Natural Hazard & Geodesign Solutions:
A Comprehensive Analysis of Curry County, Oregon

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Chapter 1 – Background & Baseline Conditions

The purpose of this chapter is to overview and examine the physical geographic, socioeconomic, and demographic conditions of the study area. After detailing the broad conditions of the county, natural hazards and the extent to which the county is affected, will be discussed. With characterization of the baseline conditions of the study area, greater understanding of community vulnerability and susceptibility to hazards can be met. This chapter will provide the foundation from which models, goals, objectives, and solutions can be extrapolated.

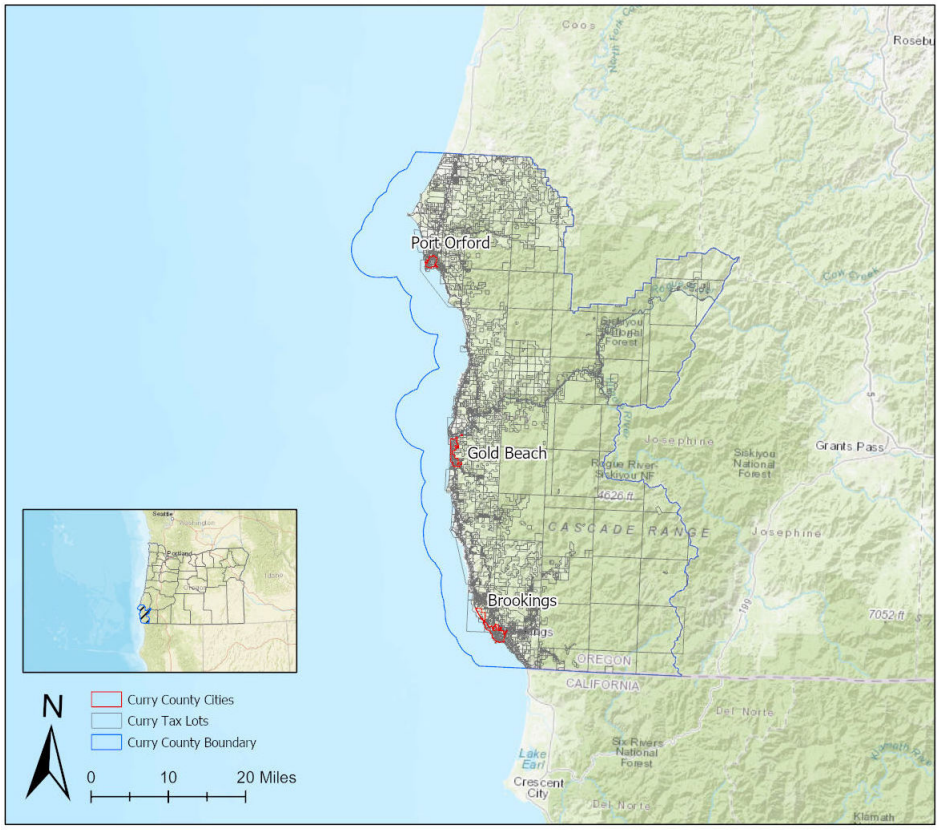


Figure 1.1: Map of Study Area – Curry County Cities

Context:

Curry County is an administrative region within the state of Oregon (see Figure 1.1). It is located in between Coos County (north) and Del Norte County of California (south). The population of the county, based on 2018 estimate, is 22, 813 with a population density of 14 person per square mile. There are three communities designated as cities – Port Orford, Gold Beach, and Brookings – while there are 4 census-designated places and 11 unincorporated communities. The largest population center is Brookings while the administrative county seat is Gold Beach. As of the 2010 census, the county has 10,417 households and 6,347 families. Within the households the median age was 53.5 years with an average household size of 2.12 and family size of 2.62. There were 18.9% of households living with children under the age of 18.

Economy:

Curry County, like much of the Oregon Coast, is highly dependent on tourism. This leads to slowing economic opportunities during winter months when there are less visitors to the region. Curry County also holds one port in Brookings, which is a source of commercial fishing, trade, and recreational employment. There are some timber interests throughout the county as well. Significantly, Curry County holds an unemployment rate higher, 5.3, than the state average of 4.0 (Oregon Employment Department, 2019). From the 2010 census, Curry County per capita income was $23,842 with a median household income of $37,469 and a median family income of $53,340. The dominant industries within Curry County with percentage of employees are as follows (Oregon Employment Department, 2014):

1. Trade, Transportation & Utilities (19.2%)
2. Government – Federal, State, and Local (18.6%)
3. Leisure & Hospitality (16.6%)
4. Education & Health Services (10.9%)
5. Manufacturing (9.1%)

Natural Hazard Risk:

Risk assessment lies at the center of natural hazards and vulnerable systems, predominately defined by exposure, sensitivity, and adaptive capacity (Wood, 2007). Thus, having overviewed background physical geography, demography, and economy of the study area, focus will now be shifted to natural hazards and the sensitivity of the population to these. Given Curry County's location it is predisposed to a number of hazards. Those hazards with their probabilities of occurrence in the county as a whole and with interest in the 3 cities are shown in the Table 1 below. Hazards of particular interest to our analysis are flood, earthquake, tsunami, landslide.

Table 1: Natural Hazard Probability Assessment Summary

Source: Curry County Natural Hazards Mitigation Plan Steering Committee 2015

Hazard	Curry County	Port Orford	Gold Beach	Brookings
Coastal Erosion	**High**	**High**	**High**	**High**
Drought	Moderate	Moderate	Moderate	Moderate
Earthquake (Cascadia)	Moderate	Moderate	Moderate	Moderate
Flood	**High**	**High**	**High**	**High**
Landslide	**High**	**High**	**High**	**High**
Tsunami	Moderate	Moderate	Moderate	Moderate
Wildfire	**High**	Moderate	Moderate	Low
Windstorm	**High**	**High**	**High**	**High**
Winter Storm	Low	Low	Low	Low

Flood –

Flooding events occur in response to heavy rainfall or coastal storm surge overwhelming their typical hydrological boundaries. Flooding within Curry County most often occurs surrounding the Chetco, Elk, Pistol, Rogue, Sixes, and Winchuck River systems. While there is also coastal flooding along beaches and estuaries.

Flooding events within this region have occurred most commonly from October through April. Flooding impacts have a high potential of damaging infrastructure, particularly, highways, roads, and residences. There are several buildings, roads, and other infrastructure within the FEMA 100-year flood extent (see Figure 1.2). While the probability of this hazard occurring is high within the county, the severity of occurrences within past year has been moderate and there have only been three repetitive flood loss buildings (Curry County HMP). Observing annual infrastructural monetary damages attributed with flooding can inform policy objectives.

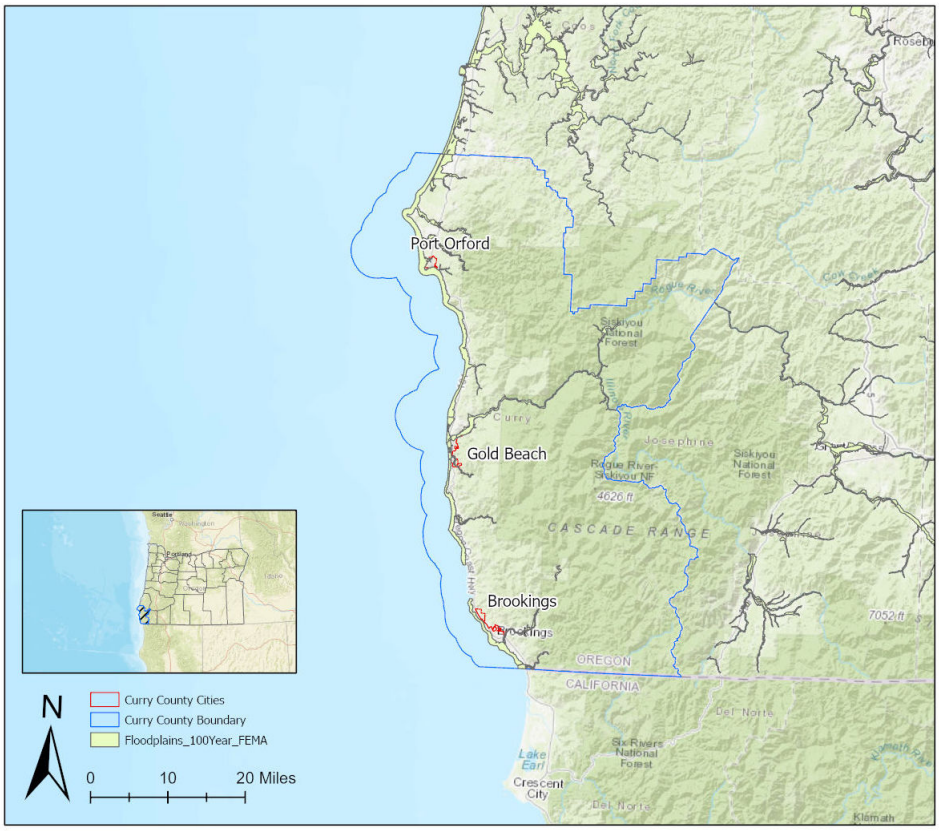


Figure 1.2: 100-Year Floodplains of Curry County

Earthquake –

Curry County, along with the rest of the Oregon Coast, is situated in close proximity to the Cascadia Subduction Zone (CSZ). The CSZ has high potential for catastrophic (magnitude 8.0 and above) earthquake. This significant seismic event would have crippling effect on public infrastructure, residences, and economic activity. Academic literature details that CSZ endures large movements with a recurrence of approximately 240 years; the last known event occurred 315 years ago (Goldfinger et al., 2012). Outside of the CSZ there are several smaller active faults within the county and within close proximity of the cities (see Figure 1.3). We can measure losses by property and infrastructural damage monetarily. Significantly, there are 88 bridges in the county which could be critically damaged in a serious seismic event. This analysis will assess the vulnerability of these bridges that are in close proximity to active faults in chapters 3 and 4.

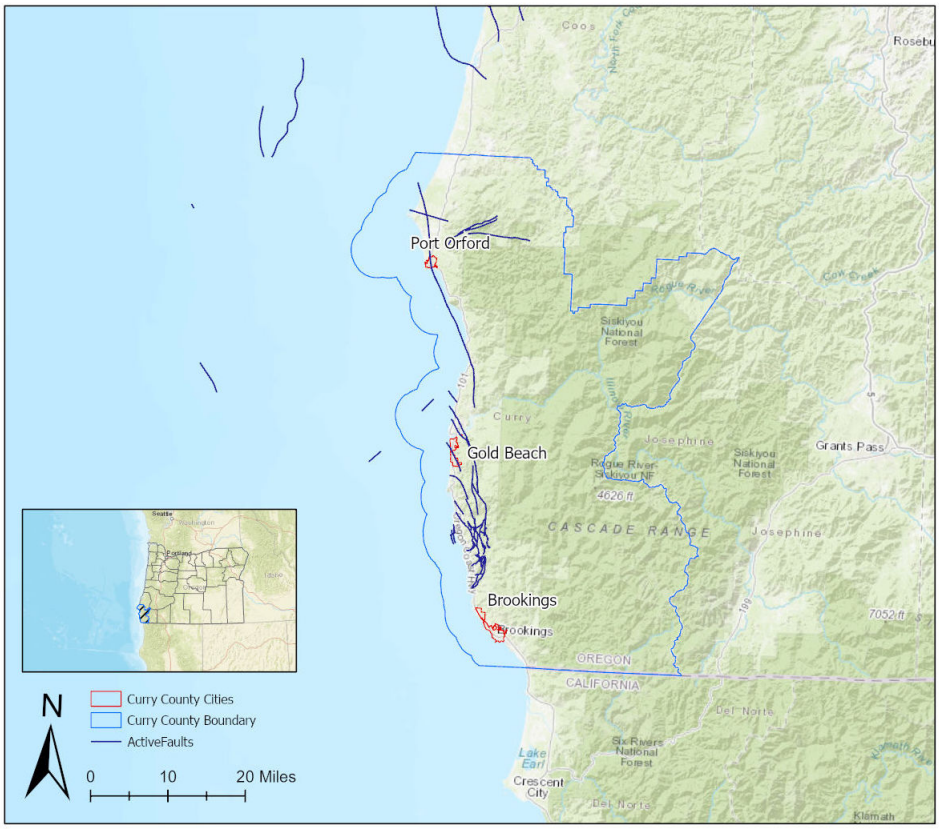
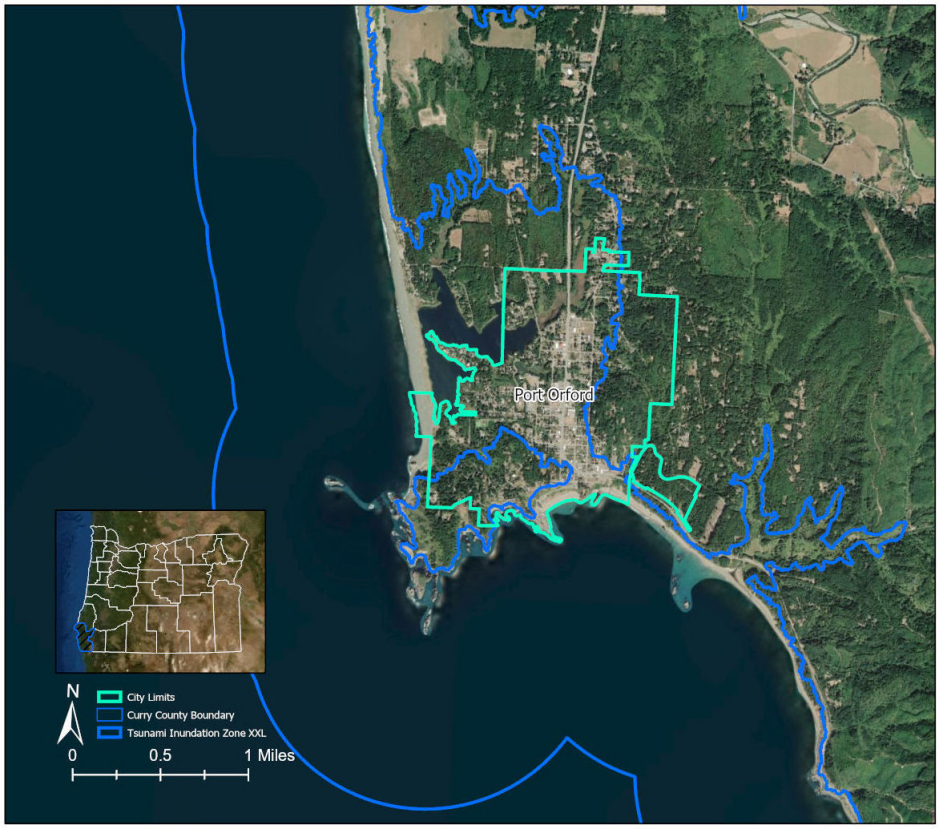


Figure 1.3: Active Faults within Curry County

Tsunami –

Destructive ocean wave surges are generated via underwater volcanic activity or earthquake. Because of the local proximity of the CSZ and the distant sources located near Alaska and Japan, Tsunami is an especially potent coastal hazard for Curry County (see Figure 1.4). As stated, a movement of the CSZ within the foreseeable future (100 years) is likely based off of historical frequency (re: Goldfinger et al., 2012). There are currently 0 tsunami land-use overlay zones within Curry County. In 2011, the Oregon Coast was damaged from a magnitude 9.0 earthquake-tsunami event originating in Japan. Significantly, this event resulted in extensive damage to the Port of Brookings and a $1.2 million FEMA relief funding to repair damages. Metrics involved in measuring losses due to tsunami include households lost, monetary infrastructure damages, and even casualties. Qualitatively, metrics to be assessed for a CSZ tsunami could include changes to quality of life including losses of community areas and recreational facilities. We will consider critical infrastructure within the tsunami inundation zone and prioritize these structures for relocation in chapters 3 and 4.


Port Orford
N
City Limits
Curry County Boundary
Tsunami Inundation Zone XXL
0
0.5
1 Miles

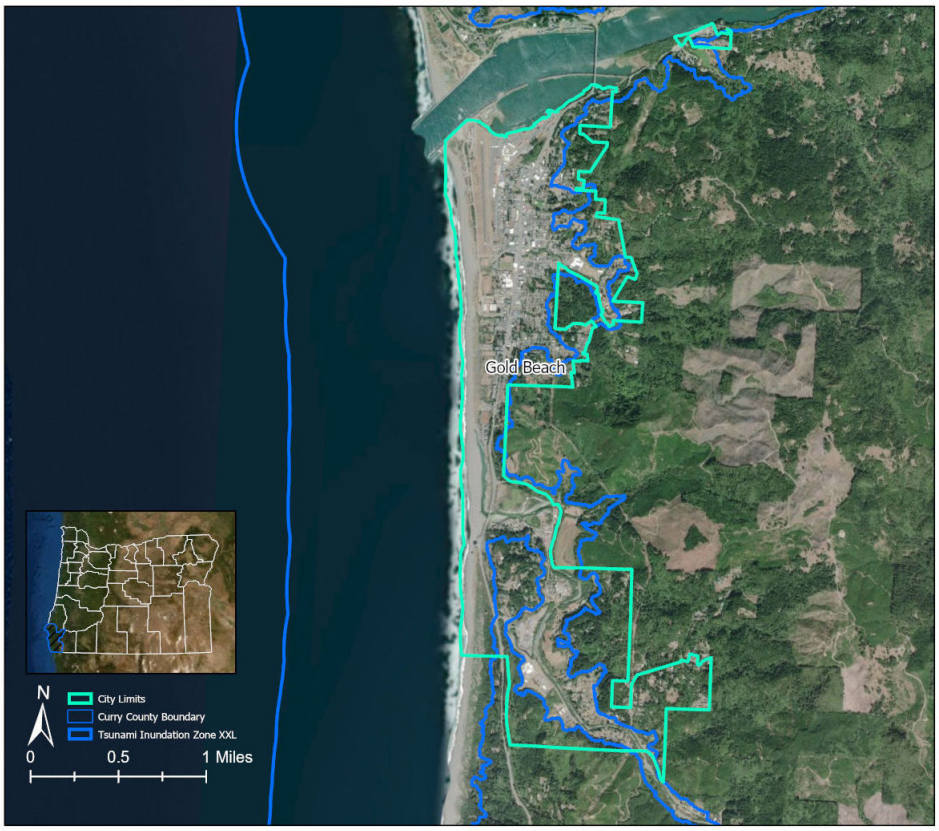

Gold Beach
N
City Limits
Curry County Boundary
Tsunami Inundation Zone XXL
0
0.5
1 Miles

Figure 1.4: Tsunami XXL Inundation Zone within Cities of Curry County

Landslide –

Landslides are a reoccurring natural hazard throughout Curry County with over 3,000 instances recorded. Landslides occur when mass of soil, rock, and other conglomerated materials flows down a slope or stream channel. Vital transportation infrastructure is most susceptible to damages due to landslides. Measuring damages via landslide is done mostly through time and costs associated with infrastructural repair.

Natural Hazards Summary –

Overall, Curry County faces many hazards but this analysis has chosen to design solutions intended for those concerned with flood, earthquake, and tsunami with particular attention to mitigation of a CSZ event. Overarching concerns with all of these hazards are connectivity and accessibility to critical infrastructure, decaying transportation infrastructure (primarily bridges), and medical facilities/fire stations located within tsunami/100-year flood zones.

Chapter 1 Conclusions –

This chapter discussed the setting and broad context of the study area of Curry County. Following discussion on demographics and economy, a narrative of natural hazards within the study area was discussed. This chapter created a foundation for hazard analysis and geodesign solutions to follow in the next chapters.

Chapter 2 – Stated Goals & Objectives

This chapter seeks to identify the goals of the county along with objectives to satisfy these goals. This chapter will provide a guide to accomplishing spatially explicit geodesign solutions to natural hazards described in chapter 1.

County Goals & Objectives:

Curry County should remain committed to the primary first and second goals of most hazard mitigation plans:

1. Protect life and reduce injuries resulting from natural hazards.
2. Minimize public and private property damages and the disruption of essential infrastructure and services from natural hazards.

With these goals in mind, a series of objectives have been developed for this analysis to be viewed by decision-makers of the county and implemented, if deemed acceptable. The following objectives and descriptions are intended to enhance efforts to accomplish goal number one:

1. Prioritize medical infrastructure within the City of Port Orford to be moved out of tsunami inundation zone.

   Increasing accessibility to critical infrastructure in case of catastrophic disaster is paramount to the protection of life and injury reduction.

2. Improve accessibility of assembly areas within the City of Gold Beach

   Evacuation centers are only effective if located within strategically connected hubs accessible from multiple roads and paths. This policy objective will work to improve the transportation network surrounding existing evacuation centers within the City of Gold Beach

The following objectives are intended to enhance efforts to accomplish county goal number two:

1. Prioritize the retrofitting of bridges located along active fault lines.

   With over 88 bridges located within Curry County, most of which built prior to 1975, seismic retrofits are essential to protecting the integrity of key public infrastructure.

2. Enhance connectivity to and from the City of Brookings.

   As the largest population center in the county, Brookings remains very isolated. In the event of catastrophic event access to services from outside the county will be essential to rebuilding and redeveloping.

Chapter 2 Conclusions

From this chapter, we have identified the overarching goals of Curry County and derived policy objectives from these. We have outlined a clear pathway from the hazards described in chapter 1 and how decision-makers of the county can confront these hazards with our policy objectives.

Chapter 3 – Policy Objective Models

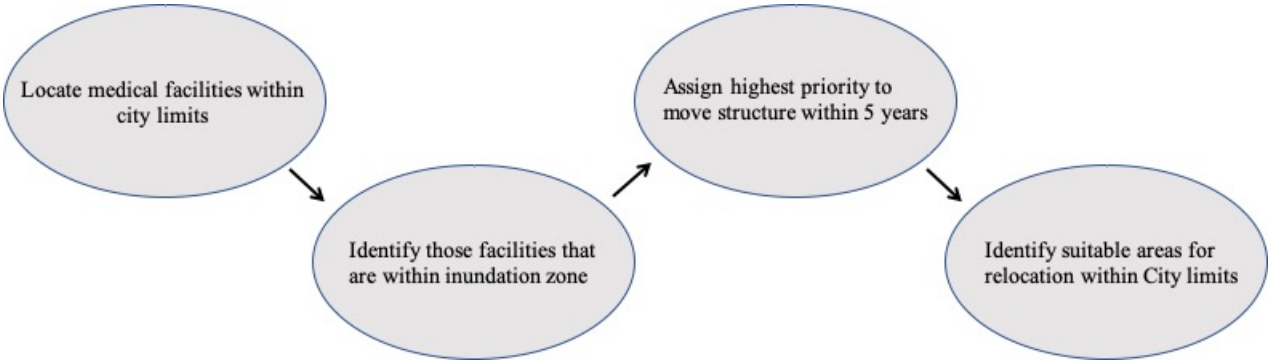
The purpose of this chapter is to demonstrate a process forward with technical and conceptual models for each of the stated policy objectives. Through these spatially-driven models, methods of meeting overarching county goals are discussed.

Conceptual Models

In an effort to advance Curry County's ability to meet the goals and objectives outlined previously, conceptual models of methods and/or processes have been created. Beginning with goal number one and objective one, models will be in sequential order.

Goal 1, Policy Objective 1

Prioritize medical infrastructure within the City of Port Orford to be moved out of tsunami inundation zone.



Methods:

In this model I focused on the medical infrastructure within the city limits of Port Orford. There are currently 3 medical facilities located inside city limits, all of which are inside the Tsunami XXL inundation zone. For my analysis I focused on the facility with the largest capacity called "Curry Family Medical". I used this data point as the input in a location-allocation network analysis. I examined tax lots inside of the urban growth boundary but outside of Tsunami XXL inundation zone. I used select by location and then select by attribute to convert all non-vacant and residential tax lots (including multi-family dwellings, mobile homes, single family residences) to point data to be used as the demand points in the location-allocation. I then selected 4 suitable locations for a new medical facility based on vacant tax lots that were closest to demand points and outside of the inundation zone. All data used in this policy objective is readily available in the class geodatabase and includes, tsunami inundation boundary, Oregon tax lots, and Oregon city limits and urban growth boundaries. The main limitations of this model involve monetary barriers involved with the relocation of a medical facility which currently remains to be resolved.

Goal 1, Policy Objective 2

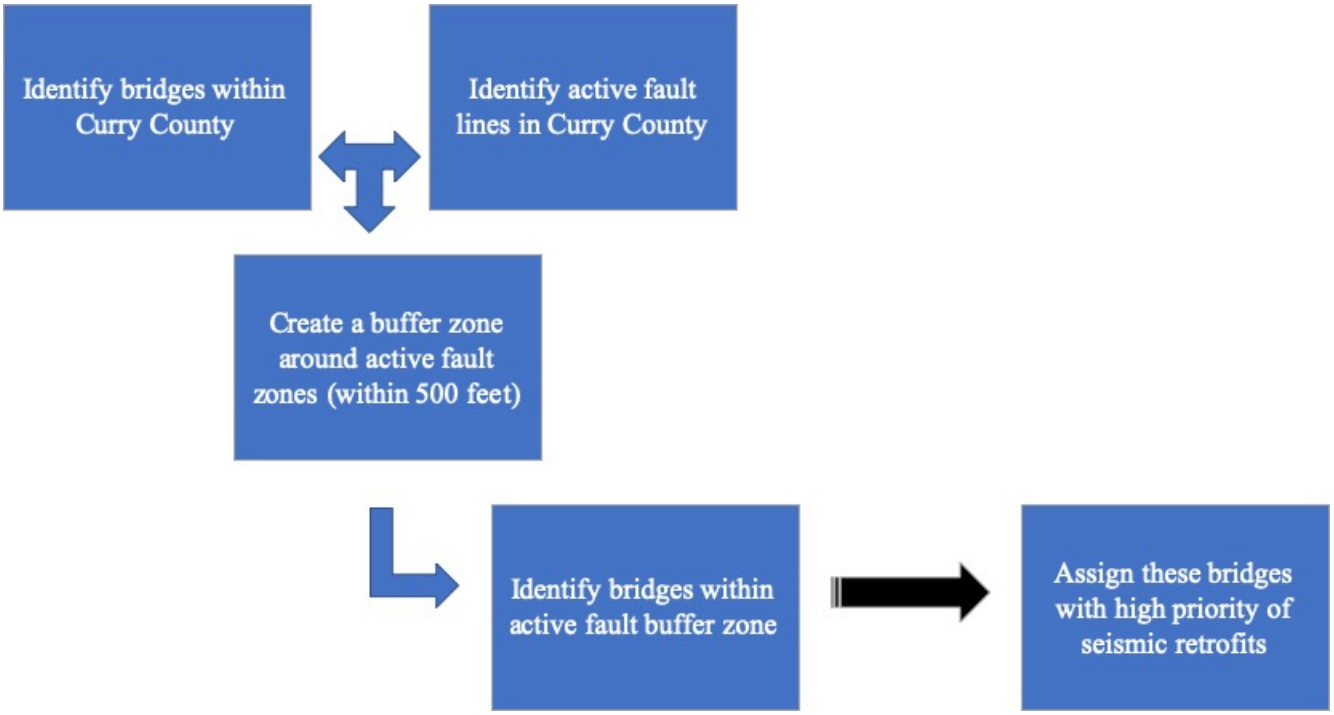
Improve accessibility of assembly areas within the City of Gold Beach.

Methods:

This model focused on the assembly area point data directly within the city limits of Gold Beach. I examined current assembly areas within city limits and assessed accessibility using a service area network analysis by walking time. Bridges were used as point barriers in the analysis. Based on the observed isolated or non serviced areas I created additional assembly areas in currently undeveloped vacant tax lots outside of Tsunami XXL inundation zone. After adding additional assembly areas I used the same service area analysis with the same parameters and used select by location to find out how many residential tax lots are being serviced by the new assembly areas. All data utilized in this policy objective comes from the class geodatabase and consists of the Oregon tax lots, Tsunami inundation boundary, Oregon city limits boundary, and assembly area shapefile (clipped to within city limits). Limitations of this model include the unpredictability of road and path conditions that result from a high magnitude earthquake. Significantly impaired road conditions could greatly impact ability for residents within service area of assembly areas to reach their destination.

Goal 2, Policy Objective 1

Prioritize the retrofitting of bridges located along active fault lines.

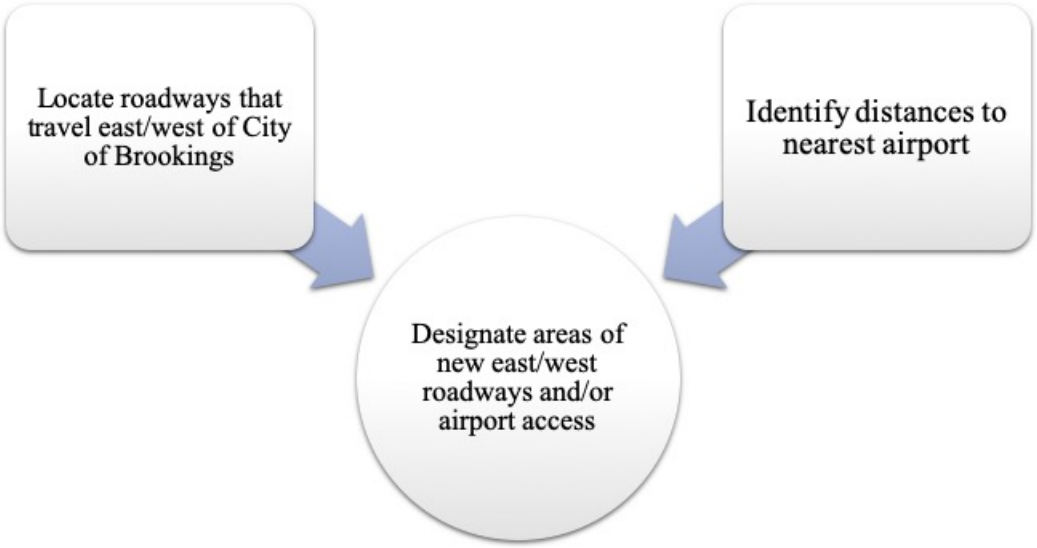


Methods:

This model utilized bridge point data clipped to the Curry County administrative boundary and the active fault line data. I created a rounded buffer that extends 500 feet around the active faults data. I then used select by location to select bridges that fell within the this buffer. I created a new feature with only these bridges and symbolized them to stand out from the other bridges outside of the fault lines buffer. The limitations involved with this model include the size of buffer zone and the unknown quantity as to what extent the active fault can damage the selected bridges.

Goal 2, Policy Objective 2

Enhance connectivity to and from the City of Brookings.



Methods:

In this model I analyzed the Oregon Department of Transportation (ODOT) road network and airport point data. I used simple measure tools to determine distances to nearest airport facilities outside of Brookings and the Tsunami XXL inundation zone. I looked for potential road networks leading east out of the county. I utilized digital elevation models where available to examine feasibility of road construction in rural areas. I edited the road network to add new roadway that followed topography and geographical barriers as best able. I then measured again to find out distances and travel times to nearest airport facilities. Data for this policy objective is available from the Oregon Spatial Data Library and the class geodatabase. Limitations of this model is mainly lack of elevation data in rural Curry County to accurately create a comprehensive output.

Chapter 3 Conclusions

This chapter established conceptual models that clearly connect the natural hazards described in chapter 1 with the policy objectives established in chapter 2. These conceptual models are described in detail with processes and data sources as well as possible limitations. These models are meant to illuminate the process and potential methodology of satisfying policy objectives identified in chapter 2.

Chapter 4 – Findings

The purpose of this chapter is to examine the results of running conceptual models discussed in the previous chapter and determine the success of results in accomplishing their respective goals. This chapter is meant to be a culmination of all previous chapters and retrospectively compare baseline conditions with model results using quantitative and qualitative metrics.

Cost & Social Metrics:

It is vital to quantify effects of natural hazards, indeed, it could be the determining force in whether a decision-making body moves forward with changes. In the case of many policy objectives, the solutions being explored are attempting to mitigate catastrophic hazard events, namely a Cascadia Subduction Zone event. The impacts of a CSZ are largely unknown and this analysis attempts to quantify the impact based off of financial costs incurred primarily from infrastructure loss or repair located within inundation zones or along active faults. The social costs incurred from a CSZ would be tremendous, this analysis will focus on the dramatic changes to character and quality of life, such as loss of recreational areas and livelihood opportunities. Other possible quantitative metrics include loss of industry revenue which could be measured from loss of hotels or lodges within inundation zone or annual revenue taken in from ports within the county. Each policy objective will be listed with a quantitative metric and a cost metric in a table. Social and qualitative metrics will be discussed in the description following each table.

Policy Objective 1.1

Prioritize medical infrastructure within the City of Port Orford to be moved out of tsunami inundation zone.

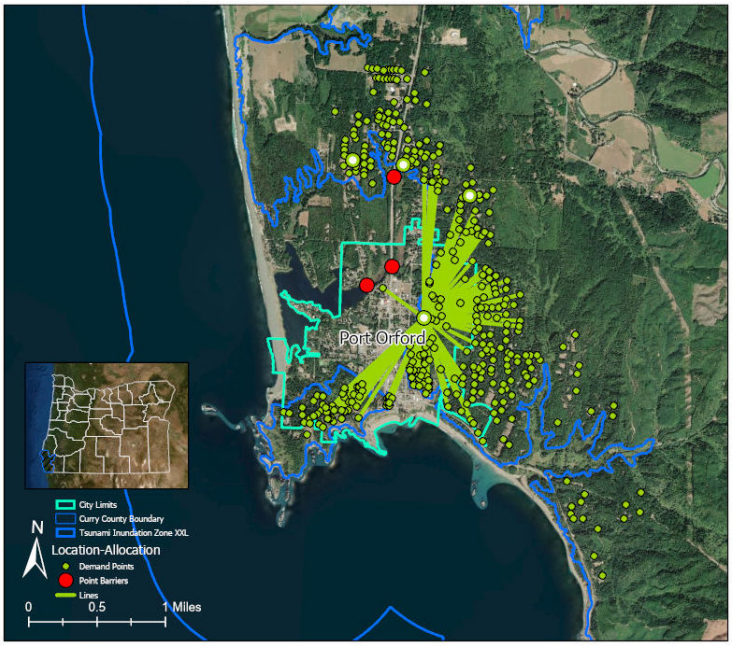


Figure 4.1: Policy Objective 1.1 Results

This objective sought to limit loss of life from a local CSZ Tsunami event. The relocation of the "Curry Family Medical" hospital is critical to limiting loss of life after such an event. The location of the medical center currently lies at the heart of the city and the inundation zone. From running a location-allocation network analysis (see methods in Chapter 3) I was able to determine the most suitable location with optimum service of residential areas outside of the inundation zone (see Figure 4.1).

Table 2: Policy Objective 1.1 Metrics

Policy Objective	Metric Evaluated	Total	Cost Estimate
1.1 Relocate medical facility in Port Orford	Households serviced by relocated facility	150 of 365 households	~$5.0 Million

Metrics associated with this policy objective (see Table 2) is primarily households being served by the relocated facility. The assumption here is that if the current location of the medical facility is maintained then there will be no households served as the facility would be disabled from the Tsunami event. The cost estimate associated is mainly the costs of designing and constructing a new facility in an undeveloped plot determined from my analysis. Social metrics involved with this policy objective involve the peace of mind of the residents of this community that in the case of such a disaster there will be a facility out of the danger zone.

Policy Objective 1.2

Improve accessibility of assembly areas within the City of Gold Beach.

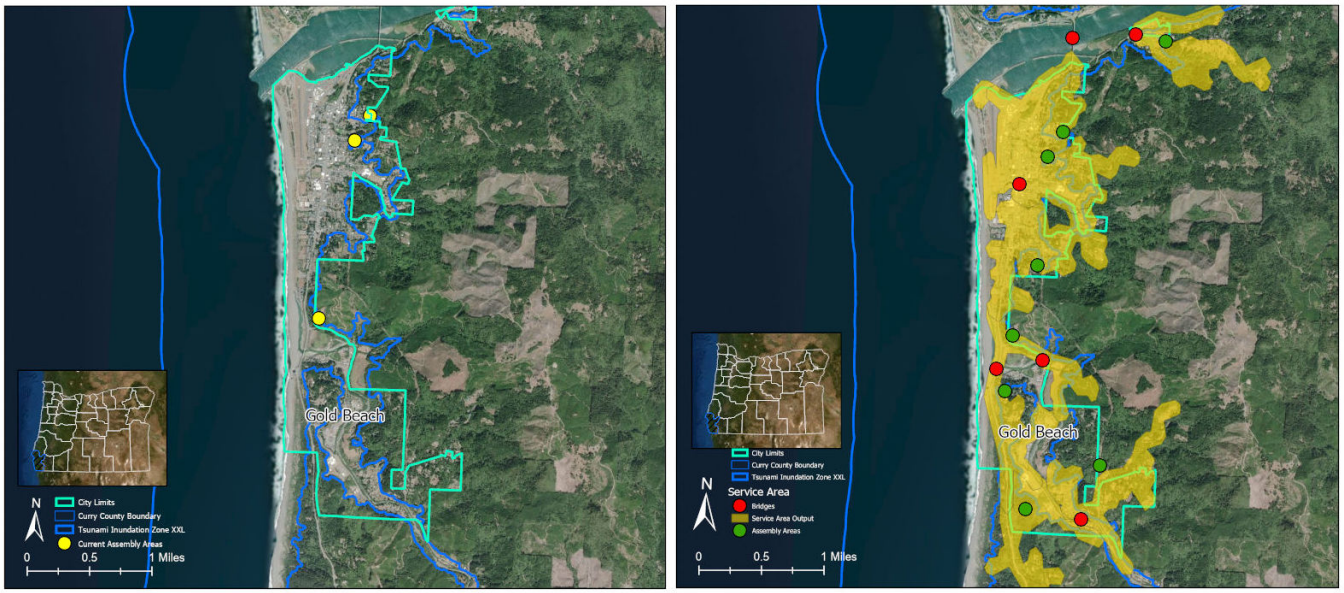


Figure 4.2: Policy Objective 1.2 Results with Baseline Assembly Areas (left)

The aim of this policy objective was to prevent loss of life by increasing access to assembly areas within city limits of Gold Beach. Assessing the service areas of the current three assembly areas, I found it to be inadequate accessibility for many households within the city limits (see Figure 4.2). These three service

areas only covered 567 out of 1,800 households. Following the addition of 5 new service areas this coverage was expanded to a total of 1,234 of 1,800 households.

Table 3: Policy Objective 1.2 Metrics

Policy Objective	Metric Evaluated	Total	Cost Estimate
1.2 Improve accessibility of assembly areas in Gold Beach	Households serviced by assembly areas	1,234 of 1,800 households	~$500,000

Metrics associated with his policy objective (see Table 3) are the households serviced by assembly areas. An assumption of this policy objective is that road and path networks would be intact enough after a CSZ event to navigate to the designated assembly area. The cost estimated for this objective was mainly based on the time of city and county employees to designate these assembly areas and for the printing and outreach efforts to educate residents. The social metric associated with this objective is the quality of life and livelihood change that a local Tsunami event would cause in Gold Beach. Gold Beach is an extremely popular location for tourists on the southern Oregon Coast and the majority of the city limits are within the Tsunami inundation zone. The changes to livelihoods and daily life would be immeasurable.

Policy Objective 2.1

Prioritize the retrofitting of bridges located along active fault lines.

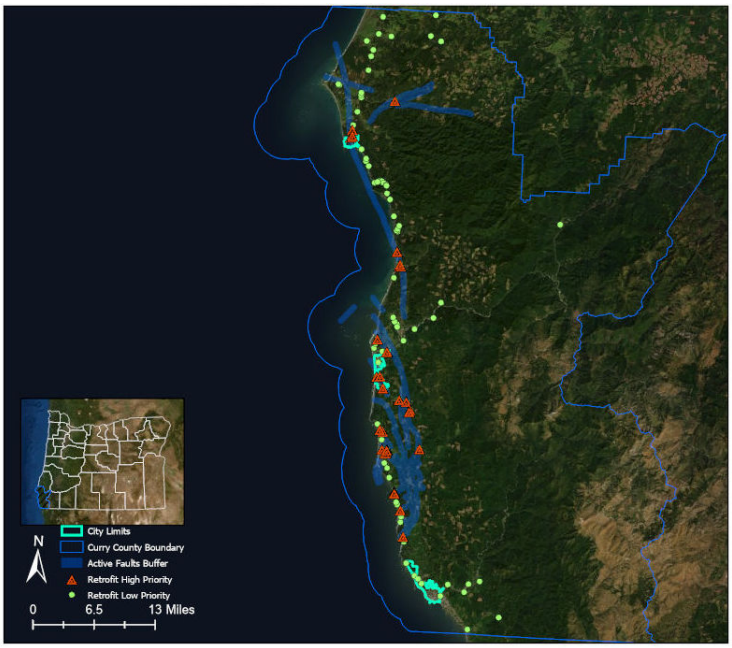


Figure 4.3: Policy Objective 2.1 Results

This policy objective is designed with maintaining access to lifeline services and amenities in the event of a local seismic event. Curry County has an extensive bridge network with over 88 throughout the region. The majority of these bridges were built prior to 1975 and lack the capability to withstand a moderately large seismic event. My analysis utilized local fault lines to determine bridges within 500 feet as a way of creating

a higher priority subset for retrofitting. The mapped results of these high and lower priority bridges can be seen above (see Figure 4.3).

Table 4: Policy Objective 2.1 Metrics

Policy Objective	Metric Evaluated	Total	Cost Estimate
2.2 Enhance connectivity of Brookings	Brookings households served by new roadway	~3,675 households	~$25.6 million

The primary metrics associated with this policy objective are tied to a main economic industry of the region, tourism (see Table 4). The tourism spending along the southern Oregon Coast is estimated to be about $400 million annually (Travel Oregon). The assumption of the metric is that in the event of a moderate to large local seismic event a bridges along the main north-south corridor (Highway 101) would be disabled and require replacement. Further, my analysis found 29 bridges located within active fault line buffers with 12 located along Highway 101. In this event, a lengthy amount of time would render many parts of the southern coast inaccessible and would create economic losses. Social metrics involved would involve change to the quality of life and isolation to many recreational areas that residents cherish about the southern coast including Samuel H Boardmen State Park renowned for its outstanding natural beauty.

Policy Objective 2.2

Enhance connectivity to and from the City of Brookings.

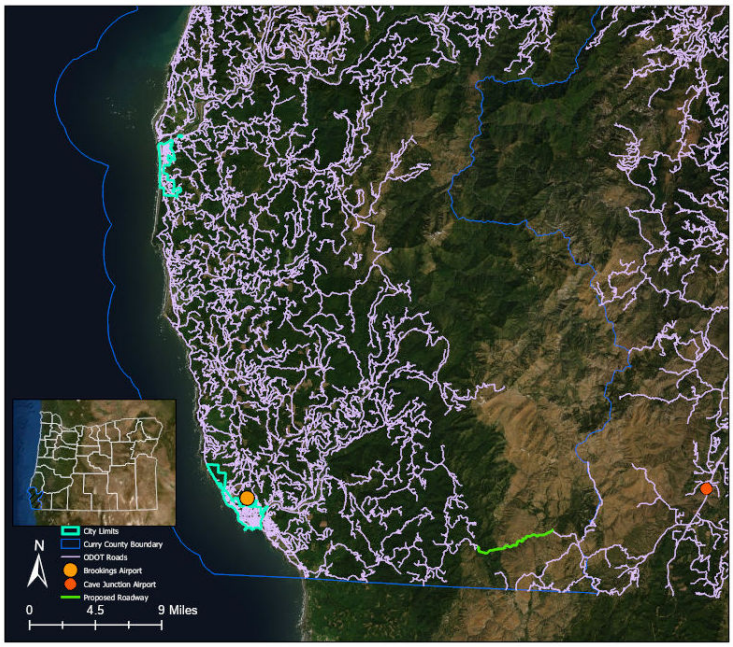


Figure 4.4: Policy Objective 2.2 Results

The final policy objective was intended to preserve existing economic activity and sense of normalcy as much as possible after a local CSZ event. Given the City of Brookings significantly isolated geographic location (see Figure 4.4) and its prominence as a very busy and active recreational and commercial port, access to

outside services and amenities post-disaster is essential. The Port of Brookings is the busiest recreational port on the Oregon Coast with over 5,000 commercial fishing vessels that visit annually (Port of Brookings Harbor website). With this significant economic activity, enhanced east-west connection is necessary to recover post-disaster. While the Brookings airport is located outside of the inundation zone the next closest accessible airport outside of the inundation zone is in Port Orford (56 miles north) or with traveling into California. The nearest east-roadway is either north of Gold Beach or Highway 198 out of Crescent City in California. This objective designed a new roadway to connect Brookings to an inland airport in Cave Junction (˜32 miles east).

Table 5: Policy Objective 2.2 Metrics

Policy Objective	Metric Evaluated	Total	Cost Estimate
2.2 Enhance connectivity of Brookings	Brookings households served by new roadway	~3,675 households	~$25.6 million

Metrics for this objective were concerned primarily with the households within the Brookings' urban growth boundary (see Table 5). The assumption accompanying this metric is that the additional east-west connection would allow services and amenities to flow more freely to the area both during the event of disaster and day-to-day life. The cost metric was based on rural road development and maintenance estimates nationally. A possible social metric involved with this objective is the potential benefit of increased visitors and economic benefit associated with increased outside accessibility.

Chapter 4 Conclusions:

This chapter discusses the quantitative and qualitative metrics involved with potential impacts from natural hazards explored in previous chapters. This section also included findings from the conceptual models with figures and discussion of success with meeting overarching policy goals.

Chapter 5 – Recommendations

The primary goal of this analysis is to report the most effective design alternative based on all metric and parameters being evaluated. This chapter will give a basis for which policy objective should be incorporated by decision-makers of Curry County.

Table 6: Recommended Policy Objective

Policy Objective	Metric Evaluated	Total	Cost Estimate
1.1 Relocate Medical facility in Port Orford	Households serviced by relocated facility	150 of 365 households	~$5.0 Million
1.2 Improve accessibility of assembly areas in Gold Beach	Households serviced by assembly areas	1,234 of 1,800 households	~$500,000
2.1 Bridge retrofits	Potential revenue loss from tourism	~$206.5 million	~$1.2 million per bridge
2.2 Enhance connectivity of Brookings	Brookings households served by new roadway	~3,675 households	~$25.6 million

Recommendation – Policy Objective 1.2

Considering all policy objectives with metrics (see Table 6) one policy objective clearly offers high benefits with the lowest cost associated. Policy objective 1.2 creates a better environment of safety within the City of Gold Beach and can serve as an example to the rest of Curry County. Increasing the designated assembly areas within city limits shows a greater value in the safety and peace of mind of the area's residents. This policy objective also could provide visitors to the community improved risk perception. For this objective to be successfully implemented it will require outreach and education of local residents and visitors to the community. The next steps of implementation is gaining approval from County and City officials and acquiring easements of the proposed new assembly areas. Signage and local outreach should be conducted to inform the public of updates to the local disaster plans. Indicators of progress towards implementation can be affiliated with success of outreach and education of residents and visitors. This indicator can be measured with surveys and questionnaires of both residents and tourists. There are limitations with this objective, as with any new design intervention, in this case it is the uncertainty of the effectiveness of the assembly areas given the magnitude, extent, and awareness of the population in the hazard vicinity.

Chapter 5 Conclusions:

This chapter is a culmination of this entire report. Drawing on the context and baseline of Curry County, I suggested the most economically feasible and beneficial policy objective to be implemented. With continued vigilance and analysis of natural hazard susceptibility Curry County can be an example of resilience to the rest of the state.

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