# Applying Geodesign Principals for Climate Change Adaptation with Capitol Land Trust

by

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# Abstract

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Within the field of conservation, climate change adaptation has become a common topic in recent years. The destabilizing effects of climate change on natural landscapes are increasingly apparent, spurring concern within many conservation-based organizations. Some large conservation groups such as The Nature Conservancy have invested considerable resources and time into exploring the climate resilience of their lands and easements (Buttrick et al., 2015). Smaller land trusts may lack the time and resources to make such ambitious assessments, requiring a rapid, inexpensive, and effective way to begin planning climate change adaptation measures for their trust lands.

In this thesis the principals of Carl Steinitz's framework for geodesign are used to attempt climate change adaptation planning for Capitol Land Trust, based out of Lacey, Washington, USA. Geodesign offers an effective and widely used approach for complex problems such as implementing climate change adaptation. The application of geodesign is a novel approach for climate change planning and shows promise for planning and implementing rapid on-the-ground climate adaptation measures. A story map was produced before the geodesign to compile maps of climate change related processes to increase climate change impacts of Capitol Land Trust properties. Products of the geodesign included a decision support tool for climate-smart land acquisition, a presentation of results to the Capitol Land Trust board of directors, and lists of recommendations for; restoration, acquisition, policies, and cross organizational collaboration. After the geodesign, participants were asked to give anonymous feedback for the project.

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# Acknowledgements

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# Introduction

*"To expect the unexpected shows a thoroughly modern intellect" -Oscar Wilde*

Geodesign offers a process that is adaptive and effective for many types of land uses and land management decisions. In this thesis, geodesign is used in planning to adapt Capitol Land Trusts' lands to climate change. Localized climate data, sea level rise data, tree inventories, project requirements, and other site-specific data were used to model potential change and impacts to assess vulnerability as well as more physical impacts. The geodesign process incorporates design of multiple potentials for future restoration projects and development that is informed by the impacts of climate change.

## Need for Adaptation of Conserved Lands

Humans have built a world based on ideas of organization, viability, and perpetuity. The built environment must be viable and must suit a purpose deemed acceptable to the people in and around it (Brandt et al., 2016). If the built environment's viability is in question society must alter infrastructure and development to appear more viable, or else be abandoned (Ekstrom & Moser, 2014).

People construct areas of development including major infrastructure projects with the intent of having them last many years. These areas are meticulously planned to avoid an array of potential catastrophic failures i.e. earthquakes storms etc. Designing new development based on historic climatic precedents underscores ideas of perpetuity but with a perceived lack of environmental change (Curran, 2017). Climate change challenges the premise of predictability on which the built environment has been planned, by introducing an unexpected change element that defies the model of how we perceive our environment. Inevitability we must adapt or retreat from areas that will become uninhabitable because of the effects of climate change (Forzieri et al., 2018).

Conserved natural areas within and around the built environment provide a buffer against the effects of climate change by providing ecosystem services. Ecosystem services can act in mitigating storm runoff, conserving water resources, reducing storm surges, and bolstering biodiversity (Kabisch et al., 2016).

Natural or “green” areas are considered an essential tool for climate change adaptation, but these natural lands face uncertain futures because of the effects of climate change. Increasing development and natural resource consumption will result in the future disturbance of natural lands, amplifying the uncertainty of future impacts to those lands (Vargas-Moreno & Flaxman, 2012). Assessing potential degradation and loss of natural areas due to future climate change and land use change is a critical step in planning for the resilience of the built environment (Bonan & Doney, 2018).

Geodesign offers methods for collaboration across an organization to address complex problems such as climate change adaptation. Through using geodesign organizations can assess risks related to climate change and act in planning to mitigate their effects.

# Literature Review

## Geodesign in Climate Change Adaptation

Experimentation concerning climate adaptation frameworks shows promise for geographically based approaches to climate adaptation. Geodesign is the "development and application of design related processes intended to change the geographical study areas in which they are applied and realized" (Steinitz, 2012, p. 2).

The impacts of climate change affect the landscape differently and are scale and location dependent. Scale and location are spatial components that contribute to the framework of a geodesign process.

There are successful examples of using geodesign to support the climate adaptation of agricultural and other natural resource lands. Examples include projects coordinating water resources of the Mekong River in Vietnam (Hartman, n.d.) and predicting large fire events in Oregon's Willamette Valley that are fueled by climate change, land management, and development (Hulse et al., 2016).

Geodesign often uses a multidisciplinary approach by bringing together technical experts, designers, people of place, and geographers, while utilizing a broad expertise (Steinitz, 2012). Climate adaptation processes are multidisciplinary and don't have a design structure to facilitate cross disciplinary decision making. The collaborative structure of geodesign offers a potential option to organize these complicated and collaborative design/planning processes into an ordered framework. Siloing of knowledge is when a group within an organization lacks the will or ability to share essential knowledge with other parts of the organization. Knowledge siloing can be a potent barrier to the implementation of climate change adaptation (Ekstrom & Moser, 2014). By using a collaborative method of planning and implementation there can be a breakdown of the siloing of knowledge.

**Why Geodesign?**

*"GeoDesign is geography by design"* -Carl Steinitz

When planning for the change of a landscape that is as unprecedented as climate change, deliberate design is becoming an apparent necessity. To design for climate change requires altering landscapes and components of their related systems to address the potential effects of the changing climate on specific study areas based on the following 3 concepts:

- Impacts: What are the effects on systems based on change?
- Vulnerability: What capacity do processes, or systems have in their ability to endure stress?
- Resilience: How effective are processes or systems in recovering from the impacts of stressors.

Climate change adaptation plans, or climate action plans can determine the scale of climate change adaptation projects, which are compiled by varied administrative and organizational entities such as corporations, nonprofits, cities, tribes, states, countries, or coalitions. Within a geodesign the designers should be careful not to ignore the larger systems that affect their area of interest by focusing only on the area that an organization is responsible for, otherwise there will likely be undesirable outcomes (Steinitz, 2012).

The geodesign framework addresses questions or problems in a way that recognizes systems, their components, and functions. The framework also allows technical, geographic, design, and local experts to collaborate with planners in a kind of round table that reduces the siloing of knowledge. By reducing organizational barriers inherent to implementing on the ground CCA, geodesign can be a potent tool in a transition toward active climate informed planning (Ekstrom & Moser, 2014). Design in the context of private conservation is likely be founded on the politics, values, duties, and desired outcomes of the organizations that initiate the process.

The framework of an organizational planning is often goal oriented. By making the extent of design take the form of discreet project goals or actions, projects may ignore the impact of widespread change to a system. By instead using process-oriented planning, the result can be systemic change. Change that exists as the cumulative effect of many smaller projects i.e. climate resilience, water conservation, or regional flood mitigation are examples of process based planning projects that aim to affect systems (Steinitz, 2016). What makes geodesign different from many other types of design is its integration of systems thinking.

Steinitz conceptualizes systems as falling into two categories regarding changes posed by a geodesign: systems that are vulnerable to change and systems that are attractive to change. The two categories provide an answer to the question of what to conserve and what to develop within an urban planning context. Geodesign was originally created to make design plans for cities, but it was different from conventional urban planning by recognizing conservation and development as actions that affected larger systems (Steinitz, 2012).

## Geodesign Process

| | |
|---|---|
| How should the study area be described? | Representation models |
| How does the study area operate? | Process Models<br><br>Direct (experientially based ex. local knowledge)<br>Thematic (processes that occur over a large area)<br>Vertical (3d)<br>Horizontal (2d)<br>Hierarchic (allowing for the variable scale and nesting nature of phenomena)<br>Temporal (time based)<br>Adaptive (observation of change over time informing predictable outcomes)<br>Behavioral (what things or whom is affecting what or whom) |
| Is the current study area working well? | Evaluation Models |
| How might the study area be altered? | Change Models:<br>Allocation decisions (how much? where? when?) emphasized in regional scale projects<br><br>Organization Decisions (how are the pieces put together?)<br><br>Expression Decisions (how are changes perceived by the public?) emphasized in small scale (localized) projects |
| What differences might the change cause? | Impact Models |
| How should the study area be changed? | Decision Models |

*Figure 1 Geodesign questions and their models/considerations. Based off of Steinitz Change and Geodesign (2012).*

The foundation of the process of a geodesign project is guided by 6 questions that were originally developed by Steinitz. Each question is answered by models which inform each other as elements of a system, where a change to one part of a system has potential effects on other parts of the system. Using Steinitz's approach the questions should be asked in order 1-6 to determine the scope of the project, then from 6-1 backwards to develop the method of the design, and then again 1-6 to accomplish the study (fig. 7) (Hulse et al., 2016).

Geodesign is a useful approach to climate change adaptation planning because it is inherently probabilistic. Planning in a probabilistic manner incorporates weighing costs, benefits, and uncertainty. Probabilistic planning is also differentiated from deterministic planning and can incorporate the element of time as well as adaptation to change. Geodesign focuses more on influencing system processes to address a problem and less on reaching a goal (Hulse et al., 2016).

## Reducing Vulnerability Via Geodesign

Vulnerability is a word often associated with climate change adaptation. Vulnerability can be defined as the propensity to experience harm from a hazard owing to an inability to adapt (Füssel, 2007). The phrase "impacts, adaptation, vulnerability" (IAV) is a common concept within the context of climate change planning and is a common thread within the fifth Intergovernmental Panel on Climate Change (IPCC 2014).

Vulnerability to environmental and social change is widely recognized as hard to define and conceptualize. Vulnerability can be nearly impossible to empirically quantify. Vulnerability is a concept used in many different disciplines and lacks uniformity in its definition between disciplines (Adger, 2006). The lack of consensus about vulnerability has resulted in a plethora of approaches to quantify the potential elements of vulnerability, evaluate metrics for vulnerability's variability with scale, and establish methods that account for site specificity of vulnerable populations (Jones & Preston, 2011).

The development of frameworks to plan and implement the reduction of future harms inflicted by climate change has been a richly published topic, with climate modeling, decision making, and natural processes being common topics within the research (Bonan & Doney, 2018; Giupponi, Giove, & Giannini, 2013;

Matthews, Iverson, Prasad, Peters, & Rodewald, 2011; Weaver et al., 2013). Harm reduction via building resilience and adaptive capacity is becoming a visceral necessity as species declines, altered disturbance regimes, and species migrations are becoming more apparent (Anderson & Ferree, 2010).

**Novel Communities**

Climate conscious adaptive management (CCAM) of lands may help create novel communities of plants, well adapted to novel climates (Williams & Jackson, 2007). Novel communities are likely to occur because of the unprecedented current rate of climate change which is a faster warming event than any other in the past 66,000,000 years (Williams & Jackson, 2007; Zeebe, Ridgwell, & Zachos, 2016). Novel communities occur when new species compositions arise within ecosystems, that have never cohabited in observable history.

Climate conscious adaptive management (CCAM) is like the practice of adaptive management, where changes are made in land management practices (ex. riparian restoration), and then observed to see the reaction of those changes. Observations ideally will show what practices are more effective and will influence future management decisions. This cycle of action, observation, and reaction is then repeated indefinitely. CCAM is like conventional adaptive management but brings into account the effects of climate change (Brandt et al., 2016). By planning, observing, and responding to how novel communities interact in an adaptive/cyclical manner land manager can facilitate the success of novel communities. However, with some species the rate of climate change is too fast for them to respond, making predictive management a necessity for the survival of sensitive species.

An effort to implement predictive methods for adaptive management has been attempted in New South Wales, Australia. Adaptive management and risk assessment techniques were developed for the region's national parks. The tool establishes potential changes to management strategies relating to dynamic risk related to processes affected by climate change (Jacobs, Boronyak, Mitchell, Vandenberg, & Batten, 2018).

## Overcoming Hesitancy Via Climate Modeling

Predictive technology such as climate-based models can help overcome the uncertainty barrier of climate change action for land managers. Land managers are hesitant to act because of the uncertainty of effects on the landscape caused by climate change. Some climate scientists believe that modeling must play a definitive role in the transition to include climate change within the adaptive management framework (Bonan & Doney, 2018; Weaver et al., 2013). One of the drawbacks related to modeling is that models are not completely reliable concerning accuracy to real world phenomena. Model selection can be rife with error because of inappropriate model use and the reductionist number of variables in some models (Boiffin, Badeau, & Bréda, 2017; Watling, Brandt, Fish, Mazzotti, & Romañach, n.d.).

Climate change models that allow greater predictive capacity can be a major step in overcoming the hesitancy to start proactive land management projects to address the effects of climate change. Current models can assist adaptive measures that may not immediately be seen as climate related, such as habitat connectivity or fire modeling (Weaver et al., 2013).

This thesis questions whether modeling can improve the willingness of private conservation organizations to create and act on climate adaptation strategies. Private conservation organizations have more flexibility concerning what they are legally allowed to do and what they have the social license to do. The higher level of flexibility allows private conservation groups to circumvent several barriers to implementation of climate adaptation when compared to public land management agencies.  For example, city owned lands are managed under heavy political influence, compared to private land trusts. Even though cities tend to have more flexibility in their land management practices than larger administrative entities, political constraints can still cause many barriers to CCA implementation.

Land trusts are more able to experiment with the process of CCA than public organizations, lacking the political barriers inherent in implementing climate change adaptation practices.

## Climate Modeling and Barriers to CCA

Many administrative and state bodies hesitate to implement CCA, ultimately leading to an adaptation deficit. An adaptation deficit is when governments neglect to invest in climate change adaptation measures, leading to greater negative effects than if they had invested in adaptation measures (Field et al., 2014). Reducing uncertainty of decision makers regarding the potential effects of climate change can help overcome their hesitancy to act. Modeling potential effects of climate change can be extremely complex and seen as too technical to be useful for use by decision makers. The use of modeling as a method of inciting CCA implementation is complicated because it is not just the climate that is changing, it is whole ecosystems and chemical cycles that are changing (Bonan & Doney, 2018).

Weaver et al. (2013) rebukes the use of global and regional climate models as predict then act models for climate change action. Predict-then-act models predict when and where phenomena will occur, so that efforts can be made to focus time and resources in the areas that may be affected.  Weaver et al. (20313) views this kind of thinking as missing the complexity of CCA planning. By neglecting to consider sociological and contextual variables that determine how institutions and societies react, regional climate models lack essential information necessary for effective CCA. Climate models are useful for decision making but they should be used as components of scenarios that are supplemented by other inputs that together create insight into sophisticated systems. Climate models should not be perceived as being an end all for inquiry into vulnerability, exposure, and adaptation (Weaver et al., 2013).

Realizing the limits of regional climate models in enacting change and realizing the multidisciplinary nature of CCA offers a more holistic perspective to the spatial problem of predicting change. The incorporation of vulnerability models into geodesigning CCA can be very informative to decision makers. The development of models which address systems and are evaluated by scenarios for a probabilistic planning framework are at the core of geodesign. The use of these geodesign principals address some of the concerns articulated by Weaver et al. (2013) surrounding the use of models in informing planning.

Predicting the future effects of climate change has been expressed in the sciences by extensive attempts at predictive modeling (USGCRP, n.d.). Climatic drivers of local ecology are variables that are essential to assessing the impact of climate on conservation lands (Sofaer et al., 2017). Species distribution models (SDM) are used to predict the extent of species. Climatic drivers of species level occurrence have been explored using climate envelope modeling (CEM). CEM is a type of species distribution model called a correlative SDM that predicts the extent of a species (Watling, Brandt, Fish, Mazzotti, & Romañach, n.d.). Prediction of the extent of a species using a CEM is achieved by using location information of ecological and climatic variables, presence point locations and analyses variables using multiple regression statistical analysis. The output of CEMs are maps displaying areas of high to low probability of occurrence for a given species (Matthews et al., 2011). The outputs for climate envelope models represent a species' predicted current ranges or predicted future ranges within climate change scenarios. The amount of error within SDMs is often suspect especially in no analogue climates where there will be temperature/precipitation patterns unlike any other in observable history. A robust assessment framework within climate envelope modeling exists called modification factors (ModFacs) which can help overcome some of this error (Boiffin, Badeau, & Bréda, 2017).

Matthews et al. (2014) used modification factors to incorporate biological characteristics, life history factors, disturbance characteristics that address species level resistance/resilience to the effects of climate change, projected change in GCM using emissions scenarios, novel climate conditions for species, and long-distance extrapolations beyond a species' range. Their study was an attempt to identify aspects of species that will assist in their adaptation to climate change. Modification factor interpretation has high potential for creation of scenarios that correlate a large number of environmental and ecological variables instead of the projected extents produced by SDMs which use a limited number of variables. Matthews et al, (2011) addressed the assumptions of SDMs (Fig 2).

| | | |
|---|---|---|
| Unlimited dispersal Capacity | Equilibrium and environment | Biotic interactions |
| $CO_2$ effects | Unaccounted environmental variables | adaptation |
| Non-representative of disturbance | GCM projection uncertainty | Variation in SDM algorithms |

*Figure. 2 Assumptions of SDMs outlined by Matthews, Iverson, Prasad, Peters, & Rodewald, (2011)*

After observing the different variables that SDMs do not account for, SDMs appear to not be an effective "predict-then-act" tool. SDMs are a spatially exploratory tool that requires additional assessment and inquiry to confidently place current or future assisted migration of species. Modification factors (ModFacs) are a tool to make SDMs more relevant to decision makers because they have more interpretive value (Matthews, Iverson, Prasad, Peters, & Rodewald, 2011). Using probabilistic tools like ModFacs to make specific scenarios within a geodesign follows Steinetz' framework, so within this context the criticism of SDM's failing to provide direct action would be antithetical to the proposed process of this study.

NatureServe provides quantitative methods to inform climate change plans for conservation groups. Localized GCM model data for their methods and computer programs are obtained from Climate Wizard: a collaboration between University of Washington, The Nature Conservancy, and University of Southern Mississippi. Their models have recently been used in climate adaptation plans including the tools: Climate Change Vulnerability Index for Ecosystems and Habitats and Climate Change Vulnerability Index for Species. These tools have been used and evaluated by organizations such as Florida Department of Fish and Wildlife (Dubois, N., A. Caldas, J. Boshoven, and A. Delach. 2011) Pennsylvania Natural Heritage Program (a collaboration of Pennsylvania Department of Conservation and Natural Resources, Western Pennsylvania Conservancy, Pennsylvania Game Commission, and the Pennsylvania Fish and Boat Commission) , Nevada Department of Conservation and Natural Resources, The Ontario Ministry of Natural Resources and Forestry and many more.[1]Use of NatureServe tools are gaining importance to create probabilistic decision support tools for rapid deployment of climate change adaptation plans and show spatial outputs that can be incorporated into system based scenarios (Giupponi, Giove, &

[1] A list of some of the many peer reviewed journal articles and governmental reports using the NatureServe climate change vulnerability index method can be found at: http://www.natureserve.org/sites/default/files/ccvi_publication_list_june_2015.pdf

Giannini, 2013). Use of these tools shows promise for establishing process models in a climate change oriented geodesign.

**Uncertainty and Hesitancy to Act**

The level of uncertainty associated with many potential effects of climate change makes land managers and policy makers hesitate to act (Weaver et al., 2013). If decision makers choose to wait for information from climate scientists deemed acceptably robust and definitive, then their responses may not keep pace with changes on the landscape (Ekstrom & Moser, 2014). There is a need for many land managers to have data showing what effects climate change will have on the lands they are responsible, but there doesn't appear to be an accessible "predict then act" tool readily available to achieve this (Bonan & Doney, 2018).

Persons deploying climate change adaptation measures are often called experimenters (Broto & Bulkeley, 2013). The view of climate change adaptation projects being experiments results in increased scrutiny if projects fail, making some land managers even more hesitant to create new best practices for climate change.

Because of the extensive number of climate action plans that have been created there is a perception that many organizations are actively working towards adapting to climate change. This extensive planning does not necessarily translate to adaptation efforts that will successfully adapt regions to the effects of climate change (Deetjen, Conger, Leibowicz, & Webber, 2018). If land managers continue to use the wait and see approach to climate change adaptation,

adaptation measures undertaken may be ineffective (Vargas-Moreno & Flaxman, 2012).

Generalist invasive species will have an opportunity to take the place where native species decline (Brandt et al., 2016). Invasive species may not provide the ecosystem services that are expected in conservation land planning. Certain landscapes may see dramatic conversion of plant and animal communities due to the advantage inherent in generalist species. High prevalence of invasive species can reduce the perceived conservation value of lands and make them less likely to be considered for conservation acquisitions or conservation easements (Joppa & Pfaff, 2009). Conservation land acquisitions

**The Nature Conservancy Vulnerability Assessment**

The Nature Conservancy published a vulnerability assessment titled "Conserving Nature's Stage: Identifying Resilient Terrestrial Landscapes in the Pacific Northwest"[2] (Buttrick et. al, 2015). The project's main goal was similar in intent to many private conservation organizations because they wanted to be able to strategize for more successful long-term conservation outcomes within their land acquisition process. They achieved this by taking a regional approach and attempting to quantify areas that could perpetuate high biodiversity in varying climate change scenarios. The intention to quantify these landscapes was driven by the fact that The Nature Conservancy (TNC) is a private conservation-based

[2] The funding for the assessment came from the Doris Duke Charitable Foundation

land trust and is actively acquiring new trust lands (unlike many public conservation organizations). Analysis could help identify which of their trust lands are already climate resilient lands, but also strategize for which future land acquisitions can best conserve biodiversity at a local to regional scale (TNC 2015). The methodology for the assessment was spatially and environmentally based. Experts employed by TNC developed models to represent the study area based on a set of premises that were guided by a steering committee consisting of researchers and experts that could help develop and vet their methodologies. The premises are listed as follows

*"Premise #1: Geophysical features underlie the spatial distribution of biodiversity and a region's biological richness is due, in part, to its geophysical diversity.*

*Premise # 2: Topoclimate diversity and local permeability convey resilience to a landscape or site."*

(TNC 2015)

Previous regional landscape scale assessments for biodiversity used by TNC involved plant community types. Climate change is causing a shift in plant communities and novel communities of plants are likely to form, making the previously used baselines of regional biodiversity obsolete. Anderson & Ferree (2010) showed that 1) specific land facets such as calcareous bedrock, 2) latitudinal range 3) number of geologic classes, and 4) elevation can predict species diversity at an evolutionary time scale. Anderson's analysis used 23 land facet variables comparing historical and current species diversity. Linear regression of species richness and land facets were analyzed with an $R^2$ value of 0.94 for the 4 previously mentioned variables, showing that 94% of the variability around the mean of their data is explained by their linear model. The study seemed to be taken at face value to have had application for western states as well, which warrants further study seeing extreme differences in species diversity and land facets of the American east and west. Although there is no replication of the Anderson study for the American west there is no evidence that the 4 land facets presented would not be applicable to western states. The Anderson study doesn't account for the unprecedented rate of warming that is happening with current climate change, which has no analogue in 66,000,000 years. During the Paleocene-Eocene thermal maximum there was a rapid heating of the earth, but it was not as rapid as the warming event we are experiencing now (Zeebe et al., 2016). Such an unprecedented warming event could be a confounding factor when using paleoclimate data to predict future climates (Williams & Jackson, 2007).

The new system of using land facet diversity (abiotic factors of the landscape) and landscape connectivity (the landscape's ability to help or hinder movement) was assessed to show the performance of TNC land holdings and how their trust lands might be redistributed. Land facets used in this study included climate elevation, slope, and soil type.

## Barriers to Climate Adaptation

Climate modeling can be successful in predicting future terrestrial climates, but the models are dependent on the inclusion of different greenhouse gas emissions scenarios. From an adaptation and intervention standpoint, using a high emissions scenario can be more effective than using lower emissions scenarios. If there are climate adaptation efforts that are designed to respond to a dramatic shift in climate, and the climate shift is not as severe as anticipated, then the adaptation measures are successful. If climate change scenarios are underestimated and adaptation measures are adopted for lower emission scenarios then adaptation measures may represent a failure to adapt (Nakićenović & Intergovernmental Panel on Climate Change, 2000).

Planning for a more intense scenario also risks producing a counterintuitive effect. When planners choose a high emissions scenario as a standard for adaptation projects their standards can be misconstrued as preparing for the worst. By emphasizing the worst-case scenarios of climate change effects, planners may find themselves at a disadvantage when having to get buy-in on CCA projects (Jones & Preston, 2011). Lack of buy-in may lead many climate change adaptation project managers to the perception of projects being too ambitious, ungainly, expensive, or overzealous (Moser & Ekstrom, 2010).

Strong collaboration and information exchange are components of overcoming tendencies to underpredict the effects of climate change for the purposes of planning. Political and social engagement are also needed to create a successful geodesign using the framework created by Steinitz (2012). The technology of Geographic Information Systems (GIS) provides a powerful toolset that lends itself to collaboration and public engagement. GIS is used to make maps. Maps are a strong visual artifact, that can portray complex information in an easily consumable and communicative information product. Maps are easily consumed source of information which many people intuitively understand. The broad literacy of maps can encourage the participation of experts alongside non-experts to communicate complex information in a way that is more accessible than normal statistical outputs (Obermeyer 1998).

Maps increase accessibility of plans, data, and other CCA related information. The accessibility of information in maps can contribute to a more democratic decision-making process. Geographic Information Systems computing technology allows for collaborative use of spatial statistics, qualitative, and quantitative data. The discipline of GIS allows CCA planners to create maps that are potentially highly informative and relevant to wide ranging diversity of expertise within an organization. By collaborating across an organization effectively, CCA planners may make more effective designs.

**Theory in Practice: Adaptation in California**

The following case study uses a systematic procedure to evaluate barriers to climate change adaptation. Once Moser and Ekstrom developed their "architecture" for overcoming barriers to climate change adaptation they conducted a study at varying levels of city, county, and state governments in the state of California. The goal of their study was to evaluate where barriers reside in proposed climate adaptation efforts. The range of CCA projects included the themes of sea level rise, water conservation, and flood prevention (Moser & Ekstrom, 2010). The largest barrier across all levels of government was identified as institutional government issues, broken down into:

1. legal barriers
2. jurisdictional responsibility
3. attitudes/values/motivations
4. resources/funding

(Ekstrom & Moser 2014). It should be noted that the study was performed in areas of California containing with the highest rates of affluence in the country.

A formal framework may be useful for identifying the barriers to implementing adaptation projects. Geodesign teams that are implementing climate adaptation projects. Collaborators don't have to develop their own decision models from scratch. Allowing geodesign methods to quantify barriers may reduce contention over decision models, which can be a contentious part of the geodesign process and being able to quantify barriers may lead to decision models that recognize fewer perceived barriers and more actual barriers

Some municipalities in the study were found to have certain attributes that fostered the removal of barriers to adaptation. These attributes were described as having:

1. existing climate action plans with ongoing work in climate mitigation
2. ongoing work in sustainability
3. extant scientific knowledge
4. scientific capacity for adaptation projects
5. leaders that are focused on regional prosperity
6. having good timing in addressing climate adaptation regarding the cycle of upgrading specific municipal infrastructure

(Ekstrom & Moser 2014). Most of the actions taken to overcome barriers to climate adaptation implementation involved restructuring local policy, planning, and management. More specifically these actions took place in the form of coalition building, altering development planning, and improving risk assessment requirements (Ekstrom & Moser 2014). The proposed changes were viewed by interviewees as small steps towards changing attitudes of agencies and spreading awareness of the need for adaptation at the local level.

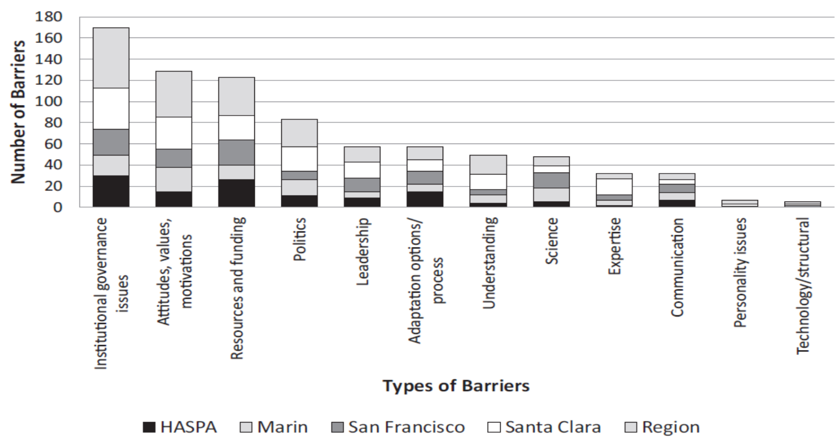


*Figure. 5 Frequency of barriers involved with implementing climate change adaptation of 4 separate case studies within northern California (Ekstrom & Moser, 2014).*

*Figure Credit:Ekstrom, J. A., & Moser, S. C. (2014). Identifying and overcoming barriers in urban climate adaptation: Case study findings from the San Francisco Bay Area, California, USA.* Urban Climate, 9, *54–74. https://doi.org/10.1016/j.uclim.2014.06.002*

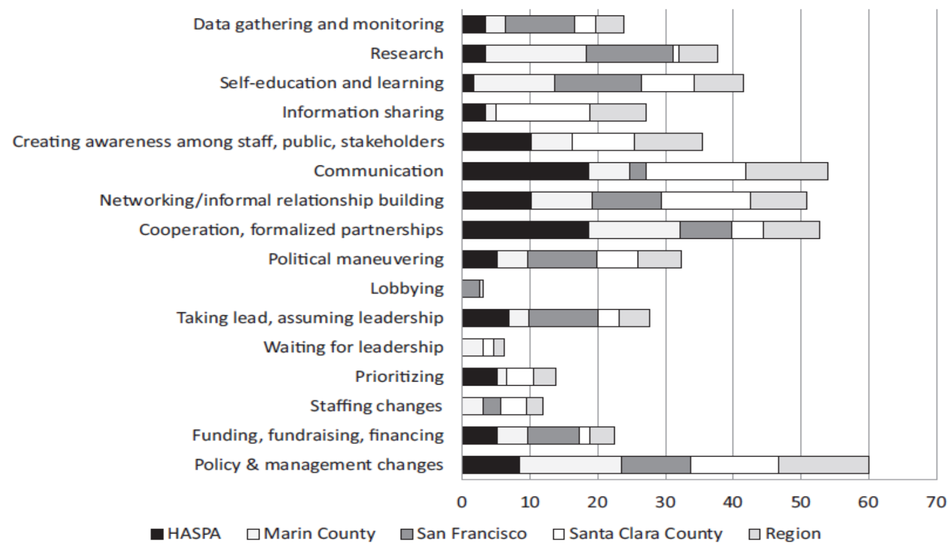


**Fig. 9.** Strategies used to overcome adaptation barriers.

*Figure. 6 Frequency of strategies used to overcome barriers to climate change adaptation in 4 separate case studies within northern Califonia (Ekstrom & Moser, 2014).*

*Figure Credit: Ekstrom, J. A., & Moser, S. C. (2014). Identifying and overcoming barriers in urban climate adaptation: Case study findings from the San Francisco Bay Area, California, USA. Urban Climate, 9, 54–74.* https://doi.org/10.1016/j.uclim.2014.06.002

### Treadmill of Production and Growth Obsession Barrier

The term "treadmill of production" describes economies that are continually focused on increasing economic growth. The cost of that growth may cause continual, irreversible, and unsustainable damage to the environment (Curran 2017).

When a governmental or non-governmental organization's driving goal is continual economic growth, a barrier arises which limits initiatives considered counterproductive to growth (Moser & Ekstrom, 2010). The expansion of green infrastructure and conservation lands are two initiatives that appear fiscally expensive and limiting to potential development. If the only measure of an initiative is its potential to contribute to growth, then there is an obvious barrier for the implementation of that initiative termed “the growth obsession barrier” (Kabisch et al, 2017). Organizations and public entities commonly have a continual plan for growth even when they are in a financial or demographic recession.

Kabisch and Haase (2013) found that between 2000 and 2006, western and southern European countries were growing economically, and their green infrastructure grew with them. At the same time in Eastern Europe, their economies, population, and green infrastructure were shrinking. Even in areas of decline, the focus of growth was on development of areas that might bring in jobs or attract investment. As a result, urban forests were made to be less emphasized in city planning (Kabisch et al, 2017). This example outlines how traditional ideas of continual growth only make publicly owned lands more susceptible to climate change through the growth obsession barrier. The same example illustrates the importance of maintaining privately conserved lands that are more resistant to the negative effects of the growth obsession barrier. It is because of the growth obsession barrier that it is risky to rely solely on public entities to maintain ecosystem services. Strategic climate conscious private conservation is a vital necessity to maintain ecosystem services within the wildland urban interface.

**Putting Principles into Action**

There has been a big push within the western United States to develop climate adaptation planning that benefits forestry. However, many of the resources that are being developed for land managers are not being utilized on the ground. Land managers have a vital need for a framework to address climate adaptation issues with actionable procedures, but many managers are not familiar with adaptation strategies or CCA information resources (Janowiak et al., 2014). The Climate Change Response Framework (CCRF)[3] is currently being used by private, public, and tribal natural land managers to influence their land management decisions in the face of climate change. This framework is a component that could be very informative for creating change models for conservation based geodesign projects within heavily forested lands. The documentation from the USFS for the CCRF includes a 6-stage planning framework that shows some resemblance to Steinitz' framework for geodesign but lacks the incorporation of stakeholder input, systems thinking, predictive planning, process models, and impact models.

[3] The CCRF was created through a partnership between the United States Forest Service, the United States Department of Agriculture, American Forests, and the Northern Institute of Applied Climate Science.

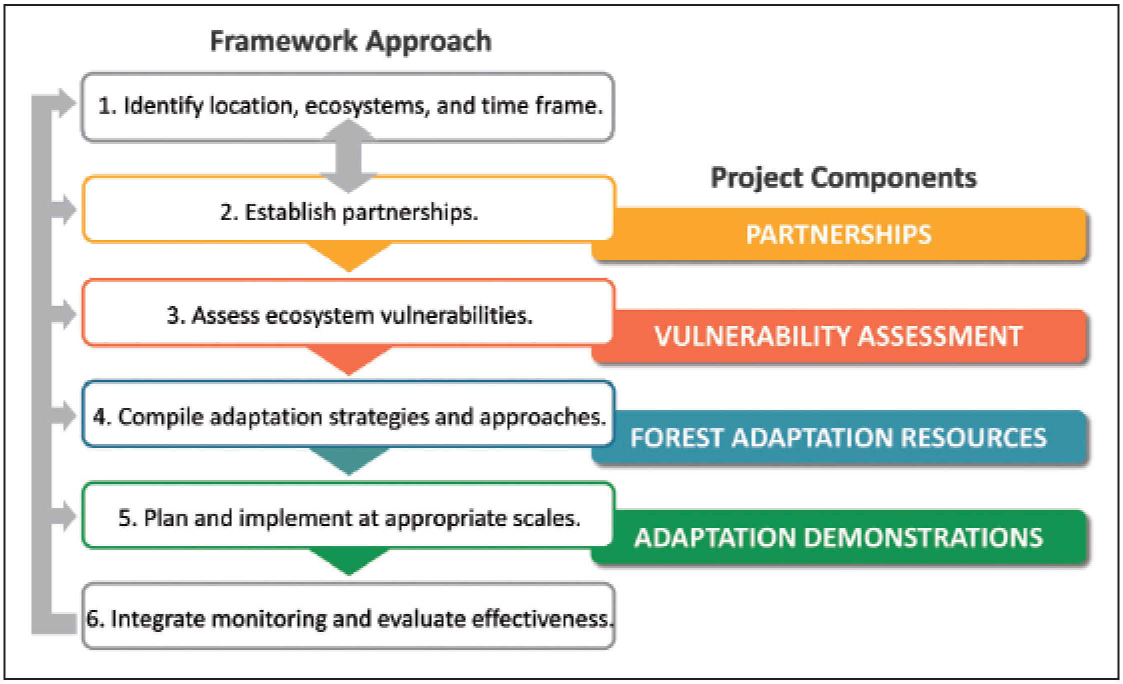


*Figure. 3 Climate change aadaptation framework for land managers United States Forest Service (Swanston et al., 2016)*

*Figure Credit: Swanston, C. W., Janowiak, M. K., Brandt, L. A., Butler, P. R., Handler, S. D., Shannon, P. D., … Darling, L. (2016). Forest Adaptation Resources: climate change tools and approaches for land managers. 2nd ed. (No. NRS-GTR-87-2). https://doi.org/10.2737/NRS-GTR-87-2*

Strategy 1: Sustain Fundamental Ecological Functions

Strategy 2: Reduce the impact of existing biological stressors

Strategy 3: Protect forests from fire and extreme wind disturbance.

Strategy 4: Maintain or enhance Refugia.

Strategy 5: Maintain and enhance species and structural diversity.

Strategy 6: Increase ecosystem redundancy across the landscape.

Strategy 7: Promote landscape connectivity.

Strategy 8: Enhance genetic diversity.

Strategy 9: Facilitate community adjustments through species transitions.

Strategy 10: Plan for and respond to disturbance.

*(See Butler et al (2012) for complete descriptions)*

*Summarized from* (Janowiak et al., 2014)

*Figure. 4 List of adaptation strategies summarized in the CCRF from a more comprehensive list by Butler et al., (2012) (Janowiak et al., 2014).*

*Figure Credit: Janowiak, M. K., Swanston, C. W., Nagel, L. M., Brandt, L. A., Butler, P. R., Handler, S. D., … Peters, M. P. (2014). A Practical Approach for Translating Climate Change Adaptation Principles into Forest Management Actions. Journal of Forestry, 112(5), 424–433. https://doi.org/10.5849/jof.13-094*

## Adaptation by Stealth

Sometimes barriers to adaptation may originate from widespread stigma/denial of climate change or negative connotations with climate adaptation (Di Giulio, Bedran-Martins, Vasconcellos, Ribeiro, & Lemos, 2018). One method in which managers may overcome the barriers to ecosystem-based climate change adaptation is through implementing CCA projects without using the conspicuous label of “adaptation” on the project. This process is known as “adaptation by stealth” (Di Giulio et al., 2018). For example, climate adaptation can be disguised as the normal operation of an institution or municipality and circumvent specific political or social pushback. Implementing CCA when organizations are in the process of upgrading or replacing aging infrastructure is an opportune time to take the approach of adaptation by stealth. The immediate result may have positive effects, but it may neglect the equity of the benefits of the design because of the exclusion of stakeholders from the review/decision process.

The process of urban gentrification provides an example of exclusion of stakeholders. When many urban areas become gentrified due to green infrastructure improvements, the residents may end up being effectively priced out of the area. Another result of adaptation by stealth may be a newfound distrust in the designers or the institution they are working for because of a feeling of voicelessness within key decisions. Feelings of disenfranchisement may happen when major infrastructure projects are built in neighborhoods without the input or consent of the people that are directly affected by the project (Keir, Watts, & Inwood, 2014).

The disenfranchisement of key demographics has been a problem within the geodesign planning process when decisions are made concerning which stakeholders are deemed worthy for collaboration. Sometimes the legitimacy of the decision of who is chosen to make key decisions has been suspect (Crampton, Huntley, & Kaufman, 2017). However, there are success stories within geodesign where collaboration happens successfully at the community level. One success story is the conservation efforts of the Jane Goodall Institute in the creation of the Lake Tanganyika Catchment Reforestation and Education project. By using collaboratively hand drawn maps to create chimpanzee preserves, communities in the Lake Tanganyika Basin have maintained access to natural resources and economically important ecotourism. (Alin et al., 2002)

**Community Buy-In**

The expansion of natural lands in the wildland urban interface (WUI) is sometimes referred to as soft infrastructure and is more socially acceptable approach to climate adaptation than the creation of hard infrastructure. Hard infrastructure (manmade physical infrastructure ex. roads, dykes, etc.) has more negative connotations because it is seen as expensive and technocratic (ex. the Thames Barrier that protects London from storm surges). A socially based pushback that could arise in implementing soft infrastructure as an ecosystem-based CCA approach is the change in character of the forest. Pushback caused by changing the character of existing forests can come from using climate adapted trees that may have a different historical, aesthetic, or spiritual context than the trees they are replacing. Communities may even protest the removal of trees that are being replaced by less vulnerable trees such as the protest over the removal of eucalyptus in the San Francisco Bay area by the Sierra Club in 2015 (Rohrs 2015). This sentiment typically fades with time into a general acceptance of the new character of an area (Chu 2017). In future ecosystem-based adaptation (EbA) projects, trees of high cultural value should be included in plant inventories so that they may be protected from removal and considered for vulnerability assessments. This may increase social acceptance of EbA projects.

**CCA Failure in the Megacity of Sao Paulo, Brazil**

Focusing on conspicuous failures concerning climate change adaptation projects can give us an idea of what ***not to do*** in CCA planning methodologies concerning collaboration, politics, scale and participatory structure. A real-world example of a failed green infrastructure project is in Sao Paulo, Brazil. Green infrastructure was a component of the Department of Urban Development's (SMDU) 10-year master plan established in 2014, enacted by Mayor Fernando Haddad (Haddad et al., 2014). At the time it was implemented, Sao Paulo's new plan was hailed as a leader in sustainable infrastructure planning (Di Giulio et al., 2018). Their plan includes many sustainability goals, but many of their plans including their green infrastructure projects never came to fruition, owing to many barriers. The barriers to implementing their green infrastructure plans include "political disputes, successive leadership changes, as well as pressures from the private housing market" (Di Giulio et al., 2018). Problems implementing the proposed climate adaptation goals of their master plan in general include: disconnections among sectoral policies, sectoral siloing of knowledge, lack of definition of responsibilities, competencies, and priorities in terms of investments (Di Giulio et al., 2018). Problems and barriers within adaptation planning occur at a scale dependent level. At the local level, "political will, risk perception, power and influence of social groups, social capital, economic resources, and technical capacity" (Di Giulio et al., 2018) were the driving forces to failure to implement their green infrastructure plans.

The entities that carry out infrastructure improvements also may have a collective culture that prohibits change in specific directions. Departments within the city of Sao Paulo may also be in a culture of maintaining a status quo. Within the political realm reinforcement of the status quo can be manifested by policymakers executing politically framed decisions that do not bring into account available data and opinion, but rather make politically advantageous decisions that may not effectively address the problem (Kato & Ahern, 2008).

To combat sectorial pushback to change there must be interagency cooperation and planning, with clear “on the ground” work rather than vague resolutions that are the result of simply planning with no intention of implementing a plan (Zolch 2018). Collaborative reform can be seen in projects accomplished by landscape research cooperatives, intergovernmental organizations, and private conservation groups such as the Nature Conservancy who has been a firm advocate for private conservation organizations to be strong advocates for addressing climate change. By addressing barriers to climate change adaptation, learning from success stories in CCA as well as failures, collaborators can build from that information to incorporate it into a geodesign for CCA and create well informed decision models to address the scope, methods, and implementation of the project.

| General Setbacks | Local Setbacks | Mid-Level Setbacks |
|---|---|---|
| political disputes<br>successive leadership changes<br>pressures from the private housing market | political will<br>risk perception<br>power and influence of social groups<br>social capital<br>economic resources<br>technical capacity<br>maintenance of status quo | Disconnections among sectoral policies<br>sectoral siloing of knowledge<br>lack of definition of responsibilities<br>competencies<br>priorities in terms of investments |

*Figure. 5 Setbacks found by Di Giulio et al. (2014) in implementing climate change adaptation measures in Sao Paulo Brazil's 2009 strategic master plan.*

# Methods

Capitol Land Trust (CLT) is a conservation-based land trust serving Southwest Washington state. The lands they conserve include fee-simple properties owned by the trust, as well as conservation easements. CLT conserves over 6,000 acres on over 77 properties. Preserves consist of marine shorelines, prairies, rivers, forests, woodlands, farms, ranches and timberlands. All of their lands will be affected by climate change. At the start of this thesis CLT had not performed CCA planning. Four members of the Lands Committee at CLT (which oversees land acquisition, land management, and public access lands) showed interest in doing climate adaptation planning via a geodesign as part of my thesis for the Master of Environmental Studies program at the Evergreen State College. Geodesign meetings occurred 3 times for a duration of approximately 3 hours. The following are the methods for the entire geodesign, not to be confused with the "methodology phase" of the geodesign (described later).

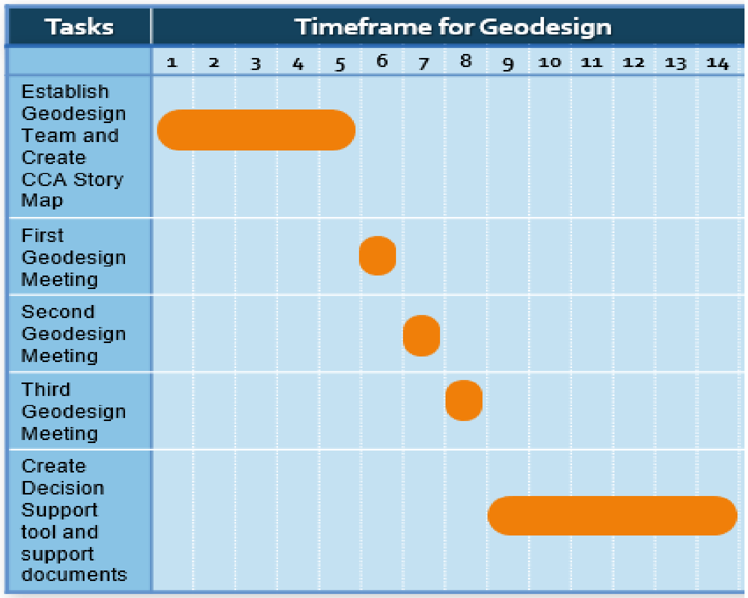


*Figure 6. An estimated timeframe for a geodesign based on the methodology suggested in this thesis.*

## A Collaboration of Whom?

The members of CLT's lands committee, several CLT staff and me (K. Albert McConathy) as the technical facilitator were the core of the geodesign team.

The geodesign (GD) project requirements were developed by CLT's experts and other stakeholders. I asked the group to identify the roles in the geodesign. I would be the facilitator and GIS expert and 4 other members/I would constitute the geodesign team. The stakeholder group that we would be beholden to was identified as the CLT board and the executive director.

The GD team began by evaluating predictions of climate change impacts on CLT lands and developing new climate informed procedures for land management and acquisition. Evaluation of potential risks, impacts, and improvements were used in developing products informing land management and land acquisition for CLT owned lands as well as strategies that CLT could develop for climate change adaptation. The results of the geodesign team were presented to the CLT board as a presentation and a document outlining recommendations for the 2020 CLT strategic plan. The recommendations were informed by an ArcGIS Online story map showing outside resources and localized effects of climate change on CLT lands. The story map was presented before the geodesign to describe the study area within the context of climate change related processes on CLT lands (represented in appendix A.). Climate change projections in the story map predict future effects and the story map was intended as a tool to help inform probabilistic decision making of future events. Geodesign attempts to be decision-driven rather than data-driven. The use of climate change data and process data were a necessity for this project in the scoping process. The use of the story map as an informational background tool was affirmed to comply with the geodesign framework by a colleague of Carl Steinitz (Hrishikesh Ballal March 2018) via a private skype conversation.

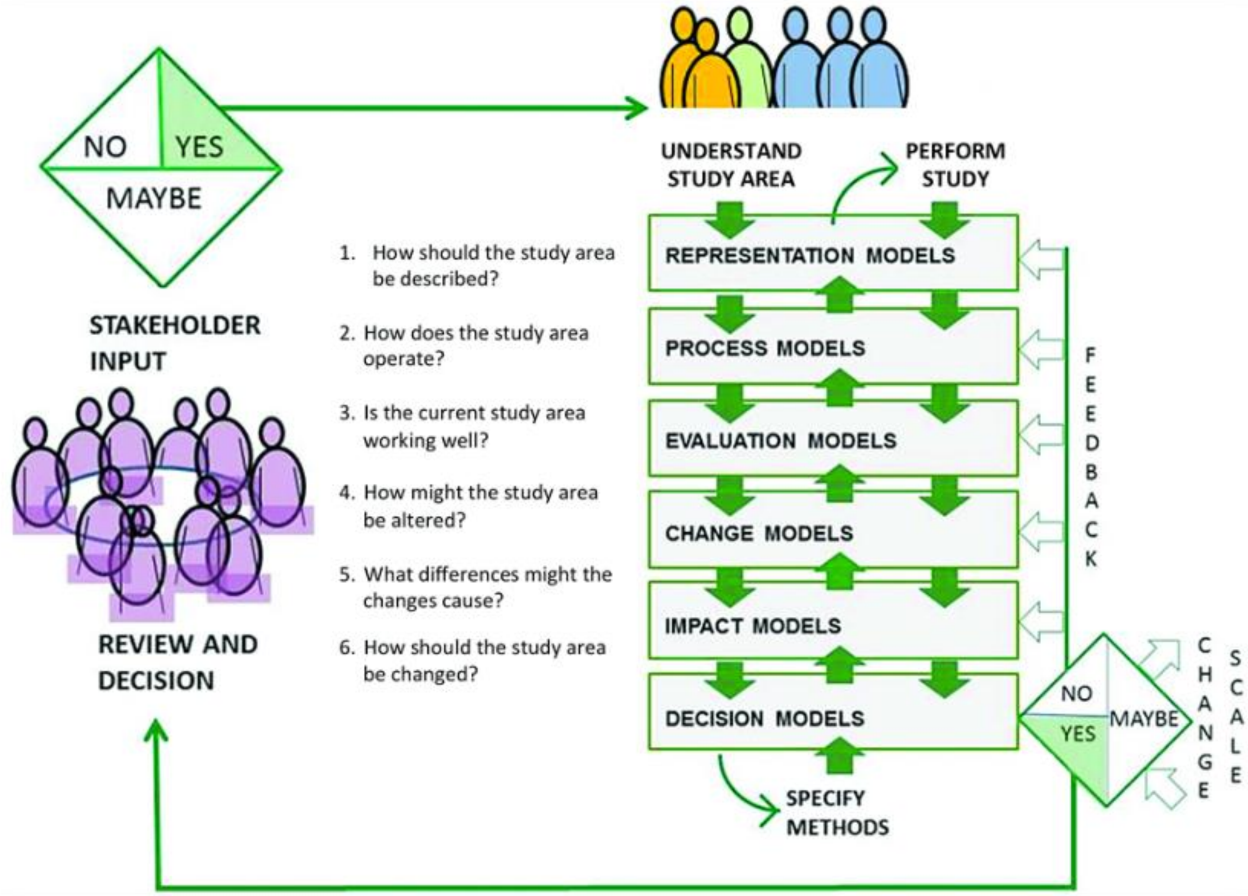


*Figure. 7 Diagram of the steps used in Stenitz's geodesign framework (Steinitz,2012) A Framework For Geodesign*

*Figure Credit: Steinitz, C. (2012). A framework for geodesign: changing geography by design; [the people of the place, design professions, geographic sciences, information technologies] (1. ed). Redlands, Calif: Esri Press.*

## Phases of the Geodesign

The geodesign team first establishes a problem question that the project endeavors to address. The problem question focuses participants in the geodesign around subjects and elements that the organization wishes to change.

To identify the geographic problem that would be addressed by the geodesign I first asked the CLT GD team: "What is our problem statement?"

There are three phases of the geodesign process:

- First: scoping phase
- Second: methodology phase
- Third: implementation phase

Each phase operates by asking a series of questions (fig.8) that inform each other often in a nonlinear manner but are asked in sequence to the geodesign team. To answer each question, models are created by answering sub questions. These models are informed by local knowledge, quantitative and qualitative data, knowledge of the organization, and personal expertise. The complexity of the models is decided by the participants involved. In the case of this study models were quite simple, consisting mostly of:

- potential changes and impacts to trust lands
- knowledge gaps
- potential considerations for future land acquisitions

The first phase of the project begins when the questions are all answered by the 6 separate models in order 1-6. During the successive methods and implementation phases the questions are asked in reverse order to reinforce decision based, but data informed geodesign (Steinitz 2012) (Fig. 8). Before starting the geodesign I asked a series of questions to the CLT Lands Committee as a starting point for developing the sub-questions that inform the models for the initial scoping process: based off of Carl Steinitz's work "A Framework For Geodesign" (Steinitz 2012). Only after this process is done can the methodology phase begin. The implementation stage of a geodesign project is the most important but is beyond the scope of this thesis. Implementation is a lengthy process that is subject to decisions from the staff, board of directors, and executive director of Capitol Land Trust which does not conform to the time restrictions of this thesis.

**Story map**

Before starting the geodesign a story map (shown in appendix A) was used to inform the geodesign team and the CLT board (the stakeholders) about the localized modeled effects of climate change. The story map was designed to fill a knowledge gap in the geodesign team. The knowledge gap was made apparent in my preliminary interest-scoping performed prior to starting the geodesign. The goal of the story map was to show the potential effects of climate change to CLT owned lands[4]. The story map incorporated maps and apps, including localized variables such as

1.) modeled percent change of temperature and precipitation for A2 and A1B midcentury climate projections (downscaled Climate Wizard data)

2.) Foot interval inundation of sea level rise (NOAA sea level rise data)

3.) Geomorphological change affecting land subsidence in the region (UW Climate Impacts Group) 3). King tide and flooding extents (FEMA flooding data)

4.) Microclimates based on aspect (USGS DEM data). Still images of the story map are included in Appendix A.

By using scientifically rigorous sources, the story map was presented with the intention of establishing a common awareness of climate related processes for the geodesign team concerning the potential effects of climate change for the area of study. Story map data consisted of projected effects of climate change at a regional scale that could inform locally oriented decision making.

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[4] Conservation easements were not included in this study due to privacy concerns protecting the owners of the easement lands and legal agreements with CLT.

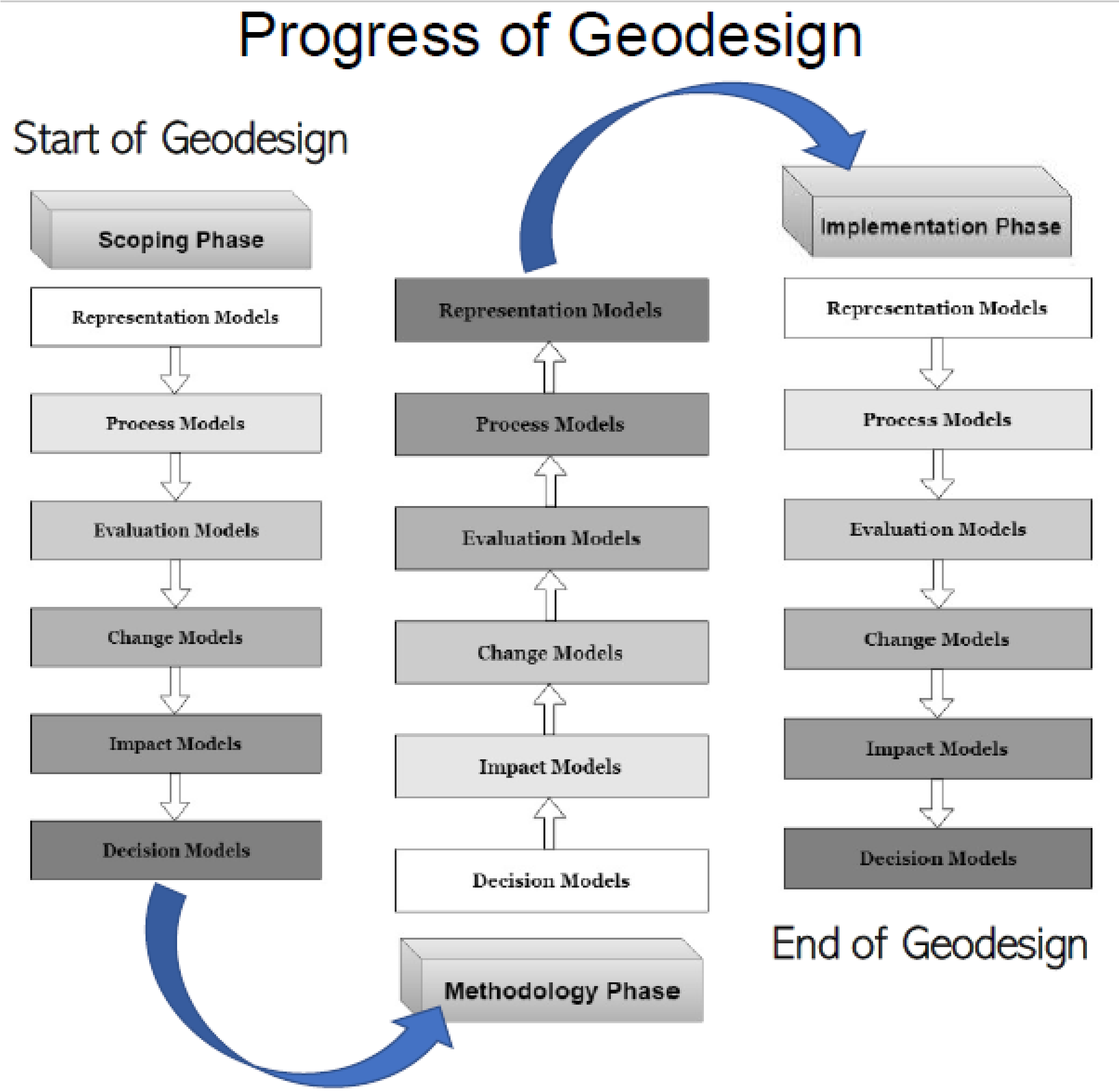


*Figure 8.* *Progress of geodesign by going through the three phases, starting with: 1) Scoping Phase 2) Methodology Phase 3) Implementation Phase. Each phase is informed by models of the previous phase.*

## Starting the Geodesign

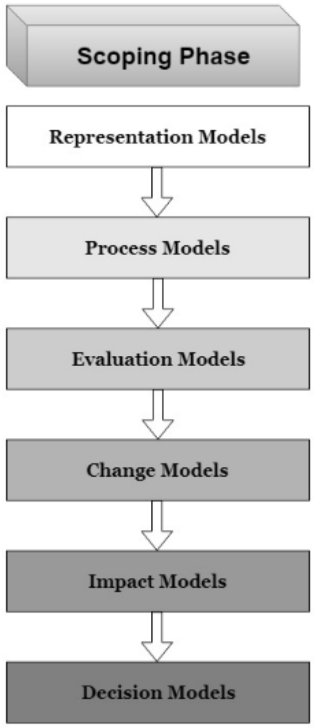


*Figure. 9 Beginning the scoping phase of the geodesign.*

*Question 1*

By following the 6-question based geodesign framework designed by Carl Steinitz we start with the first question: "How should the study area be described?" Another way of defining the study area is to catalog the ecological, physical, economic and social geography/histories of the study area. This question is generally answered by *representation models*, by using a geographic database, expert knowledge, and local knowledge.

*Question 2*

The next question in the framework: "How does the study area operate?" is answered by process models. Questions asked to address the models included: "What are the major processes affecting properties?" Emphasis was given to climate change related processes affecting the properties.

*Question 3*

The third question asks: "Is the current study area working well?". Questions asked to provide evaluation models included: "What properties are attractive for change/planning and which ones are vulnerable to change/planning?” Examples were given for attractiveness, vulnerability, and problems such as:

- Attractiveness for adaptation measures
- Vulnerability to climate impacts
- Problems including environmental, legal, etc.

The CLT GD project focuses on assessing whether the study area will be working well in the future. By asking about the past and present state of the study area, we can also assess whether an area is currently improving or declining in its main functions. Some changes were immediately apparent and readily happening, but some changes were informed by seeing them spatially via the story map.

*Question 4*

The Fourth question asks: “How might the study area be altered?”. The main question that was asked to provide the change models was: “What are the perceived effects of change?” Examples of potential changes of the study area include:

- Growth
- Decline
- Conservation
- Ecology
- Institutional pressure
- Degraded ecosystems

*Question 5*

**“**What differences might the changes cause?”

The answers to this question are informed by Impact models and impact assessments. Questions asked address topics such as:

- Potential consequences, costs, benefits, resulting from change

- Variables to be considered in assessing impacts for our study area to successfully adapt to climate change
- Severity and likelihood of the impacts
- Whether the impacts are irreversible.

*Question 6*

The question “How should the study area be changed?” Is answered by decision models. The main statement used to create models: Evaluate relative importance of consequences and other concerns that the board might find important that we have not already addressed.

**Scenarios**

When disagreements arise concerning specific goals or requirements, the creation of multiple “scenarios” elucidates potential steps to achieve alternate futures. Through creating different options for the decision makers to choose from the geodesign team devises a potential plan that appeases the largest number of stakeholders involved and can resolve conflicts within the geodesign group. Scenarios explored potential future outcomes based around areas of disagreement to narrow the focus of the scope, but with the requirements of the board in mind. Requirements that may be important to the board were assessed on a Likert scale from 1-5, with the value 1 to indicate no importance and the value 5 to indicate highest importance.

When all these questions were asked to the geodesign team, they were then revisited in reverse order to develop the methodology phase of the geodesign.

**Methodology Phase**

Question 6:

The question "How should the study area be changed?" Is answered by decision models. The CLT GD team assessed knowledge gaps that would need to be addressed before making further decisions. Information standards of decision makers were also assessed.

Question 5: What differences might the changes cause?

Impact models required by decision makers were established as well as their complexity.

*Question 4: How might the study area be altered?*

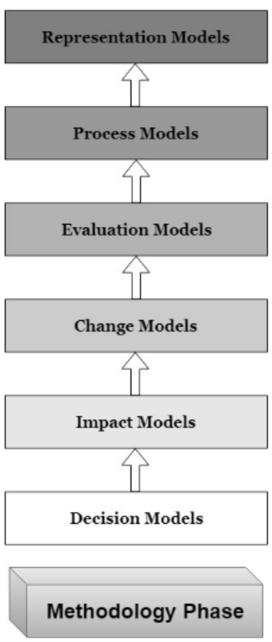


*Figure. 10 beginning the methodology phase of the geodesign*

The Vision, strategy, tactics, and actions were developed

*Question 3: Is the current study area working well?*

Changes that should and shouldn't happen were assessed as well as the nested scales of change, including site, location and administrative scales. The questions: 1.) What changes are important to evaluate? 2.) How are they important to evaluate? 3.) How important are they to evaluate? were asked.

*Question 2: How does the are operate?*

What data is required for the geodesign study and how will it be represented?

What models will be used?

What level of model complexity is appropriate?

What process models are beyond our expertise?

What spatial or time scales do we measure processes and how do we represent them?

*Question 1: How is the study area described*

What is the minimum amount of data required?

How will the data be visualized?

Create a data needs list.

Vote on what data needs are necessary.

**Streamlining Process**

The geodesign eventually lost momentum towards the end of the methodology phase because of the complexity of the interrelatedness of questions. Questions were not clear in how they should inform each other, and a streamlining of the process was devised. I took all of the main elements of the models that were created and compiled them into a PowerPoint that was presented to the group. The PowerPoint is represented in appendix B. The geodesign team then gave feedback regarding the streamlining presentation and next steps were discussed.

**Geodesign Feedback**

After the streamlining meeting we convened again to get feedback about the geodesign process as well as the decision support tool. I called participants individually and discussed takeaways from the geodesign process. Potential improvements to the process, participant's views on the preliminary story map, and what materials would be effective as a presentation to the board were discussed.

# Results

This section of results is comprised of two main sections:

First: The CLT geodesign team's answers from the questions asked in the geodesign.

Second: The presentation and feedback that occurred for the geodesign streamlining process.

## CLT Geodesign Answers

The geodesign team described their problem statement as follows:

*Given a changing climate and changing ecosystems, how will acquisition and management, (including restoration) change [for Capitol Land Trust]?*

The roles in designing change were identified by the GD team as the different portions of the organization that will be involved with the changes addressed by the geodesign team. These groups included:

- The acquisition team
- The lands committee
- The restoration team
- Outside experts

The design was ultimately seen as an exploration of alternatives rather than a tool for specific organizational change.

What issues and decisions are most likely to change the geographic context for the better? The answers to this question included a list of potential actions.

1.) Increase biodiversity to increase climate resilience.

2.) Identify and manage risk elements related to climate change.

3.) Address the increasing threat of fires and floods to CLT lands and their risks to personal safety

4.) Know how climate change may damage future structures (know where not to build)

5.) Where land is experiencing more drought stress, make plantings of drought tolerant plants.

6.) Understand species level reactions to climate change.

7.) Source climate tolerant seed.

8.) Employ cultural practices to improve the landscape, ex. mushroom compost, mulching, site prep, etc.

9.) Employ corridors for plants and animals to migrate as the climate changes and improve resilience of preserves.

The list above represents a significant finding for CLT. The organization has never produced a written list of actions to respond to climate change, and this list is a baseline for future climate change adaptation procedures.

*Question 1.*

*How is the study area described?*

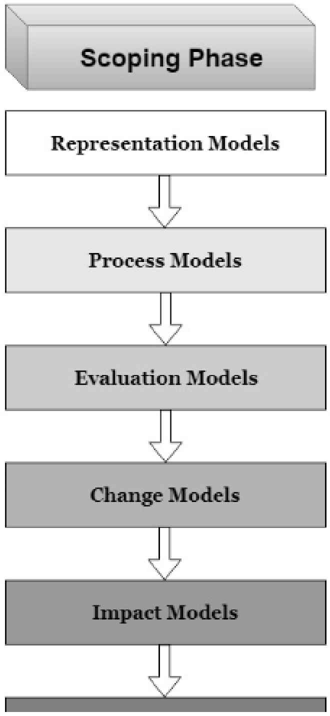


*Figure. 11 The scoping phase of the geodesign.*

During the preliminary scoping process done before the geodesign process, the lands committee and the restoration team's members wanted to focus on selected properties that were perceived as high priority from having active projects. The selected properties which they initially identified were mostly coastal. Some properties contained salmon bearing streams that are associated with salmon habitat restoration related grant funding.

Lands that were not owned by CLT (but which had a land easement) were ignored during the geodesign due to complications including unique legal wording of each easement and privacy concerns of easement holders. Some members of the Lands Committee wanted to first know what properties would be impacted the most from climate change to then narrow the focus of the future geodesign based off potential impacts and risks. Variables related to potential risks/impacts were important data requirements for lands committee members so that they could show due diligence to the board in their potential planning duties.

Before the geodesign, research into climate change had been done by the lands committee to have a climate informed decision-making process. Material was disseminated within the group from authoritative sources such as the Puget

Sound State of Knowledge Report from the Climate Impacts Group based at the University of Washington (2015). Since CLT is implementing a new 4-year strategy in 2020, the geodesign team determined that an emphasis on the entire service area would be appropriate for elements such as acquisition planning. The majority of the geodesign ended up discussing models related to service area level instead of specific properties. The CLD GD team also established that focusing on the extent of properties with high investment in restoration and work hours was a priority. These properties included the newly opened public access preserves and the highly anticipated "Inspiring Kids Preserve" (IKP).

*Question 2.*

*How does the study area operate?*

Major processes were described as the following:

| | | | |
|---|---|---|---|
| Microclimates | Potential Precipitation | Actual Precipitation | Extreme Weather Events |
| Wind | Evapotranspiration | Water table | Pest Outbreaks |
| Solar radiation | Drainage | salt water intrusion | Pathogens |
| Increased Regional Development | Fire | | |

*Figure. 12 major processes described by the geodesign team in the scoping phase.*

Many of the processes presented were concerns of the geodesign team, given the potential negative effects of climate change in the region.

Microclimates were seen as important features of properties that can buffer against the effects of a changing climate and act as refugia for plants and animals that would otherwise perish in a new climate.

Wind was seen as a concern because windfall from trees may become more prevalent due to tree death and weakened root systems caused by drought stress and increased prevalence of tree pathogens.

Solar radiation on CLT lands was a concern as it effects many systems including evapotranspiration of soils, stream temperature, UV stress on plants as well as many other effects.

Increased development was seen as a problem for the service area as it reduces the potential future conservation sites that CLT can acquire and can potentially increase land value, making the remaining property more expensive to acquire.

Precipitation and changes in precipitation were seen as a concern because of the projected decrease in summer precipitation with an increase in other seasons, causing problems with flooding, and longer, more intense summer droughts.

Changes in the water table were seen as a relevant process concerning climate change because of the stress on water resources, shifts in water table from drought, and sea level rise. This spurred the concern of salt water intrusion which could kill off salt intolerant plant species.

Extreme weather events were a concern including wind storms, heavy rain events, and snowstorms.

The outbreak of generalist and opportunistic pest species was a concern for plant and animal life as well as widespread sudden prevalence of pathogens especially tree pathogens.

*Question 3.*

*Is the current study area working well?*

Elements of the study area were described as 1) attractive to change 2) vulnerable to change 3) problems (Figure. 13). The responses to the three categories are detailed in the following table.

| Change Models Proposed in CLT Geodesign Scoping Process | | |
|---|---|---|
| Attractive to change | Vulnerable to change | Problems |
| • Potential carbon storage in expanding marshes<br>• Potential ecological benefits from naturalized plants<br>• Outplanting experiments as seed source for assisted migration (potential for collaboration)<br>• Assisted Migration of Oregon Spotted Frog (potential for collaboration)<br>• Establishing new riparian corridors<br>• Assisting the winners of climate change | • Increased drought and its stress on multiple systems.<br>• Decrease of beneficial insects<br>• Effects of drought on water table<br>• Increasing development/land prices (less potential for land acquisitions)<br>• Soil disturbance from restoration projects (increase in invasive species) | • What risk elements can we mitigate and what can we adapt to?<br>• Potential legacy hazards from land acquisitions (pollution)<br>• Some policies do not have accompanying written procedures for implementation. For CCA to be implemented in policies procedures should be proposed. |

*Figure. 13 Change models proposed by geodesign scoping process. The change models are seperated into three separate catagories. 1) Processes where changes can cause benefits to the systems within the study area (attractive to change). 2) Processes where changes may cause negative effects to the systems within the study area (vulnerable to change). 3) Problems that may prevent or complicate potential changes.*

*Question 4.)*

*How might the study area be altered?*

1.) Riparian corridors were acknowledged as having the least potential for development and high potential for connectivity. Maintaining riparian corridors was seen as an effective method for increasing the capacity of organisms to migrate to more habitable climates under climate change scenarios.

2.) Increased conservation was seen as a net benefit for regional climate resilience by buffering some of the negative effects of climate change. Highly vegetated areas can produce a cool island effect, increased water retention, foster microclimates that may act as refugia for sensitive species and provide other essential ecosystem services that buffer effects of climate change.

3.) Increased interorganizational collaboration between CLT and universities, land trusts, agencies, and other local groups will help CLT better tackle emerging challenges related to climate change.

4.) High uncertainty surrounding the effects of climate change makes changes difficult to predict and then act upon, making the evaluation of the perceived change unreliable.

5.) Potential for political change could have a benefit for conservation due to increased land use restrictions. Restrictions regarding developable area will increase overall conservation of the area.

*Question 5.)*

*What differences might the changes cause?*

Some of the change models were assessed for impacts, risk, and probability of occurrence (Figure. 14).

| | Probability of occurrence | Risk involved with occurrence | Impact involved with occurrence |
|---|---|---|---|
| Water from snow melt decreasing | High | High | High |
| Population Increase (increased land development) | High | High | High |
| Increasing Land Value | High | High | High |
| Risk of increased development of dams | Medium | Low | High |

*Figure. 14 Impact models created in geodesign's scoping process*.

*Question 6.)*

*How should the study area be altered?*

Models were somewhat influenced by what the CLT GD team perceived to be relevant and necessary by the board, the interests of stakeholders and the land trust in general.

Several members of the lands committee are board members or are familiar with the board. These members allow the scoping of the potential outcomes to have a higher likelihood of being compatible with the priorities of the CLT board.

The following flow charts (Figure. 15, Figure. 16, Figure. 17, Figure. 18, Figure. 19) represent changes that were seen as actions that should be taken to increase resilience of Capitol Land Trust lands. Their potential futures/outcomes were explored in the flow charts as a part of the decision model.

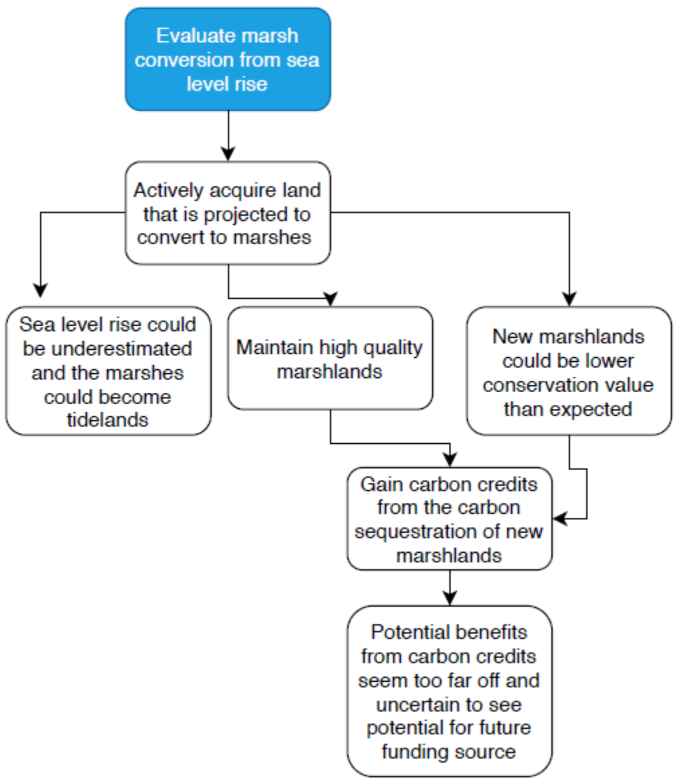


*Figure. 15 Potential futures of marsh conversion (scoping phase). This flow chart reflects the positive value that the CLD GD group attributed to marsh conversion. Marsh conversion was a popular topic during the GD as they are a rare ecosystem in our region and serve as a high conservation value area to CLT. The scope of evaluation for marsh conversion ranged from current CLT properties to potential conservation land aquistions.*

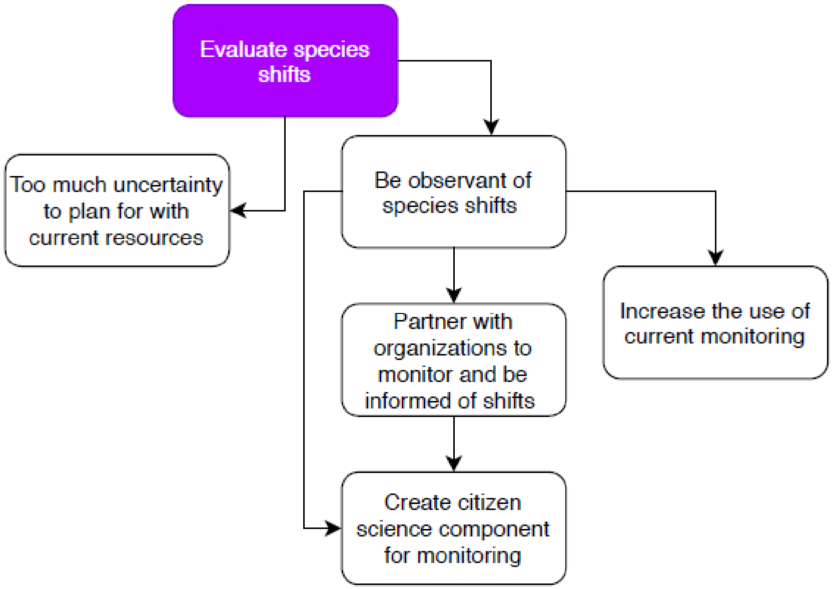


*Figure. 16 Potential futures of evaluating species shifts (scoping phase). Species shifts on the landscape caused by changing climate are a major concern for the geodesign team. The uncertainty inherent with species shifts made the geodesign tean explore the potential for bostering species monitoring efforts in order to track and anticipate shifts based off of baseline data.*

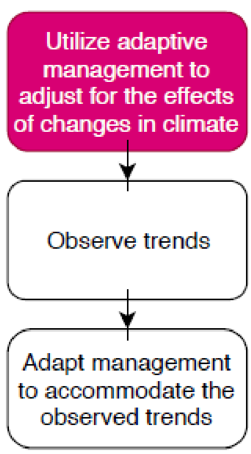


*Figure. 17 Poential futures of utilizing adaptive management to adjust for the effects of climate change (scoping phase). Adaptive management uses observations based off of the effects of management practuces to modify land management practices based off of conservatiun goals.*

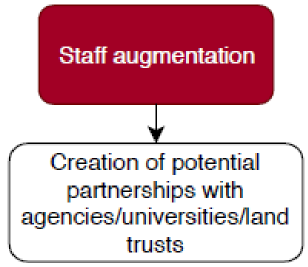


*Figure. 18 Potential futures of staff augmentation (scoping phase). With a limited staff land trusts rely on volunteer and partnering opprotunities to ensure success of new projects.*

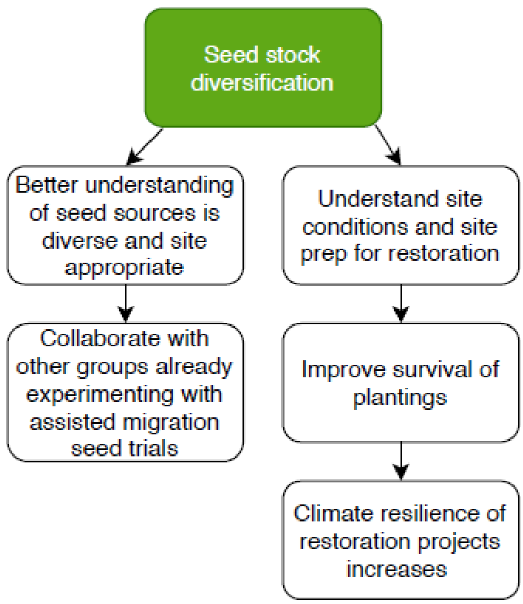


*Figure. 19 Potential futures of seed stock diversification (scoping phase). Increasing genetic diversity of plants is a non conytriversial method of increasing resillience of restoration plantings and is a rapidly dployed option for climate change adaptation of conservation projects.*

The geodesign team found the following requirements/objectives to be pertinent for the decision models based on what they perceived to be relevant to the stakeholder group (the board and executive directors). The following objectives/requirements were weighted 1-5 for their perceived importance to the board: 1 being the lowest priority for the stakeholders and 5 being the highest priority for the stakeholders.

The evaluation of project requirements by priority is a key portion of Carl Steinitz's framework for geodesign because it helps the geodesign team focus their design to accommodate the requirements of stakeholders and reconcile disagreement. Within the CLT GD team there seemed to be little disagreement. As a result, the participatory tone within the geodesign team created a process that was surprisingly linear. Because of the lack of disagreement, there seemed to be little value in weighting the requirements/objectives of the stakeholders, especially since they mostly aligned with actions that were already proposed in the first round of change models.

Requirements of decision makers are represented in the bulleted list below, with corresponding importance in brackets to the right of the requirement. Importance of requirements was rated from 1-5 with 1 having the lowest importance and 5 having the highest importance.

- Evaluating effects of sea level rise. (3)
- Community input for strategic plan. (5)
- Consider sea level rise for public access and structures. (3)
- Evaluating climate resilience within acquisition. (1)
- Adapting restoration and stand management based on observed trends to adapt to climate change. (increased fire risk due to altered fire regime, stand health/vigor, etc.) (4)

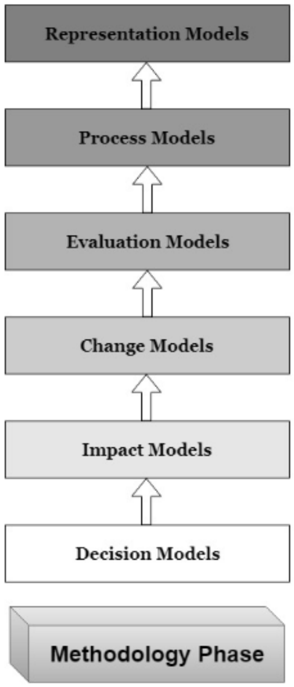


*Figure. 20 Beginning of methodology phase.*

**Methodology Phase**

During the second phase of the process the order of the questions is reversed from 1-6 to 6-1 and the models inform each other in a manner to create a methods section that answers how the design will be done.

*Question 6.*

*How should the study area be changed?*

It was agreed that knowledge gaps concerning potential effects of climate change are vast. Addressing knowledge gaps represented the lion's share of the methods for the design. The prevalence of knowledge gaps was framed by the need to reduce uncertainty within the effects of many potential effects of climate change and the potential for adaptation vs mitigation of these effects. One of the parts of the design would be to make a checklist of climate informed considerations for acquisition and management of properties.

## Acquisition and Management Considerations

An element of this checklist was a consideration of the conservation value which is already assessed by the acquisition team for new properties. There is a challenge implementing climate change considerations into assessing conservation value of potential property acquisitions. Implementing climate considerations is difficult because at the scale of CLT's service area there is great uncertainty regarding potential change.

Another goal for acquisitions was to make a metric or evaluation of how certain properties may be more or less resilient to climate change. The challenge for this type of rating is that resilience is commonly measured at a regional or species scale and the evaluation would be of properties at small multi-acre assessments (small property level) vs regional assessments (service area scale).

*Question 5.)*

*What differences might the changes cause?*

The geodesign team focused on the previously described consideration checklists and recommendations rather than focus on the impacts of the proposed decision actions. The products that they saw as relevant to the organization were:

- A document outlining considerations and recommendations for the board that might influence proposals for interorganizational collaboration/monitoring to reduce the uncertainty of the effects of climate change on CLT lands.
- A climate informed checklist for management and acquisition actions in order to have procedures for the above recommendations.
- A spatially informed decision support tool for the evaluating resilience of current and potential CLT lands. The tool would be a set of maps of

processes relevant to climate change (maps for this tool are shown in appendix C).

*Question 4.)*

*How might the study area be altered?*

The vision of why and what the methodology was attempting to accomplish was described by following actions:

1.) Collect information on the effects of climate change that are specific to CLT properties and manageable in their complexity/application. This was seen as being accomplished through:

a) A citizen science program involved in monitoring of CLT properties.

b) Through networks of volunteers engaged in monitoring, as well as through partnerships with other organizations, agencies, and universities.

2.) Present trends and changes on CLT lands that are potentially climate related to the board.

3.) Create a procedure or method of continual awareness of trends on CLT properties via long term monitoring and studies.

4.) Establish a network of collaboration that will expand the expertise and capabilities of the organization to prepare, plan for, and adapt to the potential changes of climate change.

5.) Create a checklist of climate conscious procedures for land management (including restoration) and future land acquisitions.

6.) Develop considerations for the board concerning the potential effects of climate change on CLT lands.

7.) Help the board, committees, and staff stay abreast of trends on properties.

After answering question 4 in the methodology phase, the geodesign team required a more streamlined process to follow in order to be able to make decisions based on the large amount of material that we had produced. It was agreed that the process had proved to be too ungainly for the changes that we had envisioned to implement. The CLT GD team suggested that we should regather after I had condensed what we had produced into a more easily consumable format to finish the GD process. I later made a PowerPoint to finish the evaluation, process, and representation models as well as the plans for implementing the proposed changes.

**Streamlining the Process**

I took the key elements of the scoping and methods portion of the geodesign process and created a PowerPoint presentation that is represented in Appendix B. The PowerPoint showed what the group had envisioned for the end-products, considerations, and procedures for climate change adaptation of CLT lands.

The presentation proposed potential directions for implementation of the proposed changes by incorporating an intuitive narrative for the changes. I also offered a proposal for the previously mentioned spatial decision support tool and asked for feedback concerning the scope and variables involved (shown in appendix C). After the presentation we developed a strategy for implementing the proposed changes and proposed potential futures for the project. This phase could be described as the implementation phase of the project as outlined in Steinitz's general framework for geodesign.

**Service Area**

Results from the streamlining process included a conversation about CLT's service area. Many land trusts have a specified geographic extent that they work in, however CLT has not formally specified their service area. The geodesign group mentioned how there have been many discussions within the board about what the service area should be and to date there is no consensus on its precise extent. They said that the board is now hesitant to draw a specific line on a map representing a service area because of a potential partnership to expand the lands that they are currently conserving. The lack of a formally defined service area can discourage evaluation of processes at varying geographic scales. Creating a formal service area is an opportunity to foster strategic collaboration with organizations that have interests in the area. The CLT GD group had previously established a proposed service area based off of watersheds that contained the vast majority of properties but excluded 6 properties which were mostly on the edges of the service area (Fig 62). Although the geodesign team agreed that the proposed area was sufficient for our study, further discussion within the organization is necessary to determine the conservation benefits of adopting an explicit service area.

### Reiterating Geodesign Results

Persistent topics of the geodesign process were put into slides that extracted major themes and suggested new paths for climate related action within CLT such as institutional guidance, matching strategy with other organizations, and research. The full lists of suggestions are shown in Appendix B[5].

The GD group was very receptive to the presentation and mainly wanted to change some of the wording within the PowerPoint. The changes in wording that they proposed were mainly focused on broadening or softening the intention of some statements. For example, instead of describing certain things as problems or hazards they wanted to call them changes or change conditions (denoting the potential for negative as well as positive change). Another change that they proposed was changing the order of bullets within slides to emphasize the relative importance of each concept behind the bullet going from high importance on top to low importance on the bottom. The slide titled “Research” was changed to read “Science”. They were also hesitant to call assisted migration projects on preserves “experiments”. Rather they wanted to take out the phrase “assisted migration” altogether and consolidate potential assisted migration into a category called “plant adaptability”. A portion of the presentation that brought up considerable conversation was the section mentioning networking for climate resilience. What

[5] Appendix B represents the geodesign streamlining presentation before suggested edits were made by the CLT GD team.

was additionally proposed from this discussion was the creation of a network of data sharing with organizations within the service area, to observe unprecedented trends in the landscape and how different organizations are dealing with them. It was agreed that the decisions of what actions were going to be implemented was ultimately up to CLT's board and executive director.

We all decided that the presentations I made should be edited with suggestions provided by the geodesign team, and then presented to the board this summer during a CLT board meeting. The results from the meeting will likely be held confidential within the organization, making them unusable for this thesis.

## Decision Support Tool

I proposed some map layers that would be useful for the creation of a climate smart decision support tool (Appendix C). The geodesign team agreed with the variables that I proposed for the tool, including the additional variables of

- Permeability,
- A heatmap of fire occurrence within the service area for the last 5 years
- A map to assess the spread/prevalence of invasive species.

The decision support tool consisted of a map containing these layers and my previously suggested layers, to show the current state of the landscape and inform future land acquisition. I suggested addition of a tool to weight the variables in separate raster layers that would allow algebraic functions between raster overlays. My idea of conducting spatial analysis was perceived to be a potentially useful tool but only at a regional scale and not the smaller scale of CLT property level land management. The CL saw value in the raster overlay map if CLT where to obtain a large enough property that could not be easily assessed on the ground. Currently CLT does not anticipate acquiring a property of that size.

# Discussion

## Overcoming Barriers to Implementing CCA Geodesign

Within CLT there are several attributes of the organization that increase the likelihood of CLT adopting climate change adaptation measures: the attributes present within the organization are:

1.) Existing science (monitoring, restoration experiments, etc)

2.) Strong leadership emphasizing CLT's 4-year plan

3.) The new 4-year plan will be implemented next year, allowing for the potential for new goals and procedures that bring into account the effects of climate change

4) New leadership within the board has a strong background in conservation policy and the new leaders may be receptive to incorporating climate change adaptation into their larger planning process (Ekstrom & Moser, 2014).

These attributes were found to correlate well to beneficial attributes in implementing climate adaptation measures and circumventing barriers to CCA implementation outlined by Ekstrom and Moser in a study of agencies within the San Francisco Bay area of California (2014).

CLT's commitment to resilience and sustainability is an ivitation to incorporate climate-based resilience within their 4-year plan. On the other hand there are barriers to implementing the CCA measures identified by this geodesign such as:

a) A limited staff that is less capable of expanding current practices than a larger staff.

b) Expertise of many of the staff and volunteers is not generally climate oriented.

Proximal barriers include:

(i) There is a perceived danger of branding their organization as climate-conscious. Some have concerns that if CLT is perceived as climate conscious, it may limit donor activity for the organization, possibly influencing the extent of climate change adaptation being integrated into the new 4-year plan.

ii) High uncertainty concerning the effects of climate change creates a hesitancy to implement proactive probabilistic measures for CCA.

Many habitat-restoration procedures that are currently practiced can be modified and used as climate adaptation measures within the organization. For example, the "menu" of adaptation measures that is outlined by the Forest Adaptation Resources: Climate Change Tools and Approaches for Land

Managers. 2nd ed (Fig. 75) (USDA, 2016) was shown to the geodesign team. The GD team agreed that each category for adaptation practices in the USDA menu represents an active restoration practice currently being administered by CLT. Repurposing of existing and approved language of restoration practices may encourage rapid implementation of on-the-ground climate change adaptation efforts.

A hesitancy to turn CCA into an outreach strategy makes “adaptation-by-stealth” a potent option for land management practices in implementing CCA. The CLT may consider phrasing their CCA strategy with broad categories such as Strategy 8: “Maintain and enhance genetic diversity” (Fig. 4) in the Forest Adaptation Resources paper. Certain practices that are more controversial climate-based strategies, such as assisted migration of seed sources, can fall under the less controversial category of increasing local genetic diversity.

Many of the adaptation actions proposed in the geodesign involve expanding CLT’s knowledge, expertise, and faculty. When an organization is structured to operate in a consistent manner, change can be disruptive and unwelcome. By removing the burden of adaptation away from the staff at CLT, volunteers and outside experts can do the work that staff don’t have the time to do. By augmenting the staff, CLT may increase their resilience, as well as their capacity to conserve lands.

**Geodesign Team Feedback**

Phone Interviews were arranged with each member of the geodesign team to get feedback from the geodesign process. The 4 respondents were anonymous and will be referred to as Respondents 1,2,3, and 4. Interviews were largely free form but asked the same set of questions. Questions consisted of the following:

a.) What are the main takeaways from the geodesign process?

b.) How were the models presented in the story map useful or extraneous for the geodesign?

c.) What would you recommend changing in the geodesign to make it more effective?

d.) Do you see value in other land trusts doing a similar geodesign for climate change adaptation?

e.) What should be the next steps for presentation of the geodesign process to the CLT board of directors?

**Respondent 1**

Respondent 1's main takeaway was that the geodesign showed that we can be powerful when we can freely brainstorm with some structured questions such as the ones offered by the Steinitz geodesign approach. They also replied that the geodesign discussion method helped the group think about the problem of climate change adaptation from many different angles and helped the group get ideas that they wouldn't have otherwise realized. Respondent 1 said that taking all the material and distilling it down for the final meeting was an effective way to capture findings and summarize them into potential actions and considerations.

Models within the story map were described as informative, giving the group information that they had never had before. The respondent suggested that when the models are presented to the board, the models should be summarized onto a few pages that can be reviewed quickly.

Respondent 1 said that they thought that land trust planning processes in general aren't very sophisticated, and that the geodesign framework was, by comparison, very sophisticated. They said that the geodesign should be simplified if it would be used for another land trust. When asked if staffing was an issue in implementing climate change adaptation they responded that staffing is a challenge for many land trusts (including Capitol Land Trust) in implementing climate change adaptation practices.

Respondent 1 was asked "What should be the next steps for presentation of the geodesign process to the CLT board of directors?" they said that the board will need a summary of key takeaways from the geodesign streamlining PowerPoint (Appendix B). The summary should focus on properties of interest to CLT, with a 1 page summary of precipitation and temperature projections for the service area. The summary should also highlight the top 4 strategies, and an executive summary will be needed to summarize the geodesign process for the board. Respondent 1 said that the board will have its own ideas after our findings are presented, the new 4-year strategic plan may take up to a year to complete, and this presentation will frame the start of the creation of the strategic planning process.

**Respondent 2**

Respondent 2 said the main takeaways from the geodesign included the succinct visualization of the models presented in the story map (sea level rise, temperature change, precipitation change) and validation from sea level rise models of what has been observed on properties from king tides. They said that climate change models will not likely change CLT land acquisitions. Marsh migration from sea level rise will increase biodiversity/conservation value of coastal properties. Respondent 2 said that they saw value in other land trusts doing a similar geodesign process to gain awareness of climate change effects and likely changing conditions. Suggested considerations for presentation of results to the board included:

- Considerations for restoration (prepared by the lands committee)
- Make sure the board of directors understands climate change related trends
- Have geodesign team create a draft recommendation to the board including a brief summary page and highlights from the geodesign.

**Respondent 3**

One of the takeaways that respondent 3 mentioned was the need for collaboration with public land managers and private land trusts. Another takeaway that they mentioned was the need for an initiative to plan for climate change and the evaluation of spatial predictions for climate-smart acquisitions. Respondent 3 said that CLT should find indicator species that best show the progress of climate change, to simplify climate related monitoring efforts.

Respondent 3 said that the climate modeling presented in the story map was useful. They mentioned that it was helpful to see numbers for predictions of localized effects, especially when predictions presented by the media are often concerning.

Further refinement of the geodesign process was recommended, and refinement of CLT's future climate planning process was suggested, using the best information available to guide future decisions. They said that it could be useful to have other land trusts do their own geodesign in order to compare results and conclusions and refine the geodesign process.

**Respondent 4**

Respondent 4 mentioned that the geodesign was iterative, high level and conceptual, and that going through so many iterations was helpful in looking at many different potential changes caused by climate change. They also said that their main takeaways were:

- The need to focus on more concrete actions rather than just focusing on recommendations.
- The need to establish a more formal definition of CLT's service area.
- The benefit of establishing improved seed sources for restoration projects.

In the interview Respondent 4 mentioned that reducing the scale of analysis to specific preserves could make a more productive discussion. Focusing on high profile properties would improve the impact factor for a presentation to the CLT board of directors. The context provided by the high-level discussion was seen as valuable to Respondent 4 because they said that it brought the rest of the design into context.

In the interview Respondent 4 mentioned that the geodesign could be improved by including more straightforward language in the sub questions. The questions in retrospect did have a fair amount of jargon that was specific to questions mentioned by Carl Steinitz in his book A Framework for Geodesign (2012).

Respondent 4 suggested components of the recommendations presented to the board which are listed here:

1) Distill high level discussion into issues that the geodesign team faced, how the issues were addressed, and the process that we used to address them.
2) Include analysis of high-profile properties
3) Adaptation doesn’t need to look like outreach.

## Interpreting Feedback

This thesis is an attempt to:

**1) Apply Carl Steinitz's geodesign framework to CCA of CLT's private conservation lands.**

**2) Assess use of localized climate change process modeling data outputs within the CCA geodesign.**

The story map showing the effects of climate change related processes was considered informative for all participants of the geodesign. Visualizing climate change related data into maps gave localized data that the geodesign team made decisions from. Respondent 1 commented that the story map was useful because it gave them information that they never had before.

Nearly all the data presented in the story map was spatial, and it was all contextualized with its distribution on CLT properties. By finding authoritative data, presented in maps, and contextualized to areas of interest, the story map bridged a knowledge gap for the geodesign team. All of the team members have seen climate change data, but never in detailed maps portraying data of CLT lands/service area that were exhibited in the story map (Appendix A).

Presenting the maps to the group was effective in addressing climate change concerns of some participants. Respondent 3 said that the maps of the climate change process models were useful, because they were concerned with the rate of climate change provided by the media. Another participant said that after the geodesign meetings were over, that they felt more confident that CLT could deal with the effects of climate change.

Members of the geodesign team found positive and negative changes to localized systems and processes, based on the climate change models in the story map. For example, marsh migration/expansion was an element of sea level rise that the group found positive and encouraging. Coastal marshes are an important habitat for many coastal species, and the expansion of marshes could improve coastal habitat for important species such as salmonids. By anticipating the migration of marshes through the NOAA marsh migration models, as well as monitoring, marshes can be managed around restoration goals such as increasing biodiversity and maintaining ecological functions.

By having data-based projections of future climates within an ad hoc service area, general trends were noted and accounted for such as longer/dryer summers, warmer seasons in general, and an increase in rainfall for all seasons excluding summer. These general trends have been included in a list of recommendations for CLT's restoration team. Other themes in the recommendation include:

- awareness of climate trends
- enhanced site preparation before planting
- assisted migration

- watering of high priority plants
- seed source diversification
- selected tree thinning

One barrier to agreement within this geodesign effort was the complexity of the sub questions that were posed. Further refinement of the initial questions would have benefited the geodesign process. Geodesign questions should ultimately be tailored, from the original Steinitz Framework for Geodesign (2012), to the specific problem that the geodesign is trying to address. but the problem for this geodesign was established after the creation of the sub questions. Future geodesigns using these methods should tailor their questions to their problem statement before beginning the geodesign.

The geodesign team consisted of CLT volunteers that are influential, highly active in the organization, and receptive to climate science. These qualities are desirable for the people involved within a CCA based geodesign. The methods in this thesis may not be appropriate for groups containing a large proportion of people who deny the phenomenon of climate change or are not receptive to scientific data.

This geodesign has created recommendations for the CLT board of directors, acquisition team, and restoration team. It has also created a decision support tool for climate smart land acquisitions. This case study is only one example of using geodesign to implement CCA and other attempts to duplicate this methodology are highly likely to have differing results.

## Conclusion

In conclusion climate modeling paired with geodesign shows promise in implementing CCA measures for private land trusts. Land trusts can be given operational information via authoritative climate change data, data representing processes that are affected by climate change, and giving localized context to the data with parcel boundaries. Initiating a geodesign with regionally contextualized data aids land managers in implementing probability-based plans and procedures that are proactive. The recommendations outlined in this thesis offer a starting point for other land trusts in the area to start planning for climate change. Workshops within a geodesign may act as a baseline for a conservation organization to build on for future climate adaptation efforts.

The compilation of authoritative climate change related data is also a benefit for a geodesign process related to climate change. By having dedicated tasks of compiling regional climate data/process data, geodesign facilitation, and summarization of geodesign results, there will likely be a more successful geodesign. Products of these tasks can be found in Appendices A, B, and C.

Climate adaptation measures will likely begin with simple measures such as augmenting the work done by staff through volunteer labor/planning or increasing an organization's education surrounding climate change. Land trusts that lack the personnel to implement climate adaptation measures can attempt to augment their staff by creating partnerships, starting community science programs, and establishing networks of resilience.

There are myriad of reasons that organizations lack the discussion needed to start addressing climate change. By implementing a geodesign surrounding the problem of climate change, it forces a group to talk about climate change in a productive way for possibly the first time. Creating a space that considers processes on lands that an organization is responsible makes people in that space address the problem together in a way that encourages action. Showing the geodesign team probabilistic data (via maps and other exhibits ex. Appendix A, B, and C) of how the lands will be affected, encourages people to collaborate to make decisions for action.

Restoration activities on private conservation lands show a high potential for developing CCA projects and procedures that can be quickly implemented and adaptively managed as the climate changes. Many adaptation measures will be similar to traditional restoration practices but focused on transition of plant and animal communities. By creating a network of resilience, land managers can share results from CCA projects and develop best practices on preserves to facilitate migration of organisms. Restoration also offers a way to do work in CCA without branding the organization as doing climate change outreach.

Land trusts will require ways to implement on-the-ground projects as climate change starts to increasingly affect natural systems. The geodesign framework developed by Steinitz (2012) is a complicated process that CLT respondents found to be somewhat ungainly. Reorienting Steinitz's GD methods around questions typical of land trusts may help to address phenomena relevant to a trust's specific problem question, then the geodesign may prove to be more rapid and relevant than if questions are not created beforehand.

The participation of a strong facilitator and technical lead are an advantage in having an effective collaboration within a geodesign. Limitations may arise for organizations that don't have access to a GIS professional or a wide base of expertise. Although a geodesign can be performed without a digital GIS, authoritative data sources will be compelling and informative exhibits. Without the use of digital climate model outputs, it may prove difficult to perform an effective geodesign for climate change adaptation of conservation lands.

## Appendices

### Appendix A. Story map Images

The following images are screen captures from the story map created for CLT's informational climate change preliminary session before the geodesign. Many of the resources are a compilation of authoritative information regarding local effects to CLT properties. Data URL sources for maps can be found in appendix D.

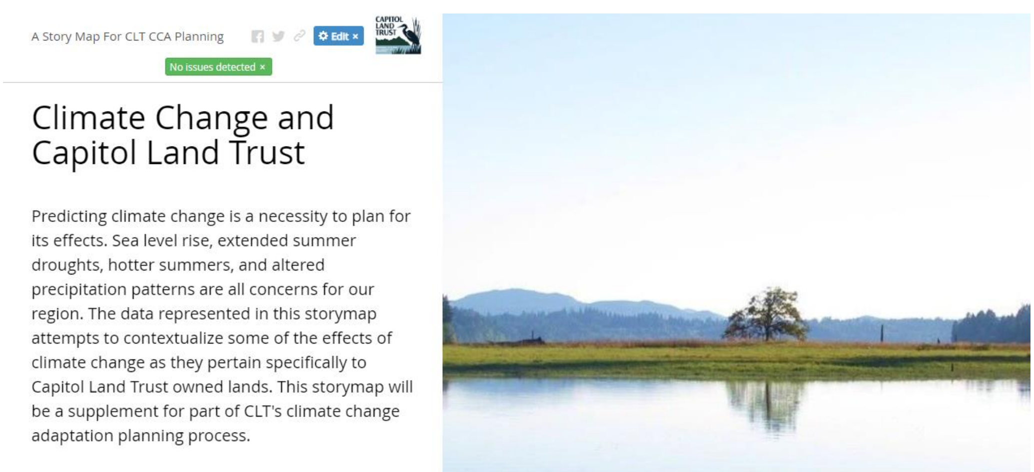


*Figure. 21 Intro slide of story map.*

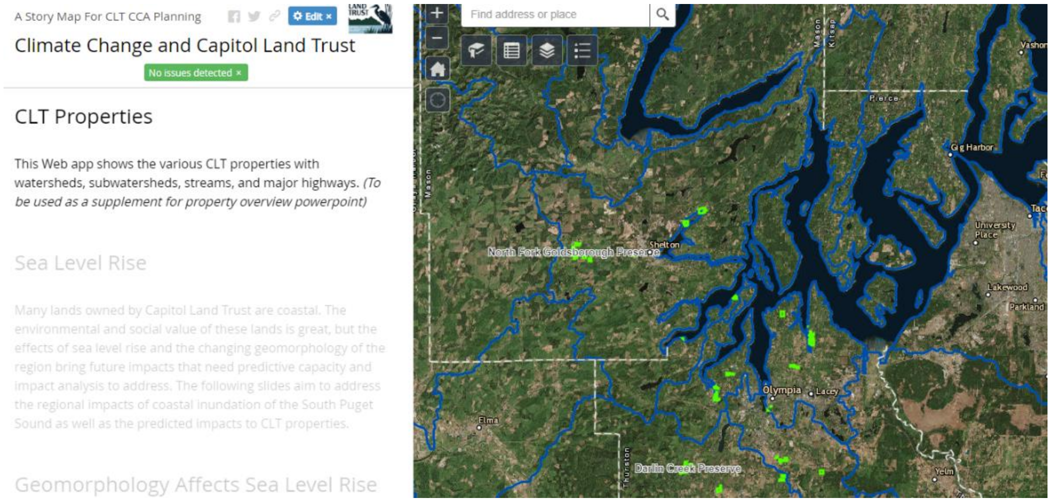


*Figure. 22 CLT property explorer app, showing outlines of properties with satelite basemap imagery.*

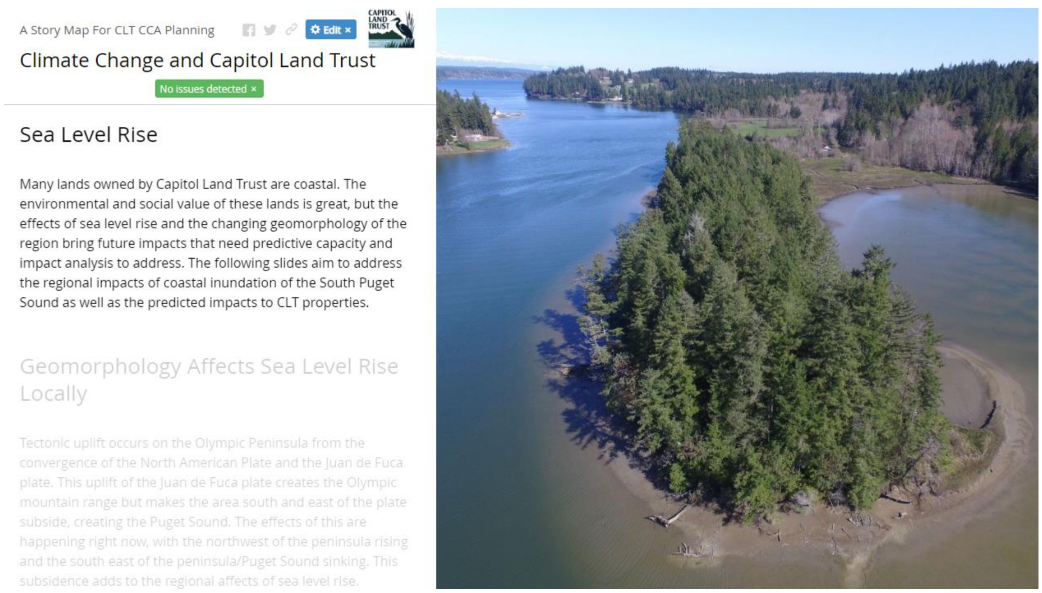


*Figure. 23 Introducing sea lavel rise*

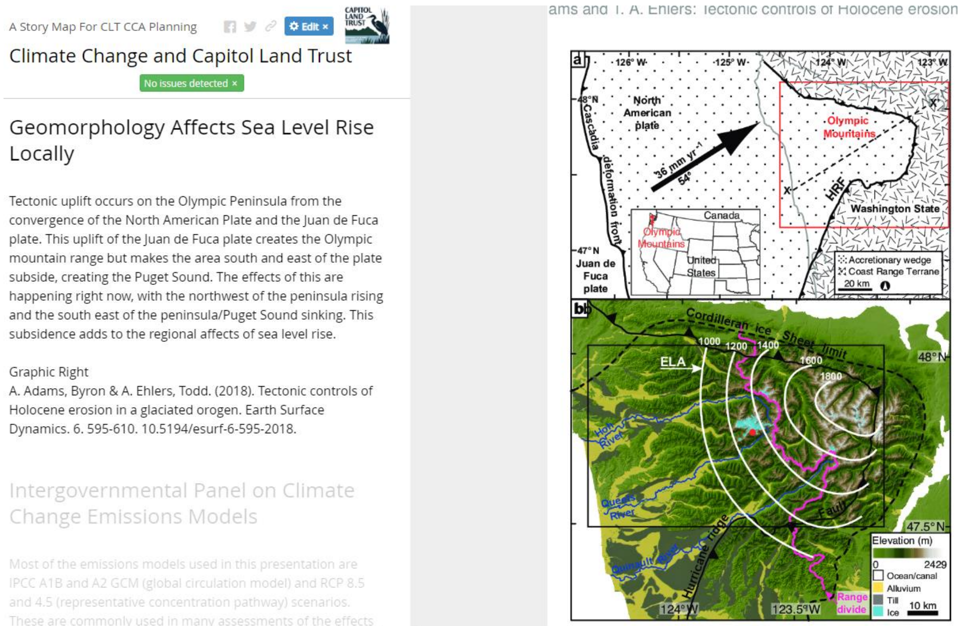


*Figure. 24 Uplift and subsidence of the Olympic Penninsula affecting sea level. Figure Credit: A. Adams, Byron & A. Ehlers, Todd (2018). Techtonic controls of holocene erosion in a glaciated orogen. Earth Surface Dynamics. 6. 595-610. 10.5194/esurf-6-595-2018*

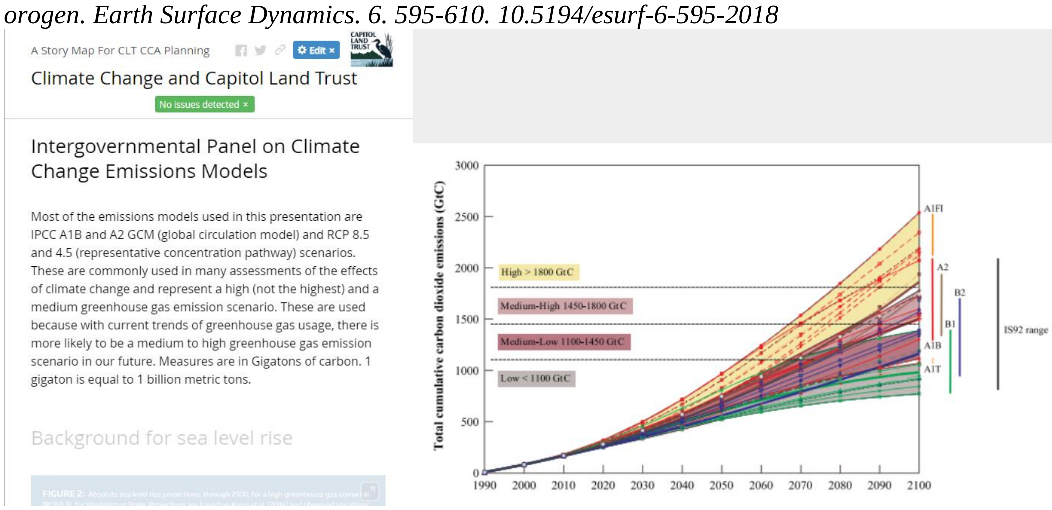


*Figure. 25 Explainataion of IPCC climate scenarios & emissions models.*

*Figure Credit: Intergovernmental Panel on Climate Change*

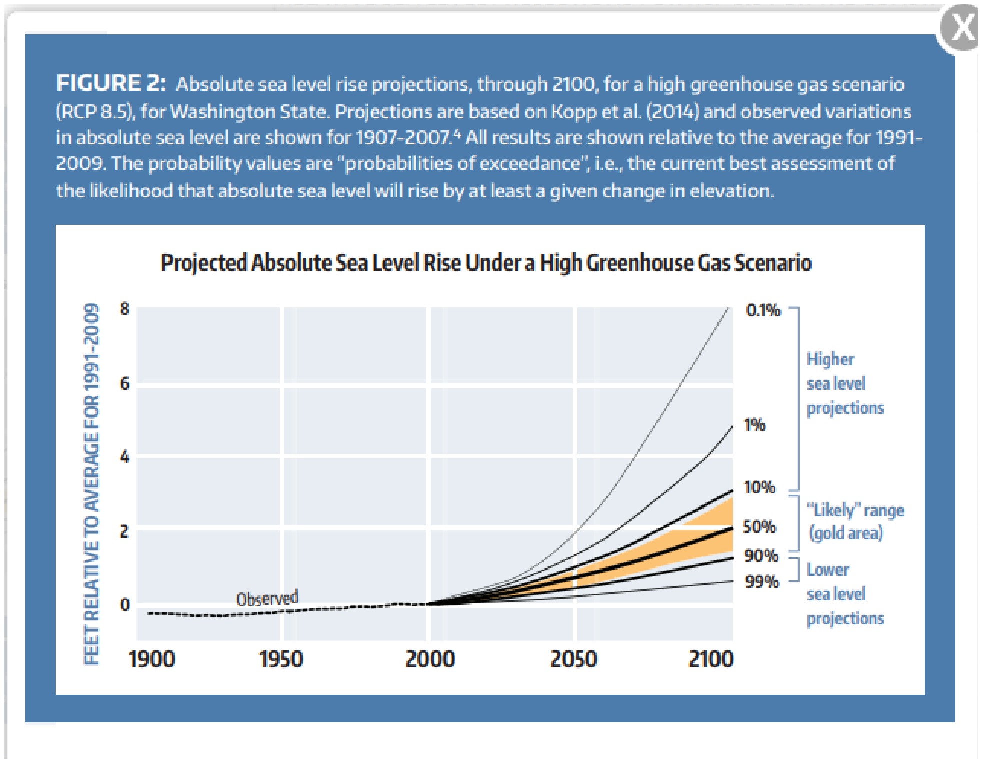


*Figure. 26 Likeleyhood of sea level rise models relative to average sea level 1991-2009. Figure Credit: University of Washington Climate Impacts Group.*

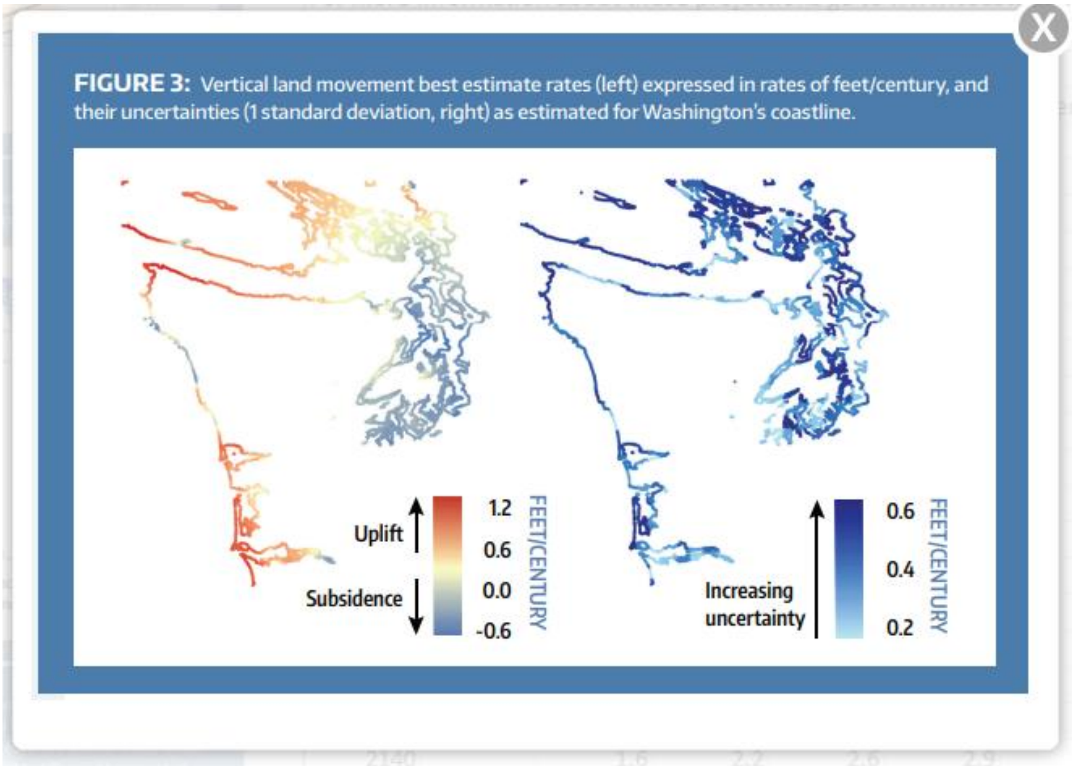


**FIGURE 3:** Vertical land movement best estimate rates (left) expressed in rates of feet/century, and their uncertainties (1 standard deviation, right) as estimated for Washington's coastline.

*Figure. 27 Left graphic: Predicted geomorphological uplift and subsidence of the Olympic Penninsula and Puget Sound. Right graphic: Uncertainty of the predicted uplift and subsidence of the Olympic Penninsula and Puget Sound. Figure Credit: University of Washington Climate Impacts Group.*

**TABLE 2:** Relative sea level projections, in feet, for three of the 171 locations along Washington's coastline. Example locations in Washington include the Taholah, Neah Bay, and Long Beach. Projections are expressed in terms of the "probability of exceedance" for 2100 (2090-2109) under two different greenhouse gas scenarios (RCP 4.5 ["Low"] and RCP 8.5 ["High"]; van Vuuren et al., 2011). Projected changes are assessed relative to contemporary sea level, which we define as the average sea level over the 19-year period 1991-2009. Data for all 171 locations are available at www.wacoastalnetwork.com/wcrp-documents.html.

**PROJECTED RELATIVE SEA LEVEL CHANGE FOR 2100**
(feet, averaged over a 19-year time period)

| Location | Vertical Land Movement Estimate | Greenhouse Gas Scenario | Central Estimate (50%) | Likely Range (83-17%) | Higher magnitude, but lower likelihood possibilities | | |
|---|---|---|---|---|---|---|---|
| | | | | | 10% probability of exceedance | 1% probability of exceedance | 0.1% probability of exceedance |
| Tacoma (47.3N, 122.4W) | -0.5 ± 0.2 | Low | 2.1 | 1.5-2.7 | 3 | 4.6 | 7.9 |
| | | High | 2.5 | 1.9-3.3 | 3.6 | 5.3 | 8.8 |
| Neah Bay (48.4N, 124.6W) | 1.1 ± 0.3 | Low | 0.5 | -0.1 - 1.2 | 1.5 | 3.1 | 6.3 |
| | | High | 1 | 0.3 - 1.7 | 2 | 3.8 | 7.4 |
| Taholah (47.4N, 124.3W) | 0.3 ± 0.5 | Low | 1.3 | 0.6-2.1 | 2.4 | 3.9 | 7.1 |
| | | High | 1.7 | 1.0-2.6 | 2.9 | 4.6 | 8.1 |

*Figure. 28 High and low emission scenario sea level rise predictions for Tacoma, Neah Bay, and Taholah. Differences in hight in feet are based on changes in geomorphology Figure Credit: University of Washington Climate Impacts Group.*

RELATIVE SEA LEVEL PROJECTIONS FOR RCP 8.5 FOR THE COASTAL AREA NEAR: 47.0N, 122.9W

For more information about these projections go to www.coastalnetwork.com/wcrp-documents.html

Table 1: Projected average sea level magnitudes, in feet, for different assessed likelihoods and time periods

| | Assessed Probability of Exceedance: | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 19 year period cente | 99 | 95 | 90 | 83 | 50 | 17 | 10 | 5 | 1 | 0.1 |
| 2010 | 0 | 0 | 0.1 | 0.1 | 0.1 | 0.2 | 0.2 | 0.2 | 0.3 | 0.3 |
| 2020 | 0.1 | 0.1 | 0.2 | 0.2 | 0.3 | 0.4 | 0.4 | 0.5 | 0.5 | 0.6 |
| 2030 | 0.2 | 0.3 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.7 | 0.8 | 0.9 |
| 2040 | 0.3 | 0.4 | 0.5 | 0.5 | 0.7 | 0.9 | 1 | 1 | 1.2 | 1.5 |
| 2050 | 0.4 | 0.5 | 0.6 | 0.7 | 1 | 1.2 | 1.3 | 1.4 | 1.7 | 2.3 |
| 2060 | 0.5 | 0.7 | 0.8 | 0.9 | 1.3 | 1.6 | 1.7 | 1.9 | 2.2 | 3.2 |
| 2070 | 0.7 | 0.9 | 1.1 | 1.2 | 1.6 | 2 | 2.1 | 2.3 | 2.9 | 4.4 |
| 2080 | 0.8 | 1.1 | 1.3 | 1.4 | 1.9 | 2.4 | 2.6 | 2.9 | 3.7 | 5.7 |
| 2090 | 0.9 | 1.3 | 1.5 | 1.7 | 2.3 | 2.9 | 3.2 | 3.5 | 4.5 | 7.2 |
| 2100 | 1 | 1.5 | 1.7 | 2 | 2.7 | 3.4 | 3.7 | 4.2 | 5.5 | 8.9 |
| 2110 | 1.3 | 1.7 | 1.9 | 2.1 | 2.8 | 3.7 | 4 | 4.5 | 6.2 | 10.4 |
| 2120 | 1.4 | 1.9 | 2.2 | 2.4 | 3.2 | 4.2 | 4.7 | 5.3 | 7.3 | 12.4 |
| 2130 | 1.5 | 2.1 | 2.4 | 2.7 | 3.6 | 4.8 | 5.3 | 6 | 8.4 | 14.5 |
| 2140 | 1.6 | 2.2 | 2.6 | 2.9 | 4 | 5.3 | 5.9 | 6.7 | 9.5 | 16.4 |
| 2150 | 1.7 | 2.4 | 2.8 | 3.1 | 4.4 | 5.9 | 6.6 | 7.6 | 10.9 | 19.9 |

*Figure. 29 Bud bay high emissions scenario (RCP 8.5) sea level rise predictions in feet, and their likelyhoods. Data Credit: Coastal Resillience Network*

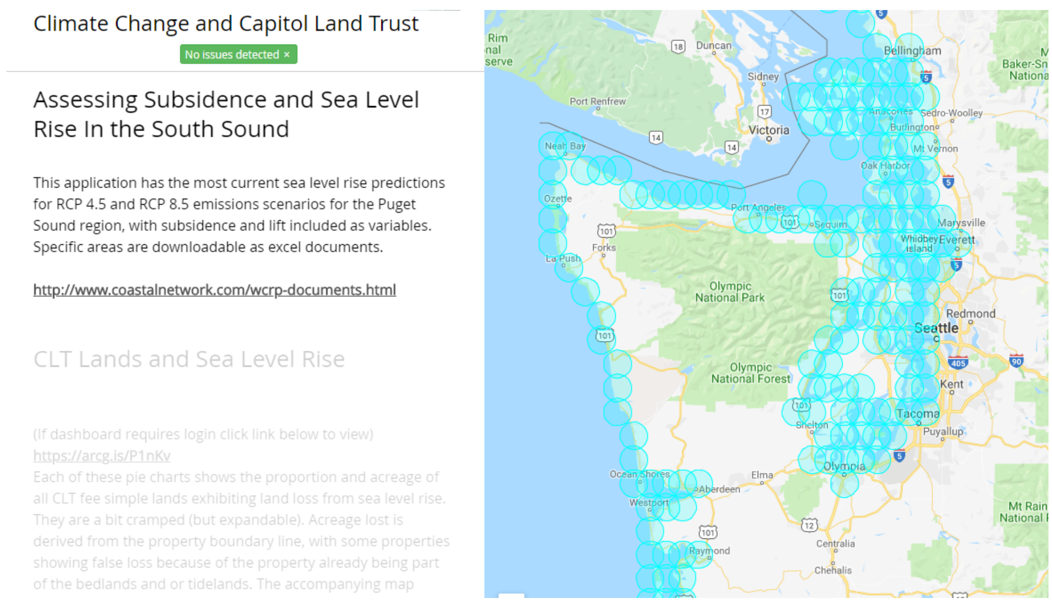


*Figure. 30 Washington Coastal Hazards Resillience Network sea level rise map. Clicking circles gives the localized predictions in feet for sea level rise shown in Figure. 29. Data Credit: Coastal Resllience Network*

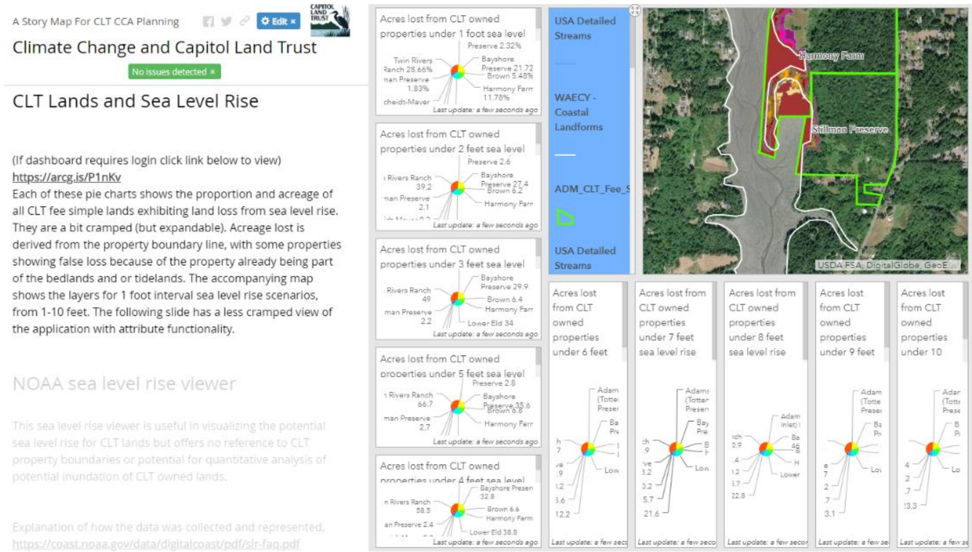


*Figure. 31 Operations dashboard of CLT lands affected by foot intervals of sea level rise. The next 10 Figure.s are pie graphs representing acres of property covered by each foot interval of sea level rise for CLT properties. Data Credit: NOAA*

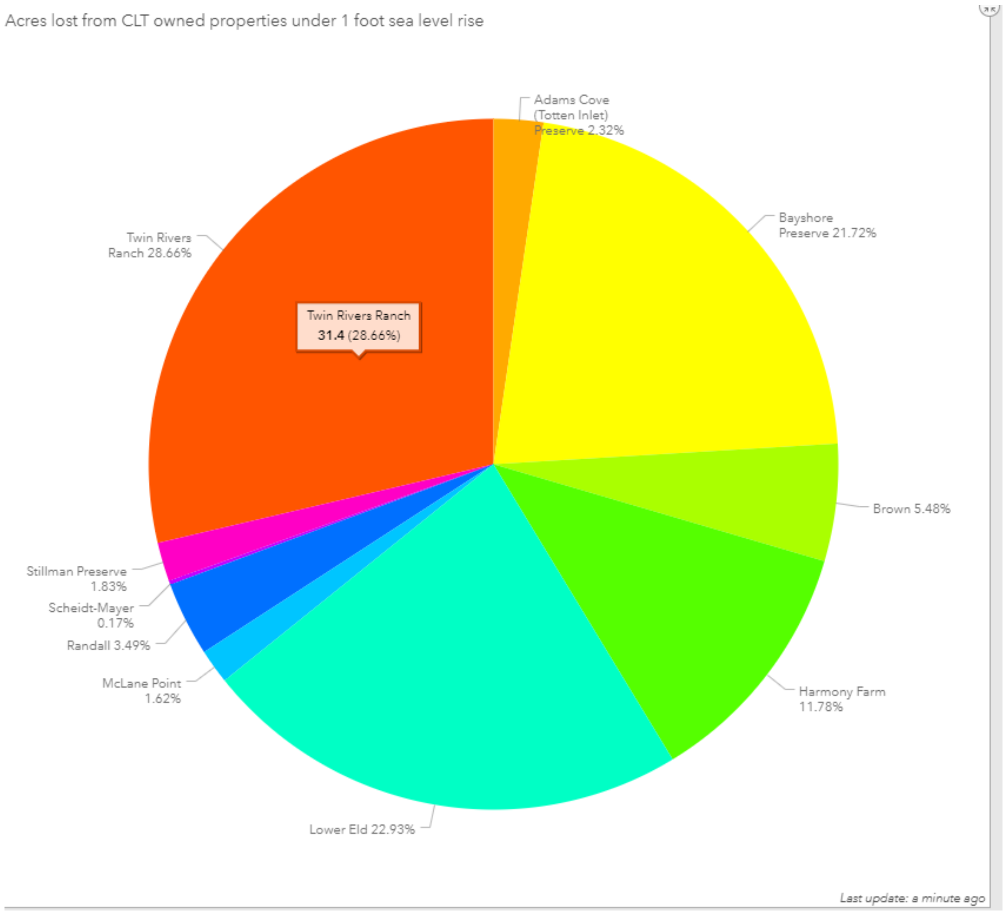


*Figure. 32 percentage of land inundated from 1 foot sea level rise for all CLT properties exhibiting sea level rise.*

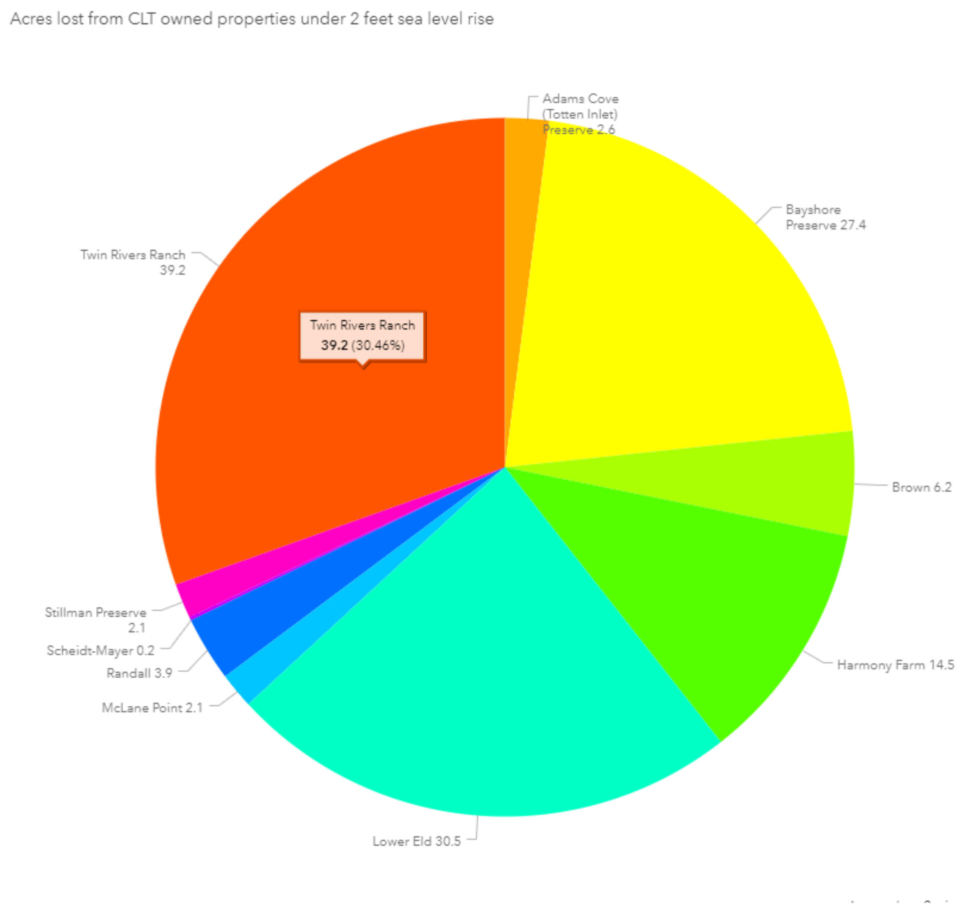


*Figure. 33 Count of acres of land inundated from 2 feet sea level rise for all CLT properties exhibiting sea level rise*

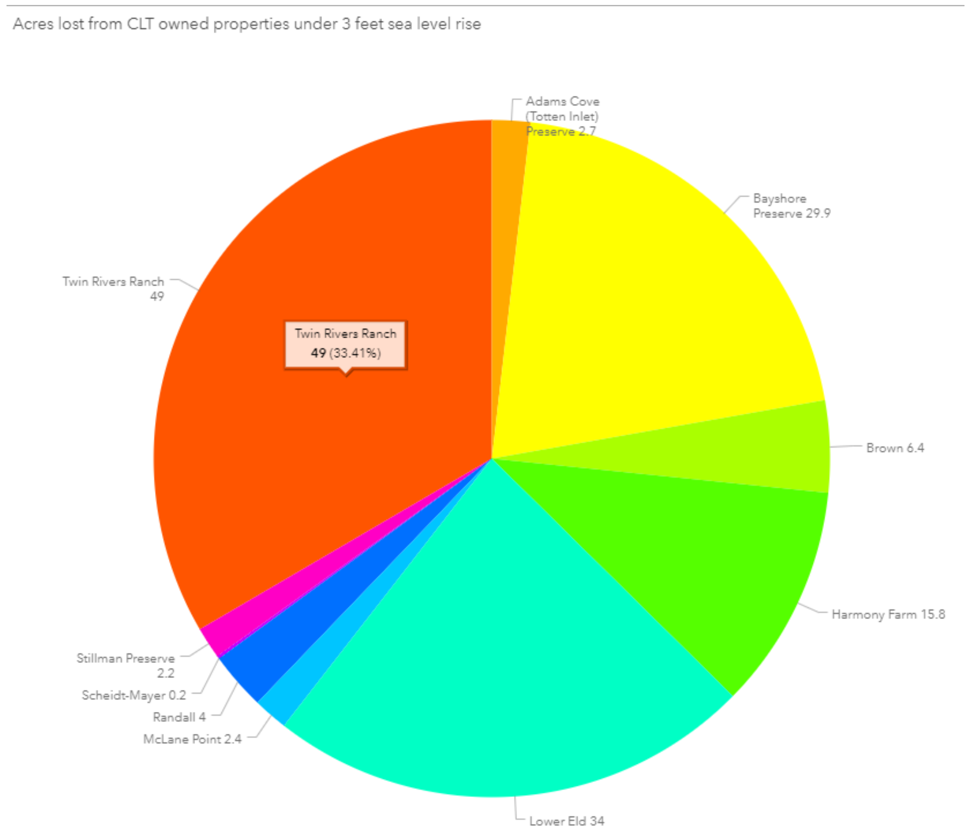


*Figure. 34 Count of acres of land inundated from 3 feet sea level rise for all CLT properties exhibiting sea level rise*

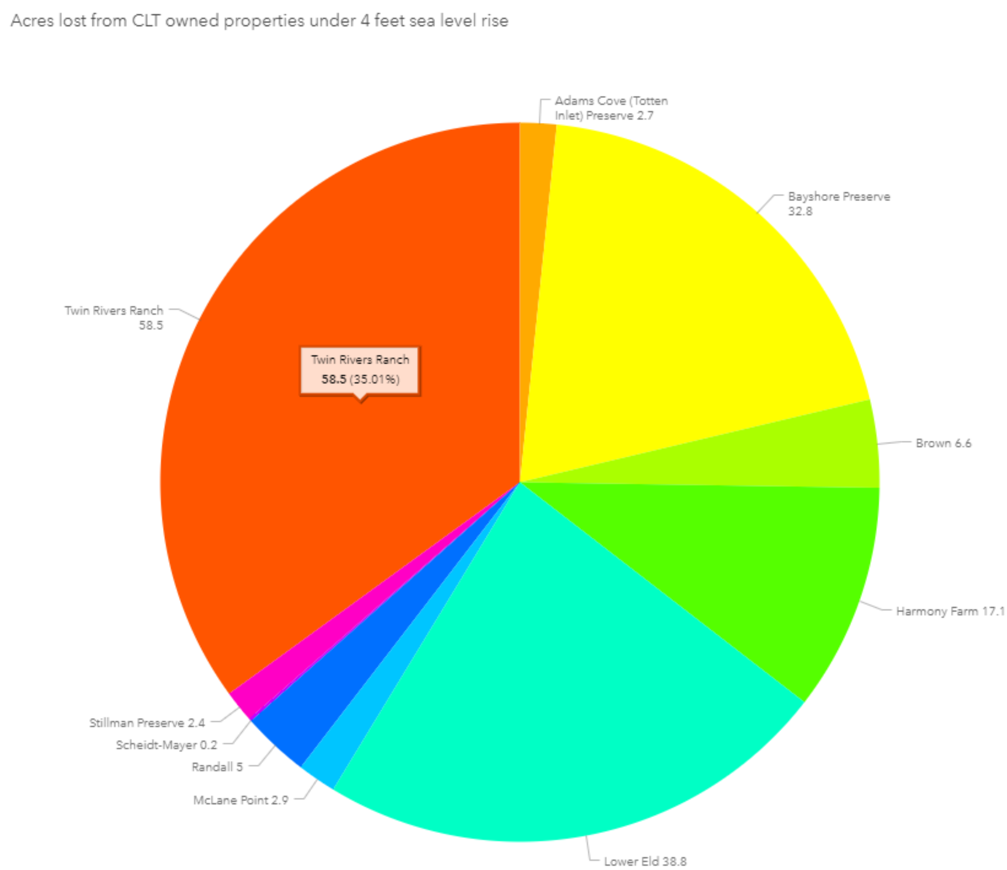


*Figure. 35 Count of acres of land inundated from 4 feet sea level rise for all CLT properties exhibiting sea level rise*

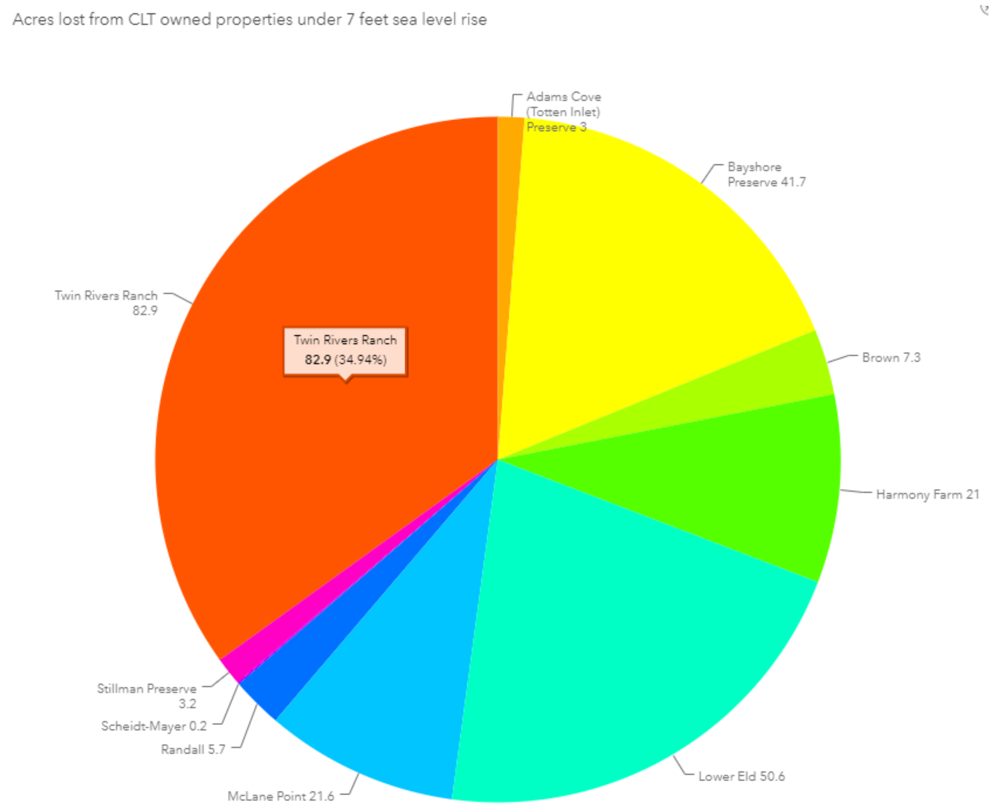


*Figure. 36 Count of acres of land inundated from 7 feet sea level rise for all CLT properties exhibiting sea level rise*

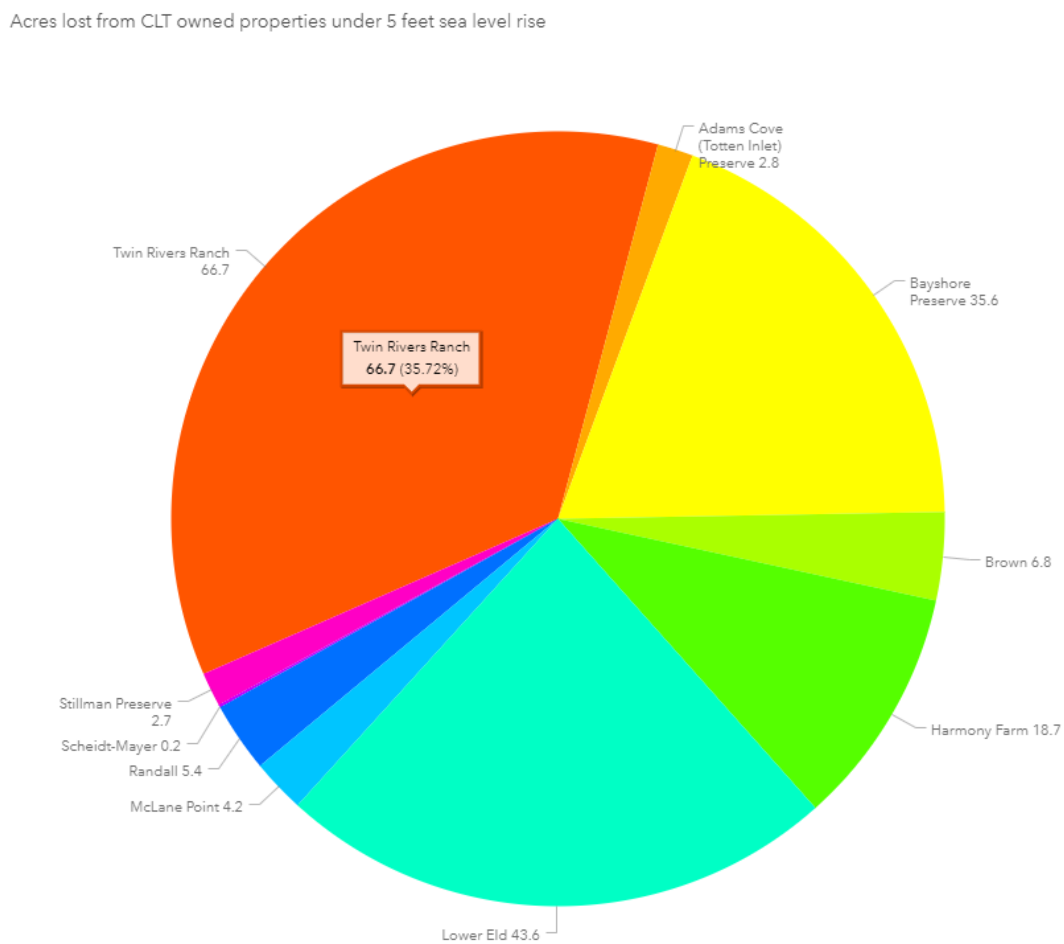


*Figure. 37 Count of acres of land inundated from 5 feet sea level rise for all CLT properties exhibiting sea level rise*

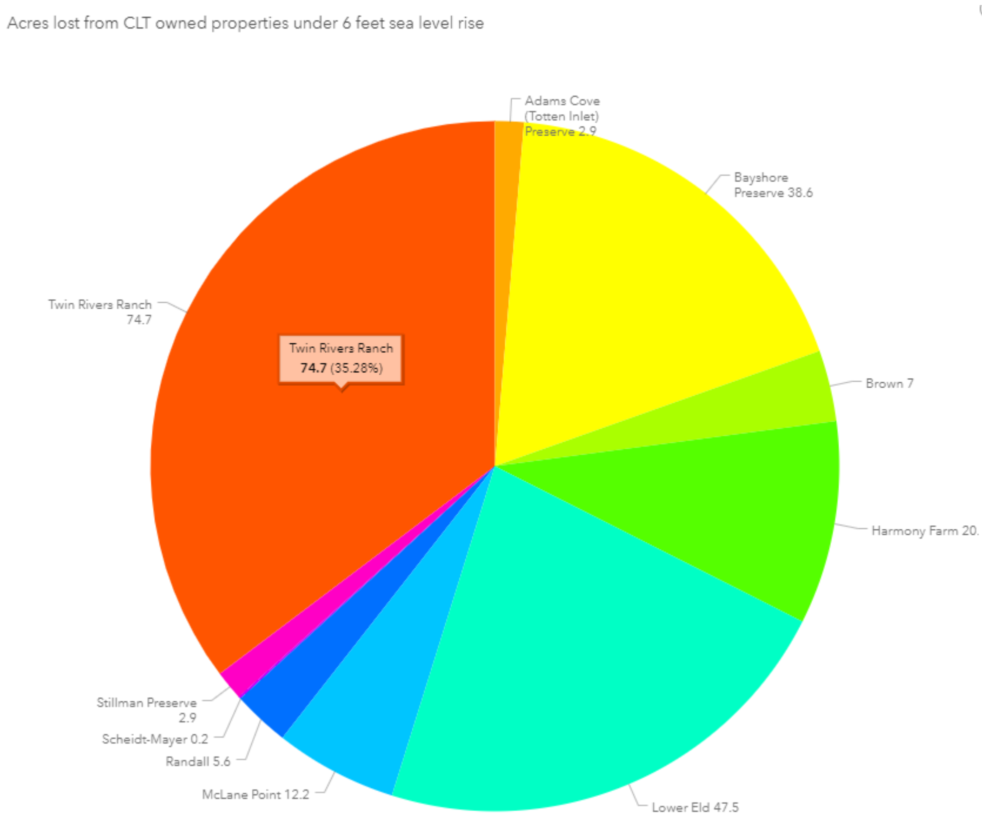


*Figure. 38 Count of acres of land inundated from 6 feet sea level rise for all CLT properties exhibiting sea level rise*

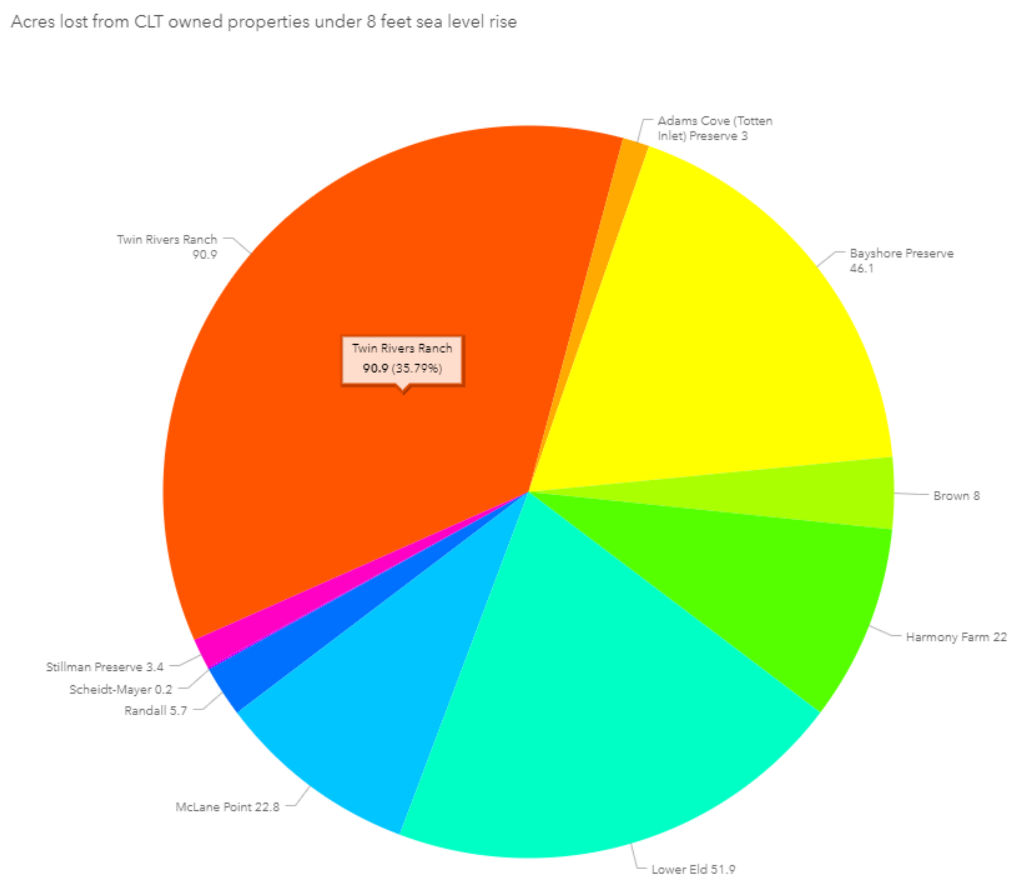


*Figure. 39 Count of acres of land inundated from 8 feet sea level rise for all CLT properties exhibiting sea level rise*

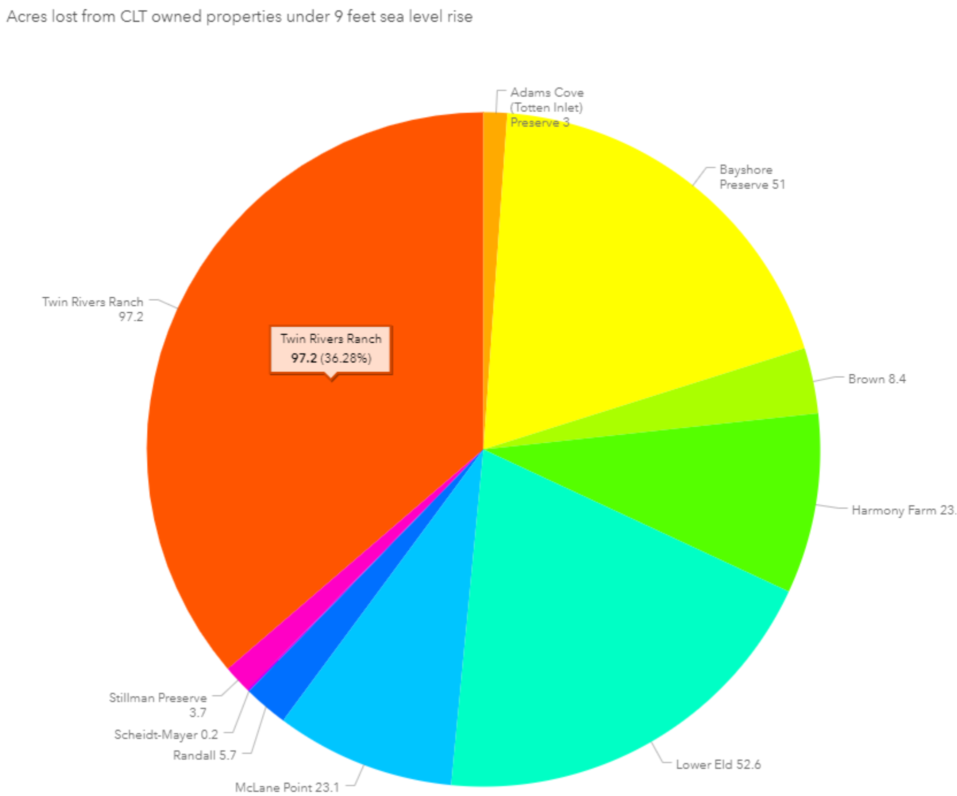


*Figure. 40 Count of acres of land inundated from 9 feet sea level rise for all CLT properties exhibiting sea level rise*

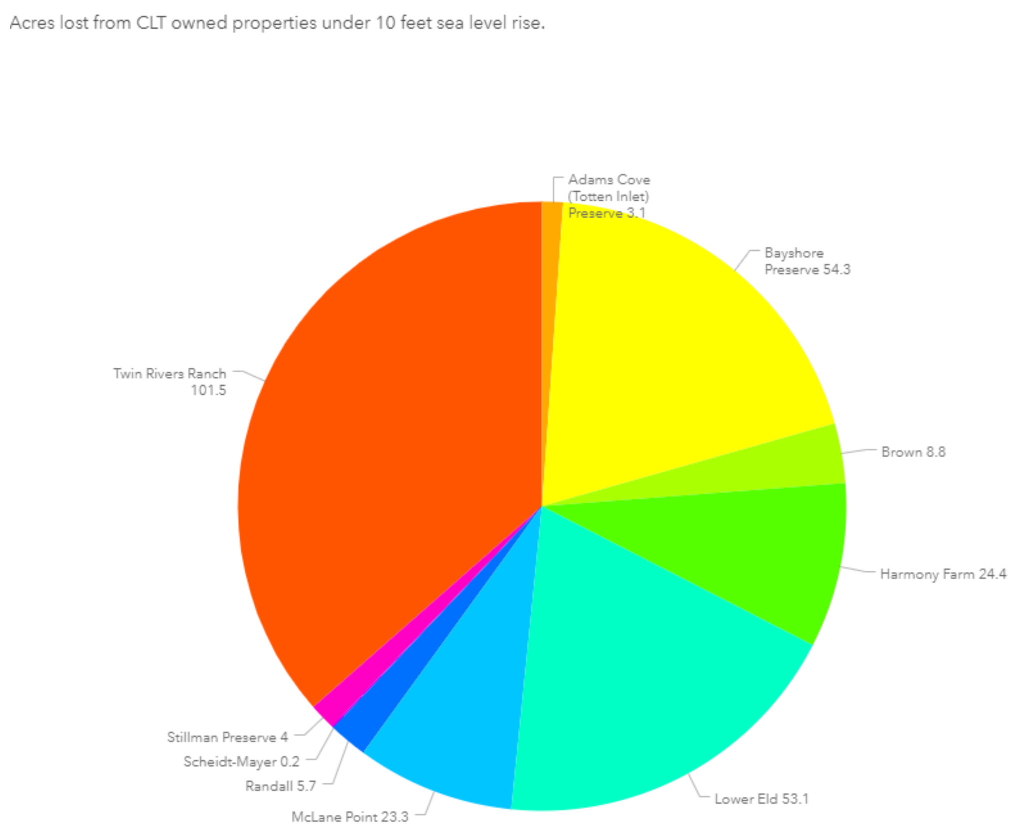


*Figure. 41 Count of acres of land inundated from 10 feet sea level rise for all CLT properties exhibiting sea level rise*

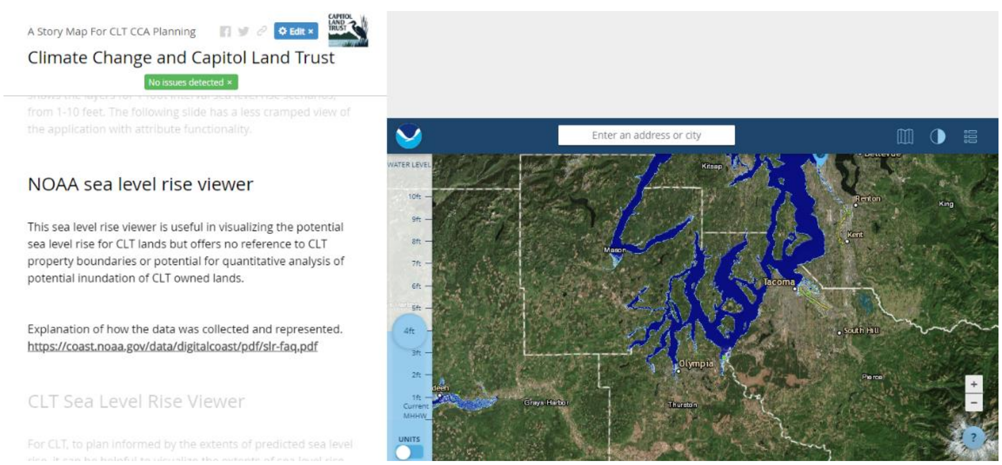


*Figure. 42 Sea level rise viewer app. Data Credit: NOAA*

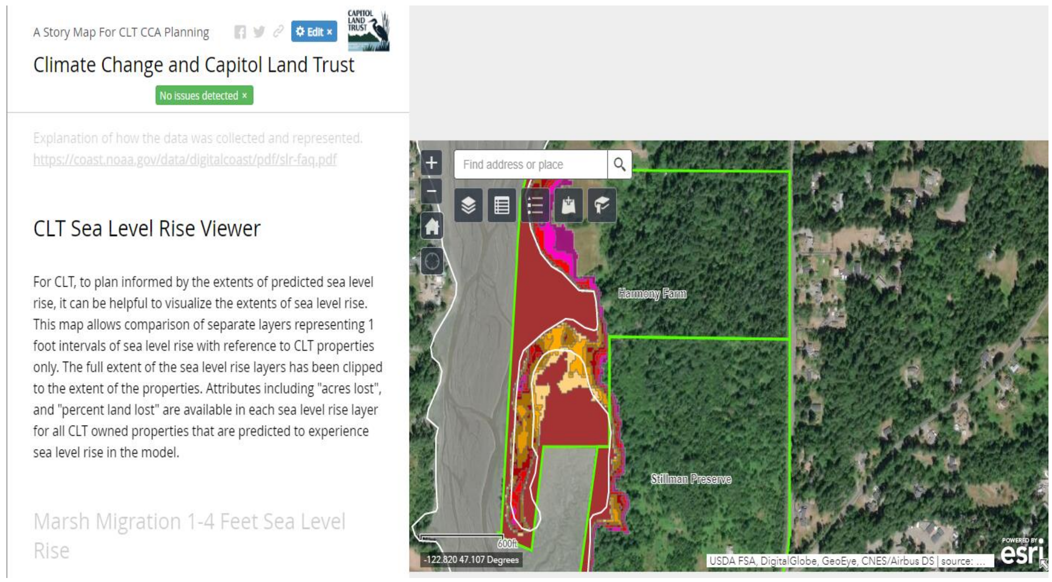


*Figure. 43 ArcGIS Online app created with foot interval data from NOAA, and CLT parcel outlines. Properties subject to sea level rise have slectable layers for each foot of sea level rise to visualise different sea level rise scenarios. Operations dashboard showing acres covered by the different layers is visualised in the operations dashbord app through interactive pie graphs for each foot interval of sea level rise fig. 31-41. Data credit: NOAA*

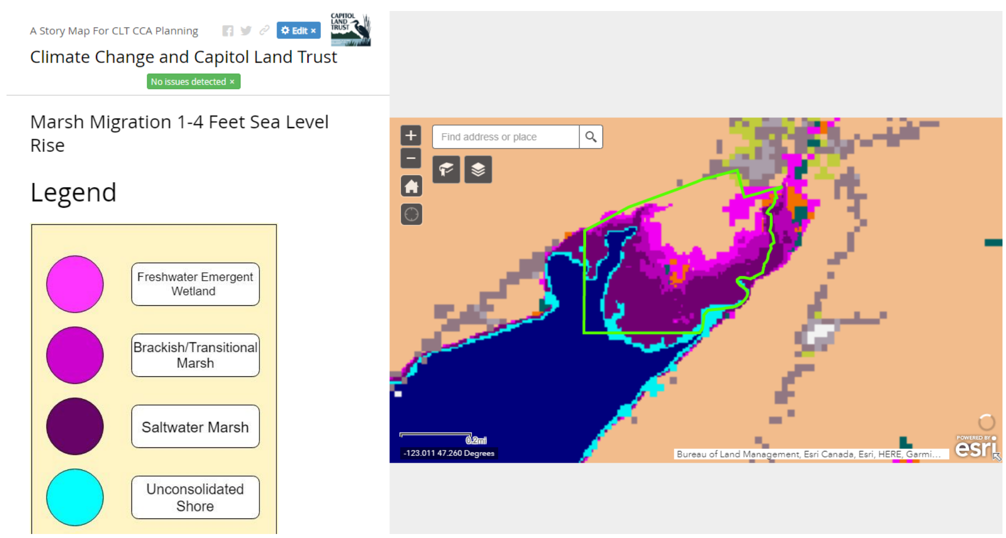


*Figure. 44 Marsh migration map app showing CLT property outlines for analysis. Projections include varying climate change scenarios. Data credit: NOAA*

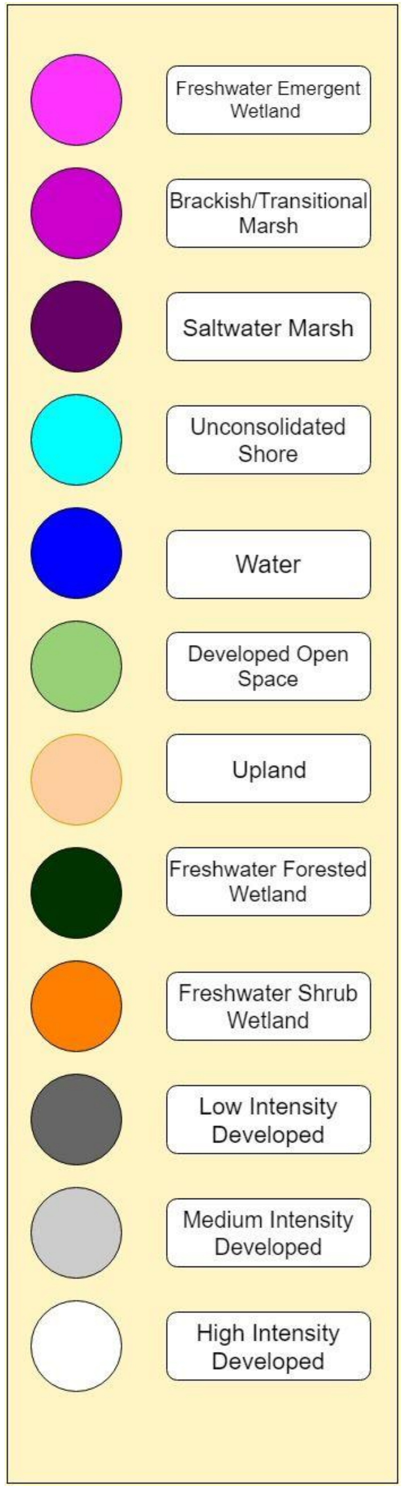


*Figure. 45 Key for marsh migration map. Credit: NOAA*

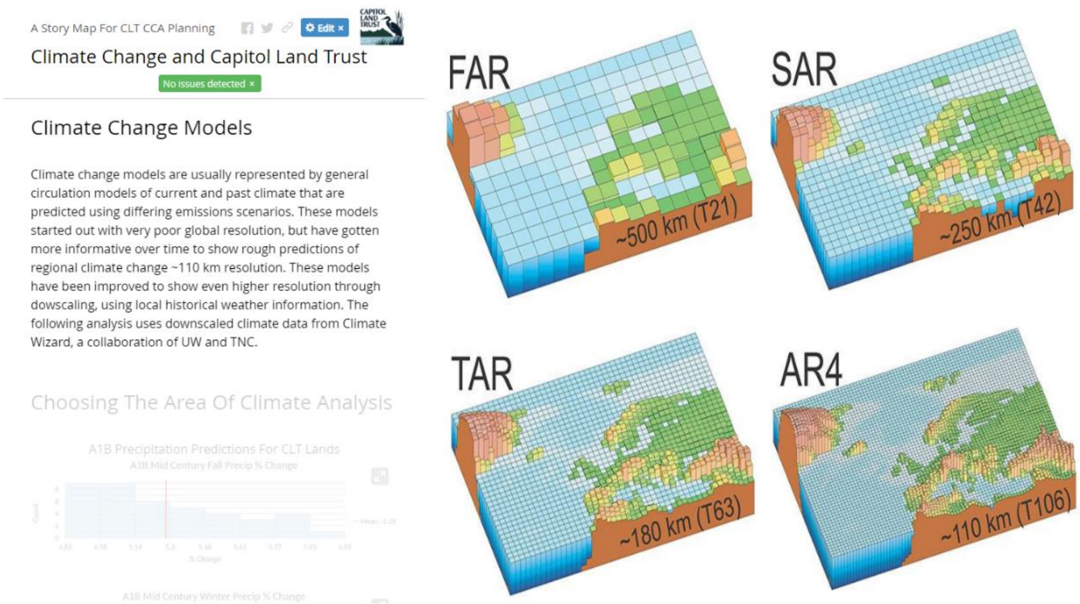


*Figure. 46 Explaination of the poor resolution of many climate change models, and how downscaling of climate models by using historical weather data can improve ressolution of climate change projections.*

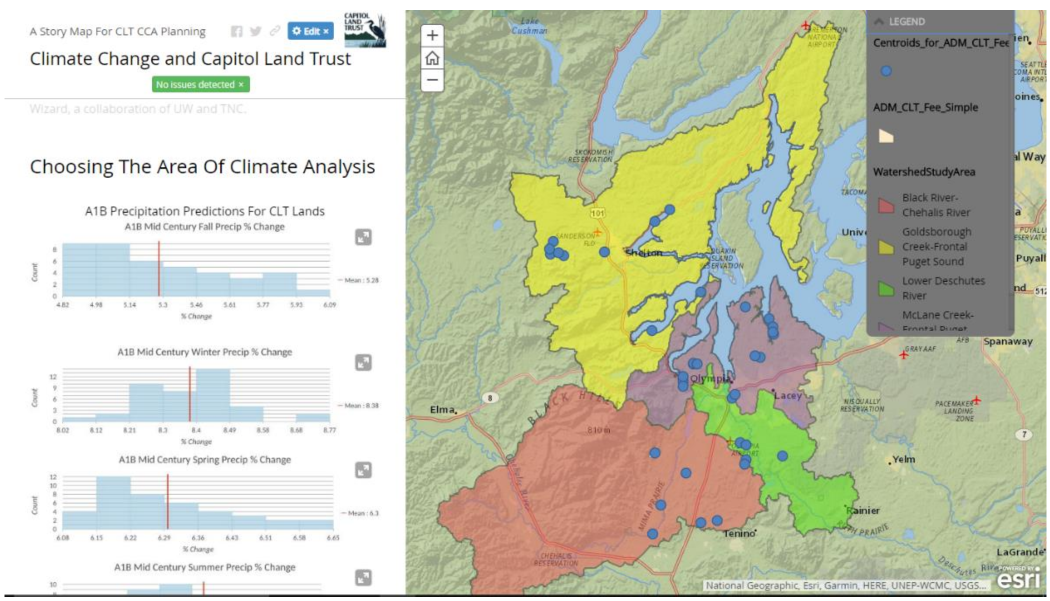


*Figure. 47 Watershed level area used to limit scope of climate change analysis. The different polygons represent watersheds containing the vast majority of CLT owned preserves. Serveral preserves outside of the area of analysis were agreed to be omitted as outliers by the geodesign team.*

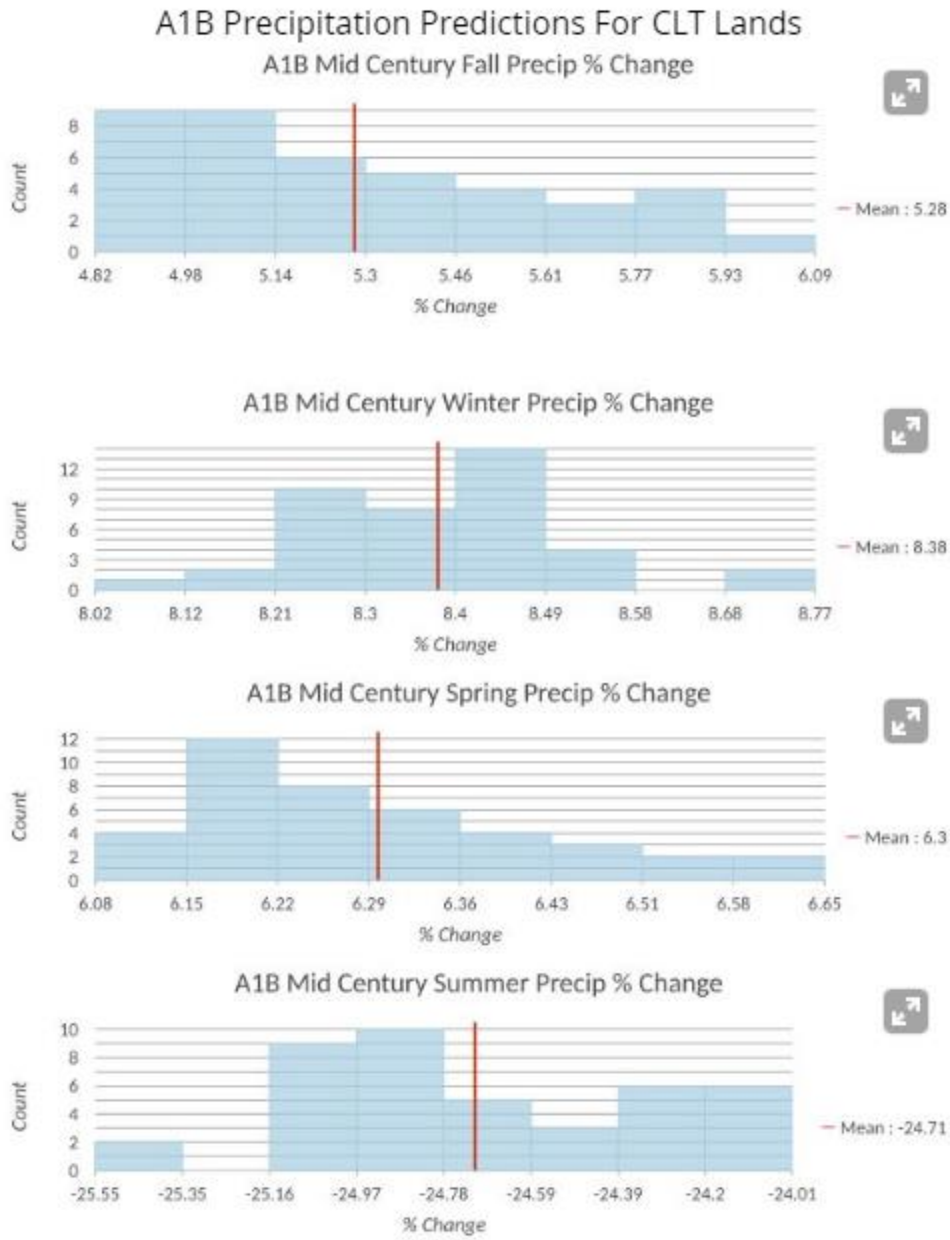


*Figure. 48 A1B scenario Mid century Climate Wizard precipitation predictions of watersheds containging the majority of CLT owned properties. Data represents percent change.*

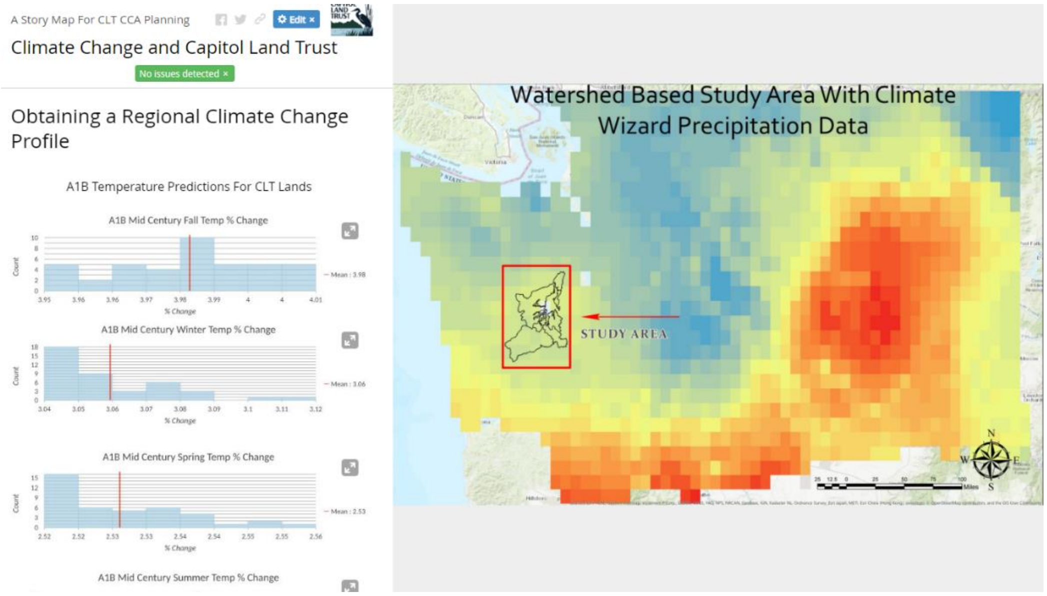


*Figure. 49 Main stage shows the resolution of the Climate Wizard data for the state of Washingtton and the footprint of the agreed upon study area.Side panel shows A1B scenario Mid century Climate Wizard tempearture predictions of watersheds containging the majority of CLT owned properties. Data represents percent change.*

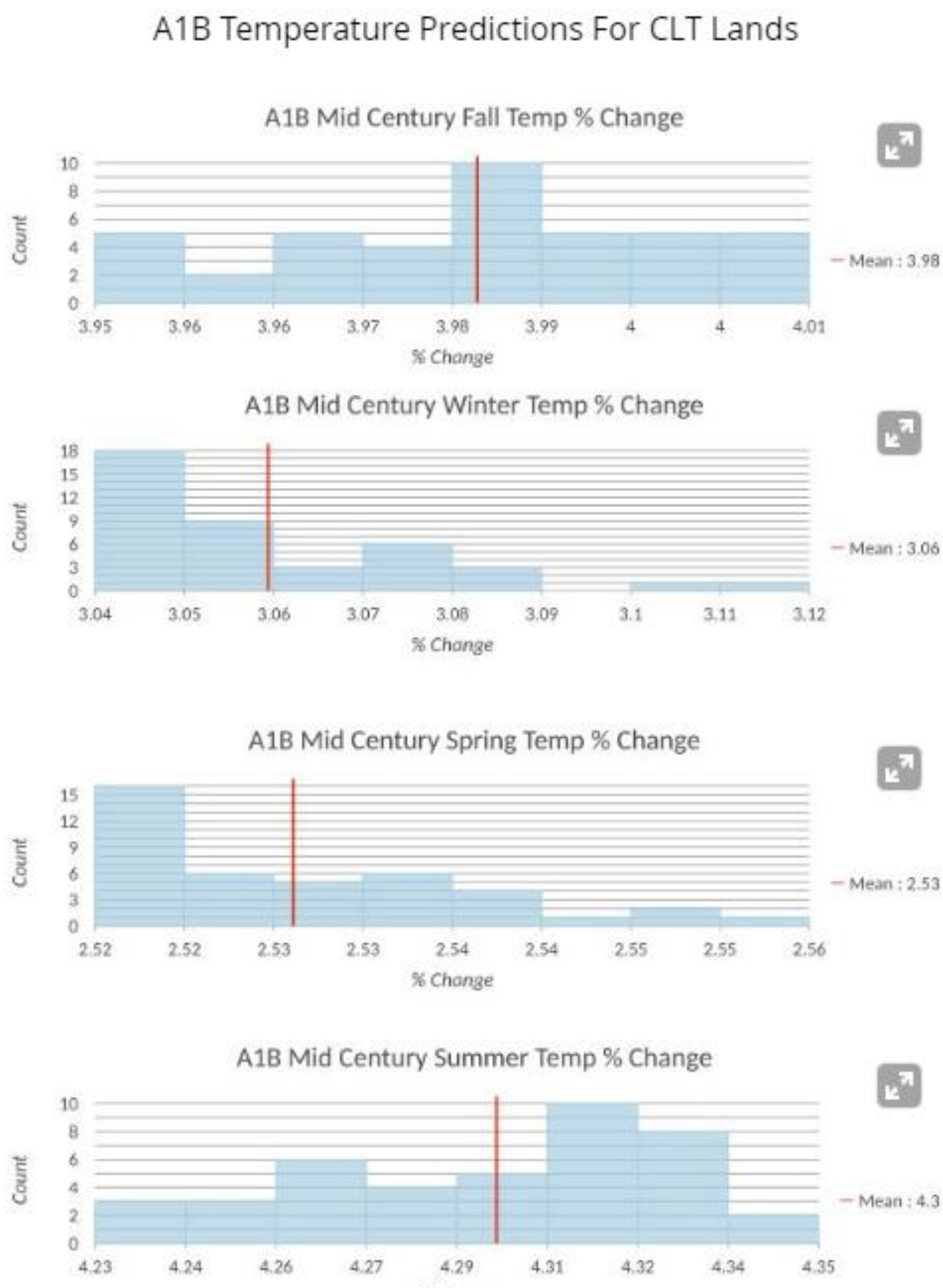


*Figure. 50 A1B scenario Mid century Climate Wizard temperature predictions of watersheds containging the majority of CLT owned properties. Data represents percent change.*

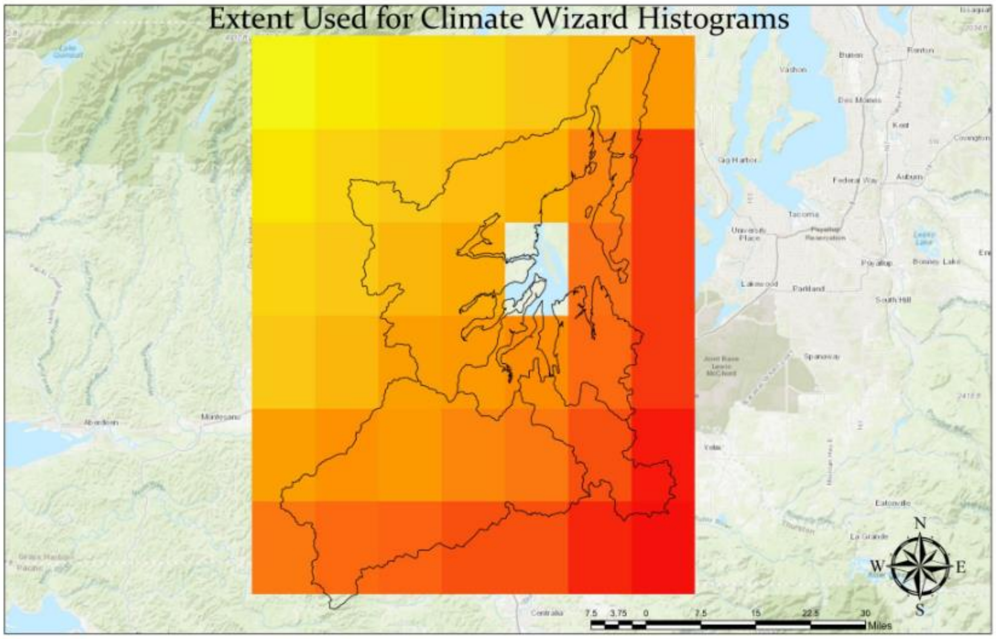


*Figure. 51 Extent of Climate Wizard data used in climate change histograms. Thin black polygon is the outline of watersheds containing the majority of CLT fee simple lands.*

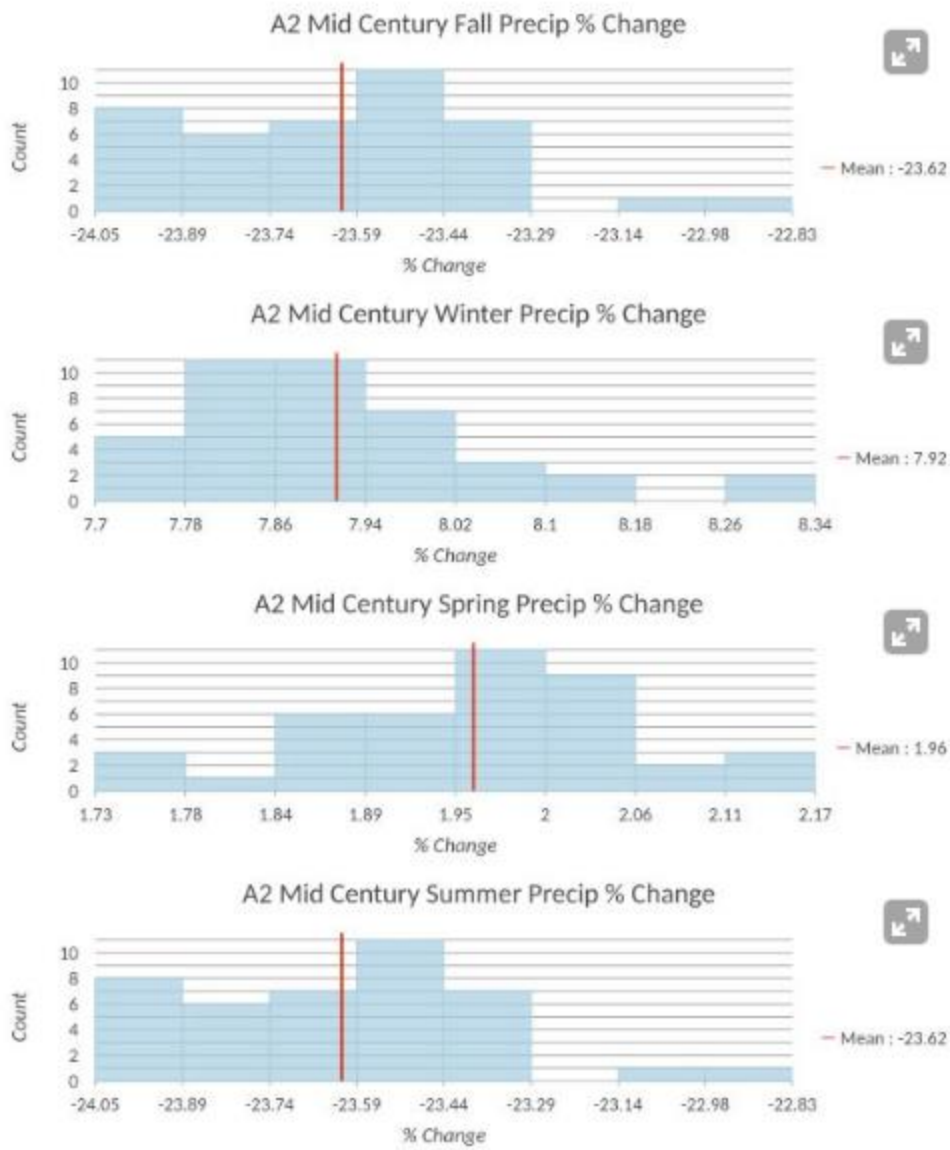


*Figure. 52 A2 scenario Mid century Climate Wizard precipitation predictions of watersheds containging the majority of CLT owned properties. Data represents percent change.*


*Figure. 53 A1B & A2 emission scenario Climate Wizard data for ad hoc service area. Variables represented are percent change of precipitation and temperature. Data represents mid century 2040-2060 projections. Histograms in side pane are seasonal A2 Temperature predictions.*

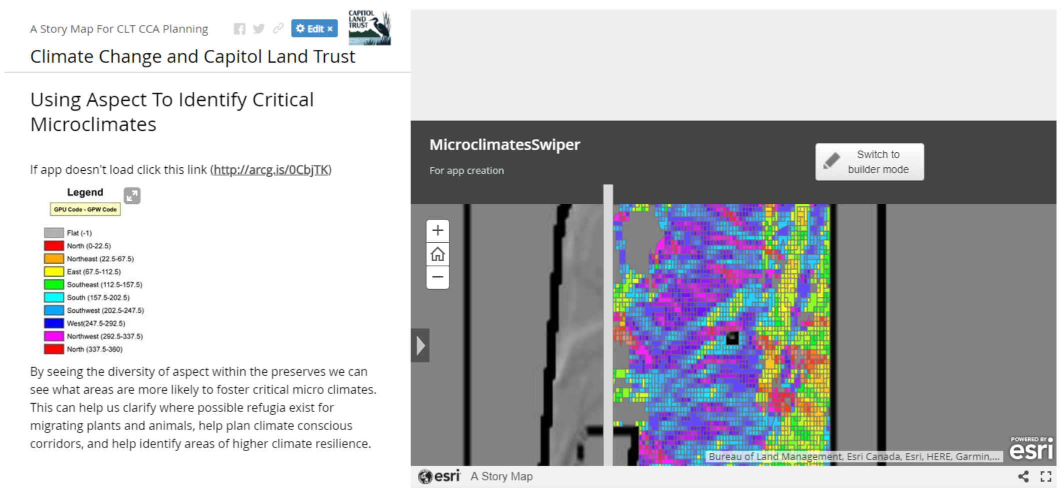


*Figure. 54 Aspect map app showing the aspect of CLT properties. Aspect is important to understand in order to establish microclimate sites that may be important refugia for species sensitive to climate change.*

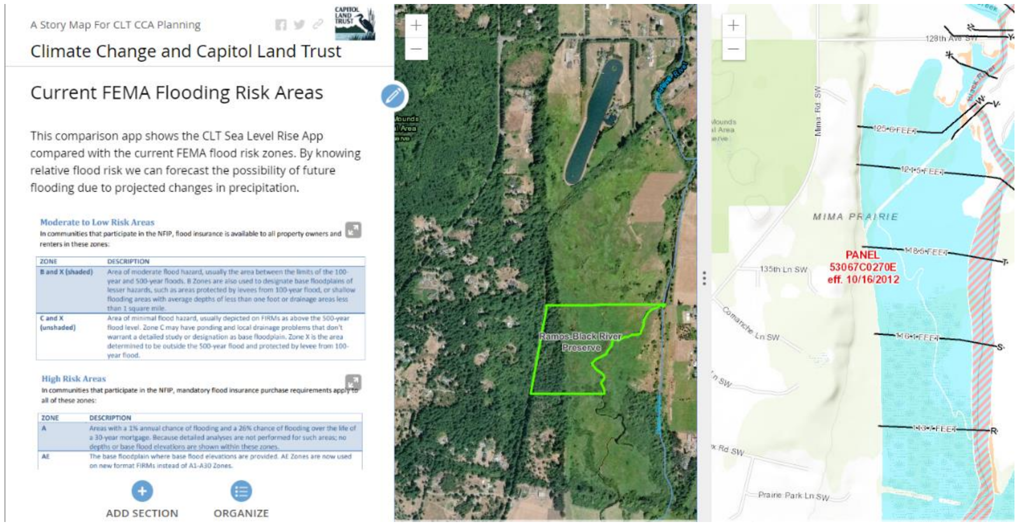


*Figure. 55 comparison app showing FEMA flood risk maps next to CLT property maps. Increased frequency of flooding events caused by climate change is important to assess for climate change adaptation. Understanding current risk is a step towards the goal of understanding future risk.*

**Moderate to Low Risk Areas**

In communities that participate in the NFIP, flood insurance is available to all property owners and renters in these zones:

| ZONE | DESCRIPTION |
|---|---|
| B and X (shaded) | Area of moderate flood hazard, usually the area between the limits of the 100-year and 500-year floods. B Zones are also used to designate base floodplains of lesser hazards, such as areas protected by levees from 100-year flood, or shallow flooding areas with average depths of less than one foot or drainage areas less than 1 square mile. |
| C and X (unshaded) | Area of minimal flood hazard, usually depicted on FIRMs as above the 500-year flood level. Zone C may have ponding and local drainage problems that don't warrant a detailed study or designation as base floodplain. Zone X is the area determined to be outside the 500-year flood and protected by levee from 100-year flood. |

*Figure. 56 FEMA codes for different flood class designations.*

## High Risk Areas

In communities that participate in the NFIP, mandatory flood insurance purchase requirements apply to all of these zones:

| ZONE | DESCRIPTION |
|---|---|
| **A** | Areas with a 1% annual chance of flooding and a 26% chance of flooding over the life of a 30-year mortgage. Because detailed analyses are not performed for such areas; no depths or base flood elevations are shown within these zones. |
| **AE** | The base floodplain where base flood elevations are provided. AE Zones are now used on new format FIRMs instead of A1-A30 Zones. |
| **A1-30** | These are known as numbered A Zones (e.g., A7 or A14). This is the base floodplain where the FIRM shows a BFE (old format). |
| **AH** | Areas with a 1% annual chance of shallow flooding, usually in the form of a pond, with an average depth ranging from 1 to 3 feet. These areas have a 26% chance of flooding over the life of a 30-year mortgage. Base flood elevations derived from detailed analyses are shown at selected intervals within these zones. |
| **AO** | River or stream flood hazard areas, and areas with a 1% or greater chance of shallow flooding each year, usually in the form of sheet flow, with an average depth ranging from 1 to 3 feet. These areas have a 26% chance of flooding over the life of a 30-year mortgage. Average flood depths derived from detailed analyses are shown within these zones. |
| **AR** | Areas with a temporarily increased flood risk due to the building or restoration of a flood control system (such as a levee or a dam). Mandatory flood insurance purchase requirements will apply, but rates will not exceed the rates for unnumbered A zones if the structure is built or restored in compliance with Zone AR floodplain management regulations. |
| **A99** | Areas with a 1% annual chance of flooding that will be protected by a Federal flood control system where construction has reached specified legal requirements. No depths or base flood elevations are shown within these zones. |

*Figure. 57 FEMA codes for different flood class designations (continued).*

### High Risk - Coastal Areas

In communities that participate in the NFIP, mandatory flood insurance purchase requirements apply to all of these zones.

| ZONE | DESCRIPTION |
|---|---|
| V | Coastal areas with a 1% or greater chance of flooding and an additional hazard associated with storm waves. These areas have a 26% chance of flooding over the life of a 30-year mortgage. No base flood elevations are shown within these zones. |
| VE, V1 - 30 | Coastal areas with a 1% or greater chance of flooding and an additional hazard associated with storm waves. These areas have a 26% chance of flooding over the life of a 30-year mortgage. Base flood elevations derived from detailed analyses are shown at selected intervals within these zones. |

### Undetermined Risk Areas

| ZONE | DESCRIPTION |
|---|---|
| D | Areas with possible but undetermined flood hazards. No flood hazard analysis has been conducted. Flood insurance rates are commensurate with the uncertainty of the flood risk. |

From FEMA Map Service Center:
http://msc.fema.gov/webapp/wcs/stores/servlet/info?storeId=10001&catalogId=10001&langId=-1&content=floodZones&title=FEMA%20Flood%20Zone%20Designations

*Figure. 58 FEMA codes for different flood class designations (continued).*

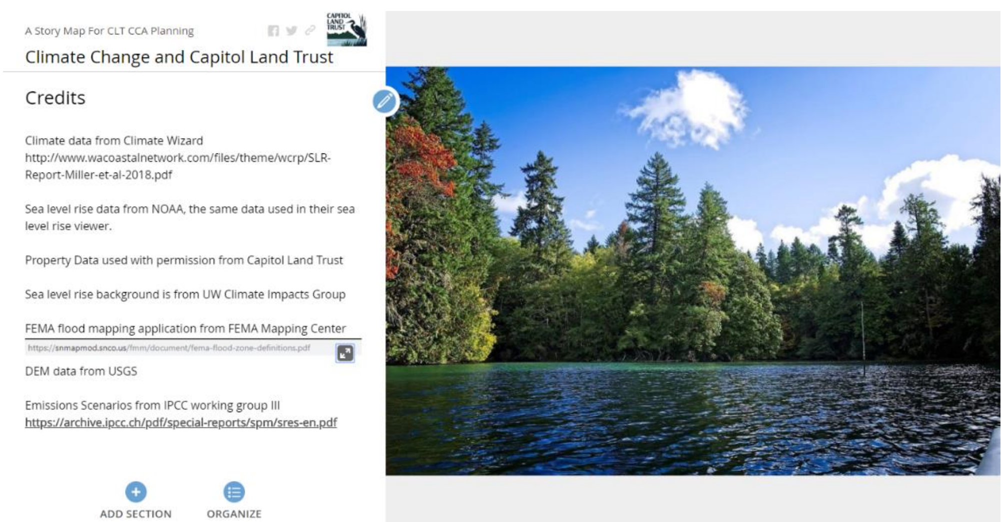


*Figure. 59 credits for data used in story map*

## Appendix B. Geodesign Streamlining PowerPoint


*Figure. 60 Title slide*

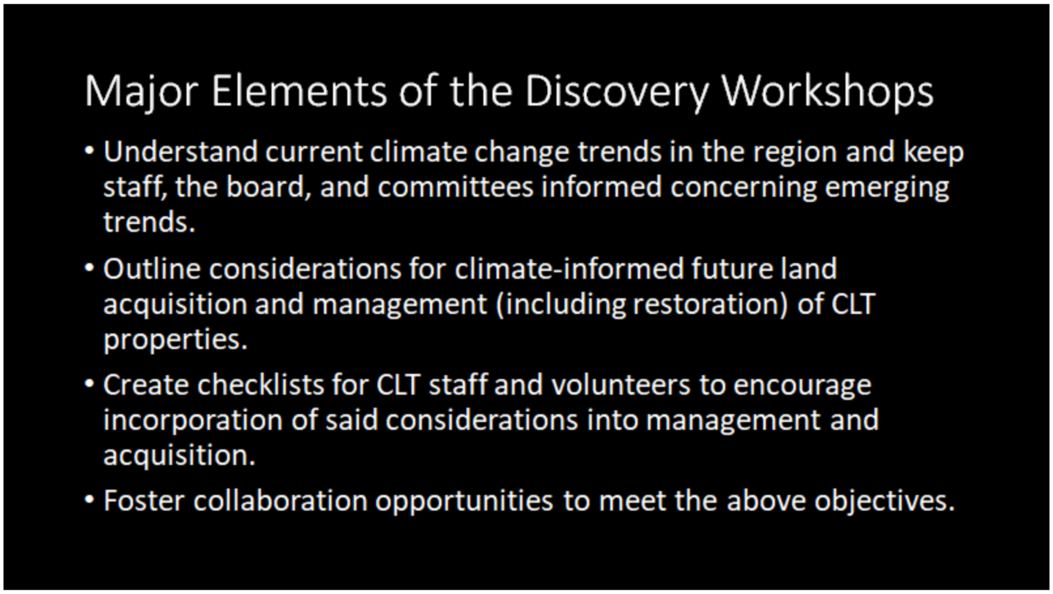


*Figure. 61 Major themes from geodesign workshop.*

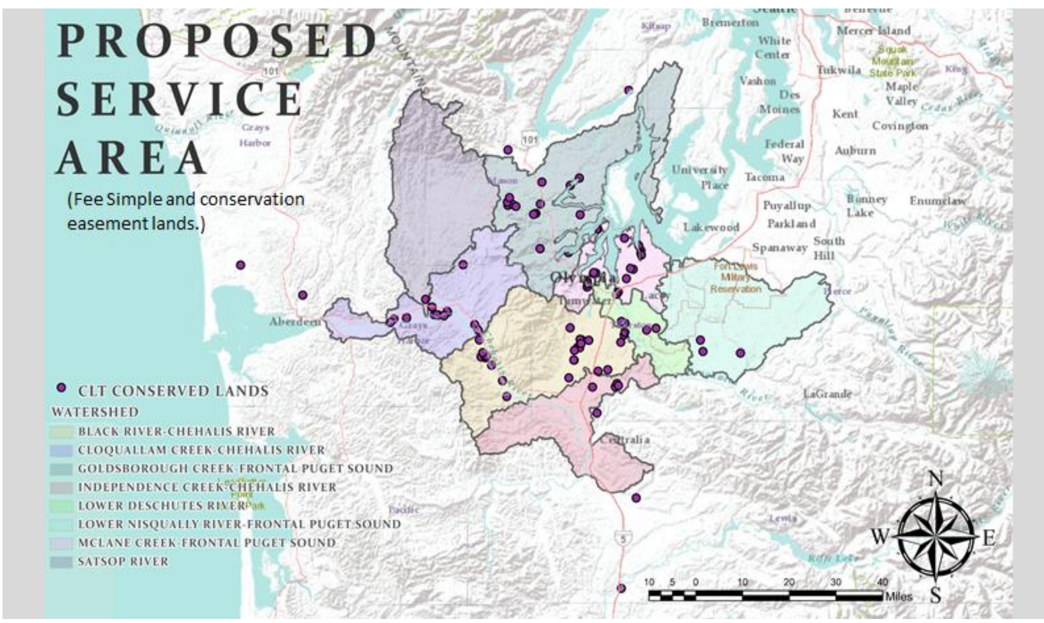


*Figure. 62 Map of watersheds containing the majority of CLT owned preserves & conservation easements. Establishment of an ad hoc service area was required for climate change analysis. Basemap imagery by ESRI.*

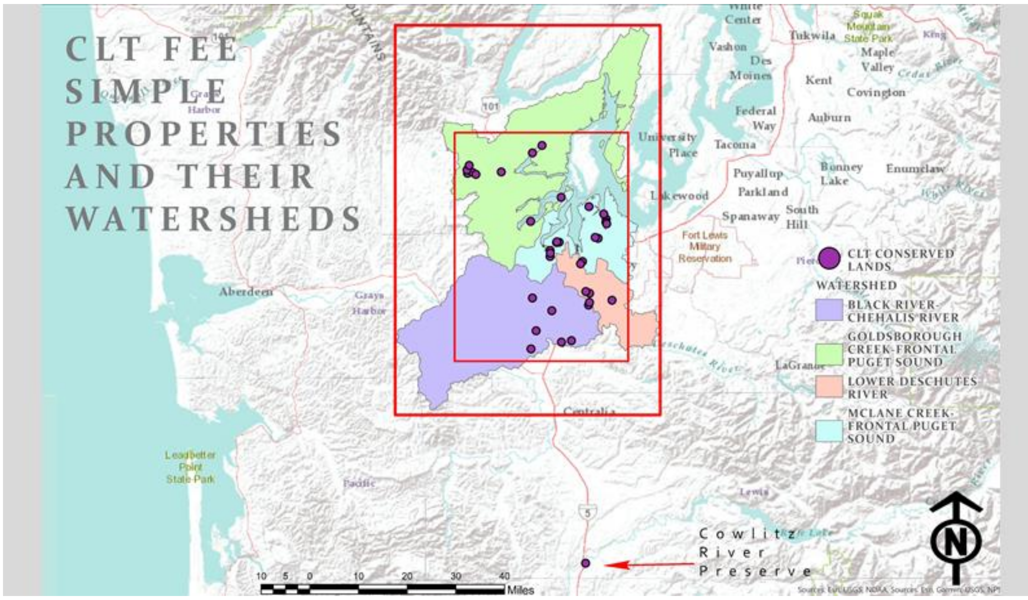


*Figure. 63 example of showing scales of analysis by using propert extents and service area extents. Service area extents were decided as preffered for analysis because of the need to include watershed level analysis of properties.*

## Changes outlined in the workshop, The good, the bad, the problems

| Attractive to change | Vulnerable to change | Problems |
|---|---|---|
| Potential carbon storage in expanding marshes | Increased drought and it's stress on multiple systems. | What risk elements can we mitigate and what can we adapt to? |
| Potential ecological benefits from naturalized plants | Decrease of beneficial insects | Potential legacy hazards from land acquisitions (pollution) |
| Outplanting experiments as seed source for assisted migration (potential for collaboration) | Effects of drought on water table | Policy statements do not currently have any procedures. For CCA to be implemented in policies procedures should be proposed. |
| Assisted Migration of Oregon Spotted Frog (potential for collaboration) | Increasing development/land prices (less potential for land acquisitions) | |
| Establishing new riparian corridors | Soil disturbance from restoration projects (increase in invasives) | |
| Assisting the winners of climate change | | |

*Figure. 64 change models from geodesign*

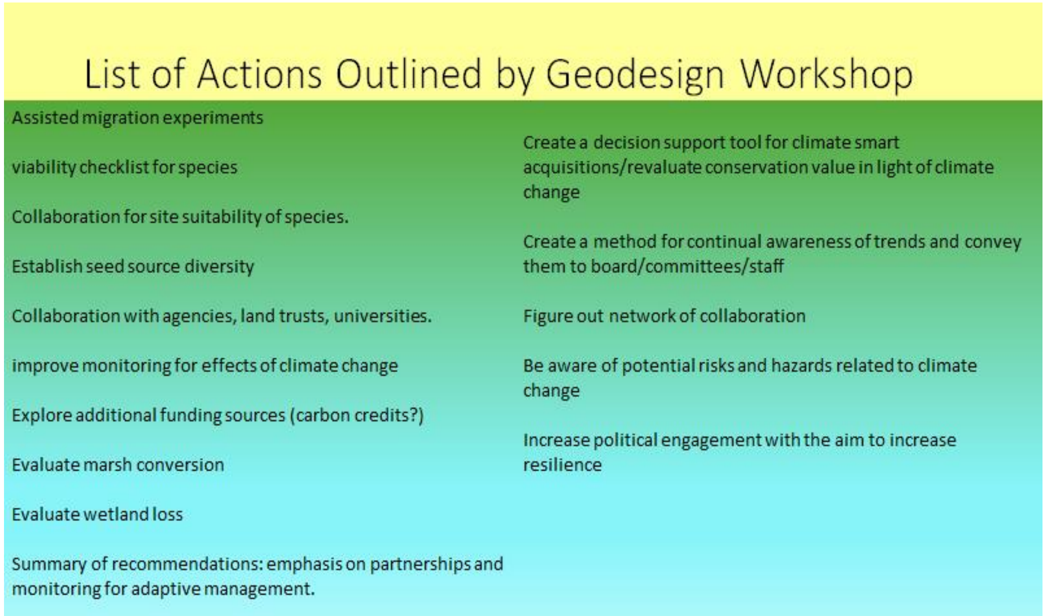


*Figure. 65 Actions proposed in CLT gesodesign*

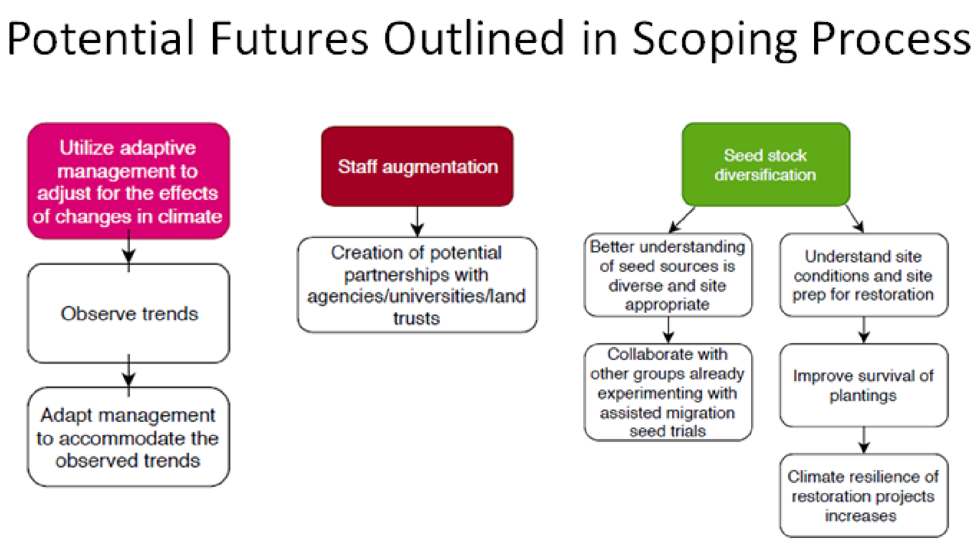


*Figure. 66 Potential Futures of using adaptive management, staff augmentation, and seed stock diversification for the purpose of climate change adaptation.*

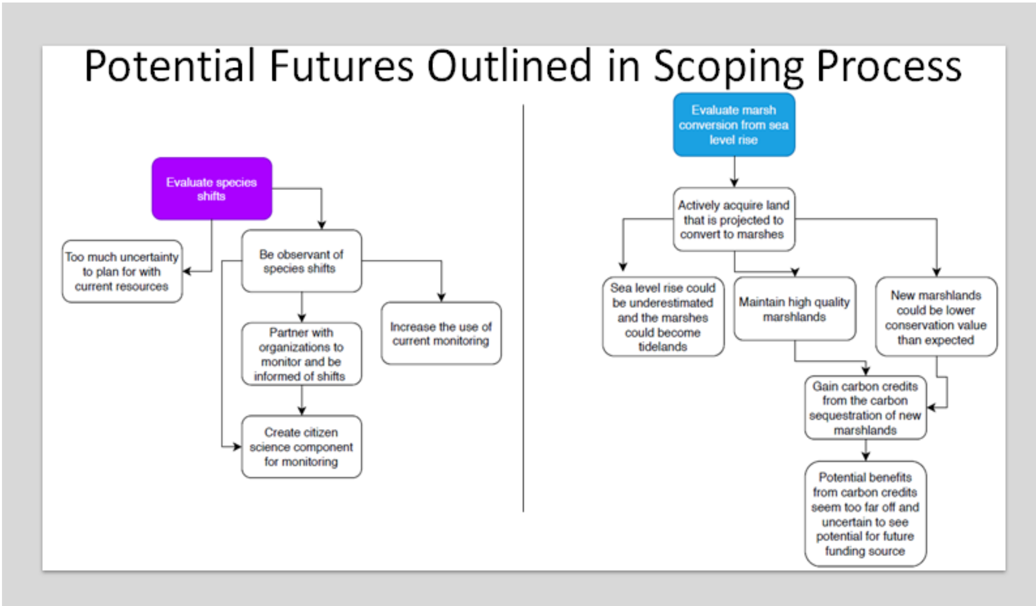


*Figure. 67 Potential futures highlighting the potential of evaluating marsh migration and species shifts with their relation to climate change.*


*Figure. 68 Three catagories of climate adaptation derived from the geodesign.*

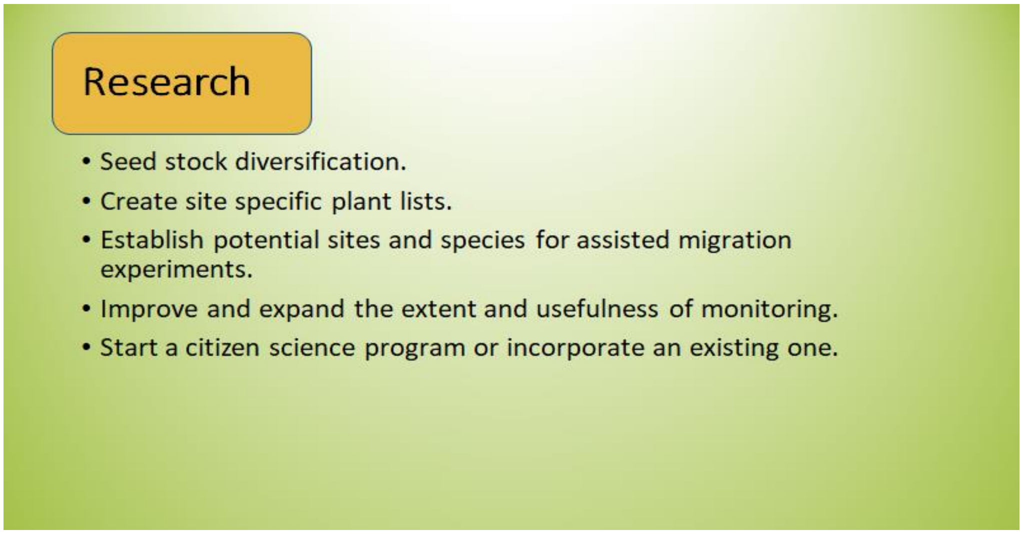


*Figure. 69 Research recommendations created by the geodesign team. Title of slide was later recommended to say Science instead of Research.*

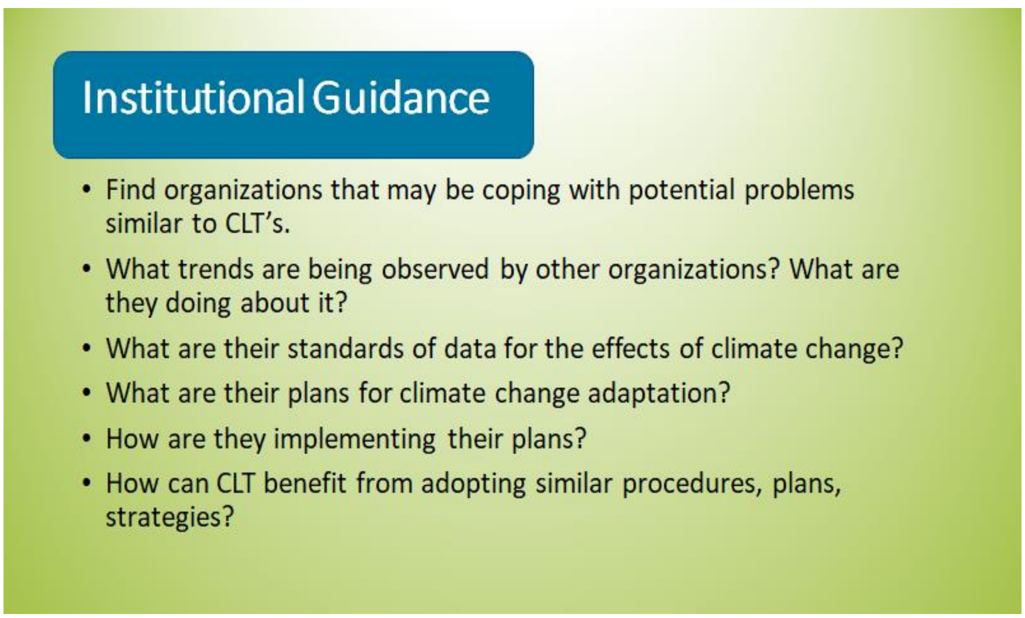


*Figure. 70 Recommendations for seeking institutional guuidance from other orginizations to create effective climate change policies/procedures.*


*Figure. 71 Recommendations for matching strategy with other orginizations to create effective partnerships/collaborations for resillience.*

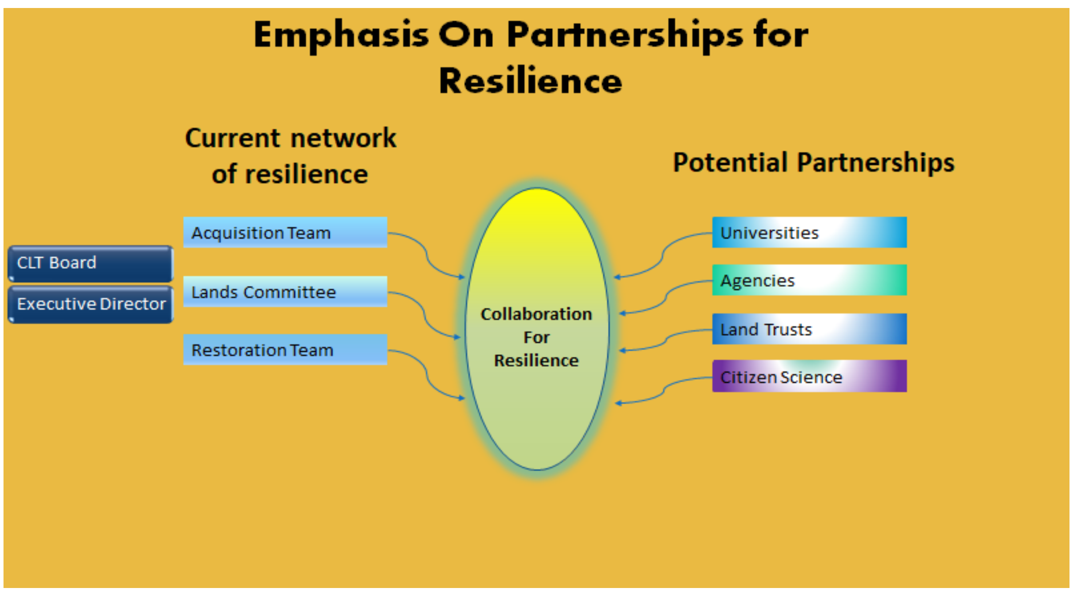


*Figure. 72 Visual depicting an orginizational strutcture for creating partnerships in climate change resillience.*

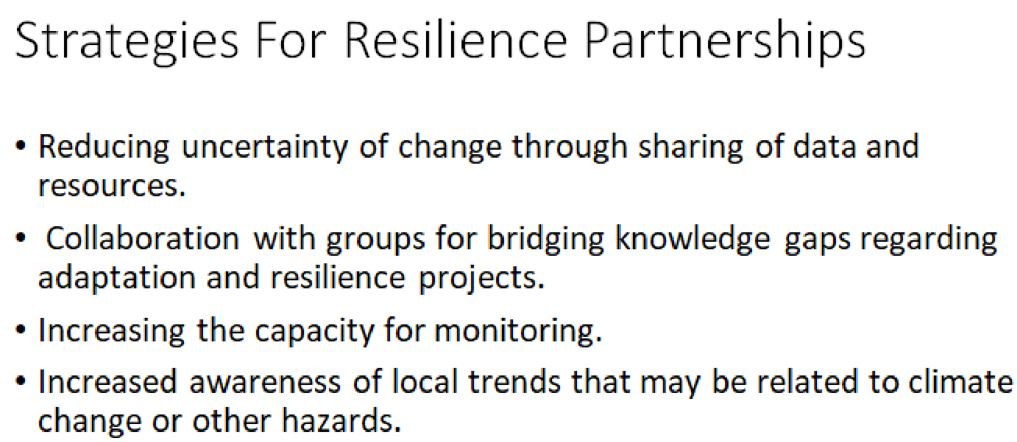


*Figure. 73 The four main actions that the geodesign proposed regarding the creation of partnerships for climate change adaptation.*

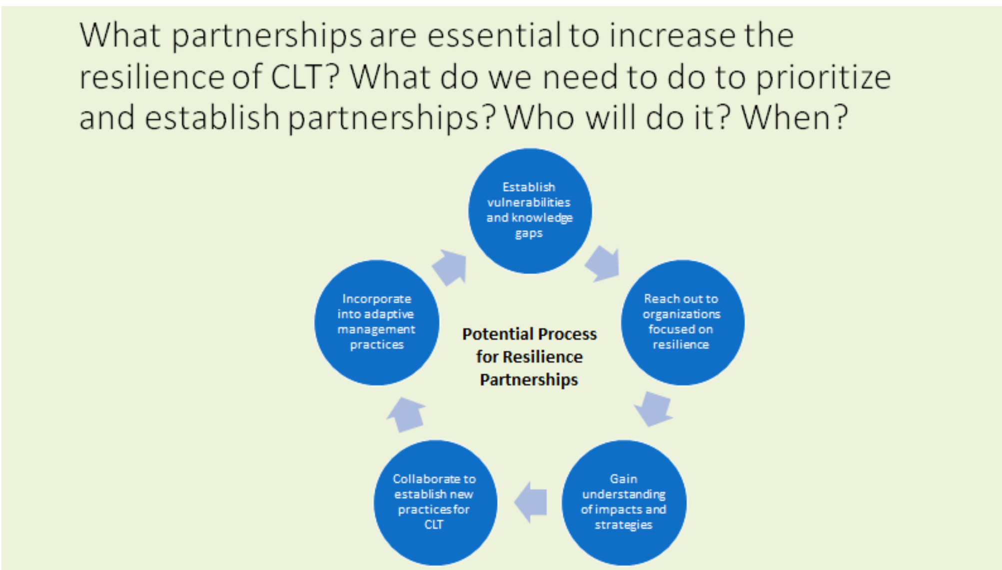


*Figure. 74 Proposed process for building partnerships for climate change resillience.*

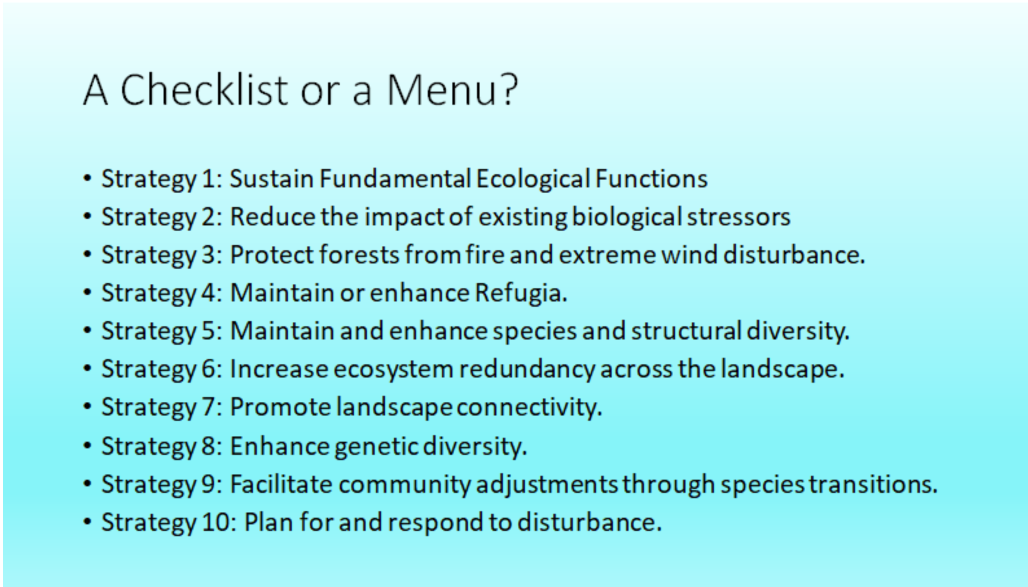


*Figure. 75 common climate change adaptation strategies. Part of: Forest Adaptation Resources, climate change tools (Swanston et al. 2016).*

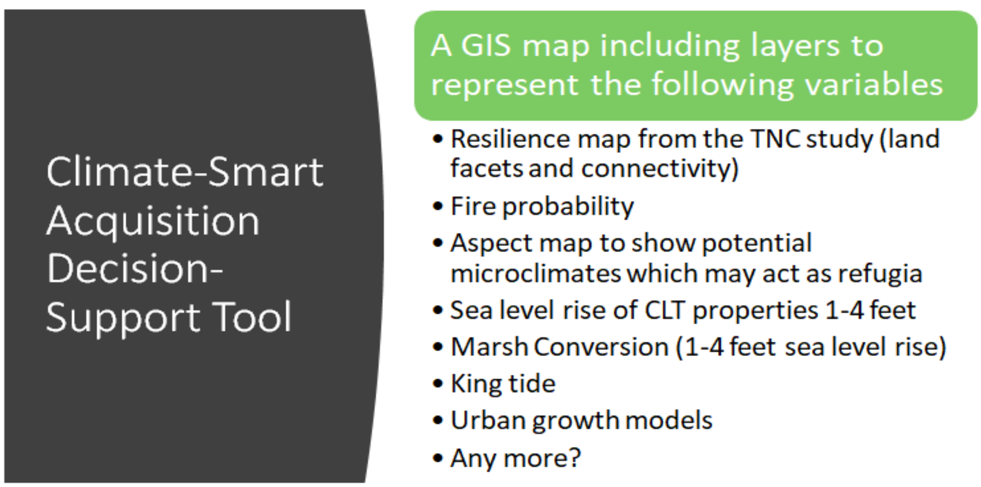


*Figure. 76 Maps created from this tool are represented in Appendix C. King tide was not able to be included. The tool is meant to be interactive so the maps created are only a crude visualization of the data. The tool is made to show potential effects to the landscape from climate change. The purpose of the tool is to include these variables into the considerations for future land acquisition.*

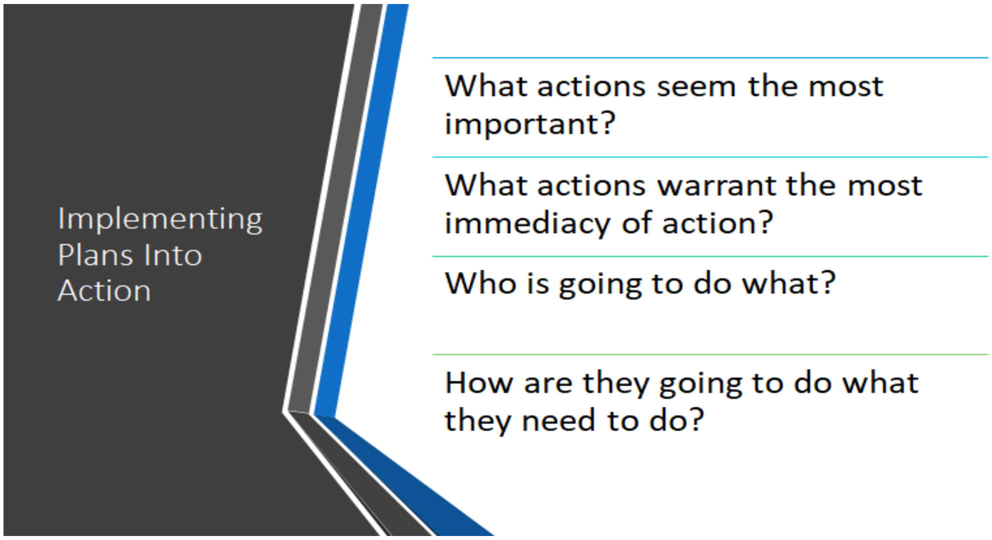


*Figure. 77 Questions spurring what actions need to occur.This section was seen as a decisions that would be made by the executive committee and the board.*

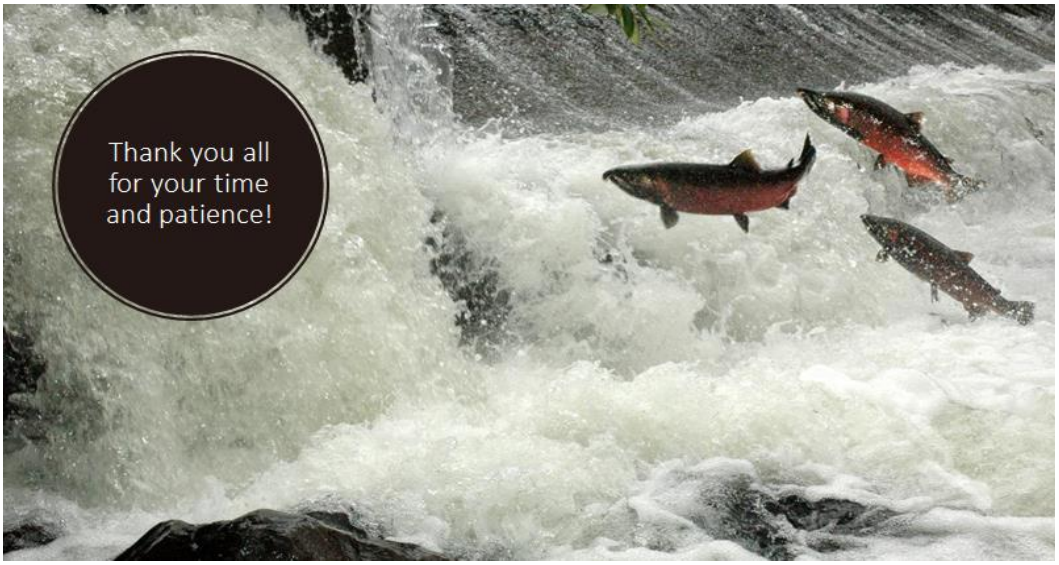


*Figure. 78 Concluding slide for streamlining of geodesign*

## Appendix C. Decision Support Tool

# Permeability of CLT Service Area

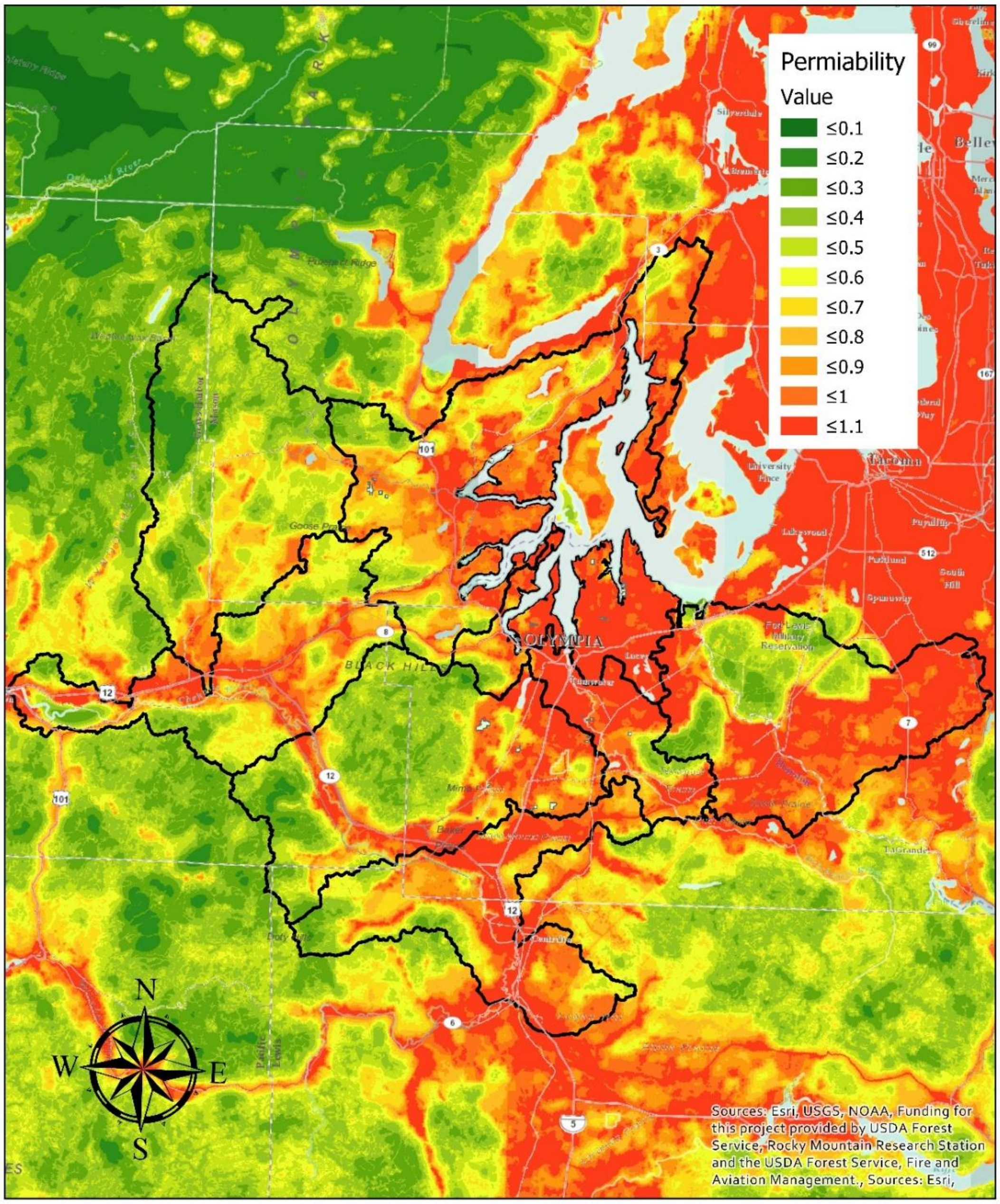


*Figure. 79 Landscape permeability of CLT's service area. Higher values indicate less permeability and lower values indicate higher permeability. Data Credit: (Buttrick et al., 2015)*

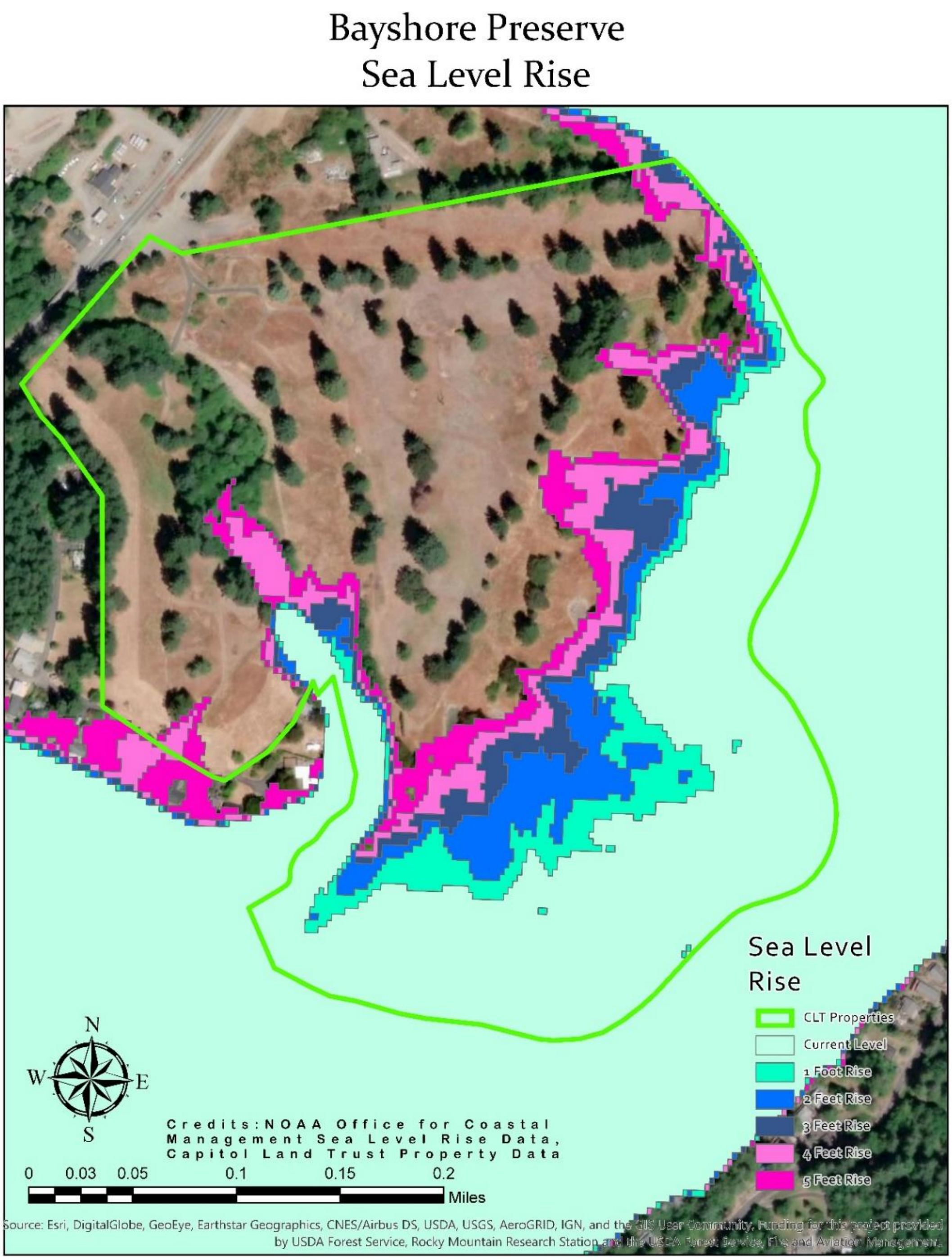


*Figure. 80 Close up of 1-foot intervals of sea level rise on one of CLT's public access properties: Bayshore Preserve.*

CLT Service Area Aspect Map

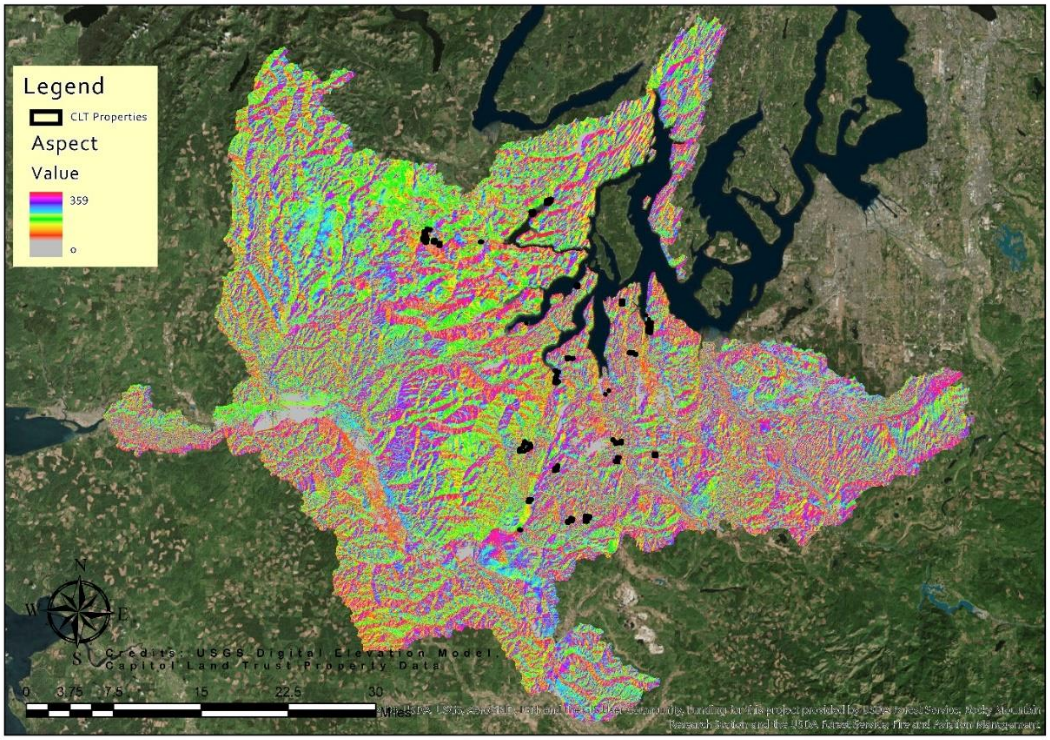


*Figure. 81 Aspect map symbolizing the cardinal direction that land is facing. By identifying aspect, potential microclimates can be identified. Microclimates can act as refugia for species migration.*

## Land Facet and Connectivity Resilience Map

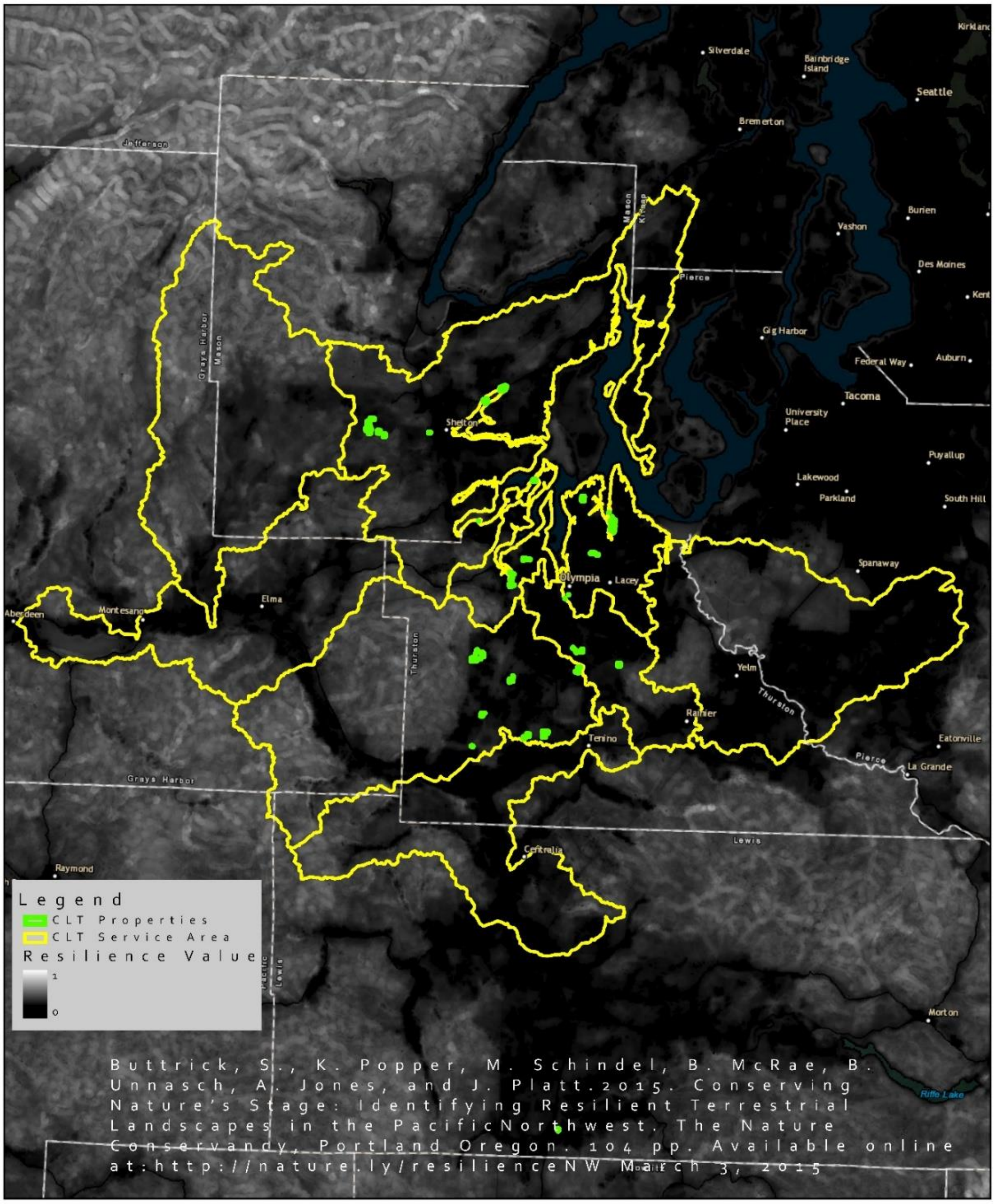


*Figure. 82 Map of TNC Resilience based on land facets and landscape connectivity. CLT service area is symbolized in yellow and properties in green. Resilience is scored on a decimal scale from 0-1 with 1 being higher resilience. Data Credit: (Buttrick et al., 2015)*

Fires Reported By WADNR 2000-2019

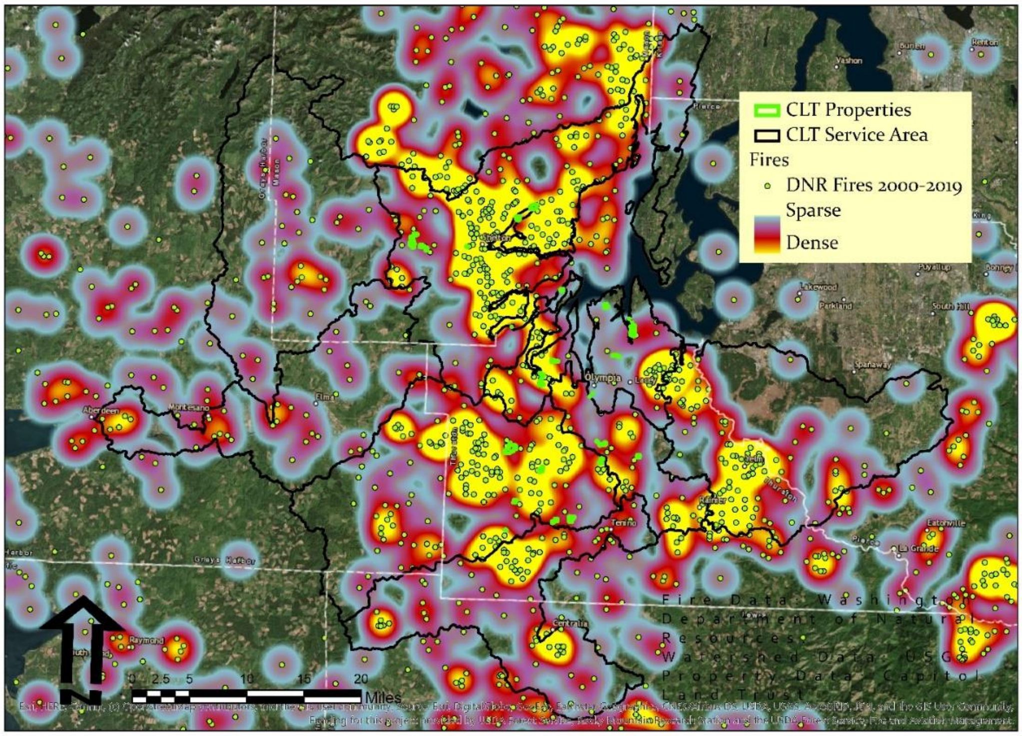


*Figure. 83 Heat map and point locations of fire locations within the CLT service area. CLT properties are outlined in neon green.*

2019 Land Cover Projection of CLT Service Area

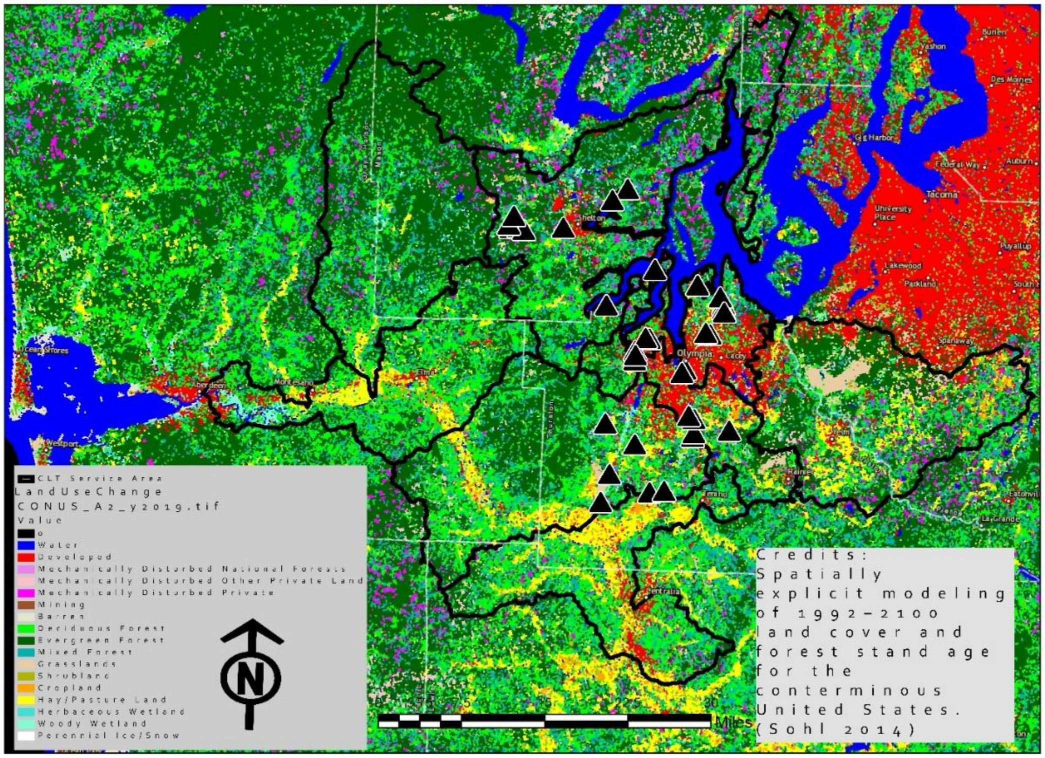


*Figure. 84 Projected land cover change for the year 2019. (Sohl 2018)*

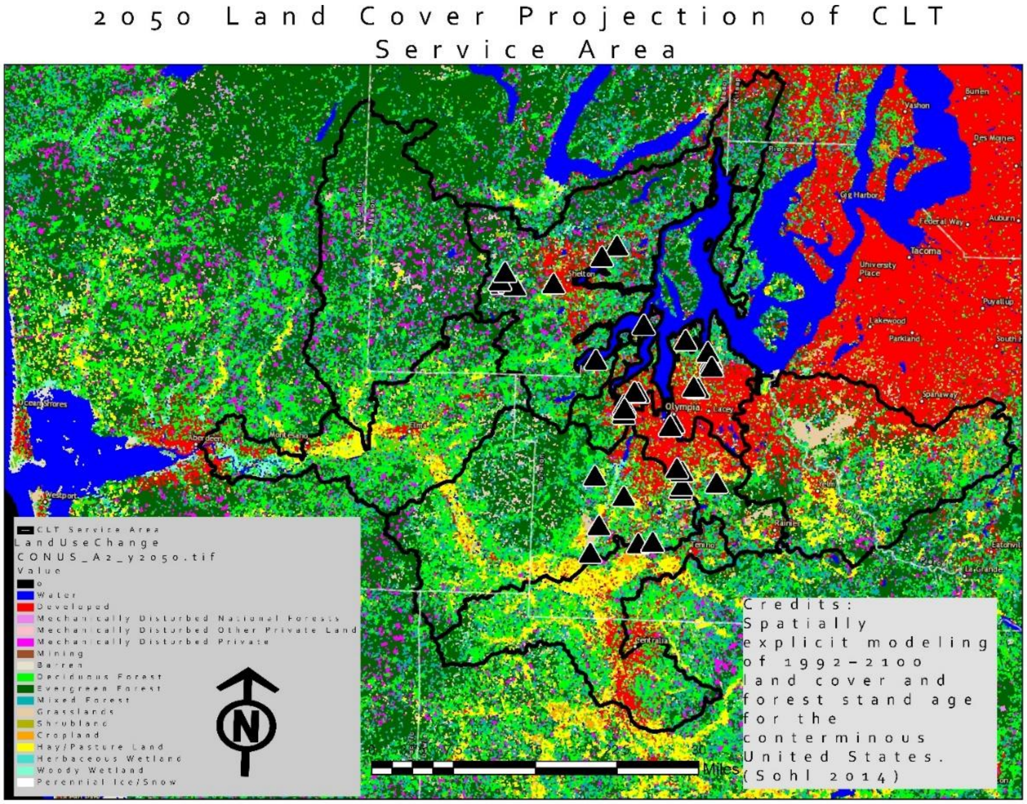


*Figure. 85 Projected landcover change for the year 2050. (Sohl, 2018)*

2019 WSDA Noxious Weed Sites

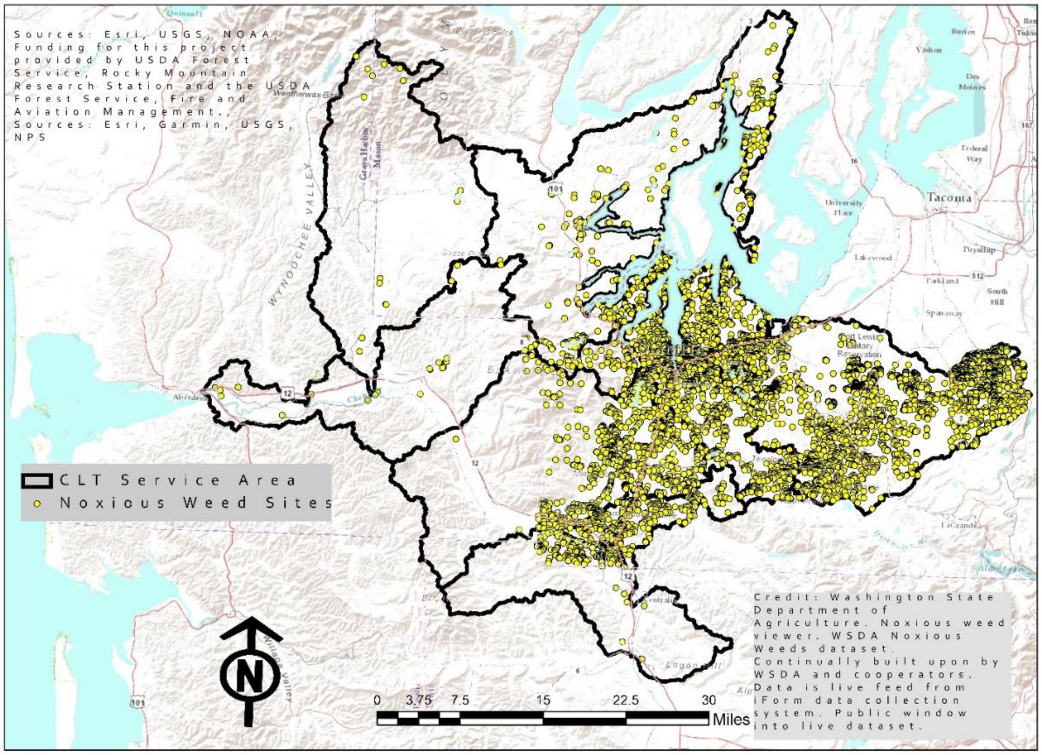


*Figure 86. Noxious weed locations located in CLT service area. Credit: Washington State Department of Agriculture. Retrieved 5/13/2019 from: https://services1.arcgis.com/cgAtrI0lk5jKC8Wy/arcgis/rest/services/WSDA_Weeds_Ongoing_PublicView/FeatureServer*

**Appendix D. Links to Data Sources: Story Map & Decision Support Tool**

WA DNR Fire Point Data

http://data-wadnr.opendata.arcgis.com/datasets/dnr-fire-statistics-2008-present

NOAA Sea Level Rise Data

https://coast.noaa.gov/slrdata/

NOAA Marsh Migration

https://www.coast.noaa.gov/arcgis/rest/services/dc_slr

Thurston County Weed Sites

https://gisdata-thurston.opendata.arcgis.com/datasets/thurston-noxious-weed-sites

USFS Fire Probability Model

https://www.fs.usda.gov/rds/archive/Product/RDS-2016-0034

Nature Conservancy Resilience and Permeability

https://s3-us-west-1.amazonaws.com/orfo/resilience/PNW_Scripts_BaseData_Results.zip

USGS DEMs

https://earthexplorer.usgs.gov/

TIGER county shapefile

https://catalog.data.gov/dataset/tiger-line-shapefile-2016-nation-u-s-current-county-and-equivalent-national-shapefile

USGS HUC-10 Watersheds

https://catalog.data.gov/dataset/usgs-national-watershed-boundary-dataset-wbd-downloadable-data-collection-national-geospatial-

Land Cover Projections (A2 scenario)

https://www.sciencebase.gov/catalog/item/5b96c2f9e4b0702d0e826f6d

Hamon AET: PET

Available upon request from NatureServe

Climate Wizard Climate Change Rasters (No longer available: Now available through the Climate Change Knowledge Portal: http://climatewizard.ciat.cgiar.org/index1.html)

http://www.climatewizard.org/

FEMA Flood Web Map

https://msc.fema.gov/portal/search?AddressQuery=thurston%20county%20wa

NOAA Sea Level Rise Viewer Web Map

https://coast.noaa.gov/slr/

Puget Sound Sea Level Rise Predictions with uplift and subsidence

https://www.google.com/maps/d/viewer?mid=1pV5E5BrM8wcsSF0ZguaSkk3C2u0xtH23&ll=47.52320314858822%2C-123.45035099999996&z=7

WSDA Noxious Weed Data

https://services1.arcgis.com/cgAtrI0lk5jKC8Wy/arcgis/rest/services/WSDA_Weeds_Ongoing_PublicView/FeatureServer

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