MEMO

TO: Nadia Toloa, Executive Director of the Akua Coastal Commission

FROM: Team Carolinalytics

RE: Informing the Coastal Development of Akua Island

DATE: April 7, 2017

This report intends to propose an assignment of each zone in Akua Island based on its need for coastal development in the next five years.

STRATEGIC APPROACH AND POTENTIAL TRADEOFFS

As a general strategic approach, our team assigned zones in a conservative manner. With the two goals of maximizing economic output and conserving the Akua environment, we looked to place high economic activity and value in zones with low long-term sea level rise risk. Conversely, we looked to place relatively low economic activity and value in zones with greater potential for destruction from rising sea levels. In this case, we found that designating high-risk zones as conservation, recreation, and agriculture would likely decrease the overall potential for economic loss due to rising sea levels. This follows from the fact that these three designations would likely have few high-value assets. There were trade-offs required for the zones, as will be explained in further detail below, but the above reasoning was the premise for each zone designation.

The team also recognized the potential for *adjacency bonuses* and looked to maximize this potential. In designating the zones, we saw that a zone would be preferable for one designation if another specific zone were to be placed nearby. For example, placing a residential housing zone adjacent to a recreation zone provides several tangible and intangible benefits. A survey by the National Association of Realtors found that nearly fifty-percent of homebuyers would pay “10 percent more for a house located near a park or protected open space.” Indeed, this would lead to higher property values, greater municipal revenues (via property taxes), and other benefits, such as many quality of life metrics (“Economic Development”, n.d.).

DATA MODELLING AND DATA LIMITATIONS

In projecting the mean sea level for each of the zones over the five-year period, we employed several techniques to account for the missing data and to ensure our projections are precise. For the data that was missing due to lack of a gauge, the team studied the correlation of the mean sea levels between the different zones. For each zone that had a significant amount of data missing due to the absence of a gauge, we found the neighboring zone with the highest level of correlation between the two zones using available data. We then fit the data for the missing values using a regression on the zone with a significant amount of data (Appendix A).

Many of the zones with significant amounts of missing data have a neighboring zone with few missing data points. The high correlation between neighboring zones is intuitive because if the sea level were to rise in one zone, it is natural that the sea level would also rise in the neighboring zones.

In fitting the missing values, the team decided not to fit the missing values that were caused by a reading error and instead only focused on missing values due to a missing water level gauge. We decided this was the best course of action because the missing data from reading errors seemed to happen randomly, whereas the missing data due to a missing gauge were more systematic across the board.

SEA LEVEL MODELING

In order to model the sea level for the next five years, we converted the sea level data provided into a time series using the R package 'forecast'. We split up each zone into its own data frame in order to focus on their individual predictions, since the zones have differing elevation. Since there were 20 different projections needed and only a few of those would have an impact, we decided to automate the projections. This created a new problem since there are missing observations and not all of the functions of the package will work when missing data is present in a data set. We tested two automotive prediction functions, exponential time series and ARIMA, on Zone 1, since this zone had no missing data points. While both had residuals centered around zero, the exponential times series failed the Ljung-Box test while ARIMA passed it. The Ljung-Box test measure the overall randomness of the model to see if the data is random or not. Passing the Ljung-Box test requires getting a p-value greater than 0.05, which signifies that the model is not random. Other advantages of the auto-ARIMA function are that it makes the time series stationary and it can control for seasonality. While not all of the projections seem accurate, they were good enough to base the decisions upon, as we were being conservative with placing any development near lands that could flood.

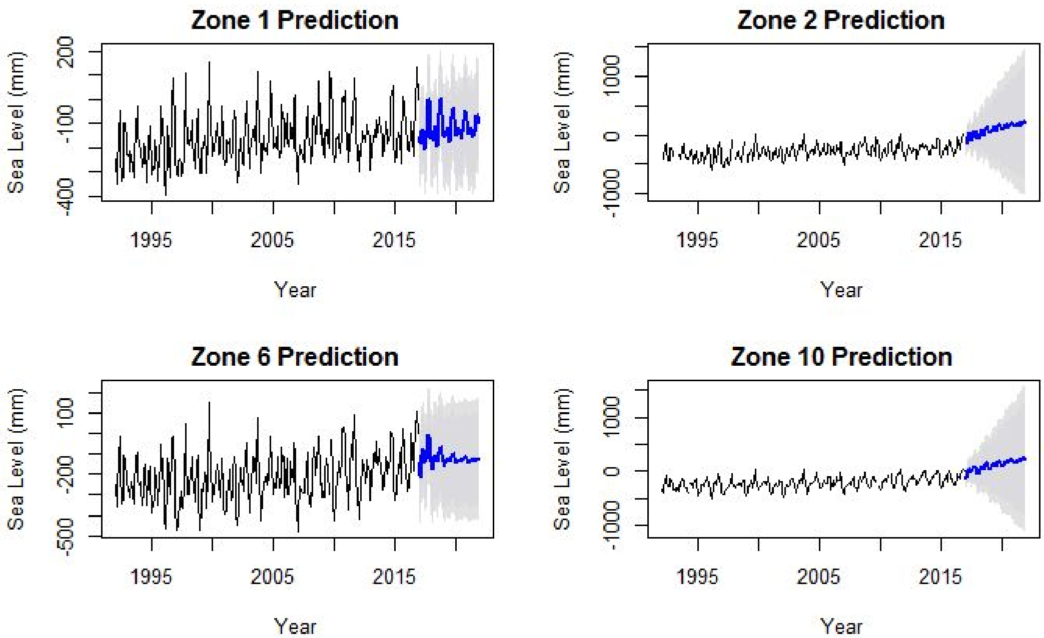
DECISION RATIONALE

We used the following table, which indicates each zone's rank for each category of data, for much of our decision rationale. The ranking depends on the attributable data; for instance, Rank 1 for Snapper Exploitation rate corresponds with the lowest rate, while Rank 1 for Wetland Surface Area corresponds with the largest area.

	Zone Surface Area (square km)	Wetland Surface Area (square km)	Grassland Surface Area (square km)	Forest Surface Area (square km)	Other Surface Area (square km)	Akua Duck Population (number of birds)	Snapper Exploitation Rate (% of total fish removed by fishing over the past year)	Average amount of Soil Organic Matter measured in grassland soil as of December 2016 (% organic matter per hectare furrow slice*)	Coastline Length (km)	Average altitude measurement 100m inland from December 2016 Mean Sea Level (m)
Zone 1	16	15	18	7	13	T-15	20	T-16	7	1
Zone 2	5	5	8	3	11	T-15	19	T-16	2	3
Zone 3	20	18	20	20	20	T-15	18	T-18	17	10
Zone 4	2	1	19	1	12	T-15	17	T-1	4	15
Zone 5	10	12	6	12	5	T-15	16	T-9	19	18
Zone 6	9	11	3	14	10	T-15	15	T-5	12	6
Zone 7	14	6	9	10	6	14	14	T-18	5	16
Zone 8	11	7	12	6	8	13	13	20	15	13
Zone 9	4	20	2	14	16	12	12	T-14	20	12
Zone 10	19	9	16	18	17	11	T-9	T-7	11	4
Zone 11	3	10	14	4	1	10	1	T-3	14	5
Zone 12	8	16	4	13	4	9	T-6	T-9	13	7
Zone 13	18	19	17	8	7	8	T-6	T-13	18	8
Zone 14	6	14	15	2	9	6	T-9	T-13	16	14
Zone 15	12	8	10	5	14	5	T-9	T-14	9	19
Zone 16	13	4	11	11	2	3	T-6	T-9	8	20
Zone 17	1	2	1	9	15	1	2	T-1	1	11
Zone 18	7	3	5	16	3	2	5	T-5	6	17
Zone 19	15	17	7	17	18	4	4	T-7	3	9
Zone 20	17	13	14	19	19	7	3	T-3	10	2

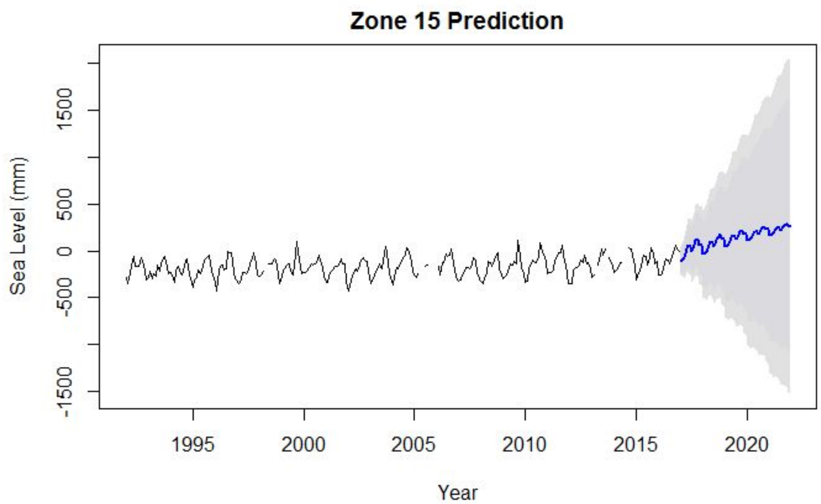
Our team first examined the sea level projection in determining housing zones. As previously discussed, housing zones contain high-value assets. In countries such as the United States, coastal population density is two to three times higher than its national density (Felter and Morris, 2016). Therefore, we intended to assign residential housing to zones with high coastline altitude (See Appendix B.2) and with little variability and increases in mean sea level (See

Appendix B.1). The zones that met this criteria were Zones 1, 2, 6 and 10. Included below are charts of predicted sea level against years:



Additionally, we sought to place zones reserved for other economic activities near residential housing because it would allow for easy access to employment, entertainment, and shopping. Possible development suggestions include waterborne cargo ports in Zone 7, which has a large coastline (ranked 4th), seasonal beach tourism and hospitality sectors in Zone 3 due to its small area and proximity to housing zones, and industrial development in Zone 8 with its relatively large surface area and relatively low risk for flooding.

We sought to designate zones with significantly rising sea levels as conservation zones since rising sea levels do not pose a significant problem to the conservation of wetlands or the Akua duck population, for unimpeded wetlands can feasibly migrate inland. Included below is sea level projection for Zone 15:



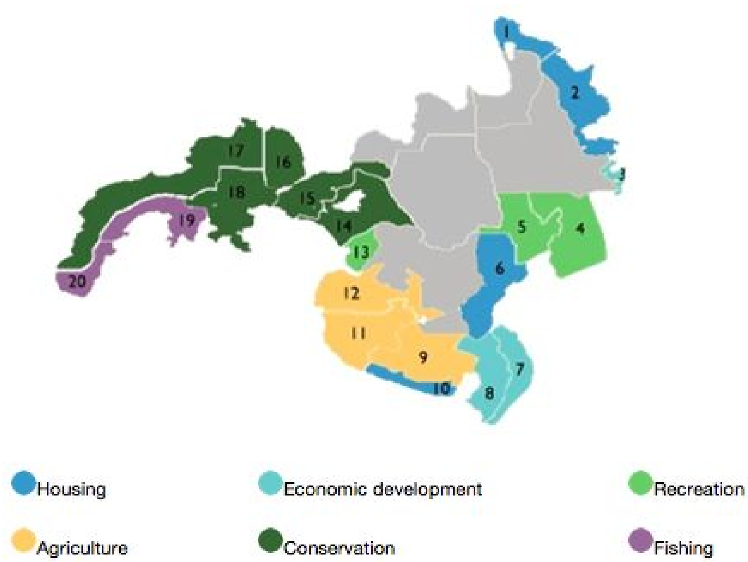
In assigning the conservation zones, we also examined the duck population. Zones 17, 18, and 16 had the largest population. In designating Zones 14, 15, 16, 17, 18 as conservation zones, the team believed that this would provide a bonus in conserving the Akua duck population and wetlands. This idea stemmed from the popular debate of "Single Large of Several Small" in ecology and conservation biology. Our team, based on the literature, sided with the "Single Large" position. We agreed with the reasoning that a "Single Large" conservation area allowed for greater biodiversity, a more stable habitat, and decreased the "edge effect". Indeed, in further support of our decision, the popular counter-arguments supporting the "Several Small" conservation areas hardly applied to Akua Island's particular environmental case (Bove, 2017).

We chose to make an enclave of fishing zones within the large tract of land set aside for conservation (Zones 19 and 20). Allocating these two zones to fishing might boost economic output locally. The placement of these two zones will encourage healthy snapper extraction and reproduction. This will lead to long-term stability in the Akua fishing industry by allowing the snapper populations in Zones 14, 15, 16, 17, and 18 (all conservation zones with less than 10% snapper exploitation) to reproduce without burden from over-exploitation. Then, the spawning and migration of snappers would allow Zones 19 and 20 to have a steady stream of fish within their areas.

We designated zones with a large amount of grassland or organic matter as zones for agriculture (Zones 9 and 12). Our team again considered the importance of clustering the agricultural zones to ensure that large tracts of land will be available for purchase and crop diversity(Zone 11); this furthers our idea of the benefit of adjacency bonuses.

Alternating zone assignments on the east coast was implemented to maximize the use of land for their designated purposes. The economic development zones and recreation zones were placed between the private housing zones to attract the residents from both sides for employment and entertainment. Also, since the zones (Zones 4, 5) were at a relatively high threat from rising sea levels, they were assigned with the low-value recreation.

A map of our final zone designations is included below:

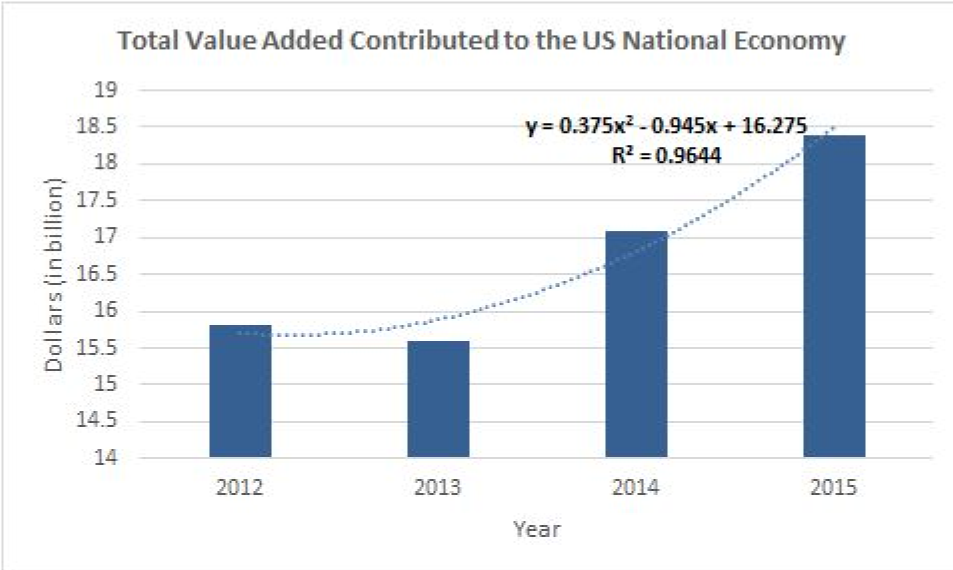


TRADEOFFS AND CHALLENGES

Our team placed a high importance on putting distance between conservation zones and residential housing zones in order to maximize the conservation effort. Indeed, coastal conservation is crucial to various forms of Akua development. The team saw several potential environmental hazards if the conservation zones were to be in very close proximity to large population centers (littering, local pollutants, chemical runoff, etc.).

We were not able to place agricultural zones in locations with a very large presence of organic matter. However, we found this to be an apt decision because organic matter can be feasibly introduced from zones 10 and 8. Organic matter can easily be increased over time through introducing "off-farm sources of organic matter, such as food processing wastes or manure from neighbors" ("Organic Matter Management," n.d.).

Human-focused developments such as housing and recreation were assigned to the east coast whereas the categories involving conservation and industry concentrate on the west side of the island. This is primarily based on the geographical traits and data of the respective sides of the island to maximize both conservation effort and management efficiency, both of which are the goals of assignment(Butler and Leatherberry, 2004). However, literature suggests that such arrangements might lead to future economic development gap, such as the rural-urban divide in Indonesia (Douglass, 1998). With reference to the national parks built in the United States, which generated 32 billion dollars economic output and created 2,953,000 jobs locally in year 2015, our assignment of Zone 13 sought to develop ecotourism to support local gateway economy in the long run (Cullinane Thomas and Koontz, 2016). Below is a chart illustrating the in value the national parks contributed to the US national economy:



One challenge that the government faces is dealing with projections only five years into the future. With such a short time horizon, the government might be overlooking the long-term effects of sea level rise and how that may affect the allocation of zones. We believe that long-term projections would be more beneficial to the zone allocations, especially because the buildings and infrastructure would be in place for much longer than five years.

One objective of the Coastal Act that our team found challenging to address was that the required adjacency included both conservation and recreational zones. Heavy foot traffic, litter, and other factors associated with recreation could have an adverse effect on conservation locally and in the adjacent zones, including decreased plant biomass, increased bulk density, soil erosion and water quality issue (Beckman, 2012)(Whitecotton, et al., 2000). This inclusion of both types of public land could prove problematic for Akua Island and perhaps, in the future, the adjacency requirement could be restricted to just conservation zones.

In conclusion, the zone assignments fulfill the objectives given by the Akua Island Commission. Our strategy of conservative choices, while taking into account adjacency bonuses, is effective because it prevents any potential flood damage while also keeping zones with similar interests near each other. This way, economic development does not interfere with conservation and vice versa. While there were challenges due to missing data and effectively separating ones with different objectives, our proposal overcomes these and presents a feasible plan for the island.