohomish River watershed, projections indicate the acreage inundated in a 2-year flood will more than double, going from 16,946 acres to 40,134 acres. More severe changes are projected for the more frequent 2- and 10-year flood events, while the 100-year event (1% chance) will see smaller increases in the amount of land inundated.

Modeled flood extents for specific locations can be viewed in an online web map that can be accessed from https://snohomishcd.org/ag-resilience. However, it is important to note that the model is at a coarse scale and most appropriate for high-level risk assessment and planning, not site-level analysis.

Agricultural producers in the county have expressed that yearly flood frequency is as important as flood height when assessing the potential for future risk. CIG completed an analysis looking at the change in number of

Table V-2. Projected Days Per Year Stage Thresholds are Exceeded

	STAGE	HISTORIC	2050s		2080s	
			RCP 4.5 – LOW (AVG)	RCP 8.5 – HIGH (AVG)	RCP 4.5 – LOW (AVG)	RCP 8.5 – HIGH (AVG)
Stillaguamish River at Arlington	17 ft	1.2	2.9	3.0	3.5	3.5
	19 ft	0.5	1.3	1.4	1.6	1.7
Snohomish River near Monroe	17 ft	1.1	2.6	2.9	3.2	3.9
	23 ft	0.2	0.4	0.4	0.5	0.7

days a year the rivers reach specific flood stages based on farmer input into key flood stage thresholds (e.g. when levees overtop, livestock must be evacuated, structures flood, etc.). In the Stillaguamish River floodplain, farmers identified the 17-foot and 19-foot flood stages as critical, which correspond roughly to the 2- and 3-year events. In the Snohomish River floodplain, farmers identified the 17-foot and 23-foot stages, which correspond roughly to the 3- and 13-year flood events.

Table V-2 shows the average number of days per year these stage thresholds are exceeded using historic data alongside projections for the 2050s and the 2080s at the Stillaguamish River at Arlington gauge (#34) and the Snohomish River near Monroe gauge (#12150800).[3] Average estimates are shown here for two climate projection scenarios (low or high greenhouse gas emissions). The modeling indicates increases in flood frequency of all stage heights by the 2050s and again for the 2080s. For example, the models show that the 17-foot stage on both rivers is exceeded for 3 days per year, on average, by the 2050s, whereas historically it has only been exceeded about one day per year, on average. The more extreme stages on both rivers – 19-foot on the Stillaguamish and 23-foot for the Snohomish – also occur more frequently in the future, happening about two to three times as often by the 2050s and three to four times as often by the 2080s.

Groundwater Levels

Groundwater levels are a major variable affecting agricultural operations in the lower Snohomish and Stillaguamish River floodplains. The timing and extent of groundwater saturation affects when farmers can get out on their fields in the spring; accessing when fields are too wet can cause damage to equipment and soils. Wetter years will result in delayed access to fields and drier years may allow earlier access depending on crop types. In the fall, rain and the associated rise in the groundwater table effectively ends the cultivation season.

Climate change is expected to impact groundwater conditions and timing in both watersheds. A rise in relative sea level is expected to raise groundwater levels and extend the period of saturation in the spring, thereby delaying field access. The impact of sea level rise on groundwater levels may also shorten the agricultural season in the fall as groundwater levels return to pre-spring conditions earlier.

Table V-3 shows relative sea level rise projections at the Snohomish River and Stillaguamish River mouths (RCP 8.5 high emissions scenario).

Table V-3. Relative Sea Level Rise Projections

	YEAR 2050	YEAR 2080	YEAR 2100
Snohomish River	0.8 feet	1.5 feet	2.2 feet
Stillaguamish River	0.7 feet	1.5 feet	2.2 feet

[4]

To better understand the impacts of sea level rise on groundwater, the Conservation District hired Cardno to assess the impact of rising sea levels on groundwater levels in the spring and fall on floodplain agricultural land.[3] The study examined the lower Snohomish and Stillaguamish basin floodplains from the mouth upstream to the extent of tidal influence on groundwater levels for each river system. For the Snohomish River, the study area extended from the mouth of Possession Sound to Thomas' Eddy at river mile 16.1. The Stillaguamish River study area extended from the mouth of the river at Hatt Slough upstream to the Pioneer Highway Bridge at river mile 7.4.

In order to confirm assumptions about geology and to document groundwater levels across seasons, Cardno installed wells throughout the study areas. They also used data from existing wells operated by Snohomish County, the Stillaguamish Tribe, and the Washington Department of Fish and Wildlife. Cardno used the recently released *Projected Sea Level Rise for Washington State – A 2018 Assessment*[4] to incorporate projections of relative sea level rise into the analysis. Sea level rise was assumed to affect river channels up to the current extent of tidal influence.

Examination of existing groundwater conditions showed that groundwater at farms in both the Snohomish and Stillaguamish watersheds tend to decline about one foot per month through the spring. In the fall, higher river flows cause groundwater levels to increase to early-spring elevations. Based on this information about current conditions, the groundwater study was able to project delays in spring cultivation by calculating how long it would take future groundwater levels, raised by sea level rise, to fall to current spring conditions.

Results indicate that rising sea levels are anticipated to delay the time when farmers access their fields in the spring. While natural variation will continue, sea level rise will generally increase the delay of start times for working fields and this increase will become more and more pronounced with time. For low-lying farmland, delays could reach three weeks by the 2050's and four to five weeks by the 2080s. Areas closer to the Puget Sound coast (within a few miles) will feel the greatest effects of this change because of their proximity to rising marine waters. Figures V-1 through V-4 at the end of this chapter show 2050 and 2100 groundwater projections for both the Snohomish and Stillaguamish watersheds.

The Take-Away: Groundwater

Rising sea levels are anticipated to delay the time when farmers can access their fields in the spring by up to four weeks by the 2050s and up to five weeks by the 2080s.

The study found that the effects of sea level rise on the timing of groundwater conditions in the fall are not likely to be significant because anticipated changes in levels would be within the range already experienced under natural tidal cycles. Therefore, the delay in start times for working fields in the spring would not be made up in the fall.

A separate analysis was conducted for Ebey Island in the Lower Snohomish River floodplain. Because no groundwater data is available for Ebey Island, well data from nearby Smith Island was used as an analog. It was found that groundwater levels on Smith Island track the levels of Puget Sound tides and are within a foot of the height of the adjacent slough during summer months. If we apply this relationship to Ebey Island, it indicates that sea level rise could have a direct impact on groundwater levels. The analysis shows that a number of areas on the island would lie below the groundwater table and be inundated without active drainage and pumping (see Figure V-5 at the end of this chapter). However, farmers on Ebey Island have stated that pumping and drainage effectively dry out all cultivated areas. This emphasizes the critical role pumping plays in maintaining agricultural viability, a role that will become even more important with sea level rise.

Saltwater Intrusion

Agricultural areas located near marine waters can suffer from saltwater intrusion, which occurs when saline waters move into groundwater aquifers. In the Lower Stillaguamish and Snohomish River floodplains, groundwater with increased salinity due to saltwater intrusion could affect the growing conditions for crops if that salinity reaches root zones. Though salts are crucial plant nutrients, high concentrations of any one salt or many different salts can be toxic to plants. Sea level rise could increase saltwater intrusion into groundwater in these areas as the saltwater interface rises in relation to freshwater aquifers.

In addition to analyzing groundwater levels and ponding, the aforementioned groundwater study completed by Cardno also assessed the effect of sea level rise on saltwater intrusion into shallow groundwater. Cardno measured salinity levels in the wells drilled for the groundwater level study, as well as analyzed data from partner's wells. Salinity impacts are measured in millisiemens per centimeter (mS/cm), a metric that measures conductivity values as a surrogate to salinity. Based on the salt tolerance of crops most commonly grown in the Lower Stillaguamish and Snohomish River floodplains (corn, grass, beets, spinach, and cabbage) and the depth of the wells used in the study, it was assumed that 3 mS/cm would best indicate potential impacts of saltwater intrusion on agricultural production. The response of plants to 0-2 mS/cm is mostly negligible, while sensitive plants can experience yield impacts with 2-4 mS/cm. Most plants would be restricted by 4-8 mS/cm, and only tolerant plants can grow under conditions with 8 mS/cm or more.

In the Lower Stillaguamish, existing conductivity measurements at wells within 1,000 feet of Hatt Slough showed a range of 0.1 to 6.7 mS/cm in late August 2016. These readings suggest that crops in the lower estuary may already be stressed by existing salinity conditions. Farmers in this area confirm that this is true in patches, but that most land is still highly productive. Data suggests that rising sea levels of one foot will increase conductivity measurements by approximately 1 mS/cm in the groundwater of farms near the coast. Figure V-6 at the end of this chapter shows the late spring/early summer salinity threshold in the Stillaguamish estuary currently, as well as predictions for where the salinity impact will expand to in the future.

The Take-Away: Saltwater Intrusion

On Florence Island in the Lower Stillaguamish, patches of farmland already experience saltwater intrusion above crop tolerance thresholds, and those impacts are likely to increase in severity over the next 50 years.

Areas closest to the shoreline are at the highest risk of saltwater intrusion. Areas within 5,000 feet of the shoreline are especially vulnerable, and areas within 10,000 feet could also experience increases over time.

Increasing pumping on Florence Island is not recommended unless additional groundwater analysis negates the finding of this study, as pumping could result in increasing the amount of agricultural land impacted by salinity.

Geographic location is a key factor in saltwater intrusion impacts. Areas closest to the shoreline have the highest risk of increased groundwater salinity intrusion due to rising sea levels. Areas within 5,000 feet of the shoreline are especially vulnerable to groundwater salinity intrusion to the shallow rooting zone of crops but areas within 10,000 feet may also experience measurable increases over time. To a high level of certainty, Florence Island (near the mouth of the Stillaguamish River) already experiences salinity above crop tolerance thresholds, and those impacts are likely to increase in severity over the next 50 years. In contrast, agricultural land on Ebey Island in the Snohomish River floodplain may not experience significant increases in salinity intrusion to shallow groundwater due to its location further from marine waters. Because the Marshland and French Slough Flood Control Districts are greater than 20,000 feet from the marine boundary, sea level rise is not expected to cause significant increases in salinity intrusion to shallow groundwater.

Traditional pumping and infrastructure solutions to rising seas may not provide adequate protection for the future. For example, installation of pumps to reduce groundwater impacts to drainage could draw deep, salty groundwater upward, closer to the rooting zone of crops. Future improvements to pumps and drainage systems must consider groundwater salinity intrusion effects from rising sea levels. In the Snohomish River, pumping in the Marshland and French Slough Diking Districts is not likely to impact groundwater salinity, but additional analysis is recommended before implementing a more aggressive pumping approach further downstream on Ebey Island. In the Stillaguamish River, increasing the amount of pumping on Florence Island is not recommended unless additional groundwater analysis negates the finding of this study, as pumping could result in increasing impact of salinity on agricultural land.

The interplay of sea level rise, groundwater, and surface water management for the lower Stillaguamish and Snohomish River floodplains is complex and many uncertainties remain that have not yet been resolved. The study recommends a focused data collection effort to evaluate the degree to which salinity already affects crop yields in the region.

Land Subsidence and Channel Aggradation

Subsidence refers to the downward sinking of the ground surface. Subsidence of agricultural lands can occur from the lack of sediment inputs to the floodplain, soil compaction, groundwater withdrawals, and decomposition of soil organics. Aggradation refers to the rising of the ground surface and, in this study, refers to the accumulation of sediment within the river channel. Aggradation can increase the risk of flooding because it decreases the capacity of the river to carry flood volumes. Subsidence contributes to drainage issues in agricultural fields and can increase the risk of levee failure through settling and shifting. Therefore, aggradation within the river channel and subsidence of adjacent farmland can increase the flood and drainage impacts to some agricultural areas.

The Take-Away: Subsidence and Aggradation

The analysis of subsidence for both the Stillaguamish and the Snohomish floodplains showed little direct evidence for regional subsidence, and limits the calculation of localized subsidence to no more than 2.4 inches per decade if it is occurring at all.

The Stillaguamish River channel is aggrading near the mouth, and this trend is likely to continue into the future. The Lower Snohomish River is not aggrading, but upper reaches (from the SR-9 Bridge to the Skykomish) show some aggradation.

In order to study whether land subsidence and aggradation is affecting agriculture in the Snohomish and Stillaguamish River floodplains, the Conservation District contracted Cardno to conduct subsidence and aggradation studies for each watershed. To evaluate subsidence, Cardno re-surveyed elevations in areas that have been surveyed in the past, including monuments and benchmarks, roads, agricultural lands, and levees. The study also involved analysis of the vertical difference between elevations from multiple LiDAR datasets. To evaluate aggradation, Cardno compared recent channel cross-sections to historical surveys, evaluating 48 cross-sections of the Stillaguamish River and its tributaries and 19 cross-sections of the Snohomish River.

The analysis of subsidence[5] in the Stillaguamish floodplain was inconclusive. The accuracy of LiDAR data comparisons was suspected to be influenced by varying heights of vegetation, making accurate conclusions difficult. The resurvey of benchmarks suggests localized subsidence in known locations, but does not provide an indication of larger-scale agricultural land subsidence. In general, the data shows little direct evidence for regional subsidence and limits the magnitude of localized subsidence to no more than 2.4 inches per decade in some areas. The study concludes that the impact of sea level rise on groundwater levels and salinity as well as the impact of larger winter flood events should be a greater concern than subsidence.

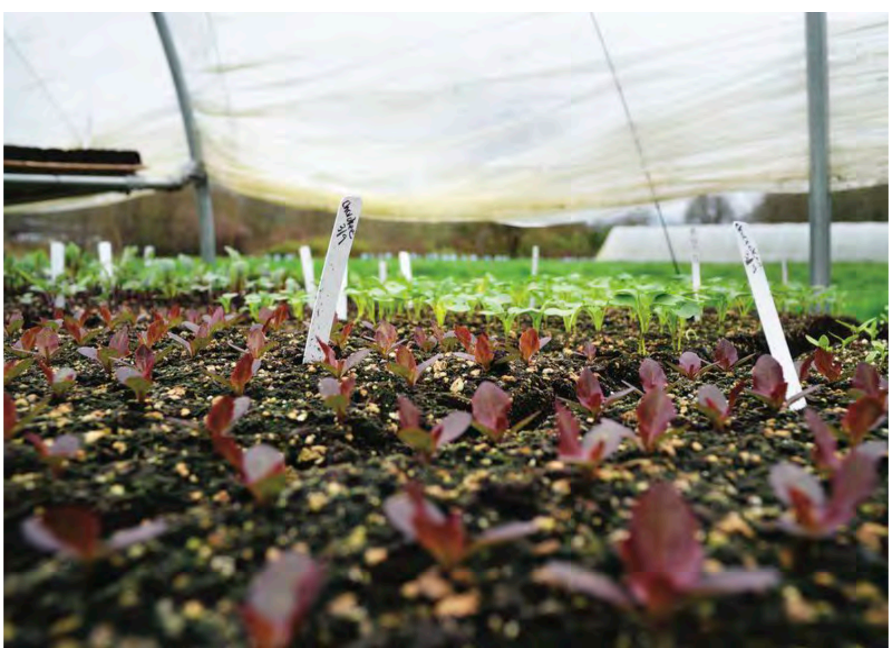
Potential subsidence in the Snohomish River floodplain was also assessed using LiDAR data as well as re-survey of benchmarks. This analysis showed a range of subsidence from 1 to 6 inches approximately every 10 years in some areas.[6] In general, however, the uncertainty in the LiDAR comparisons exceed the magnitude of elevation change that may have occurred, so the datasets are not conclusive. Similar to the Stillaguamish River, the data limits the likely magnitude of subsidence to no more than 2.4 inches per decade, and primarily in areas with high organic soils on Ebey Island and in the Marshland and French Slough Flood Control Districts. Local farmers indicate that organic soils subside more quickly in the years after initial clearing, draining and cultivation than in subsequent years.

In the Stillaguamish River, cross-sections of the river channel showed that both the main channel and the Old Main Channel experienced aggradation from 1997 to 2011.[5] The general trend of aggradation is expected to continue into the future. Dredging in the Lower Stillaguamish River is not considered to be an option for mitigating this risk because it would not reduce future sediment inputs that would continue to aggrade the river and because it would only cause a negligible decrease in the peak flood stage.

Analysis of the Lower Snohomish River showed that the river channel has remained stable from year to year and has not aggraded.[6] However, the upper reach of the river (from the SR-9 Bridge to the confluence of the Skykomish and Snohomish Rivers) showed aggradation. This reach may experience modest aggradation into the future.

Crops

The *State of the Knowledge: Climate Change in Puget Sound* reports that the impacts of climate change on local agriculture include increased temperatures, changes in seasonal precipitation and a lengthening of the growing season, all of which may positively or negatively impact specific agricultural products or farmland.[1] Washington State University's Center for Sustaining Agriculture and Natural Resources developed an online Climate Visualization Tool that allows farmers to visualize



Climate Change

"Seeds are planted and sprout undercover and we, as farmers, wait for the rain to stop and fields to dry out enough to do soil work and prepare beds for getting all of these plants in the ground. This past spring was similar to ones in the past, only the rains didn't let up in April as they normally do. While a little extra rain might be a small inconvenience to some, this kind of climatic event makes a very real impact on farmers and food production. Most farmers are 4-6 weeks behind schedule because of delays brought on by abnormal rainfalls, but nature itself is also behind. Asparagus, a perennial crop, was also weeks late in coming up this year. What will next Spring bring? How much added resilience is necessary to withstand these changes?"

Libby Reed, Orange Star Farm, Photovoice 2017 projected climate changes as they relate specifically to agricultural crops in the Pacific Northwest. The tool shows crops grown in 6 km x 6 km grids across the landscape and provides projections to the years 2040, 2060 and 2080 for impacts associated with:

- Temperature
- Growing degree day accumulation
- Growing season length
- Precipitation
- Climate analogues

The tool can be found at http://agclimatetools.cahnrs.wsu.edu/cbcct/.

Below is a summary of the projected impacts of climate change on temperature, growing season, and precipitation as they relate to future crop viability in Snohomish County.

The Take-Away: Crop impacts

Increasing air temperatures in summer months are projected to negatively impact some existing crops while at the same time providing opportunities for new types of agricultural production. This warming will result in a longer growing season but also an accelerated growing degree day accumulation, which can have a negative impact on yields. Models project a decrease in summer precipitation and an increase in winter precipitation.

By the 2040s, Snohomish County is predicted to have similar growing conditions to Santa Cruz County, CA, just south of San Jose. And by the 2080s, conditions are expected to be most similar to Santa Barbara County, CA, just north of Los Angeles.

TEMPERATURE

Increasing air temperatures in summer months are projected to negatively impact some existing crops while at the same time provide opportunities for new types of agricultural production. The agricultural areas in the lowlands of the Puget Sound region have warmed 1.3°F in the last 120 years with nighttime temperature rising faster than daytime temperature.[1] In Snohomish County, climate models consistently project continued warming in the lowlands, although the magnitude of change can vary by model. Depending on the emissions scenario used (low or high greenhouse gas emissions), average projected increases in annual average temperatures are 4.0°F - 5.5°F by midcentury and 5.5°F - 8.5°F by the end of the century. Projections also indicate that we will see an increase in extreme heat events, while the frequency of extreme cold events will decrease.[1] In addition to the potentially positive or negative impacts to growing degree day accumulation described below, warming related risks include exposure to heat stress events and insufficient chill accumulation before bloom for perennial trees.[7]

GROWING DEGREE DAYS

Warming can result in accelerated growing degree day accumulation, which can lead to earlier maturity and decreases in yields for some crops or more time under optimal conditions resulting in yield increases for other crops.[8] Growing degree days are the plant's calendar, determining its phenology or timing of growth stages. It is a measurement of heat accumulation based on minimum and maximum daily temperatures and crop-specific optimal high and low temperature thresholds. Overall yield impacts are very crop- and location-specific and depend of the relative balance between temperature effects which can be positive or negative and a carbon dioxide fertilization effect which is generally positive.[8]

The maturity of annual crops such as corn, barley, and potatoes in Snohomish County is projected to advance by about a month by midcentury, and by a couple of months by end of the century. This will open up new opportunities, including the potential to double crop if there is sufficient water availability as well as the potential to access new markets via crops that become suitable under these new conditions.[9,10]

GROWING SEASON LENGTH

The growing season length, defined as the number of frost free days (number of days between the last frost in spring and the first frost in fall), is also predicted to increase.[11] While the current growing season length in Snohomish County is approximately 260 days, projections show approximate lengthening of the growing season of 75 days by midcentury and 100 days by the end of the century. This measurement of the growing season length does not take into account other factors influencing the ability to grow crops such as groundwater levels and the availability of light during winter months.

PRECIPITATION

Natural variability in annual precipitation is high, making future projections highly variable. Models consistently indicate, however, a projected decrease in summer precipitation under all greenhouse gas emissions scenarios. Most models predict a decline in summer precipitation of 22%, on average, by the 2050s.[1]

While winter, spring, and fall precipitation projections show only modest increases (2 – 11% on average) by mid-century, precipitation extremes are projected to increase and occur more frequently. As temperatures increase, models predict that rain will be the dominant form of precipitation in most watersheds in the Puget Sound by the end of the century – watersheds such as the Snohomish River that have historically been highly influenced by snowfall.[1] These shifts in the hydrologic cycle will mean more flooding in winter months and lower stream flows in summer months.

CLIMATE ANALOGUES

Researchers at WSU conducted an analysis of crop growing condition analogues that can help farmers plan for future conditions.[12] Using soil and climate data for the Western U.S., this analysis answers the question "is there another county whose current growing conditions are similar to what is predicted for Snohomish County?" This information is shown by county for Washington, Oregon, and Idaho using the Climate Visualization Tool linked above.

By the 2040s, Snohomish County is predicted to have similar growing conditions to Santa Cruz County, CA, just south of San Jose. And by the 2080s, conditions are expected to be most similar to Santa Barbara County, CA, just north of Los Angeles. Information such as the types of crops, management practices, and pest control in analogue counties can provide valuable information to Snohomish County farmers wanting to plan for and manage risk into the future.

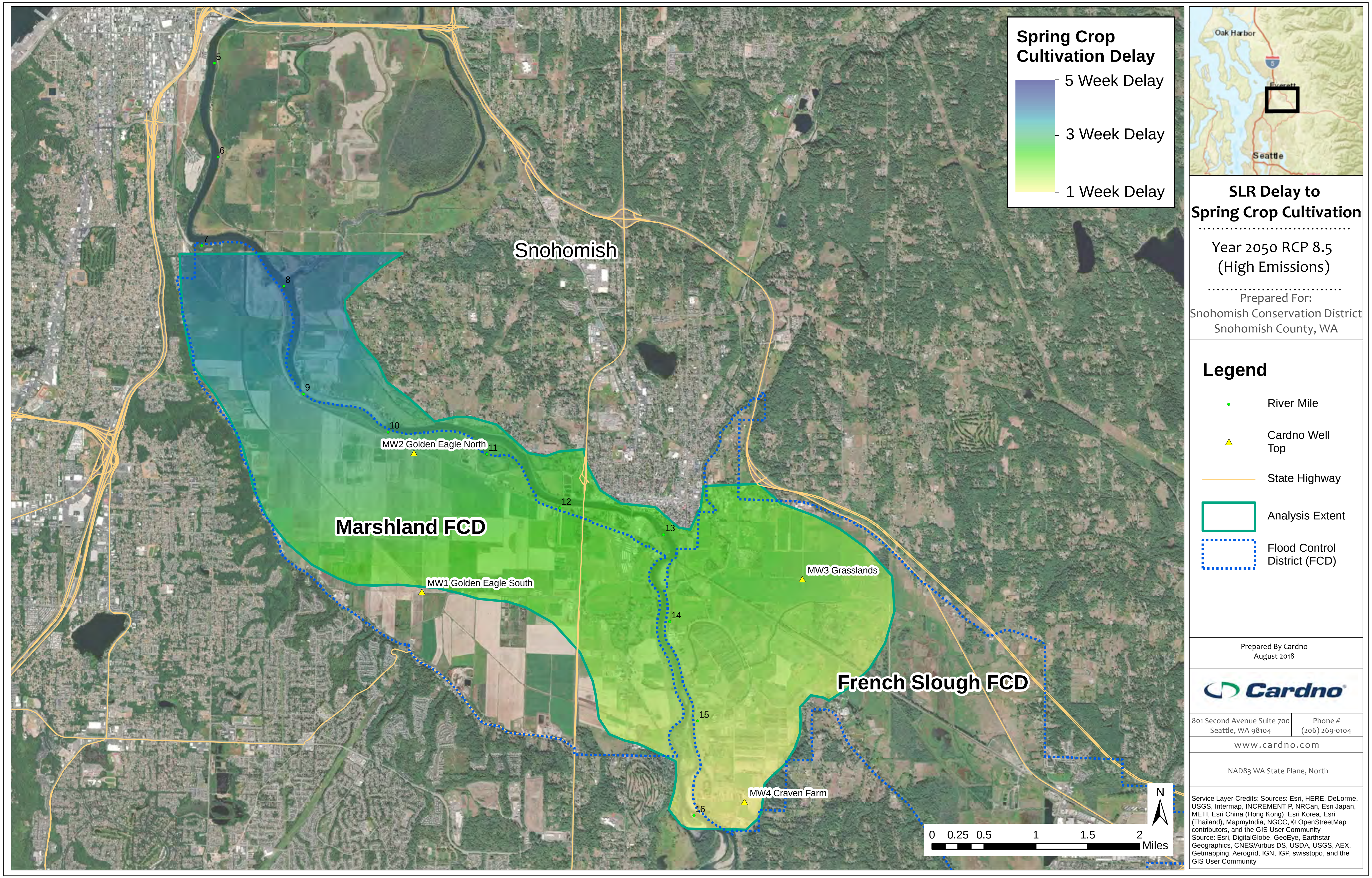


Figure V-1. SLR Delay to Spring Crop Cultivation, Snohomish Floodplain, Year 2050. This figure shows the projected delay to spring crop cultivation due to changes in groundwater levels. The projection is shown for the year 2050 using RCP 8.5 scenario (high emissions).

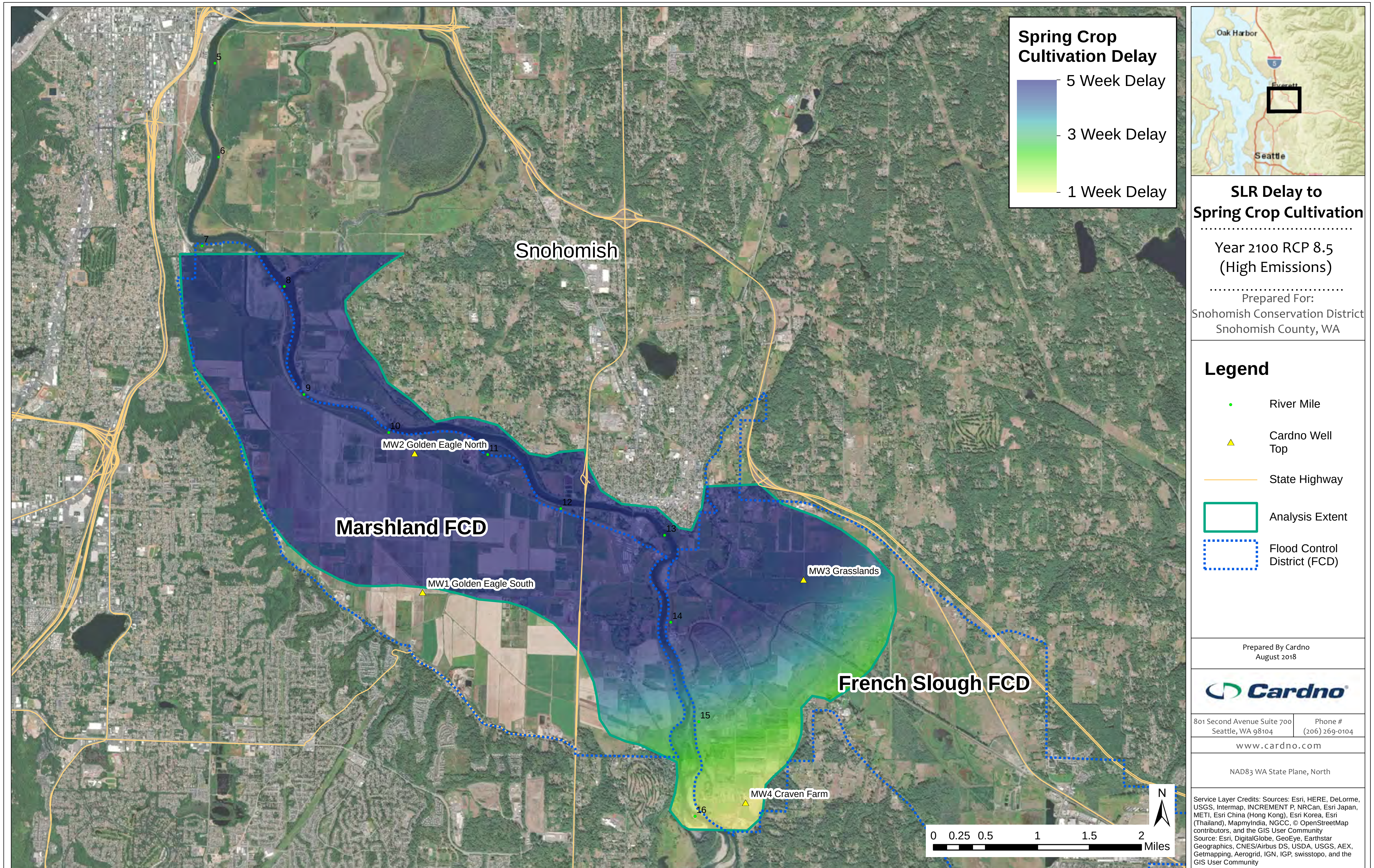


Figure V-2. SLR Delay to Spring Crop Cultivation, Snohomish Floodplain, Year 2100. This figure shows the projected delay to spring crop cultivation due to changes in groundwater levels. The projection is shown for the year 2100 using an RCP 8.5 scenario (high emissions).

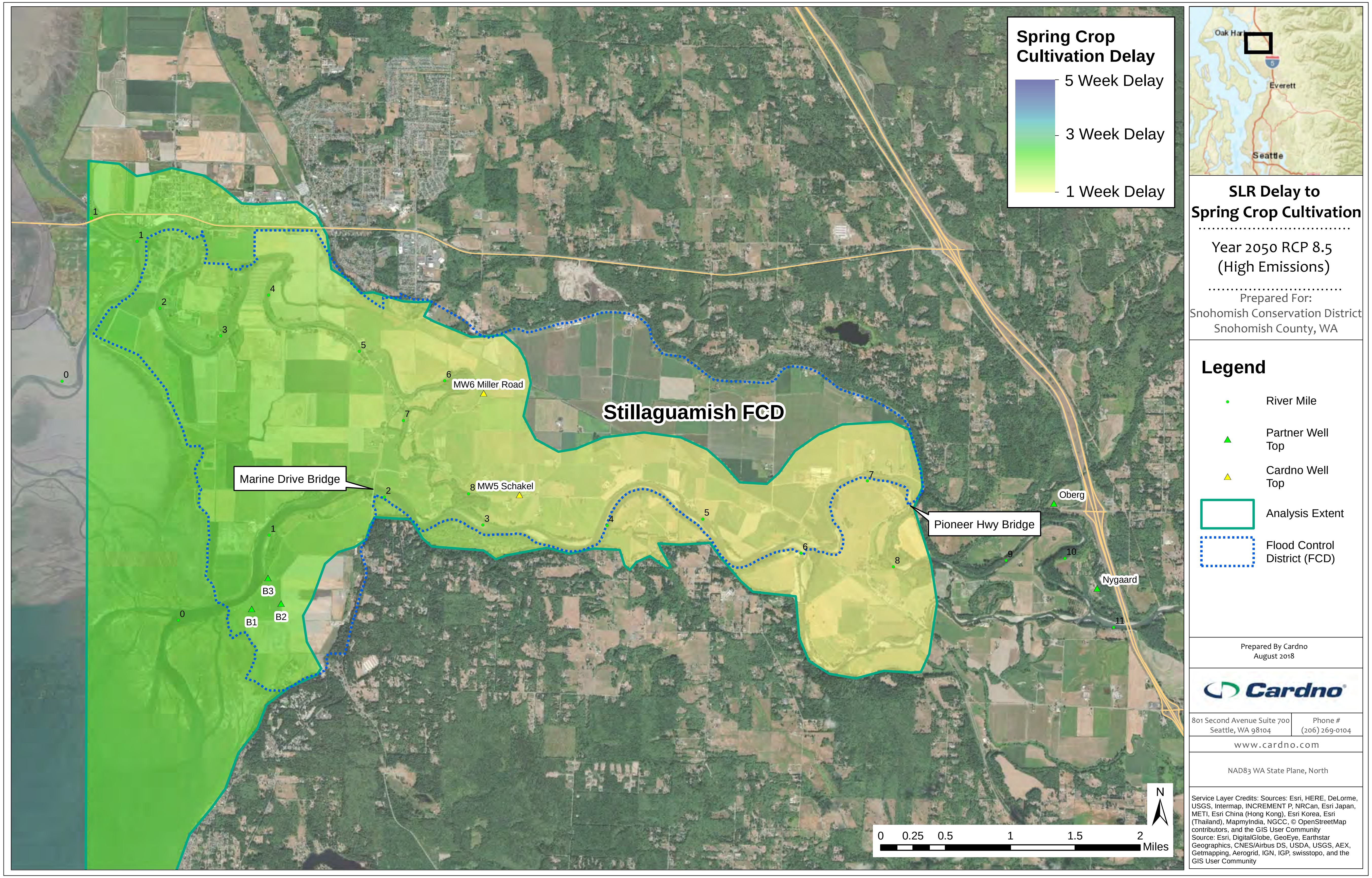


Figure V-3. SLR Delay to Spring Crop Cultivation, Stillaguamish Floodplain, Year 2050. This figure shows the projected delay to spring crop cultivation due to changes in groundwater levels. The projection is shown for the year 2050 using an RCP 8.5 scenario (high emissions).

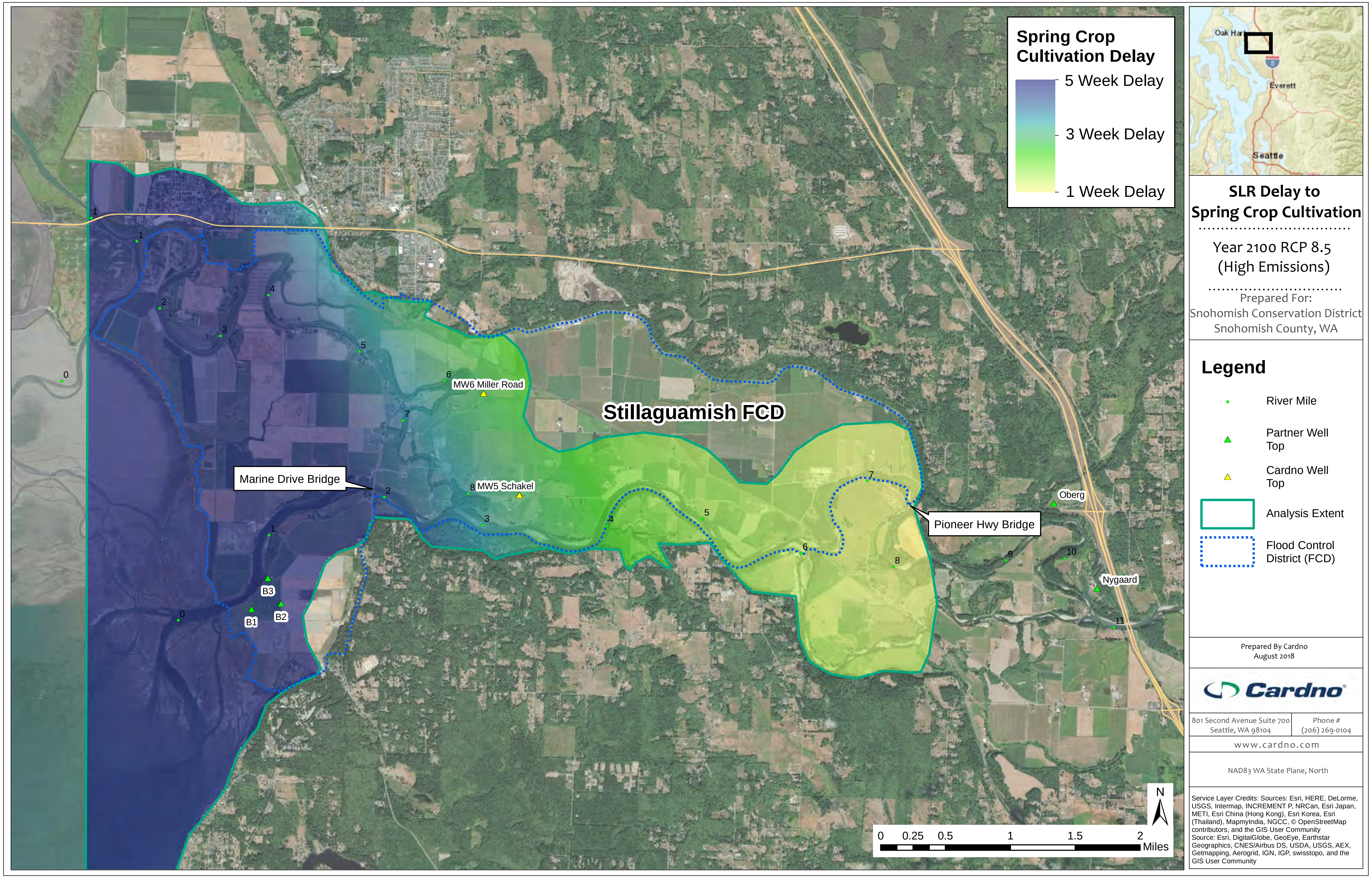


Figure V-4. SLR Delay to Spring Crop Cultivation, Stillaguamish Floodplain, Year 2100. This figure shows the projected delay to spring crop cultivation due to changes in groundwater levels. The projection is shown for the year 2100 using an RCP 8.5 scenario (high emissions).

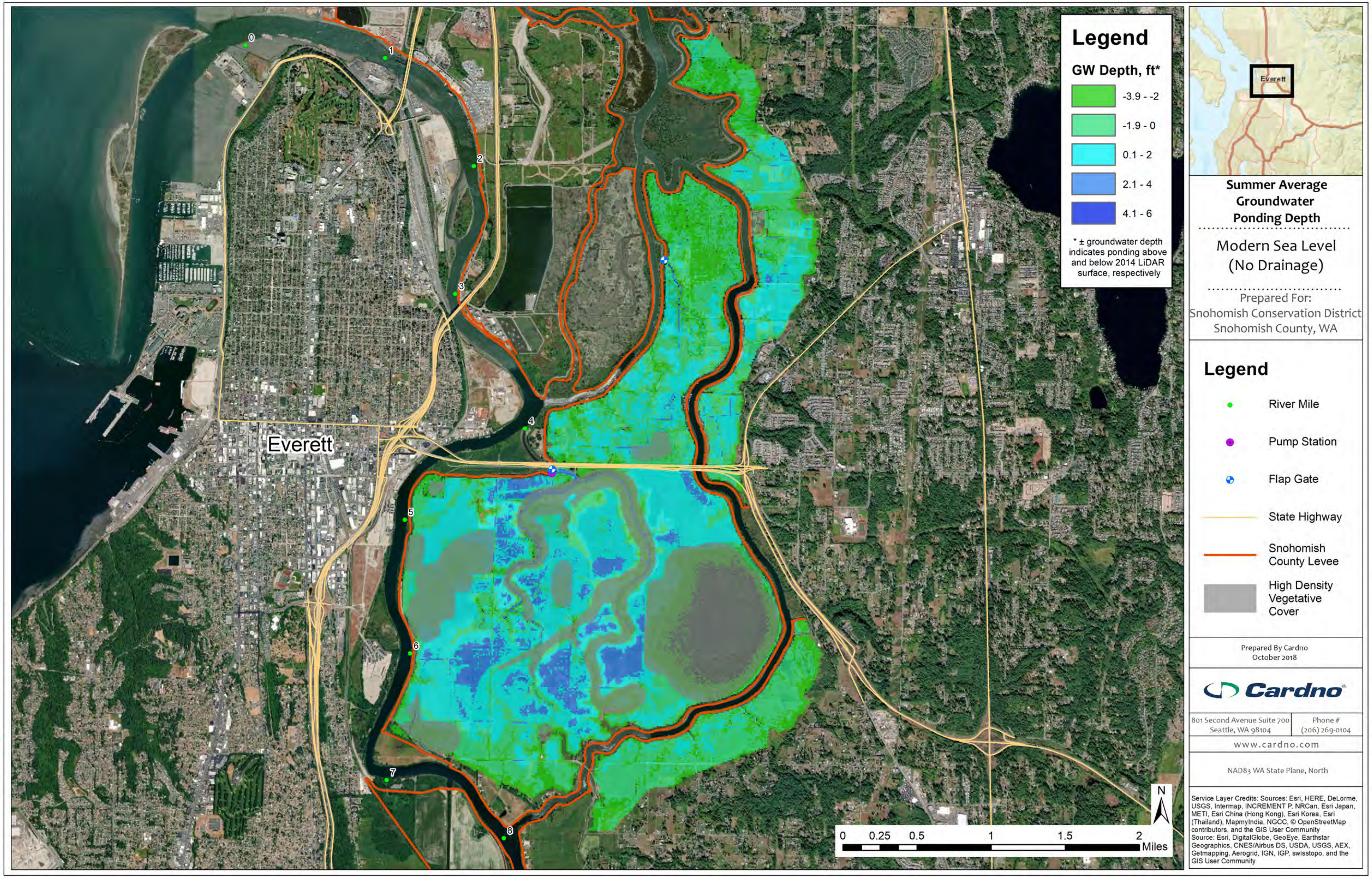


Figure V-5. Projected Depth-to-Groundwater Map for Ebey Island and Vicinity. This figure shows the projected depth-to-groundwater map for Ebey Island under modern sea level and assuming no pumping. The blue areas lie at elevations below the assumed groundwater table, and so are currently dependent on active drainage measures to remain dry. In general, the darker blue areas closely correspond to wet areas or boils that are readily observed on aerial photographs.

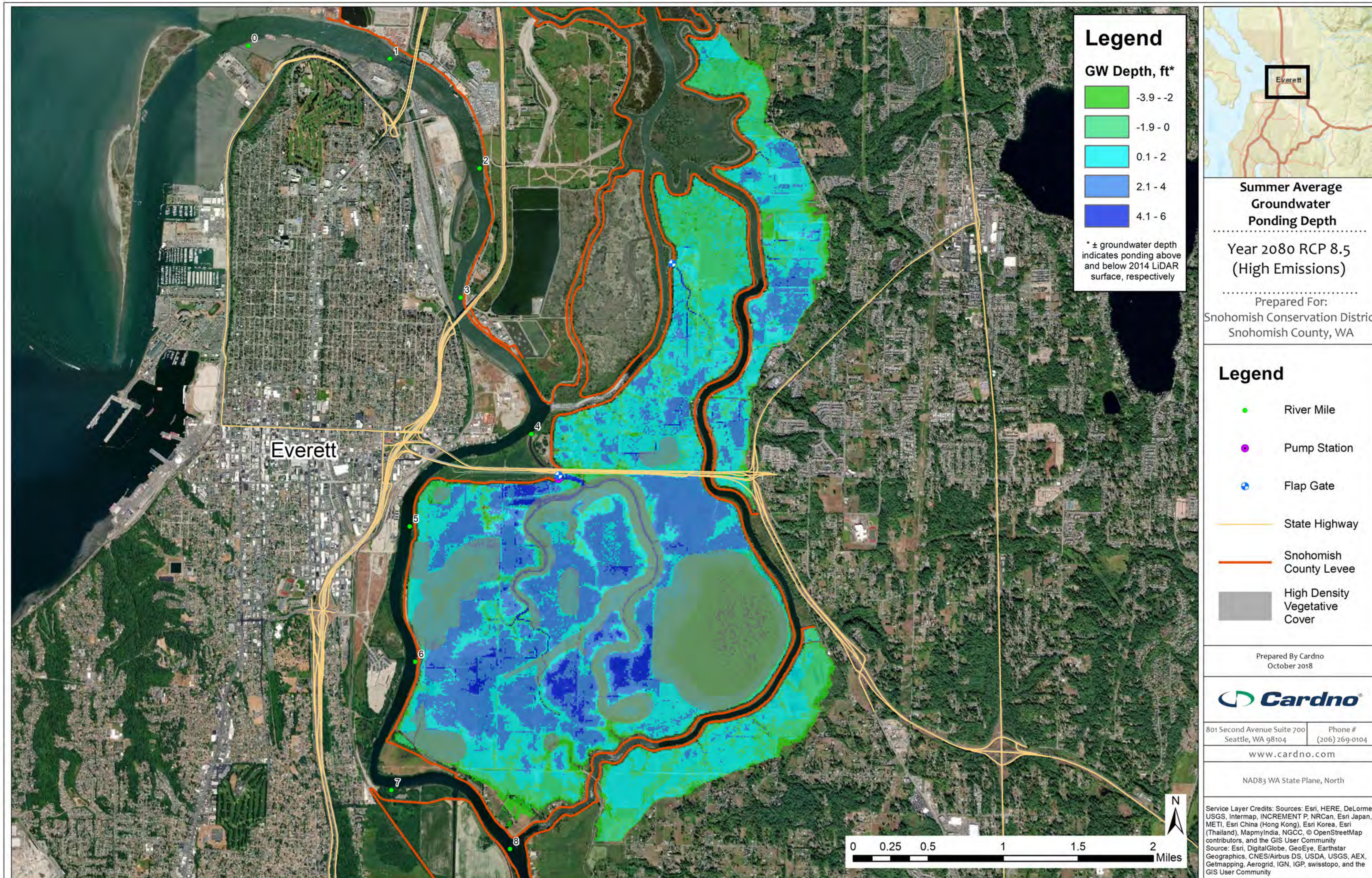
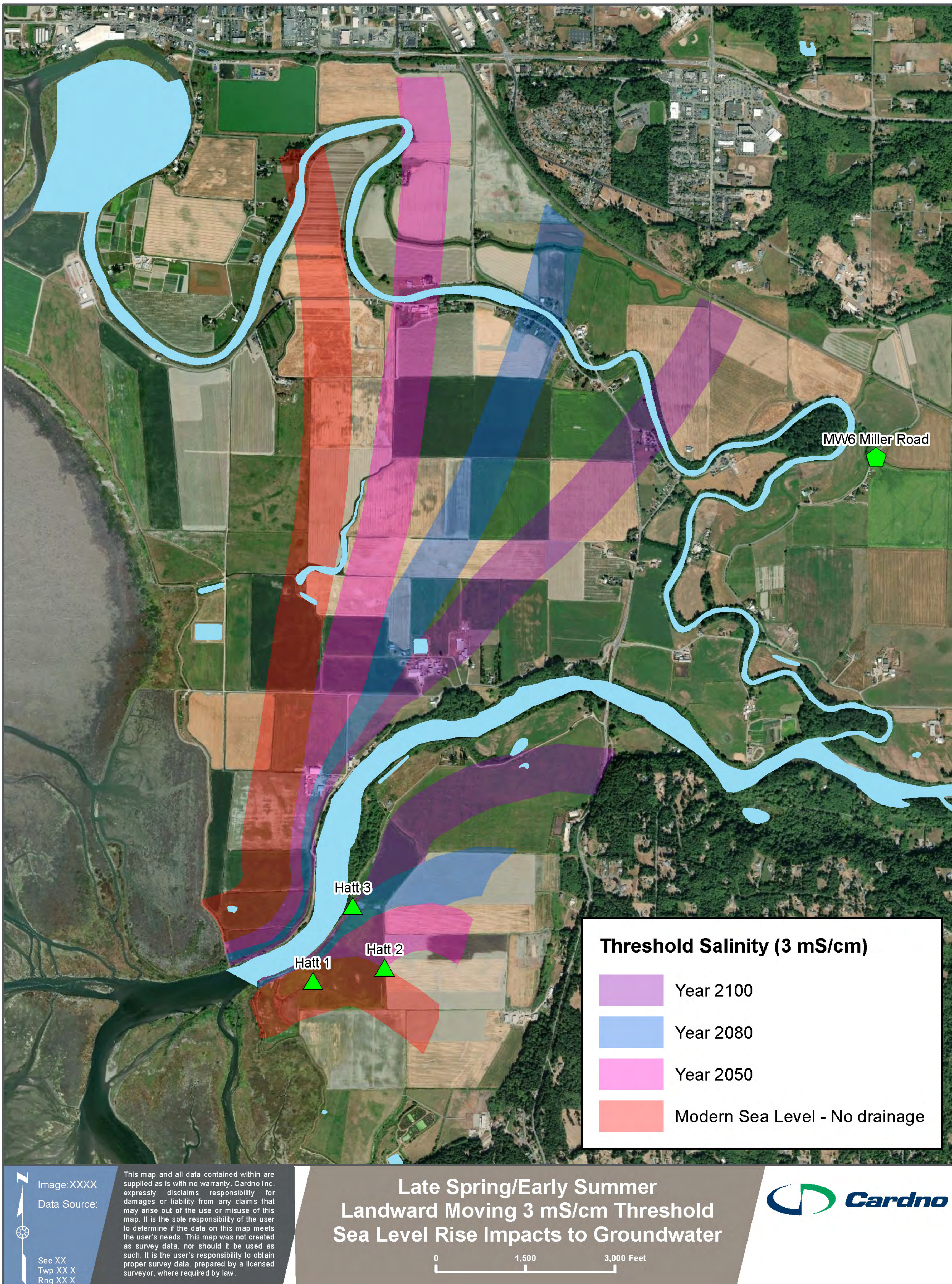


Figure V-6. Future Conditions Depth-to-Groundwater Map for Ebey Island and Vicinity. This figure shows the projected depth-to-groundwater map for Ebey Island in 2080 under an RCP 8.5 (high emissions) scenario.



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GIS Analyst: maggie.wilbanks

Figure V-7. Early Summer Salinity Intrusion to Groundwater. This figure shows the projected level of salinity intrusion in the Stillaguamish Estuary out to 2100. The shaded lines represent where the threshold for crop impacts is expected to reach for that year.

1 Mauger, G.S., J.H. Casola, H.A. Morgan, R.L. Strauch, B. Jones, B. Curry, T.M. Busch Isaksen, L. Whitely Binder, M.B. Krosby, and A.K. Snover, 2015. State of Knowledge: Climate Change in Puget Sound. Report prepared for the Puget Sound Partnership and the National Oceanic and Atmospheric Administration. Climate Impacts Group, University of Washington, Seattle. doi:10.7915/CIG93777D

2 Fathom, 2019. Puget Sound Hazard Mapping Report.

3 Cardno, 2019. Climate impacts to groundwater in the Lower Snohomish and Stillaguamish River basins. Report produced for the Snohomish Conservation District. Lake Stevens, WA.

4 Miller, I.M., H. Morgan, G. Mauger, T. Newton, R. Weldon, D. Schmidt, M. Welch, and E. Grossman, 2018. *Project Sea Level Rise for Washington State – A 2018 Assessment*. A collaboration of the Washington Sea Grant, University of Washington Climate Impacts Group, Oregon State University, University of Washington, and US Geological Survey, Prepared for the Washington Coastal Resilience Project.

5 Cardno, 2019. Technical Memo: Stillaguamish Flood Control District subsidence and sedimentation study. Report produced for the Stillaguamish Flood Control District. Lake Stevens, WA.

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