Envisioning Puget Sound Alternative Futures

PSNERP Final Report

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PUGET SOUND nearshore ECOSYSTEM RESTORATION PROJECT

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Executive Summary

Oregon State University, with support from the Washington Department of Fish and Wildlife and in support of the Puget Sound Nearshore Ecosystem Restoration Project, completed an analysis of alternative future regional trajectories of landscape change for the Puget Sound region. This effort developed three scenarios of change: 1) Status Quo, reflecting a continuation of current trends in the region, 2) Managed Growth, reflecting the adoption of an aggressive set of land use management policies focusing on protecting and restoring ecosystem function and concentrating growth within Urban Growth Areas (UGA) and near regional growth centers, and 3) Unmanaged Growth, reflecting a relaxation of land use restrictions with limited protection of ecosystem functions. Analyses assumed a fixed population growth rate across all three scenarios, defined by the Washington Office of Financial Management county level growth estimates. Scenarios were generated using a spatially- and temporally-explicit alternative futures analysis model, Envision, previously developed by Oregon State University researchers. The model accepts as input a vector-based representation of the landscape and associated datasets describing relevant landscape characteristics, descriptors of various processes influencing landscape change, and a set of *policies*, or decision alternatives, which reflect scenario-specific land management alternatives. The model generates 1) a set of spatial coverages (maps) reflecting scenario outcomes of a variety of landscape variables, most notably land use/land cover, shoreline modifications, and population projections, and 2) a set of summary statistics describing landscape change variables summarized across spatial reporting units. Analyses were run on each of such sub-basins in the Puget Sound, and aggregated to providing Sound-wide results. This information is being used by PSNERP to project future impairment of ecosystem functions, goods, and services. The Puget Sound Nearshore Ecosystem project data also provide inputs to calculate aspects of future nearshore process degradation. Impairment and degradation are primary factors being used to define future conditions for the PSNERP General Investigation Study.

Introduction

Like many areas, the Puget Sound is experiencing a number of drivers of change that are creating stressors on various ecosystem processes and functions. Key to successful management of growth and development in the area is a capability to explore alternative future scenarios capturing trajectories of change resulting from a range of possible management policies, strategies and plans. We have been involved in a number of the alternative futures analyses over the last fifteen years, and have developed a set of approaches and tools that has been effective in capturing policy and management alternatives reflecting different strategies for managing growth, playing those alternatives out in spatially and temporally explicit ways, assessing resulting impacts on a variety of ecological, social and economic processes using models defensibly capturing current available scientific knowledge, and presenting those results in forms that are easily understood by stakeholders and managers. This is not a trivial task, and to generate credible alternative landscape scenarios requires : 1) robust geospatial datasets which reflect important landscape attributes relevant to representing landscape change, 2) a rich capability for representing management policies explicitly in a decision-theoretic framework and capturing these as alternative scenarios, 3) understanding of and incorporation of both anthropogenic and natural processes affecting landscape change, and 4) a clear understanding of community goals and benchmarks by which to measure and compare sets of scenarios and the capability to assess these benchmarks in scientifically defensible ways.

In this report, we document the application of an alternative futures analysis framework that incorporates these capabilities to the analysis of alternative future trajectories in the Puget Sound region. This framework, *Envision* (Bolte et al, 2007; Hulse et al. 2008) is a spatially and temporally explicit, standards-based, open source toolset specifically designed to facilitate alternative futures analyses. It employs a multiagent-based modeling approach that contains a robust capability for defining alternative management strategies and scenarios, incorporating a variety of landscape change processes, and creating maps of alternative landscape trajectories, expressed though a variety of metrics defined in an application-specific way.

Scenario-based alternative futures studies are ways to explore plausible options for the future of a place, an organization, or a community, and to assess resulting impacts on relevant outcome metrics. These types of studies are being used in a widening array of situations in which people seek choice in their future and evidence that the future they are achieving is one they will want when it arrives (Carpenter 2002; Meadows 2003; Robinson 2003; Van Dijk 2003; Hulse et al. 2004; Busch 2006; Liotta and Shearer 2007). As they are more widely used, scenario-based studies are increasingly scrutinized for their adequacy within a growing range of modeling and decision-making constructs.

Envision creates probabilistic representations of hypothetical future land use trajectories based on a defined set of plausible future scenarios and can be used to track both economic and ecological consequences of those trajectories. Envision incorporates several ecosystem and economic models to create metrics of landscape services. It provides a policy-centric, spatially-explicit alternative futures scenario capability that is well suited to modeling key biophysical and socio-cultural processes at the temporal and spatial grains of human decision-making that drive landscape change. It also has the important characteristic of allowing users to model, for any single future scenario, a large number (100s to 1000s) of landscape change trajectories that are consistent with the values and policy choices of any given scenario. This allows a user of *Envision* to explore more fully the range of possible land use and land cover outcomes through stochastic sampling of parameter value probability distributions in multiple runs for each scenario, enabling not only the exploration of cross-scenario variability, but within-scenario variability and uncertainty associated with landscape- and site-level change, an important but generally overlooked aspect of scenario analysis.

The fundamental organizational structure used in Envision is shown in Fig. 1. Key elements in this organizational scheme are a landscape representation, agents, policies, landscape evaluators and autonomous landscape processes. Taken together, these elements provide a basic platform for assembling agent-based models of landscape change. Fundamental to Envision is the concept that agents make decisions in response to various socially-valued landscape products as well as their internal value systems, societal pressures resulting from the emergence of scarcity (as used in economics to indicate an insufficient supply of desired goods or services), and perceptions of the utility of adopting various policies in response to their goals. Envision models the feedbacks between the relationships of agent's values and behaviors, policy intentions and scarcity expressed through metrics of valued landscape productions. Taken together, Envision provides a framework for examining and simulating the coupled interactions and cyclical feedbacks among human actions, policy effects and landscape productions.

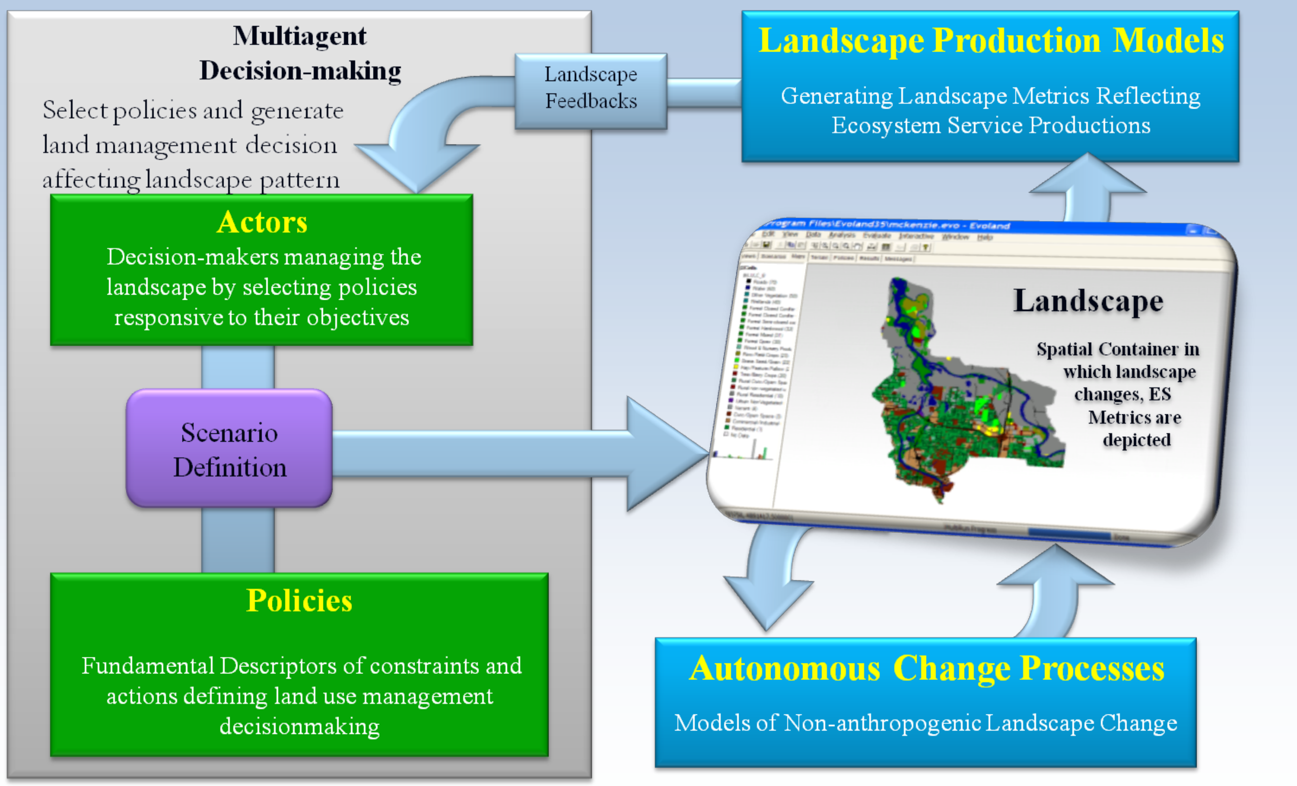


Figure 1. Envision Conceptual Structure

Policies in Envision are defined here as a decision or plan of action for accomplishing a desired outcome (Bolte et. al., 2007). Policies may be formal rules promulgated by government agencies or plans by individuals or private sector groups to accomplish a desired goal. Policies operationalize values and preferences within the constraints of means at hand to accomplish desired ends. A logically coherent group of policies assumed to be in force comprise a *scenario*. Within a scenario, agents adopt policies consistent with their values to bring about change. In our approach to landscape change modeling, this can be seen by changes in the trajectory of agent choices regarding policy options within and across multiple scenarios.

Envision uses a "pluggable" architecture that allows conformant models of landscape productions and autonomous landscape change processes to be included in its simulations and provide information that can be fed back into agent policy selection and decision-making. These models can span ecological, economic or socio-cultural dimensions. Autonomous landscape change models are used to model landscape change processes that are not a result of human decision-making, but occur independent of that decision-making. Characterizing emergent scarcity of valued landscape productions is an important aspect of Envision that is one factor that may influence agent decision-making. Envision allows user definition of which productions are considered valuable in a given study area. These productions are expressed in terms of scarcity, allowing a consistent framework to be used across ecological, economic and socio-cultural dimensions.

Multiagent models such as Envision have emerged recently as a useful paradigm for representing human behaviors and decision-making (Brown et al. 2005, Parker et al. 2003, Janssen and Jager 2000, Ostrom 1998) within the context of analyzing biocomplex interactions (Beisner et al. 2003, Holling 2001, Jager et al. 2000, Levin 1998, O'Neill et al. 1986). Multiagent modeling is a broad endeavor, relevant to many fields and disciplines with interest in modeling the behavior of autonomous, adaptive agents (actors). We choose Envision for this study because it provides a unique capability to explicitly represent policy alternatives, is spatially explicit, allows integration of multiple submodels, allows rich representation of both individual actor and institutional interaction and behaviors, and can model uncertainty in scenario outcomes via monte-carlo support. Furthermore, we have already used this model successively and are actively expanding its capabilities. Envision allows a rich description of human behaviors related to land management decision-making through the three-way interactions of *agents*, who have decision making authority over parcels of land, the *landscape* which is changed as these decisions are made, and the *policies* that guide and constrain decisions. In Envision, agents are entities that make decisions about the management of particular portions of the landscape for which they have management authority, based on balancing a set of objectives reflecting their particular values, mandates, and the policy sets in force on the parcels they manage. These values are correlated with demographic characteristics and, in part, guide the process agents use to select policies to implement. Policies consistent with agents' values are more likely to be selected. Policies in Envision capture rules, regulations, and incentives and other strategies promulgated by public agencies in response to demands for ecological and social goods, as well as considerations used by private landowners/land managers to make land use decisions. They contain information about site attributes defining the spatial domain of application of the policy, whether the policy is mandatory or voluntary, goals the policy is intended to accomplish, and the duration for which the policy, once applied, will be active at a particular site. Envision represents a landscape as a set of polygon-based geographic information system (GIS) maps and associated information containing spatially explicit depictions of landscape attributes and patterns. As agents assess alternative land management options, they weigh the relative utility of potentially relevant policies to determine what policies they will select to apply at any point in time/space, if any. Once applied, a policy outcome is triggered, modifying site attributes, resulting in landscape change. Policies may also be constrained to operating only with selected agent classes (e.g., homeowners, owners near federal lands, owners with scenic views etc.).

Assumptions, Limitations and Constraints of this Analysis

A number of limitations and constraints were imposed during the data development and modeling phases of this project. These are summarized below:

1) Only datasets that were available for the entire Puget Sound study area were employed in the analysis. This affected a number of data attributes, most notably zoning and land use/land cover (LULC). A consistent zoning coverage for Puget Sound does not currently exist. Zoning coverages were collected for each county and a consolidated zoning designation was developed and is included in the IDU coverage; however, county datasets generally did not include zoning within Urban Growth Areas (UGA). For LULC, only a limited-attribute coverage (NOAA-CCAP, based on National Landcover Data (NLCD) classes) is available Sound-wide: this lack of detailed LULC classes significantly limits the expression of detail of land use/land over in the representation of current (ca. 2002) and projected future conditions.

2) No satisfactory methods for extending road networks in the future scenarios currently exists. Therefore, road networks are considered fixed in this analysis.

3) UGA's were assumed to be fixed through the analysis period

4) The same policy sets were applied in each sub-basin – no sub-regional differences in policies were considered.

5) Climate change impacts, including sea-level rise or increased migration due to severe climate impacts (i.e. climate refugees), were not considered in this analysis.

6) Population growth was assumed to be the same in all scenarios, and was based on the medium estimates of population growth for each county provided by the Washington State Office of Financial Management, distributed across each sub-basin using area-weighted county-level estimates.

7) No demographic shifts or corresponding shifts in choice behavior were considered throughout the analysis period.

8) For certain processes (armoring, dock/marina counts/areas), fixed ratios by development class were assumed based on existing Sound-wide relationships.

Approach

In this section, we describe the approach used to develop three alternative futures scenarios. This approach involves three primary aspects: 1) dataset development, 2) policy development, and 3) modeling efforts using the Envision alternative futures toolkit.

Dataset development

Envision employs a spatially-explicit representation of the landscape, consisting of a set of polygons, termed Integrated Decision Units (IDUs) that contain multiple attributes describing polygon characteristics. These IDUs form the fundamental spatial unit for actor decision-making in Envision. The IDU coverage for this analysis was create by intersecting several primary data sources: 1) NLCD Landcover data, as summarized by the PSNERP Change Analysis project 2) watershed boundaries defined by the PSNERP Change Analysis datasets, and 3) UGA boundaries. This resulted in a coverage with roughly 450,000 polygons (IDU's) for the Puget Sound region. These were divided into sub-basins (Figure 2) for this analysis to simplify data handling tasks. These polygons were further attributed with a variety of relevant datasets summarized in the Table 1:

Dataset	Source	Use
Geographic Survey Units	PSNERP Change Analysis –derived from many additional sources	Used in part to delineate IDUs; primary source of attribute data
Ownership	PSNERP Change Analysis –derived from many additional sources	Primary source of attribute data, used in policies
Protected lands	PSNERP Change Analysis –derived from many additional sources	Primary source of attribute data, used in policies
NLCD landcover	PSNERP Change Analysis –derived from many additional sources	Used in part to delineate IDUs; primary source of attribute data
Census2000 block-groups	Geolytics, Inc. http://www.censuscd.com/USCensus,Census-2000-Long-Form,Products.asp	Used in part to delineate IDUs; primary source of attribute data
Urban growth areas	County GIS datasets	Used in part to delineate IDUs; primary source of attribute data
Incorporated areas	Washington State Office of Financial Management	Used in part to delineate IDUs; primary source of attribute data
County zoning data	Washington State Office of Financial Management	Used in part to delineate IDUs; primary source of attribute data
FEMA 100 yr floodplain	Washington State Department of Ecology	Used in part to delineate IDUs; primary source of attribute data
Puget Sound viewsheds	Developed as part of FRAP. Based on elevation data from USGS NHD+ data	Used in part to delineate IDUs; primary source of attribute data
Coastal landslide hazards	Washington State Department of Ecology	Used in part to delineate IDUs; primary source of attribute data
NHD+ stream network	USGS	Attribute data
Road network	PSNERP Change Analysis –derived from many additional sources	Attribute data
Coast line geometry	PSNERP Change Analysis –derived from many additional sources	Attribute data
Inactive railroads	PSNERP Change Analysis –derived from many additional sources	Attribute data
Active railroads	PSNERP Change Analysis –derived from many additional sources	Attribute data
Over water structures	PSNERP Change Analysis –derived from many additional sources	Attribute data
Impervious area	PSNERP Change Analysis –derived from many additional sources	Attribute data
Historical nearshore wetlands	PSNERP Change Analysis –derived from many additional sources	Attribute data
Nearshore wetlands	PSNERP Change Analysis –derived from many additional sources	Attribute data

Armor length	PSNERP Change Analysis –derived from many additional sources	Attribute data
Tidal barriers	PSNERP Change Analysis –derived from many additional sources	Attribute data
Herring spawning areas	PSNERP Change Analysis –derived from many additional sources	Attribute data
Regional growth centers	Developed as part of FRAP.	Attribute data

Table 1. A listing of datasets from which IDU attributes were developed.

Complete metadata is included in Appendix 1. Descriptions of each field used in the analysis are available at http://envision.bioe.orst.edu/StudyAreas/PugetSound/FieldInfo/PS_Fieldinfo.html

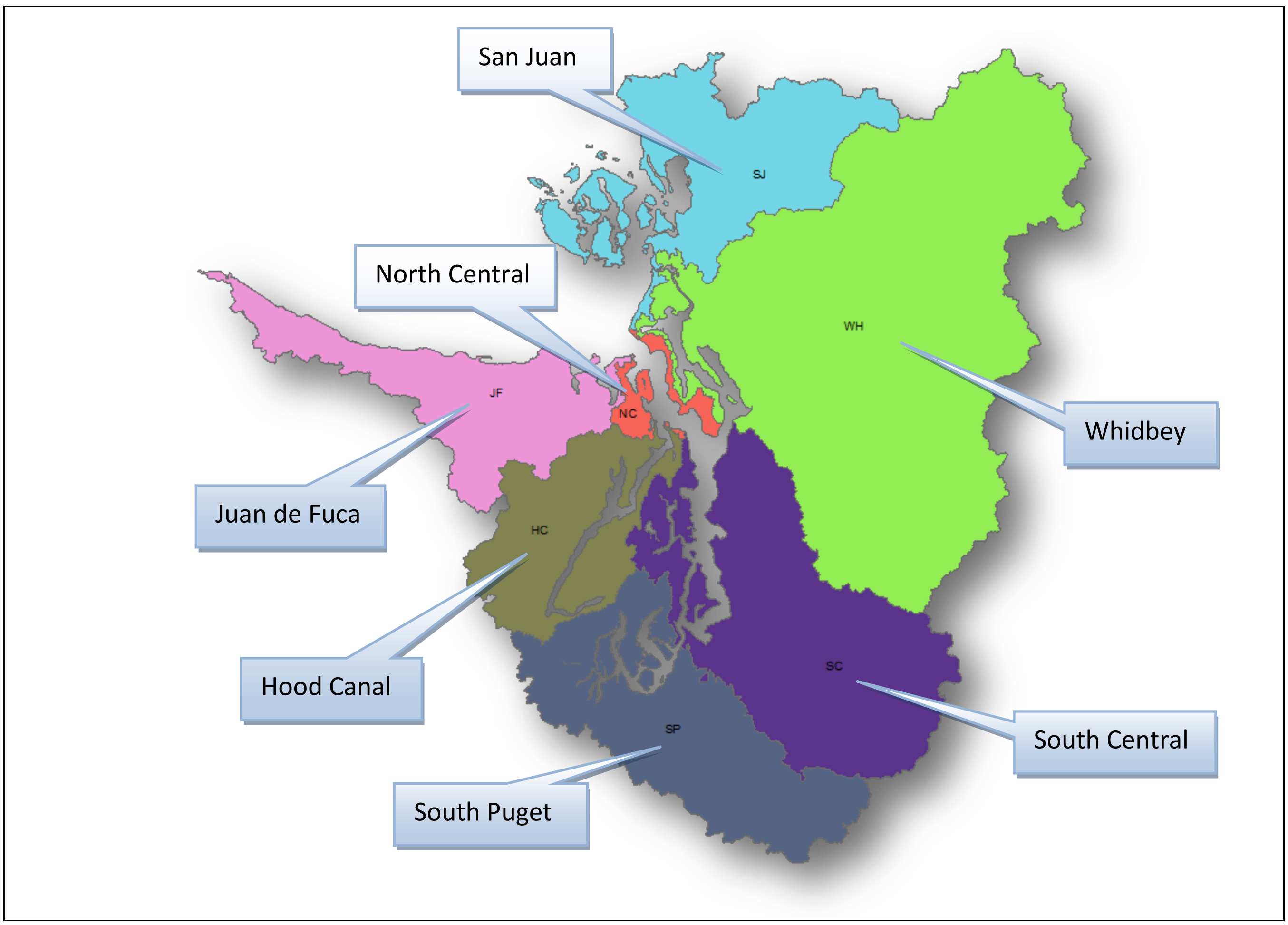


Figure 2. Sub-basins used in this analysis

Population Growth Estimates

County level medium growth population estimates from Washington State Office of Financial Management (OFM) were used to develop sub-basin level population growth increments representing the yearly population growth needed to achieve the OFM 2060 population totals for each county. A linear relationship was assumed, and developed for 2007 estimates downloaded from http://www.ofm.wa.gov/pop/gma/projections07.asp. The area of each county within each sub-basin was used as the weight to produce the sub-basin level growth parameter, pictured below, from the county level growth estimates.

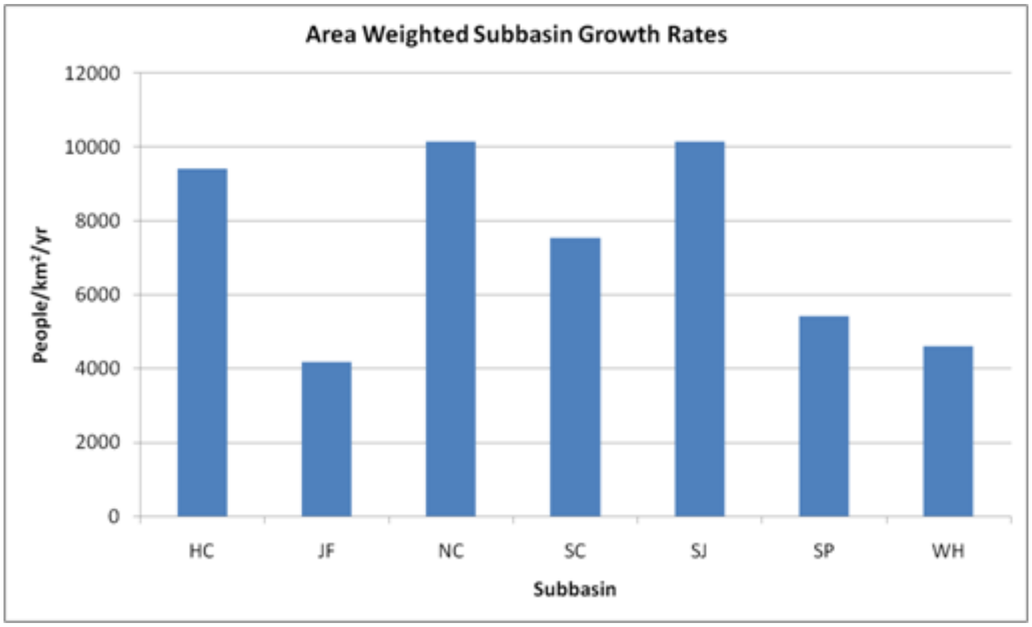


Figure 3. Area weighted sub-basin growth rates derived from the OFM county–level growth projections. (HC=Hood Canal, JF=Juan de Fuca, NC=North Central, SC=South Central, SJ=San Juan, SP=South Puget, WH=Whidbey)

Mean linear growth rates estimated from this procedure were input into Envision and processed using Envisions *PopulationTarget* process and applied to each sub-basin, as described below.

IDU level Population Density Estimates

Population density was available from the year 2000 Census at the block-group level. The population within each block group is targeted with an optimal value of 1500 individuals and a min/max of 600/3000 individuals. Because the target is a number of individuals, the size of each block group varies considerably. The mean area of yr2000 block-groups across the counties that make up the Puget Sound watershed is 167.5 ha (995.1 ha s.d.). On the other hand, the mean area of the IDUs in the South Central (SC) watershed of Puget Sound is, for example 0.62 ha (6.1 ha s.d.), a fact that indicates the need for a downscaling procedure to estimate IDU level population density from the coarser block-group data. We used a double weighting procedure to account for the area of each IDU and the LULC within each IDU. The first was simply an area weight, calculated as areaIDU/areaBlockGroup, and the second was a subjectively defined LULC weight. The LULC weight (Table 2) was designed to recognize general differences in population density between different NLCD landcover classes, providing the deallocation strategy a capacity to better reflect the variation in population density at the IDU level. These LULC population weights are subjective; however, their development was primarily based upon the NLCD LULC class descriptions available at http://www.mrlc.gov/nlcd_definitions.php . While measured values of IDU-level population would be preferable, these data are unavailable. We view this simple procedure of estimation as an effective strategy to develop a plausible alternative.

This estimating procedure is designed to provide a reasonable estimate of IDU-level population that is entirely consistent with the year 2000 census at the block-group level.

LandCover	LCWeight
Developed, Open Space	0.1
Developed, Low Intensity	0.6
Developed, Medium Intensity	1.0
Developed, High Intensity	0.5
Hay/Pasture	0.1
Cultivated Crops	0.1
Open Water	1E-8
All other LC classes	0.01

Table 2. Landcover weights used to disaggregate bock-group census data to the IDU level.

Policy Development

Policy sets were developed based on discussion with the PSNERP Nearshore Science Team and review of a variety of planning documents available for Puget Sound. General descriptions of the policies used in each scenario are given below. A complete summary of the specific policy descriptors used in this analysis is available at http://envision.bioe.orst.edu/StudyAreas/PugetSound/Policies/PS_Policies.html

Envision Puget Sound - Scenario Descriptions

Three scenarios were developed for this study: 1) **Status Quo** (SQ), 2) **Managed Growth** (SG), and 3) **Unconstrained Growth** (UG). Primary characteristics of each scenario are defined in Table 3. These scenarios were developed in consultation with the PSNERP science team and additional stakeholders. The scenarios were intended to provide representation of feasible outcomes under a "business as usual" assumption (SQ scenario) and two additional sets of assumptions bracketing policies that 1) aggressively manage growth and provide environmental protections (MG scenario) and 2) significantly relax growth management rules and environmental protections (UG scenario). In all cases, scenarios are represented in *Envision* as a set of policies, described in Table 3 below, and a set of model parameterizations reflecting population densities capacities as a function of zoning class. The specific policy representations and model parameterizations used are available at http://envision.bioe.orst.edu/StudyAreas/PugetSound

Scenario Quality	Status Quo (SQ)	Managed Growth (MG)	Unconstrained Growth (UG)
Population Allocation	Maintain existing allocation distributions	Greater allocation to UGA's; greater emphasis on concentrating growth around Regional Growth Centers	Greater allocation to areas outside UGA's through explicit preferences and relaxed development standards; less emphasis on concentrating growth around Regional Growth Centers
Urban Growth Pattern	Maintain existing development pattern, mix of densities, uses	Emphasize higher densities; mix of residential/commercial/ industrial; primarily urban form in residential development; floodplain avoidance	Emphasize commercial/ industrial; lower residential densities, primarily suburban form in residential development
Rural Growth Pattern	Maintain existing development pattern, mix of densities, uses	Resource lands protected: Where conversion occurs, growth concentrated near existing density, away from resource uses, sensitive habitats, viewsheds	Distribute growth relatively uniformly, without consideration of resource uses, sensitive habitats
Nearshore /Coastline Development	Maintain existing development pattern, mix of uses	Restrict development in nearshore areas, particularly in areas near sensitive lands, certain shoreform types, away from wetlands, sensitive lands, unstable areas, viewsheds	Unrestricted development in nearshore areas
Shoreline Modifications	Maintain existing relationship between modification amounts/densities, population densities	Reduce amounts/densities of nearshore modifications relative to existing conditions	Increase amounts/densities of nearshore modifications relative to existing conditions
Sensitive Areas/Open Space	Maintain moderate level of protection of wetlands, some restoration of historic wetlands; Moderate level of new park/open spaces	High level of protection of existing, undeveloped historic wetlands; aggressive restoration of historic wetlands, protections of sites with high conservation/ restoration potential; Aggressive levels of park/open space acquisition, both within and outside UGA's	Low level of wetlands protection; no restoration of historic wetlands; no new parks/open space

Table 3. Scenario Descriptions

Model and Process Descriptions

Population Growth and Allocation

Population growth and development is modeled as a two step process involving interplay between policies setting up development opportunities and an autonomous process, *Target*, that allocates new population. *Target* works by creating and examining two surfaces: 1) a current population density surface, and 2) a population capacity surface. The population capacity surface represents the potential of the IDU's to contain population density. It is defined in spatially-dependent and scenario-specific terms in the input file to the target.dll process. Total population targets were computed for each sub-basin based on medium growth projection provided by the Washington State Office of Financial Management Allocation through 2030. Annual growth estimates used in the scenarios were extrapolated from these estimates. Sub-basin estimates were developed by area-weighting the county level estimates within each sub-basin.

Population capacity estimates were computed dynamically during scenario runs using these DEV_CODE and sub-basin-specific capacity estimates and scenario-specific scalars based on proximity to regional growth centers. These population capacity surfaces were derived from estimates of maximum population density achieved within a development class at build out. Current population capacity surfaces were generated by relating existing population density surfaces to a set of a relevant underlying landscape attributes, expressed as a spatial query. An available population capacity (APC) is generated as the difference, at any given time, between the total population capacity and the current population capacity. To allocate new population as a scenario unfolds temporally, an allocation of growth is determined based on OFM-estimates for the sub-basin, which is then disaggregated down to the IDU level based on the APC at the IDU relative to the APC expressed across the entire analysis area. Thus, locations with larger APC received a proportionally larger share of the total allocation compared to locations with a smaller APC. Note that as underlying land use/development class changes in response to policies choices, the total population capacity and APC change dynamically.

Representations of population input files for each sub-basin are available at
http://envision/bioe.orst.edu/StudyAreas/PugetSound/PS_Population.html

Shoreline Modifications

Three shoreline modifications were considered in the project: 1) armoring, 2) dock count and area, and 3) marina count and area. Shoreline modifications were modeled using a custom Envision plug-in, *ShoreMods.dll*, developed for this project. During a scenario run in Envision, this plug-in examined the shoreline region for new development in the shoreline resulting from actor policy selection. If new development is detected, the ShoreMods process examines the type of development and determines if a sufficient level of development has accumulated to necessitate the placement of armoring, docks or marina to accommodate the development. Specific levels of accommodation were determined by examining current relationships between shoreline modification and existing development classes. These were modified by scenario using scenario-specific scalars and applied uniformly in each sub-basin. Summaries of the input files capturing these relationships are provided at http://envision.bioe.orst.edu/studyareas/PugetSound.

It is important to recognize that this model assumes that the density of shoreline modifications is related to the development density, and that this relationship is used to project new shoreline modifications. This represents a simple approach to the projection of future shoreline modifications that explicitly assumes that the development of modifications follows from population growth and the development of landscapes. Of course, that is not always the case, for example armoring may be created in an effort to protect perceived future value of development – well before that development may occur.

Despite these potential deficiencies, the model used in this project was limited to the use of explanatory variables that were projected by Envision. Development pattern was selected as the explanatory variable but if future work looks at a more sophisticated suite of actor-based outcomes, the shoreline modifications model could potentially be improved by including other explanatory variables. Additionally, extensions to FRAP could be developed to provide actors the capacity to implement nearshore modifications in response to policy choices, but this too was outside the scope of this project.

Additional Models

In addition to the models described above, a set of evaluative metrics providing landscape feedbacks were employed in this analysis. These are summarized in Table 4 below.

Evaluative Model	Description
Impervious Surfaces (%)	Impervious surfaces, expressed as a percent of the sub-basin area
Growth Capacity within UGAs (%)	Available capacity to accommodate new growth within Urban Growth Areas across the sub-basin
Growth Capacity outside UGAs (%)	Available capacity to accommodate new growth outside Urban Growth Areas across the sub-basin
Nearshore Growth Capacity within UGAs (%)	Available capacity to accommodate new growth within Urban Growth Areas within 1 km of the shoreline
Nearshore Growth Capacity outside UGAs (%)	Available capacity to accommodate new growth outside Urban Growth Areas within 1 km of the shoreline
Resource Lands (%)	Amount of private lands in agricultural or forest use, expressed as a percentage of the sub-basin area
New Development within UGA (%)	Percentage of all new development occurring within existing UGAs
New Development outside UGA	Percentage of all new development occurring outside existing UGAs
New Low-Density Development within UGA	Percentage of new low-density development occurring within existing UGAs
New Low-Density Development outside UGA	Percentage of new low-density development occurring within existing UGAs
New Medium-Density Development within UGA	Percentage of new medium-density development occurring within existing UGAs
New Medium-Density Development outside UGA	Percentage of new medium-density development occurring outside existing UGAs
New High-Density Development within UGA	Percentage of new high-density development occurring within existing UGAs
New High-Density Development outside UGA	Percentage of new high-density development occurring outside existing UGAs

Table 4. Evaluative metrics used in this analysis.

These metrics were chose because the captured current understanding of relevant outcomes metrics, could be supported by the available datasets, and were capable of being projected under each of the scenarios. For the purposes of these metrics, “nearshore” was defined as occurring within 1 km of a shoreline; this was used for summary purposes only and does not reflect a process-based perspective on shoreline influences.

Policies

In *Envision*, *policies* are the basic decision rules that guide and constrain actor behavior. They contain a number of attributes, most importantly a set of *site attributes,* expressed as a spatial query on the underlying IDU coverage, that determine where on the landscape the policy is potentially applicable, and zero or more *outcomes,* expressed in *Envisions* outcome specification language, that determines what happens, in terms of changes to the underlying IDU coverage, if an actor chooses to adopt a specific policy.

Policies were developed based on discussions with PSNERP and reflect several broad categories of policies, including 1) urbanization, 2) shoreline modifications, 3) preservation/conservation/restoration of sensitive lands, and 4) miscellaneous additional policies. In most cases, general policies were developed with variations specific to each scenario. These are described below.

Many policies and scenarios are responsive to landscape feedbacks of various types. Examples include scarcity of resource lands and availability of residential capacity. These are described in more detail in the “Model and Process Descriptions” above.

Urban/Rural Growth and Resource Lands Conversion

<u>Conversion of resource lands</u>. Policies reflecting conversion of private agricultural and forested lands to developed uses were created. They varied based on scenario, spatial location, and additional spatial attributes including location in floodplain, proximity to sensitive lands (defined as wetlands, eelgrass beds, herring spawning areas, and areas with good/very good conservation potential), proximity to streams and major roads, and location of UGAs. Only lands outside of the nearshore zone were considered; nearshore conversions are addressed separately below. In all cases, policies are applicable only to those IDUs outside the 1 km nearshore area. IDUs in a protected status (those set aside for conservation purposes) are excluded from development in all scenarios. Only private lands were considered for development; no public lands were converted in any scenario.

SQ Scenario. Within the SQ scenario, conversions were applied at rates consistent with current ratios within and outside of UGAs. These rates of conversion were moderately responsive to proximity to Regional Growth Centers (RGC, as defined by the Puget Sound Regional Council); the rate of conversion decreased as distance to an existing RGC increased within a 25km radius of the center of the RGC. Moderate levels of conversion of agricultural and forest land to residential uses occurs, with roughly 60 to 80 percent of new growth accommodated with UGAs (this varies by sub-basin).

MG Scenario. The MG scenario more aggressively limited conversion of resource lands to residential uses; conversion is limited to areas near regional growth centers, and away from areas with good conservation potential, floodplains, viewsheds, or near streams. Resulting residential uses tends to be higher density development compared to SQ.

UG Scenario. The UG scenario significantly reduces development constraints on resources lands. UGAs become less important as determiners of development pattern. Resource lands, including those zoned for agriculture a forestry, are generally developable at low densities. Proximity to sensitive lands and RGC's is not a factor in determining development potential. Viewsheds are more likely to be developed for residential uses. Floodplains are available for development, although development is restricted in floodways.

<u>Redevelopment and Infill</u>. Redevelopment and infill involves the conversion of underdeveloped, private residential lands within UGA's that are to higher densities. Underdeveloped lands are defined as those areas where available population density capacity exceeds 50 percent of total capacity. Within the scenarios, redevelopment was represented as changing zoning to allow higher densities in those areas currently zoned at low to moderate densities; infill was represented as preferential development in undeveloped areas zoned for development. Details varied by scenario, with the SQ scenario having moderate conversion rates, MG emphasizing conversion to higher-density uses as well as parks, and UG emphasizing conversion to commercial/industrial uses.

SQ Scenario. Moderate emphasis is placed on redevelopment and infill. Preference is given to those areas within a 25 km radius of a RGC, although redevelopment and infill also occurs outside this radius.

MG Scenario. Infill and redevelopment is emphasized to accommodate growth within UGAs, particularly near RGCs. Where infill and redevelopment occurs, higher densities are allowed. Reservations are made for parks and urban open spaces.

UG Scenario. Infill and redevelopment is not emphasized. Where infill and redevelopment occurs, densities are only moderately increased.

<u>Conversion of Barren Land</u>. Barren Lands are defined as undeveloped, unvegetated lands that have typically been cleared of vegetation via human modification, for example brownfield areas of historical industrial uses where redevelopment is complicated by the presence of pollutants. Conversion of barren land occurs both within and outside UGAs. Development to both Commercial, Urban and Park uses occurs within UGAs; outside UGAs conversion to Residential and Park uses occurs. Scenario differences mirror those for Redevelopment and Infill described above.

Nearshore/Shoreline Development

Nearshore development is treated separately from other development. Nearshore development is defined as development occurring in one of two regions: 1) within 200m of a shoreline (shoreline development), and 2) beyond 200m but within 1 km of a coastline (nearshore development). Nearshore development processes are impacted by proximity to existing road network, location in a viewshed, and development opportunity expressed via IDU proximity to sensitive lands, shoreforms, and similar attributes. Because scenarios differ widely in their treatment of nearshore/coastline development, we provide policy descriptors for each scenario below. In all cases, policies are constrained to those parcels within 1 km of the coastline.

SQ Scenario. Allows moderate levels of development on private lands in most areas. No development is allowed on deltas, within floodplains, or in areas with unstable slopes; development on existing wetlands is limited. Development pattern emphasizes moderate density uses. Some conversion of undeveloped lands to both commercial, residential and park uses is allowed. Areas within a UGA, near roads or with a water view are more likely to be developed. Areas containing significant wetlands are less likely to be developed.

MG Scenario. No new development is allowed within 200m of the shoreline. Outside the 200m zone development is severely restricted in areas near sensitive lands, including current and historic wetlands, lands with significant conservation opportunities, or lands adjacent to streams. Water views are protected from development. Development is focused on areas within UGAs, near RGCs, or near roads. In existing developed areas, focus is on increasing density. Create of parks in developed areas is included.

UG Scenario. The Unconstrained Growth scenario allows significant new development in the nearshore. No development is allowed on deltas or on unstable slopes, but other shoreforms are developable. Development pattern emphasizes low-density uses. Those areas with water views are more likely to be developed for residential uses, as are those within existing UGAs or near roads. Areas with significant wetlands have a reduced probability of development.

Sensitive Areas/Conservation Lands/Open Space

Policies for protection of sensitive areas and open spaces are included in the scenarios. Sensitive areas are defined as wetlands, eelgrass beds, herring spawning areas, and areas with good/very good conservation potential. Generally scenarios vary in terms of their overall level of protection of sensitive areas.

SQ Scenario. The SQ scenario maintains moderate level of protection of wetlands, some restoration of historic wetlands; moderate level of protection of existing open space areas, and moderate level of protection of IDUs adjacent to eelgrass beds, herring spawning areas.

MG Scenarios. This scenario reflects a high level of protection of existing and undeveloped historic wetlands; aggressive restoration of historic wetlands and protection of sites with high conservation/ restoration potential. No development is allowed next to Eelgrass/Herring Spawning areas. Existing open space is precluded from development.

UG Scenario. Under the unmanaged growth scenario, no additional protection of conservation areas/sensitive areas/open space is provided above and beyond those protections described above.

Development rules and scenario-specific modifications are summarized in Appendix 4, Tables 5 - 9.

Results and Discussion

A brief summary of run results is presented below for a subset of modeled output variables. Complete results, included dynamics maps and a complete set of output variables, is available on the web at http://envision.bioe.orst.edu/studyareas/pugetsound.

We first examine land use/land cover (LULC) results. These are presented in map form in Figure 4 for base year condition and each of the three scenarios projected to 2060. The scenario results show significant differences between scenarios. The MG scenario tends to concentrate development in existing UGAs, while the UG scenario creates a much more dispersed development pattern. SQ is somewhere in between. This difference is most noticeable in the area south of Seattle on the northwestern edge of Mt. Rainier, where a large expanse of low density residential zoning is utilized within the SQ and in particular the UG scenarios to accommodate new growth. Most development occurs as a result of conversion of forest lands, but this impact is significantly higher in the UG scenario.

Sub-basin level summaries of LULC for the nearshore area only (defined here as within 200m of the shoreline) are provided in Figures 5 – 12. Significant variation in both base year LULC distributions and scenario outcomes exists, reflecting the wide variation in LULC pattern throughout the Puget Sound. There are also significant differences in percentage of shoreline developed throughout scenario in each sub-basin, reflecting both availability of convertible lands and shoreline length/sub-basin area ratios (Figure 13). In all sub-basins except San Juan, the SQ scenario resulted in less conversion of nearshore lands for development as compared to the UG scenario. Because the MG scenario essential precluded new nearshore development, it was excluded from this analysis.

One of the more notable features of the sub-basin results in the consistency of change between the scenarios, across all of the projected metrics. The number of docks and marinas as well as the impervious area and amount of armoring are projected to have the largest increases in the unconstrained growth scenario, and the smallest increases in the constrained growth scenario. The status quo is intermediate. Figures 14-20 outline these results as time series for each of the sub-basins, while Figure 21 provides a summary of all sub-basins across Puget Sound. Docks, marinas and armoring were assumed to be strongly discouraged under the constrained growth scenario, and for this reason remain essentially unchanged throughout the 60 year projection for that scenario. Across Puget Sound, The number of docks and marinas, as well as the percentage of armored shoreline, is projected to increase by approximately twice as much in the unconstrained growth scenario as in the status quo scenario (Figure 21). There is a much larger range in variation between the sub-basins, due primarily to differences in the near shore land cover on which the projection depends.

The percent of impervious area displays a cross-scenario pattern that is very similar to that for the near shore modifications, with unconstrained growth showing the largest increases at the Puget Sound level and also across each of the sub-basins. Figure 22 is a set of maps outlining the degree of impervious area across Puget Sound for each of the different scenarios, which can be used to explain these cross-scenario differences. The footprint of new impervious area (Figure 22) is the largest under the unconstrained growth scenario because more of the landscape transitions to residential development, which has a larger degree of imperviousness than

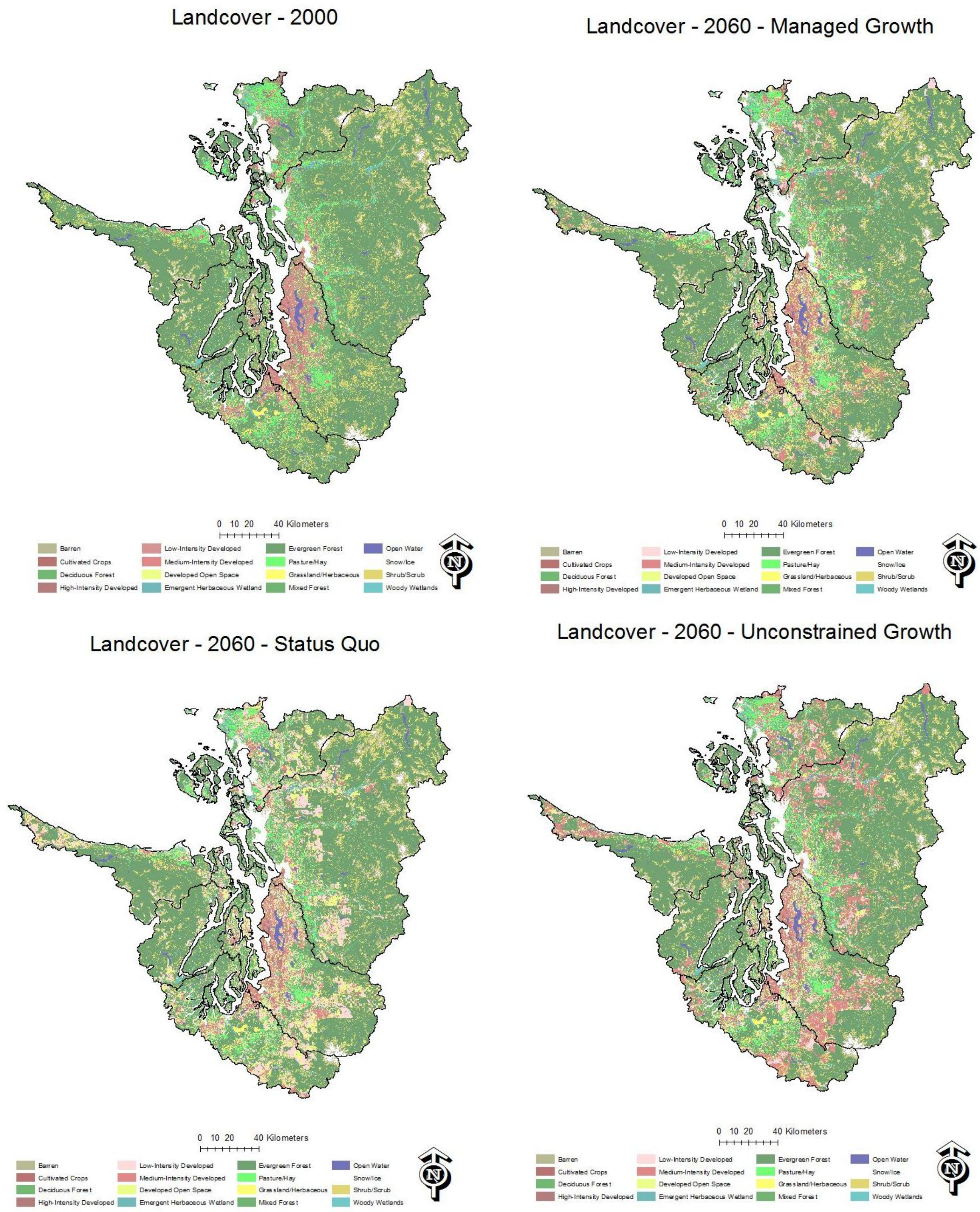


Figure 4. Land Use/Land Cover for Year 2000 and 2060 under Each Scenario

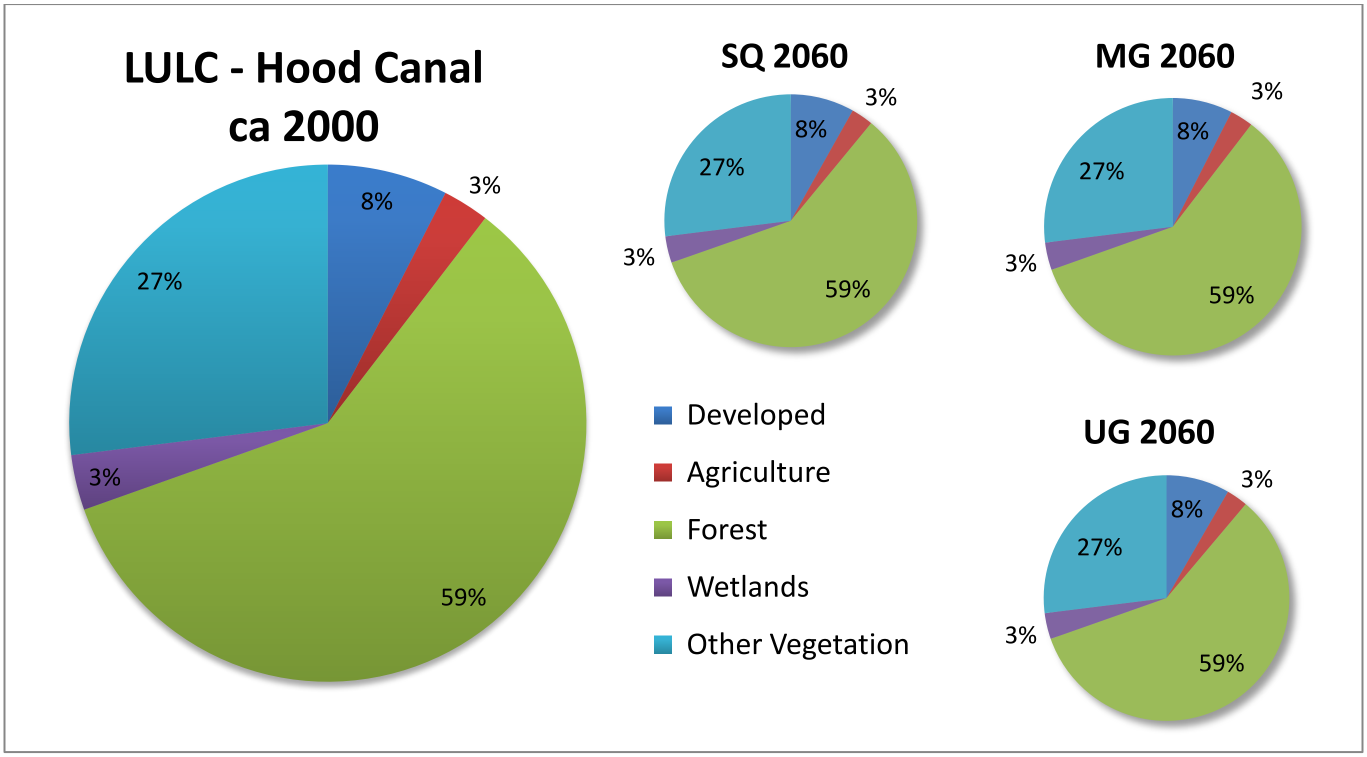


Figure 5. Nearshore Land Use/Land Cover for Year 2000 and 2060 under Each Scenario – Hood Canal

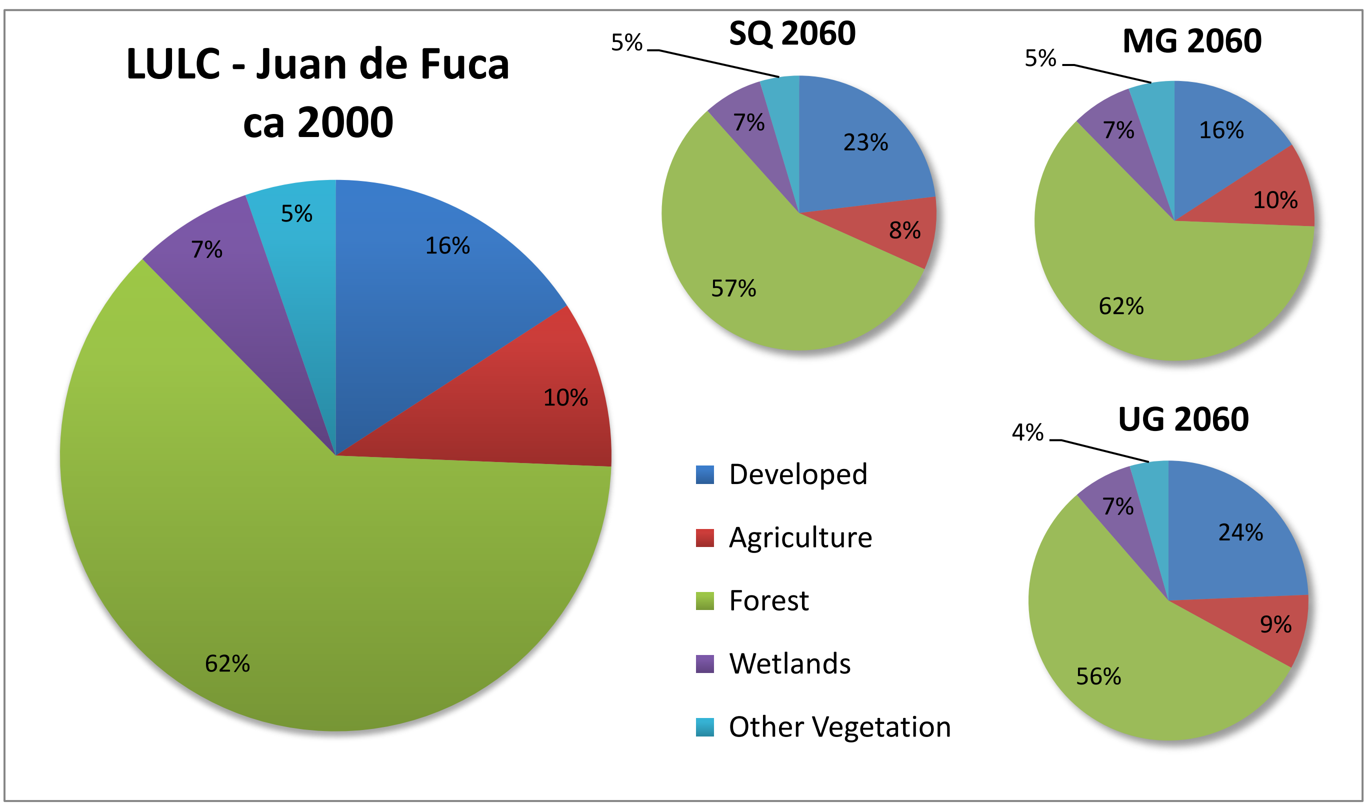


Figure 6. Nearshore Land Use/Land Cover for Year 2000 and 2060 under Each Scenario – Juan de Fuca

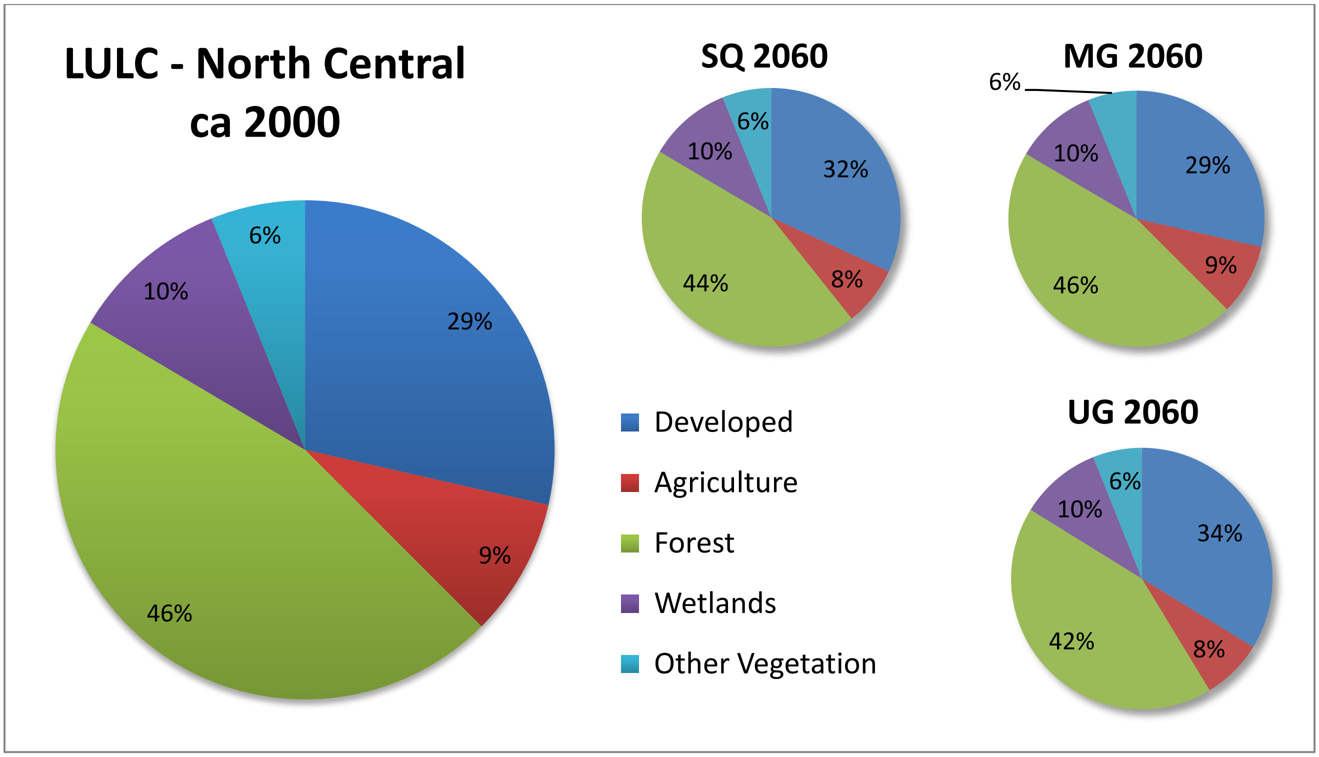


Figure 7. Nearshore Land Use/Land Cover for Year 2000 and 2060 under Each Scenario – North Central

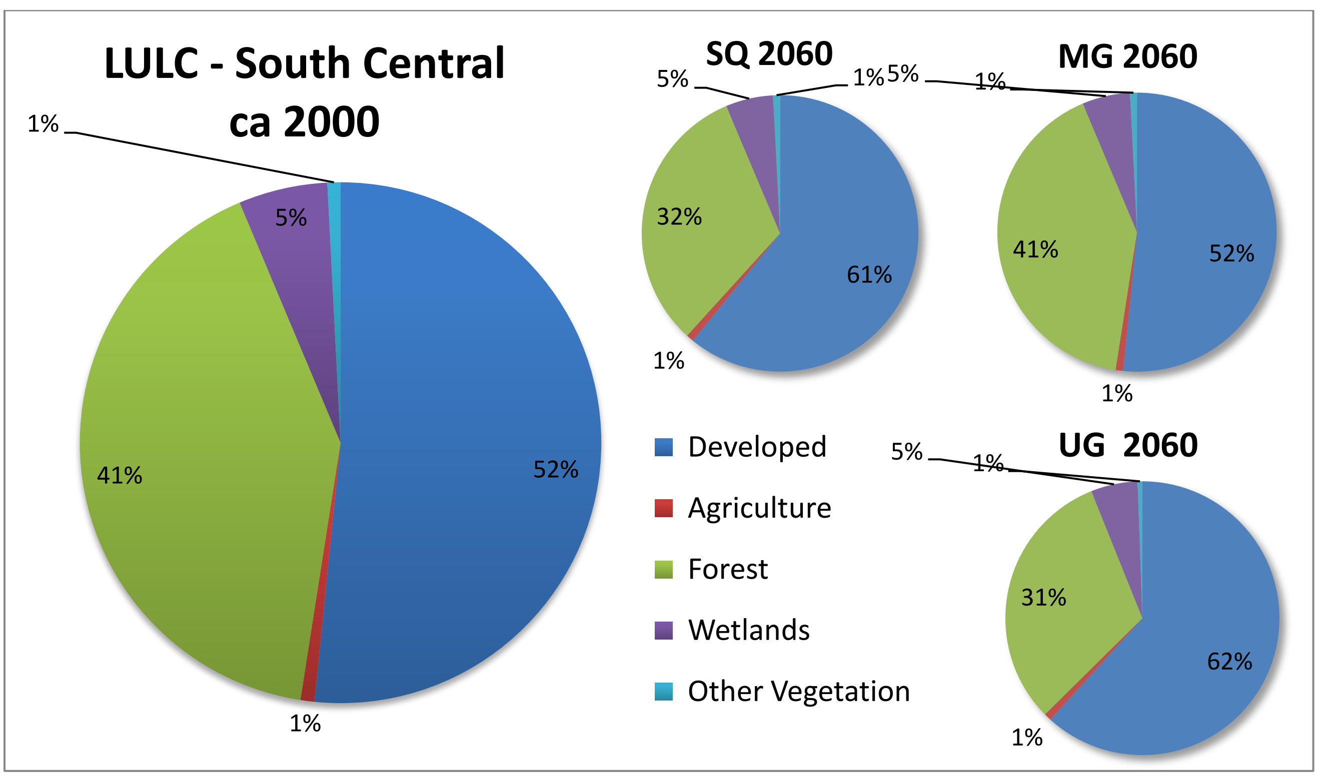


Figure 8. Nearshore Land Use/Land Cover for Year 2000 and 2060 under Each Scenario – South Central

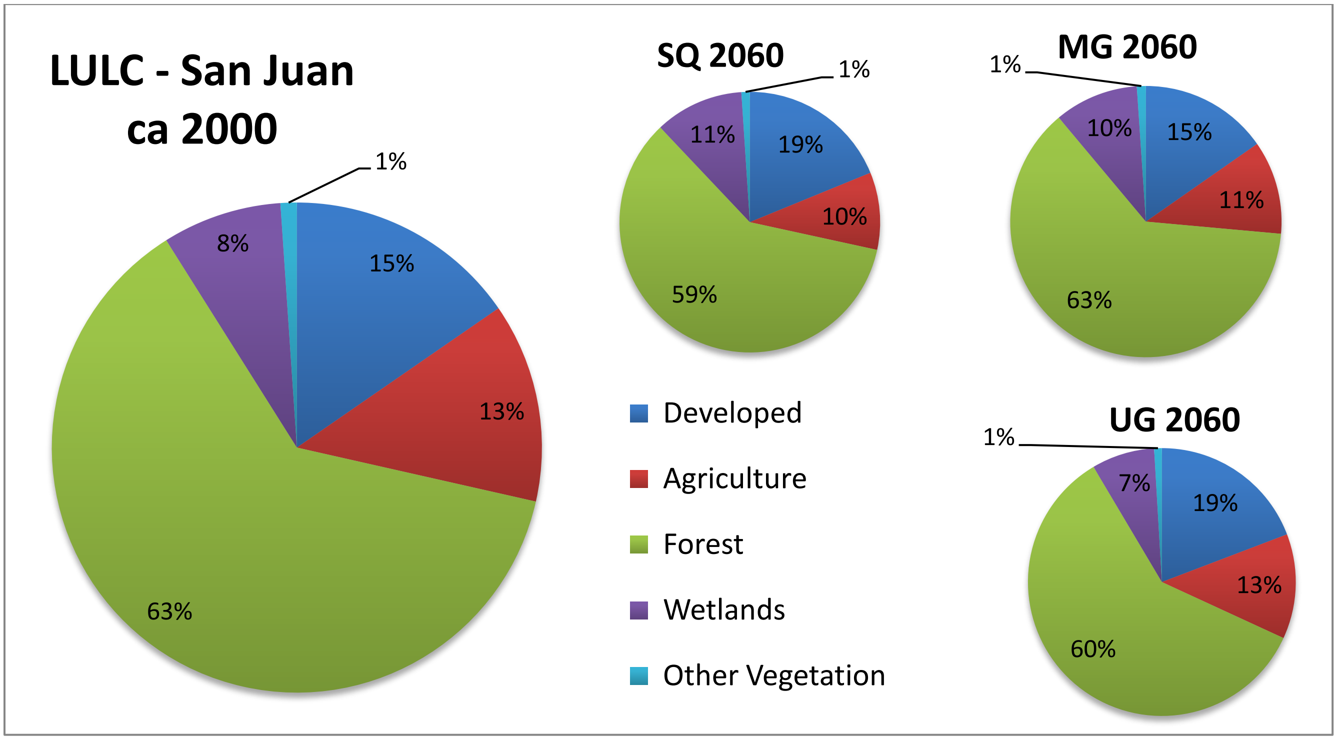


Figure 9. Nearshore Land Use/Land Cover for Year 2000 and 2060 under Each Scenario – San Juan

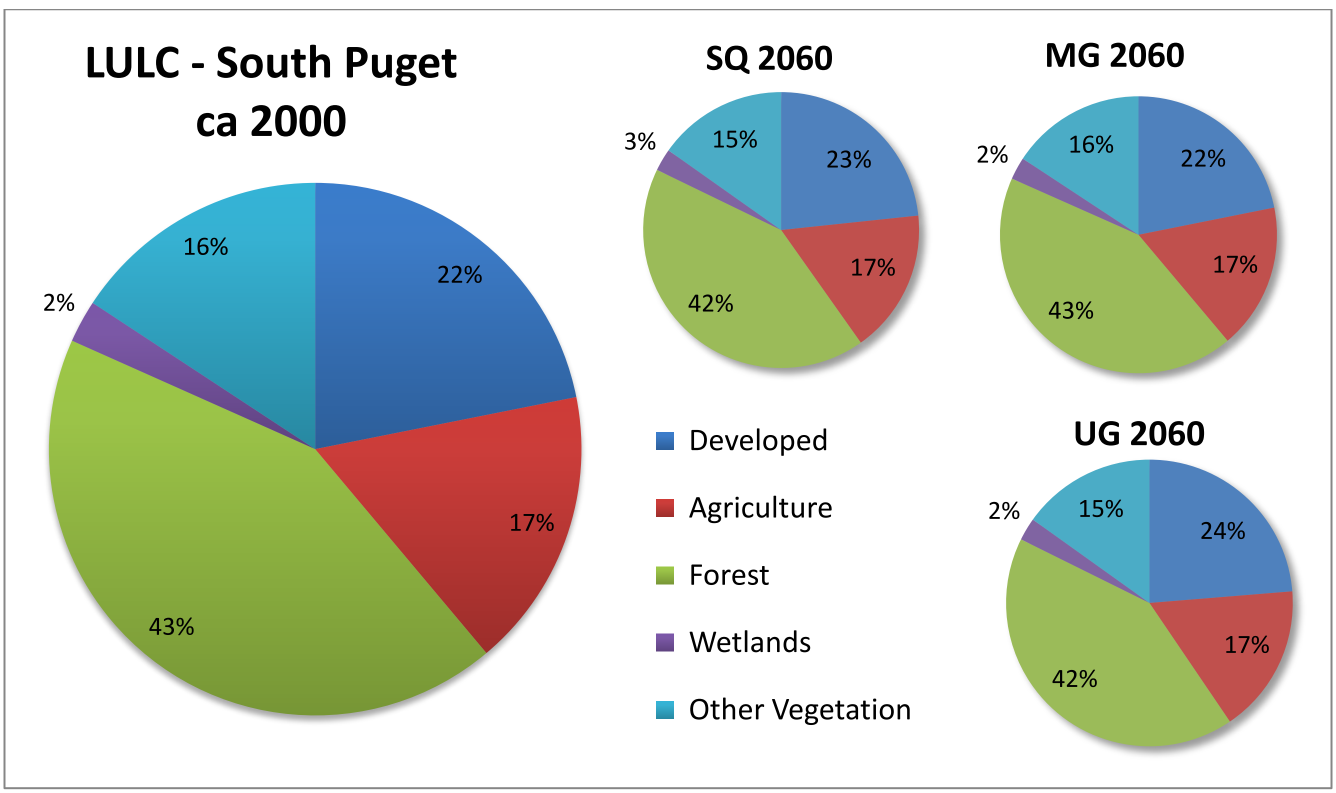


Figure 10. Nearshore Land Use/Land Cover for Year 2000 and 2060 under Each Scenario – South Puget

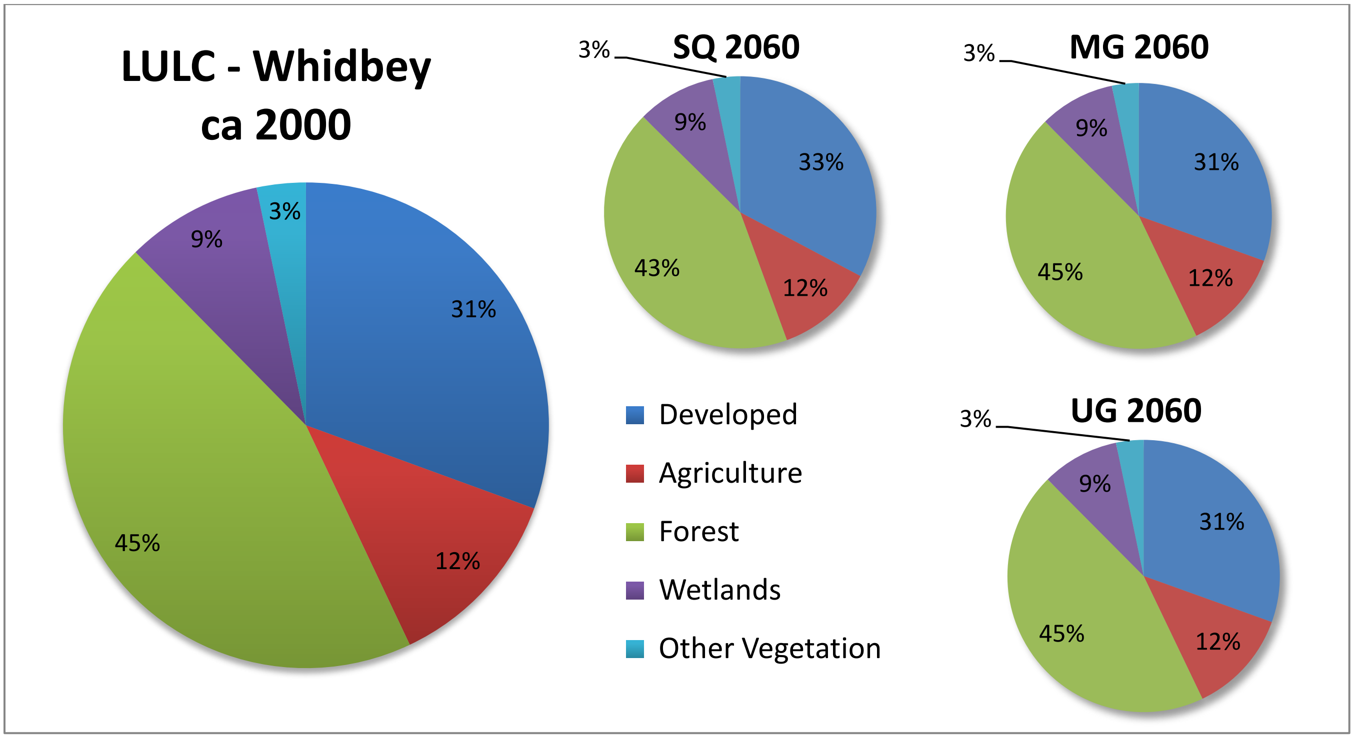


Figure 11. Nearshore Land Use/Land Cover for Year 2000 and 2060 under Each Scenario - Whidbey

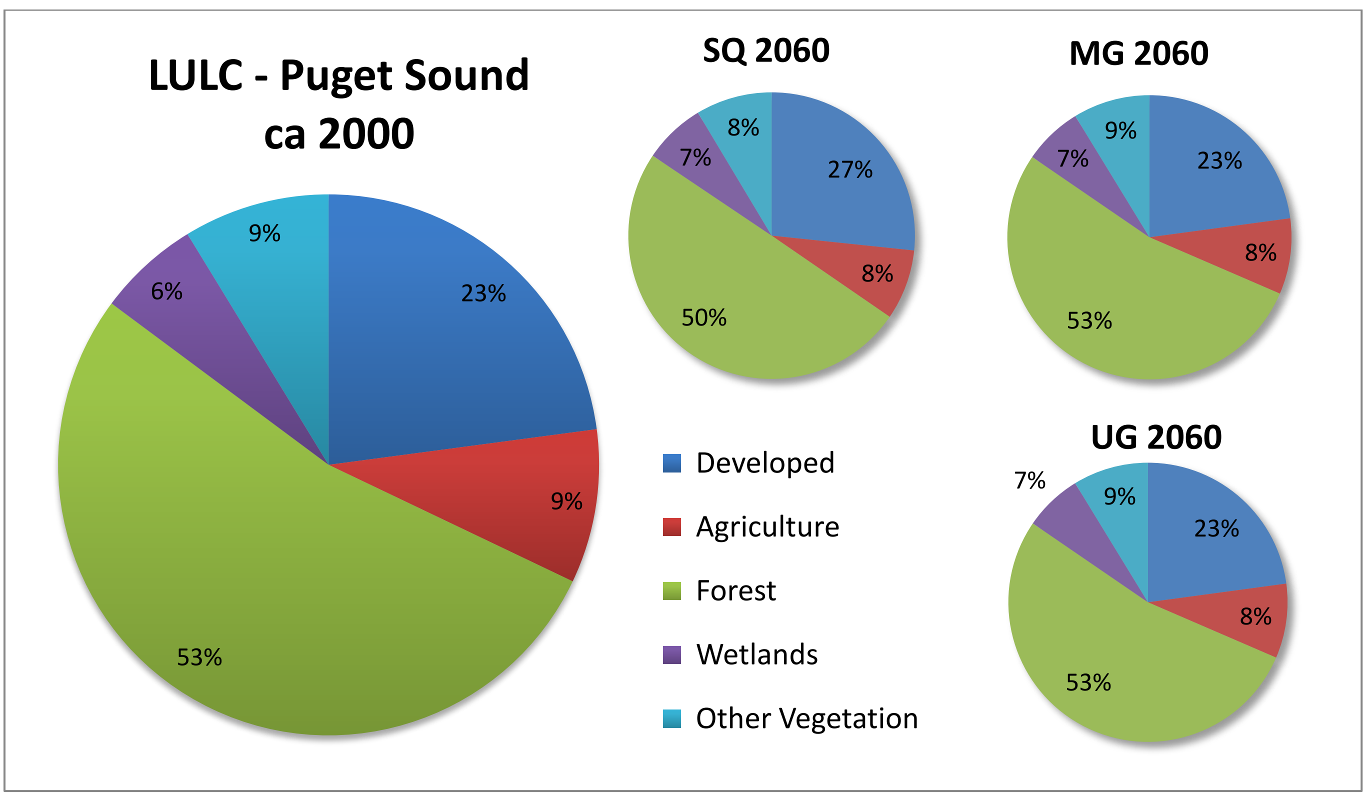


Figure 12. Nearshore Land Use/Land Cover for Year 2000 and 2060 under Each Scenario – Entire Puget Sound

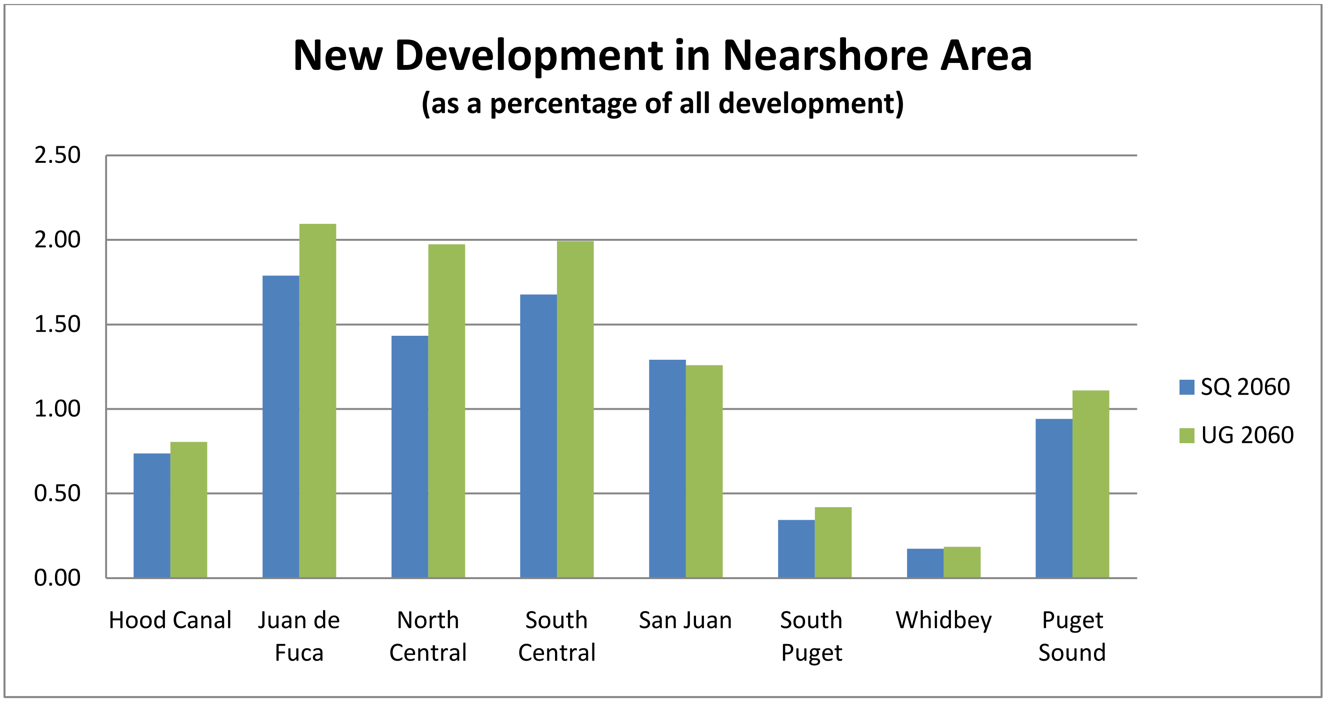
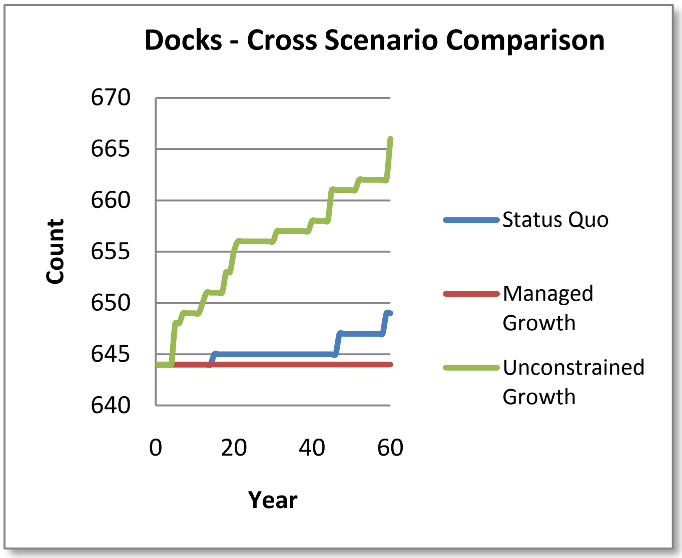
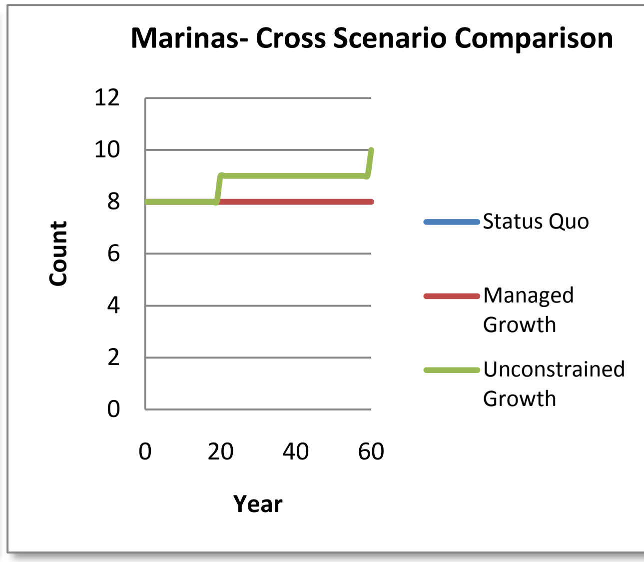


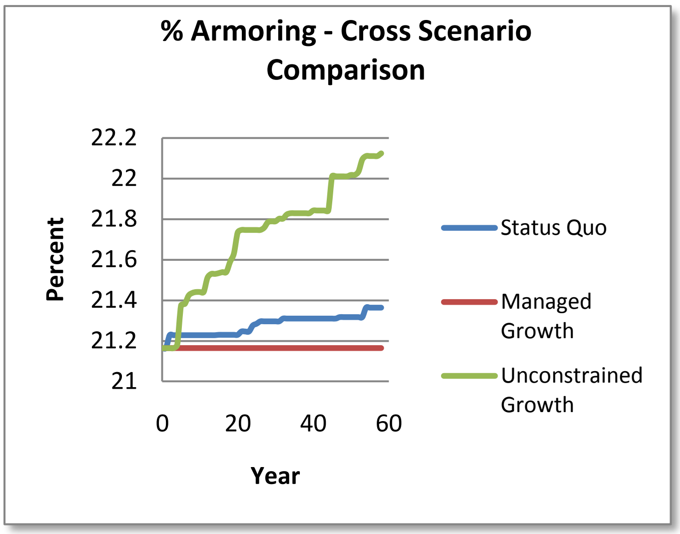
Figure 13. New Development 2000-2060 for SQ and UG Scenarios by Sub-basin

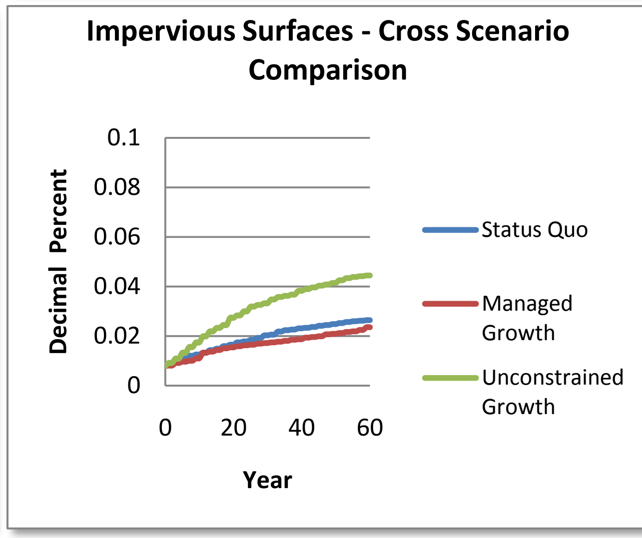
other land cover classes, in particular agriculture and forestry. The status quo scenario shows a degree of change, measured both in terms of land cover and impervious area change that is intermediate between unconstrained and managed growth.

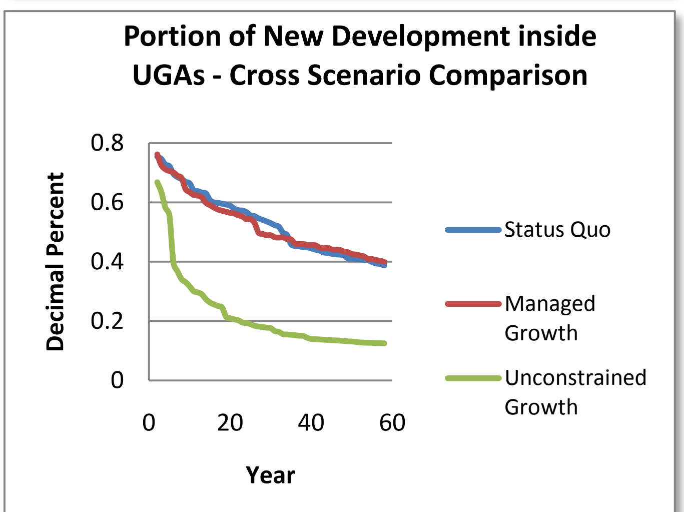
The portion of new development occurring within established UGAs (summed across all three development classes) is outlined for each sub-basin in the lower left plot in Figures 14-20 and for Puget Sound as a whole in Figure 21. Again, the cross-scenario pattern is consistent across the summary areas, with unconstrained growth having the smallest portion of growth in UGAs and the managed growth having the largest amount of growth in the UGAs. The difference between status quo and constrained growth is, however, very small for most summary areas. This results from the fact that these scenarios both were designed to respect established UGAs, while the unconstrained growth scenario essentially ignored them. Interestingly, this pattern diverges in the North Central sub-basin, where the status quo scenario shows a greater amount of growth in the UGAs than the managed growth scenario, and where the amount of growth in the UGAs is smaller (approximately 20% of growth in 2060 inside UGAs for the managed growth scenario) than in other sub-basins. This observation is explained by the recognition that there is only one UGA, in the Jefferson County area of the sub-basin, and this UGA does not include most of the developed area, including Port Townsend. Was the North Central basin large enough to include additional UGAs, this pattern would likely appear more similar to other sub-basins. This result highlights one of the simplifying assumptions guiding the analysis – that the UGAs do not expand over the coming 50-60 years. In future analyses, it may be worth giving more consideration to how UGAs may need to develop to accommodate growth in different regions of Puget Sound.











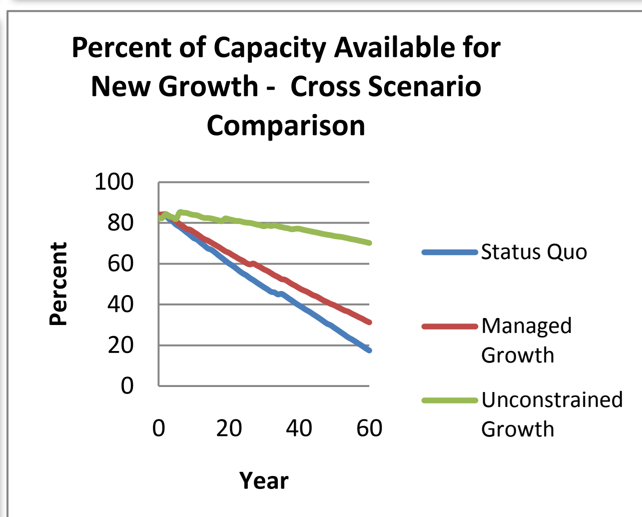


Figure 14. Time Series Results - Hood Canal

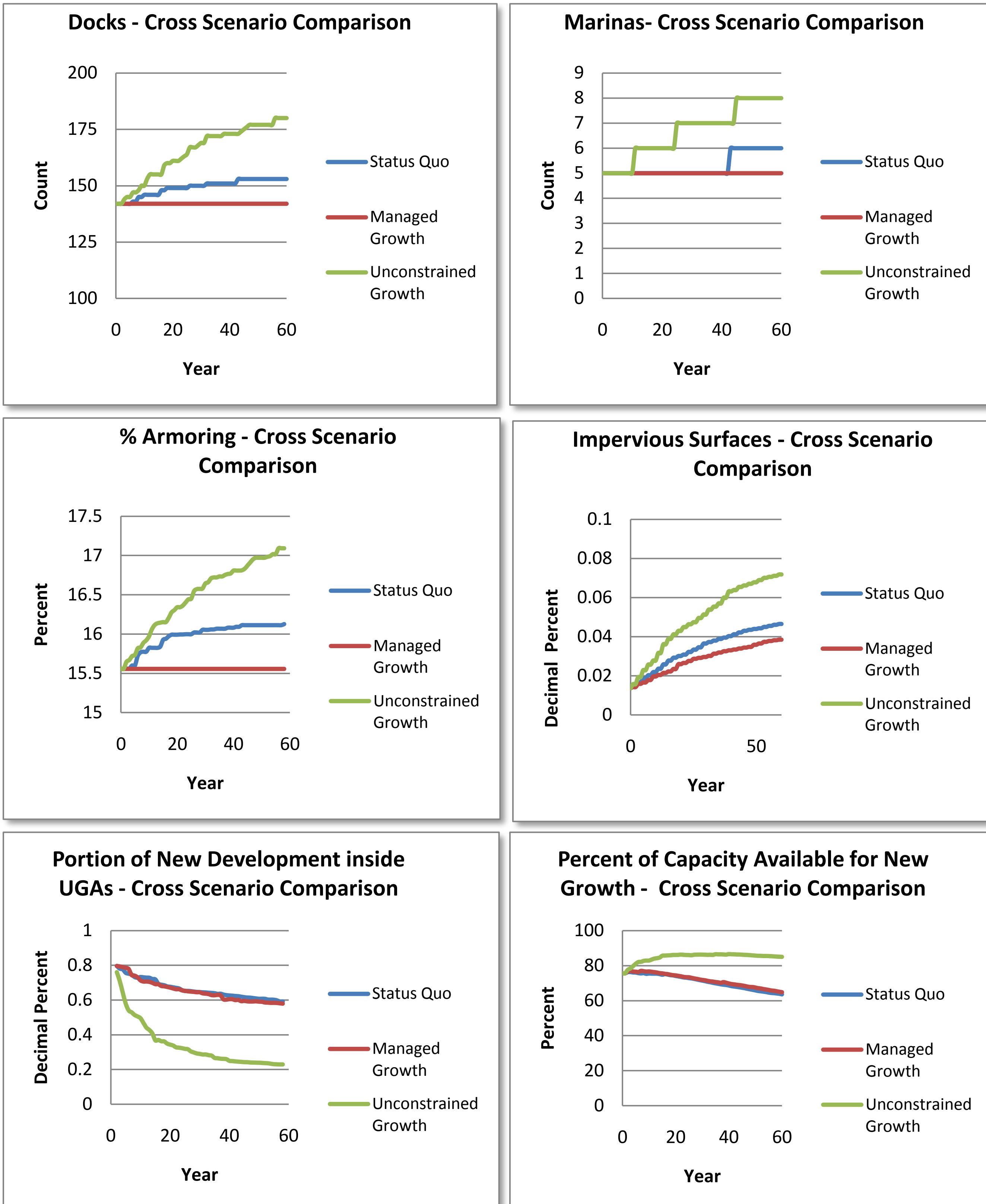


Figure 15. Time Series Results - Juan de Fuca

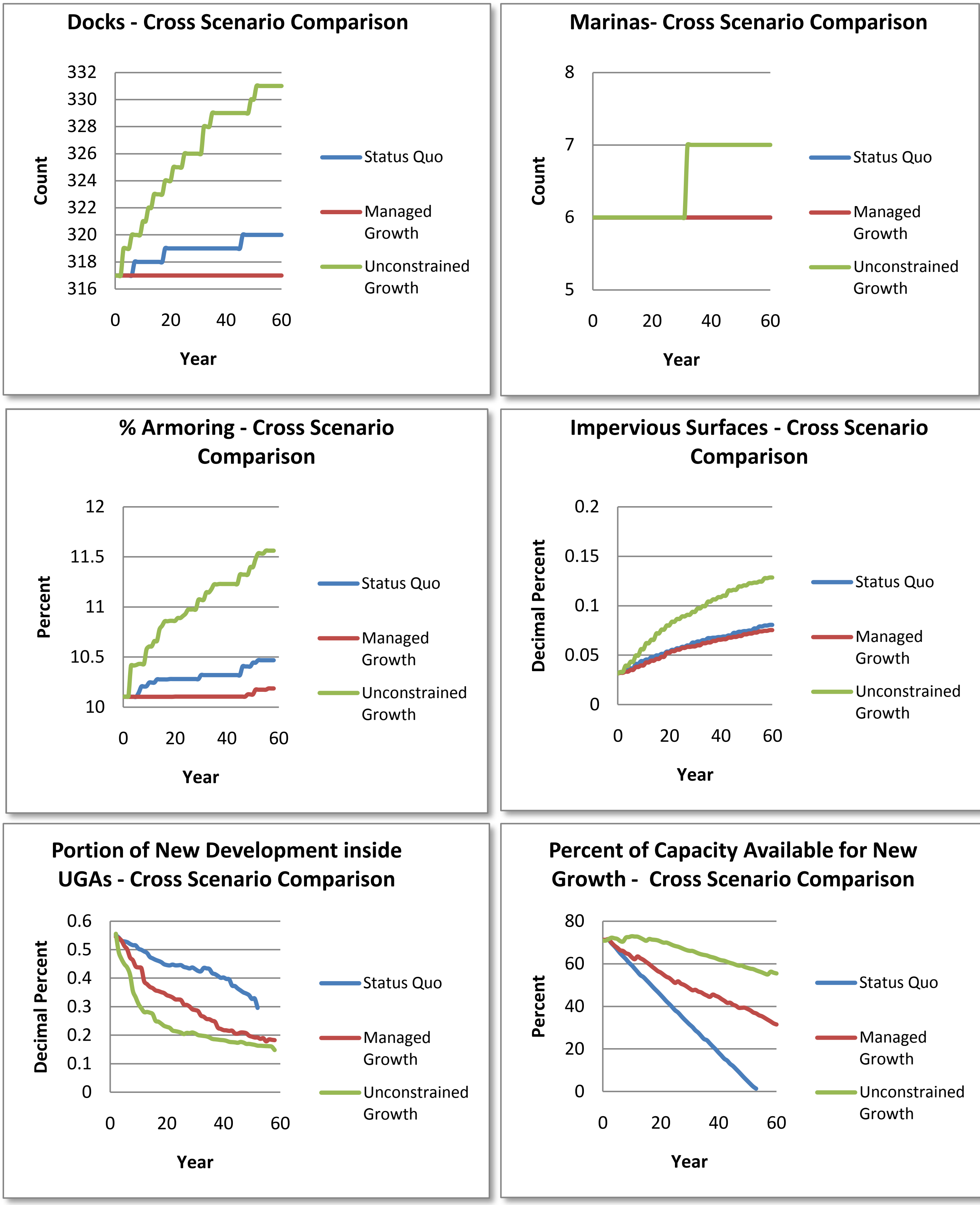


Figure 16. Time Series Results - North Central

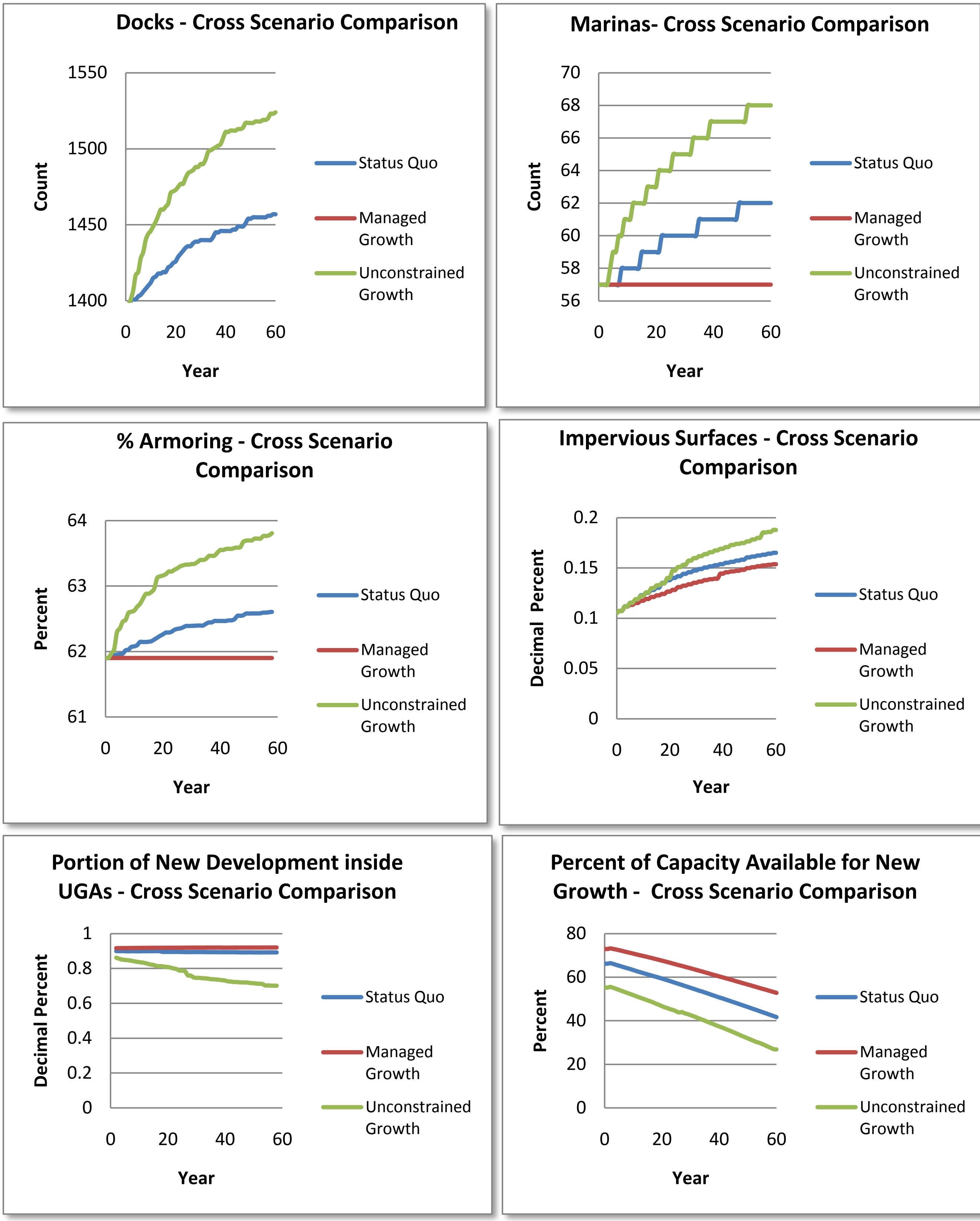


Figure 17. Time Series Results - South Central

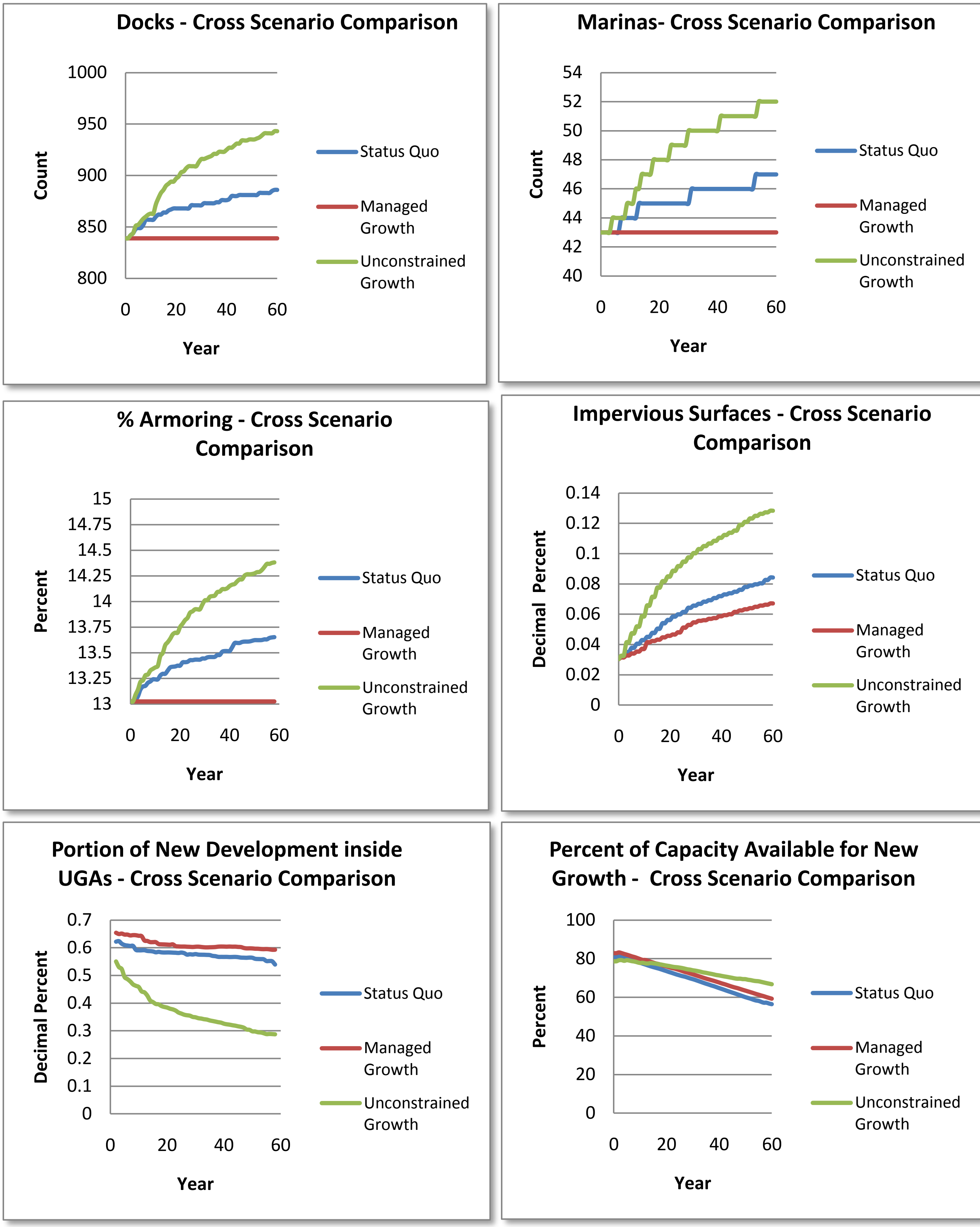


Figure 18. Time Series Results - San Juan

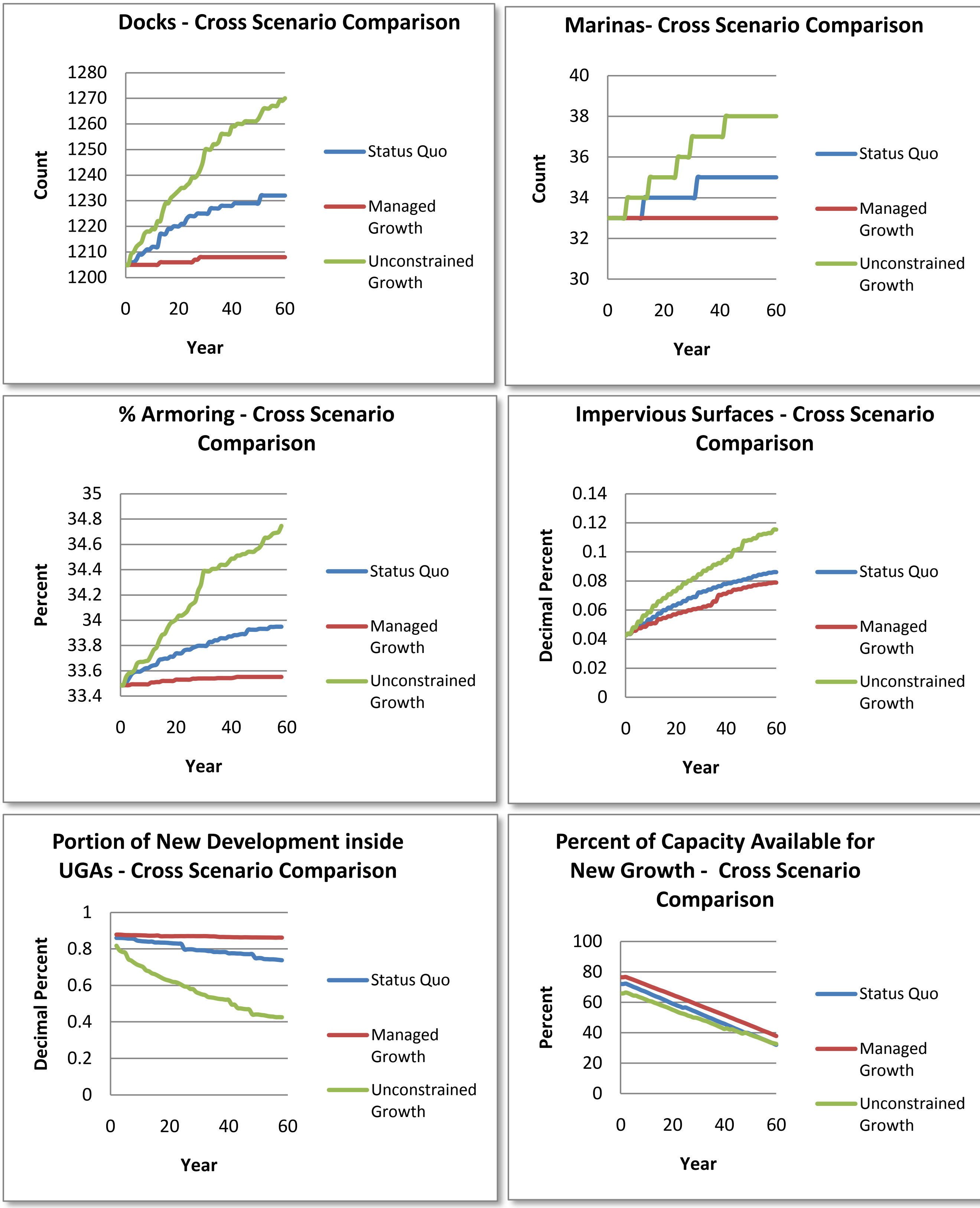


Figure 19. Time Series Results - South Puget

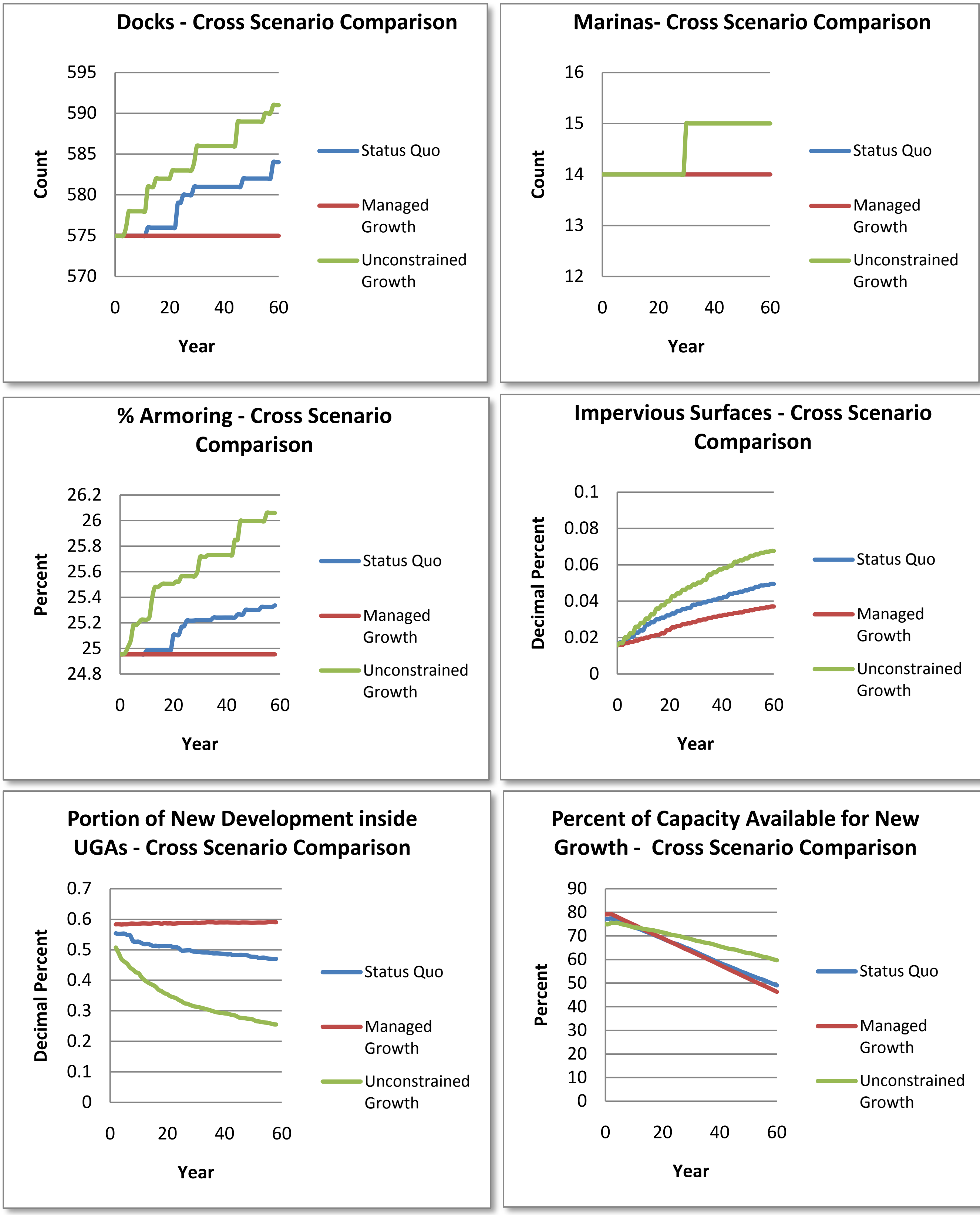


Figure 20. Time Series Results – Whidbey

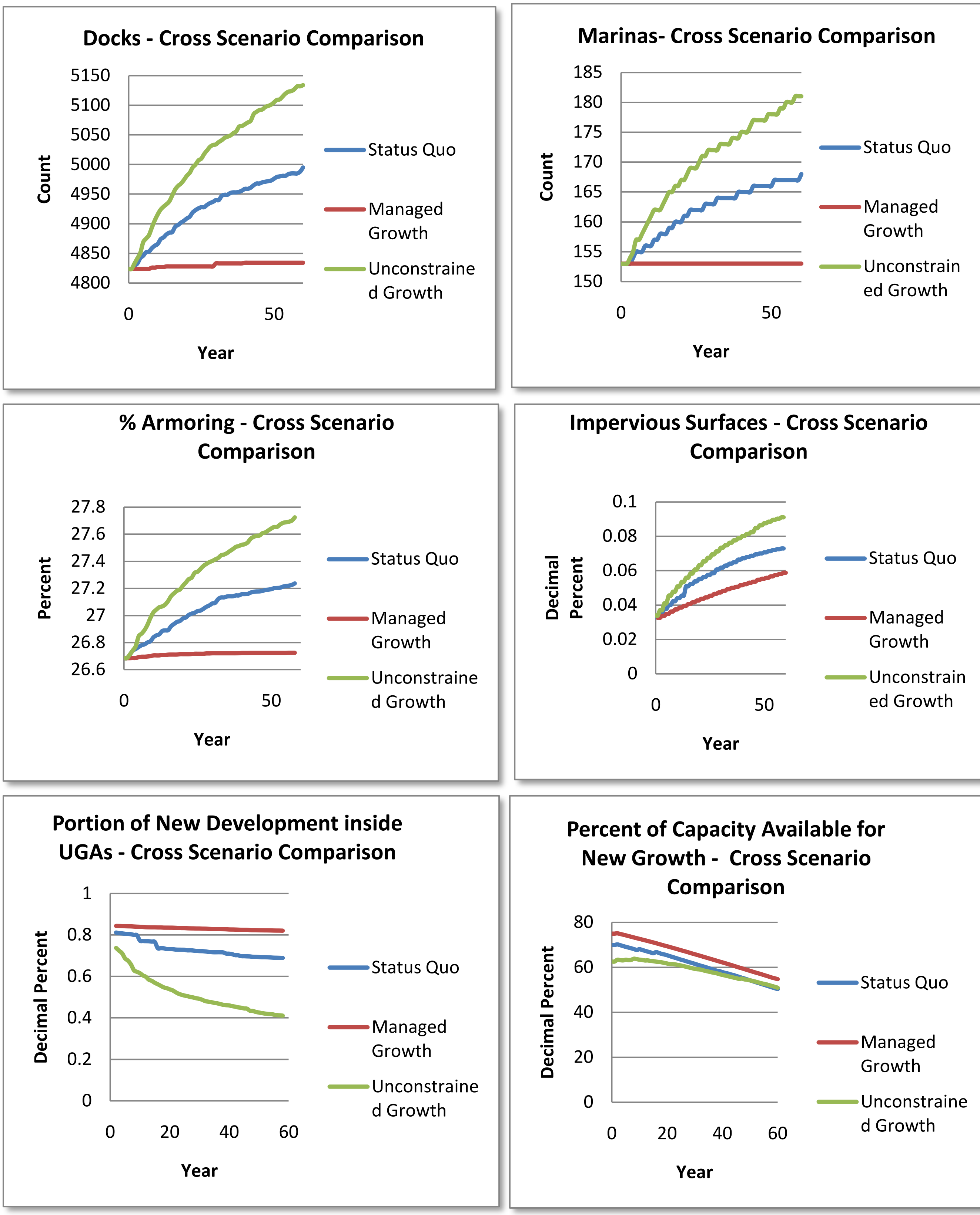


Figure 21. Time Series Results - Puget Sound (Entire Basin)

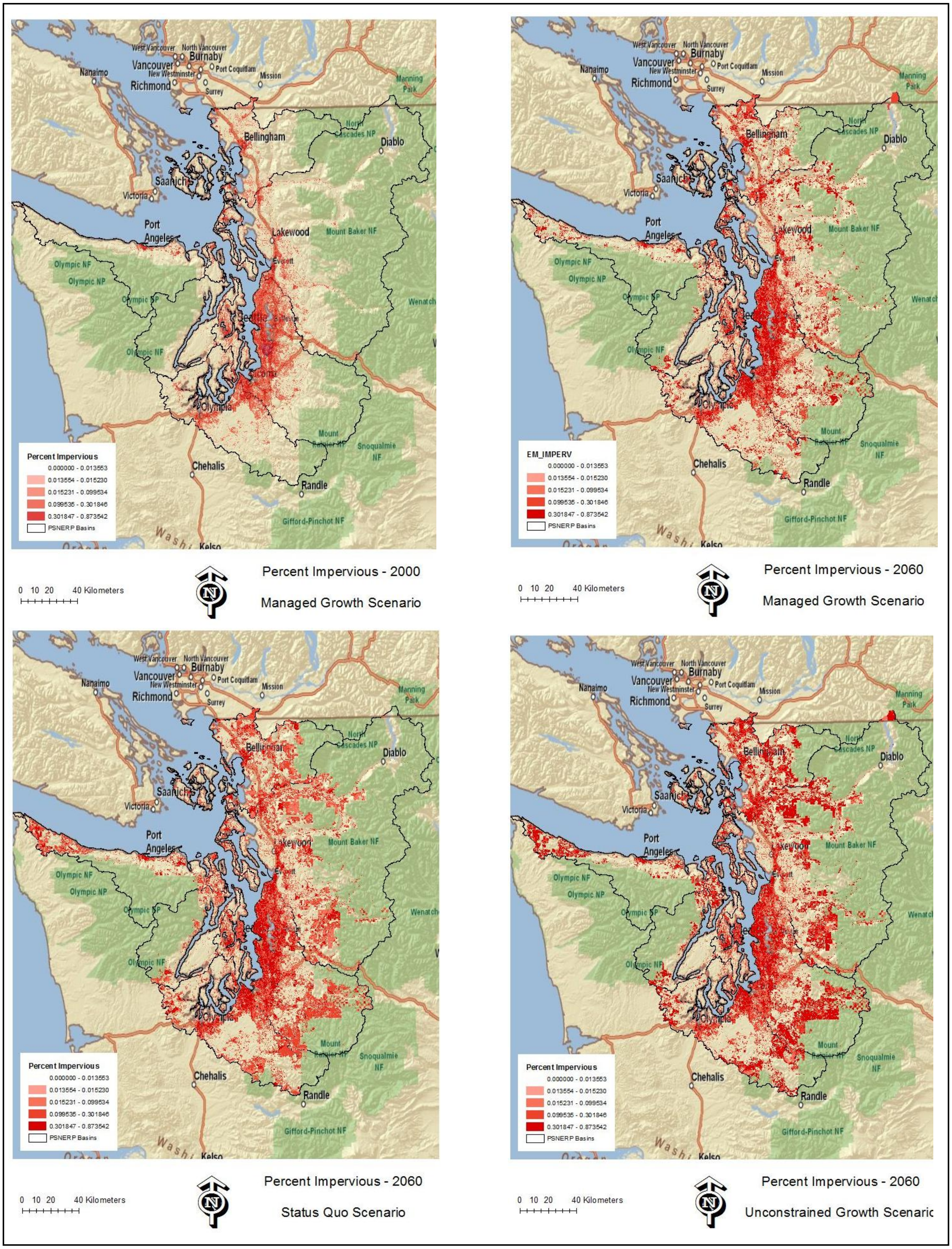


Figure 22. Impervious Surfaces Density under Base Year and 2060 Scenarios

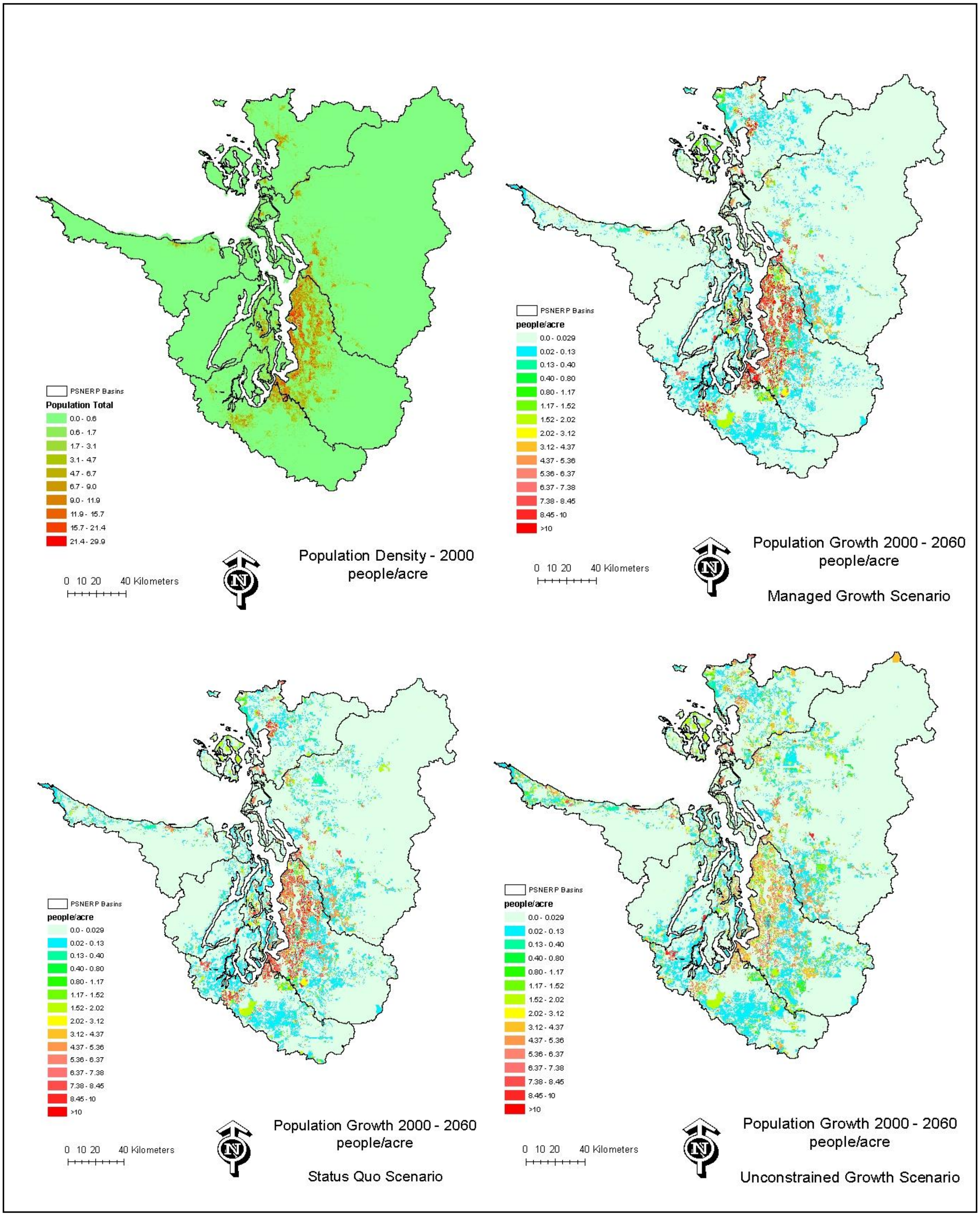


Figure 23. Population Density (ca. 2000) and Population Growth (2060) Maps for each Scenario

The overall pattern for population density across Puget Sound is outlined in Figure 23 for the year 2000 and for each of the scenarios in 2060. In this case, the upper left plate represents current (year 2000) population density, and the other three plates represent the change in population density between 2000 and 2060. The patterns are similar to those for land cover and impervious area, with the unconstrained growth scenario depicting a much larger population footprint. The figures also indicate the focus on regional growth centers in the managed growth scenario, where the amount of growth within the cities is greater for this scenario than for the other two.

Conclusion

This effort successfully generated three scenarios of change for the Puget Sound region reflecting three distinct sets of policy drivers and model parameterizations. We believe the ability to represent landscape change in both space and time, employing the policy-centric multiagent-based approached used in *Envision*, was a useful approach to address the task of scenario representation and projection. The spatial and temporal pattern of changes was largely consistent with expected results, with distinct sub-basin differences observed in some variables. A full analysis of these results is beyond the scope of this project; however, the spatial detail and relatively rich landscape characterization employed provides numerous possibilities for additional analysis.

We note that there were many limitations to procedures used here. Chief among these are: 1) a more complete set of policy descriptors address a broader range of decision alternatives, 2) a more complete consideration of landscape feedbacks that might influence land management choices represented in the Envision model, 3) a more complete set of landscape change process descriptors (e.g. climate change, vegetative succession, estuarine dynamics), a result in some cases of data limitations, in other cases forced by the tight schedule employed in this effort, 4) assumptions of fixed Urban Growth Areas and fixed transportation networks, and 5) a need to employ relative simple descriptors of shoreline modification processes and a reduced set of shoreline stressors. However, given these limitations, we believe the results generated by this analysis provide sufficient spatial and temporal detail, and sufficiently capture some important landscape change drivers, to provide useful insights into possible alternative future scenarios for the Puget Sound region.

Appendices

Appendix 1: IDU and Associated Spatial Data Metadata

Envision IDU datasets are initially developed using GIS-based methods of spatial intersection to produce a set of polygons representing key landscape features. Additional attributes representing different landscape features can then be added to the database. We refer to those spatial datasets used to produce IDU geometry as base datasets, and those used to augment the IDUs as auxillary data. For those datasets developed outside of the FRAP analysis, the dataset description has been developed from metadata supplied with the original data.

The polygon geometry was based on the intersection of 13 individual data sets

- PSNERP Change Analysis GSU polygons
- Ownership
- Protected lands
- NLCD landcover
- Census200 block-groups
- Urban growth areas
- Incorporated areas
- Counties
- County zoning data
- FEMA 100 yr floodplain
- Puget Sound viewsheds
- Coastal landslide hazards

The auxillary data were based on 14 datasets and include:

- Herring spawning areas
- Tidal barriers
- Armor length
- Nearshore wetlands
- Historical nearshore wetlands
- Impervious area
- Over water structures
- Active railroads
- Inactive railroads
- Coast line geometry
- Road network
- NHD+ stream network
- Regional growth centers

1. PSNERP GSUs

Source: PSNERP Change Analysis

Description: This polygon dataset contains multiple scales of nested spatial units that form the assessment units for the Puget Sound Nearshore Ecosystem Restoration Project (PSNERP) Change Analysis. This Geographic Scale Units (GSUs) spatial organizational structure allows for comparison of historic (late 1800s) and current (circa 2000) watershed conditions at multiple analysis scales. The GSUs nested spatial units area delineated based on watershed topography, drift cells, and major rivers. The basic GSUs over which change analysis metrics will be summarized are the Drainage Unit (DU), the Shoreline Accounting Unit (AU), the Shoreline Process Unit (SPU), Delta Accounting Unit (DAU), Delta Process Unit, and the Zone Unit (ZU).

Geography: Soundwide

Data Format: Polygon featureclass

Attribute(s): GSUID

2. Ownership

Source: PSNERP Change Analysis

Description: This polygon feature class depicts land ownership type in the Puget Sound region. It is derived from data prepared by The Nature Conservancy (TNC).

Geography: Soundwide

Data Format: Polygon featureclass

Attribute(s): OWNER

3. Protected Lands

Source: PSNERP Change Analysis

Description: This polygon feature class depicts land protection status in the Puget Sound region. It is derived from data prepared by The Nature Conservancy.

Geography: Soundwide

Data Format: Polygon featureclass

Attribute(s): PROTECTED

4. NLCD Landcover

Source: PSNERP Change Analysis

Description: This polygon feature class depicts land-cover and land-use in the Puget Sound region. It is derived from the Multi-Resolution Land Characteristics Consortium 2001 National Land Cover Data (MRLC NLCD).

Geography: Soundwide

Data Format: Polygon featureclass

Attribute(s): LULC_B

5. Census 2000 block-group data

Source: GeoLytics, Inc. http://www.censuscd.com/USCensus,Census-2000-Long-Form,Products.asp

Description: This polygon feature class depicts census-block groups, land area and total populations.

Geography: Soundwide

Data Format: Polygon featureclass

Attribute(s): POP_DEN

6. Urban growth areas

Source: Puget Sound counties

Description: This polygon feature class depicts defined urban growth areas (UGA) across the Puget Sound region. The sound-wide dataset is a composite of data available for each of the 13 counties which contain some portion of the Puget Sound basin. Data from Lewis county was not available.

Geography: Soundwide

Data Format: Polygon featureclass

Attribute(s): UGA

7. Incorporated areas

Source: Washington State Office of Financial Management at: http://www.ofm.wa.gov/geographic/00tiger.asp

Description: Polygons depict the boundaries of Washington State's incorporated municipalities, as recorded by the Washington State Office of Financial Management. Attributes include city names as provided by the Washington State Office of Financial Management, and Federal Information

Processing Standard codes (FIPS) as provided by the National Institute of Standards and Technology. The Washington State Office of Financial Management provided FIPS codes for cities incorporated after the National Institute of Standards and Technology's FIPS code publication date. GNIS (Geographic Name Information System) codes provided by the Washington State Department of Revenue have been included for this quarter. For this particular update, all annexations approved by Office of Financial Management for Second Quarter of 2009 are included.

Geography: Soundwide

Data Format: Polygon featureclass

Attribute(s): INCORP

7. Counties

Source: Washington State Department of Ecology (http://www.ecy.wa.gov/services/gis/data/data.htm)

Description: This polygon feature class depicts the borders of Washington's 39 counties

Geography: Statewide

Data Format: Polygon featureclass

Attribute(s): COUNTY

8. County zoning data

Source: Puget Sound counties

Description: This polygon feature class depicts defined zoning classes across the Puget Sound region. The sound-wide dataset is a composite of data available for each of the 13 counties which contain some portion of the Puget Sound basin. Data from Lewis county was not available. Data from each of the 32 incorporated areas was not collected. In those areas where data was unavailable, landcover information was used to approximate the zoning status. In all cases, the zoning classifications were hierarchically summarized to a coarser representation of development potential that is consistent across the Puget Sound region.

Geography: Soundwide

Data Format: Polygon featureclass

Attribute(s): DEV_CODE

9. FEMA 100 yr floodplain

Source: Washington State Department of Ecology

Description: The Q3 Flood Data are derived from the Flood Insurance Rate Maps (FIRMS) published by the Federal Emergency Management Agency (FEMA). The files for each county were downloaded from http://www.ecy.wa.gov/services/gis/data/flood/q3flood.htm and intersected to produce a sound wide floodplain map for further IDU development

Geography: Soundwide

Data Format: Polygon featureclass

Attribute(s): FLOOD

10. Puget Sound viewsheds

Source: Oregon State University Biological and Ecological Engineering

Description: This polygon feature class outlines those areas of the Puget Sound watershed that have the possibility of a view of nearshore Puget Sound. The dataset was derived from a 30 m Digital Elevation Model from the NHD+ data set for Region 17, downloaded from http://nhd.usgs.gov/

Geography: Soundwide

Data Format: Polygon featureclass

Attribute(s): PS_VIEW

11. Landslide hazards

Source: Washington State Department of Ecology

Description: The digital maps presented here were originally published as hard copy maps in the Coastal Zone Atlas of Washington between 1978 and 1980. The data extends only 200 ft inland from the shore Although the Atlas has been out of print for many years, the maps contain information that remain the basis for local planning decisions. After receiving multiple requests for electronic versions of portions of the Atlas, an effort was made to scan, georeference and digitize aspects of the Atlas, beginning with the slope stability maps. These maps indicate the relative stability of coastal slopes as interpreted by geologists based on aerial photographs, geological mapping, topography, and field observations. Such methods are standard, but may occasionally result in some unstable areas being overlooked and in some stable areas being incorrectly identified as unstable. Further inaccuracies are introduced to the data through the process of converting the published maps into digital format. Important land use or building decisions should always be based on detailed geotechnical investigations. This mapping represents conditions observed in the early and mid-1970s. Shorelines and steep slopes are dynamic areas and many landslides have occurred since that time that are not reflected on these maps. Subsequent human activities may have increased or decreased the stability of some areas.

Geography: Soundwide (200 ft inland from shore

Data Format: Polygon featureclass

Attribute(s): SLOPE_STAB

13. Shoreform

Source: PSNERP Change Analysis, Washington State Department of Natural Resources ShoreZone inventory

Description: These data are a compilation of current and historic shoreform typology (Shipman, et. al.) applied to the current WDNR ShoreZone shoreline. Change in shoreform is also depicted. Historic and current shoreforms in Puget Sound were independently delineated using Geographic Information System (GIS) techniques and image interpretation. These two data sets were then combined to provide a comparison of historic to current conditions.

Geography: Soundwide (nearshore)

Data Format: Polygon featureclass

Attribute(s): CURR_SHORE; HIST_SHORE

14. Herring Spawning Areas

Source: Washington State Department of Fish and Wildlife Critical Habitat Survey

Description: Polygons in Puget Sound showing locations of documented Pacific Herring (culpa harengus pallasi) spawning areas through 1991. The polygons were later edited by Kurt Stick, and digitized by Dale Gombert, both WDFW, 12/2003. Polygons show documented pacific herring spawning areas at specific sites throughout Puget Sound and Washington coastal areas and bays. Along the Washington coast, small populations spawn in Willapa Bay and Grays Harbor, and some spawning has been reported in the Columbia River estuary (Monaco et al. 1990). Larval and juvenile herring have also been found in Grays Harbor (Monaco et al. 1990). Herring deposit their eggs on marine vegetation: eelgrass and various algae, in the shallow subtidal and intertidal zone generally at tidal elevations from +3 feet to -20 feet Mean Low Low Waterline (MLLW). Forage fish are small, pelagic schooling fish which are important as forage for predatory fish, birds, and mammals. They provide an important link in the food chain between zooplankton and piscivorous (fish-eating animals). Because herring migrate considerable distances from their spawning grounds, impact on the critical habitats they utilize in one area could affect harvest or the food chain at other locations.

Geography: Soundwide (nearshore)

Data Format: Polygon shapefile

Attribute(s): P_HERRSPAWN. Areal percentage of each IDU that is classified as herring spawning area

14. Armor Length

Source: PSNERP Change Analysis

Description: This dataset depicts the distribution of shoreline armoring in Puget Sound. It is a compilation of several datasets contributing discrete armor location data. The armoring data have been transferred onto the WDNR Washington State ShoreZone Inventory (2001) shoreline.

Geography: Soundwide (nearshore)

Data Format: Line featureclass

Attribute(s): L_ARMOR. The length of armoring (m) within each IDU

P_ARMOR: The percentage of shoreline that is armored in each IDU

15. Tidal Barriers

Source: PSNERP Change Analysis

Description: The Salmon and Steelhead Habitat Inventory and Assessment Program (SSHIAP) used LIDAR, ortho and aerial oblique photos, transportation layers and an existing levee dataset to identify and digitize dikes, levees, roads and other man-made structures that impede tidal hydrology such that historic wetlands become lost or isolated from Puget Sound nearshore waters. This inventory was limited to selected tidal wetland classes within large river deltas, barriers estuaries, barrier lagoons and open coastal inlets as identified by the Puget Sound Nearshore Ecosystem Restoration Project Nearshore Science Team.

Geography: Soundwide (nearshore)

Data Format: Line featureclass

Attribute(s): L_TIDAL_BAR. The length of tidal barrier (m) within each IDU

16. Nearshore Wetlands

Source: PSNERP Change Analysis

Description: This polygon feature class depicts current wetland distribution in Puget Sound. It is derived from data prepared by the Puget Sound River History Project.

Geography: Soundwide (nearshore)

Data Format: Line featureclass

Attribute(s): P_CURRWET. The areal percentage of each IDU that is wetland (applies only to nearshore areas)

17. Nearshore Historical Wetlands

Source: PSNERP Change Analysis

Description: This polygon feature class depicts historic (late 1800s) wetland distribution in Puget Sound. It is derived from data prepared by the Puget Sound River History Project.

Geography: Soundwide (nearshore)

Data Format: Line featureclass

Attribute(s): P_HISTWET. The areal percentage of each IDU that was historically wetland (applies only to nearshore areas)

18. Impervious Area

Source: PSNERP Change Analysis

Description: This polygon feature class depicts impervious surface distribution in the Puget Sound region. It is derived from the Multi-Resolution Land Characteristics Consortium 2001 National Land Cover Data (MRLC NLCD).

Geography: Soundwide

Data Format: Polygon featureclass

Attribute(s): P_IMPERV. The areal percentage of each IDU that is impervious

19. Over water structures

Source: PSNERP Change Analysis

Description: This polygon feature class depicts locations of overwater structures in Puget Sound. It is derived from data prepared by the Washington Department of Natural Resources (WDNR). The enhanced delineation of marinas (marina definition: ten or more slips) increased accuracy (Anchor Environmental/U.S. Army Corps of Engineers effort). Systemic topological errors in the original dataset were eliminated to prevent inaccurate counting of area.

Geography: Soundwide

Data Format: Polygon featureclass

Attribute(s): N_DOCK. The number of docks in each IDU

N_MARINA. The number of marinas in each IDU

N_BUOYS. The number of buoys in each IDU

N_OTHERWS. The number of other OWS in each IDU

N_BRIDGE. The number of bridges in each IDU

A_DOCK. The footprint area (m^2) of docks in each IDU

A_MARINA. The footprint area (m^2) of marinas in each IDU

18, 19. Active and Inactive Railroads

Source: PSNERP Change Analysis

Description: These two polygon feature classes depict areas of active and abandonded railroads in the Puget Sound region. They are derived from data prepared by the Washington State Department of Transportation (WSDOT).

Geography: Soundwide

Data Format: Polygon featureclass

Attribute(s): D_RAIL_A; D_RAIL_I. The distance (m) of each polygon to the nearest point on an active or inactive railroad.

20. Coastline

Source: PSNERP Change Analysis

Description: The coastline geometry from fd_shoreform change, as described above, was used to calculate coastline distances

Geography: Soundwide

Data Format: Line featureclass

Attribute(s): D_COAST. Shortest (m) from each polygon to the nearest point on the coastline.

21. Roads

Source: PSNERP Change Analysis

Description: This polygon feature class depicts area of roads in the Puget Sound region. It is derived from data prepared by the Washington State Department of Natural Resources.

Geography: Soundwide

Data Format: polygon featureclass

Attribute(s): D_ROAD. Shortest distance (m) from each polygon to the nearest point in the road network.

22. Streams

Source: PSNERP Change Analysis

Description: Nearest distance (m) to NHD+ streams as downloaded from from the NHD+ data set for Region 17, downloaded from http://nhd.usgs.gov/

Geography: Soundwide

Data Format: Line shapefiles

Attribute(s): D_STREAM. Shortest distance (m) from each polygon to the nearest point in the NHD+ stream geometry data.

23. Regional growth centers

Source: OSU Biological and Ecological Engineering

Description: The regional growth centers developed as part of PSRC Vision 2040, and depicted on page 20 of http://www.psrc.org/projects/vision/pubs/vision2040/vision2040_021408.pdf were digitized. In addition, points representing the centers of the cities of Bellingham and Olympia were included as regional growth centers for these analyses.

Geography: Soundwide

Data Format: Point shapefiles

Attribute(s): D_RGC. Shortest distance (m) from each polygon to the nearest regional growth center

Metadata for the IDU coverage is available at http://envision.bioe.orst.edu/StudyAreas/PugetSound/Data/IDU_Metadata.html

Appendix 2: IDU Field Descriptors

A current set of field descriptors for the IDU coverage is available at http://envision.bioe.orst.edu/StudyAreas/PugetSound/Data/PS_FieldInfo.html.

Appendix 3: Policy Summary

A current set of policy descriptors is available is several formats on the web. See http://envision.bioe.orst.edu/StudyAreas/PugetSound for these documents.

Appendix 4: Scenario Descriptions

Resource Lands Conversion Policies

Policy Intention	Site Attribute(s)	Policy Outcomes	Scenario-specific Modifications
Conversion of Agricultural Lands within UGAs	DEV_CODE =Ag and OWNER=Private and UGA=1	DEV_CODE, LULC converts to Urban or Suburban with associated probability	SQ: probability of transition across all development classes consistent with current ratios. Moderately responsive to proximity to Regional Growth Centers. MG: limited conversion; where conversion occurs, probabilities biased to higher-density development patterns, limited to areas near regional growth centers (DIST_RGC), and away from areas with good conservation potential, floodplains, and near streams. UG: probabilities biased to lower-density development patterns; viewshed lands more likely to be developed.
Conversion of Agricultural Lands outside UGAs	DEV_CODE=Ag and OWNER=Private and UGA=0	DEV_CODE, LULC converts to Rural Residential or Suburban with associated probability	
Conversion of Forested Lands within UGAs	DEV_CODE=Forest and OWNER=Private and UGA=1	DEV_CODE, LULC converts to Urban or Suburban with associated probability	
Conversion of Forested Lands outside UGAs	DEV_CODE=Forest and OWNER=Private and UGA=0	DEV_CODE, LULC converts to Rural Residential or Suburban with associated probability	

Table 5. Resource Land Conversion Policies

Redevelopment and Infill Policies

Policy Intention	Site Attribute(s)	Policy Outcomes	Scenario-specific Modifications
Redevelopment/ Infill of Commercial/ Industrial	UGA=1 and OWNER=Private and DEV_CODE = Commercial and LULC_B=low or medium density development	DEV_CODE/LULC converts to High-Density Development with associated probability	SQ: Moderately responsive to proximity to Regional Growth Centers. MG: limited conversion; where conversion occurs, probabilities biased to higher-density development patterns; strongly biased towards areas near regional growth centers. UG: probabilities biased to lower-density development patterns
Infill/ Densification to Residential Uses	UGA=1 and OWNER=Private and DEV_CODE = Urban/Suburban Low Density	DEV_CODE/LULC converts to Urban/Suburban Med/High Density and Parks with associated probability	

Table 6. Redevelopment and Infill Policies

Barren Land Conversion Policies

Policy Intention	Site Attribute(s)	Policy Outcomes	Scenario-specific Modifications
Within UGA Conversion	LULC_B=Barren and OWNER=Private and UGA=1	DEV_CODE, LULC converts to Comm/Urban/Parks with associated probability	SQ: probability of transition consistent with current ratios across all development classes. MG: probabilities biased to higher-density development patterns; sensitive lands converted to protected vegetated lands (outside UGAs) and Parks (within UGAs) Unconstrained Growth: probabilities biased to lower-density development patterns.
Outside UGA Conversion	LULC_B=Barren and OWNER=Private and UGA=0	DEV_CODE, LULC converts to Rural Residential/Parks with associated probability	

Table 7. Barren Land Conversion Policies

Nearshore/Shoreline Development Policies

Status Quo		
Policy Intention	Site Attribute(s)	Policy Outcomes
Conversion of undeveloped lands to commercial/ residential development	DEV_CODE = Ag or Forest and OWNER=Private and CURR_SHORE != Delta and FLOOD != 1 and SLOPE_STAB != unstable • IDU's near roads have an increased likelihood of development; • Those containing wetlands (P_CURRWET > 0.20) have a reduced likelihood of development; • Those with a water view have an increased likelihood of development; • Those in an existing UGA have a higher probability of development	DEV_CODE/LULC converts to Comm/Urban/ Suburban/Parks with associated probability, emphasizing a mix of densities
Infill/Densification of Residential Development	DEV_CODE = Urban/Suburban/Rural Residential and OWNER=Private and CURR_SHORE != Delta and FLOOD != 1 and SLOPE_STAB != unstable • IDU's near roads have an increased likelihood of development; • Those containing wetlands (P_CURRWET > 0.20) have a reduced likelihood of development; • Those with a water view have an increased likelihood of development; • Those in an existing UGA have a higher probability of development	DEV_CODE/LULC converts to higher-density Urban/ Suburban/ Rural Residential with associated probability, emphasizing a mix of densities

Managed Growth		
Policy Intention	**Site Attribute(s)**	**Policy Outcomes**
Conversion of undeveloped lands to commercial/ residential development	DEV_CODE = Ag or Forest and OWNER=Private and CURR_SHORE != Delta and FLOOD != 1 and SLOPE_STAB != unstable and DIST_COAST > 200 and P_CURRWET < 0.10 and CONSERV < good/very good and DIST_STR > 10 • IDU's near roads have an increased likelihood of development; • Those with a water view have an decreased likelihood of development; • Those in an existing UGA have a higher likelihood of development; • Those near regional growth centers have an increased likelihood of development; • Those occupying historic wetlands are less likely to be developed.	DEV_CODE converts to Comm/Urban/ Suburban/Parks with associated probability, higher density classes; parks emphasized
Unconstrained Growth		
Policy Intention	**Site Attribute(s)**	**Policy Outcomes**
Conversion of undeveloped lands to commercial/ residential development	DEV_CODE = Ag or DEV_CODE = Forest and OWNER=1 and CURR_SHORE != Delta and FLOOD != 1 and SLOPE_STAB != unstable • IDU's near roads have an increased likelihood of development; • those with a water view have an increased likelihood of development; • those in an existing UGA have a higher probability of development	DEV_CODE/LULC converts to Comm/Urban/ Suburban/Parks with associated probability, emphasizing lower density uses
Infill/Densification of Residential Development	DEV_CODE = Urban/Suburban/Rural Residential and OWNER=1 and CURR_SHORE != Delta and FLOOD != 1 and SLOPE_STAB != unstable • IDU's near roads have an increased likelihood of development; • those containing wetlands (P_CURRWET > 0.20) have a reduced likelihood of development; • those with a water view have an increased likelihood of development; • those in an existing UGA have a higher probability of development	DEV_CODE/LULC converts to higher-density Urban/ Suburban/ Rural Residential with associated probability, emphasizing lower-density uses

Table 8. Nearshore/Shoreline Development Policies

Sensitive Areas/Conservation Lands/Open Space Policies

Status Quo		
Policy Intention	Site Attribute(s)	Policy Outcomes
Protection of existing wetlands	LULC_B = wetlands and P_CURR_WET > 0.4 • those outside an existing UGA have a lower probability of protection	protected
Restoration of historic wetlands	DEV_CODE = Ag or Forestry, P_CURR_WET < 0.1, P_HIST_WET > 0.5 • those outside an existing UGA have a lower probability of protection	LULC_B=wetlands, protected
Protection of Eelgrass/Herring Spawning areas	Distance to Eelgrass beds /Herring spawning areas < 100m and DEV_CODE = Ag or Forestry	protected
Open Space Protection	DEV_CODE = open space	Protected
Managed Growth		
Policy Intention	Site Attribute(s)	Policy Outcomes
Protection of existing wetlands	LULC_B = wetlands and P_CURR_WET > 0.1 • All IDUs outside an existing UGA are protected. Within UGAs, a higher probability of protection is specified	protected
Restoration of historic wetlands	DEV_CODE = Ag or Forestry, P_CURR_WET < 0.1, P_HIST_WET > 0.50 • those outside an existing UGA have a lower probability of protection	LULC_B=wetlands, P_CURR_WET= P_HIST_WET, protected
Protection of Eelgrass/Herring Spawning areas	Distance to Eelgrass beds/Herring spawning areas < 200m and DEV_CODE = Ag or Forestry • Applies to all undeveloped IDUs	protected
Open Space Protection	DEV_CODE = open space	protected

Table 9. Sensitive Areas/Conservation Lands/Open Space Policies