Estimating and Forecasting Ecosystem Services within Pine Island Sound, Sanibel Island, Captiva Island, North Captiva Island, Cayo Costa Island, Useppa Island, Other Islands of the…

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Estimating and Forecasting Ecosystem Services within Pine Island Sound, Sanibel Island, Captiva Island, North Captiva Island, Cayo Costa Island, Useppa Island, Other Islands of the Sound, and the Nearshore Gulf of Mexico

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Introduction and Background

The natural world, its biodiversity, and its constituent ecosystems are critically important to human well-being and economic prosperity, but are consistently undervalued in conventional economic analyses and decision making. Ecosystems and the services they deliver underpin our very existence. Humans depend on these ecosystem services to produce food, regulate water supplies and climate, and breakdown waste products. Humans also value ecosystem services in less obvious ways: contact with nature gives pleasure, provides recreation and is known to have positive impacts on long-term health and happiness (Watson and Albon 2011).

Human societies get many benefits from the natural environment. Especially in Southwest Florida, we are well aware of how important eco-tourism, sport and commercial fishing, and natural products such as locally produced fruits, vegetables, and honey are to our regional economy. The natural environment also provides, for free, services that we would otherwise have to pay for, in both capital outlay, and operation and maintenance costs.

Ecosystem Services are the multitude of resources and processes that are supplied by natural ecosystems. "Ecosystems Services" refers to a wide range of natural processes that help sustain and fulfill human life, such as:

- Purification of air and water
- Detoxification and decomposition of wastes
- Pollination of crops and natural vegetation
- Cycling and movement of nutrients
- Protection of coastal shores from erosion by waves
- Moderation of weather extremes and their impacts
- Provision of aesthetic beauty and intellectual stimulation that lift the human spirit

The United Nations 2004 Millennium Ecosystem Assessment grouped ecosystem services into four broad categories:

- <u>Provisioning</u>, such as the production of food and water
- <u>Regulating</u>, such as the control of climate and disease
- <u>Supporting</u> (Habitat), such as nutrient cycles and crop pollination

- Cultural (Socio-economic), such as spiritual and recreational benefits

Ecosystem services values can be used by decision makers when establishing and maintaining conservation lands, siting utilities, or making development decisions, putting numbers to the impacts associated with those decisions, and adding data when critical trade-offs are being discussed. These values can also be useful in justifying grant funding and in leveraging restoration dollars.

Documented recognition of how ecosystems provide complex services to mankind date back in Western culture to at least Plato (c. 400 BC) (Marsh 1965). The term 'environmental services' was introduced 1970 in a report of the Study of Critical Environmental Problems (SCEP 1970), which listed services including insect pollination, fisheries, climate regulation and flood control. In following years, variations of the term were used, but eventually 'ecosystem services' became the standard in scientific literature (Ehrlich, P.R. and A. Ehrlich. 1981). Modern expansions of the ecosystem services concept include socio-economic and conservation objectives (de Groot, et al.2012).

There has resistance, particularly from living science academics and environmentalists, to establishing monetary values for ecosystem services because it is difficult to capture the total value and there is always the potential to risk under-valuing the services. However, assigning value to ecosystem services is necessary and important tool to demonstrate the economic values being lost to society. Ecosystem evaluation is field that requires great amounts of innovation; developing communication tools that can relate tangible value to ecosystem services will be meaningful in protecting healthy watersheds. The important message is that conservation provides myriad economic and social benefits at the local level. Protecting these systems will provide society with greater economic security, healthy, bountiful fisheries, a higher quality of life and clean drinking water (Dlugolecki 2012).

Location

Pine Island Sound is located in Lee County, Florida, lying between Pine Island (Lee County, Florida) and the barrier islands of Sanibel Island, Captiva Island, North Captiva Island and Cayo Costa, which separate the Sound from the Gulf of Mexico (Figure 1). The Sound connects to Gasparilla Sound and Charlotte Harbor to the north, and to San Carlos Bay and the Caloosahatchee River to the south. The Sound is conterminous with the Pine Island Sound Aquatic Preserve, which was established in 1970 and consists of 54,000 acres (220 km^2) of submerged land. Important habitats in the Sound include mangrove forests, sea grass beds, salt marshes, oyster reefs and tidal flats.

Pine Island Sound has the most extensive sea grass beds in the greater Charlotte Harbor complex. The three most commonly found species are turtle grass (*Thalassia testudinum*), manatee grass (*Syringodium filiforme*), and shoal grass (*Halodule wrightii*). On the western side of Pine Island, a nearly continuous broad band of sea grass about 17 miles (27.3 kilometers) long extends from north to south. Areas of Pine Island Sound deeper than 6 feet (1.8 meters), generally do not have any of the three common species, but can have another species, star grass (*Halophila* sp.) appearing in some years. Sea grasses are abundant on the eastern (bay) sides of the barrier islands and on the eastern depositional fan areas of Captiva, Redfish and Blind Passes.

Large areas of oyster reef-hard bottom communities are comparatively rare in the estuary, and are often found associated with the shoreline, yet at a distance from it. The total estimated mangrove acreage for the Pine Island Sound/Matlacha sub basin is 19,107 acres (7,732 hectares). The mangroves in this region are extensive and fringe all of the protected shorelines of the barrier islands. The mosaics of mangroves in the southern portion of this region, on the northern coast of Sanibel Island, are particularly noted for the living resources they support, such as large populations of endangered roseate spoonbills.

The establishment of ecosystem services values for this ecologically rich area will be among the first valuations of this type in this region and will serve as an example for future projects. Ecosystem services values can be used by decision makers when establishing and maintaining conservation lands, siting utilities, or making development decisions, putting numbers to the impacts associated with those decisions, and adding data when critical trade-offs are being discussed. These values will also be useful in justifying other grant funding and in leveraging future restoration dollars.

Prior Ecosystem Services Studies Involving the Study Area

In 1995 the CHNEP commissioned the study *Consumer Surplus and Total Direct and Indirect Income in the CHNEP in 1995 dollars* from Hazen and Sawyer (1998). The study calculated consumer surplus and total direct and indirect income.

Consumer surplus may be thought of as consumer “profit.” Although this money doesn’t actually change hands, it represents the value of human well-being associated with current use of the resources. For example, if you purchased a boat for $10,000, but were willing to pay up to $12,000, you would get a benefit of $2,000 in consumer surplus above the price you actually paid.

Total Direct and Indirect Income is described in the report as follows. Any business that relies on natural resources to make money typically depends also on supplies and services from other companies. Most businesses rely on other companies to provide support such as food, transportation, utilities, office supplies, and business/professional services. These related goods and services also produce an income, and additional benefit to our community. The combined income of a business and the related sales it generates from other companies is the total income that business generates in the region’s economy. For example, if a family on vacation rented kayaks at the wildlife refuge, they likely spent money at a hotel for lodging, rented a car for local travel, and purchased meals. In this case, total income would attempt to capture expenditures associated with this resource use.

In southwest Florida, 80% of commercial and recreational harvested marine species depend on mangrove estuaries for at least a portion of their lifecycles (Lewis *et al.* 1985). Evaluation of mangroves values in a Federal enforcement action in Lee County in 1986 involving a development known as "The Estuaries", utilizing conservative estimators, found that a mature 6 meter (20 ft.) tall canopy of red mangrove forest contributed $2,040.54 per year in commercial fisheries landings in 1970 dollars, not adjusted for inflation. This translates into $12,169.98 per acre per year in 2012 dollars. For all of 10,543.93 acres of mangroves in the shoreline of the project study area this sums to $128,319,417.22. For the entire CHNEP this sums to $776+ Million per Year in 2012 dollars.

However smaller and shorter mangrove canopies, including trimmed canopies, contribute less to fishery values than taller, natural canopies because there is less net primary productivity (NPP) available as export from shorter canopies (Beever 1999). The difference is non-linear. A 1.5 m (5 ft.) height contributes $143.70 per acre/yr and a 10.7 m (35 ft.) tall canopy contributes $6,514.40 per acre/yr. in 1975 dollars, unadjusted for inflation. This is $618.09 and $28,020.03 per acre/yr. in 2012 dollars. In order to apply this adjustment factor it is necessary to have an accurate map of the eight different types of mangrove forest and the variety of human altered mangrove shorelines to have accurate areas for calculation. Unfortunately this information does not currently exist, although studies have been proposed to obtain this information.

These mangrove ecosystem service values do not reflect recreational fisheries values, including the prey base, which range from 5.6 to 6.5 times the primary sales of commercial fisheries (Lewis *et al.* 1982). This would range from $146 Thousand to $169+ Thousand per acre per year in 2012. This would be an additional $1,539,413,780.00 to $178,1924,170.00 for the study area

Nor do they include the ecosystem services provided by mangroves in the areas of the erosion protection value, the tourist income generated from tours, bird watching, canoeing and recreational non-fishing boating in mangrove estuaries, the water quality enhancement of point and non-point sources of water pollution, the privacy screen value and habitat value of these mangroves to endangered and threatened species.

Coastal wetlands reduce the damaging effects of hurricanes on coastal communities. A regression model using 34 major US hurricanes since 1980 with the natural log of damage per unit gross domestic product in the hurricane swath as the dependent variable and the natural logs of wind speed and wetland area in the swath as the independent variables was highly significant and explained 60% of the variation in relative damages. A loss of 1 ha of wetland in the model corresponded to an average $33,000 (median ¼ $5,000) increase in storm damage from specific storms. Using this relationship, and taking into account the annual probability of hits by hurricanes of varying intensities, we mapped the annual value of coastal wetlands by 1km 3 1km pixel and by state. The annual value ranged from $250 to $51,000 ha/year, with a mean of $8,240 ha/year (median ¼ $3,230 ha/year) significantly larger than previous estimates. Coastal wetlands in the US were estimated to currently provide $23.2 billion per year in storm protection services. Coastal wetlands function as valuable, self-maintaining ‘‘horizontal levees’’ for storm protection, and also provide a host of other ecosystem services that vertical levees do not. Their restoration and preservation is an extremely cost-effective strategy for society (Costanza et al. 2008).

Low trace gas emissions and high soil carbon sequestration from mangroves and salt marshes make a robust case for carbon credit projects. Coastal habitats mangroves and salt marsh store up to 50 times more carbon in their soils by area than tropical forests, and ten more than temperate forests. Mangroves are highly efficient carbon sinks, holding large quantities of carbon in standing biomass and in sediments. They have among the highest measured levels of carbon sequestration per acre of any system measured to date.

Fixation of 1 ton of Carbon was worth $7 per ton in 2008 in the United States and $10 to $25 in 2011 in the world markets including California. Peak mangrove carbon fixation is 16 tons per acre per year (Hicks and Burns 1975) in brackish water conditions. Peak southern slash pine carbon fixation is 14 tons per acre per year in a 50 year old stand. For the CHNEP just these two habitats could provide 3 Million tons of carbon fixation per year. For the project study area carbon fixation rates form mangroves alone would be 168,702.88 tons per year with a value of $1.6 to $4.2 in 2011 dollars/ year.

In another method of calculating carbon credit values, the monetary value of the carbon fixation of mangroves has been estimated by Leaird (1972) at $4,000 per acre per year, using the conversion rate of $1 = 10,000 kilocalories. This would be $21,871.75 per acre per year in 2012 dollars. This indicates a total carbon fixation value of $230,614,200.98 for the project study area and a total carbon fixation value in the CHNEP mangroves valued at $1.4+ Billion per year.

The travel and tourism industry is one of the United States' largest industries, generating $739 billion in travel expenditures this past year and $116 billion travel-generated tax revenue. Travel and tourism also is one of America's largest employers, with 7.7 million direct travel-generated jobs. Tourism is one of the largest economic industries in Florida, with approximately 82.4 million travelers visiting the Sunshine State in 2007. During their time here, visitors generated more than $65 billion in taxable sales. That amount of spending generated $3.9 billion in tax-related revenue to the state of Florida, which is spent on public necessities such as schools, transportation, museums and enhancing Florida's offerings to entice even more visitors. Nearly 1 million Floridians are employed by the tourism industry, creating a combined annual payroll of$15.4 billion.

In Lee County, tourism employs 1 out of every 5 people. Lee County receives approximately 5 million visitors a year that generate approximately $3 billion in economic impact. In 2011, the Tourist Tax collection generated $23.1 million dollars. Lee County benefits from the economic impact of the industry in dollars and cents, and also benefits from the quality of life to which it contributes.

The Lee County Visitor & Convention Bureau has gathered data on tourism expenditures and the distribution of visitor interest and activities. From this it is possible to calculate the Beach Visitor Expenditures from the Annual Visitor Profile and Occupancy Analyses and The Beaches of Fort Myers and Sanibel Attitude & Usage Study conducted by the Clerk of Courts that a linear mile of swimming beach generates $345,228.73 per acre in 2002 dollars. Accounting for inflation this is $443,898.13 per acre in 2012 dollars. For the study area that contains 859.45 acres of swimming beach this is $381,508,218.56 in 2012 dollars per year in Total Direct and Indirect Income.

In a presentation of some estimates of the economic values of ecosystem services provided by natural habitats found on conservation lands of southwest Florida at the Estero Bay Agency On Bay Management Cela Tega, FGCU Beever (2011) calculated the Mangrove Forest Total Economic Value for 63,831.96 total acres in the CHNEP as $49.2 Billion in 2012 dollars; the

Sea Grass Bed Total Economic Value for 65,247.52 acres in CHNEP at $6.1 Billion in 2012 dollars; and the Salt Marsh Total Economic Value for 14,856.1 total combined acres in the CHNEP as $77.25 Million in CHNEP in 2012 dollars.

METHODS

We identified all the existing habitat types found in the study area through GIS analysis of existing aerial imagery. The most recent available GIS layers were utilized included the NOAA bathymetry (CHNEP 2011) (Figure 2), the CHNEP Benthic Habitat Map (CHNEP 2007) (Figure 3), the SFWMD sea grass mapping (2008) (Figure 4), the SFWMD land use map (2008) (Figure 5), and the salt marsh by type map created by the SWFRPC in the salt marsh study (Beever et al. 2012) (Figure 6).

Functional assessment methods utilized in the study, *A Watershed Analysis of Permitted Coastal Wetland Impacts and Mitigation Methods within the Charlotte Harbor National Estuary Program Study Area* (Beever et al 2011), were utilized, linking the derived ecosystem function measurements with geo-spatially positioned ecosystem services information.

The combined land and bottom cover map (Figure 7) was constructed with the NOAA bathymetry layer placed first. Then the CHNEP Benthic Habitat Map was placed within the estuary extents that it covers and given priority as the cover type. Then the SFWMD sea grass mapping was overlaid with priority over other benthic types. Then the SFWMD land use map was then placed in the project map. Finally the salt marsh by type map was placed and given priority over other land covers it overlaid. Where there were small edge with no land use indicated, mostly at the meeting of the benthic layer and land cover the blank area was assigned the value of the nearest adjacent benthic or bathymetric value.

The range and quantity of ecosystem services provided by existing habitats was estimated, including the marine, estuarine and freshwater wetlands, and associated native uplands of Pine Island Sound, Sanibel Island, and Captiva Island were estimated. Dollar values for ecosystem services were obtained either directly or through calculation from Allsopp et al. 2008, Beever III and Cairns 2002, Beever III 2011, Beever III, et al. 2012, Bolund and Hunhammar 1999, Casey and Kroeger 2008, Committee on Assessing and Valuing the Services of Aquatic and Related Terrestrial Ecosystems (CAVSARTE) 2004, Costanza et al. 1997, Costanza 2008, Costanza et al. 2008, Dale and Polasky 2007, Dlugolecki 2012, Engeman et al. 2008, Goulder and Kennedy 2007, Goulder and Kennedy 2011, Hazen and Sawyer 1998, Henderson and O'Neil 2003, Isaacs et al. 2009, Krieger 2001, Kroeger and Casey. 2007, Kroeger et al. 2008, Lee County Clerk of Courts 2002, Losey and Vaughan 2006, Lugo and Brinson 1979, McLeod and Salm 2006, Paling, et al. 2009, Quoc Tuan Vo et al. 2012, Metzger et. al. 2006, Morales 1980, Sathirathai 2003, South Florida Water Management District 2007, Spaninks and van Beukering, 1997,Watson and Albon 2011, and Wells, et al. 2006 (Appendix 1). For developed land use types (FLUCCS 100, 200, and 800) the Total Ecosystem Services Value (TEV) calculation involved the estimation of the amount of non-impervious surface on the specific land use type and the vegetation type on that lands use. This information was obtained from Thompson et al. (2011), the Sanibel Plan (2012), and information provided by the U.S. Census (2010) and the Sanibel-Captiva Conservation Foundation.

We produced a current map of ecological services value topographies (ECOSERVE) using combined GIS map and the total estimated ecosystem services value for each habitat type. This provides a visual representation of the geographic distribution of the TEV within the study area. We then calculated the TEV for the total acreage of each habitat type within the study area. Each dollar value for ecosystem service provided by a particular habitat was specified for its year of estimation. The dollar value of the ecosystem service estimate was then normalized using the inflation rate form the consumer price index (Bureau of Labor Statistics 2012) to a 2012 dollar value using the appropriate inflation multiplier. The resulting ecosystem service value per acre was then multiplied by the number of acres of that habitat type to obtain the total ecosystem services value for that habitat type in the study area. All the habitat values were then be summed to obtain a total ecosystem services value for the entire study area (Table 1).

An ecosystem services topography (ECOSERVE) geographic information system (GIS) layer was generated from the TEV value per acre mapped within each habitat. This geographic representation of the TEV for the study area provides a visual representation of where the highest value habitats are and how different changes on the landscape can change and transform the value and nature of the ecosystem services provided by the estuary and barrier islands (Figure 8).

The ECOSERVE map that can be combined with other geographic information system (GIS) layers for functional analyses by service type, by geographic boundary (watershed, municipality, etc.), and in combination. This process is a tool that can generate projections of ecosystem services that may result from land use changes, anticipated climate changes, natural and man-made disasters, the implementation of alternative wetland protection and land conservation programs, or the landscape which would reflect the eventualities resulting from making no changes to current land use, management or regulatory policy.

We generated two alternate future ECOSERVE topographies related to the anticipated land use changes that come with the future land use projection for the year 2030 (Figure 9) and for a one-foot sea level rise in the study area (Figures 10 and 11).

Results and Discussion

This work is intended to identify the range and quantity of ecosystem services provided by marine, estuarine and freshwater wetlands and native upland habitat and to determine how the functional types of wetlands and native uplands, their distribution and position in the landscape, and their ecological condition affects ecosystem services within the Pine Island Sound, and on Sanibel Island, Captiva Island, North Captiva Island, Cayo Costa Island, Useppa Island and Islands of the Sound.

Experts currently recognize four categories of ecosystem services: This project will involve establishing the acreage of all the various habitat types; identification of the ecosystems services provided by each habitat type; definition of the extents of each habitat type; identification of the distribution and position of these habitats in the southwest Florida landscape; identification of the ecological condition of these habitats; and quantification of how these factors alter provisioning, regulating, supporting, and cultural ecosystem services that these habitats provide in their existing and potentially restored status.

<u>Current (2012) Total Ecosystem Services Value (TEV) for the Study Area</u>

Based on current calculations of TEV for the study area the 2012 TEV is $7,033,362,634.63. (Figure 8, Table 1). It is notable that the majority (98.59 %) of the TEV is found in the top seven habitats including mangrove swamp (38.28%), continuous sea grass beds (36.52%) estuarine embayments (10.66%), swimming beaches (5.42%), the nearshore Gulf of Mexico (3.69%), discontinuous sea grass beds (2.25%), and unvegetated shallow subtidal bottoms (1.77%). These seven habitats make up 83.87% of the physical area of the study area.

<u>Future Land Use Projection (2030) of Total Ecosystem Services Value (TEV) for the Study Area</u>

Projecting to the build-out scenarios envisioned on the Future Land Use Map for the study area which projects to a future at 2030 and beyond it is possible to see using the ECOSERVE what the future anticipated ecosystem services value would be. The future land use map is not as detailed in specific development and conservation lands lad covers and uses simplified land use covers. Subsequently some cover types are subsumed into large categories such as Coastal Rural, Conservation Lands Upland, Conservation Lands Wetland, Outer Island, Outlying Suburban, Public Facilitates, Rural, Suburban, Urban Community, and Wetlands. For these larger land use categories mean TEV per acre were derived from the specific land uses included in that category (Table 2). The resulting FLU 2030 map indicated loss of native upland and wetland habitat, some conversions of existing developed land uses to more intense developed land uses, the elimination of most exotic plant communities with their development into human land uses (Figure 9). In the land use changes associated with the 2030 build out the following land use categories are no longer present: mobile home parks, dry prairie, pine flatwoods, Brazilian pepper, upland melaleuca, saltwater ponds, shrub black mangrove, freshwater marsh, algal marsh, and saltern. The resulting landscape has a reduced TEV for the study area of $5,146,537,673.59 measured in 2012 dollars. (Table 3). This constitutes a 26.83% loss of 2012 TEV.

If a projected level of inflation between 2012 and 2030 is applied then the dollar value of the TEV would increase. This study does not have a projection for what that inflation rate might be since in the prior 18 year period inflation rates have ranged from 0.03 to 4.3 per year with an average of 2.47 $\pm$ 1.02 (U.S. Bureau of Labor Statistics 2012). If one assumes that same rates of inflation (which the authors do not consider likely) then inflation would make up the loss of TEV for a total of $7,434,688,323.27 in 2030 dollars. Of course those 2030 dollars would be worth $0.69 in 2012 currency.

<u>Future Land Use Projection of Total Ecosystem Services Value (TEV) for the Study Area with the Future Land Use Projection (2030) and One Foot of Sea Level Rise</u>

Projecting to a future with the build-out scenarios envisioned on the Future Land Use Map for the study area which projects to a future at 2030 and a one foot sea level rise in the study area it is possible to project, using the ECOSERVE, what the future anticipated ecosystem services value would be in the resulting landscape.

The point at which one-foot of additional sea level will occur in the project study area depends on several variables that influence the local relative sea level rise including global sea level rise from thermal expansion, global sea level rise from non-replaced land ice melt; local sediment deposition; local accretion from wetland plant activity; local accretion from storm effects; local erosion from storm effects and long term erosive forces; human mediated sediment loss including shoreline hardening, disruption of coastal dynamics, reduction of alluvial deposition by dams and water control structures: plate tectonic lift, recession and tilt; and the geomorphic migration of barrier islands.

The 2009 Comprehensive Southwest Florida/Charlotte Harbor Climate Change Vulnerability Assessment (Beever et al. 2009) initially considered three climate change “severity” scenarios: *least case* (90% probability of occurrence), *moderate case* (50% probability of occurrence), and *worst case* (5% probability of occurrence). These scenarios are based upon the USEPA Report "The Probability of Sea Level Rise." Basically, the formula multiplies the historic sea level rise (2.3 mm/yr) in southwest Florida (closest point used is St. Petersburg, Fl., Table 9-2) by the number of future years from 1990, plus the Normalized Sea Level Projections in Table 9-1. (Table 4)

While the Intergovernmental Panel on Climate Change (IPCC) (2007) has been a standard for current planning purposes, several researchers and scientists that express non-empirical opinions (Rahmstorf 2007) based on other methods of modeling consider the IPCC projections to be conservative and expect climate changes to be more severe. This is because the scenarios presented in IPCC’s Fourth Assessment Report (2007) exclude some of the feedback mechanisms that could accelerate the melting of the Greenland and Antarctic ice sheets.

During our literature review we found that Stanton and Ackerman (2007) foresee a different set of climate future extremes that include either a response to climate change by humans to reduce green house gases, or inaction, a likely scenario at the time of their report’s publication.   Stanton and Ackerman (2007) compared the two scenarios: an optimistic *rapid stabilization case* and a pessimistic *business-as-usual case*. The scenarios represent extremes of what is expected to happen if the world succeeds in a robust program of climate mitigation, versus what is expected to happen if very little to nothing is done to address climate change. The difference between the two allows numerical calculation of climate change damage to Florida resources and economics. This calculation can be perceived as the benefits of mitigation, or, from an opposite perspective, the costs of inaction.

The *rapid stabilization case* (of green house gas (GHG) emissions) includes the lowest levels of future emissions under discussion today including a 50% reduction in current global emissions and an 80% reduction in current U.S. emissions by 2050, where precipitation remains stable and hurricane intensity remains in the current ranges. The *business-as-usual case* or *no-action case* includes steadily increasing GHG emissions throughout this century modeled on the high end of the likely range of the IPCC's A2 scenario (2007). This includes climate instability impacts of less rain in Florida and increased hurricane intensity (IPCC 2007).

The Stanton and Ackerman (2007) "Rapid Stabilization Case" is the scenario with the highest probability and least impact related to Table 4, which shows the IPCC (2007) scenarios The more severe "Business-as-Usual Case" is the scenario with approximately 1% probability and greatest impact according to Table 4. So, one could consider the "Rapid Stabilization Case" as the very best and the "Business-as-Usual Case" as the very worst case scenarios.

Newer projections using the MIT Integrated Global Systems Model, Sokolov, et al. (2009) indicate a median probability of surface warming of 5.2 degrees Celsius by 2100, with a 90% probability range of 3.5 to 7.4 degrees. This falls between the IPCC worst case scenario and the Business-as Usual "worstest" case scenario of Stanton and Ackerman (2007). Therefore this extent of severity is accounted for in this project.

The level of sea level rise discussed for Florida in the report entitled "Global Climate Change Impacts in the United States" (Karl et al. 2009) falls between the moderate case and worst case scenarios predicted by the IPCC (2007) with a 30% probability of 24 inches of sea level rise by the year 2100.

Projecting future sea level rise presents special challenges (Karl et al. 2009). Scientists have a well-developed understanding of the contributions of thermal expansion and melting glaciers to sea level rise, so the models used to project sea level rise include these processes. However, the contributions to past and future sea level rise from ice sheets are less well understood. Recent observations of the polar ice sheets show that a number of complex processes control the movement of ice to the sea, and thus affect the contributions of ice sheets to sea level rise. Some of these processes are already producing substantial loss of ice mass. Because these processes are not well understood it is difficult to predict their future contributions to sea level rise. (Alley et al. 2005)

Because of this uncertainty, the 2007 assessment by the IPCC could not quantify the contributions to sea level rise due to changes in ice sheet dynamics, and thus projected a rise of the world's oceans from eight inches to two feet by the end of this century (Meehl et al, 2007). More recent research has attempted to quantify the potential contribution to sea level rise from the accelerated flow of ice sheets to the sea or to estimate future sea level based on its observed relationship to temperature (Rahmstorf 2007). The resulting estimates exceed those of the IPCC, and the average estimates under higher emissions scenarios are for sea level rise between three and four feet by the end of this century. An important question that is often asked is "What is the upper bound of sea level rise expected over this century?" Few analyses have focused on this question. There is some evidence to suggest that it would be virtually impossible to have a rise of sea level higher than about 6.5 feet by the end of this century (Pfeffer et al. 2008).

The changes in sea level experienced at any particular location along the coast depend, not only on the increase in the global average sea level, but also on changes in regional currents and winds, proximity to the mass of melting ice sheets, and on the vertical movements of the land due to geological forces (Mitrovica et al. 2009). The consequences of sea level rise at any particular location depend on the amount of sea level rise relative to the adjoining land. Although some parts of the U.S. coast are undergoing uplift (rising), most shorelines are subsiding (sinking) to various degrees from a few inches to over two feet per century (Karl et al. 2009).

The year of when sea level will have risen one foot above its current level will vary depending upon the level of human mitigation and adaptation. Utilizing the most recent available land cover data and currently available Lidar elevations, it is possible to project the amount of habitat that would be subject to future inundation from various levels of sea level rise. The following tables and graphs display the results for Lee County. The elevations analyzed (0.5, 1.0, 1.5, 2.0, 3.0, 4.0, and 9.0 feet NGVD) correspond to the climate change scenarios discussed above. Depending on the SLR rise rate prediction the one foot level of increase will occur in a range of years from 2222 in the very best case scenario where all mitigation and adaptation measures are undertaken by all nations to 2027 in the worst case scenario in which no action is taken to mitigate climate change (Figure 12, Table 5).

The current measured sea level rise rate for Lee County is approximately 9 inches in 100 years. Assuming this rate continued without acceleration then a one foot sea level rise above 2012 levels would be attained in the year 2162.

The resulting one-foot sea level rise map (1FSLR) map indicates significant loss of native upland and wetland habitat, some conversions of existing developed land uses to open water, and the elimination of most exotic plant communities (Table 6). The resulting landscape has a TEV for the study area of $4,184,956,813.96.

The effect of sea level rise varies with the habitat type. It is important to remember that while a habitat may change from a current above water land cover to a open water submerged condition that the new open water habitat has a ecosystem services values that must be accounted for. If only the loss of above water habits to open water is accounted for than the TEV loss in the study area for a 1 foot sea level rise is $4,019,726,568.16. However, the gain of open water generates $165,230,245.80 of TEV with 1 foot sea level rise. Therefore the net loss of TEV from sea level rise in the study area for 1 foot of sea level rise separate from the 2030 land use changes is $1,126,811,105.43. This a 16.02% loss of 2012 TEV from the sea level rise alone. Combined the sea level rise of 1 foot with the future land use changes results in a $3,013,636,066.47 loss of TEV. This constitutes a 42.85% loss of 2012 TEV.

Conclusion

The output of this project is an assessment of the total ecosystem services provided by all habitat types in the Pine Island Sound, Sanibel Island, and Captiva Island study area. This assessment will be made available to local governments for use in developing wetlands planning, restoration and enhancement plans.

In addition, an ecosystem services topography (ECOSERVE) layers were generated that can be combined with other ecosystem services layers for functional analyses by geographic boundary (watershed, municipality, county, etc.). Projections of alternate futures of ecosystem services resulting from land use changes and anticipated climate changes were completed.

This project identified all the habitat types found in the study area which encompassed Pine Island Sound, Sanibel Island, Captiva Island, North Captive Island, Cayo Costa, Useppa Island and other islands within Pine Island Sound and included the tidal extents of Pine island Sound on the western side of Pine Island and the nearshore Gulf of Mexico west and south of the barrier islands. In the process we updated the existing crosswalk reference for the varied definitions of habitat types utilized by the federal government, the state of Florida, regional agencies, local government and other resource management agencies in southwest Florida, to obtain a unified set of defined southwest Florida wetland types. We identified existing referred and gray scientific literature that provides measures of the ecosystem services for each habitat type indentified. We identified and defined the ecosystem services provided by each wetland type. We identified defined reference condition habitats within the study area utilizing existing reference sites and locating new valid reference sites for evaluation. This includes provisioning services; regulating services; supporting services; hydrologic, water quality, water storage, vegetative, biogeochemical cycle, wildlife, fishery, recreational aesthetic, and cultural services.

We utilized a existing assessment of reference sites (Beever wt al. 2011) for the identified ecosystem services utilizing the standardized methods developed by the federal (HGM) and State of Florida (UMAM) governments. As needed we ground truthed for type and functional assessment a representative sample of wetland type sites within Pine Island Sound, and on Sanibel Island, Captiva Island and Cayo Costa.

We identified and evaluated available digital and hard copy map products and wetland occurrence information held by federal, state, regional and local agencies for the study area.

We compiled digital information for the wetland areas in a variety of functional conditions with a concurrent evaluation of the ecosystem services provided by wetlands in each relative condition. From these sources we generated an combined updated map of the habitat extents and types for the study area. This is the first map of its kind for the study area and indeed in south Florida.

We then geographically positioned the ecosystem services values information on the combined map to create a map of ecological services topographies (ECOSERVE) in a GIS form. The intersected ECOSERVE GIS information layers were combined to generate a total ecosystem services provided map.

We then generated two alternate future ECOSERVE topographies related to anticipated land use changes resulting form build out of the future land use map for the year 2030 and a future with one-foot of additional sea level rise that could occur in a period from 2027 to 2222, but most likely by 2162 if current rates of sea level rise continue.

The ECOSERVE method can be utilized to forecast and back cast alternate future and past landscapes. With more time and funding we could look at increased sea level rise extents, the benefits and costs of different land acquisitions, the consequences in terms of ecosystem services of various changes in wetland and upland extents resulting from restoration or development plans, the consequences of natural and man-made disasters, the implementation of alternative wetland protection and land conservation programs, as well as the potential impacts of making no changes to current land use, management, or regulatory policy. Utilization of the ECOSERVE layers will allow permit reviewers to evaluate the impact, for example, of development and restoration on the ecosystem services attributable to the wetlands types being impacted.

Subsequently the tables associated with the ECOSERVE mapping can include:

- A quantification of observed habitat condition information linked to ecosystem services and their contributions to human well-being,
- A quantification of the pollution prevention or mitigation services (e.g., chemical pollutant removal, sediment removal) provided by ecosystems with a comparison to the cost of providing them through built infrastructure,
- A quantification by habitat of the amount of food or fiber produced per unit area in well-protected areas versus that of poorly protected or unprotected areas,
- The economic value of recreational opportunities provided by a specific habitat provision or by protection of fishable/swimmable water,
- Construction costs avoided by the presence of habitats that slow and absorb floodwaters (flow mitigation or flood control)

Given more time and resources the maps and tables of this project could be improved by a detailed mapping of mangrove forest type to better estimate the ecosystem services provided by each type and better represent the relative functions of each forest type in location and landscape. As indicated by an internal separate analysis of salt marsh combined average vs. salt marsh by detailed type estimates significant TEV differences can be obtained. We would expect the difference for a detailed mangrove forest type could be even more pronounced. Another refinement would be to apply a sea grass extent light extinction model to predict future sea grass extent losses as estuarine waters deepen. In this analysis the level of sea level rise (one foot) would not cause major sea grass bed losses as new shallow water is generated. With higher level of sea level rise the deeper edge of sea grass beds would move landward as light attenuation losses occurred in the deeper waters.

More alternate futures could be evaluated with additional climate change perturbations, alternate land use plans, and regulatory environments. The differential benthic habitats in the Gulf of Mexico could be further refined and mapped with methods utilized in identifying the source locations of benthic drift algae.

This development of the Arc View-friendly ECOSERVE protocol for statistical and geographical analysis and interpretation can be used with the types of information generated by surveys of ecological condition indicators to quantify ecosystem services. ECOSERVE can be used to quantify the relative importance of perturbation stressors (e.g., land clearing, hydrologic alteration, development, climate change) that impact habitats and the ecosystem services they provide,. ECOSERVE is a GIS tool that can be used to develop regionally relevant ecosystem services measurement and assessment programs and that can be used to assist in implementing efficient and effective decision-making by local and regional regulatory, mitigation, enforcement programs. The ECOSERVE method protocol is applicable elsewhere southwest Florida in the southeastern United States, and around the Gulf of Mexico, provided that the ecosystem services values are recalibrated to the specific conditions of the subject watershed.

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FLUCCS Code and Description	TEV	year of estimate	Source(s)
1110 FIXED SINGLE FAMILY UNITS	$1,885.92	1980	Morales 1980, Bolund and Hunhammar 1999
1130 MIXED UNITS - FIXED AND MOBILE HOME UNITS	$75.44	1980	Morales 1980, Bolund and Hunhammar 1999
1180 RURAL RESIDENTIAL	$2,087.09	1980	Morales 1980, Bolund and Hunhammar 1999
1210 FIXED SINGLE FAMILY UNITS	$1,885.92	1980	Morales 1980, Bolund and Hunhammar 1999
1220 MOBILE HOME UNITS	$50.29	1980	Morales 1980, Bolund and Hunhammar 1999
1320 MOBILE HOME UNITS	$50.29	1980	Morales 1980, Bolund and Hunhammar 1999
1330 MULTIPLE DWELLING UNITS - LOW RISE	$1,257.28	1980	Morales 1980, Bolund and Hunhammar 1999
1340 MULTIPLE DWELLING UNITS - HIGH RISE	$628.64	1980	Morales 1980, Bolund and Hunhammar 1999
1400 COMMERCIAL AND SERVICES	$377.18	1980	Morales 1980, Bolund and Hunhammar 1999
1411 SHOPPING CENTERS	$377.18	1980	Morales 1980, Bolund and Hunhammar 1999
1700 INSTITUTIONAL	$125.73	1980	Morales 1980, Bolund and Hunhammar 1999
1710 EDUCATIONAL FACILITIES	$628.64	1980	Morales 1980, Bolund and Hunhammar 1999
1810 SWIMMING BEACH	$345,228.73	2002	Lee County Clerk of Courts 2002
1820 GOLF COURSE	$1,760.19	1980	Morales 1980, Bolund and Hunhammar 1999
1840 MARINAS AND FISH CAMPS	$377.18	1980	Morales 1980, Bolund and Hunhammar 1999
1850 PARKS AND ZOOS	$804.00	1997	Morales 1980
1900 OPEN LAND	$804.00	1997	Costanza et al. 1997
2410 TREE NURSERIES	$969.00	1997	Costanza et al. 1997, Dale and Polasky 2007
2610 FALLOW CROPLAND	$37.25	1997	Dale and Polasky 2007
3100 HERBACEOUS (DRY PRAIRIE)	$120.00	1997	Costanza et al. 1997
3200 UPLAND SHRUB AND BRUSHLAND	$3,430.31	1997	Allsopp et al. 2008
3220 COASTAL SHRUB	$3,692.27	1997	Allsopp et al. 2008
3300 MIXED RANGELAND	$93.93	1997	Allsopp et al. 2008
4110 PINE FLATWOODS	$14,154.12	1997	Allsopp et al. 2008, Krieger 2001
4200 UPLAND HARDWOOD FORESTS	$6,907.09	1997	Allsopp et al. 2008, Krieger 2001

4220 BRAZILIAN PEPPER	$392.31	1997	Allsopp et al. 2008, Krieger 2001
4240 MELALEUCA	$392.31	1997	Allsopp et al. 2008, Krieger 2001
4260 TROPICAL HARDWOOD HAMMOCK	$1,033.00	1997	Allsopp et al. 2008, Krieger 2001
4280 CABBAGE PALM	$6,684.28	1997	Allsopp et al. 2008, Krieger 2001
4340 UPLAND MIXED CONIFEROUS - HARDWOOD	$4,838.15	1997	Allsopp et al. 2008, Krieger 2001
4370 AUSTRALIAN PINE	$392.31	1997	Krieger 2001
5110 NATURAL RIVER - STREAM - WATERWAY	$4,375.00	1997	Costanza et al. 1997
5120 CHANNELIZED WATERWAYS - CANALS	$102.02	1997	Costanza et al. 1997
5200 LAKES	$4,375.00	1997	Costanza et al. 1997
5300 RESERVOIRS	$3,440.49	1997	Costanza et al. 1997
5410 EMBAYMENTS OPENING DIRECTLY TO GULF OR OCEAN	$9,243.72	1997	Costanza et al. 1997
5420 EMBAYMENTS NOT OPENING DIRECTLY TO GULF OR OCEAN	$9,243.72	1997	Costanza et al. 1997
5430 SALTWATER PONDS	$577.00	1997	Costanza et al. 1997
5720 GULF OF MEXICO 0.0 to 2.5	$5,213.53	1997	Costanza et al. 1997
5720 GULF OF MEXICO 2.5 to 5	$4,533.50	1997	Costanza et al. 1997
5720 GULF OF MEXICO 5 to 7.5	$3,005.28	1997	Costanza et al. 1997
5720 GULF OF MEXICO 7.5 to 10	$830.88	1997	Costanza et al. 1997
5720 GULF OF MEXICO 10 to 18	$830.88	1997	Costanza et al. 1997
6120 MANGROVE SWAMP	$222,672.06	2006	Wells, et al. 2006, Allsopp et al. 2008, Beever III and Cairns 2002, Beever III 2011, Costanza et al. 2008, Lugo and Brinson 1979, McLeod and Salm 2006, Quoc Tuan Vo et al. 2012, Sathirathai 2003, Spaninks and van Beukering, 1997
6122 SHRUB BLACK MANGROVE	$4,008.10	2006	Wells, et al. 2006, Allsopp et al. 2008, Lugo and Brinson 1979
6170 MIXED WETLAND HARDWOODS	$10,082.00	1997	Allsopp et al. 2008, Costanza et al. 1997
6172 MIXED SHRUBS	$804.00	1997	Allsopp et al. 2008, Costanza et al. 1997
6191 WET MELALEUCA	$392.31	1997	Costanza et al. 1997
6410 FRESHWATER MARSHES - GRAMINOID PRAIRIE - MARSH	$11,470.00	1997	Costanza et al. 1997
6420 SALTWATER MARSHES - HALOPHYTIC HERBACEOUS PRAIRIE	$5,144.00	1997	Wells, et al. 2006, Beever III 2011, Costanza et al. 2008, Lugo and Brinson 1979
6421 CORDGRASS	$8,260.32	2006	Beever III 2011, Costanza et al. 2008, Lugo and Brinson 1979
6422 NEEDLERUSH	$8,260.32	2006	Wells, et al. 2006, Beever III 2011, Costanza et al. 2008, Lugo and Brinson 1979
6423 LEATHER FERN	$4,456.19	2006	Wells, et al. 2006, Beever III 2011, Costanza et al. 2008, Lugo and

			Brinson 1979
6430 WET PRAIRIES	$3,310.31	1997	Costanza et al. 1997
6433 MARSH MEADOW SUCCULENTS	$3,125.91	2006	Wells, et al. 2006, Beever III, et al. 2012, Costanza et al. 2008, Lugo and Brinson 1979
6434 MARSH MEADOW MIXED	$3,125.91	2006	Wells, et al. 2006, Beever III, et al. 2012, Costanza et al. 2008, Lugo and Brinson 1979
6435 MARSH MEADOW GRASSES	$3,125.91	2006	Wells, et al. 2006, Beever III, et al. 2012, Costanza et al. 2008, Lugo and Brinson 1979
6510 TIDAL FLATS	$4,533.50	2006	Wells, et al. 2006, Lugo and Brinson 1979
6511 UNVEGETATED TIDAL FLATS	$1,835.43	2006	Wells, et al. 2006
6513 UNVEGETATED SHALLOW SUBTIDAL BOTTOMS	$4,533.50	2006	Wells, et al. 2006
6512 ALGAL MARSH	$1,835.43	2006	Wells, et al. 2006, Beever III, et al. 2012, Lugo and Brinson 1979
6510 INTERTIDAL MUD FLAT	$4,533.50	2006	Wells, et al. 2006
6510 INTERTIDAL SAND BAR	$4,533.50	2006	Wells, et al. 2006
6540 OYSTER BARS	$31,518.60	2003	Henderson and O'Neil 2003
710 BEACHES OTHER THAN SWIMMING BEACHES	$2,087.00	1997	Costanza et al. 1997
720 SAND OTHER THAN BEACHES	$50.29	1997	Costanza et al. 1997
7203 SALTERN	$2,205.26	2006	Wells, et al. 2006, Beever III, et al. 2012, Lugo and Brinson 1979
7430 SPOIL AREAS	$50.29	1997	Costanza et al. 1997
8115 GRASS AIRPORTS	$2,514.56	1997	Bolund and Hunhammar 1999
8140 ROADS AND HIGHWAYS	$0.00	1997	Bolund and Hunhammar 1999, Costanza et al. 1997
8330 WATER SUPPLY PLANTS - INCLUDING PUMPING STATIONS	$0.00	1997	Bolund and Hunhammar 1999, Costanza et al. 1997
8340 SEWAGE TREATMENT	$51.58	1997	Bolund and Hunhammar 1999, Costanza et al. 1997
9110 CONTINUOUS SEAGRASS	$66,117.81	1998	Beever III 2011, Engeman et al 2008, Hazen and Sawyer 1998, Paling 2009
9111 PATCHY (DISCONTINUOUS) SEAGRASS	$33,058.91	1998	Beever III 2011, Engeman et al. 2008, Hazen and Sawyer 1998, Paling 2009

Appendix 1 Sources for TEV values

FLUCCS Code and Description	TEV in dollars/ acre in year of estimate	year of estimate	multiplier for inflation	2012 dollars/acre	Acres in Study Area	2012 TEV with Detailed Salt Marsh
1110 FIXED SINGLE FAMILY UNITS	$1,885.92	1980	2.807	$5,293.78	1,531.63	$8,108,112.20
1130 MIXED UNITS - FIXED AND MOBILE HOME UNITS	$75.44	1980	2.807	$211.76	0.04	$9.07
1180 RURAL RESIDENTIAL	$2,087.09	1980	2.807	$5,858.46	70.66	$413,954.22
1210 FIXED SINGLE FAMILY UNITS	$1,885.92	1980	2.807	$5,293.78	1,333.69	$7,060,263.28
1220 MOBILE HOME UNITS	$50.29	1980	2.807	$141.16	0.92	$129.48
1320 MOBILE HOME UNITS	$50.29	1980	2.807	$141.16	33.04	$4,664.54
1330 MULTIPLE DWELLING UNITS - LOW RISE	$1,257.28	1980	2.807	$3,529.18	265.41	$936,678.05
1340 MULTIPLE DWELLING UNITS - HIGH RISE	$628.64	1980	2.807	$1,764.59	236.54	$417,398.31
1400 COMMERCIAL AND SERVICES	$377.18	1980	2.807	$1,058.74	245.04	$259,433.38
1411 SHOPPING CENTERS	$377.18	1980	2.807	$1,058.74	28.21	$29,865.56
1700 INSTITUTIONAL	$125.73	1980	2.807	$352.92	25.55	$9,016.57
1710 EDUCATIONAL FACILITIES	$628.64	1980	2.807	$1,764.59	25.75	$45,430.67
1810 SWIMMING BEACH	$345,228.73	2002	1.29	$443,898.13	859.45	$381,508,218.56
1820 GOLF COURSE	$1,760.19	1980	2.807	$4,940.85	335.92	$1,659,715.85
1840 MARINAS AND FISH CAMPS	$377.18	1980	2.807	$1,058.74	1.70	$1,795.96
1850 PARKS AND ZOOS	$804.00	1997	1.44	$1,157.76	22.12	$25,606.34
1900 OPEN LAND	$804.00	1997	1.44	$1,157.76	7.43	$8,601.89
2410 TREE NURSERIES	$969.00	1997	1.44	$1,395.36	0.12	$171.21
2610 FALLOW CROPLAND	$37.25	1997	1.44	$53.64	0.02	$0.84
3100 HERBACEOUS (DRY PRAIRIE)	$120.00	1997	1.44	$172.80	71.27	$12,315.46
3200 UPLAND SHRUB AND BRUSHLAND	$3,430.31	1997	1.44	$4,939.65	393.96	$1,946,002.06
3220 COASTAL SHRUB	$3,692.27	1997	1.44	$5,316.87	373.90	$1,987,952.76
3300 MIXED RANGELAND	$93.93	1997	1.44	$135.26	32.99	$4,462.37
4110 PINE FLATWOODS	$14,154.12	1997	1.44	$20,381.93	0.37	$7,524.35
4200 UPLAND HARDWOOD FORESTS	$6,907.09	1997	1.44	$9,946.21	99.32	$987,813.05
4220 BRAZILIAN PEPPER	$392.31	1997	1.44	$564.93	0.63	$354.49
4240 MELALEUCA	$392.31	1997	1.44	$564.93	7.47	$4,220.53

4260 TROPICAL HARDWOOD HAMMOCK	$1,033.00	1997	1.44	$1,487.52	193.02	$287,121.11
4280 CABBAGE PALM	$6,684.28	1997	1.44	$9,625.36	1,391.04	$13,389,235.71
4340 UPLAND MIXED CONIFEROUS - HARDWOOD	$4,838.15	1997	1.44	$6,966.94	14.40	$100,342.81
4370 AUSTRALIAN PINE	$392.31	1997	1.44	$564.93	159.81	$90,279.97
5110 NATURAL RIVER - STREAM - WATERWAY	$4,375.00	1997	1.44	$6,300.00	136.86	$862,236.86
5120 CHANNELIZED WATERWAYS - CANALS	$102.02	1997	1.44	$146.91	119.82	$17,602.67
5200 LAKES	$4,375.00	1997	1.44	$6,300.00	1.59	$10,029.02
5300 RESERVOIRS	$3,440.49	1997	1.44	$4,954.31	321.32	$1,591,923.90
5410 EMBAYMENTS OPENING DIRECTLY TO GULF OR OCEAN	$9,243.72	1997	1.44	$13,310.96	56,356.24	$750,155,517.59
5420 EMBAYMENTS NOT OPENING DIRECTLY TO GULF OR OCEAN	$9,243.72	1997	1.44	$13,310.96	355.03	$4,725,726.19
5430 SALTWATER PONDS	$577.00	1997	1.44	$830.88	36.92	$30,677.68
5720 GULF OF MEXICO 0.0 to 2.5	$5,213.53	1997	1.44	$7,507.48	4880.26	$36,638,495.42
5720 GULF OF MEXICO 2.5 to 5	$4,533.50	1997	1.44	$6,528.24	11909.67	$77,749,165.42
5720 GULF OF MEXICO 5 to 7.5	$3,005.28	1997	1.44	$4,327.60	27517.26	$119,083,785.02
5720 GULF OF MEXICO 7.5 to 10	$830.88	1997	1.44	$1,196.47	20294.10	$24,281,220.37
5720 GULF OF MEXICO 10 to 18	$830.88	1997	1.44	$1,196.47	1328.83	$1,589,900.98
6120 MANGROVE SWAMP	$222,672.06	2006	1.15	$255,495.20	10,543.93	$2,693,923,820.11
6122 SHRUB BLACK MANGROVE	$4,008.10	2006	1.15	$4,609.32	90.86	$418,802.36
6170 MIXED WETLAND HARDWOODS	$10,082.00	1997	1.44	$14,518.08	347.12	$5,039,582.00
6172 MIXED SHRUBS	$804.00	1997	1.44	$1,157.76	1,975.98	$2,287,706.51
6191 WET MELALEUCA	$392.31	1997	1.44	$564.93	1.36	$770.42
6410 FRESHWATER MARSHES	$11,470.00	1997	1.44	$16,516.80	27.23	$449,670.49
6421 CORDGRASS	$8,260.32	2006	1.15	$9,477.94	2.72	$25,780.00
6422 NEEDLERUSH	$8,260.32	2006	1.15	$9,499.37	18.28	$173,648.53
6423 LEATHER FERN	$4,456.19	2006	1.15	$5,124.62	7.23	$37,050.99
6433 MARSH MEADOW SUCCULENTS	$3,125.91	2006	1.15	$3,594.80	1,261.04	$4,533,183.53
6434 MARSH MEADOW MIXED	$3,125.91	2006	1.15	$3,594.80	504.18	$1,812,425.04
6435 MARSH MEADOW GRASSES	$3,125.91	2006	1.15	$3,594.80	44.98	$161,693.99

6510 TIDAL FLATS	$4,533.50	2006	1.15	$5,213.53	1,244.02	$6,485,750.35
6511 UNVEGETATED TIDAL FLATS	$1,835.43	2006	1.15	$2,110.74	6,317.00	$13,333,537.42
6513 UNVEGETATED SHALLOW SUBTIDAL BOTTOMS	$4,533.50	2006	1.15	$5,213.53	23,876.00	$124,478,122.90
6512 ALGAL MARSH	$1,835.43	2006	1.15	$2,110.74	340.52	$718,750.72
6510 INTERTIDAL MUD FLAT	$4,533.50	2006	1.15	$5,213.53	453.64	$2,365,065.15
6510 INTERTIDAL SAND BAR	$4,533.50	2006	1.15	$5,213.53	3005.34	$15,668,407.70
6540 OYSTER BARS	$31,518.60	2003	1.26	$39,623.85	25.87	$1,025,262.04
7203 SALTERN	$2,205.26	2006	1.15	$2,536.05	50.51	$128,096.02
7430 SPOIL AREAS	$50.29	1997	1.44	$72.42	9.35	$677.36
8115 GRASS AIRPORTS	$2,514.56	1997	1.44	$3,620.97	6.65	$24,085.92
8140 ROADS AND HIGHWAYS	$0.00	1997	1.44	$0.00	0.91	$0.00
8330 WATER SUPPLY PLANTS - INCLUDING PUMPING STATIONS	$0.00	1997	1.44	$0.00	13.56	$0.00
8340 SEWAGE TREATMENT	$51.58	1997	1.44	$74.28	12.89	$957.36
9110 CONTINUOUS SEAGRASS	$66,117.81	1998	$1.42	$93,829.29	27,387.65	$2,569,763,614.52
9111 PATCHY (DISCONTINUOUS) SEAGRASS	$33,058.91	1998	$1.42	$46,914.65	3,369.58	$158,082,527.04
TOTALS					211,957.71	$7,036,981,960.25

TABLE 1 TEV for the Study Area in 2012 Dollars

Future Land Use	TEV 2012
Coastal Rural	$6,000.13
Conservation Lands Upland	$6,552.50
Conservation Lands Wetland	$73,533.75
Outer Island	$6,552.50
Outlying Suburban	$5,293.78
Public Facilitates	$24.76
Rural	$6,000.13
Suburban	$2,752.77
Urban Community	$976.41
Wetlands	$73,533.75

Table 2: TEV of Combined Future Land Use Categories from the Future Land Use Plan 2030.

FLUCCS Code and Description	Acres in Study Area	2030 TEV with Detailed Salt Marsh
1110 FIXED SINGLE FAMILY UNITS	12.69	$67,193.65
1130 MIXED UNITS - FIXED AND MOBILE HOME UNITS	0.04	$9.07
1160 SUBURBAN	364.62	$1,003,707.37
1180 RURAL	4.24	$25,465.44
1180 RURAL RESIDENTIAL	0.27	$1,569.05
1180 COASTAL RURAL	5.14	$30,842.05
1110 OUTLYING SUBURBAN (Native Landscaping)	4,034.45	$21,357,483.31
1210 FIXED SINGLE FAMILY UNITS	2.91	$15,402.39
1330 MULTIPLE DWELLING UNITS - LOW RISE	0.40	$1,414.57
1340 MULTIPLE DWELLING UNITS - HIGH RISE	0.19	$327.43
1400 COMMERCIAL AND SERVICES	0.33	$349.77
1411 SHOPPING CENTERS	28.21	$29,865.56
1300-1400 URBAN COMMUNITY	0.02	$20.03
1700 INSTITUTIONAL	25.55	$9,016.57
1700 PUBLIC FACILITIES	442.28	$10,950.92
1710 EDUCATIONAL FACILITIES	25.75	$45,430.67
1810 SWIMMING BEACH	182.88	$81,180,637.49
1820 GOLF COURSE	0.31	$1,539.40
1840 MARINAS AND FISH CAMPS	0.03	$28.17
1850 PARKS AND ZOOS	0.01	$9.99
1900 OUTER ISLAND	573.38	$3,757,042.08
1900 OPEN LAND	0.02	$17.85
2410 TREE NURSERIES	0.12	$171.21
2610 FALLOW CROPLAND	0.01	$0.28
3200 UPLAND SHRUB AND BRUSHLAND	2.00	$9,884.00
3220 COASTAL SHRUB	9.75	$51,862.51
3300 MIXED RANGELAND	0.05	$7.03

4000 CONSERVATION LANDS UPLAND	2,496.96	$16,361,297.64
4200 UPLAND HARDWOOD FORESTS	99.32	$987,813.05
4260 TROPICAL HARDWOOD HAMMOCK	193.02	$287,121.11
4280 CABBAGE PALM	0.05	$470.23
4340 UPLAND MIXED CONIFEROUS - HARDWOOD	14.40	$100,342.81
4370 AUSTRALIAN PINE	1.96	$1,105.53
5110 NATURAL RIVER - STREAM - WATERWAY	0.19	$1,169.00
5120 CHANNELIZED WATERWAYS - CANALS	132.78	$19,506.58
5200 LAKES	1.59	$10,029.02
5300 RESERVOIRS	42.00	$208,084.91
5410 EMBAYMENTS OPENING DIRECTLY TO GULF OR OCEAN	56,356.24	$750,155,517.59
5420 EMBAYMENTS NOT OPENING DIRECTLY TO GULF OR OCEAN	355.03	$4,725,726.19
5720 GULF OF MEXICO 0.0 to 2.5	4,880.26	$36,638,495.42
5720 GULF OF MEXICO 2.5 to 5	11,909.67	$77,749,165.42
5720 GULF OF MEXICO 5 to 7.5	27,517.26	$119,083,785.02
5720 GULF OF MEXICO 7.5 to 10	20,294.10	$24,281,220.37
5720 GULF OF MEXICO 10 to 18	1,328.83	$1,589,900.98
6000 CONSERVATION LANDS WETLAND	7,755.40	$570,283,447.34
6000 WETLANDS	6,131.10	$450,842,547.16
6120 MANGROVE SWAMP	374.11	$95,582,855.96
6170 MIXED WETLAND HARDWOODS	0.05	$761.00
6172 MIXED SHRUBS	1,975.98	$2,287,706.51
6191 WET MELALEUCA	1.36	$770.42
6421 CORDGRASS	2.72	$25,780.00
6422 NEEDLERUSH	8.33	$79,129.77
6423 LEATHER FERN	7.23	$37,050.99
6433 MARSH MEADOW SUCCULENTS	0.11	$400.70
6434 MARSH MEADOW MIXED	0.37	$1,316.42
6435 MARSH MEADOW GRASSES	44.98	$161,693.99
6510 TIDAL FLATS	1,169.56	$6,097,527.32

6511 UNVEGETATED TIDAL FLATS	5,193.48	$10,962,070.57
6513 UNVEGETATED SHALLOW SUBTIDAL BOTTOMS	23,826.76	$124,221,408.93
6510 INTERTIDAL MUD FLAT	430.06	$2,242,152.55
6510 INTERTIDAL SAND BAR	2,879.73	$15,013,545.33
6540 OYSTER BARS	25.87	$1,025,262.04
7430 SPOIL AREAS	0.87	$63.02
8115 GRASS AIRPORTS	6.65	$24,085.92
8140 ROADS AND HIGHWAYS	0.03	$0.00
8330 WATER SUPPLY PLANTS - INCLUDING PUMPING STATIONS	13.56	$0.00
8340 SEWAGE TREATMENT	12.89	$957.36
9110 CONTINUOUS SEAGRASS	27,387.65	$2,569,763,614.52
9111 PATCHY (DISCONTINUOUS) SEAGRASS	3,369.58	$158,082,527.04
TOTAL	211,957.71	$5,146,537,673.59

Table 3 TEV for 2030 Build-Out Landscape

Probability (%)	2025		2050		2075		2100		2150		2200	
	cm	inches	cm	inches	cm	inches	cm	inches	cm	inches	cm	inches
Rapid Stabilization Case	41	1.8	9	3.5	13	5.3	18	7.1	22	8.8	27	10.5
90 (least)	7	2.8	13	5.0	20	7.7	26	10.4	40	15.7	53	21.0
80	9	3.6	17	6.6	26	10.1	35	13.9	53	20.8	71	28.1
70	11	4.4	20	7.8	30	11.6	41	16.3	63	24.7	85	33.6
60	12	4.7	22	8.6	34	13.2	45	17.8	72	28.3	99	39.1
50 (moderate)	13	5.1	24	9.4	37	14.4	50	19.8	80	31.4	112	44.2
40	14	5.5	27	10.6	41	16.0	55	21.8	90	35.4	126	49.7
30	16	6.3	29	11.3	44	17.1	61	24.1	102	40.1	146	57.6
20	17	6.7	32	12.5	49	19.1	69	27.3	117	46.0	173	68.2
10	20	7.9	37	14.5	57	22.3	80	31.6	143	56.2	222	87.5
5 (worst)	22	8.7	41	16.1	63	24.6	91	35.9	171	67.2	279	110.0
2.5	25	9.9	45	17.6	70	27.4	103	40.7	204	80.2	344	135.6
1	27	10.6	49	19.2	77	30.1	117	46.2	247	97.2	450	177.3
Business as Usual	29	11.3	57	22.6	86	34	115	45.3	247	97	450	177

***The results of this table are based on using Tables 9-1 and 9-2 of the USEPA Report "The Probability of Sea Level Rise". Basically, the formula is multiplying the historic sea level rise (2.3 mm/yr) in Southwest Florida (closest point used is St. Petersburg, Fl., Table 9-2) by the future number of years from 1990 plus the Normalized Sea Level Projections in Table 9-1 and Table ES-2. Two Future Climate Scenarios for Florida Stanton and Ackerman 2007**

Table 4 Projected Rates of Sea Level Rise for Southwest Florida, from the 2009 Comprehensive Southwest Florida/Charlotte Harbor Climate Change Vulnerability Assessment (Beever et al. 2009)

Elevation in NGVD	Rapid Stabilization Case	90% (least)	50% (moderate)	5% (worst)	Business as Usual
Half Foot	2084	2059	2030	2014	2011
One Foot	2222	2107	2063	2036	2027
Two Feet	2398	2214	2109	2075	2053
Three Feet	2575	2270	2158	2100	2079
Four Feet	2751	2327	2208	2109	2101
Nine Feet	3633	2610	2338	2174	2153

Table 5 Predicted year of different elevation levels (NGVD) of sea level rise for different future scenarios

FLUCCS Code and Description	**Acres in Study Area**	**2012 TEV**
1110 FIXED SINGLE FAMILY UNITS	11.85	$62,741.57
1130 MIXED UNITS - FIXED AND MOBILE HOME UNITS	0.04	$9.07
1160 SUBURBAN	356.56	$981,532.82
1180 RURAL	3,828.30	$22,970,291.50
1180 RURAL RESIDENTIAL	0.26	$1,547.21
1180 COASTAL RURAL	5.14	$30,842.05
1110 OUTLYING SUBURBAN (Native Landscaping)	504.47	$2,670,539.17
1210 FIXED SINGLE FAMILY UNITS	2.78	$14,731.97
1330 MULTIPLE DWELLING UNITS - LOW RISE	0.19	$654.86
1340 MULTIPLE DWELLING UNITS - HIGH RISE	0.19	$327.43
1300-1400 URBAN COMMUNITY	0.02	$20.03
1400 COMMERCIAL AND SERVICES	0.30	$317.01
1411 SHOPPING CENTERS	28.21	$29,865.56
1700 INSTITUTIONAL	25.55	$9,016.57
1700 PUBLIC FACILITIES	408.52	$10,114.89
1710 EDUCATIONAL FACILITIES	25.75	$45,430.67
1810 SWIMMING BEACH	158.25	$70,244,785.74
1820 GOLF COURSE	0.31	$1,539.40
1840 MARINAS AND FISH CAMPS	0.03	$28.17
1850 PARKS AND ZOOS	0.01	$9.99
1900 OPEN LAND	0.02	$17.85
1900 OUTER ISLAND	356.56	$2,336,371.65
2610 FALLOW CROPLAND	0.01	$0.28
3200 UPLAND SHRUB AND BRUSHLAND	1.95	$9,637.94
3220 COASTAL SHRUB	7.60	$40,433.19
3300 MIXED RANGELAND	0.05	$7.03
4000 CONSERVATION LANDS UPLAND	2,496.96	$16,361,297.64

4200 UPLAND HARDWOOD FORESTS	99.32	$987,813.05
4260 TROPICAL HARDWOOD HAMMOCK	193.02	$287,121.11
4370 AUSTRALIAN PINE	1.96	$1,105.53
5110 NATURAL RIVER - STREAM - WATERWAY	0.19	$1,169.00
5120 CHANNELIZED WATERWAYS - CANALS	119.82	$17,602.67
5200 LAKES	1.59	$10,029.02
5300 RESERVOIRS	42.00	$208,084.91
5410 EMBAYMENTS OPENING DIRECTLY TO GULF OR OCEAN	56,356.24	$750,155,517.59
5420 EMBAYMENTS NOT OPENING DIRECTLY TO GULF OR OCEAN	355.03	$4,725,726.19
5400-5700 SEA LEVEL RISE 0.0 to 1.0	22,008.74	$165,230,245.80
5720 GULF OF MEXICO 0.0 to 2.5	2,873.94	$21,576,056.27
5720 GULF OF MEXICO 2.5 to 5	9,052.96	$59,099,895.59
5720 GULF OF MEXICO 5 to 7.5	21,268.36	$92,041,022.79
5720 GULF OF MEXICO 7.5 to 10	23,183.36	$27,738,129.83
5720 GULF OF MEXICO 10 to 18	9,280.36	$11,103,646.34
6120 MANGROVE SWAMP	341.31	$87,201,901.50
6170 MIXED WETLAND HARDWOODS	0.04	$567.42
6172 MIXED SHRUBS	1,975.98	$2,287,706.51
6191 WET MELALEUCA	1.36	$770.42
6420 SALTWATER MARSHES - HALOPHYTIC HERBACEOUS PRAIRIE	0.10	$740.74
6422 NEEDLERUSH	18.28	$173,648.53
6433 MARSH MEADOW SUCCULENTS	0.12	$431.38
6434 MARSH MEADOW MIXED	0.11	$395.43
6510 TIDAL FLATS	340.52	$1,775,309.53
6511 UNVEGETATED TIDAL FLATS	5,193.27	$10,961,634.41
6513 UNVEGETATED SHALLOW SUBTIDAL BOTTOMS	16,769.54	$87,428,403.39
6510 INTERTIDAL MUD FLAT	429.45	$2,238,972.35
6510 INTERTIDAL SAND BAR	2,878.94	$15,009,449.93
6540 OYSTER BARS	25.87	$1,025,262.04
7430 SPOIL AREAS	0.79	$56.97

8340 SEWAGE TREATMENT	1.95	$144.92
9110 CONTINUOUS SEAGRASS	27,387.65	$2,569,763,614.52
9111 PATCHY (DISCONTINUOUS) SEAGRASS	3,369.58	$158,082,527.04
TOTAL	211,791.60	$4,184,956,813.96

Table 6 TEV in 2012 dollars for one foot sea level rise and the 2030 build-out in the study area.

Figures for *Estimating and Forecasting Ecosystem Services within Pine Island Sound, and on Sanibel, Captiva, North Captiva, Cayo Costa, Useppa Islands and Islands of the Sound*

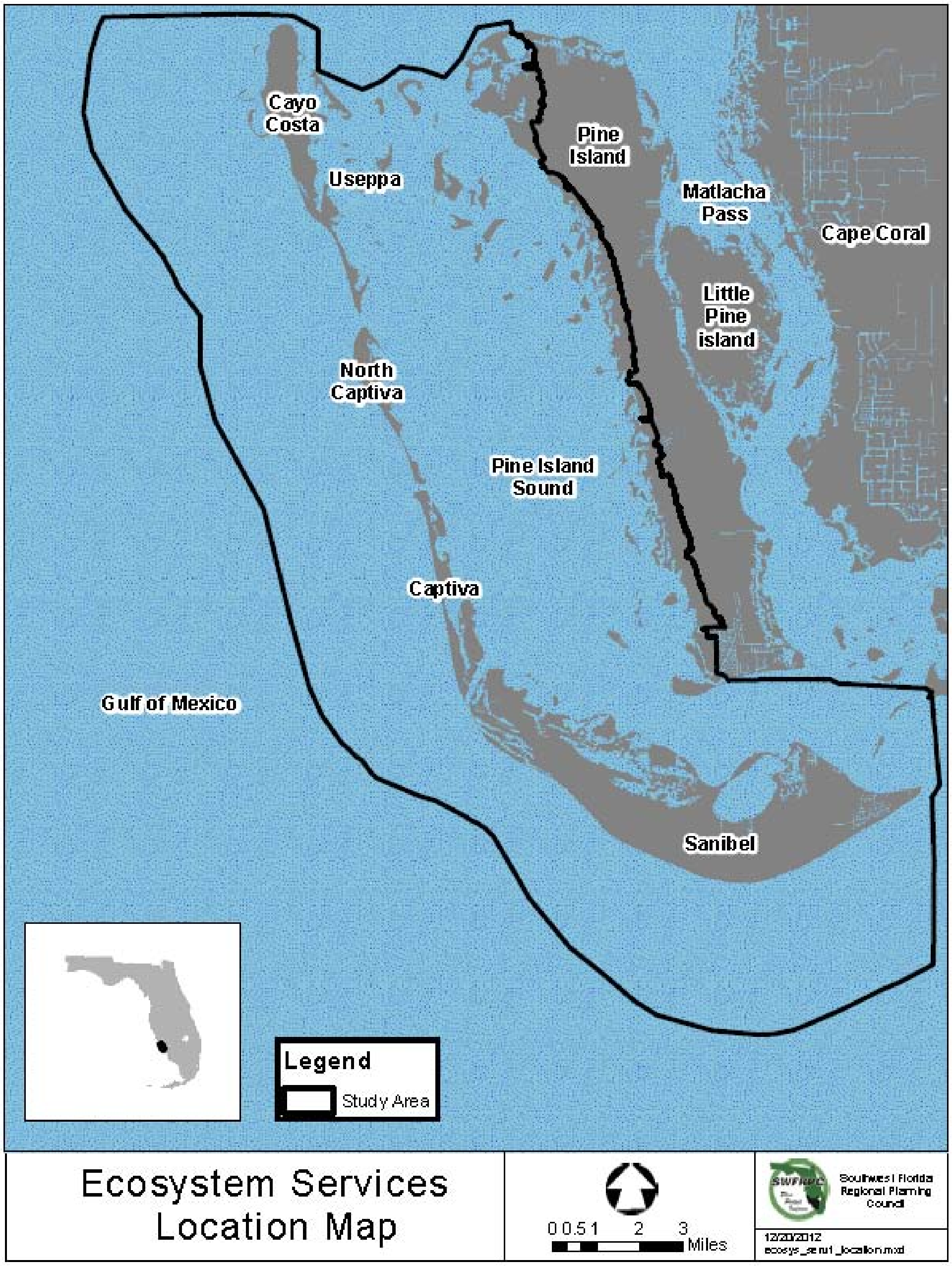

Figure 1: Project Study Area

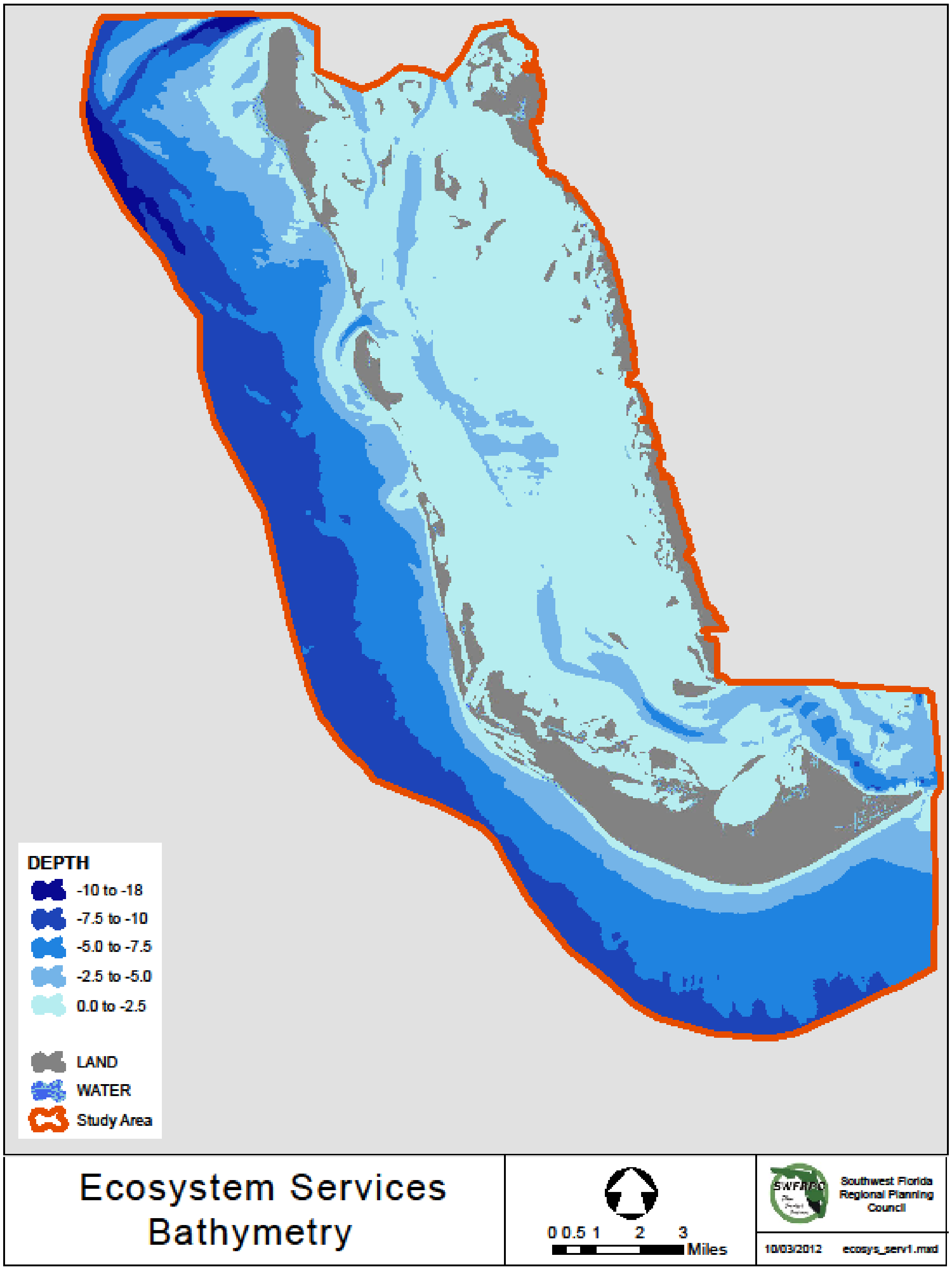

Figure 2: NOAA Bathymetry (CHNEP 2011)

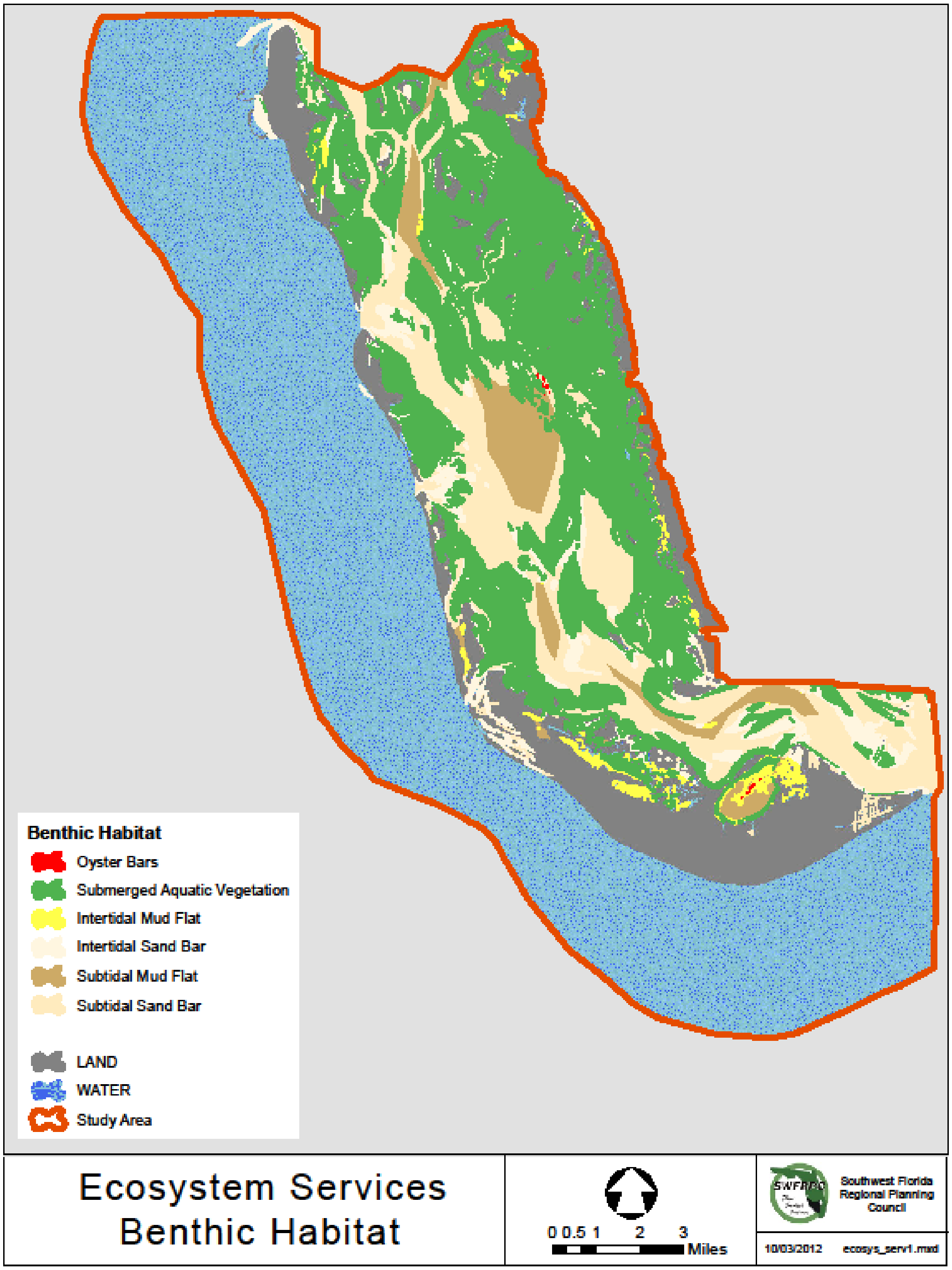

Figure 3: CHNEP Benthic Habitat Map (CHNEP 2007)

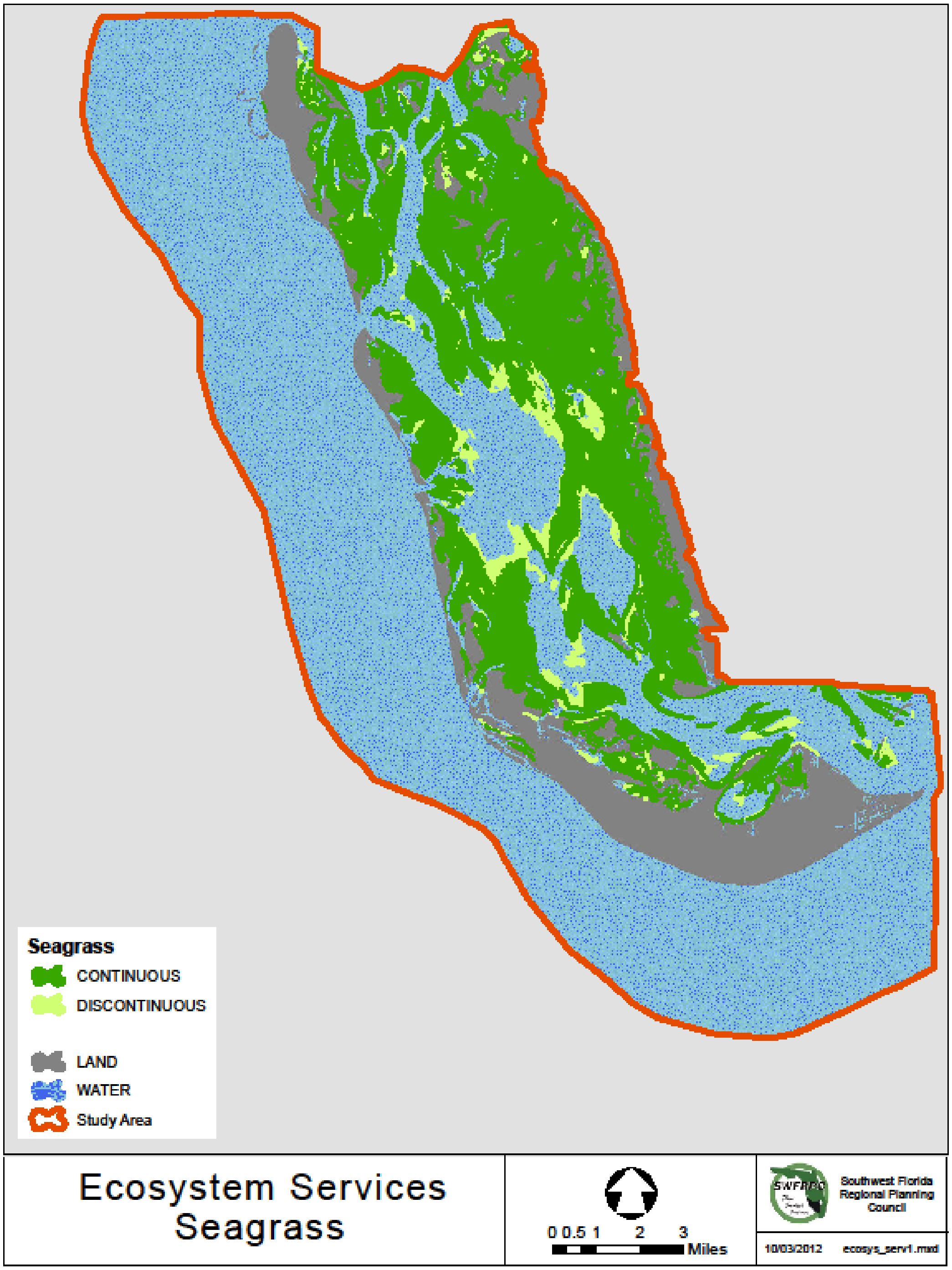

Figure 4: SFWMD sea grass mapping (2008)

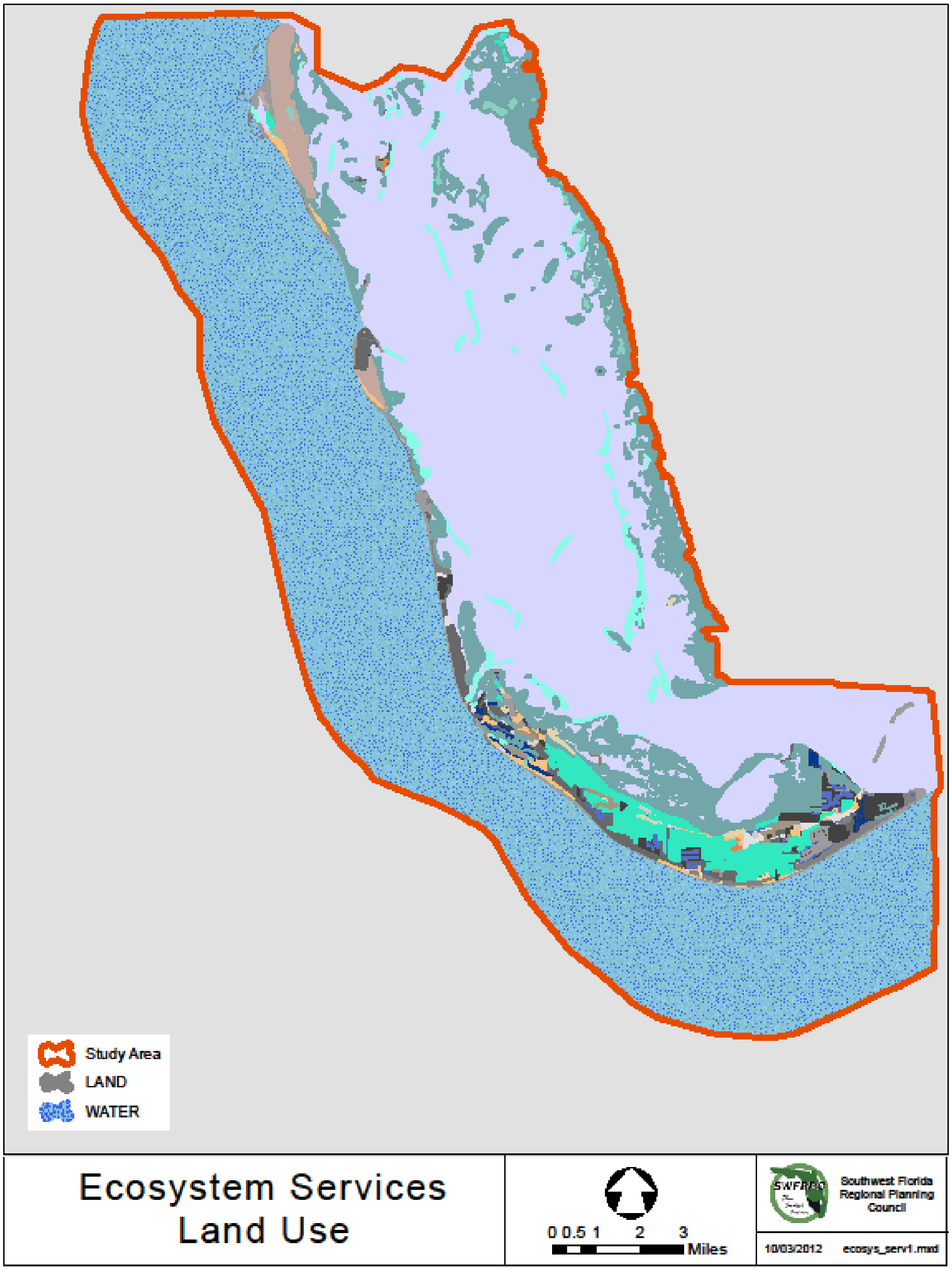

Figure 5: SFWMD land use map (2008)

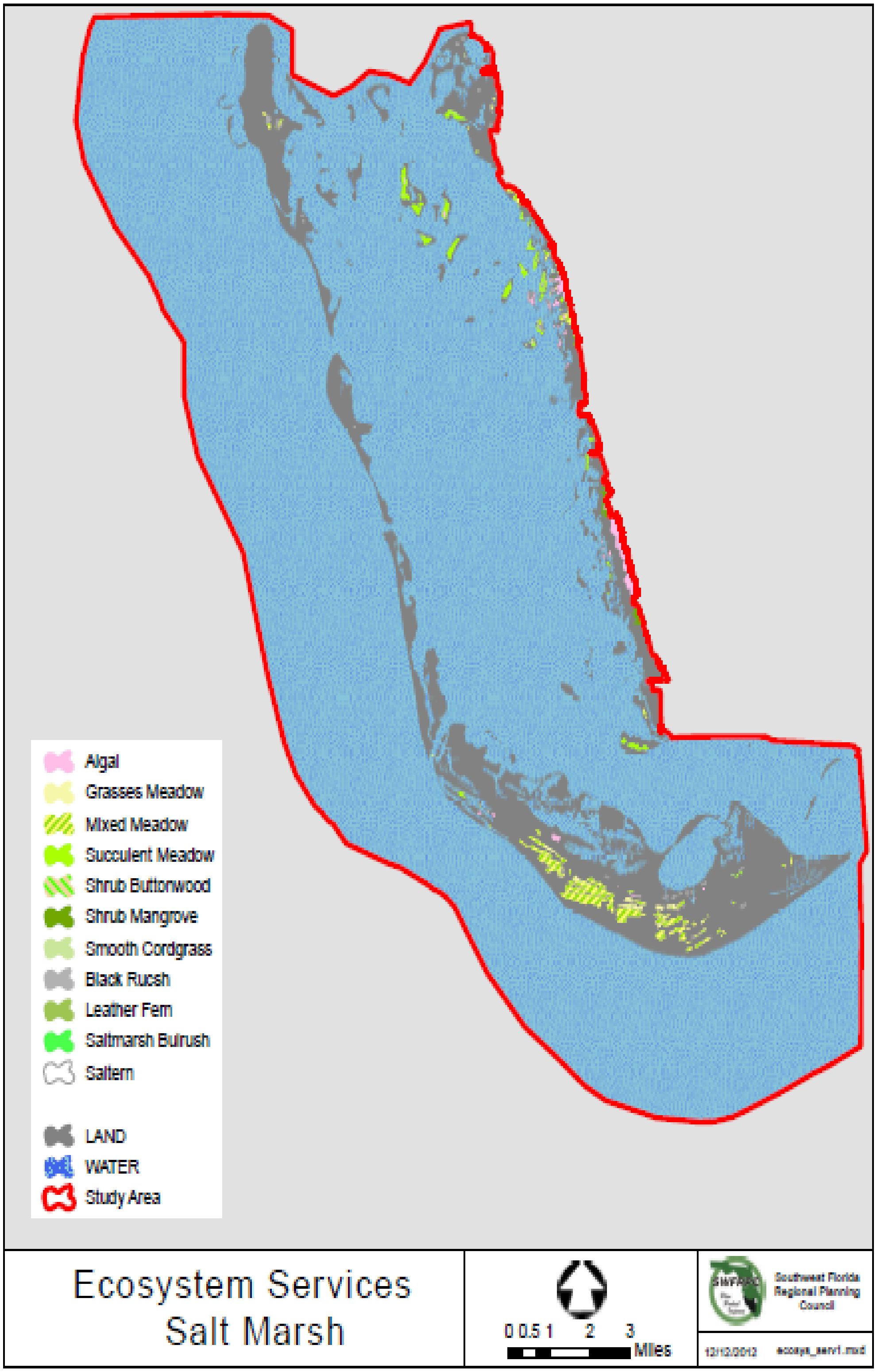

Figure 6: SWFRPC/CHNEP Salt Marsh Map by Type (2012)

Figure 7: Combined Land Cover and Benthic Cover Map for the Study Area

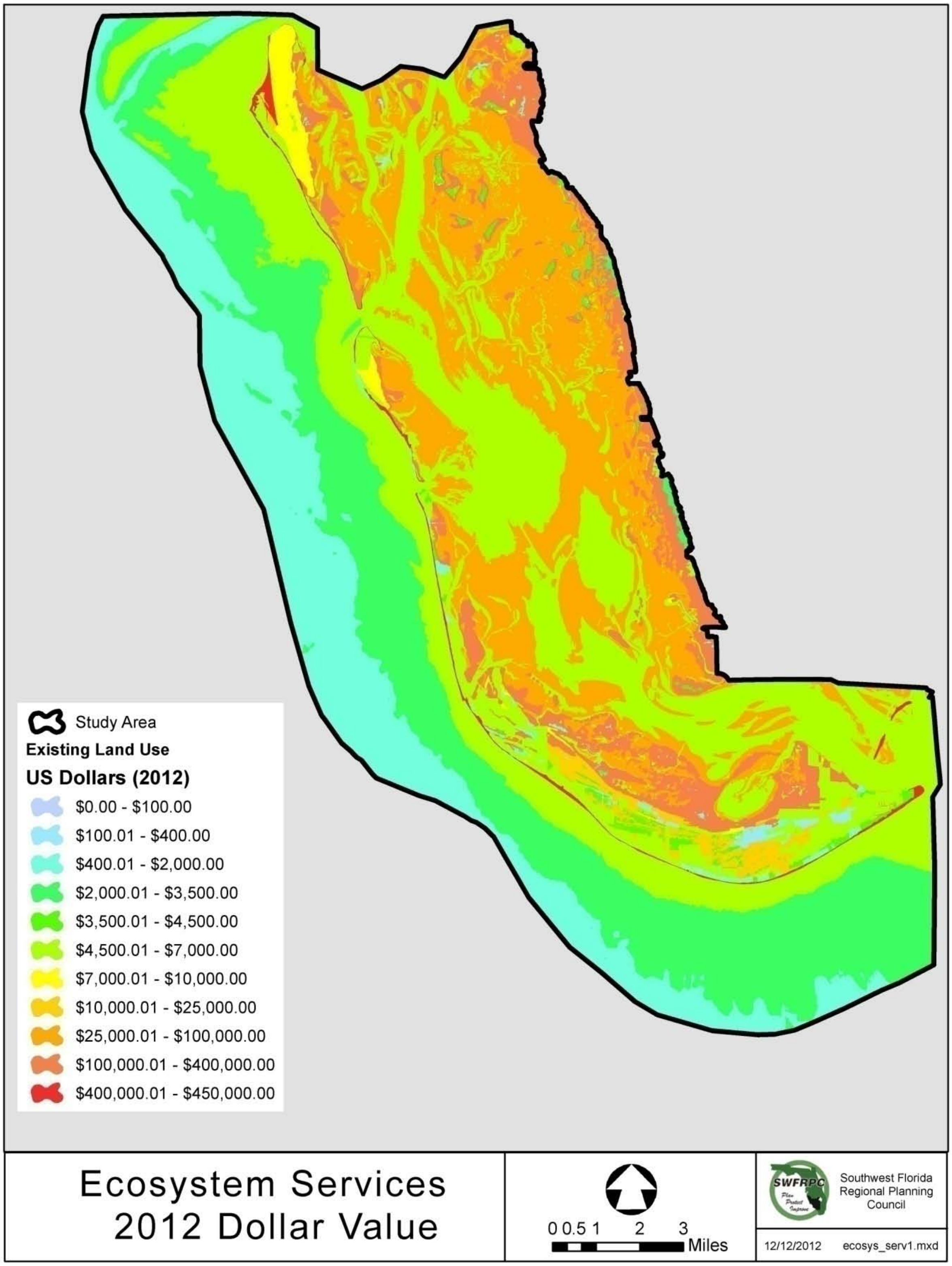

Figure 8: Ecosystem Services 2012 Dollar Values in the Year 2012 (Baseline Condition) for the Study Area

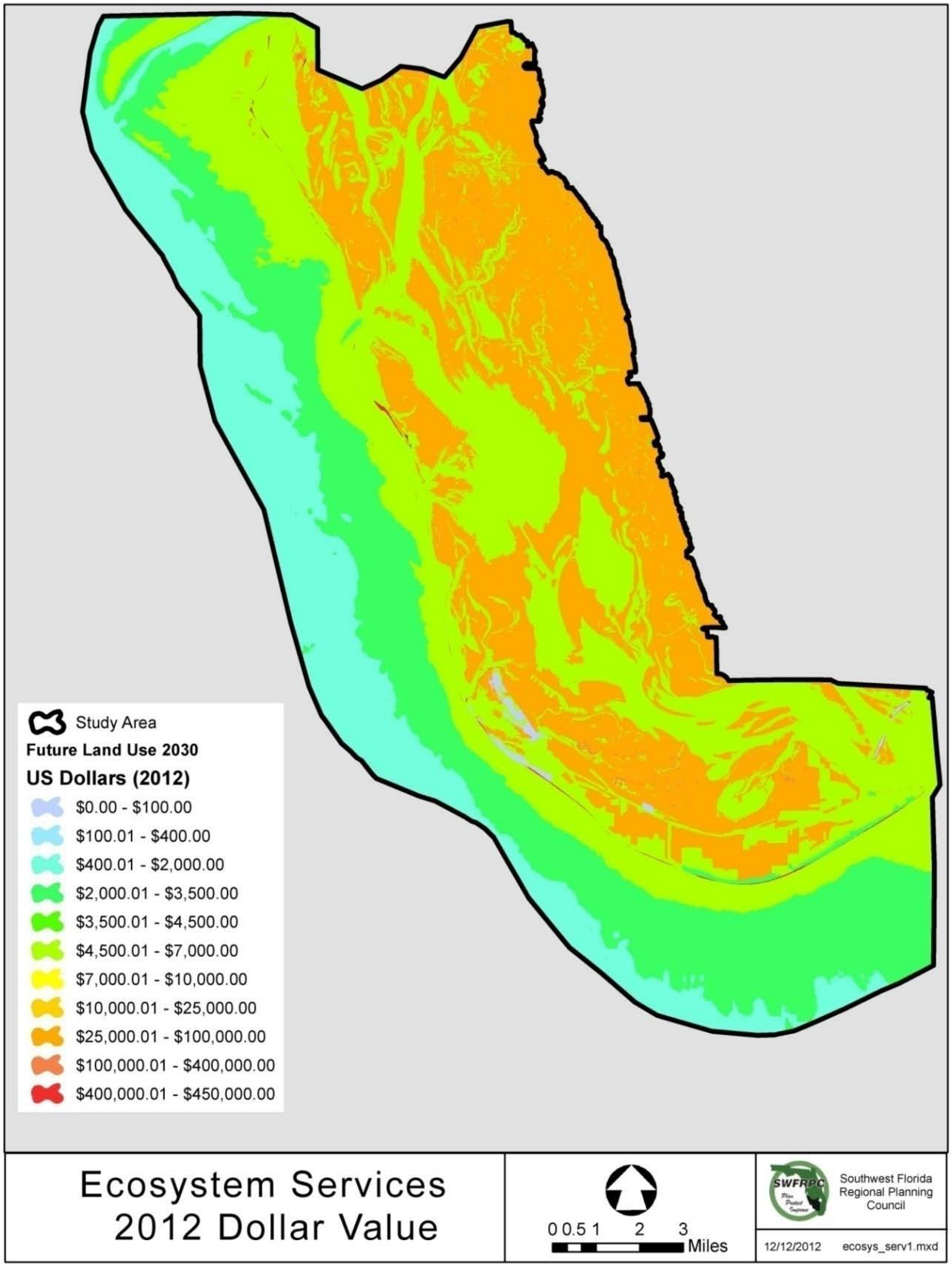

Figure 9: Ecosystem Services 2012 Dollar Values Projected for the Year 2030 (Future Land Use Map Condition) for the Study Area

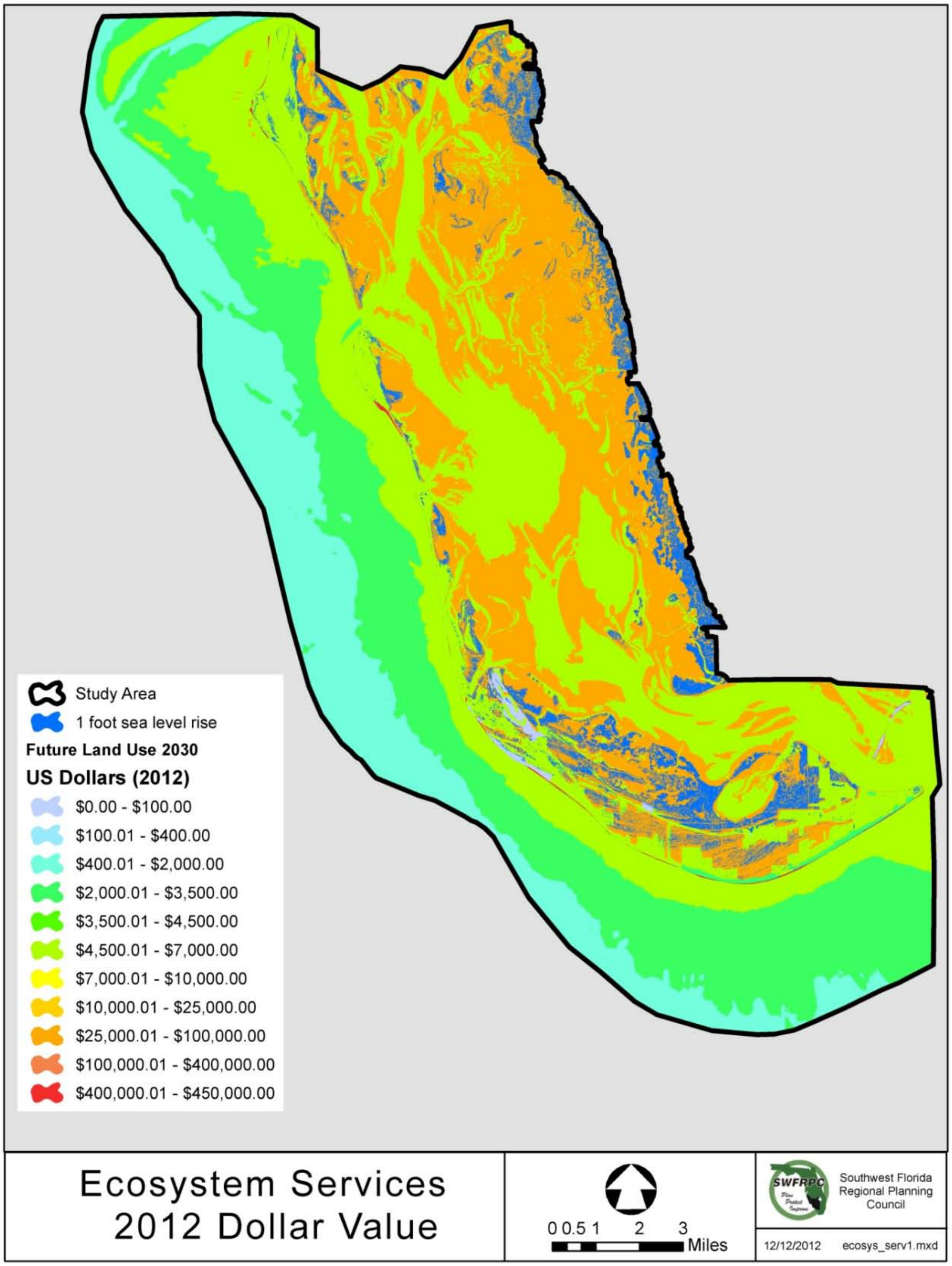

Figure 10: Ecosystem Services 2012 Dollar Values Projected for the Year 2100 (80% IPCC probability) with 1 foot of Sea Level Rise (indicated in deep blue) for the Study Area

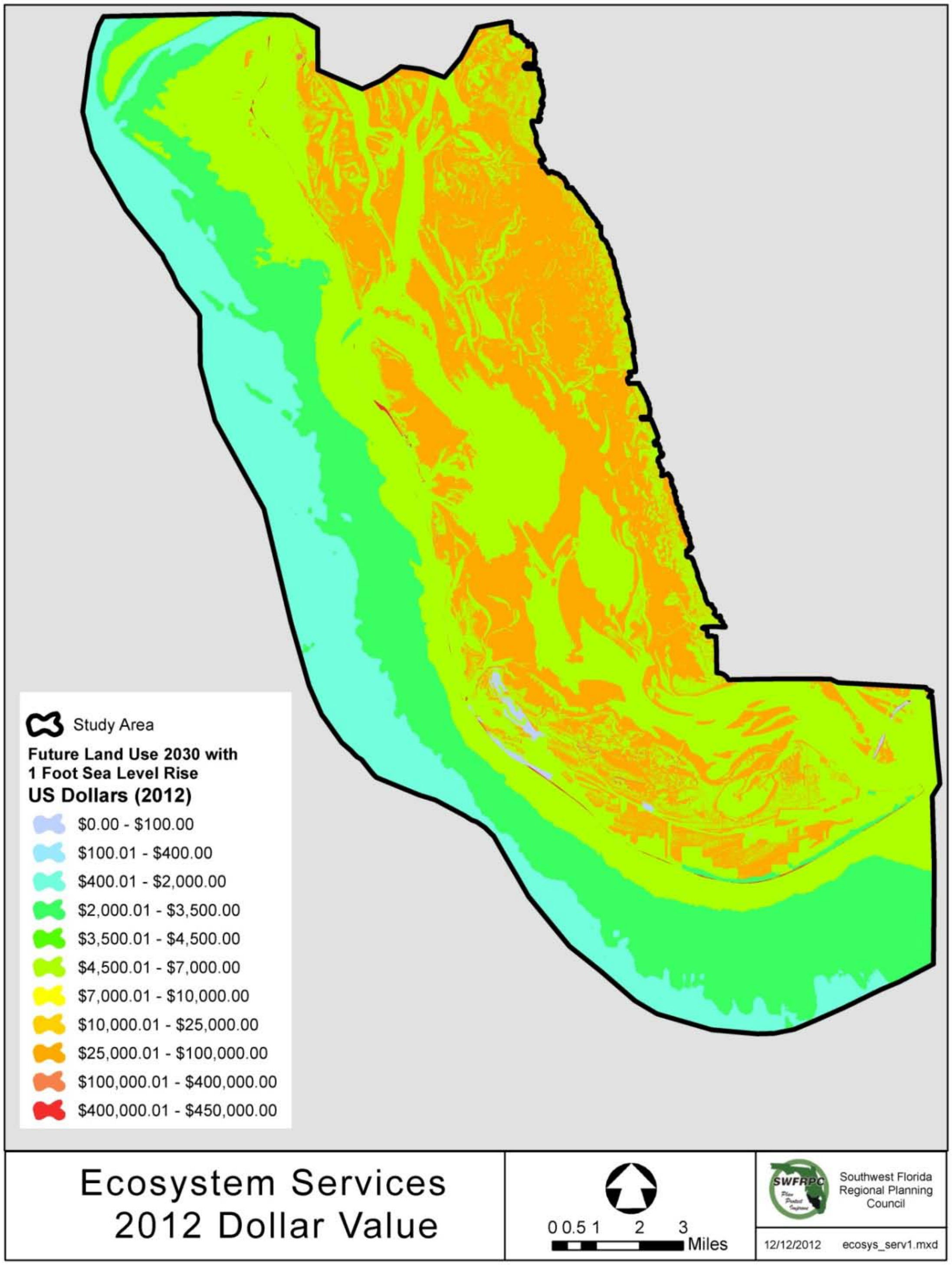

Figure 11: Integrated Ecosystem Services 2012 Dollar Values Projected for the Year 2100 (80% IPCC probability) with 1 foot of Sea Level Rise for the Study Area

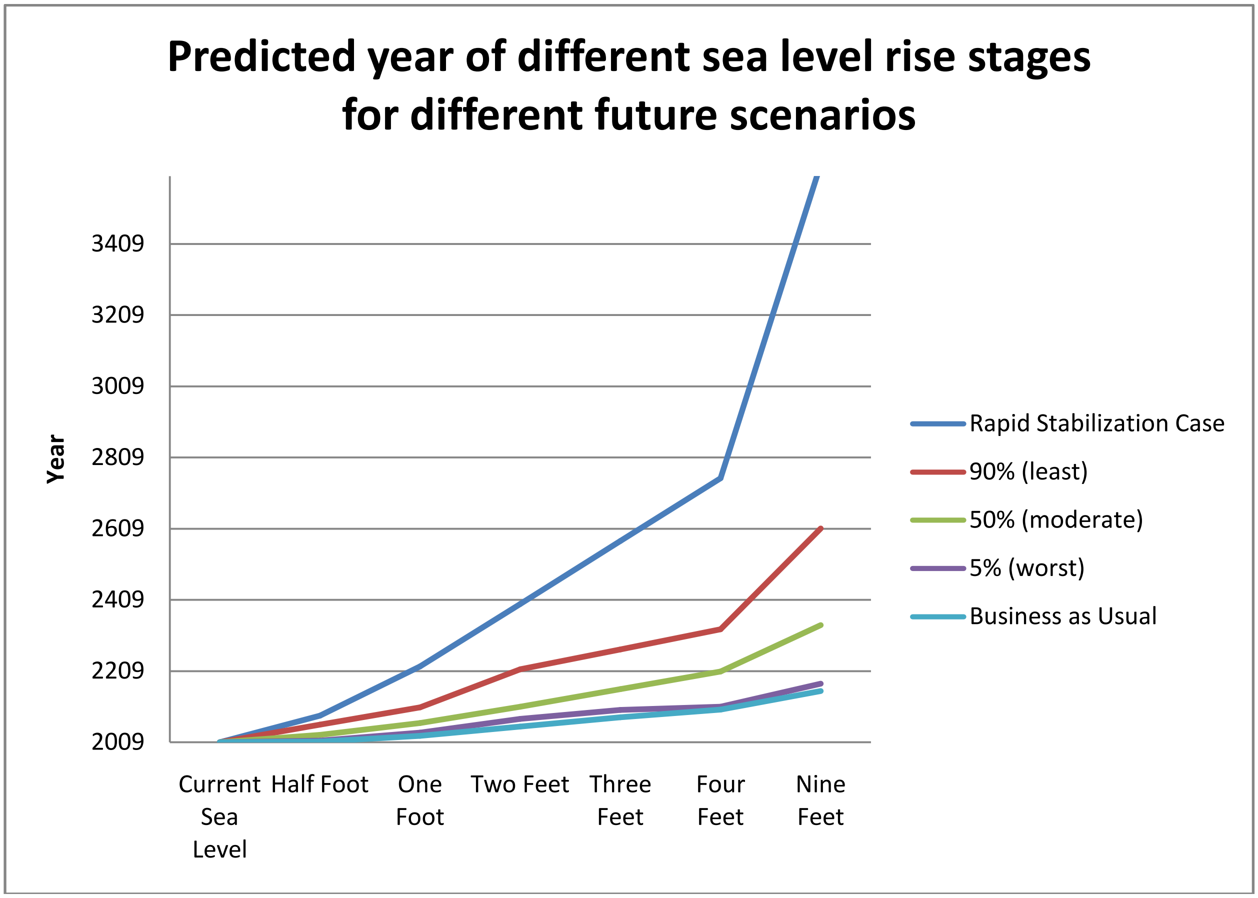

Figure 12: Approximate predicted year of different elevation levels (NGVD) of sea level rise for different future scenarios