UCLA
Institute of the Environment and Sustainability

Evaluating Physical Suitability, Land Use, and Cost Feasibility for Acquiring Land for Wetland Transgression in Selected Southern California Wetlands

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SOUTHERN CALIFORNIA WETLANDS RECOVERY PROJECT

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Executive Summary

In California, most wetlands were drained and used for farming and grazing. Wetlands that were not drained are becoming degraded due to human development, pollution, and changes in water flow. Additionally, coastal wetlands are threatened by sea level rise. With the pressure of rising sea levels, wetlands would naturally transgress inland to avoid inundation. The transgression process is often hindered by urban coastal development, as they leave little or no area for the wetlands to move inland. Using the Ballona Wetlands, Malibu Lagoon, and Ormond Beaches as case studies, this project explored multiple variables around these sites to determine feasible transgression areas. In this project, we demonstrated a method for prioritizing land acquisition to make space for wetland transgression. We find that the important variables for consideration include physical land suitability and land use. These physical land suitability variables include flood risk, elevation, history of the land, and connectivity. We then analyzed the acquisition feasibility through the land use type and cost of the land. Considering all of the variables, we made three land acquisition recommendations for Malibu Lagoon, four recommendations for Ormond Beaches, and two recommendations for Ballona Wetlands. Our project also considered some possible policy solutions for agencies to acquire the recommended parcels of land. We concluded that conservation easements may be the best solution for land acquisition. Based on these suggestions, we hope that our project can serve as a resource and provide data to conservation agencies for obtaining these lands for future wetland restoration purposes.

Table 1: Summary of Land Parcel Recommendations for Each Case Study

Study Site	Parcel Recommendations	Amount of land (Acres)	Cost (US Dollars)	Land Use Scale level	Page # in document	Wetland Habitat Use
Malibu Lagoon (see Figure 13)	Perenchio Golf Course	9.88	$3.6 Million	3	30	WMZ and/or UTZ
	West Parcels (low density commercial)	11	$890,000	5	31	UTZ
	East of Hendler Open Space	1.7	$448,000	varies	31	UTZ
Ormond (see Figure 21)	Undeveloped Parcels North of Nature Conservancy	42	$1.5 million	2	46	UTZ

	Land					
	Agricultural Parcels	218	$10,275,000	3	47	UTZ and WMZ
Ballona (see Figure 27)	Partial Acquisition of SoCal Gas Land	7	n/a	5	57	WMZ
	Possible Acquisition of Commercial Area	varies	n/a	5	57	WMZ

Introduction

Wetlands are an important ecosystem that are severely threatened by many human activities. Between the 1780s and the 1980s, California lost 91 percent of its original wetlands (Dahl, 1990). Additionally, California's coastal wetlands are now threatened by sea level rise. The 2012 National Research Council report on sea level rise predicts a 0.6m sea level rise by the middle of the 21st century (NRC, 2012). Wetlands must transgress inland in order to avoid permanent inundation by rising waters (Morris et al. 2002, FitzGerald et al. 2008). This is a problem in places like Southern California where coastal areas are highly developed and highly populated. With pressure from urban coastal development as well as agriculture, wetlands may have little or no area to move inland. When transgression is hindered, wetlands will slowly transition into open water causing the diverse species of plants and animals to disappear along with it (Torio and Chmura, 2013).

A 2009 California Energy Commission report assessed the impact of sea level rise and the ability of wetlands to respond to this threat. This report studied California coastal wetlands by county and measured the ability of wetlands to migrate inland. They looked at land adjacent to the current wetlands and evaluated it for its ability to become future wetland habitat. They categorized this land as either "viable for wetland migration" (55 percent), "viable for wetland migration but will cause property loss" (15 percent), or "not viable for wetland migration" (30 percent). For Los Angeles County specifically there are 0.28 square miles of potential migration, 60 percent of potential wetland migration area is not viable wetland habitat. This result may be misleading because only 23 percent of the Los Angeles County coastline was mapped (Herberger et al, 2009). Thus, we need more local research to understand how sea level rise will impact wetlands and this habitat will adapt.

The higher elevation land surrounding the wetland itself is called upland habitat. Typically, upland habitat is higher than the flowing water, or the wetland areas that get periodically saturated with water. While the upland areas have different conditions than the wetland itself, they serve as important buffer zones that create connectivity, animal migration, and protect wetland species from human development.

The goals of this project were to create a method for prioritizing the acquisition of land in order to expand wetland and upland habitat as it transgresses inland. As the water rises, there is a potential for wetland areas to expand inland when there is a low elevation gradient. In other areas where the elevation gradient is steeper, sea level rise will not lead to much wetland habitat expansion. We completed three case studies of Malibu Lagoon, Ballona Wetlands, and Ormond Beach in order to demonstrate how coastal managers could accommodate the migration of wetlands and their associated wildlife in response to sea level rise (See study areas in *Figure 1*). While exploring these areas of interest, our research questions were as follows:

- Which lands should be acquired to make space for wetland transgression and its associated upland habitat?

    - What are the immediate physical barriers and how might other characteristics affect wetland expansion?
- How can you use existing policies to obtain the recommended parcels of land?

Overall the objectives of this research were to understand how sea level rise will affect local wetlands and evaluate upland properties in order to prioritize acquisition. We developed a method to determine which land areas would provide the best opportunities for wetland transgression. Using our methods, we put together a comprehensive analysis of land surrounding Malibu Lagoon and Ormond Beach, and Ballona Wetland to make land acquisition recommendations.

Figure 1: Map of Selected Case Study Sites

Methods

Our methodology involved evaluating land properties within the current and projected upland area of each wetland. We first evaluated these properties according to physical barriers of the land such as elevation and flood risk. Then we assessed each parcel of land for secondary characteristics that would affect land acquisition such as land use and cost per acre. Next we combined all these variables to evaluate which parcels of land should be recommended to acquire in order to facilitate wetland expansion. Finally we looked at what policy tools are in place that would help obtain these preferred pieces of land.

For our project, we referred to the area between current and predicted wetland extent as the Wetland Migration Zone (WMZ). The WMZ is the area that would become future wetland space with inundation from sea level rise, assuming no human infrastructure interferes. The extent of wetland migration was informed by the 0.6 m prediction of sea level rise from the 2012 National Research Council report (NRC, 2012). Our client SWRP recommended this level because it is the 2050 upper limit of projected sea level rise for southern California. Using sea level rise data from the National Oceanic and Atmospheric Association (NOAA), supplied to us by the San Francisco Estuary Institute (SFEI), we mapped predicted wetland extent in response to 0.6 m sea level rise for our study sites (for example: Malibu Lagoon Figure 2).

Surrounding the WMZ, a 250m buffer zone was created called the Future Shoreline Upland Transition Zone (UTZ). SFEI conducted a literature review and determine that a 250m UTZ around the wetland is suitable to ensure upland habitat for wildlife. The WMZ and UTZ for one of our study sites are shown in Figure 2.

Figure 2: Map depicting key terms, using Malibu Lagoon as an example.

Physical Land Suitability

Before acquiring land for wetland transgression and the restoration of upland habitat, it is important to consider the physical suitability of the land. This ensures that the land acquired will be able to support wetlands and associated species before resources are spent evaluating ease of land acquisition and cost.

Elevation is one of the most significant factors affecting wetland transgression. Future wetland extent, from NOAA's sea level rise data, uses elevation in determining the future mean higher high water line. Therefore, the WMZ on our maps reflects how current elevation will influence wetland extent. We further analyzed 2009-2011 California Coastal Conservancy Light Detecting and Ranging (LiDAR) elevation data to determine where large changes in elevation would inhibit wetland transgression, specifically the WMZ and UTZ. In consultation with Dr. Richard Ambrose, we estimated that areas of elevation greater than about 5 m would not be suitable for wetland migration without modification of the slope. Published literature does not provide an agreed upon maximum elevation change that would prevent transgression from occurring, thus 5m is an estimate. This elevation limit provided a rough idea of areas with suitable elevation for the WMZ. We also considered how elevation changes would affect the UTZ. We assumed there is more flexibility in suitable elevation for the UTZ in comparison to the WMZ. However, most animals would not be able to climb steep slopes to access nearby habitat. Thus, we considered areas of elevation changes greater than approximately 20 m to be unsuitable for acquisition within the UTZ. Again, this number is an estimate but it gave us an idea of which land most animals would be able to navigate in the UTZ.

We analyzed the USGS's Coastal Storm Modeling System to examine how climate change will affect the hydrology of the area beyond sea level rise alone. We specifically analyzed the 100-year storm flood hazard data from CoSMoS v1. CoSMoS does not consider a 0.6 m sea level rise scenario, so we looked at the 0.5 m and 1 m sea level rise in comparison to the current flood risk. By examining how flood risks are expected to change, we determined which areas will be at an increased risk for flooding. The owners of these areas may become more likely to sell as their risk of flooding and storm damage increases and thus may represent locations where land acquisition for habitat makes sense.

We also researched the history of the land. First, we looked at T-sheets. T-sheets are maps of the southern California coastline drafted between 1851 and 1889 for the purpose of navigation as part of the United States Coast Survey. They have been digitize and are available to view on caltsheets.org. These T-sheets informed us where wetlands existed historically. A wetland's historical extent gives us an idea of where wetland may occur in the present day if human development barriers were removed. Next, we researched how humans have modified the land in and around the wetland. In general, we sought to determine if there has been any land filling, soil or water pollution, or other noteworthy anthropogenic modifications of the landscape in and around the wetlands that may decrease the suitability of the land for transgression or upland habitat restoration. We did this through simple internet research. In particular, websites dedicated to the health and restoration of each wetland, such as friendsofballona.org, were used as a baseline of information to construct a timeline of major development. We also read the restoration plan for each wetland, if one existed, to include any noteworthy recently completed or planned changes to add to our timelines.

Finally, we considered the connectivity of our recommended parcels to current and projected wetland and upland habitat. Connectivity refers to the ability of species to move through the wetland and between the wetland and upland habitats. Not all parcels within our study area border the currently protected wetland or upland. This means more parcels may need to be purchased to ensure newly acquired lands are connected to currently protected lands for the new land to be accessible to wetland species. This was done via visual inspection of land using satellite imagery and the requirement that at least one side of the parcel be adjacent to the wetland.

Ground Truthing Protocol

There are limitations that remain even with today's advanced imagery and available data sources. In order to gather detailed qualitative observations that might not be observable from satellite imagery we ground truthed the physical land suitability and confirmed some of the variables mentioned above: elevation, flood risk, and history of the land data. This data helped inform the final recommendations. All of our study sites were ground truthed, however the study areas were limited based on permits, any restricted habitats, or special conditions. The ground truthing protocol was derived from the original ground truthing protocol provided by the San Francisco Estuary Institute (SFEI). A Garmin eTrex 10 Hiking GPS Navigator was used to record coordinates. All mapping was done using ArcGIS.

Before collecting data in the field, a satellite map was created on ArcGIS with noticeable map elements that appear as barriers. This exercise was performed before collecting field data to figure out which variables were not easily observable through satellite imagery. We recorded distance from the wetland migration zone to the closest development, property lines, large barriers, large vegetation, and useful upland area for habitat restoration. We also recorded coordinates of barriers and significant changes in vegetation or soil. The data was mapped and we also attached a qualitative summary of the field observations.

Land Acquisition Feasibility

After considering physical suitability, we created a methodology to determine which parcels should be prioritized for acquisition. Ease of acquisition was determined by current land use (ownership and infrastructure) and parcel value (dollar/acre). We created an individual scale ranging from 1-5 for land parcels for both land use and cost. A score of 1 represented the most feasible options and a score of 5 represented the most difficult to acquire. The score for land use and cost were combined for each parcel creating a new scale of 2-10. This allows one to easily see a parcel's overall suitability using only one metric. Land that is in the process of being acquired, including land that is willed to the state, is not considered to be currently protected. This is so that we can compare our conclusions to the existing plans of wetland managers to informally test the accuracy of our methods.

1. Land Use

We evaluated the land value and property type of land parcels within the counties of Los Angeles and Ventura. To determine the level of feasibility for land acquisition, we considered parcel ownership, land use, and policies that facilitate land purchasing or conversion. Each parcel was given a number (1-5) that considered these factors in addition to anticipated public opinion (See Land use Acquisition Scale Table in Appendix A).

Level 1 is given to land parcels that are a wetland, government protected habitats, state beach, and wildlife refuge. Most land parcels in this category are government owned land. These lands are already protected for wetland and upland habitat.

Level 2 is given to open land without anything built on it that is not designated as a protected land as described by level 1. The term "open" is defined as not currently in use.

Level 3 is given to land parcels that are government or privately owned. However, the land has some or no development. If there is development, then use of land would be defined as agricultural or recreational. This includes tennis courts and city owned parks.

Level 4 is given to land parcels that are privately owned residential land. This is land that is usually occupied by single family residential homes.

Level 5 is given to land parcels that are major highways, protected structures, government or privately owned commercial land, and government buildings or schools. Protected structures include historical landmarks. The level of feasibility for level 5 would be considered unattainable due to high value by the public.

2. Cost

Cost is another variable we evaluated as a parameter for land acquisition feasibility for wetland transgression and upland habitat restoration (Table 2). There is no universally agreed upon threshold for cost. Ultimately, it is up to the purchasing entity, such as the Coastal Conservancy or the Department of Parks and Recreation to make the final judgement depending on their expertise or how valuable a piece of land is to a wetland restoration project.

We discussed land acquisition budgets with a finance specialist from the State Coastal Conservancy to gather additional information of the cost per acre. He estimated that wetland acquisition can range from $40,000 to $60,000 per acre. This average is reflective of a wide variety of land acquisition projects, however many of our wetlands are in developed areas and thus we also reviewed land acquisition projects for wetland restoration in southern California.

We analyzed data from previous land acquisition budgets in highly developed areas or areas similar in nature to our study sites to synthesize a baseline for a reasonable budget. We utilized the land acquisition costs from five examples: Ballona Wetland, two for Ormond Beach, and two for Los Cerritos Wetland (Table 1). Our purpose for selecting these sites is due to their variable land type. For example, land acquired at Ballona Wetland was residential, land acquired at Ormond Beach was owned by Southern California Edison and the Metropolitan Water District, and land acquired at Los Cerritos was mixed wetlands and lowlands. Land parcels values for each city were obtained from the Los Angeles County Assessor Portal and the Ventura County Assessor's Office. We calculated land parcels values to be dollars per acre since this is the unit commonly used for wetland acquisition. The average of the 5 cases was $240,000 per acre and we used this as the median (level 3) in our feasibility scale (Table 2).

For our project, we maintained our level 5 cost amount at $480,000, but we are not using it as a maximum cap but more as an indicator for decreasing feasibility. For example, $729,000 per acre was spent for land acquisition for Ballona Wetlands. Although this may be an outlier, it also represents the budget flexibility and varying objectives of restoration projects. We constructed a feasibility scale to evaluate transgression opportunities and our level 5 for the cost variable does not eliminate a property or parcel from consideration. It informs us that this property or parcel is not the preferred choice if more opportunities exist.

Table 2: Southern California Land Acquisition Case Studies

Wetland	**Acres Obtained**	**Amount Spent**	**Cost per Acre**	**Land owner (If Available)**	**Land Type (If Available)**
Ormond Beach	265	$9,700,000	$36,603	Southern California Edison	Private
Ormond Beach	276	$12,900,000	$46,739	Metropolitan Water District	Government
Los Cerritos	100	$17,350,075	$173,500	Tellman Property	Private
Los Cerritos	66	$14,244,000	$216,000	Bryant Property	Private
Ballona Wetlands	190	$14,000,000	$729,000	Playa Vista	Residential Acreage

Table 3: Land Acquisition Cost Scale for Wetland Transgression

Land Acquisition Cost Level	**1 (Highly Probable)**	**2**	**3**	**4**	**5 (Highly Improbable)**
Cost per Acre	$0	$120,000	$240,000	$360,000	$480,000

3. Combining Land Use and Cost

Examination of land use or cost alone would not give coastal managers enough information to prioritize which land parcels to acquire. As the previous section illustrates, cost is an inherent consideration during land acquisition as no organization has an unlimited budget. However, one must also consider how the public would respond to the acquisition of land. For these reasons, we have summed the land type and cost levels for each parcel. The scale ranges in value from 2 (parcels that received 1s in both cost and land type), the easiest to obtain, to 10 (parcels that received 5s in both categories), the most difficult to obtain.

We chose to weigh cost and land type equally for two reasons. Firstly, we would like our methodology to be useful to a wide variety of nonprofits, such as conservation land trusts, and government organizations, such as National and State Parks. Because the budgets, goals, and values of these groups vary greatly, we did not feel we could assume whether cost or land type would be of greater importance to our stakeholders. Secondly, we expected parcels to have similar scores for cost and land type because developed land is generally more costly than undeveloped land.

Case Study: Malibu Lagoon, Los Angeles County

Malibu Lagoon State Beach which is located in Southern California within Los Angeles County (Figure 3). The State Beach currently covers 42 acres of natural area including popular beaches where Malibu creek converges with the Pacific Ocean. To the southwest of the lagoon is a strip of private homes called Malibu Colony, and to the southeast of the lagoon is the historical Adamson House and Malibu Pier. Inland of the lagoon are mostly developed commercial and agricultural zones. Malibu Lagoon State Beach is currently owned by the California Department of Parks and Recreation.

Figure 3: This map depicts the Malibu Lagoon Study Site

Results

Physical Land Suitability

LiDAR data reveals an elevation change at the border of the Perenchio Golf Course and Malibu Lagoon State Park that may inhibit wetland transgression (Figure 7). The elevation rises from sea level to 3-4 m from the edge of the Lagoon to the property boundary between the state park land and the golf course (Figure 7). There is a dramatic elevation change, shown in red in Figure 4, on the eastern portion of our study area where the elevation quickly changes from a few meters to upwards of 50 m. There is also an elevation change at the Adamson house where the land rises from sea level to 6 m over approximately 2 m of distance which would inhibit transgression (Figure 4).

Analysis of CoSMoS 100-year flood hazard predictions reveals that much of Malibu Lagoon is already at risk of flooding in a 100-year storm (Figure 5). North of the PCH, there will be little change in flood risk, likely due to steep elevation change surrounding Malibu Creek. South of the PCH, the Adamson House area will also see little change in flood risk. South of PCH to the west, the area at risk of flooding will further expand into Perenchio Golf Course and Malibu Colony.

After examining the history of Malibu we have concluded that there are no major threats to ecosystem development in the form of major pollution or known toxicity in the land. A summary of the changes to Malibu Lagoon is given in Table 3.

Connectivity has a significant impact on our land acquisition recommendations. To the west, there are some suitable land parcels that would be difficult to connect to existing protected land due to the presence of a commercial center. On the east side of our study area, there are some other suitable land parcels that are surrounded by expensive parcels. Additional care must be taken to ensure parcels that are suitable based on use and cost are physically able to connect to the wetland.

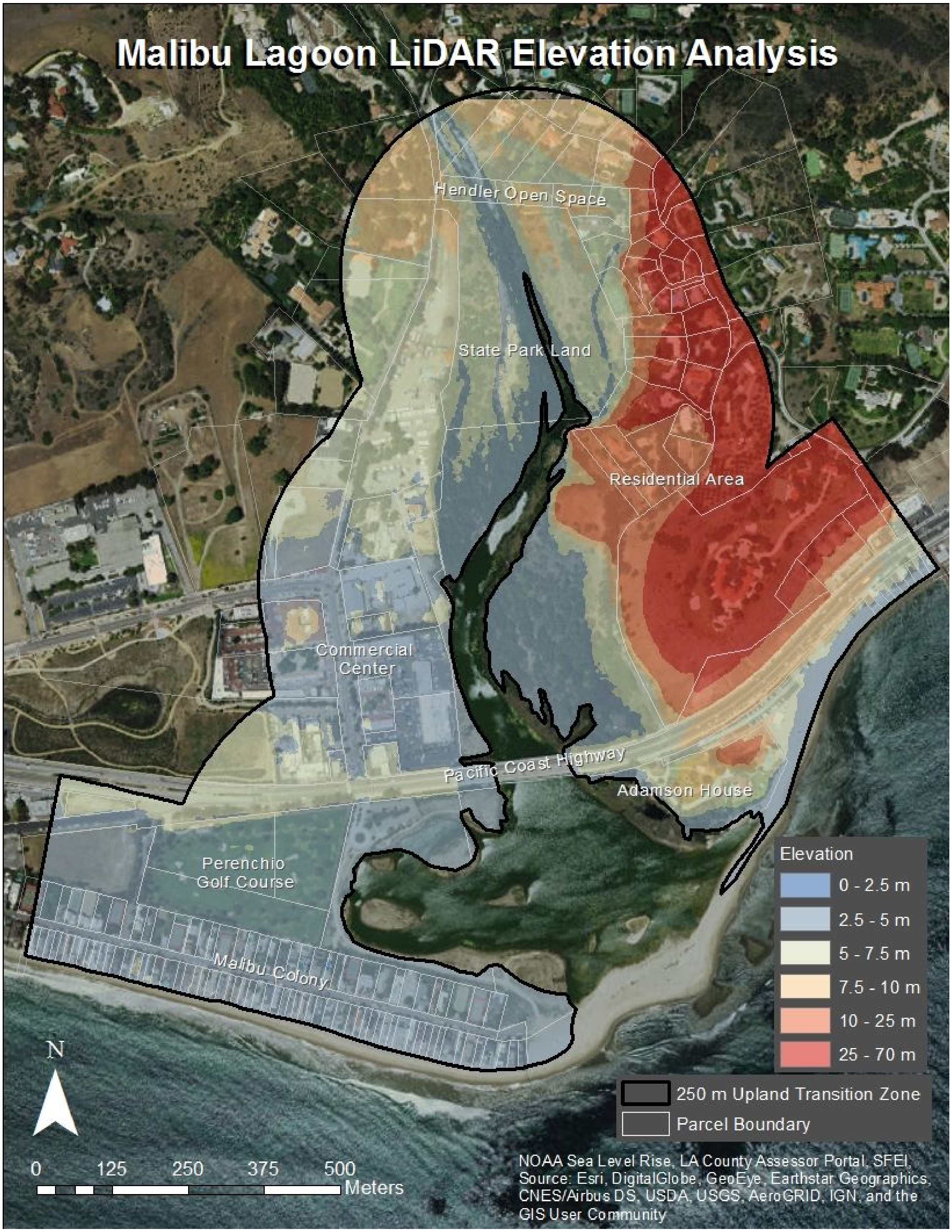

Figure 4: Map of elevation surrounding Malibu Lagoon derived from LiDAR data.

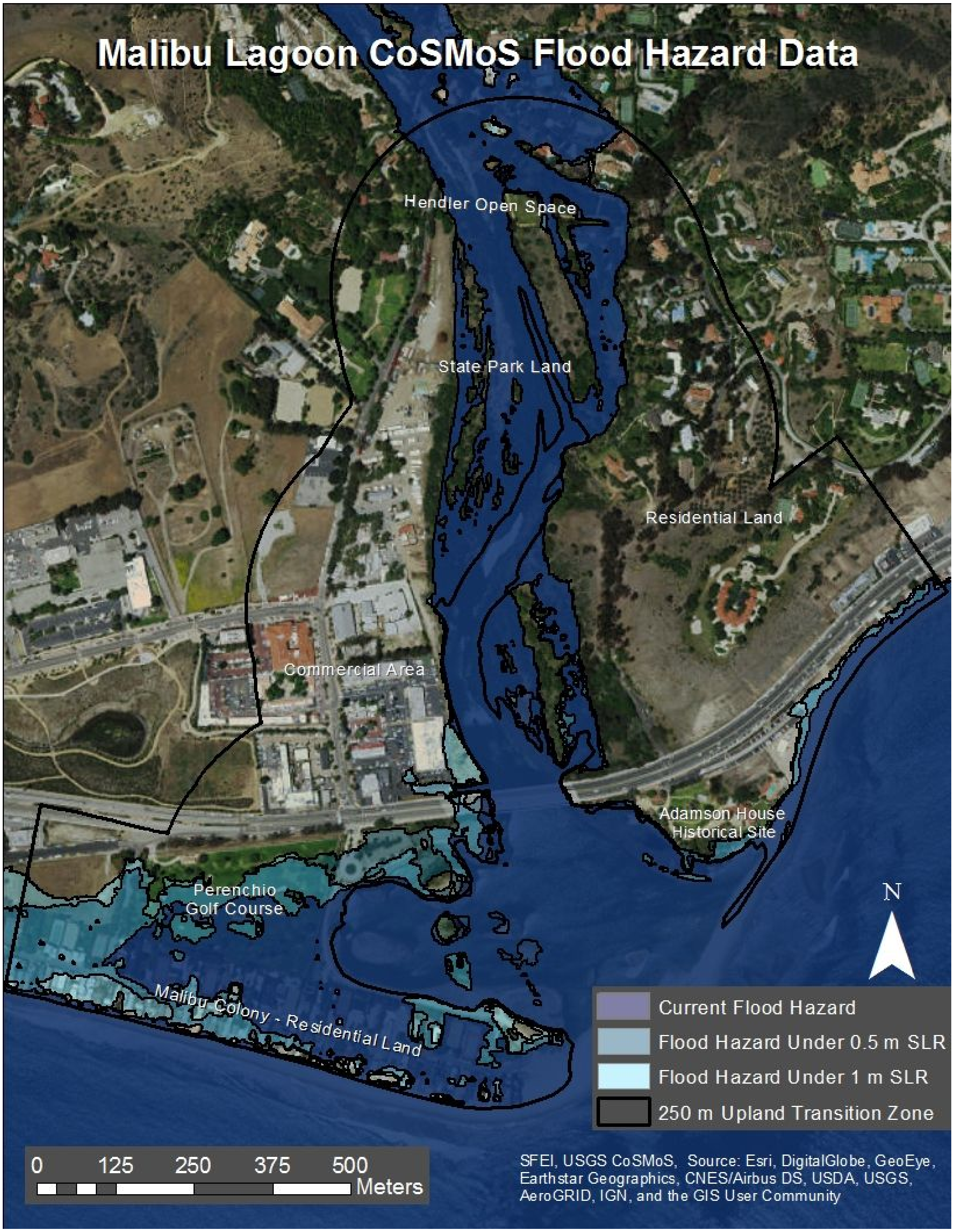

Figure 5: Map of CoSMoS 100-year storm flood risk data under current sea level and predicted sea level changes.

Table 4: Land History of Malibu Lagoon, 1850-2005.

Time Period	***Previous Use***
1850's	Land directly adjacent to the lagoon was used seasonally as an agricultural floodplain.
1926	Malibu Lagoon was first opened to development in 1926, around the time the Pacific Coast Highway was built.
1930's- 1940's	People built homes and development surrounding the lagoon
1950's	The lagoon itself was filled with construction scraps when the location of the PCH was moved in the early 1950s
1980's	In the 1980s, environmental efforts pushed for a restoration of the lagoon, but controversy stifled further restoration.
1996	In 1996, the Department of Parks and Recreation funded a project to improve areas affected by the Malibu Lagoon bridge construction. This project helped revegetate areas and remove non-native species. However, the ecological state of Malibu lagoon was still very degraded.
2002	A study was funded in 2002 to analyze and recommend improvements for the lagoon
2005	In 2005, a new restoration plan was crafted and has since been executed. This plan required post-restoration monitoring of the lagoon.

Ground Truthing: Qualitative Observations

Our Malibu Lagoon access permit included the entire wetland; however, we were restricted to the fenced pathway that surrounds the west side of the lagoon. Elevation, vegetation, and soil changes were the most noted variables followed by water quality, animal sightings, small boulders, noise pollution, broken trees, and recreational building (Figure 5).

The pathway along the lagoon was all elevated. Differences in elevation along the path ranged from 0.1 m to 0.2 m. The most distinct areas of elevation change in the wetland were the four small islands. Due to restricted access, the elevation of these small islands were not obtained. Vegetation varied along the lagoon. Along the outer perimeter of the path and nearest Pacific Coast Highway, there were taller trees and shrubs. However, west to the largest area of the migratory bird stop, vegetation was sparse. This may have been associated with the quality of the soil. The soil appeared to be affected by drought and was cracked and compacted. In some parts of this area and in others the soil was coated with a layer of bark chips, possibly to prevent erosion. Areas that were noted with dense vegetation were to the far west side of the lagoon. On the south-west side of the lagoon, vegetation becomes sparse and eventually seen on very elevated areas of land. Where the pathway meets the beach, dense vegetation resumes.

Water quality was noted in two areas of the study site. On the west side of the lagoon, there was a low, yet detectable, water flow with algae covered areas. This area also notably had muddy, wet soil. On the east side of the lagoon, water marks were noted. Dry, cracked soil and non-native flowers were present in this area. Many broken trees laid in different parts in the actual lagoon. Bird population density was most notable at two specific areas of the lagoon-- the northern and southwestern side. Noise pollution was detected near anthropogenically placed, small boulders and Pacific Coast Highway. Malibu Lagoon had about five areas for recreational activity and a sprinkler system.

Figure 6: Map of Malibu ground truthing results.

Figure 7: Ground truthing map of the west side of Malibu Lagoon and east side of Perenchio Golf Course.

Land Use

Of the 207 parcels, 70% were assigned a level 4 (Figure 8). A majority of level 4 assigned parcels' were single family residential (Figure 9). Most of the level 5 parcels were commercial or industrial. Level 3 parcels were mainly vacant residential but also included some commercial, industrial, and governmental. The level 2 parcels were mainly vacant and residential with a few listed as commercial. Level 1 (the land easiest to acquire) was only assigned to a few parcels, four of which were government owned. Two out of the seven parcels were vacant with one land use type being for commercial and the other for residential. Lastly, one out of the seven parcels had property use and type as commercial or industrial.

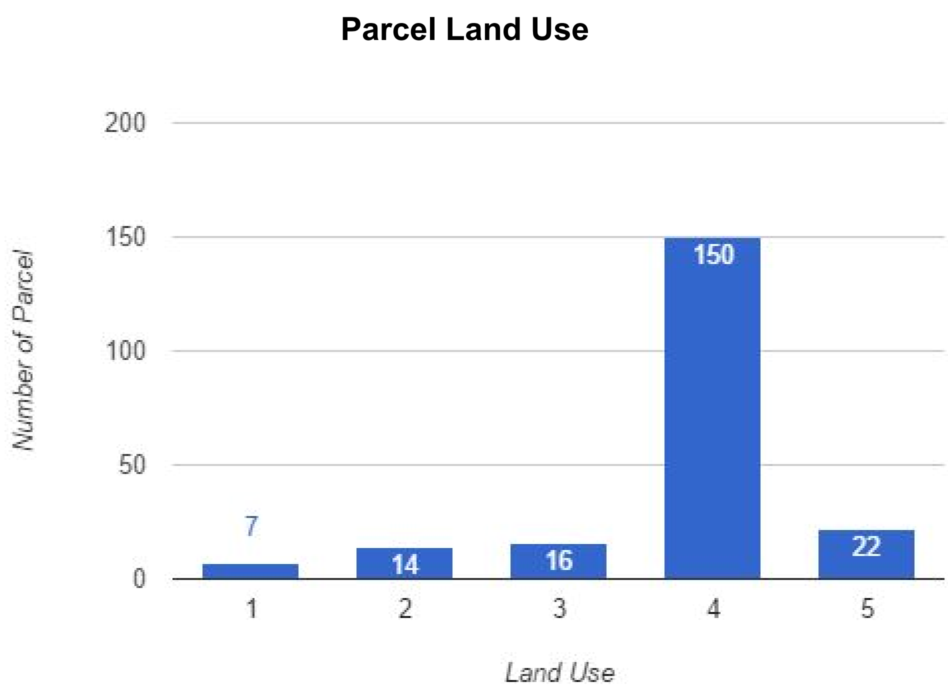

Figure 8: Bar graph for the number of land parcels belonging to each level of our land use acquisition scale.

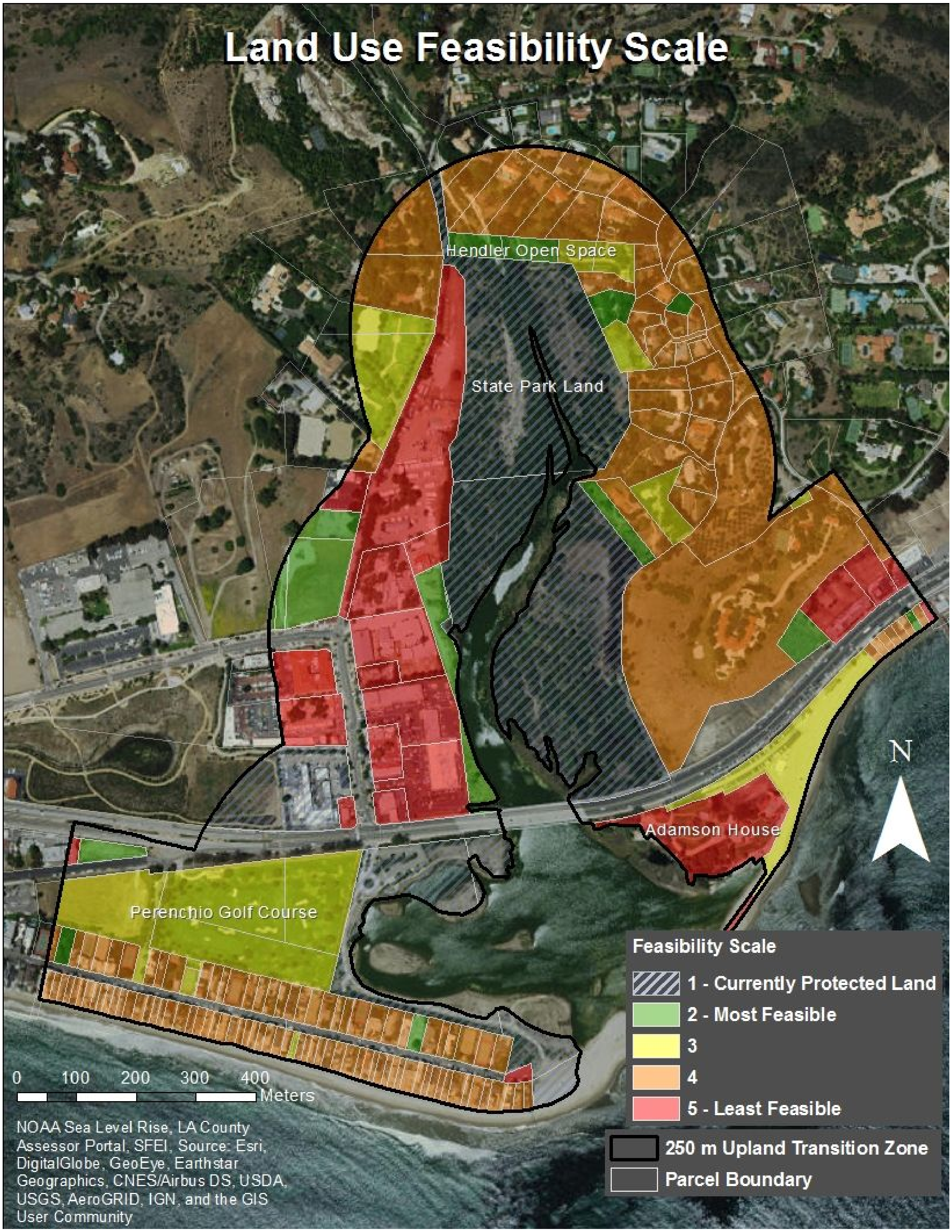

Figure 9: Map displaying our land use acquisition scale for each parcel surrounding Malibu Lagoon and within the UTZ 250m boundary.

Cost

The land acquisition cost scale was applied to the parcels within the upland transition zone (Figure 10). Approximately 70% of the parcels received a level 5 on the scale (Figure 10). In general, parcels receiving lower scores (colored green on the map) are spread out and are not concentrated in a single area (Figure 11). Other low cost parcels appear to currently be a part of the wetland or are under government jurisdiction (State Parks Land). As shown in Figure 11, there are two low cost parcels adjacent to the state parks land and one low cost parcel adjacent to Malibu Lagoon. If cost was the only consideration, south of the Pacific Coast Highway does not appear financially feasible and land acquisition should be focused northwards towards the Hendler Open Space.

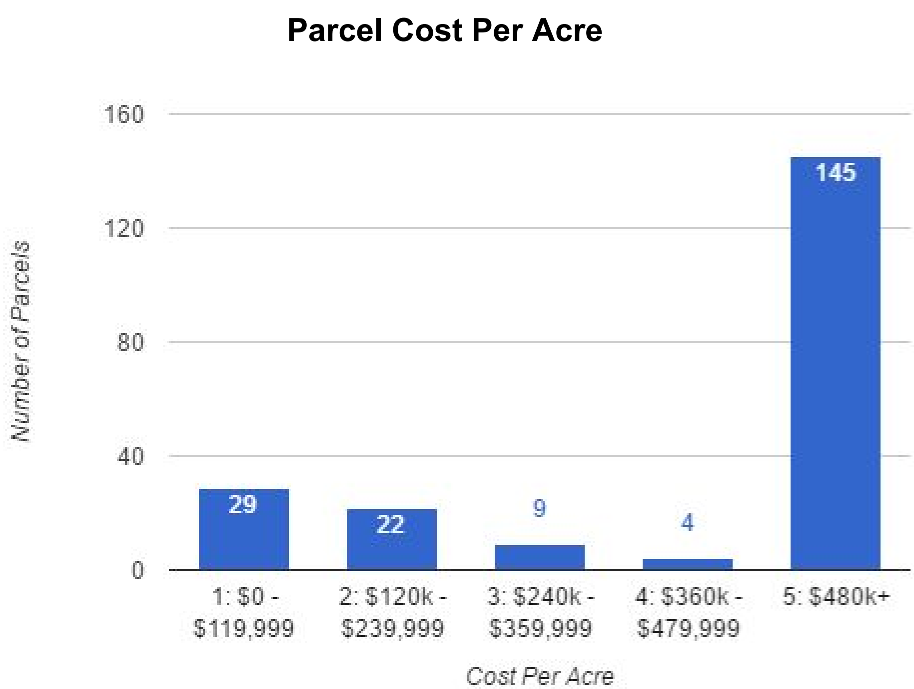

Figure 10: Bar graph for number of land parcels within each level of our cost scale.

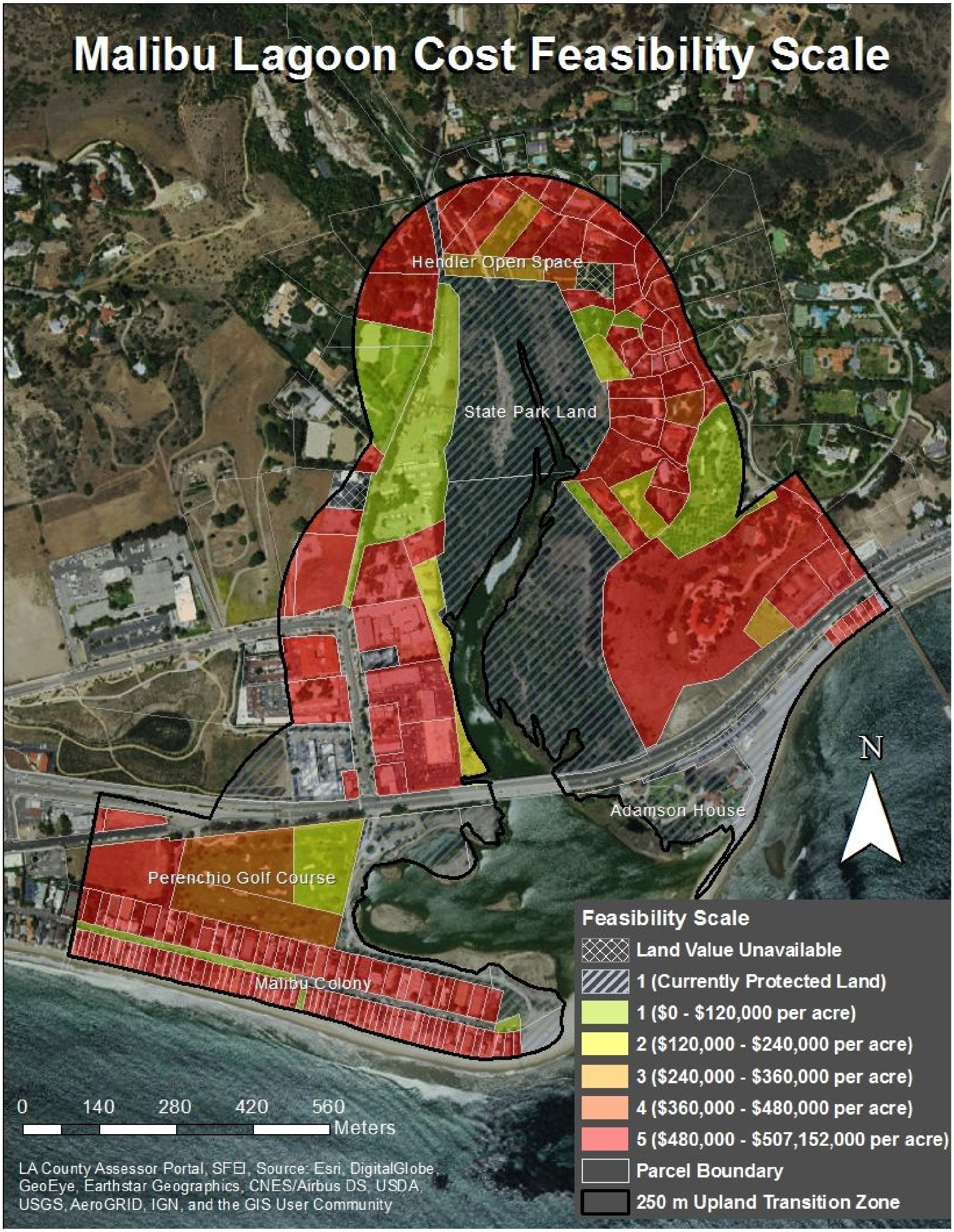

Figure 11: Map displaying land parcels and their respective cost scale levels for Malibu Lagoon and surrounding habitat.

Combining Land Use and Cost Variables

Generally, parcels received a similar ranking in cost and land type. For example, most low cost parcels were also low on the land use feasibility scale, they are government owned or open space. Using the combined scale, land that receives a 2 is considered already protected. These parcels are either already part of a protected wetland area, state park or beach, a wildlife refuge, or a similar type of protected habitat. Parcels that fall under this land type category have a cost of $0. Much of the land immediately surrounding Malibu Lagoon received a 2 because it is already part of Malibu State Beach (Figure 12).

On the other end of the scale, the area to the northwest of Malibu Lagoon is heavily commercial. These parcels are highly developed, giving them a 5 on the land use feasibility scale and they are expensive, resulting in a 5 on the cost scale. Similarly, we can see that Malibu Colony parcels had a score of 9 (Figure 12). These parcels were given 4s in land type because they were private, residential homes. Most parcels in Malibu Colony scored 5s for having a price per acre of over $480,000. The similarity between cost and land use supports our decision to weigh the cost per acre and parcel type equally. As a consequence of this similarity, parcel rankings tended towards the extremes; i.e., parcels tended to receive combined feasibility scores of 2-3 or 9-10. Nevertheless, there are still some parcels with combined feasibility scores towards the median that may be of interest to wetland managers.

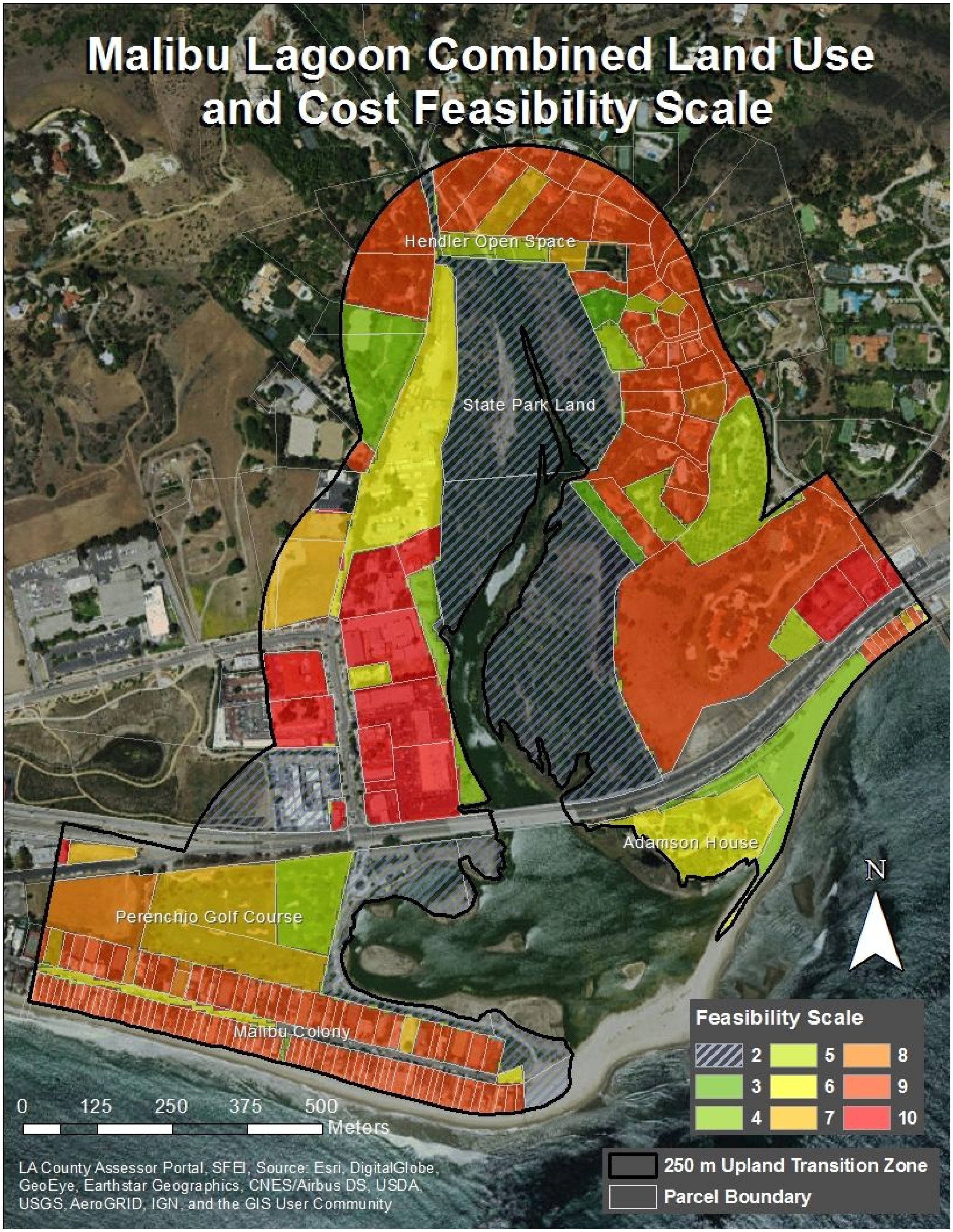

Figure 12: This map displays the sum of each parcel's land use feasibility score and cost feasibility score.

Discussion

Under a 0.6 m sea level rise, Malibu Lagoon and particularly the WMZ is not expected to transgress more than a few meters in any direction, however the UTZ habitat will decrease. By acquiring the Perenchio Golf Course and modifying its slope, the lagoon may be able to transgress further. Attention must also be paid to acquiring land for the upland transition zone. Under 0.6 m sea level rise, the mean higher high water line will be approaching Malibu Colony to the south, the Adamson House to the east, the Perenchio Golf Course to the west, and PCH to the north. This means there will be little undeveloped land adjacent to the lagoon to support the wildlife that lives around the wetland unless some developed land is acquired and restored to its natural state. Based on these results, we recommend 9 parcels be acquired for the protection of Malibu Lagoon (Figure 13). No parcels are currently within the UTZ, but the 3 parcels that make up the Perenchio Golf Course could be modified to allow wetland transgression. The golf course is just under 10 acres in size. Within the UTZ, we recommend two parcels to the west, covering 11 acres and three parcels to the west that make up 1.7 acres.

Land for the WMZ: The Perenchio Golf Course

Examination of the land immediately adjacent to Malibu Lagoon reveals only one area where wetland transgression is currently feasible: the Perenchio Golf Course. We know that managers of Malibu Lagoon already discussed acquiring the land and restoring it to a lagoon with the late owner, Jerry Perenchio. In his will, Perenchio willed the golf course to the state. The land west of the Perenchio Golf course is vacant, known as the Chili Cook-Off land, that has already been acquired by the City of Malibu for possible restoration. Acquisition of the golf course could therefore connect this vacant land to Malibu Lagoon, providing additional upland habitat.

Currently, the golf course is within the UTZ; however, T-sheets show that historically, the lagoon spread into this area. By decreasing the slope of the land in the west portion of the lagoon, wetland transgression could be feasible here. The site scored a 3 in parcel type because it is undeveloped, private land. Thus, while purchasing the land from a private individual may be difficult, the land is not heavily developed and can be more easily restored to natural habitat than parcels with buildings. The cost of the land is high at a price of $3.6 million for approximately 40,000 m^2 (9.88 acres), but given that this parcel is the most essential to the restoration of upland habitat and a possible site of expanded wetland transgression, we argue that the cost would be justified. Furthermore, the other areas adjacent to the wetland, Malibu Colony and the Adamson House, are not suitable for wetland transgression due to their high cost and importance to the public. Therefore, the golf course is the only suitable place to focus one's efforts on acquiring land for the wetland migration.

Barriers to Transgression into the Perenchio Golf Course

Decreasing the slope of land to the west of the lagoon and modifying the recreational land within Malibu Lagoon would be necessary for the transgression of Malibu Lagoon into the Perenchio Golf Course. There is currently an elevation change on the border of the golf course and state park land; it is here that wetland transgression is predicted to stop. The elevation rises from sea level to 3-4 m from the edge of the Lagoon to the property boundary between the state park land and the golf course.

The main anthropogenic barriers for wetland transgression into the golf course include a brick wall with tall vegetation just beyond it that marks the boundary between the Perenchio Golf Course and Malibu State Beach. The area between the lagoon and the brick wall contains raised elevation, more vegetation, a path, recreational areas, a sculpture, and an electric box. When modifying this area, one must consider how the public currently utilizes this area to avoid public backlash. There was no noted activity in the recreational areas when visited; however, there was a steady flow of foot traffic of families and surfers passing through the pathways around the lagoon to access the beach. If the lagoon transgressed into the Perenchio Golf Course, this path would be lost and people would have difficulty accessing the beach. A new means of access to the beach would therefore be necessary such as building a raised pathway through the wetland. This would most likely be in the form of a bridge. Otherwise, the public would be required to walk a sizable distance around the lagoon to the beach.

Land for the UTZ: Parcels North of Pacific Coast Highway

Because of the infeasibility of acquiring the Adamson House or Malibu Colony, efforts to acquire land for the upland transition zone should be focused on the area north of the Pacific Coast Highway. There are multiple areas with low combined land use and land cost scores. The land immediately surrounding Malibu Creek is already protected because it is state park land and efforts should be focused on acquiring land that can connect to state park land to ensure the movement of species between the wetland and upland areas.

On the northeast side of our study area there is more opportunity for land acquisition, however these parcels were not ground truthed because they are private property. To the east of the Hendler Open Space there are some inexpensive parcels. These three parcels could provide 7,000 m^2 (1.7 acres) at a cost of $448,000. Depending on the budget of the land purchaser, additional parcels surrounding our recommended areas could be purchased to expand the state park boundary and provide a larger area of upland habitat. However, beyond these parcels there is a significant increase in elevation that wetland managers must consider depending on the target species' ability to migrate and navigate the hillside.

On the northwest side of our study area, there is a low density commercial area that may be feasible for the habitat migration. These parcels encompass an auto repair shop. This area scored a 5 in land use because it is a commercial property, but only a 1 in cost. While the auto shop has the high public benefit of most commercial areas, it has much less infrastructure than the commercial area to the south of these parcels. Therefore, this land could be more easily converted to natural habitat than a higher density commercial area. Acquiring these three parcels would result in the protection of 11 acres for approximately $890,000.

Barriers within the UTZ: The Pacific Coast Highway

The Pacific Coast Highway poses a major barrier for the migration of wetland species. Currently, the PCH is a bridge that passes over Malibu Creek which enters Malibu Lagoon. Under the bridge, there is dry land on both sides of the creek that would allow terrestrial species to move beneath the PCH. However, the creek is expected to increase in width in response to sea level rise. We were not permitted to enter this area during ground truthing, but visual inspection and LiDAR data shows us that the land here is flat, suggesting even a small increase in sea level could cause the creek to expand enough to inundate the land beneath the PCH bridge. Managers of Malibu Lagoon should consider how to allow species to cross PCH or where species will be forced to move if they cannot cross PCH.

Parcels that are not suitable for land acquisition: Malibu Colony, Commercial Area and the Adamson House

Both Malibu Colony, the commercial area, and the Adamson House would be difficult to acquire and convert to either wetland or upland habitat.

Parcels within Malibu Colony are not ideal for many reasons. Firstly, this is a densely developed, residential area and demolition of numerous structures would be required to restore the area to wildlife habitat. Additionally, negotiation with many residents would be necessary to acquire a large enough amount of land. If not all desired parcels could be acquired, the result would be a fragmented habitat. Furthermore, most of the land parcels have a very high price per acre.

CoSMoS data shows that much of Malibu Colony is already at a flood risk and there would only be a slight increase in flood risk (Figure 5). It is unlikely that flood risk will be a bargaining chip during negotiations for land acquisition in this area because flooding has always been a concern to homeowners here.

Malibu Country Mart, labeled as “commercial area” on the maps of Malibu, is also not suitable for restoration into upland habitat. This area received a combine score of 10 because it is a commercial center and very expensive. Shops and restaurants are concentrated here, meaning it is an area of high density development. This means restoration would require significant demolition cost in addition to the cost of the land. Furthermore, during our ground truthing trip, we noted that many people were at the shopping center. Clearly, there is a significant public benefit provided by this commercial zone. Overall, it would not be worth the effort to acquire and restore this commercial area for upland habitat.

Likewise, the Adamson House would be difficult to restore as upland habitat or modify to allow transgression. The Adamson House presents a unique situation. This parcel is state park land and there is little development on it aside from the Adamson House itself, suggesting it would be a suitable site for habitat restoration. However, the Adamson House is a historical site, meaning there is a strong legal basis for its preservation and suggesting its removal would cause public backlash. In addition to potential public opposition and policy barriers, the Adamson House sits atop a hill, thus there is an elevation change from near sea level to 6 m over about a meter of distance. T-sheets show that the lagoon exist in this area historically. This land would need to be altered to allow wetland transgression. Other options should be exhausted before attempting to convert the Adamson House site into a natural area.

Figure 13: Map of Malibu Lagoon land acquisition recommendations and conclusions.

Case Study: Ormond Beach, Ventura County

Ormond Beach is located in Ventura County in Oxnard, California (Figure 14). Currently, Ormond Beach is approximately 1,500 acres and extends from Port Hueneme to the northwestern boundary of Pt. Mugu Naval Air Station. The land comprising Ormond Beach is a mixture of agriculture, industry, and natural wetland area. The California State Coastal Conservancy currently manages the Ormond Beach Wetlands Restoration Project.

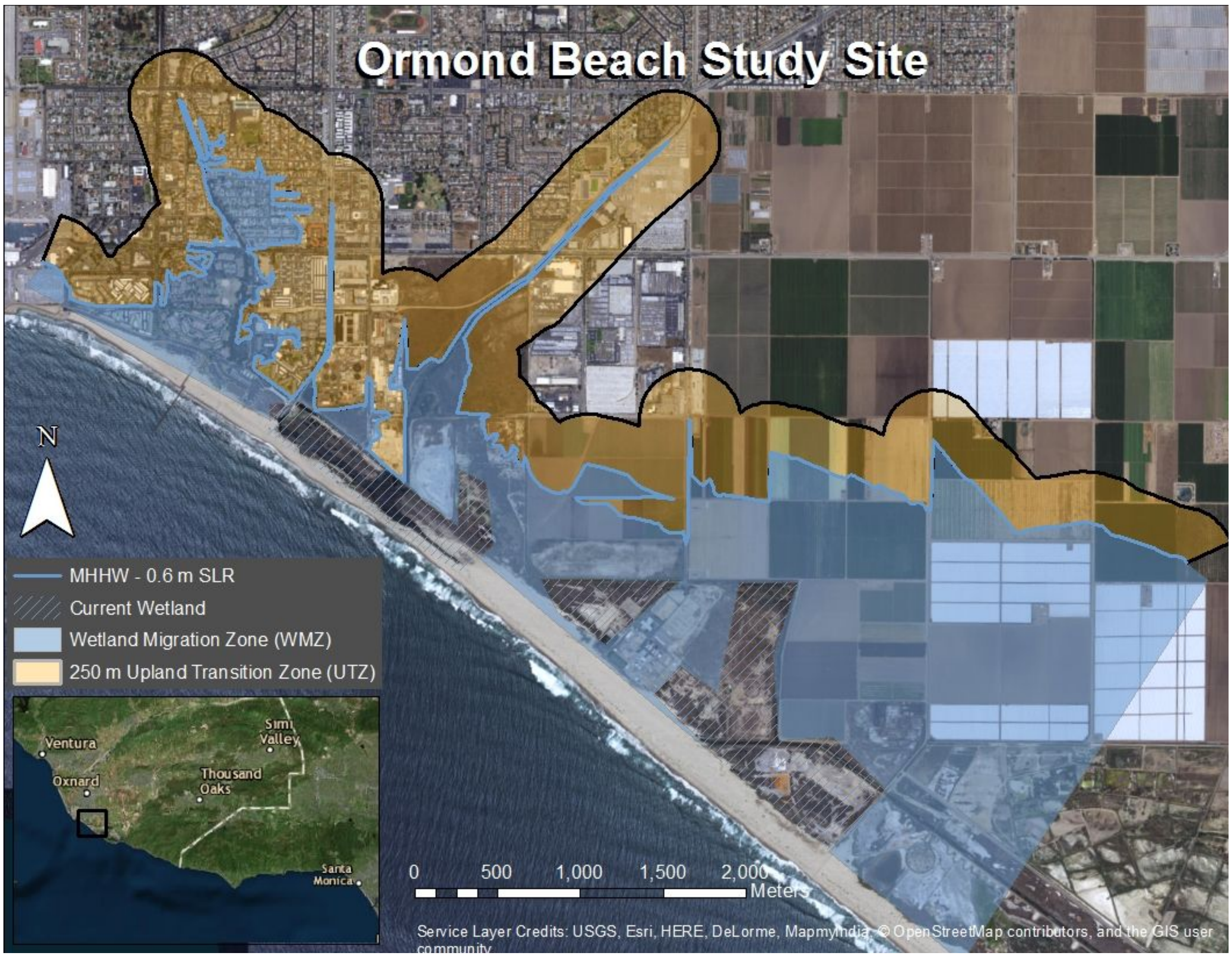

Figure 14: Map of Ormond Beach study site.

Results

Physical Land Suitability

LiDAR data shows our study area within Ormond Beach is very flat (Figure 15). Most of the land ranges from sea level to 5 m. The highest elevation is the waste pile Halaco Superfund site, which reaches 13.6 m. Low elevation throughout the wetland indicates that sea level rise can inundate land much further inland than it could at Malibu Lagoon and Ballona Wetlands. Other than the Halaco waste pile, there are no significant elevation changes to act as barriers to wetland transgression at Ormond Beach.

Analysis of CoSMoS flood and storm data shows Ormond Beach is currently not at a flood risk (Figure 16). Under 0.5 m and 1 m sea level rise, the agricultural land to the east will become a flood hazard area. The residential area to the west will not be at risk of flooding under 0.5 m or 1 m sea level rise. This is likely due to armoring and the channelization of streams, including the Ormond Lagoon Waterway that cuts through the Nature Conservancy Land.

After examining the history of Ormond Beach, T-sheets show that Ormond Beach wetlands extended inland around present-day Port Hueneme. Vegetated wetland and salt flats also extended into the land currently owned by the Nature Conservancy. It is estimated that historically, 1,100 acres of wetlands existed at Ormond Beach whereas today, only 250 acres remain ("Ormond Beach Wetlands Restoration Project").

As with our other sites, coastal development has destroyed and degraded many of the original wetlands along Ormond Beach. Ormond Beach is unique, however, in that it contains an EPA Superfund site, known as the Halaco site. For 40 years, the Halaco Engineering Company ran a metal smelter that deposited aluminum zinc, magnesium, copper, lead and other metals along Ormond Beach ("Halaco"). The U.S. EPA added the site to the Superfund list in 2007; they have completed testing for environmental impacts and are planning to release their clean-up plan in 2017 or 2018. Currently, the site consists of a large waste pile covering 11 acres that has been fenced off by the EPA ("Removal Action Planned to Address Immediate Environmental Concerns"). The history of the Halaco site is described along with other developments at Ormond Beach in Table 4.

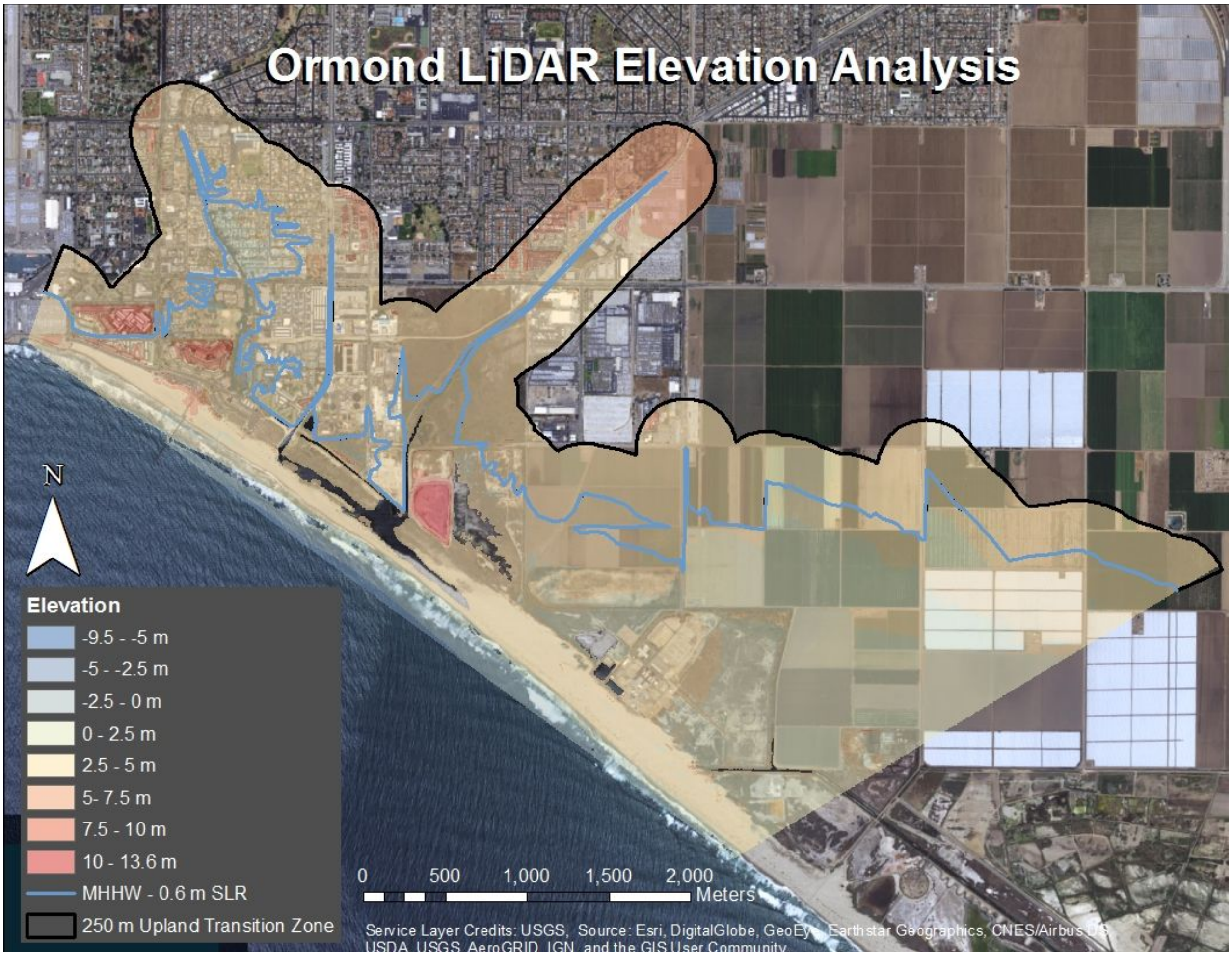

Figure 15: Map of elevation within Ormond Beach derived from LiDAR data.

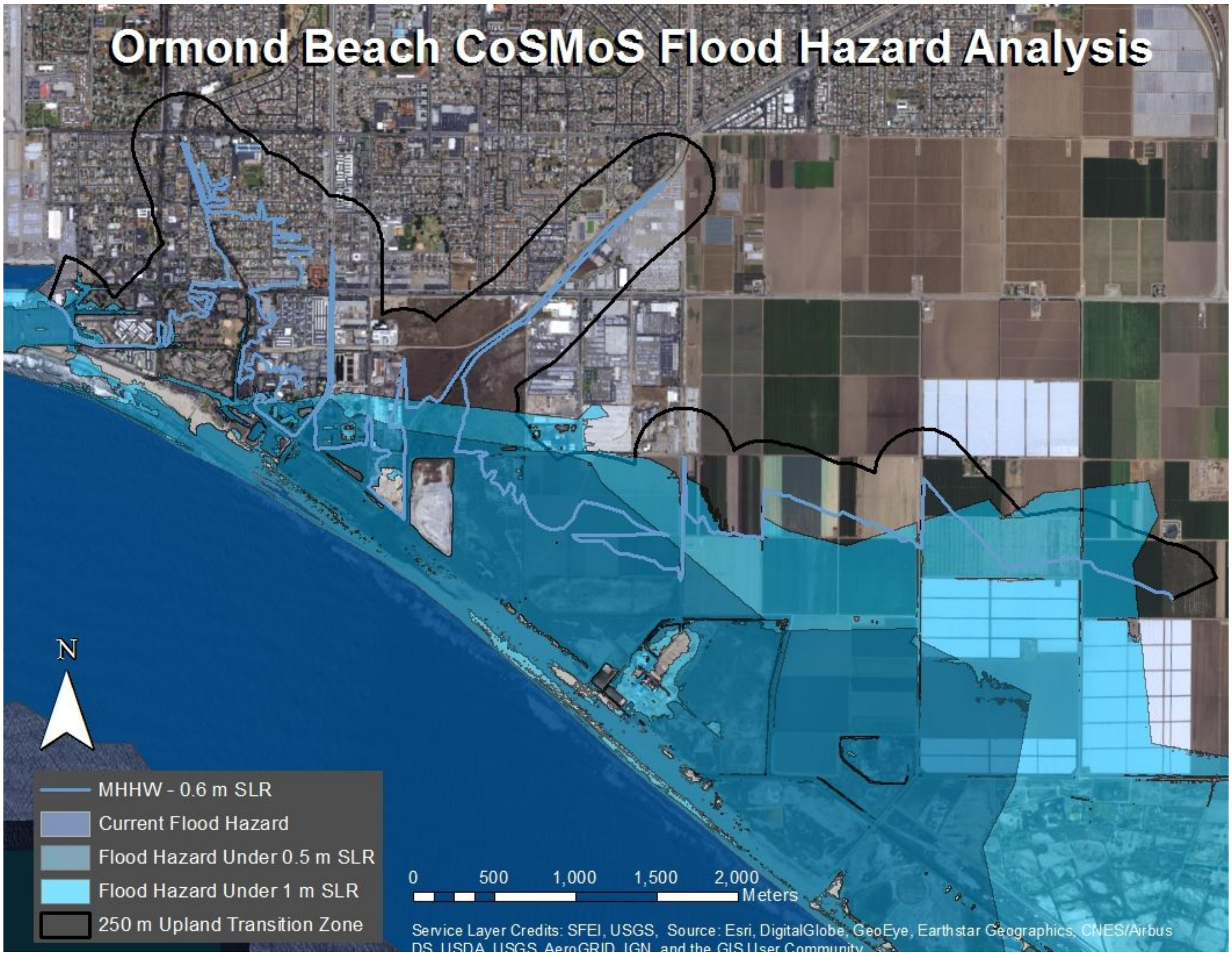

Figure 16: Map of CoSMoS 100-year storm flood risk data under current sea level and predicted sea level changes.

Table 5: Land History of Ormond Beach, 1850-present

Time Period	***Previous Use***
1850s	Wetlands extended from Mugu Lagoon to present-day Port Hueneme.
1900s	Port Hueneme was built alongside the wetland.
1920s	Agricultural land extended into wetland area.
1930s	Drainage canals built.
1950s-1960s	Industrial construction began around and within the wetland.
1964	Halaco Engineering Company starts to operate and deposit base metal waste within the wetland area.
1985	City of Oxnard created a wetland restoration plan.
1990s	California State Coastal Conservancy removed lots on the beach, purchased land from Southern California Edison, and created wetland restoration plans.
2000s	Halaco Engineering Company stops operations and declares bankruptcy.
2006	Alpha and Omega Development LLC purchases Halaco Engineering Company's waste area.
2007	EPA adds Halaco site to Superfund National Priorities List.
2010	EPA demolishes Halaco Engineering Company's operational buildings.
2011-2014	EPA releases reports of their findings from contamination testing in areas where the wetlands are located (Nature Conservancy Land).
2017-2018	EPA is scheduled to release a clean up proposal for areas within and around the wetland area.

Ground Truthing: Qualitative Observations

For ground truthing purposes, Ormond Beach was separated into two locations: Nature Conservancy Land and agricultural land. The Nature Conservancy Land has two sections divided by train tracks. The Nature Conservancy leases the land east of the train tracks to celery farmers. This land will be discussed in the agricultural land section. The land to the west of the train tracks is in a more natural state and will be discussed first.

Nature Conservancy Land

Our first location is concentrated west of the train tracks (Figure 17). The train tracks showed no activity during the time we were present. However, idle box cars were present on the tracks. Litter, broken glass bottles, scrap metal, and broken concrete and tiles were noted along the tracks. Patchy vegetation followed the train tracks. As our team progressed south, there were metal pillars and a broken pipe. The soil near the northern part of the train track was dry and covered with gravel. Throughout the area, there were patches of wet soil. Continuing south along the train track, the soil becomes more dry as patches of cracked, compacted soil became visible. A stream with algae eventually appears alongside the train track when walking south, near the end of the track.

As we progressed to the area south of the train tracks near the Reliant Energy Power Plant, more wetland areas were discovered. The Reliant Energy Power Plant is not observable on our map, however, it is on the bottom right hand corner where the train tracks cut off. This wetland did not appear connected to the previously stated wetlands in the first location. This wetland was surrounded with reeds and extended to the fenced border of the power plant. Power lines stretched from the power plant, far into the distance in the direction of the agricultural land. Noises from the power plant and power lines were loud and distinctive. Dust coming from the agricultural land adjacent to the east of the train tracks was seen traveling to this area. The soil was a mixture of sand as this area was approaching the beach.

Heading west from the train tracks, we walked the border of the Nature Conservancy Land and the beach. There is tall, dense vegetation at the southern border of the Nature Conservancy Land. At the western border of the Nature Conservancy Land is an EPA superfund site. This area is fenced due to the presence of hazardous waste. A major change in elevation was clearly noted just beyond the fence. Wetland habitat was directly next to the fence of the superfund site with little room for walking. The soil around the area was muddy and silty. Shallow puddles of water (≤1 foot) were present within the wetland.

As a whole, there are only a few significant anthropogenic physical barriers noted in the areas within the Nature Conservancy land such as the train tracks. The train tracks would need to be removed in order to facilitate wetland transgression. Additionally, both areas are noted to contain high contamination; therefore, cleanup and restoration of soil and water would be recommended. Our ground truthing analysis revealed that pollution would be the biggest concern for wetland migration into the Nature Conservancy Land. The presence of an EPA Superfund Site raises concerns of soil and water contamination in the area. The noise and dust from the Reliant Energy Power Plant may also harm wetland health.

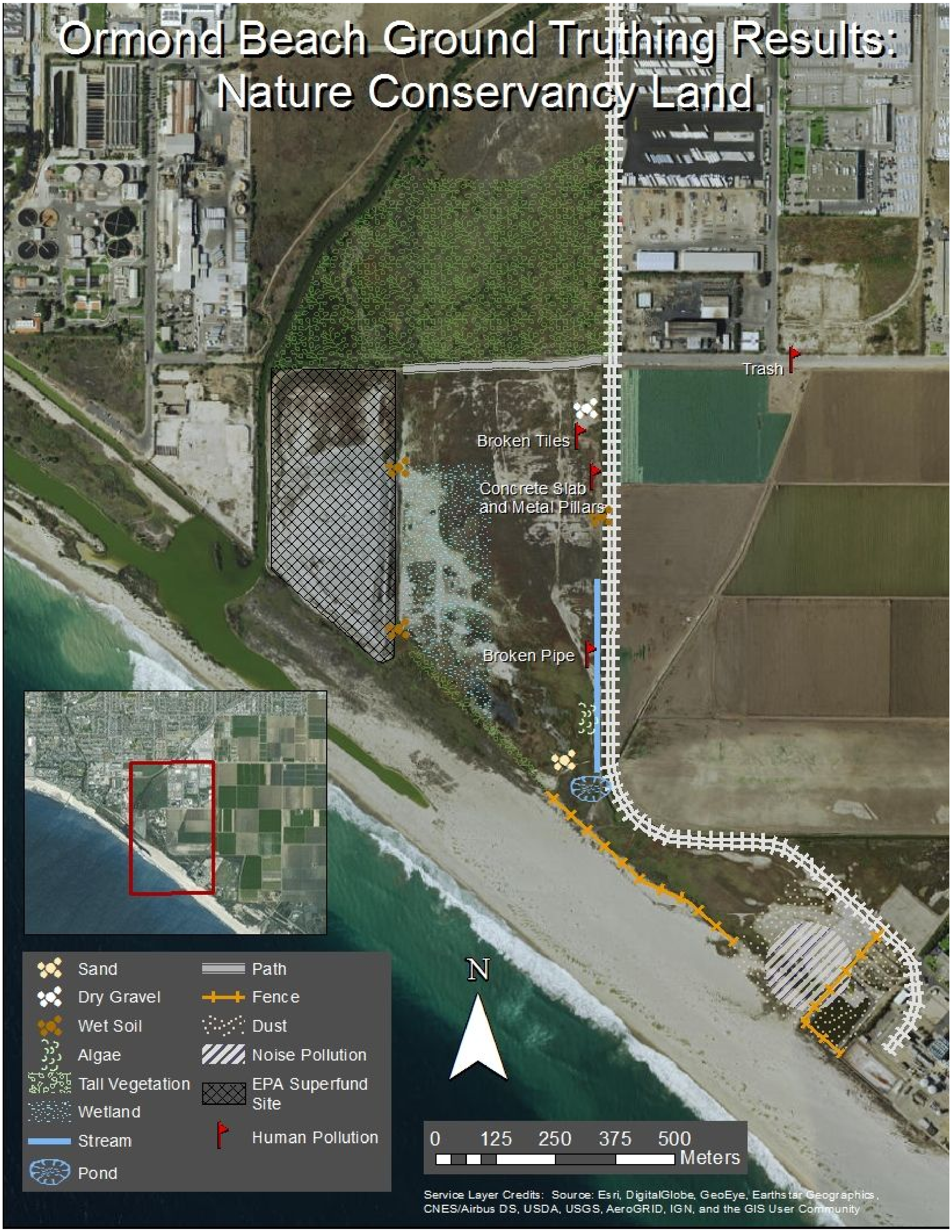

Figure 17: Ground truthing results for the Nature Conservancy Land.

Agricultural Land

The second location in our ground truthing study area primarily encompassed agricultural land within the upland transition zone (Figure 18). The area can be thought of in two areas the agricultural land within the current Nature Conservancy land bounded by E McWane Blvd. and Edison Rd. and the agricultural land between Edison Rd. and Arnold Rd.

On the left hand side of the map, there was leftover celery scattered throughout the field after it was harvested. On the border of the the agricultural land there was a lot of abandoned trash ranging from large wooden shelves to old clothing. The soil in the middle of E McWane Blvd. was very fine and appeared damp. The soil closely resembled fine loam. Then, the soil changed towards the end of E McWane Blvd. where it met Edison Rd. The change in soil is possibly due to changes in land use as the agricultural land ended when it met Edison Rd.

In the center of the map, there were two notable vegetation changes where it started with dry scrub and transitioned to what resembled taller, denser wetland vegetation on Edison Rd.. One notable characteristic on the east side of Edison Rd. was an outfall pipe that emptied into a ditch that contained agricultural pollution (i.e. algae, twigs, and branches). Also, there was a heavily inundated field adjacent to the outfall pipe. On the right side of Edison Rd. there were power lines along the entirety of the road. Our observations along Arnold Rd. were similar to Edison Rd., many of the fields were either fallow in preparation for future vegetation or appeared to be recently harvested. The east side of Arnold Rd. was dominated by strawberry fields and fallow. As we traveled south on Arnold Rd., there were another series of power lines parallel to Hueneme Rd. Most notably, there was a helicopter in use by one of the farmhouses. As a result there was a lot of noise pollution and dust in the wetland migration zone at this location. Additionally, the helicopter appeared to be releasing a liquid onto the agricultural land. It is likely that the liquid was a pesticide and could negatively affect the overall soil health.

Overall, in the wetland migration zone, there does not appear to be any significant barriers to restoring tidal inundation. Our ground truthing observations confirmed our LiDAR analysis and there were not significant elevation changes that would inhibit wetland migration. Within the wetland migration zone, pollution proved to be the largest component adversely affecting its transgression potential. Most of the trash was concentrated on the side of the roads that bordered the agricultural land. Within the upland transition zone, it would appear the largest barrier for wildlife movement would be existing roads (i.e. Edison Rd., Arnold Rd., etc.). Additionally, a large majority of the land in this area is of similar use and is a large open, green space that might be conducive to upland habitat restoration.

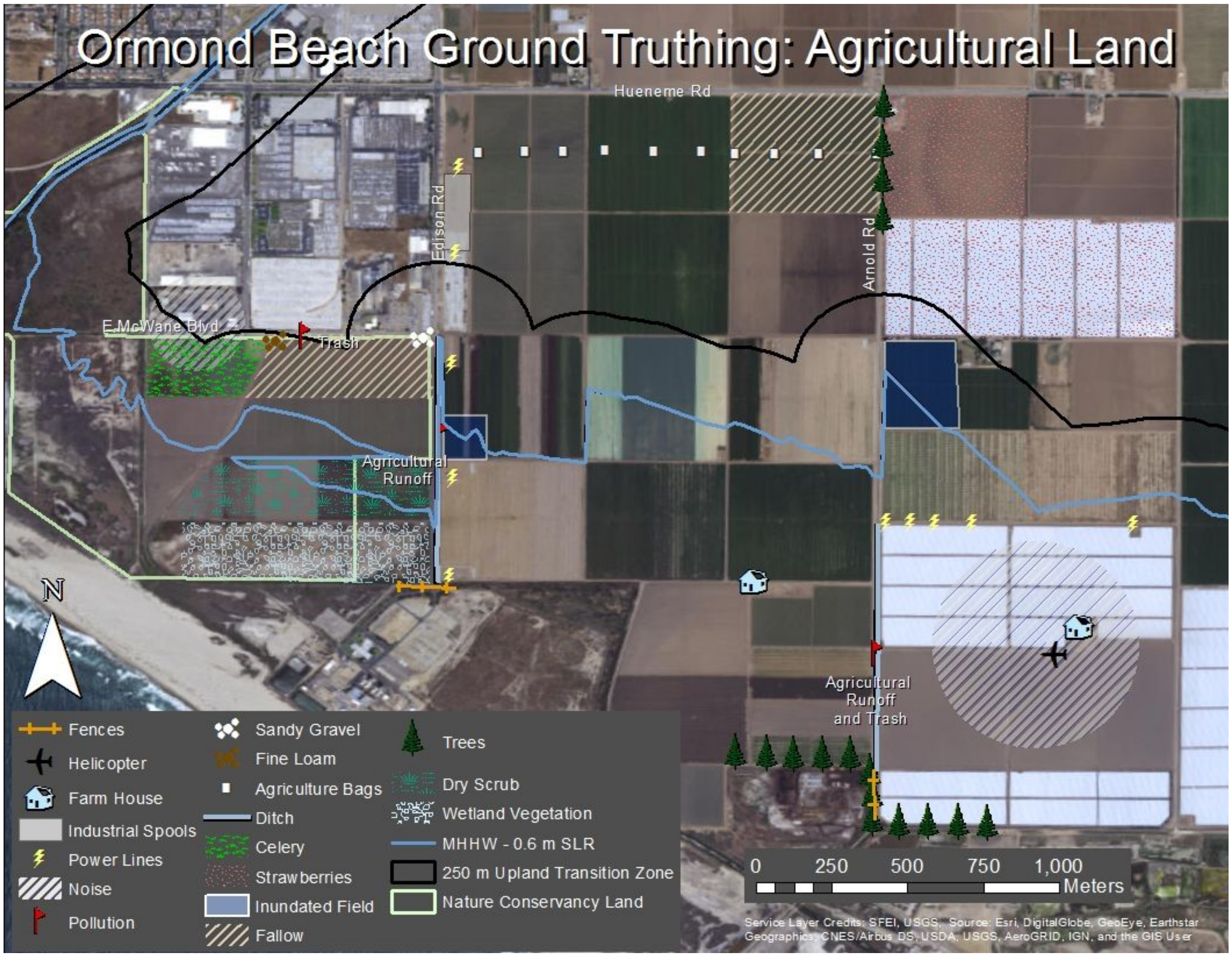

Figure 18: Ground truthing results for agricultural land.

Land Use

The land use feasibility score distribution is depicted in Figure 19. Of 3,067 parcels, 79% were assigned a value of 4. The majority of level 4 parcels were residential. Level 5 had the second highest total with 257 parcels. These parcels are mainly industrial, but includes land used for manufacturing, warehousing, packaging of crops, parking, utility district offices, medical institutions, railways, commercial centers, ports, recreation, and power plants. For level 1, 203 parcels were assigned and considered protected. This level contained government owned beach and national forests. The total land area for level 1 was 1,868 acres. Undeveloped land, given a score of 2, totaled 48 parcels, covering 714 acres. Level 3 had the least amount of parcels assigned with a total of 35. Sixteen parcels were government owned, four were industrial, and fifteen were for crop production. About 1,269 acres made up level 3's total land. 94 parcels were not classified due to lack of data. A map depicting the land use results is included in Appendix B.

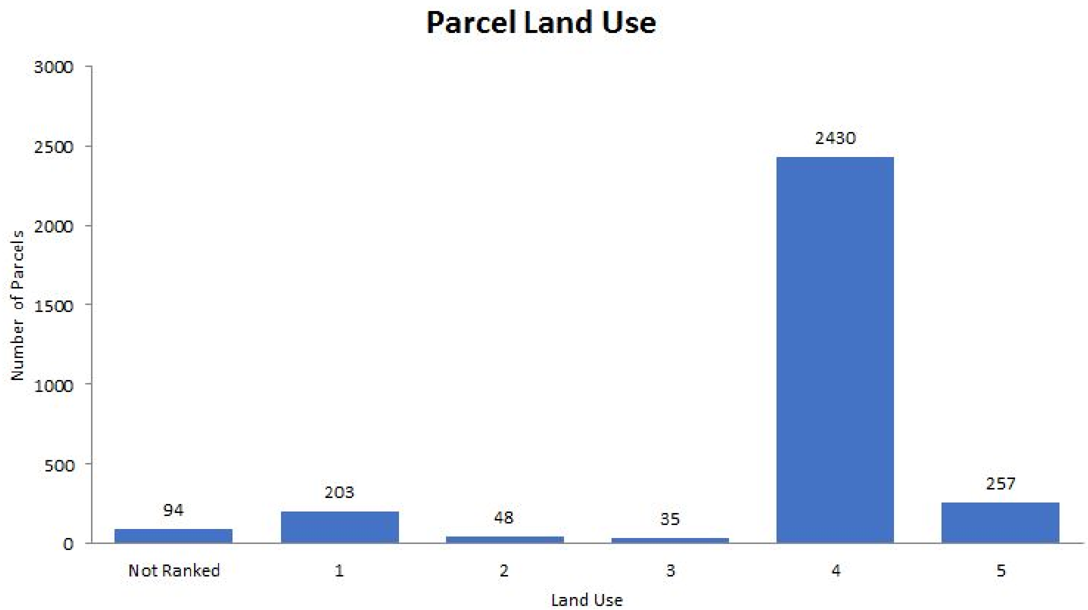

Figure 19: Bar graph for number of land parcels in each level of land feasibility scale.

Cost

The majority of parcels had an acre priced at $480,000 or higher (Figure 20). Thus, they were given a score of 5. Parcels with 5s totaled 484 acres of land. Level 1, 3, and 4 had about the same amount of parcels for cost per acre—about 30 parcels each. However, parcels ranked level 1 had the most land coverage with about 1,520 acres. Level 2 had 14 parcels and the least amount of parcels for cost per acre. 128 parcels had no value available and were not ranked. A map of cost results is included in Appendix B.

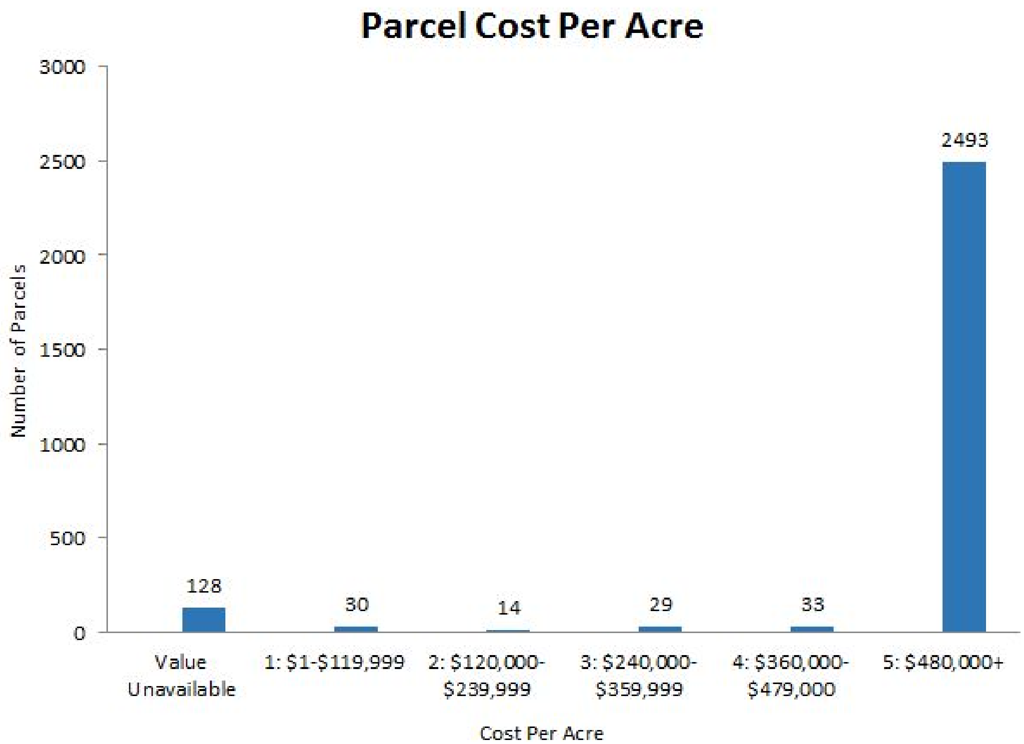

Figure 20: Bar graph for number of land parcels in each level of cost feasibility scale. Excludes parcels categorized as currently protected land.

Discussion

Ormond beach does not face as many of the challenges seen in Malibu and Ballona. The wetlands in Malibu and Ballona are surrounded by dense development, mostly residential with some commercial areas. While Ormond does feature a dense residential area to the west, it has some industrial parcels near the center of our study area, along with agricultural areas on the eastern side. Ormond beach also lacks the steep elevation changes present at Malibu Lagoon and Ballona wetlands. For these reasons, Ormond has more options for land acquisition and overall transgression opportunities (Figure 21).

Land for the UTZ: Parcels Northwest of the Nature Conservancy Land

Following a comprehensive land use and cost analysis, there are multiple land parcels northwest of the current Nature Conservancy Land that are feasible to acquire (Figure 21). The two parcels that are northwest of the currently protected Nature Conservancy land are predominantly in the upland transition zone. Both of these parcels are suitable for acquisition due to their high physical land suitability and their low score on the combined feasibility scale.

Acquiring both parcels would provide about 42 acres of land (172,880 m^2) at a total price of $1.5 million ($35,900 per acre).

Land for the WMZ and the UTZ: Agricultural Parcels

Within both the wetland migration zone and the upland transition zone, there are three highly recommended agricultural parcels that are directly adjacent to the currently protected Nature Conservancy land on the east side. These three parcels are our top recommendations because they satisfy all three major categories: physical land suitability, moderate land use feasibility (level 3), and low cost (level 1). These parcels also provide the most area for its cost. For these three parcels, the cost would be approximately $47,200 per acre or $10,275,000 for a total for 218 acres (880,190 m^2). Previous land acquisition projects for Ormond Beach inform us that it is plausible to acquire roughly about 200 acres for 10-13 million dollars. For example, in the 2002, there was the Ormond Beach Edison Acquisition project by the Coastal Conservancy that yielded 265 acres of land from Southern California Edison for $10,638,000. Furthermore, depending on how large of a budget is available or what financial resources are provided, these three parcels are also feasible individually and would provide similar wetland transgression opportunities if they were independent. There are also more parcels adjacent to our recommended parcels and the currently protected land that received low scores in our combined feasibility analysis.

The CoSMoS data takes into account a number of sea level rise scenarios and develops an understanding of which areas are at high risk for flooding. According to the CoSMoS flood risk data, a large proportion of the agricultural land at Ormond Beach is at a flood risk and will become inundated under 0.5 and 1 m sea level rise. The agricultural land and any possible infrastructure at the site is under the future risk of critical damage due to high tides, coastal erosion, and severe storms. This information is advantageous to stakeholders who are interested in acquiring the land and can be used as a bargaining chip. The landowners would maximize land value and would benefit the most from selling their land as soon as possible in order to receive a higher market price payout. In contrast, if the landowners decide against selling their land, they will inevitably encounter a decrease in land value when their land is inundated or face costly damages due to severe storms and coastal erosion in the future.

If sea level rise or flooding drives down land prices or if a larger budget is available for land acquisition, we recommend purchasing the agriculture parcel south of our primary agricultural recommendation parcels. This parcel could connect the primary recommended agricultural parcels to the beach. This parcel covers 124 acres and is currently valued at $5,821,970; yielding a cost per acre of approximately $47,000. This parcel is considered secondary because the Reliant Energy Power Plant prevents connectivity between this parcel and the Nature Conservancy Land. The area of primary recommendation is, thus, necessary to connect this land and the Nature Conservancy.

Potential Land for the WMZ: EPA Superfund Site: Halaco

The EPA Superfund Site is a unique case. Due to the fact that the land is currently controlled by government, the site would be the ideal location for land acquisition from a policy standpoint. The Halaco site was assessed to be worth about $1 million in 2015 and it covers approximately 26 acres. However, 11 acres of this is a waste pile. There is also an enormous potential for contamination if the wetland were to transgress into this area. Regardless of the pollution impacts, the waste pile has low physical suitability as it is very steep, reaching a height of about 13 m.The future suitability of this parcel will be determined when the EPA releases its plan to clean up the Halaco site. If the waste pile were to be removed and the soil cleaned of metal contamination, the site could become an area of for future wetland restoration.

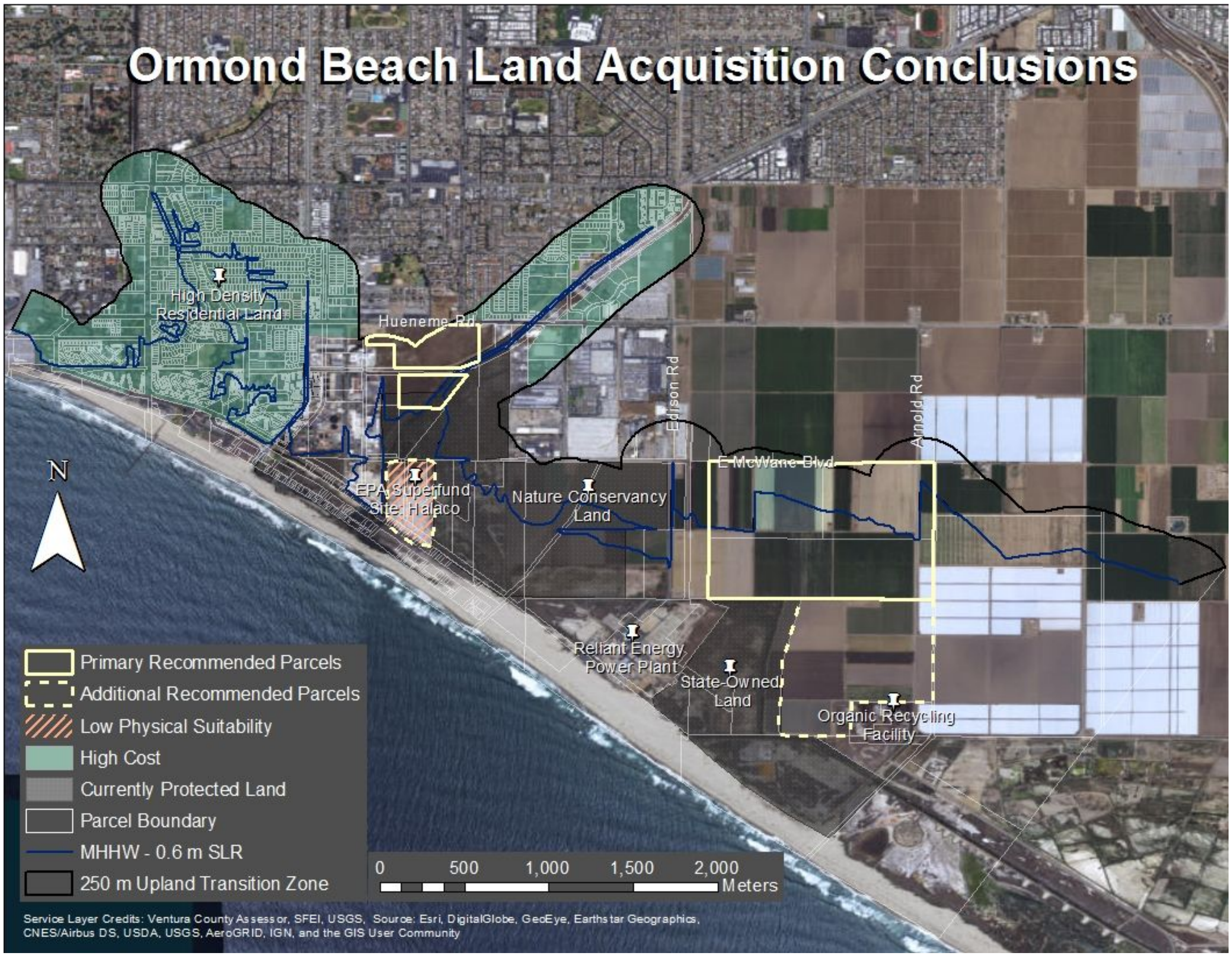

Figure 21: Map displaying land parcels with high cost or currently protected and recommended land parcels for Ormond Beach wetland transgression.

Case Study: Ballona Wetlands, Los Angeles County

Ballona Wetlands Ecological Reserve is located in Southern California within Los Angeles County. Ballona Wetlands currently encompasses over 600 acres of open space (Figure 22). The wetland is surrounded by mainly commercial and residential communities such as: Marina Del Rey and Playa Vista. The land is currently owned by the State of California and restoration project deadline is managed by the California Department of Fish and Wildlife, State Coastal Conservancy (SCC), and The Bay Foundation.

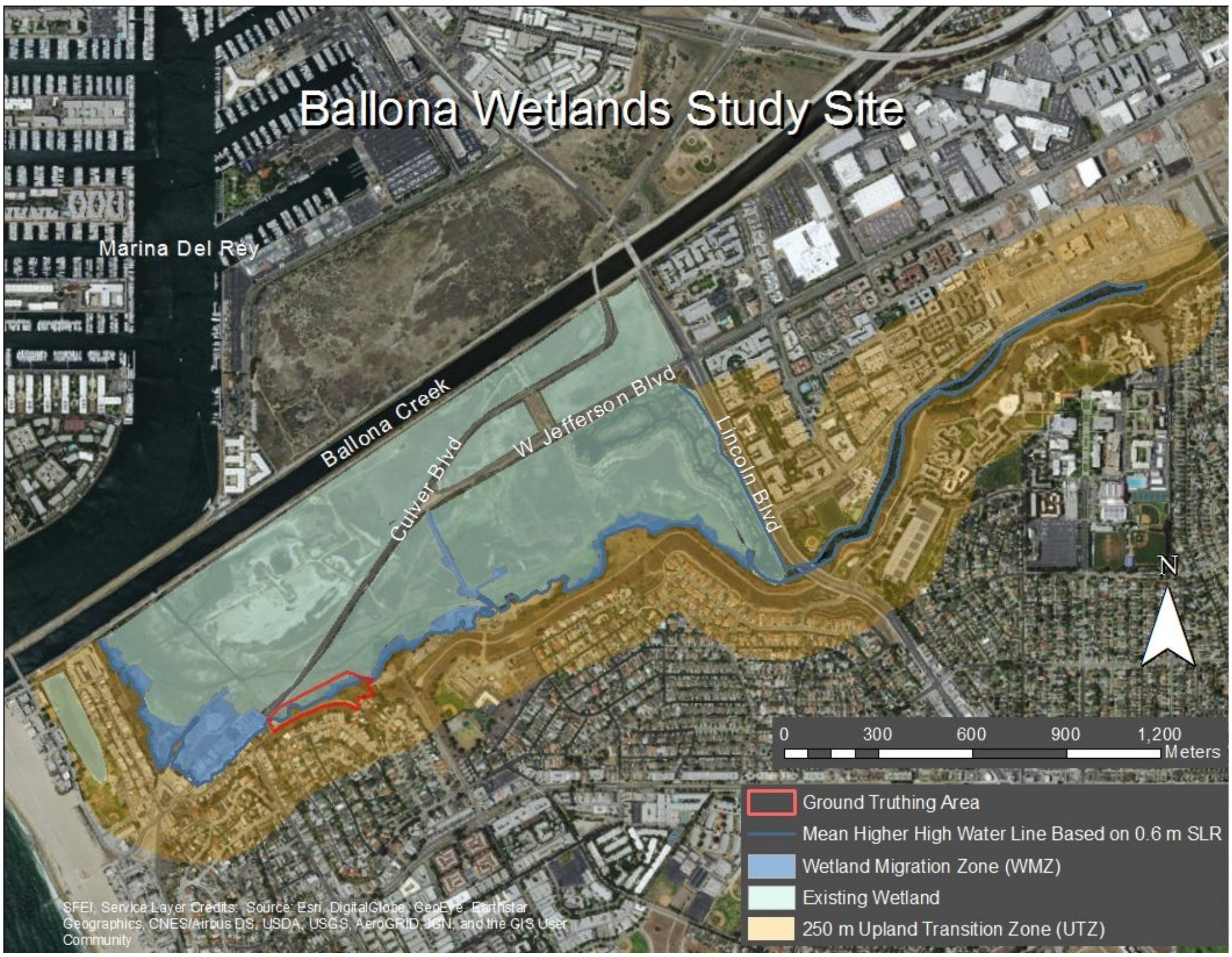

Figure 22: Map of Ballona Wetlands study site.

Results

Physical Land Suitability

LiDAR data shows that Ballona Wetlands are surrounded by a steep change in elevation. There is about 30 m of of space extending from the existing wetland that is low enough for migration before this steep elevation change. The hillsides surrounding Ballona reach an elevation of over 100 m (Figure 23).

CoSMoS Flood Risk Data shows that none of the land within our study area is currently at risk of flooding or will be at risk of flooding under 0.5 m sea level rise (Figure 24). This lack of flooding makes sense considering the channelization of Ballona Creek was carried out specifically to prevent flooding. Under 1 m sea level rise, Ballona Ecological Reserve will be at a flood risk. The homes on top of the hillsides surrounding Ballona Wetlands will not become at risk of flooding.

Historically, Ballona wetlands covered 2,000 acres, from Playa del Rey in the south, to Venice in the north, and east to Baldwin Hills (Johnston et. al, 2015). Much of this wetland has been destroyed and degraded by human development; the construction of Marina del Rey alone destroyed 900 acres of wetland Table 5. Marina del Rey is a man-made harbor which prevents any wetland restoration from occurring to the north of Ballona Creek. Other developments in and around Ballona Wetlands are discussed in Table 5.

Currently, there are about 600 acres of wetlands south of Ballona Creek that make up the Ballona Ecological Reserve (Johnston et. al, 2015). Due to the impossibility of wetland restoration to the north, our research only examines the transgression of the wetlands in the reserve.

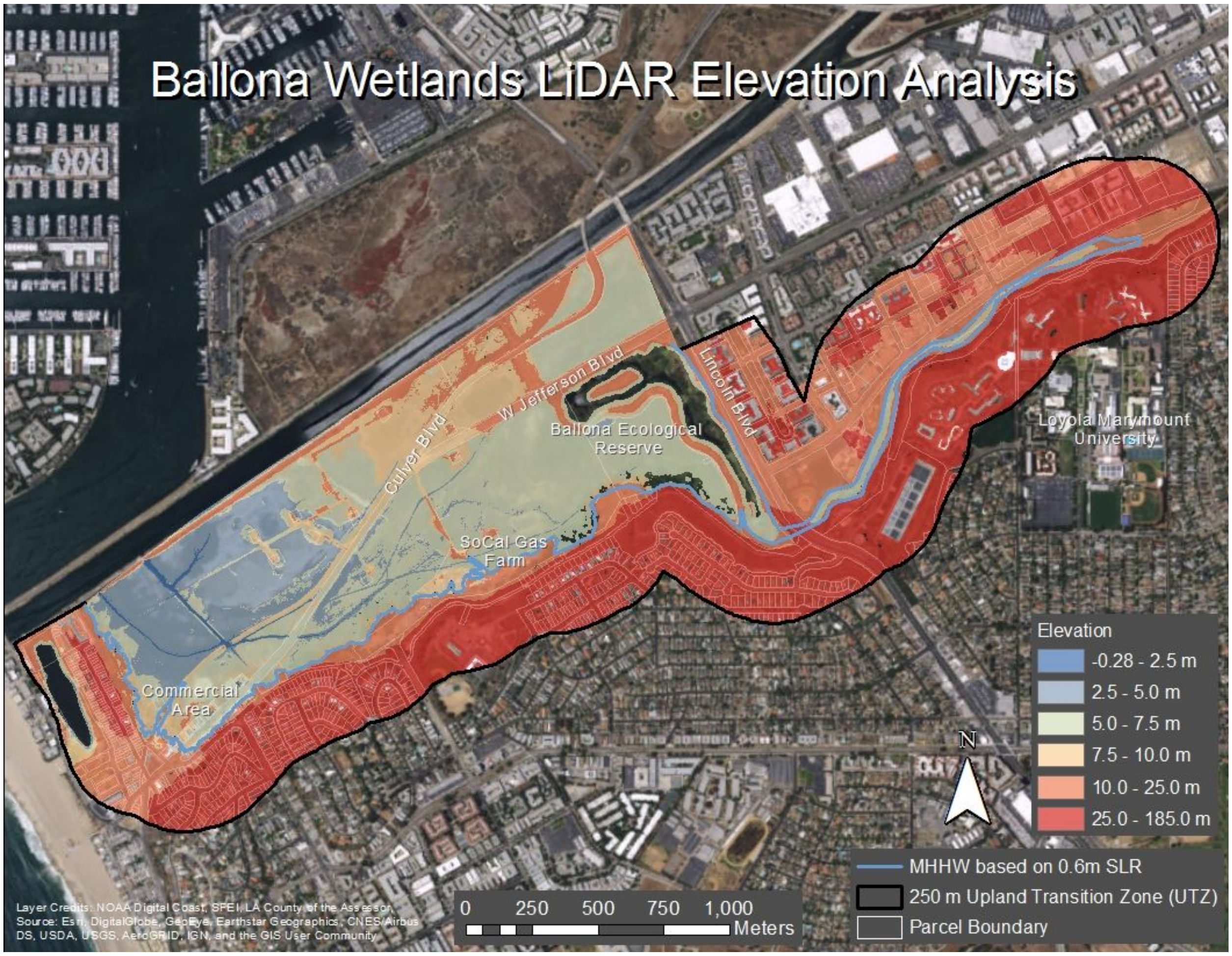

Figure 23: Map of elevation surrounding Ballona Wetlands derived from LiDAR data.

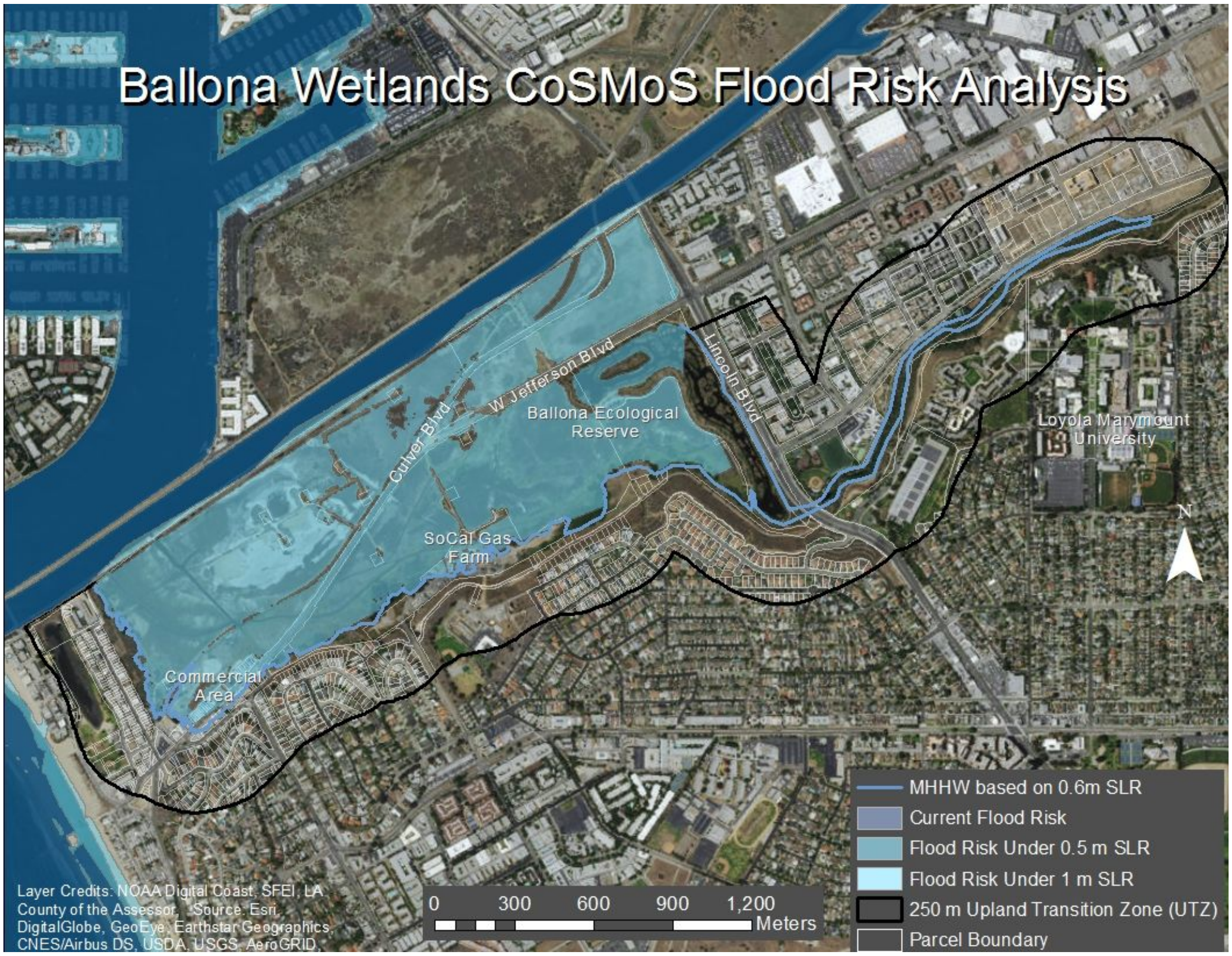

Figure 24: Map of CoSMoS 100-year storm flood risk data under current sea level and predicted sea level changes.

Table 6: Land History of Ballona Wetlands, 1820-2000's

Time Period	***Previous Use***
1820's	Land was used for cattle grazing.
1920's	There was more infrastructure built such as Palisades del Rey, and oil was discovered in the area which increased interest for mining.
1930's	The Army Corp of Engineers dredged and channelized Ballona Creek.
1930's-1960's	Hughes Airport constructed and operated to the east of Lincoln. Required 50 foot pilings for the building's construction due its location and placed them into the wetlands.
1960's	Marina del Rey constructed.
1960's-1980's	Lima beans and celery grown on the wetlands. Horses trampled vegetation, creating a circular area where nothing grows to this day.
1990's	Land acquired for restoration.
2003	Department of Fish and Wildlife spent $140,000,000 on 192 acres of land for the purpose of Ballona Wetlands' restoration.

Ground Truthing: Qualitative Observations

In our ground truthing study site for Ballona Wetlands, there were only three areas our team was able to physically access on foot and where our ground truthing data is concentrated. Figure 25 shows an inaccessible area and adjacent to it on the east, south, and west side were areas we were able to access. There are significant elevation changes that are not identifiable from basic satellite imagery (i.e. Google Maps).

Our team noted there is an abundance of dense, tall vegetation such as wildflowers, non-native, or burnt vegetation. Other vegetation that was identified included wild radish, miner's lettuce, poppies, and *Encelia californica* adjacent to the property line at the higher elevation. Vegetation growing on the higher elevated area displayed greater density, volume, and height. There were a lot of ice plants grown over deceased ice plants around the lower, flat areas. The deceased ice plants appear to have been burned previously, but perhaps due to intentional removal of these invasive species.

At a higher elevation, the soil is more compacted possibly due to human interaction, like foot traffic, and as we progressed down along the slope the soil is very loose and sandy. At the lower, flat areas the soil remains looser compared to the soil available at higher elevation but it is not as loose as along the slope. However, there are areas with compacted soil revealing short paths created overtime from being repeatedly walked on in the lower slope area.

Ground Truthing: Map

For Figure 25 shows observed features. Our ground truthing data validates many of the major features visible in satellite imagery (i.e. shrubs, dirt paths, etc.) and reveals characteristics that are not apparent from viewing satellite imagery alone (changes in elevation).

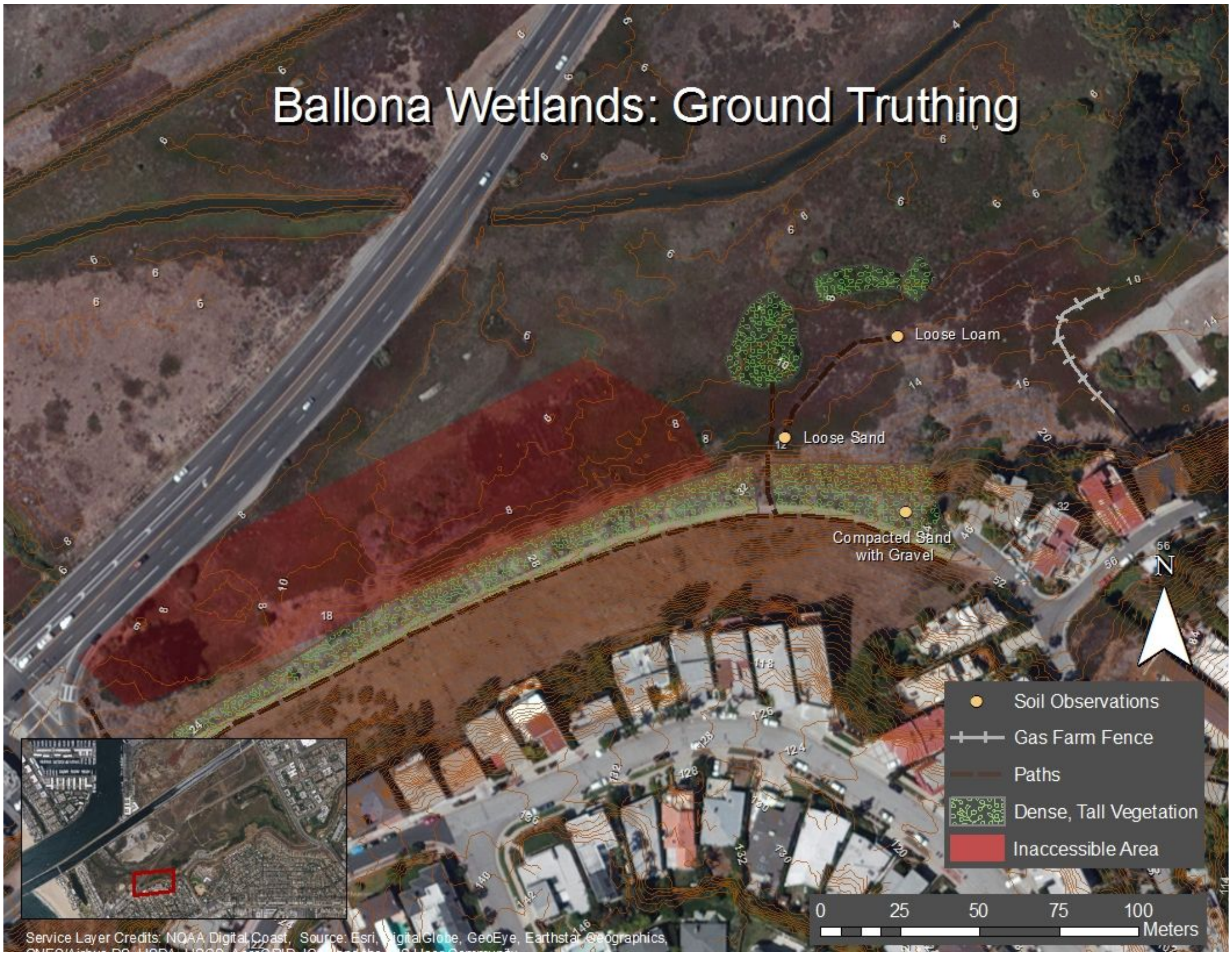

Figure 25: Map of Ballona Wetlands ground truthing results.

Land Acquisition Feasibility

Following a land use analysis, most of the parcels scored a level 3 or 4 on the feasibility scale (Figure 26). This indicates moderate to high difficulty to acquire the land. Nearly all of the parcels from within the wetland migration zone (WMZ) and upland transition zone (UTZ) scored a level 4 because it is a residential parcel and would receive backlash due to its high public benefit. Few parcels are ideal for land acquisition based on land use or cost.

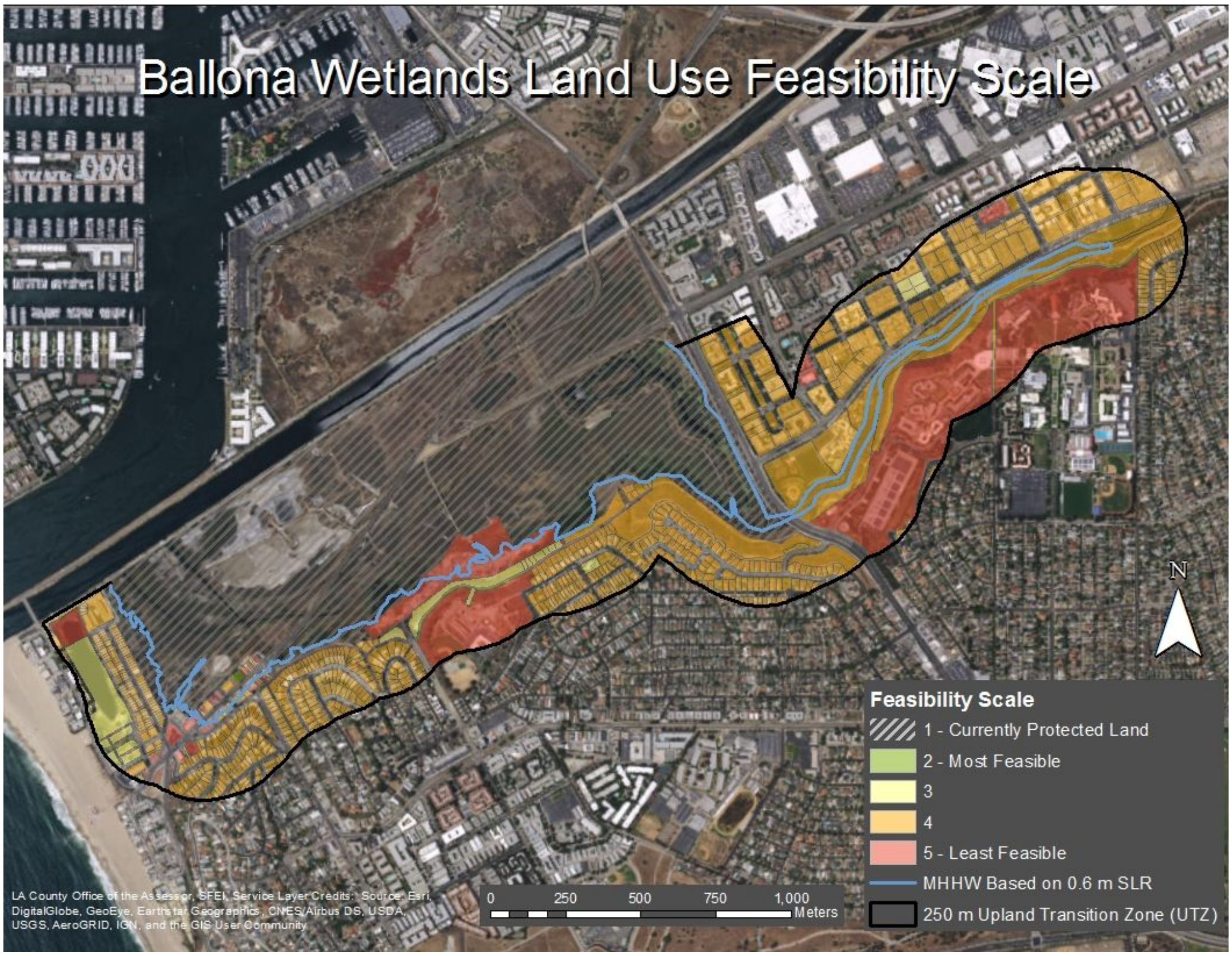

Figure 26: Map displaying wetland transgression feasibility for Ballona Wetlands using land use as the variable.

Discussion

Our analysis of physical suitability variables revealed that it would be very difficult for Ballona Wetlands to transgress because of the surrounding steep change in elevation. The mean higher high water line is expected to rise to the base of the surrounding hillsides in response to 0.6 m sea level rise. The LiDAR analysis informs us of an abrupt, steep elevation change at the end of the wetland migration zone and beginning of the upland transition zone. Due to the steep slope, it would be nearly impossible for a wetland to transgress beyond the lower elevation area. In order to make the land suitable, a stakeholder would need to acquire the costly land and pay an additional exorbitant amount to flatten the land. Additionally, if land was acquired at the top of the hillsides, species would have to be able to climb steep slopes to move between the wetland and these newly protected areas. Overall, the land parcels that are at a greater elevation do not serve as great wetland transgression opportunities, not to mention surrounding parcels have high cost. Restoration and efforts to increase transgression opportunities should be focused on the lower elevation area where the elevation is around 1 meter and a majority of the land is surrounded by invasive ice plants and burnt vegetation.

If stakeholders were nonetheless interested in purchasing land, there are two areas of interest for land acquisition based solely on physical suitability (Figure 27). First, there is a parcel of land that overlaps the WMZ and UTZ boundary that falls under SoCalGas ownership and scores a level 5 due to its commercial value. However, there is a portion of the SoCalGas farm that is northeast of the parcel with significantly less paved land and appears vegetated that would yield about 7 acres if acquired. Another area of interest has parcels of mixed use including a hotel, an apartment complex, stores, and restaurants. These parcels are projected to be inundated under 0.6 m sea level rise which can be used to negotiate price with the business owners. It is not feasible in term of cost at the moment, but there is a potential that the property value will decrease in the future. For example, landowners may become more motivated to sell their property if sea level rise threatens their structures.

Within the WMZ, there are two major roads Jefferson Blvd. and Culver Blvd. that may affect connectivity of the wetland or the traffic and human presence might hinder the species that inhabit the wetland. The wetland does exist currently with this barrier and it is not clear how removing the roads would improve the wetland. This does not eliminate the possibility that it would positively affect the wetland, but we are unclear if it is worth potential backlash from removing the value of a road from this area. Contrastly, removing the roads is potentially mutually beneficial to increase connectivity as well as to prepare for sea level rise because it is projected to flood under 1 m of sea level rise (Figure 24).

Final Recommendations

The wetlands are currently surrounded by high density residential and commercial areas, and our analysis of Ballona Wetland shows these would be difficult land parcels to acquire. Although there is a possibility remaining to acquire land in the WMZ and UTZ, it is ultimately not worth it because it does not yield a significant area. Also, acquiring these areas of interest would be high cost and receive potential public backlash. Efforts should not necessarily be focused on expansion or land acquisition and conversion of residential land, but rather maintenance of the wetland to prevent loss over time.

Figure 27: Map displaying land parcels with high cost or currently protected and recommended land parcels for Ballona Wetlands wetland transgression.

Conclusion

Sea level rise will alter the structure of California's wetlands and managers must be prepared to adapt their management or restoration plans accordingly. Our research demonstrates how physical land characteristics, land use type, and land value can be integrated to make decisions about acquiring land for wetlands and their associated upland habitats.

One of the main findings of our report is that examining elevation should be the first step when looking for land for wetland migration. If there is high elevation, the wetland will not be able to transgress no matter how feasible the area is in terms of cost, ownership, or what's built on the land.

Our research also shows that once you consider all the variables important to wetland transgression, there is often few suitable areas for acquisition. Malibu Lagoon and Ballona Wetlands demonstrate that wetlands are often surrounded by development, leaving little to no land that is suitable in terms of land use or cost. Considering that both Malibu Lagoon and Ballona Wetlands are located in Los Angeles, there may be more success in acquiring land for wetlands outside of dense urban centers. Ormond Beach demonstrates not only that there are still wetlands in southern California with the potential to migrate based on physical land suitability, but also that there are wetlands surrounded by land that is feasible to acquire based on use and cost.

When land is suitable for wetland transgression, the easiest method for acquiring it it is to purchase the land outright. Methods utilizing litigation, such as trying to cease land with the taking clause, are not feasible routes for land acquisition. However, land can be acquired through conservation easements, which protect a portion of a land parcel while allowing landowners to retain ownership.

Ultimately, the amount of land acquired for wetlands will be depend on the public's willingness to sell and donate land for wetlands. The communities surrounding wetlands have often already heard about plans for restoration; they must now be informed about the threat of sea level rise to wetlands. If the amount of public engagement in past wetland restoration projects is any indication, future wetland transgression projects will be met with an engaged and passionate public.

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Appendices

Appendix A: Table of Land Use Acquisition Scale for Wetland Transgression

Level of Feasibility for Acquisition	**1**	**2**	**3**	**4**	**5**
	Already a Wetland	Government Owned Open Land	Privately/ Government Owned Undeveloped Land	Privately Owned Residential Land	Major Highways
Description	Protected Habitat	Privately Owned Open Land	Privately/		Protected Structures

			Government Owned Land with Minor Development		
	State Beach		Agricultural Land		Government/Privately Owned Commercial Land
	Wildlife Refuge				Government Buildings/Schools

Appendix B: Ormond Beach Maps

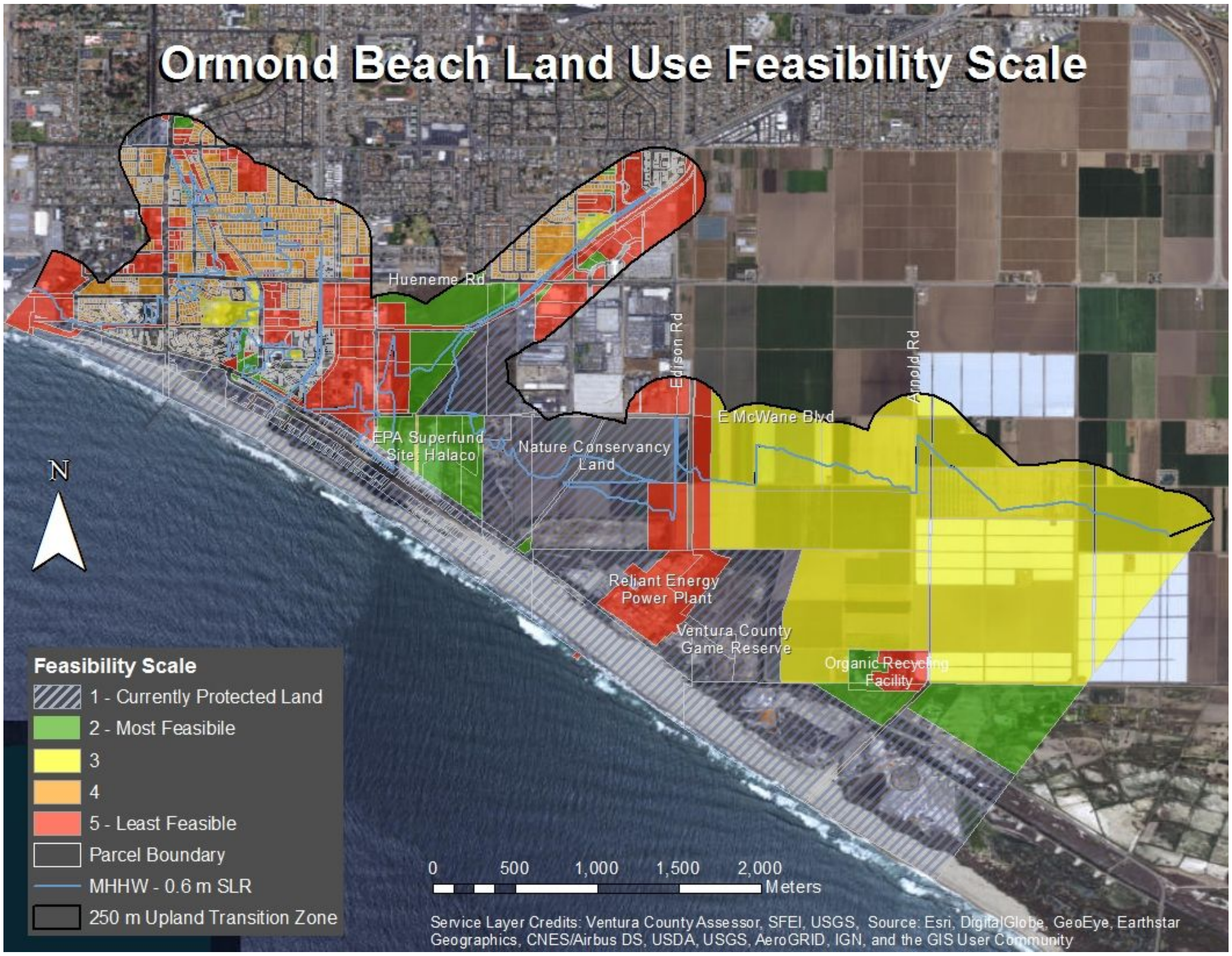

Figure 1B: Map displaying wetland transgression feasibility for Ormond Beach using land use as the variable.

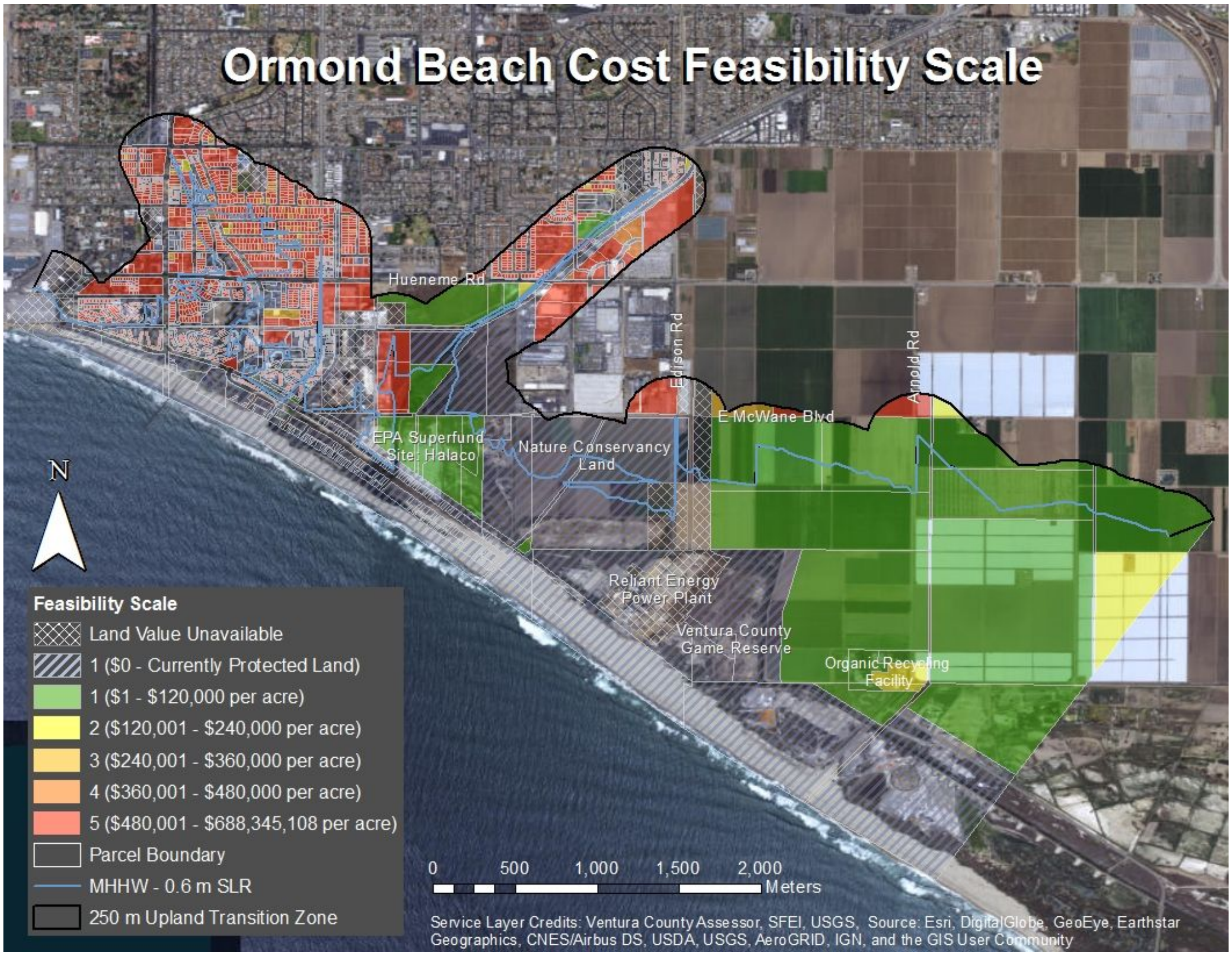

Figure 2B: Map displaying wetland transgression feasibility for Ormond Beach using land acquisition cost as the variable.

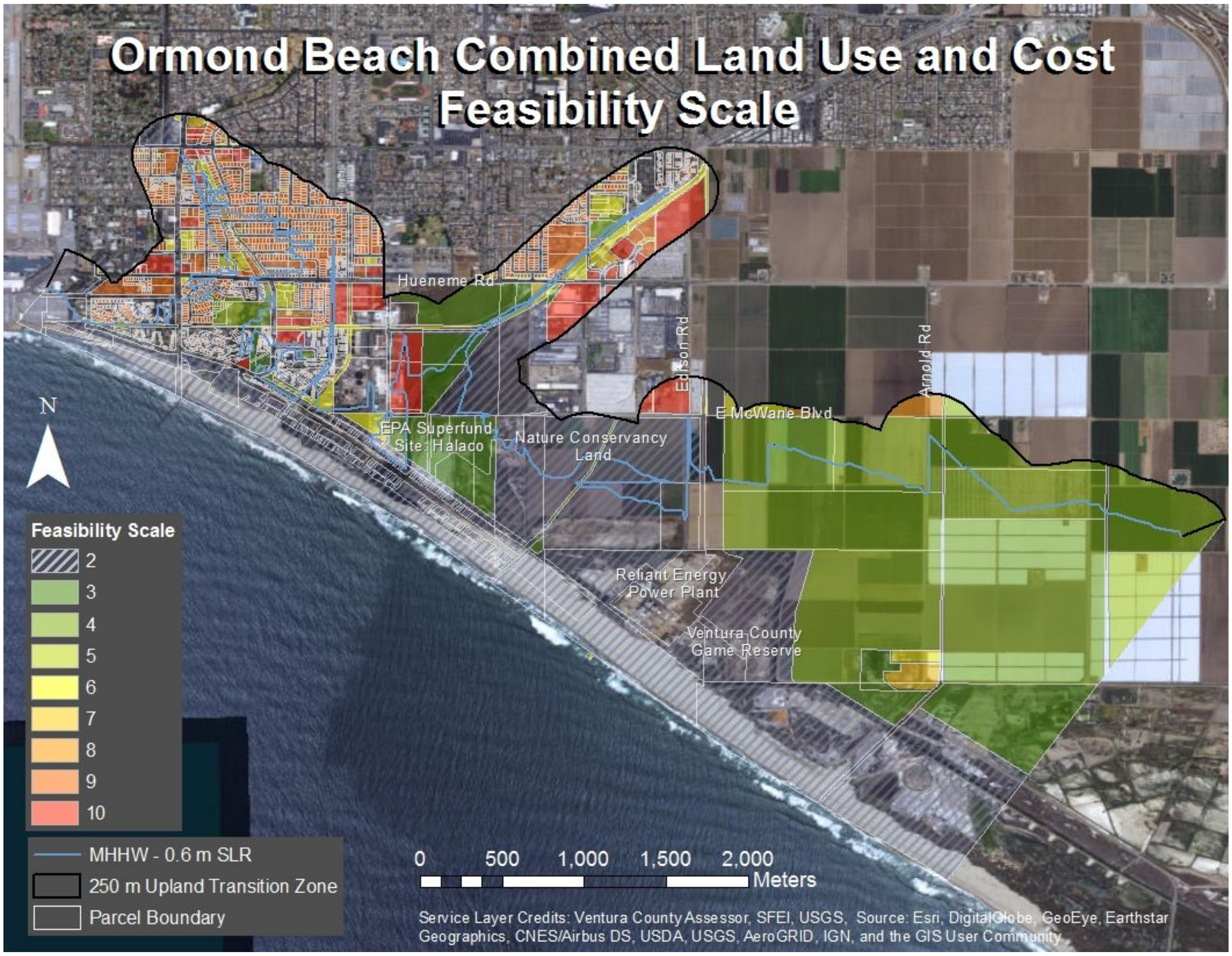

Figure 3B: This map displays the sum of each parcel's land use score and cost score.

Appendix C: Malibu Lagoon Restoration Plan - Providing background information of relevant section specifically regarding water management and habitat maintenance to better inform parcel feasibility for scale.

Section Number:	Content:
2	Water Management Plan
2.1	Focuses on stormwater management when stormwater runs off the existing surface of the parking lot, entry road and turfing area and flows toward the lagoon. These runoffs input pollutants such as metals, bacteria, petroleum hydrocarbons, nutrients, oil and grease into the lagoon, and affects the quality of the water.
2.1.1	The first method to treat storm water which is permeable pavement for parking lot and entrance roads that can provide gaps to allow infiltration of stormwater, which eventually enters the groundwater zone or designated swales.
2.1.2	The redirection of stormwater away from the lagoon to other drainage facilities. The two options for redirection are sloping the parking lot towards the PCH or routing the parking lot drainage to the future city drainage systems.
2.2	The irrigation system which includes supplemental irrigation to assist plant growths, but it has to be temporary to minimize disturbance to the wetland when it's established.
2.3	The importance of circulation for a suitable habitat. The two methods for circulation are tidal flushing and directly measuring flow velocity
3	Habitat Design and Maintenance
3.1.2	Focuses on design, the restoration plan takes into account various slopes and sediment type since each will lead to the development of a different type of wetland habitat. The plan lays out each types, elevation, and guidelines for the slope and sediment, these guidelines must be met in order to ensure proper soil conditions for native plant species. However, the plan states that these are initial guidelines and the project design must develop and refine them in order to achieve the best results.
3.1.3	Focuses on vegetation restoration once the soil and slope and been adjusted accordingly. Vegetation restoration is said to rely on not just

	intentional direct revegetation of the land but also combination with natural recruitment.
3.2,3.3,3.4	Focuses on the maintenance and minimization of loss of the habitat during various stages, before vegetation, during restoration, and long term after restoration.
3.2	Maintaining unvegetated habitat in the lagoon area, done through various methods. The plan highlights two methods that would be effective for avian islands, both are centered around fluctuations in salinity in order to decreased vegetation spread and maintain what is there. Furthermore, this section includes a step by step plan for reducing effects of the seasonal inundation on the land because the summer months can be very harsh for the lagoon.
3.3	Establishes maintenance practices that are focused on ensuring restored areas are not overrun with invasive species.
3.4	Focuses on long-term maintenance of the habitat through considerations of invasive species, adverse oxygen levels for aquatic life, and nutrients and control son exotic species.

Appendix E: City of Malibu - Local Implementation Plan - Summarizing and highlighting of specific sections of LIP in regards to land use and new development permits.

Section Number:	Content:
Section 1.2	Provides a general summary of the LIP. It explains the document is focused on implementation of policies in the Coastal Act and the Malibu Land Use Plan.
Section 2.1	Elucidates which locations are regulated for wetland protection. It defines Environmentally Sensitive Habitat Area (or ESHA) which includes wetland habitat. It also defines the Upland limit of a wetland as transgression areas.
Section 3.3	Defines zoning codes. Wetlands are classified as Public Open Space (OS) which encompasses public land that is for preservation of habitat. Other zoning codes can help determine area that can be obtained by knowing beforehand what the city has classified as the use.

Section 3.4	Refers to overlap zones which become significant when the document laters refers to ESHA and the restrictions placed on developments in those areas. In this section overlay zones are defined as areas in which "location, topography, existing development conditions, or other circumstances, development impacts may be greater or circumstances may necessitate additional site-specific regulation to further the purposes of this ordinance." The section further lays out broadly restrictions on height, maintenance, and setbacks in various overlay zones in Malibu. There is no restriction specific to wetlands in this area but these restrictions appear in a later section referring to ESHA overlay zones.
Section 4.4.2	Referring to biological assessments of land, near or in ESHA boundaries, for developers states that if "site inventory indicates presence or potential for wetland species or indicators" the developer must submit a delineation of where exactly the wetland habitat exists. This delineation is done based on the definition provided in the California Code of Regulations, and that area must be mapped and submitted in a supplemental application in order to ensure that the project region is not disturbing the ESHA.
Section 4.5.1	Highlights uses of wetland regions that are permitted. These uses include scientific research, wetland restoration projects, as well as public service purposes. Unfortunately, public service purposes can disturb the wetland habitats because they include burying of pipes and cables for certain developments, but it must be shown that there is no other less environmentally damaging alternative for these projects to continue.
Section 4.6.1	To development standards for new developments, this section is important because it states that there must be natural buffer regions between new development and any of the ESHA. Specifically, for wetlands the required buffer region is minimum "100 feet in width from the upland limit of the wetland."
Section 4.6.2 & 4.6.3	Refers to lighting and fencing minimization and prohibition on ESHA habitats. These regulations are meant to be restrictive but overall if development will ultimately disturb or fill wetlands within these jurisdictions there is ability for the developer to still develop but with

	the contingency of providing more land to be restored and fostered into habitat.
Section 4.8.2	Lays out the requirements for identifying degraded habitat that can be restored and the city determines if the developer's proposal is sufficient enough to allow the filling of the current wetland habitat.
Section 10	Permits for Shoreline and Bluff Areas
Section 10.2	Developments occurred after the effective date of the Coastal Act or the Coastal Zone Conservation Act that was not authorized in a coastal development permit cannot make any repairs or modification to the development unless the city approves another coastal development permit. These types of improvements include repair of a seawall, revetment, bluff retaining wall, breakwater, types of improvements that will be constructed on any sand area, bluff or environmentally sensitive habitat areas.
Section 10.4	New developments located on a bluff top needs to be set back less than 100 feet to ensure that it will not be affected by erosion for a projected 100 year economic life, but the distance can be reduced to 50 feet if the geotechnical staff decide otherwise. In addition, these requirements do not apply to structures that do not require foundations, so the distance requirements do not apply to structures like decks, patios or walkways.
Section 13	Coastal Development Permits
Section 13.3	developments that require permits from the City of Malibu, or additional permits specified by the Coastal Commission. It stated that any person wishing to perform or undertake any development in the coastal zone other than a facility subject to Public Resources Code Section 25500, shall obtain a coastal development permit.
Section 13.4	The exemptions to the requirement to obtain a Coastal Development Permit. These exemptions include improvements to single-family residences such as fixtures and structures that are directly attached to the residence as such garages or, pools. These developments may cause adverse environmental effect and public access, such as developments located on a beach, in wetland, stream or lake.
Section 13.4.2	Described repair and maintenance activities that require the additional Coastal Development Permit, such as repairing shoreline work near beach, coastal waters, streams or wetlands.

Appendix D: Data Sources

Data For	**Source**
Land Parcels (Value, Type, and Use)	Los Angeles County Assessor Portal, Jeffrey Prang
Cost for Land Acquisition	Land Acquisition Budgets for Ballona, Ormond, and El Cerritos Wetlands Interviews of Experts: Richard Ambrose, Ph.D., University of California, Los Angeles; Phyllis Grifman, University of Southern California Sea Grant; Kerstin Kalchmayr and Greg Gauthier, State Coastal Conservancy
Policy	State Coastal Conservancy United States Constitution Local Coastal Plan of Malibu Restoration Plan of Malibu Lagoon
GIS Layers	Los Angeles County GIS Data Portal, 2015 Tax Roll National Oceanic and Atmospheric Administration, Sea Level Rise of 60 cm San Francisco Estuary Institute, Upland Transition Zone Environmental Systems Research Institute file geodatabase, GeoEye, Earthstar Geographics, CNES/Airbus DS, United States Department Agriculture, United States Geological Survey, AeroGRID, IGN, and GIS User Community, Base Layer