Title
San Elijo Lagoon and Sea Level Rise

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I. Abstract

Projected future global mean sea level rise is causing wetlands resource managers to begin looking at wetlands in a new light. This project hopes to answer some of those questions and to create discussion regarding the value of wetlands in California by examining the San Elijo Lagoon in San Diego County. There is still discussion regarding what models to use when examining future potential sea level rise. Discussion continues regarding how vegetative habitats will adjust to the physical changes that may be encountered as the rate of global mean sea level increases due to anthropomorphic Global Warming. A difficult question that all wetlands managers are dealing with is assessing the value of the habitat that they manage. This paper examines the issues regarding global mean sea level rise models and how to interpret them. GIS tools are presented for evaluating the areas of a wetland at greatest risk from simple inundation. Finally, this paper looks at the benefits associated with averting potential impacts from global mean sea level rise.

II. Introduction

Wetlands were once a much larger part of the California landscape, but there has been a loss of 90% of the wetlands that once existed within California (Heberger 2009). Numerous factors continue to threaten the stability of this habitat as the California population continues to increase and the habitat faces threats from climate change. Wetland habitats are under particular stress within southern California due to the relative low rainfall coupled with the large urban population situated along the coastline. Sea level rise is one of a number of threats to the stability of the southern California lagoons in San Diego County. This paper attempts to look at the benefit of "pre-emptive restoration," which is considering and planning for global sea level rise in restoration projects within southern California at current and future time periods. The San Elijo Lagoon, located between Solana Beach and Cardiff-by-the-Sea, CA has been used as a case study for this project.

III. San Elijo Lagoon

San Elijo Lagoon is located between the towns of Cardiff by the Sea to the north and Solana Beach to the south. The town of Cardiff by the Sea has a population of 10,366 as of 2000 (U.S. Census Bureau). It is a small coastal community dominated by housing with some restaurants and a small business district. Along the northwest corner of the lagoon, at the entrance to the Pacific Ocean, there are a few restaurants and businesses bordering the lagoon and beach. The City of Solana Beach is at the southern end of the San Elijo Lagoon. Solana Beach is a larger community with a population of 12,979 as of the 2000 U.S. Census (U.S. Census Bureau).

The lagoon is crossed by two major roadways and a rail line. Interstate 5 runs through the center of the lagoon and has a 60-ft long bridge on the north side of the interstate, which has been in place since 1965. Built in 1912, Highway 101 crosses the lagoon on the far western boundary; a bridge over the lagoon exists at the Pacific Ocean entrance to the lagoon. The current Santa Fe railroad was built through the lagoon in 1925 just east of Highway 101 and is built on a levee with a bridge on the northern end of the rail line. (San Elijo Lagoon Conservancy)

Additionally, major historical influences to the lagoon include: 1887 construction of a narrow gauge railroad, Lake Wohlford Dam built in 1895 which greatly reduced the stream flow into San Elijo, in 1940 the cities of Encinitas, Escondido, and Solana Beach began dumping treated sewage into the lagoon until 1973, 1969 development begins around the lagoon, Lake Dixon Dam is constructed in 1971 which reduces the flow of water to Escondido creek, and in 1973 the beginning of protection for the lagoon with the Endangered Species Act. (San Elijo Lagoon Conservancy)

San Elijo Lagoon is fed by the Escondido Creek Watershed, which covers about 54,112 acres. The watershed begins in Bear Valley and comprises about 40% of the Carlsbad hydrologic unit; three dams are established within the watershed. Additionally, there is a large freshwater influence to the lagoon from the housing communities in Cardiff, Encinitas, and Solana Beach (Clean Water Project). This freshwater influence has increased dramatically within recent years and has shown to include fertilizers, pollutants, trash, and animal waste (San Elijo Lagoon Conservancy). Additionally, this freshwater influence is believed to be partially the cause for an increase in non-native species of plants and animals within the lagoon (San Elijo Lagoon Conservancy).

San Elijo Lagoon is comprised of ten different primary habitats as can be seen in Figure 1. The habitats are defined by the dominate vegetation. From restoration efforts throughout the southern California region, it has been shown that many species have developed site- specific genotypes that favor the original habitat (Hufford 2003). The vegetation within each habitat greatly affects the plant and animal distributions within the lagoon, habitat zones, and many physiological processes.

An understanding of the vegetation habitats within San Elijo Lagoon is of great importance for the future of the lagoon with respect to potential sea level rise. Whitcraft and Levin (2007) demonstrated that the vegetation canopy within the marsh plays a key role in maintaining the biotic and abiotic communities in southern California marshes and lagoons. Whitcraft and Levin (2007) conclude that there is a high probability that any change to the marsh will influence vegetation cover. Of particular note is the finding that the plant canopy has light reduction values that are necessary for the natural biotic community. From the roots and due to photosynthesis, vegetation adds oxygen to the soil in what is otherwise an oxygen-poor environment; the root structure also adds stability to the marsh soils (Callaway 1995). Changes to abiotic factors can have direct effects on the vegetation within the lagoon. Experimental work done with both *S. patens* and *S. alterniflora* suggests that reductions in oxygen within the soil have a direct effect in the photosynthetic capabilities of each plant (Pezeshki and DeLaune 1996). In this case it was shown that both hydrology and the resulting soil reduction greatly affected the physiology of the two species but gave a distinct advantage to *S. alterniflora*.

The interaction between hydrology and the lagoon concerning sedimentation, nutrient transport, and flow dynamicscan be seen in work done by Leonard and Luther (1995) in Florida and Louisiana and later by Leonard and Reed (2002) in both the United States and the United Kingdom. Both studies looked at sedimentation caused by flow dynamics that have been altered by vegetation within multiple wetland canopies (Leonard and Reed 2002). Vegetation within the lagoon causes a decrease in water flow, thereby increasing sedimentation within the vegetation canopy (Leonard and Luther 1995). Closely associated with this, and a cause for concern with respect to sea level rise is accretion within San Elijo Lagoon. Accretion is the rise of the marsh in elevation from sedimentation; historically the lagoons and marshes within San Diego County have had accretion rates that closely mirrored sea level (Cahoon 1996); over the last 1100 years Tijuana estuary has averaged about 1mm per year of accretion while sea level rise has risen by about 1-3 mm per year (Cahoon 1996). This holds true for the San Elijo lagoon and has changed as the primary source of sedimentation within the lagoon is the Escondido creek watershed. This watershed has been dammed and no longer supplies the large pulses of sediment that the San Elijo Lagoon once depended on. Cahoon et al. (1996) demonstrated that the Tijuana Estuary received the majority of its sediment from episodic storm events and a minimal amount from tidal influence. The estuary accretes by 1 to 2 mm per year, which is much less than potential future sea level rise rates (Cahoon 1996). In San Elijo Lagoon, reduced sediment from Escondido creek is more than offset by increased sediment from construction associated surface erosion and road fill failures (San Elijo Lagoon Conservancy).

The habitats within San Elijo Lagoon comprise a total of 813.54 acres and include channels, coastal strand, freshwater brackish marsh, mudflat, open water, riparian, salt marsh-high, salt marsh-mid, salt panne, upland, and berms and roads. Figure 1 shows the location and acreage area of each of the habitats within the San Elijo Lagoon Conservancy study area. These habitats are home to birds, mammals, fish, aquatic invertebrates, and insects. Many of these animals play an important role in influencing the vegetation community through such processes as deposition of nitrogenous waste, burrowing through the sediment, removal of vegetation, and pollination (Callaway 1995). Of great importance to many of the human visitors to the lagoon are the numerous migratory species of birds that visit throughout the year. All of these species play an important role in the function of the lagoon.

Table 1. San Elijo Lagoon Vegetation Habitats
*Habitat type code is used in Figure 1.

Habitat Type	Habitat Type Code*	Area in Acres of Study Area
Berms and Roads	br	18
Channels	ch	23
Coastal Strand	cs	4
Freshwater Brackish Marsh	fw	108
Mudflat	mf	135
Open Water	ow	8
Riparian	rp	45
Salt Marsh High	smh	85
Salt Marsh Mid	smm	102
Salt Panne	sp	32
Upland	up	254
Total		813.54

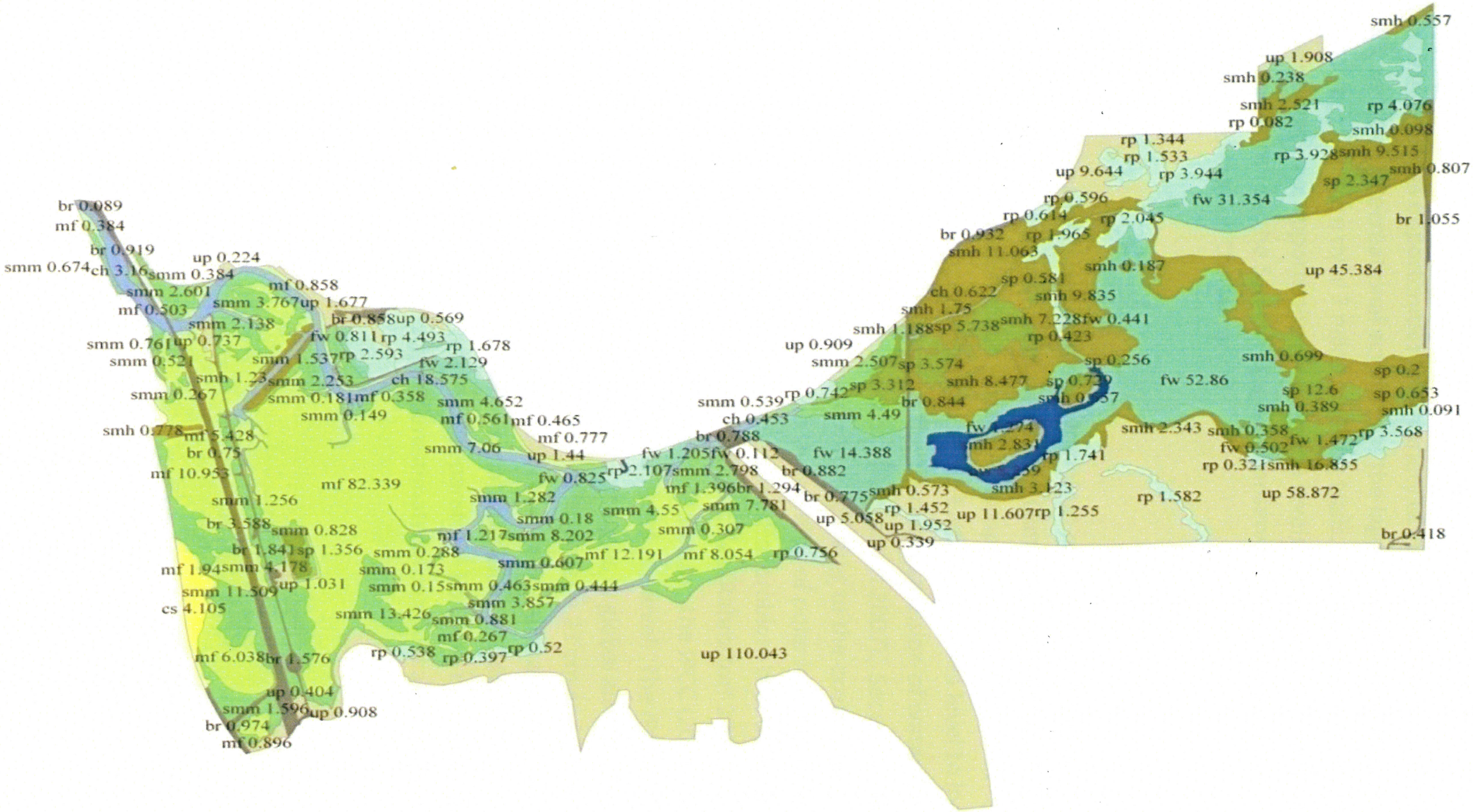

Figure 1. Map showing San Elijo Lagoon vegetation in 2007 (provided courtesy of the San Elijo Lagoon Conservancy).

*Habitat type code is shown in Table 1.

San Elijo Lagoon provides opportunities for a variety of visitors including recreation, education, and scientific research. Recreational activities at the lagoon include hiking on the many trails and bird watching; there are over 7 miles of hiking trails. The lagoon is used by many local schools as an educational opportunity for all grade levels. In addition scientific research and monitoring is done both by the San Elijo Lagoon Conservancy and numerous research institutions (San Elijo Lagoon Conservancy).

III. Sea Level Rise

The ultimate cause of sea level rise is "global warming" related to an increase in atmospheric greenhouse gases. The Intergovernmental Panel on Climate Change (IPCC 2007) estimates that there will be an increase of global mean surface air temperature of 1.4 °to 5.8 °C by 2100. So why do increased global air temperatures cause the Earth's mean sea level to increase? There is more than one reason, the first of which is the thermal expansion of water due to "the uptake and penetration of heat into the oceans" (Rahmstorf 2007). Secondly, the melting of water stored on land will contribute a large portion of water to the oceans; sources include high elevation ice pack, the melting of glaciers, and the melting of polar ice. The difficulty in understanding sea level rise is that it is a complex physical problem that deals with multiple intricate mechanisms that operate on different time scales (Rahmstorf 2007).

In addition to scenarios for changes in global air temperature, the IPCC (2007) has formulated scenarios for the possible future increase in global mean sea level. The IPCC sea level rise scenarios take into consideration the scenarios for changes in global air temperature. The IPCC estimates that by 2100 global mean sea level will rise between 21 cm and 77 cm (including the range of error); Figure 5 shows the projected sea level rise for all scenarios without the included range of error (IPCC 2007). The IPCC (2007) did not take into consideration the change to land-stored ice specifically, but addressed this issue separately. For this reason the IPCC's estimation of global mean sea level rise may greatly underestimate what could actually occur (Rahmstorf 2007).

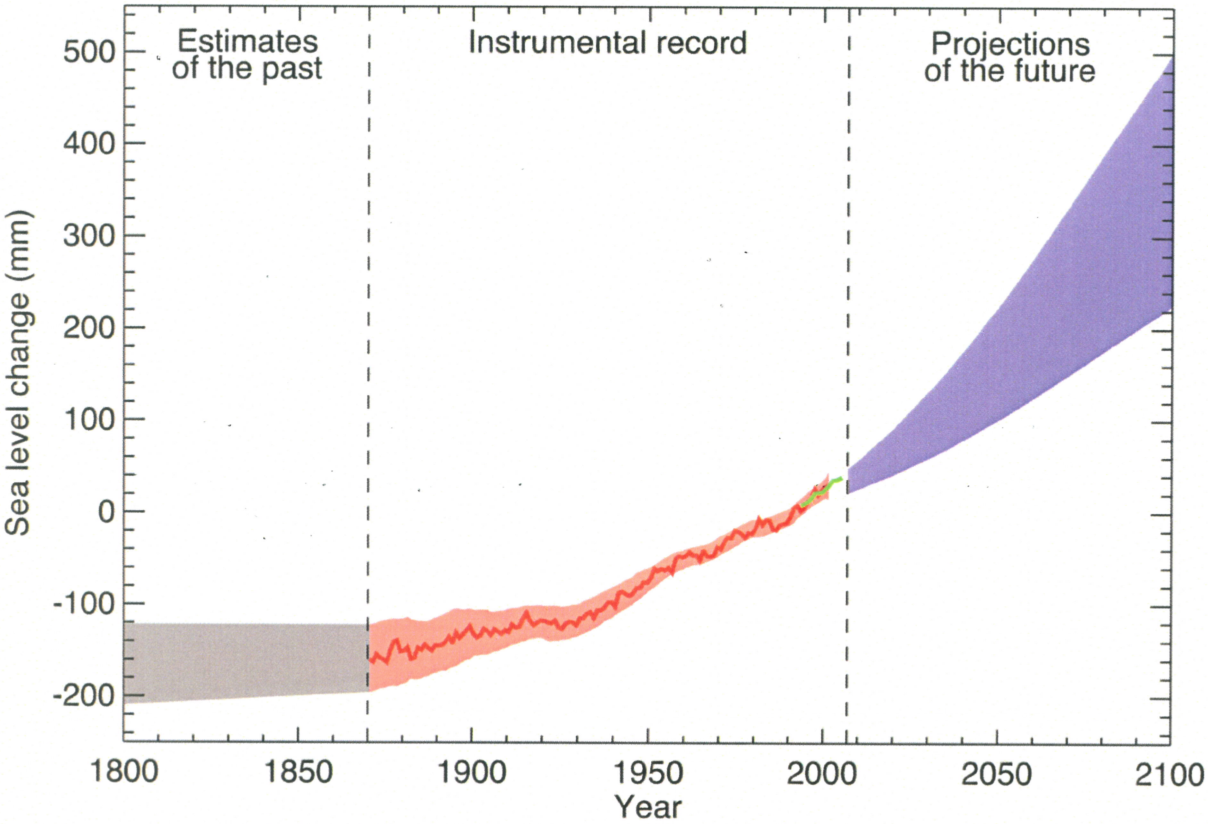

Figure 4. Range of past and projected future global mean sea level scenarios from IPCC (2007).

Unlike the IPCC, Dr. Stefan Rahmstorf has in his modeling implicitely taken all processes affecting sea level rise into account, including ice melting. Rahmstorf (2007) found that a linear correlation existed between the rate of rise in sea level and the increase in global mean air temperature over the pre-industrial age. This linear relationship together with the assumption that the sea level rise response time is on the order of millennia, points toward possible mean sea level increases of 20-50 cm by the year 2050 and 50-140 cm by 2100. "The possibility of a faster sea-level rise needs to be considered when planning adaption measures, such as coastal defenses, or mitigation measures designed to keep future sea-level rise within certain limits" (Rahmstorf 2007). The middle to upper end of sea level rise increase projections would be a much greater rate than the San Diego area has seen in at least over 100 years (Cayan et al. 2008). The Rahmstorf projections will be used for this project.

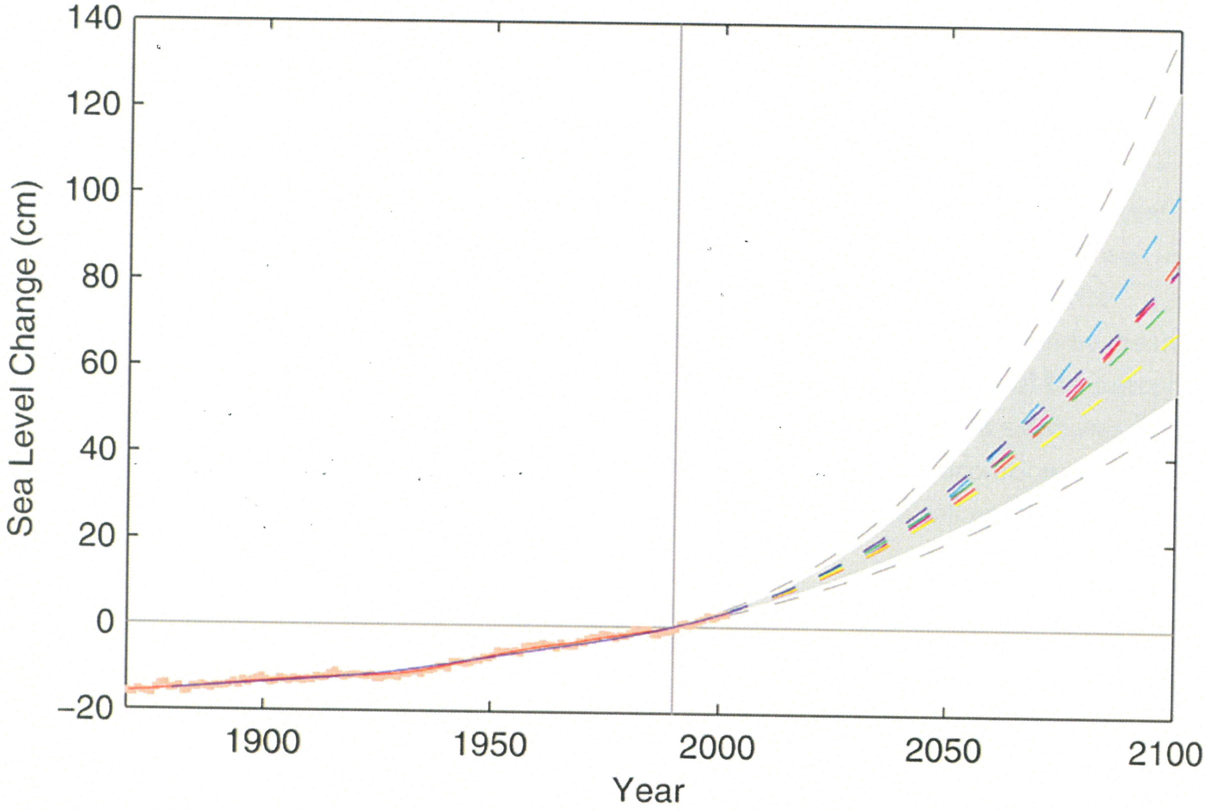

Figure 5. Curves showing sea level rise scenarios with projected mean sea level rise of 50-140 cm by 2100 from Rahmstorf (2007).

In addition to the rise of global mean sea level, the coastlines, including San Elijo Lagoon, will also be affected by both the increase in tide level variation and potential storm surge -both of which will exacerbate the effects of sea level rise. It has been shown that the daily range between the high tide and low tide has become greater over time (Flick, et al. 2003). If this trend continues, it will become especially pronounced during both the winter and summer months, which already show the greatest daily tidal range. In addition to extreme high tides is the potential threat that could be caused by large storm events exacerbated by El Niño/Southern Oscillation effects. Coastlines will suffer the greatest damages when both extreme high-tide events and storm surges occur at the same (Cayan et al. 2008).

IV. Habitat Affected by Sea Level Rise

"Tidal marshes are likely to be particularly vulnerable to climate change impacts due to changes in salinity and inundation patterns"(Calloway 2007). For this reason it was decided to take a look at how many acres would be affected by a rise in mean sea level. For this project, each habitat was not considered separate in order to determine the area affected, since each microhabitat within the lagoon is dependent on the others and should not be valued separately (Gren 1994, Ehrenfeld 2000). As mentioned earlier, the study area for this project is that of the

San Elijo Lagoon Conservancy's habitat study area of 2007. The total amount of known habitat within this area is 813.54 acres.

This project used elevation and bathymetry maps created by Philip Williams and Associates (1990) and Terrill (2001). In order to determine the area coverage of a given mean sea level rise within San Elijo lagoon, both ArcView GIS and Google Earth were used. First, ArcView was used to map the shoreline positions corresponding to 20, 50, and 140 cm mean sea level rise scenarios in San Elijo Lagoon. This was done to find the area of possible inundation by mean sea level rise and to also present a simple framework for discussing what some of the outcomes may be from mean sea level rise. The scenario maps, unfortunately, are gross estimates of pure sea level inundation and are not capable of estimating the effects of accretion, vegetation, and animal response to sea level rise and changes in climate, beach and soil erosion, and other abiotic and biotic responses to sea level rise.

The 20 cm sea level rise by 2050 scenario was chosen, as it is the lowest current credible projected future sea level rise elevation. The 50 cm sea level rise scenario was chosen as it is both the upper estimated value by 2050 and the lower-end value by 2100. The final (140 cm) scenario was chosen as it is the maximum projected elevation for the year 2100 in the Rahmstorf (2007) model. ArcView was then used to determine the area of the created sea level rise polygon for each of the sea level rise scenarios. The estimated sea level rise area from each scenario was subtracted from the total number of acres within the habitat study area.

Table 2. Lagoon Habitat Area Affected by Mean Sea Level Rise

Sea level Rise (cm)	20	50	140
Acres Affected	169	229	449

Figure 6. Map showing inundation area for 20-cm mean sea level rise (green) in San Elijo Lagoon.

In the 20 cm sea level rise scenario, expected to be a possibility by 2050, there will be flooding and loss of low and mid-marsh area as well as a loss of some of the channels. There will be deepening of the channel, mudflat, habitats. The low and mid- marsh will experience "habitat squeeze" along with many of the transition zones as the habitats migrate towards the San Elijo Lagoon canyon walls. The back section of the lagoon, which is a freshwater brackish habitat, will be mostly unaffected by sea level rise as the area is higher in elevation and there is a levee and pumps in place to control the amount of freshwater that flows out of the lagoon. The mouth of the lagoon will continue to temporarily close, and will still require opening each year. The upland and riparian areas will remain unaffected.

Figure 7. Map showing inundation area for 50-cm mean sea level rise (blue) in San Elijo Lagoon.

The 50-cm sea level rise scenario, which could occur by either 2050 or 2100, will no longer resemble the San Elijo Lagoon as it is currently recognized. The lagoon with this much sea level rise will begin to resemble San Dieguito Lagoon, which is located to the south, between the cities of Solana Beach and Del Mar. There will be a continued loss of low marsh, mid-marsh, and channels. In this scenario, the high marsh area would be greatly reduced with some loss of both the transitions zones and the riparian habitats. The entrance to the lagoon would continue to close during the year and the freshwater brackish section of the lagoon would continue to remain unaffected.

Figure 8. Map showing inundation area for 140-cm mean sea level rise (turquoise) in San Elijo Lagoon.

By the year 2100, 140cm of mean seal level rise may occur as the high end of the scenarios being put forth today. In this case, most of the lagoon would be greatly changed. The lagoon entrance would likely remain open year round, and the lagoon would act more like a shallow bay. The marsh habitats would be squeezed into a thin corridor along the edges of the lagoon. Freshwater and brackish habitats would be lost as high sea level would bring salty ocean water over the concrete levee and pumps. There would still be no direct consequences to man-made structures such as roads, railroads, or structures. However, with this magnitude of mean sea level increase, it can be expected that all of the man-made structures will be threatened by high tide and storm surge events.

Table 4. Habitat Area Affected at 140 cm Scenario

	Berms and Roads	Channel	Coastal Strand	Freshwater brackish marine	Mudflat	Open water	Riparian	Salt marsh high	Salt marsh mid	Salt panne	Upland	Total
Acres of Habitat Affected	1	22	0	2	114	0	0	2	28	0	0	169
Percent change from 2009	4.3%	96.3%	0.3%	1.5%	84.3%	0.0%	0.0%	2.6%	27.2%	0.4%	0.2%	20.7%

Table 5. Habitat Area Affected at 140 cm Scenario

	Berms and Roads	Channel	Coastal Strand	Freshwater brackish marine	Mudflat	Open water	Riparian	Salt marsh high	Salt marsh mid	Salt panne	Upland	Total
Acres of Habitat Affected	4	23	3	74	134	8	8	64	97	29	5	449
Percent change from 2009	20.5%	99.9%	66.1%	68.8%	99.1%	100.0%	17.9%	75.5%	94.9%	92.6%	2.0%	55.2%

Table 6. Habitat Area Affected at 50 cm Scenario

	Berms and Roads	Channel	Coastal Strand	Freshwater brackish marine	Mudflat	Open water	Riparian	Salt marsh high	Salt marsh mid	Salt panne	Upland	Total
Acres of Habitat Affected	1	22	0	1	132	0	0	2	68	1	1	229
Percent change from 2009	5.2%	96.2%	0.8%	1.2%	97.9%	0.0%	0.7%	2.8%	66.5%	4.6%	0.3%	28.2%

V. “Preemptive” Restoration of San Elijo Lagoon

For those that place a high value on the San Elijo Lagoon, and wetlands in general, the idea of adapting to the effects of sea level rise within the lagoon is a very attractive concept. The idea of “preemptive” restoration is not that of restoring the lagoon back to what existed during some historic time period, but managing for a particular known or reasonably expected unfavorable event or condition in the future. Behind this concept is the assumption that the benefits currently received from the lagoon are maximized or at least desirable. "Preemptive" restoration looks to continue those benefits into the future despite the possibility of the unfavorable event or condition.

For San Elijo Lagoon there are a number of possibilities for controlling or adapting to sea level rise. The first of which is to control the amount of sea level that enters the lagoon. This could be accomplished through the construction of a large flood gate at the entrance with which tidal fluctuations could be controlled artificially. The end effect of this would be that the lagoon would eventually exist below sea level. Similar ideas are in place in areas such as New Orleans, Louisiana and Venice, Italy. This possibility would include a very high up-front cost and require close monitoring of water levels and a large amount of control of the flood gates.

A second approach follows the example of the Mississippi Delta. There, accretion rates are being artificially accented by increasing the sediment added to marsh in small specific areas. However, the addition of diluted dredge material in areas that have experienced sediment loss due to erosion or accretion has not been able to keep pace with rise in relative sea level, which in Louisiana is greatly increased by land subsidence. The Mississippi Delta Region is also combating sea level rise by island creation using dredge material (LaCoast.gov). By incorporating possible sediment addition into a "preemptive" restoration concept, the San Elijo vegetation habitats would rise with sea level, and the current habitat regime could remain. This would incur ongoing costs for sediment and monitoring over a long period of time.

One of the more common types of restoration in a wetland setting includes a large construction-style project that artificially modifies the habitat to obtain a desired effect. For this project, this is the restoration style that is considered as there is currently a large construction restoration project in the planning stages for the San Elijo Lagoon. The San Elijo Lagoon Conservancy expects to receive approximately $120 million for restoration from TransNet, the Sothern California Highway 5 project, which includes approximately $850 million for an environmental mitigation program. The project is still in the planning stages but includes the extension of the Interstate 5 bridge to double its current length from 60 to 120 feet (Johnson 2009). Depending on budget, the San Elijo Lagoon Conservancy seeks to move the entrance of the lagoon from the northwest to the southwest, which would mean moving the Highway 101 and Santa Fe Railroad bridges. Also a part of the plan is the modification of the elevation and channels throughout the lagoon to maximize the benefit from the altered bridges. This will be done by dredging the marsh and using the dredge material to fill other areas. The purpose of this part of the project is to increase diversity within the lagoon (Gibson

2008). A large construction-style "preemptive" restoration project of this type would include a large initial cost along with additional yearly monitoring and management costs.

VI. Value of Habitats in San Elijo Lagoon

Understanding that potential future rise in sea level may cause drastic changes within the lagoon and that there is possible mitigation that can be done begs the question of what is the value of the lagoon. This determination can be a difficult task, as there are interactions in the lagoon that are still being described by the scientific community. Additionally, many of the known benefits of the lagoon are understood but it is often difficult to put a dollar value on a particular benefit. Costs for restoration can be difficult in light of the fact that these costs are not equal for all projects, and vary with the type of restoration used. For additional information regarding valuation techniques used in wetlands, please refer to Barbier (1997).

For this project, a cost benefit analysis was done to determine the value of "pr-emptive" restoration in the areas of the lagoon that may be affected by sea level rise using the four different scenarios: 20cm sea level rise by 2050, 50 cm sea level rise by 2050, 50 cm sea level rise by 2100, and 140cm sea level rise by 2100. One method of determining benefits for this type of analysis is in terms of willingness to pay.

VII. Costs of "Pre-emptive" Restoration

The first step in performing the cost benefit analysis was to determine what the costs associated with "preemptive" restoration are. Research was conducted into earlier projects at other sites to estimate the cost per acre of a large-scale restoration project within San Elijo Lagoon. The earlier project values were used to represent a willingness to pay for the cost of restoration. The use of other restoration projects per acre costs is related to the concept of contingent valuation. The additional advantage is that these are projects that have all been finished and all of the costs related to the restoration efforts have been accounted for. The projects used are reported in Table 3, and were used for this study because the values had been reported in cost/acre. One advantage of using contingent valuation is that "Cost estimates for wetland restoration, particularly in urban areas, are complex and controversial, given the many human and natural constraints" (Steere). While the average value of these projects may either under or over estimate the true cost of the initial restoration of San Elijo Lagoon, this estimation will allow for a discussion concerning the benefits supplied from the lagoon due to "preemptive" restoration.

Table 7. Costs of Pre-emptive Restoration.

Cost of lost habitat
Values reported from U.S. Environmental Protection Agency
Management Measure for Restoration of Wetland and Riparian Areas

Restoration Costs (One Time Up Front Cost)

Project	Cost per Acre in 2009 dollars
1982 tidal wetlands project in Chesapeake Bay, Maryland(included seeding and fertilizing saltmarsh cordgrass)	$413.07
1979 for tidal wetlands restoration in coastal California included seeding and fertilizing salt marsh cordgrass	$766.10
1979 for tidal wetlands restoration in coastal California included seeding and fertilizing salt marsh cordgrass	$1,271.40
1986 restoration of tidal wetlands at three California coastal sites . Big Canyon in Upper Newport Bay, Freshwater Slough, and Bracut (both in Humboldt Bay). Existing fill had to be removed from the sites before wetlands restoration could be accomplished (Anderson and Rockel, 1991).averaged	$42,494.10
	Average per Acre Cost in 2009 dollars $11,236.17

Maintenance and Operation Costs
Cost per Acre in 2009 Dollars

Low	High
$341.95	$823.58

Monitoring Costs
Monitoring Cost is 3% of total initial cost
Cost per Acre in 2009 Dollars
$337.09

Total Cost per Acre per year

For "preemptive" Restoration

Low	High
$679.04	$1,160.67

The dollar amount that the San Elijo Lagoon Conservancy has already obtained for the planned project was not used in the present analysis, as that is not a final figure for the project, nor does it specify how many acres will be affected; additional funds may need to be secured before the project is finished. The average cost per acre of restoration in 2009 dollars obtained from four different tidal wetland projects is to be considered a one-time upfront cost. Maintenance costs were also considered; maintenance costs were obtained from Siegel (2002) for the estimated cost of maintenance of levees and restored area. The maintenance costs were reported as a range, so both a high and low value was considered for this project. Monitoring costs were calculated as 3% of the total initial project cost, an industry standard as reported by (Steere). Finally, land acquisition costs were considered but ultimately not used as a part of this project due to both the size of the lagoon and physical structure of the lagoon. The sides of the San Elijo Lagoon are steep and create a bowl; acquiring additional land would not create proportional additional area for the lagoon to migrate into. Costs were determined as both high and low cost per acre values due to the fact that maintenance costs were reported as a range.

VIII. Benefits of “Pre-emptive” Restoration

In order to assess the value of the benefits of avoiding or adapting to potential sea level rise impacts, it was first important to assess what the benefits of the San Elijo Lagoon are. It is an inherently difficult task to assign value to ecosystem services; “The estimation of the economic value of natural wetlands is a difficult and complex task, but it is essential to rational management” (Costanza 1989). Numerous valuation techniques were considered as to what would best describe these benefits. The values used are from “The Economic Value of Coastal Ecosystems in California” (Raheem et al. 2008). These values were obtained by Raheem et. al through an extensive literature search. While these values represent a range of values from research into the benefits of wetlands and coastal ecosystems they do have a spatial context that is necessary for this project. The range of values represents the scope of possible benefits supplied by wetlands throughout California. Valuation studies are site-specific and for a project to fully account for the value of the benefits supplied, a site specific valuation is necessary (Raheem et al. 2008). Despite the lack of a full site specific valuation study, the benefit values supplied by Raheem et al. (2008) allow for insights into the range of possibilities of a cost benefit analysis for “preemptive” restoration at San Elijo Lagoon.

Table 8. Benefits of Pre-emptive Restoration

Benefits	Benefits per Acre in 2009 dollars	
	Low	High
Wild Plant and Animal Products	$25.74	$859.32
Capture Fisheries	$54.45	$1,812.69
Pest Regulation	$111.87*	$111.87*
Natural Hazard Regulation	$328.68	$16,177.59
Gas Regulation	$4,103.55	$16,177.59
Water Purification	$2,475.00	$2,475.00
Cultural Heritage Values	$41.58*	$41.58*
Recreation and Tourism	$45.54	$6,191.46
Habitat and Refugia	$190.08*	$190.08*
Primary Production	$1,337.49	$68,974.29
Total	$8,713.98	$113,011.47

*Not all of the benefits were reported as a range, the same value was used to calculate both low and high benefits.

IX. Benefit Value of Affected Area

In order to determine the dollar value of the benefit of retaining the area that would be potentially damaged by sea level rise four different benefit and cost scenarios were examined. The benefit and cost scenarios were: low benefit and low cost, low benefit and high cost, high benefit and low cost, and high benefit and high cost. The benefit and cost scenarios were incorporated into the three different mean sea level rise scenarios of 20 cm, 50 cm, and 140 cm. The cost was subtracted from the benefit to derive the value of the sea level rise affected area. Additionally, the benefit to cost ratio (BCR) was examined in order to compare the results with the EPA standard of a BCR greater than 1.0 equaling project acceptance.

The values shown are for year one only and do not look at the future value of "pre-emptive" restoration. It should also be pointed out that the values reported are only for the area inundated by sea level rise and does not include the entire lagoon as the value reported is the value saved from "pre-emptive" restoration. It is not surprising that both scenarios with a low benefit have a negative value for the "pre-emptive" restoration benefit at year one. Additionally, the benefit to cost ratio within the first year for low benefit scenarios do not suggest economically viable projects. But, if the benefits from the "pre-emptive" restoration are high than a "pre-emptive" restoration project is economically feasible for any mean sea level rise scenario.

Table 9. Value of Restored Area for all Benefit and Cost Scenarios

Low Benefit and Low Cost		
170 Acres Affected	230 Acres Affected	449 Acres Affected
20cm rise	50cm rise	140cm rise
Restoration Costs	Restoration Costs	Restoration Costs
$2,030,350.71	$2,735,135.01	$5,352,309.51
Benefits	Benefits	Benefits
$1,484,862.19	$2,000,294.11	$3,914,319.82
Value of Affected Area	Value of Affected Area	Value of Affected Area
-$545,488.52	-$734,840.90	-$1,437,989.69
Benefit to Cost Ratio	Benefit to Cost Ratio	Benefit to Cost Ratio
0.73	0.73	0.73
Low Benefit and High Cost		
170 Acres Affected	230 Acres Affected	449 Acres Affected
20cm rise	50cm rise	140cm rise
Restoration Costs	Restoration Costs	Restoration Costs
$2,112,420.46	$2,845,693.18	$5,568,657.70
Benefits	Benefits	Benefits
$1,484,862.19	$2,000,294.11	$3,914,319.82
Value of Affected Area	Value of Affected Area	Value of Affected Area
-$627,558.27	-$845,399.07	-$1,654,337.89
Benefit to Cost Ratio	Benefit to Cost Ratio	Benefit to Cost Ratio
0.70	0.70	0.70
High Benefit and Low Cost		
170 Acres Affected	230 Acres Affected	449 Acres Affected

20cm rise	50cm rise	140cm rise
Restoration Costs	Restoration Costs	Restoration Costs
$2,030,350.71	$2,735,135.01	$5,352,309.51
Benefits	Benefits	Benefits
$19,257,154.49	$25,941,782.94	$50,764,752.32
Value of Affected Area	Value of Affected Area	Value of Affected Area
$17,226,803.78	$23,206,647.93	$45,412,442.82
Benefit to Cost Ratio	Benefit to Cost Ratio	Benefit to Cost Ratio
9.48	9.48	9.48

High Benefit and High Cost

170 Acres Affected 20cm rise	230 Acres Affected 50cm rise	449 Acres Affected 140cm rise
Restoration Costs	Restoration Costs	Restoration Costs
$2,112,420.46	$2,845,693.18	$5,568,657.70
Benefits	Benefits	Benefits
$19,257,154.49	$25,941,782.94	$50,764,752.32
Value of Affected Area	Value of Affected Area	Value of Affected Area
$17,144,734.02	$23,096,089.76	$45,196,094.62
Benefit to Cost Ratio	Benefit to Cost Ratio	Benefit to Cost Ratio
9.12	9.12	9.12

X. Benefit Discounted Value of Affected Area

While the initial benefit received from "pre-emptive" restoration with respect to sea level rise is of importance, the far more useful concept is to consider what the benefit would be over an extended period of time. For this, the net present value (NPV) of "pre-emptive" restoration for the discount rates of 20%, 7%, 3%, 2%, and 0% were examined. The multiple discount rates were considered as there are many opinions regarding the choice of discount rates used in assessing environmental projects. The choice of a 20% discount rate places a small value on the future benefits supplied by the San Elijo Lagoon, with a preference for obtaining the benefits from the lagoon. A 0% discount rate places an equal value on the San Elijo Lagoon benefits for all times. The model used for these calculations is:

$$NPV = \sum_{t=0}^{T} \frac{V_t - C_t}{(1+\delta)^t}$$

Table 10. Net Present Value of Benefits of Area Potentially Affected by Sea Level Rise

Low Benefit Low Cost

Net Present Value with Discounting

	20%	7%	3%	2%	0%
20 cm in 2050	-$1,882,815.44	$1,588,851.58	$14,792,805.68	$23,010,020.72	$54,220,696.19
50 cm in 2050	-$2,536,386.64	$2,140,380.75	$19,927,749.67	$30,997,360.66	$73,042,023.54
50 cm in 2100	-$155,862.04	$199,740.66	$11,239,122.70	$27,531,769.07	$167,686,494.11
140 cm in 2100	-$5,047,266.49	-$4,351,397.47	$17,251,261.69	$49,133,887.49	$323,398,764.36

Low Benefit High Cost

Net Present Value with Discounting

	20%	7%	3%	2%	0%
20 cm in 2050	$29,919.89	$3,293,488.53	$15,705,972.31	$23,430,631.74	$52,770,479.50
50 cm in 2050	$40,305.81	$4,436,738.80	$21,157,898.73	$31,563,976.03	$71,088,401.23
50 cm in 2100	$9.83	$334,297.03	$10,711,957.34	$26,027,991.27	$157,781,573.46
140 cm in 2100	$19.24	$654,176.54	$20,961,930.90	$50,933,451.00	$308,758,365.49

High Benefit Low Cost

Net Present Value with Discounting

	20%	7%	3%	2%	0%
20 cm in 2050	$444,966.72	$48,980,558.73	$233,578,253.63	$348,458,913.18	$784,799,323.47
50 cm in 2050	$599,425.53	$65,982,906.44	$314,658,967.85	$469,417,508.92	$1,057,222,328.06
50 cm in 2100	$146.19	$4,971,644.80	$159,307,570.34	$387,086,684.29	$2,346,517,850.09
140 cm in 2100	$286.08	$9,728,873.21	$311,744,546.28	$757,479,148.70	$4,591,835,409.55

High Benefit High Cost

Net Present Value with Discounting

	20%	7%	3%	2%	0%
20 cm in 2050	$443,058.91	$48,770,552.54	$232,576,777.13	$346,964,881.06	$781,434,463.64
50 cm in 2050	$596,855.47	$65,700,001.97	$313,309,854.40	$467,404,861.77	$1,052,689,443.24
50 cm in 2100	$145.57	$4,950,328.67	$158,624,532.49	$385,427,033.99	$2,336,457,056.94
140 cm in 2100	$284.86	$9,687,160.26	$310,407,928.53	$754,231,425.26	$4,572,147,723.71

From the analysis for the NPV of the "pre-emptive" restoration of San Elijo Lagoon in preparation for mean sea level rise a number of interesting insights arise concerning restoration for future benefits. For a low benefit and low cost project, the benefits will never be realized from "pre-emptive" restoration at a 20% discount rate, or when the current value of the benefit is considered more important than the future value. The EPA suggests the use of examining both a 7% and 3 % discount rate, it is interesting that all but the 140 cm by 2100 sea level rise scenario at 7% show positive values for the net present value. A rather significant but not surprising finding is the fact that the low benefit and high cost scenario yields the lowest NPV benefits while the high benefit and low cost yield the highest value.

Of additional interest is the fact that the NPV for the 50 cm by 2050 and the 50 cm by 2100 scenarios suggest that it may be more beneficial to plan for 50 cm by 2050 at high discount rates but for 50 cm by 2100 for low discount rates. This fits with the theory of discount rates in that the value of the 50 cm by 2100 benefits at low discount rates are valued equally over all time periods, spreading that benefit over a large time period, 91 years. On the other hand, when 50 cm by 2050 is analyzed at the same discount rates, those same benefits are not spread out for as long of a time period, 41 years. By looking at the difference in time periods for the same mean sea level rise scenario it appears that there is a definite benefit received over time from planning for an undesirable event with a long time period versus one with a short time period.

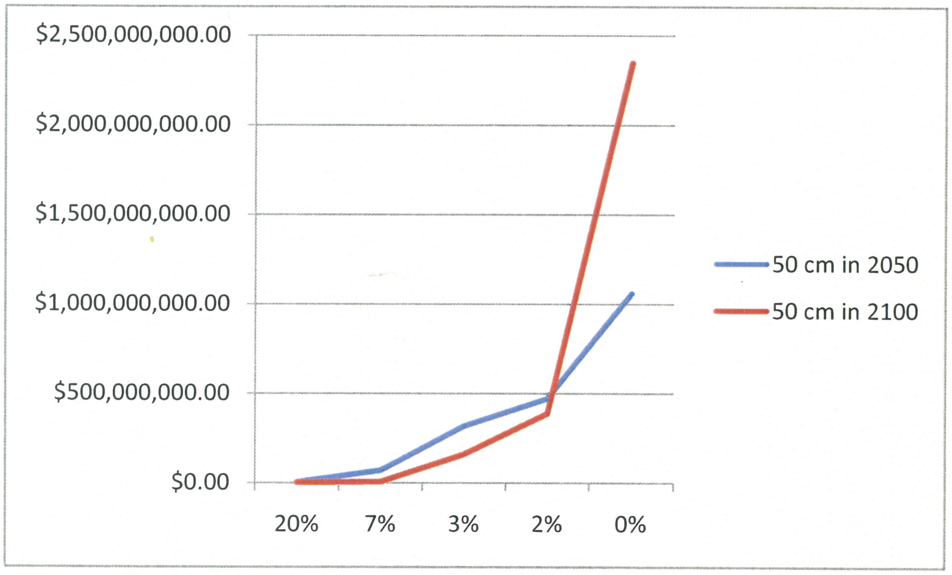

Figure 9. Comparison of 50 cm in 2050 and 50 cm in 2100 sea level rise scenario Net Present Value for "pre-emptive" restoration within San Elijo Lagoon at studied discount rates for the high benefit and low cost valuation scenario.

After examining the discounted NPV for the benefit from "pre-emptive restoration within San Elijo Lagoon the discounted benefit to cost ratio was determined for each sea level rise scenario at the studied discount rates and all four benefit and cost scenarios. The desired benefit to cost ratio was again BCR > 1 would suggest a project that should be accepted. The discounted benefit to cost ratio formula used was:

$$\textit{Benefit to Cost Ratio} = \frac{\sum_{t=o}^{T} \frac{V_t}{(1+\delta)^t}}{\sum_{t=0}^{T} \frac{C_t}{(1+\delta)^t}}$$

Table 11. Benefit to Cost Ratio of Area Potentially Effected by Sea Level Rise

Low Benefit and Low Cost

Benefit Cost Ratio with Discounting

	20%	7%	3%	2%	0%
20 cm in 2050	-698.99	6.37	11.48	11.92	12.43
50 cm in 2050	-698.99	6.37	11.48	11.92	12.43
50cm in 2100	-2918610.49	-72.99	10.15	11.73	12.65
140 cm in 2100	12.83	12.83	12.83	12.83	12.83

Low Benefit and High Cost

Benefit Cost Ratio with Discounting

	20%	7%	3%	2%	0%
20 cm in 2050	-408.94	3.72	6.71	6.98	7.27
50 cm in 2050	-408.94	3.72	6.71	6.98	7.27
50cm in 2100	-1707502.81	-42.70	5.94	6.86	7.40
140 cm in 2100	7.51	7.51	7.51	7.51	7.51

High Benefit and Low Cost

Benefit Cost Ratio with Discounting

	20%	7%	3%	2%	0%
20 cm in 2050	-545.40	159.96	165.07	165.52	166.03
50 cm in 2050	-545.40	159.96	165.07	165.52	166.03
50cm in 2100	-2918456.90	80.61	163.75	165.33	166.25
140 cm in 2100	166.43	166.43	166.43	166.43	166.43

High Benefit and High Cost
Benefit Cost Ratio with Discounting

	20%	7%	3%	2%	0%
20 cm in 2050	-319.08	93.58	96.57	96.84	97.13
50 cm in 2050	-319.08	93.58	96.57	96.84	97.13
50cm in 2100	-1707412.95	47.16	95.80	96.72	97.26
140 cm in 2100	97.37	97.37	97.37	97.37	97.37

The benefit to cost ratio suggests that all "pre-emptive" restoration projects for the 140 cm in 2100 sea level rise scenario should be feasible. When this information is combined with the discounted NPV information that conclusion is not necessarily true. What does hold true is that the BCR for a project that has a relatively large area of considered benefits for a long time period appears to stay constant as the ratio does not change due to the long time period.

XI. Discussion

This study has provided an interesting window into some of the economics relevant to considering the concept of "pre-emptive" restoration with respect to potential mean sea level rise. While the benefits used for this project do not necessarily represent accurate values for the services provided by the current San Elijo Lagoon, they do offer a framework for discussion concerning large scale "pre-emptive" restoration within the lagoon. For a more accurate discussion of the value of the benefits provided by the San Elijo Lagoon a site specific contingent valuation would be required. I suggest that it would be of great value to the San Elijo Lagoon Conservancy to perform a site specific valuation study of the lagoon for continued management into the future. On a similar note, this would be a useful exercise for all of the wetlands within San Diego County since accurate valuation studies are highly site specific.

With respect to costs, further study is recommended into the cost of "pre-emptive" restoration possibilities. This project explored the costs related to a large construction-style project due to the fact that a similar project is currently planned for the lagoon, but does not necessarily take into consideration sea level rise. The initial cost used in this study may be an underestimate as the true cost or extent of the restoration project in San Elijo Lagoon is not currently known. By using contingent valuation techniques to arrive at an initial cost of restoration, a viable discussion was made possible concerning the economic mechanisms involved with cost. Large construction-style restoration projects can have unwanted consequences that stem from the high levels of disturbance involved with the project, including movement of vegetation, compaction of soils, poorly designed hydrology, and inundation of invasive species (Zedler 2000). Additional work will need to be done to explore the site-specific economic and environmental costs involved with this type of project. Due to decreased historical accretion rates from the damming of Escondido Creek and the high impact of large scale restoration, it may be more beneficial for the San Elijo Lagoon Conservancy to consider artificially increasing the accretion rate to stay in pace with the increased rate of sea level rise.

Interesting results have been shown from this paper concerning discounting over time and valuing the benefits of a project. For many current restoration projects, the actual projected time period for the longevity of the project is closer to 10-20 years (Gibson 2008). For sea level rise projections, the scenarios suggest planning for much longer time periods; in this case 41-91 years. By planning for a longer time period, with monitoring and maintenance costs included, the benefits over time are far greater and suggest more economically feasible options than a shorter time period.

XII. References

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