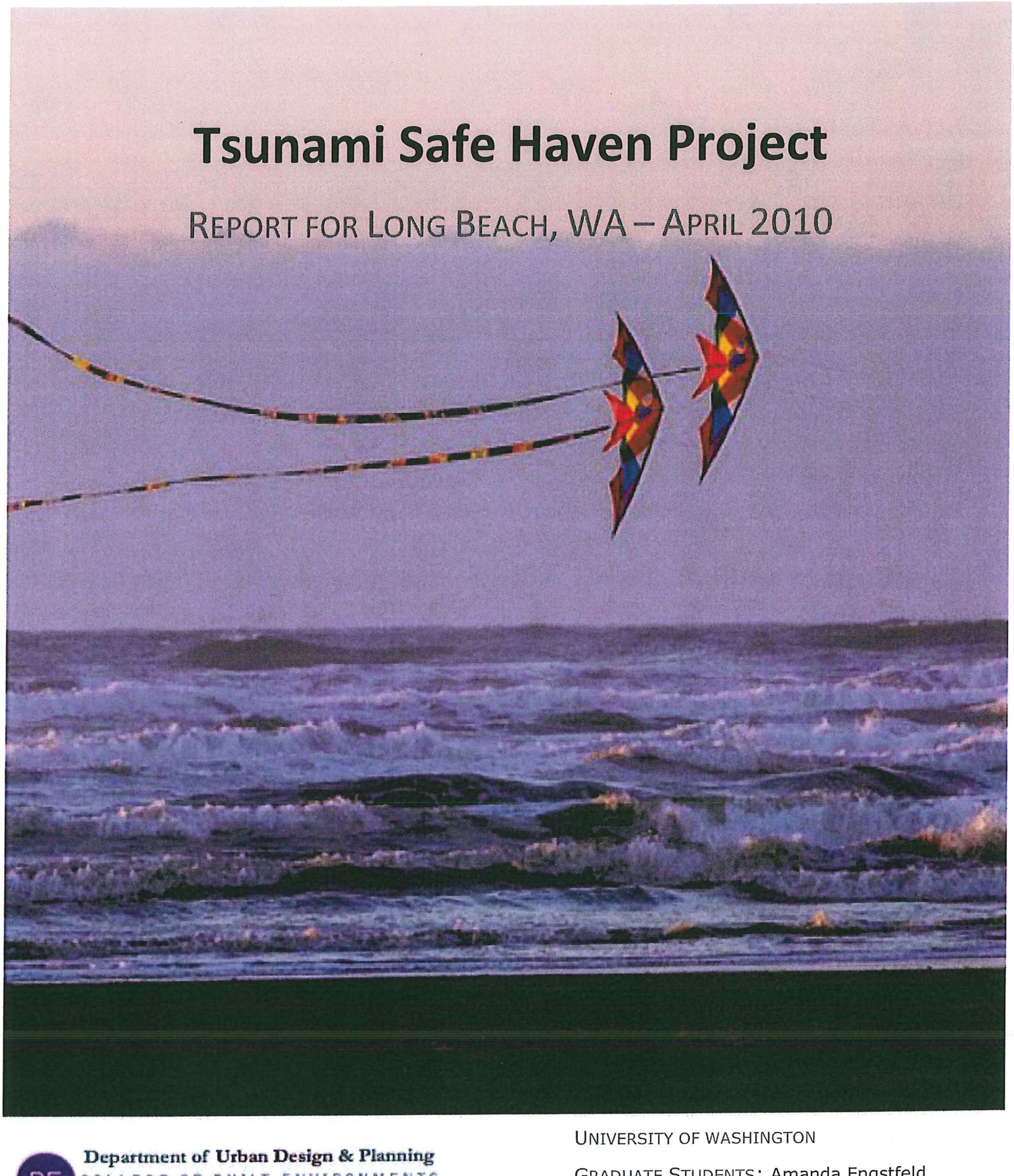
Tsunami Safe Haven Project

Report for Long Beach, WA – April 2010



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Executive Summary

Due to its proximity to the Cascadia subduction zone and lack of high ground, the Long Beach Peninsula on the Washington state coast is vulnerable to significant damage from a tsunami. A large magnitude subduction zone quake, such as the one that occurred off Washington's coast in 1700, will produce a multi-story tsunami wave that will strike the peninsula approximately 40 minutes after cessation of shaking. While the window of evacuation opportunity may be up to 40 minutes we used 25 minutes as a margin of safety in regards to planning for orientation and evacuation time. The long, low profile of the peninsula, combined with damage to roadways caused by the earthquake, will make evacuation to high ground difficult for much of the population.

The peninsula's vulnerability to a tsunami spurred interest among state and local officials in regards to evacuation options that allow people to move upwards, into vertical safe havens. The Tsunami Safe Haven Project at the University of Washington was developed out of this interest. Its purpose is to assess and propose vertical evacuation options for communities along the peninsula, with a focus on developing strategies that are based on community input and ideas.

From January to March 2010, graduate students and faculty worked with state and local officials, hazard experts, and community members to develop vertical evacuation strategies for the City of Long Beach. The project adopted a six-phase methodology to accomplish its task. In the first phase, a Steering Committee composed of local officials, emergency managers, and scientists was created to advise the project. The Steering Committee, faculty, and students selected the City of Long Beach as the first project location along the peninsula based on its vulnerability and interest in vertical evacuation expressed by local officials. In the second phase, students conducted a site visit to Long Beach to gather information and meet with the city administrator. An initial community meeting was held several weeks later to present three vertical evacuation options – earthen berms, towers, and buildings – to community members. Meeting participants used interactive maps to discuss potential sites for vertical evacuation structures.

In the fourth phase, students translated community members' ideas into three alternatives, each involving a series of berms. The strengths and weaknesses of the three alternatives were discussed at a second community meeting, and community members proposed combining two of the alternatives into one preferred strategy. In future months, the community will continue discussing the preferred strategy, and a similar series of community meetings will take place in other locations on the peninsula. Once preferred strategies are developed for other communities, a peninsula-wide meeting will take place to reassess the strategies for comprehensiveness, redundancy, and coordination.

The selected preferred strategy for Long Beach consists of one large, multi-purpose earthen berm located behind the elementary school, four additional berms dispersed along the eastern boundary of the city, and, if funding becomes available, an elevated city hall. The berm behind the school will be prioritized for construction to ensure a safe haven for the community's children.

I. Introduction

Lacking high ground and sitting within close proximity to the Cascadia subduction zone, the Long Beach Peninsula on the Washington state coast is vulnerable to significant damage from a tsunami. The purpose of the Tsunami Safe Haven Project at the University of Washington is to develop vertical evacuation options for the peninsula; ways for residents and visitors to move upwards to safety rather than need to evacuate from the peninsula. This report documents the methodology and results from the project's work with the City of Long Beach. In the sections below, the report provides an overview of the hazard and community, the steps taken to develop and refine vertical evacuation strategies for Long Beach, and a description and assessment of the preferred strategy.

II. Background

A. Hazard Profile

The Long Beach Peninsula is vulnerable to two types of tsunamis: those created by a distant seismic event (such as an earthquake near Japan), and those created by a local, offshore earthquake. Because a distant event would not cause seismic damage to roadways and would produce a tsunami requiring several hours to reach Long Beach, people might have ample time to receive warning and evacuate via automobile to high ground. However, a local earthquake event would cause tremendous damage from the earthquake itself and leave little time for people to escape to higher ground before inundation from a tsunami. The short evacuation timeframe after a local event and lack of natural high ground necessitates the development of vertical evacuation strategies that are easily and quickly accessible by foot.

To create and assess vertical evacuation strategies for Long Beach, the Tsunami Safe Haven Project uses a modeled subduction zone earthquake hazard scenario developed in part by Priest, G.R. and others, 1997 and recently referenced by Cascade Region Earthquake Workgroup (Priest et. al, 1997; Walsh et. al, 2000; CREW, 2005). The scenario is a local Cascadia Subduction Zone earthquake with a magnitude 9.1 on the Richter scale. An earthquake of this size occurs off the Washington coast every 500 years, on average, with the last one taking place in January 1700 AD. Evidence of the magnitude of the 1700 event is found in historic and geologic records of a tsunami that struck Japan following the quake (Satake et. al, 2003; CREW, 2005).

A local subduction zone earthquake will originate approximately 80 miles off of the Pacific Northwest coast and will likely cause approximately six feet of subsidence on the Long Beach Peninsula. The earthquake will last five to six minutes and will create a tsunami that will take approximately 40 minutes to reach the peninsula after cessation of shaking. While the window of evacuation opportunity may be up to 40 minutes we used 25 minutes as a margin of safety in regards to planning for orientation and evacuation time. The modeled tsunami will have a wave-height of approximately 22 feet (NGVD) at the peninsula's western shore, depending upon localized bathymetry and topography. Several other waves will likely follow the initial wave, and there will be danger of recurring waves throughout the entire post-event tide cycle. The recent 8.8 magnitude earthquake in Chile produced at least three local waves. Of these three, the third wave was the largest and most destructive (Warren and Vagara, 2010).

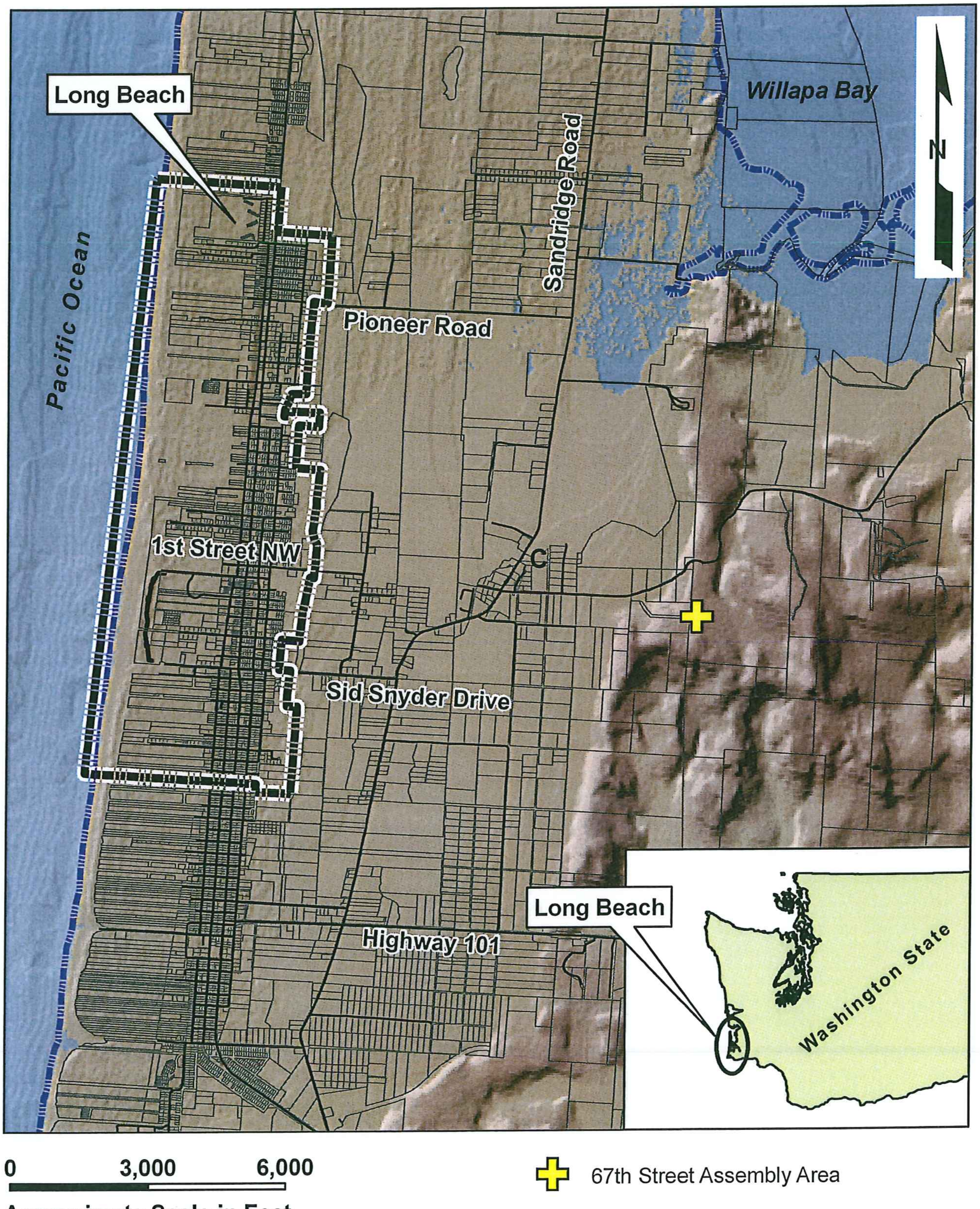
B. Community Profile

The City of Long Beach is located on the southwestern coast of Washington in Pacific County. The city itself is located on the long and narrow Long Beach Peninsula, which gains very little elevation above sea level. Because of its proximity to the Pacific Ocean, Long Beach experiences seasonal population fluxes. The permanent population of the city lies between 1,350 and 1,400. During large events and festivals in the summer, the city's population can reach 4,000 - 5,000 people. The city's housing stock reflects these population fluxes. Only 57% of the housing stock is lived in full-time, and vacation rentals comprise 43% of the housing. The city contains 147 recreational vehicle (R.V.) parking spaces, 542 hotel rooms, and 20 bed and breakfasts to accommodate seasonal tourists and visitors. See **Figure 1** for a map of Long Beach and the surrounding area.

Of Long Beach's permanent residents, 23% are under the age of 24, 23% are between the ages of 25 and 44, 29% are 45 to 64, and 25% are over 65 years (U.S. Census, 2000). The median age is 47. The project gave special consideration to the evacuation capabilities and limitations of the large number of people over the age of 50.

Permanent residents of Long Beach are both educated and familiar with the threat of a tsunami. Multiple tsunami evacuation signs are located along major arterials and thoroughfares. Local businesses have embraced the tsunami hazard in their products and logos. One may try a "Grand Tsunami Burger" at the Corral Drive-in or get a cup of coffee at the Long Beach Coffee Roasters, whose sign depicts a tsunami of coffee leaping out a coffee cup. The awareness of the residents of Long Beach to tsunamis was heightened in June 2006 when the Weather Forecast Office (WFO) of Portland, Washington Emergency Management, and Pacific County held two tsunami education workshops. More than 60 people attended each meeting.

Figure 1 - Long Beach, Washington and Surrounding Area



Sources:

NOAA National Center for Tsunami Research 1/3" DEM
Vertical Datum: Mean High Water Vertical Units: Meters

NOAA Medium Resolution Digital Vector Shoreline - NAVD 1929:
http://coastalgeospatial.noaa.gov/data_gis.html

III. Methodology

The Tsunami Safe Haven Project assessed Long Beach's vertical evacuation needs and created a recommended course of action in six phases. The six-phased methodology includes the following:

1. Selection of the project community and steering committee
2. Site survey and development of approach
3. Identification of alternatives by community
4. Assessment of alternatives and development of preferred strategy from a Strengths, Weaknesses, Opportunities, and Threats analysis (SWOT)
5. Community mulling and acceptance of preferred strategy
6. Reassessment of preferred strategy following peninsula meeting

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1. Selection of the project community and steering committee

The Tsunami Safe Haven Project is the result of concern arising from the 2004 Indonesian Tsunami. Following the event, state and local officials and residents realized that many communities along the southwestern coast of Washington have little possibility of evacuating following a local, offshore tsunami. In 2008, FEMA and NOAA released guidance on vertical evacuation (FEMA P646: Guidelines for Design of Structures for Vertical Evacuation from Tsunamis), and at-risk Pacific Coast communities began efforts to apply the guidance locally. For example, Cannon Beach, Oregon held a workshop on the possibility of building an elevated city hall that would serve as a tsunami safe haven.

In Pacific County, local officials documented the tsunami risk in the Pacific County Hazard Mitigation Plan. At the direction of the State Earthquake and Tsunami Program Officer and Pacific County Emergency Manager, the University of Washington Tsunami Safe Haven Project took a different approach to tsunami safe havens than has been used in other locations – one with greater community involvement and input. The City of Long Beach was selected as the first site for the project because of its vulnerability and interest expressed by its elected officials. When the project began, the Long Beach City Administrator became the community contact and took responsibility for community involvement.

A Steering Committee was selected to provide oversight, with members ranging from local officials to emergency managers and scientists. The students held weekly conference calls with the Steering Committee to discuss relevant, new, and changing information about the project. The Steering Committee, advising faculty, and students agreed upon the potential implementation of berms, towers, and/or buildings with guidance from FEMA P646.

The following are definitions of the three potential structures based on information in FEMA P646:

Berm: Berms are artificial high ground created from soil. They typically have 1-4 ramps providing access from the ground to the elevated surface. Berms have a large footprint on the landscape, giving the appearance of an engineered and designed hill. A small berm of 1,000 square feet can hold 200 people providing each person five square feet of space. A berm can range in size, from 1,000 square feet for 200 people extending up to 100,000 square feet for 20,000 people. Costs of berms vary due to size and height factors.

Tower: A tsunami evacuation tower can take the form of a simple elevated platform above the projected tsunami wave height, or the form of a tower, such as a lighthouse, that has a ramp or stairs leading to an elevation above projected wave height. A 500 square foot tower can hold 100 people and a 1,000 square foot tower can hold 200 people when allotting five square feet per person. Costs of vertical platforms vary due to size and height factors.

Building: A building used as a tsunami evacuation structure has a ground floor that allows the tsunami wave to move through it or is faced in a manner that the structural integrity of the building will support the force of the wave. Tsunami refugees seek safety in the upper floors of the building. Typical tsunami evacuation buildings are hotels or parking structures.

2. Site survey and development of approach

The students first visited Long Beach on January 22-23, 2010 to become familiarized with the at-risk community. Students toured the peninsula, noting the low elevation, general lack of physical features, and dune cuts near the center of town. On the second day of the visit, the students met with Gene Miles, City Administrator of Long Beach. Miles provided the students with information about the new 67th street assembly location, which is currently under construction and, when completed, may potentially house a warehouse stocked with emergency supplies. The students also visited the local school, Long Beach Elementary, located just east of the main thoroughfare, Pacific Avenue, and noted parcels of vacant land in the downtown area.

3. Identification of alternatives by community

The first community meeting was held on February 11, 2010. The meeting utilized the World Café meeting process to identify and discuss alternatives. The World Café process is a "café style" conversation that facilitates small group brainstorming. It is commonly referred to as, "conversations that matter." Participants discuss key issues at one of three stations, with one participant at each station facilitating the discussion and taking notes. When the allotted time ends, station participants rotate to another station, leaving one member behind to facilitate and share notes with the incoming group. This process typically continues until every participant has had a turn at each station.

The City Administrator invited twelve individuals representing public, private, business, resident, and nonprofit sectors to the first meeting. Seven community invitees attended the meeting and were assigned to one of three groups. Five county and state invitees also attended the meeting and participated in the discussion, and four UW students assisted in the World Café process. A student representative was located at each station and acted as facilitator and note taker. The fourth student acted as an overall meeting facilitator and note taker.

Each station was given a table-sized map of Long Beach and was asked to examine one of the three types of vertical structures (berm, building, and tower). The purpose of each table group was to propose and discuss possible sites and sizes for the structures using tools such as foam cutouts and walking circles. Each station was given foam board cutouts representing the footprints of their assigned type of structure. Station participants were also given two walking circles, one representing the radius an average healthy person can walk in 15 minutes: average four feet per second, averaging 3,600 feet in 15 minutes and the other representing the radius a person over the age of 65 can walk in 15 minutes: average three feet per second averaging 2,700 feet in 15 minutes (Manual on Uniform Traffic Control Devices, MUTCD). The participants moved the walking circles to different places on the map to assess the accessibility of different locations for berms, buildings, and towers. The students introduced the assumption that despite a warning time of approximately 40 minutes for a local tsunami, earthquake shaking, road/sidewalk conditions, and general confusion would reduce the amount of time a person had to evacuate to 15 minutes. The participants used the walking circles to determine whether residents could reach their proposed structure location given the evacuation time constraint of 15 minutes.

Participants at the first station were allotted 25 minutes to discuss siting alternatives. The second session lasted 20 minutes, and the third session lasted 10 minutes. During all three rounds, observers moved around the room to make suggestions and record observations. The observers included a Pacific County Emergency Management official, a state Emergency Management official, and a University of Washington faculty member.

Some of the recorded comments during the rounds include:

- Additional street names on maps would be helpful
- Better explanation of wave height gradient would be helpful
- Chopsticks showing water direction (dune cuts) are useful
- The use of red to show tsunami inundation levels is confusing since water is usually colored blue on maps
- Participants seemed very engaged working with the maps
- At least five minutes were needed for explanation of what was discussed during the first round
- World Café process/intention during the second round needs to be better introduced by the facilitator
- More pictorial examples of potential structures need to be provided

The World Café approach proved to be effective because each meeting attendee was engaged and participated fully. The large maps at each table facilitated participation by providing a way for participants to actively manipulate the building footprint cutouts and walking circles. After completing three rounds, the meeting participants reconvened to discuss the outcomes of each of the stations. The students recorded the information and input from this meeting to inform step four, assessment of alternatives for vertical evacuation.

Although not carried out in this meeting, in future meetings the participants may, when moving to the second round, incorporate both the original structure type and the new structure type into the discussion of siting and size of structure rather than just focus on each structure type independent from the others. For example, participants who discuss berms during the first session would examine berms and a second type of structure, such as towers, during the next session. When participants rotate in the third round, they would finish the World Café process by discussing all three safe haven structure types together.

4. Assessment of alternatives and development of preferred strategy

After the first meeting, the students compiled their notes and developed three alternatives based upon participants' proposed locations and overall input. See Appendix A for maps of the alternatives, which included the following:

1. Alternative One: Five berms located along the eastern boundary of the city
2. Alternative Two: Four berms located along the eastern boundary of the city and one public building
3. Alternative Three: Five berms and three potential hotel developments or redevelopments

After generating these alternatives, a second meeting was held with the participants of the first meeting. Students presented and explained the alternatives, and then asked the participants to conduct a Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis of the three alternatives. When used as a planning tool, a SWOT analysis can help identify supporting and unfavorable internal and external factors of a project. Students gave participants a SWOT matrix to facilitate group brainstorming and evaluation. Participants noted the strengths and weaknesses of the alternatives include the following:

1. Alternative One: Inexpensive construction costs, multi-functional, and potentially ADA accessible
2. Alternative Two: Public building, public use, close to the beach (and thus the tsunami), not easily accessible for seniors (stairs only)
3. Alternative Three: Expensive, blocks views, privately owned vs. public building, close to beach (and thus the tsunami), encourage tourism (and higher populations?)

Participants decided that alternatives one and two offered more benefits that alternative three. They proposed merging the first and second alternative into a single preferred strategy (see **Figure 2**).

5. Community mulling and acceptance of preferred strategy

The community will have the next few months to think over the preferred strategy. This mulling process will provide an opportunity for both formal and informal community discussions about the preferred strategy. Over the summer, UW students will hold open house events in Long Beach to educate the population and encourage discussion, acceptance, and excitement about the preferred strategy. There will also be signage and information at the Long Beach City Hall to initiate discussions about the preferred strategy among residents and city staff.

6. Reassessment of preferred strategy

In the future, there will be a reassessment of the preferred strategy. This reassessment will take place after the above methodologies have been applied to Ocean Park, Ilwaco, and Tokeland. Each of these peninsula communities will develop a preferred strategy suited for their individual populations. Once the preferred strategies are developed, a peninsula-wide meeting will take place to reassess the strategies for comprehensiveness, redundancy, and coordination.

IV. Results

At the second community meeting, community members reviewed three alternatives and came to consensus on a preferred strategy. This section describes the preferred strategy and examines how the preferred strategy addresses the community's strengths, weaknesses, opportunities, and threats.

1. Preferred Strategy Description

The second community meeting produced a preferred strategy with the following components:

- **One large, multi-purpose berm located behind the elementary school.** The berm will either be used as bleachers, with ball game spectators sitting on the grassy slope leading to the top of the berm, or as a playfield, with the grassy area on top of the berm serving as a sports field. The berm will accommodate approximately 1,000 evacuees and will be prioritized for construction since it will provide refuge for children.
- **Four smaller berms dispersed along the eastern edge of Long Beach.** To provide evacuation for the general population, four smaller berms will be constructed along the east side of the community. Each berm will accommodate approximately 500 evacuees and will be built after the large berm near the school is constructed.

- **Elevated city hall, if funding becomes available.** In the future, federal or state funding may become available for the construction of an elevated city hall structure. The city will pursue this element as funding allows.
- **67th street assembly area.** After the earthquake and tsunami occurs, the 67th street assembly area will serve as a site for longer-term evacuation and access to emergency supplies.

Figure 3.

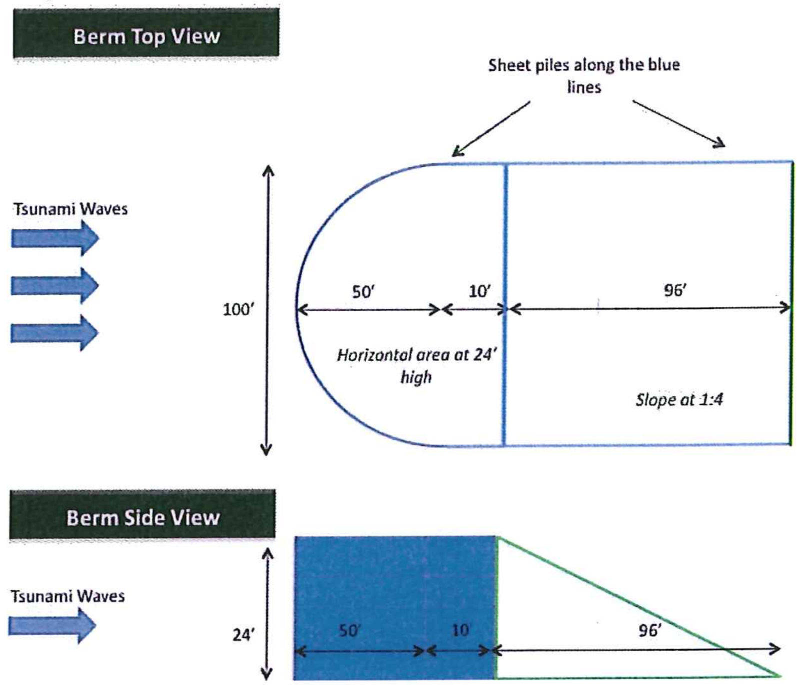
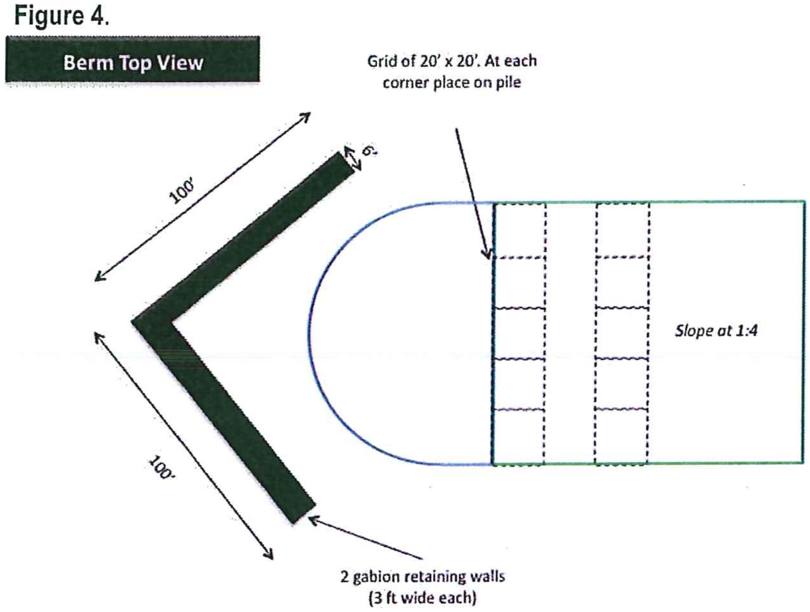


Figure 2 (See page 15) provides a map of the elements of the preferred alternative. **Figure 3** illustrates a potential design for a bleacher berm behind the elementary school. The berm will have a rounded side reinforced with sheet piling facing the oncoming tsunami wave. A sloping ramp down the backside would provide access to the top for evacuation and would serve as bleachers for ballgame spectators.

Figure 4.



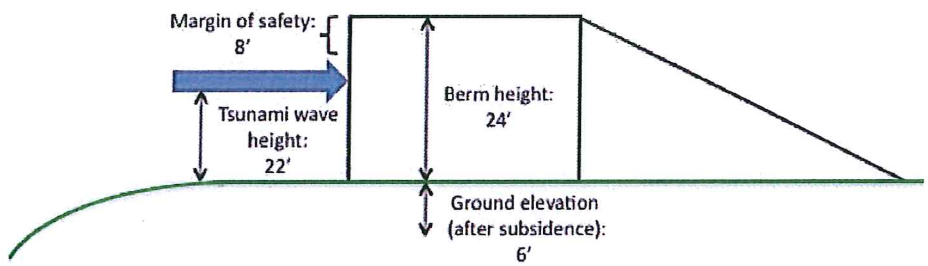
The interior of the berm, shown in **Figure 4**, would contain a network of concrete-filled sheet piling and wires for reinforcement. Gabion walls in front of the berm would mitigate the force of the tsunami wave.

The heights of each berm will depend on base ground elevations of the selected sites and the margin of safety measurement decided upon by the community. The proposed berm site behind the elementary school has a base elevation of 12 feet. Taking earthquake ground subsidence and predicted wave height into account, the school berm could either be:

- 24 feet tall, providing an 8-foot margin of safety (as illustrated in **Figure 5**); or
- 26 feet tall, providing a 10-foot margin of safety.

Figure 5.

Berm Margin of Safety

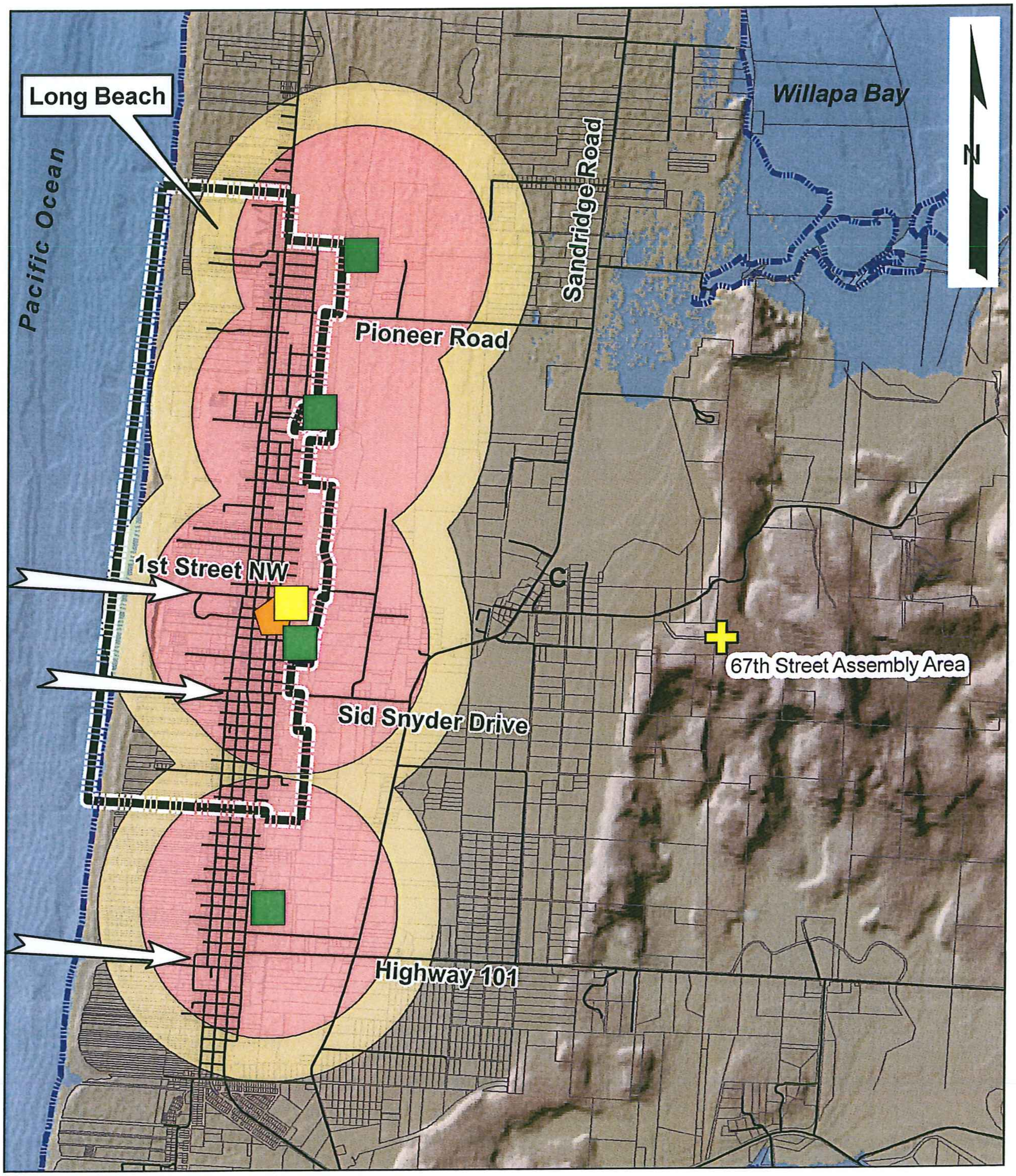


A taller berm requires a larger footprint for a longer sloping ramp, slightly raising costs. Table 1 provides estimated costs for the berms in the preferred strategy. Five 24-foot berms would cost approximately $2.5 million, and 26-foot berms would cost about $3.1 million. See Appendix B for a detailed budget.

Table 1. Berm Costs - Preferred Strategy

	Berm Height	
	24 feet	26 feet
Large berm near school	**$930,380**	**$1,006,863**
Small berm	$645,960 x 4 berms	$788,115 x 4 berms
	$2,583,839	**$3,152,460**
TOTAL	**$3,514,219**	**$4,159,323**

Figure 2 - Preferred Strategy



0 3,000 6,000

Approximate Scale in Feet

Sources:

NOAA National Center for Tsunami Research 1/3" DEM
Vertical Datum: Mean High Water Vertical Units: Meters

NOAA Medium Resolution Digital Vector Shoreline - NAVD 1929:
http://coastalgeospatial.noaa.gov/data_gis.html

- Potential Bleacher Berm Location
- Potential Berm Location
- Potential Public Building Development
- 3600 Ft - 12 to 65 Year Old Walking Distance
- 2700 Ft - Over 65 Year Old Walking Distance
- Major Dune Cut

V. SWOT Analysis of Preferred Strategy

SWOT stands for Strengths, Weaknesses, Opportunities, and Threats. Students used SWOT analysis for the Tsunami Safe Haven project to identify the features of the preferred alternative that address underlying characteristics of the community. The SWOT analysis helps demonstrate that the preferred alternative builds on the community's strengths, overcomes weaknesses, takes advantage of opportunities, and minimizes threats.

Strengths are capabilities. They are internal to the community and represent items to build upon. Categories of strengths include: financial; mobility; preparedness and awareness; and built and natural environment. As described in the table below, the preferred alternative builds on the community's strengths.

Weaknesses are impacts, exposures, or vulnerabilities. They are internal to the community and represent items to overcome. Categories of weaknesses include: financial; mobility; preparedness and awareness; and built and natural environment. The preferred alternative helps overcome the community's weaknesses.

Opportunities are capabilities. They are external to the community and represent items to exploit or enhance. Categories of opportunities include: opportunities include: business and economic; human and social capacity; natural and environmental; and built environment. The preferred alternative exploits opportunities available to the community.

Threats are hazards. They are external and generally out of the community's control. Categories of threats relate to geography, built environment, and demographics. The preferred alternative helps minimize the threat presented by a tsunami.

I. How the Preferred Strategy Builds on Community **Strengths**

Category	Strength of Community	How Preferred Strategy Builds on Strength
Financial	Tourists provide significant revenue to the area that can help finance vertical evacuation.	The preferred strategy can potentially use tourist-generated income for funding.
	A variety of vertical evacuation designs provide options for different costs.	Analysis of the three proposed alternatives suggests that berms are more cost-effective than buildings.
	A privately owned evacuation structure will reduce costs to public entities.	The preferred strategy plans to use federal funds for hazard mitigation thereby reducing costs to the local community.
Mobility	Tourists come to the area for hiking, biking, kayaking, fishing, beach combing, bird watching, horseback riding, and clam digging, thus majority of this population is physically fit and able to evacuate.	The preferred strategy takes advantage of the physically mobile population by constructing berms away from the beach within a reasonable walking distance, thereby reducing risks associated with the higher tsunami waves.
	Vertical evacuation designs allow people to access structures easily.	The preferred strategy will incorporate ramps into the berm structure potentially allowing for easy access.
Preparedness and Awareness	Pacific County Emergency Management Agency (PCEMA) helps the area mitigate, prepare, respond, and recover in the event of emergencies.	Pacific County Emergency Management will help educate and train the public on the preferred strategy.
	Pacific County's Hazard Mitigation Plan has goals that are supportive of tsunami preparedness.	The preferred strategy has been developed with the goals of the hazard mitigation plan in mind.
	Long Beach is a Tsunami Ready community.	The preferred strategy takes advantage of the community's awareness of tsunami.
	AHAB warning sirens and tsunami evacuation routes have been implemented and tested in the community.	The preferred strategy will build upon the community awareness of tsunami risks and increase overall preparedness and safety.
Built and Natural Environment	Vacant parcels exist in the community where structures could be placed.	The preferred strategy will take advantage of vacant parcels to reduce costs associated with property acquisition.
	Vertical evacuation structures can be multi-functional.	The preferred strategy incorporates multiple uses into its design.

2. How the Preferred Strategy Overcomes Community **Weaknesses**

Category	Weakness of Community	How Preferred Strategy Overcomes Weakness
Financial	Vertical evacuation structures are expensive to construct.	The preferred strategy attempts to reduce costs wherever possible; for example, by using free fill.
	Source of funding for structures is currently unknown.	The preferred strategy may be qualified to receive federal, state, and county funds.
	Public funded structures are more expensive to the City and taxpayers.	Publicly funded projects are eligible for external funding.
	Privately funded projects increase the unpredictability of planning and scheduling.	The preferred strategy will be publicly funded, allowing the community to have more control over the construction schedule.
Mobility	The population of Long Beach has a high percentage of elderly persons that walk at slower speeds and may require special accommodation.	The preferred strategy takes into account the mobility of seniors by siting potential locations in areas within reasonable walking distance. The preferred strategy also incorporates ramps instead of stairs to accommodate those with limited mobility.
	Non-permanent residents may not know where to go when evacuation is ordered.	The preferred strategy will be noticeable on the landscape and will have signage to direct people to the berms.
	The population of Long Beach fluxes depending on time of day and year, leaving the number of residents to plan for questionable.	The preferred strategy is designed to accommodate the total population plus an additional number of people covering the population of Long Beach most days of the year.
	The population is dispersed throughout the city with no central hub of high density.	The preferred strategy phases the development of multiple structures throughout the city to accommodate the dispersed population.
Preparedness and Awareness	The current proposed strategy for tsunami vertical evacuation does not include a plan for educating the public on the proposed structures or their use during times of evacuation.	Once the structures are built, plans for public education and training will be developed in accordance with Pacific County Emergency Management and the City of Long Beach.
	An evacuation structure close to the beach places more people near the tsunami.	The preferred strategy incorporates berms on the eastern city boundary, away from the tsunami. A public structure proposed near the beach will be designed to accommodate people on the beach and increase their ability to reach a safe haven.
Built and Natural Environment	Constructing a public structure near the beach may encourage refugees to run towards the tsunami instead of away from it.	The strategy assumes that people located away from the beach will take refuge on the berms located on the eastern edge of the city. A structure located on the beach will be designed to accommodate people already on the beach.
	Large structures near the beach will block views.	The preferred strategy places structures away from the beach, reducing the impact on views.

3. How the Preferred Strategy Exploits Community **Opportunities**

Category	Opportunity	How Preferred Strategy Exploits Opportunities
Business and Economic	Funding for tsunami evacuation structures may be available from state and federal sources.	The preferred strategy will take advantage of all available federal and state dollars.
	Advertising tsunami safety may make tourists more comfortable in coming to Long Beach.	The preferred strategy will be advertised with appropriate signage and may attract tourists by making them feel safer than before.
Human and Social Capacity	Geologists, oceanographers, and engineers have developed guidance about designing vertical evacuation structures.	The preferred strategy has taken advantage of previous studies completed by geologists, oceanographers, and engineers.
Natural and Environmental	Tsunamis are infrequent events.	The preferred strategy will exploit that tsunami are infrequent events by having multi-functional uses when a tsunami is not imminent.
	Some warning will be given for a tsunami, ranging from 40 minutes for a local event to several hours for a distant event.	The preferred strategy takes advantage of the 20-minute warning time, placing evacuation structures within a 15-minute walking distance to account for reduced mobility.
Built Environment	Pacific County has four ports that may receive supplies and emergency aid in the event of a disaster (although these ports may not be functional after a large subduction zone quake).	The preferred strategy will take advantage of access to emergency supplies via the port since few supplies will be stored on the berms.
	Multi-purpose structures may inspire more development.	The preferred strategy incorporates multi-functional uses into the berms to avoid wasting space and encouraging the available space to be used efficiently.
	The City of Long Beach has plans for an emergency supply storage area on the east side of the city.	The preferred strategy will exploit the resources of the emergency supply storage area as the berms have incorporated more space for tsunami refugees into their design than for emergency supplies.

4. How the Preferred Strategy Minimizes Community **Threats**

Category	Threat	How Preferred Strategy Minimizes Threats
Geography	The geography of the Long Beach peninsula is extremely flat and low, giving the population little ability to escape to high ground.	The preferred strategy will place elevated berms within walking distance to provide evacuation sites above tsunami wave height, reducing the risks associated with flat topography.
	At large cuts through the primary dunes (e.g. Bolstad Street), wave height will likely be slightly higher with faster currents due to concentration of the wave at these locations.	The preferred strategy will not place berms in primary dune cuts to avoid threats of higher wave heights and faster currents.
Built Environment	Residences and hotels cannot structurally survive a tsunami, regardless of their ability to withstand the earthquake.	The preferred strategy will be constructed to be seismically sound as well as tsunami resistant.
	Debris from the earthquake will impede the mobility of people seeking refuge from the tsunami.	The preferred strategy has taken into account the time needed to reach one of the berms and placed them closer to the city center to account for time lost due to mobility issues.
Demographics	Long Beach has a high seasonal population.	The preferred strategy includes evacuation space for many non-permanent residents.
	Long Beach has a high population of seniors.	The preferred strategy places berms within walking distance of seniors and uses ramps instead of stairs for increased ease of access.

VI. Conclusion

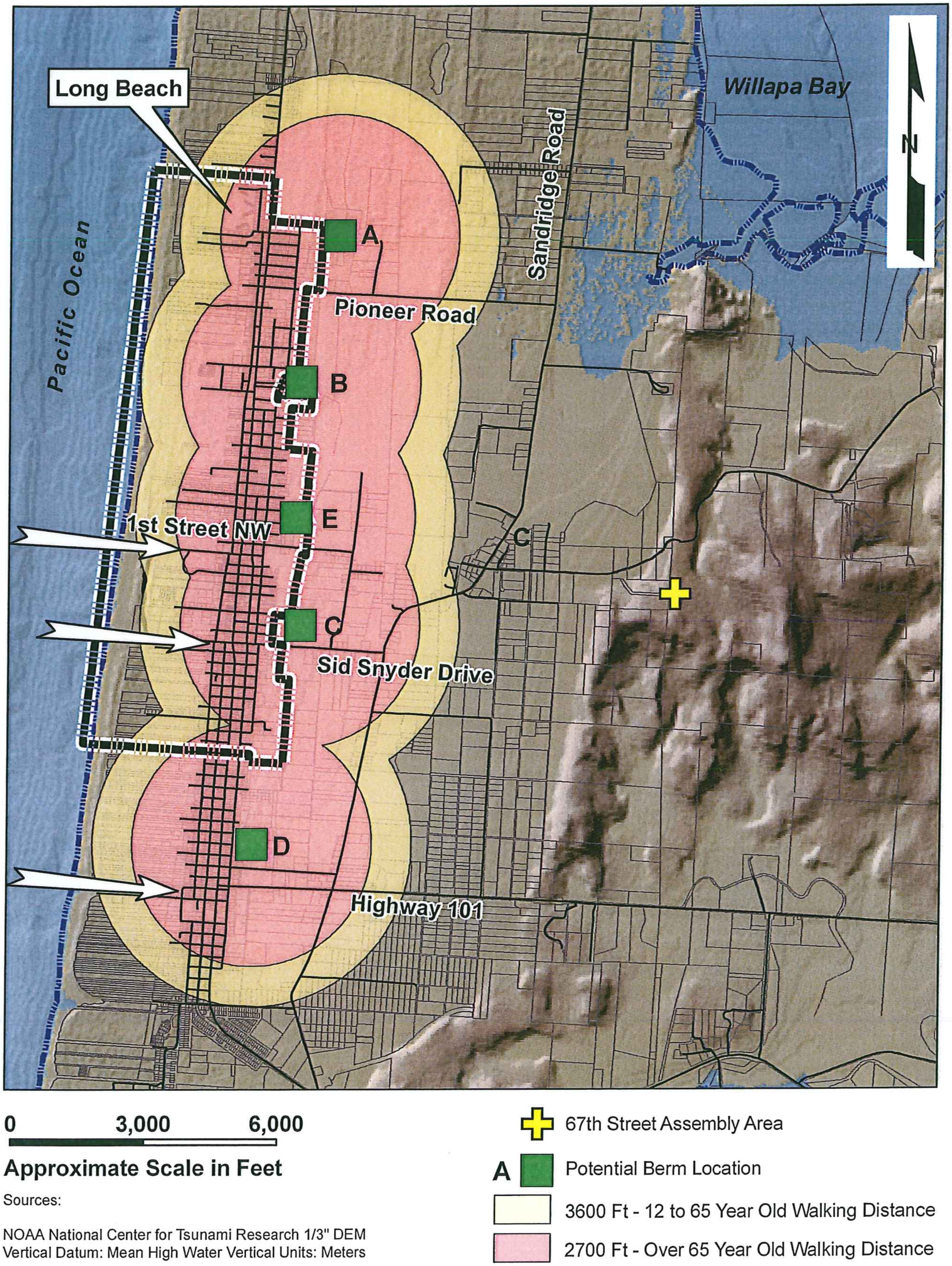
The Long Beach Peninsula is at significant risk of damage from a future tsunami. The preferred strategy developed for the City of Long Beach reduces the community's vulnerability by proposing vertical safe havens that are accessible to a significant amount of the population. The strategy was created through a process that builds upon the community's strengths and minimizes its weaknesses, making Long Beach a safer, more prepared community. In the coming months, local officials will discuss the strategy with community members, offering time for the alternative to be further refined.

During summer 2010, while Long Beach residents and officials mull over this report, UW students and faculty plan to repeat the methodologies used for Long Beach in the communities of Ocean Park, Ilwaco, and Tokeland. The process and methodologies used for Long Beach may be altered slightly to conform to the needs of each city.

After completion of the process with Ocean Park, Ilwaco, and Tokeland, the preferred strategy will be revisited and modified as needed. Funding opportunities will be researched for the implementation of the preferred strategy.

Appendix A: Mapped Alternatives Developed with the Long Beach Community

Figure 6 - Alternative 1

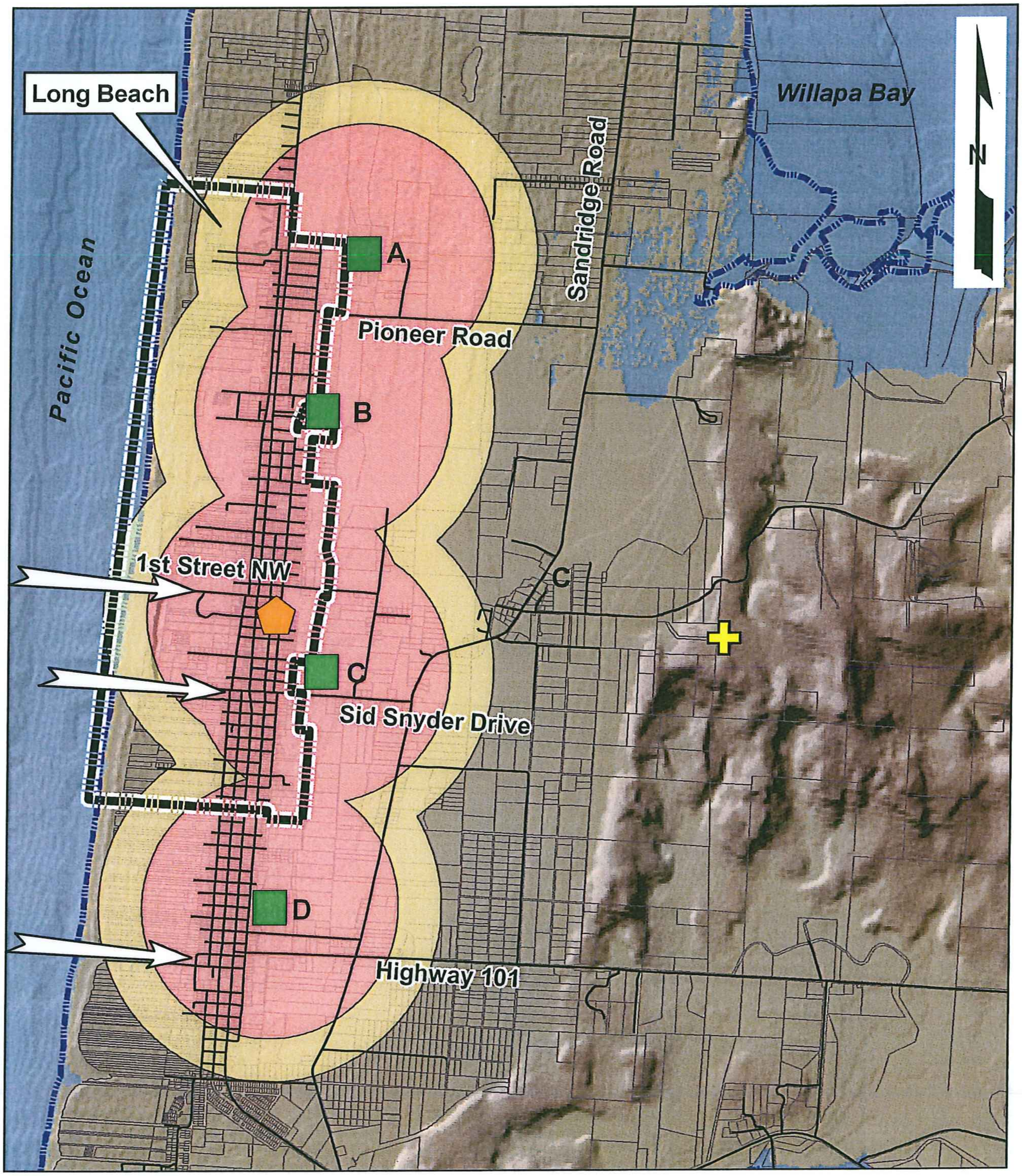


Sources:

NOAA National Center for Tsunami Research 1/3" DEM
Vertical Datum: Mean High Water Vertical Units: Meters

NOAA Medium Resolution Digital Vector Shoreline - NAVD 1929:
http://coastalgeospatial.noaa.gov/data_gis.html

Figure 7 - Alternative 2



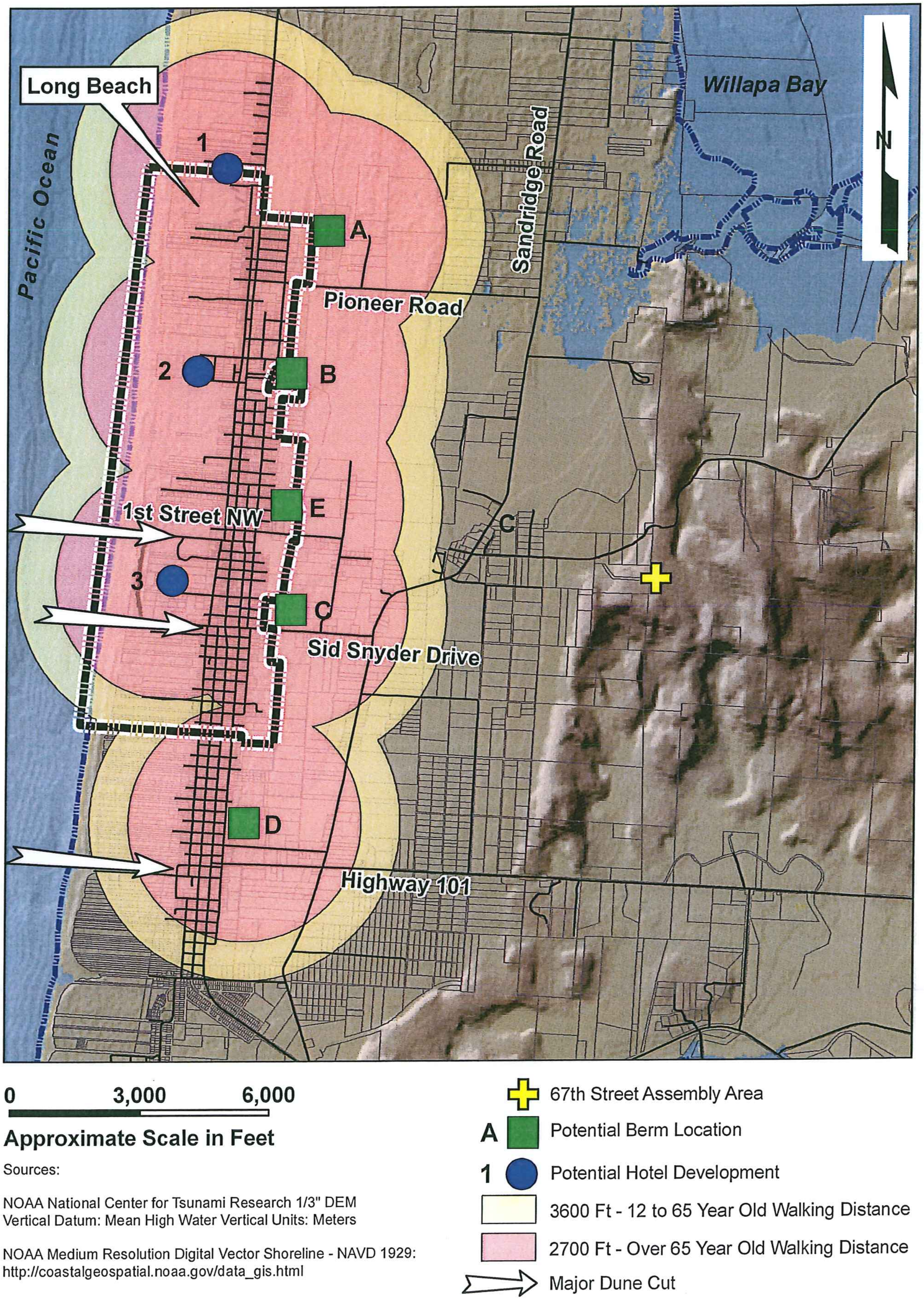
Sources:

NOAA National Center for Tsunami Research 1/3" DEM
Vertical Datum: Mean High Water Vertical Units: Meters

NOAA Medium Resolution Digital Vector Shoreline - NAVD 1929:
http://coastalgeospatial.noaa.gov/data_gis.html

- 67th Street Assembly Area
- A — Potential Berm Location
- Potential Public Building Development
- 3600 Ft - 12 to 65 Year Old Walking Distance
- 2700 Ft - Over 65 Year Old Walking Distance
- Major Dune Cut

Figure 8 - Alternative 3



Sources:

NOAA National Center for Tsunami Research 1/3" DEM
Vertical Datum: Mean High Water Vertical Units: Meters

NOAA Medium Resolution Digital Vector Shoreline - NAVD 1929:
http://coastalgeospatial.noaa.gov/data_gis.html

Appendix B: Cost Matrix- Budget for a 24-foot berm behind the elementary school

Budget line items for a 24 ft. bleacher berm (8 ft. margin of safety)					
Materials	**Cost**	**per unit**	**# of LF/CF/CY Needed**	**# of Units Needed**	**Total Cost**
Sheet pile					
Exterior sheet pile:					
Buried sheet pile	$31	vertical LF	24	193	$143,651
Above ground sheet pile	$18	vertical LF	24	193	$83,410
Interior sheet pile:					
Buried sheet pile	$49	vertical LF	18	16	$14,112
Above ground sheet pile	$49	vertical LF	18	16	$14,112
Sheet pile total:					**$255,285**
Gabion mounds	$115	linear F	100	4	**$46,000**
Fill	$-	cubic F	233,448	1	**$-**
Filter fabric	$2	square Y	1,647	1	**$3,294**
Topsoil	$36	cubic Y	1,647	1	**$59,290**
Seeding	$1	square Y	1,647	1	**$1,647**
Sprinkler system	$70	sprinkler	345	1	**$24,130**
Fence	$5,250	30 F fence	6	1	**$30,989**
Materials Total					**$396,505**
Equipment and Labor	**Unit Cost**		**# of LF/CF/CY Needed**	**Units Needed**	**Total Cost**
Truck	$22	LCY	10,203	1	**$224,456**
Backfill	$3.9	LCY	10,203	1	**$39,790**
Compaction	$2	CCY	8,646	1	**$17,292**
Equipment and Labor Total					**$281,538**
Other Costs					**Total Cost**
Indirect costs					**$101,706**
Site preparation					**$33,902**

Design and engineering	**$48,924**
Contingency	**$33,902**
Profit	**$33,902**
Other Costs Total	**$252,337**
TOTAL	**$930,380**

Appendix C: Assumptions

To create the preferred strategy and original three alternatives, the project participants made assumptions about the tsunami hazard, berm construction and design, and capabilities of the Long Beach population.

Assumptions about the tsunami hazard included:

- The event will be a 9.1 magnitude subduction zone quake approximately 80 miles off the coast of the Long Beach peninsula.
- The wave height will be approximately 22 feet depending on variations in bathymetry, topography, and the built environment.
- There will be about 40 minutes between the cessation of shaking and arrival of the first tsunami wave.
- Although subduction zone quake models propose a tsunami warning time of 40 minutes, the creation of the preferred alternative is based on 20 minutes of warning time. This reduced warning time takes into account the amount of time the ground is shaking caused by the earthquake, delayed response time of citizens, poor road and sidewalk conditions resulting from the earthquake, as well as possible panic among citizens.

Assumptions about the berm construction and design included:

- Fill dirt for construction of the berms will be available at no cost via a nearby storage pit.
- If a berm is constructed on a site where wetlands are compromised, new wetlands will be developed in the processes of borrowing fill for the berm construction.
- The margin of safety (distance between the height of the tsunami and the floor of the berm) was assumed to be between eight and ten feet. The Long Beach community will determine the final margin of safety based on specific design and cost considerations.
- Each berm will provide five square feet of space per person.
- Tsunami refugees will remain on the structure for two full tide cycles, or up to 24 hours.
- The berms will be 24 to 26 feet in height, depending upon underlying elevation of the selected sites and the final margin of safety selected by the community.

Assumptions about the capabilities of Long Beach population included:

- The majority of the Long Beach population is physically mobile and can walk to the proposed tsunami evacuation sites.
- People on the beach have average to high physical mobility.
- People ages 13 to 64 can walk on average four feet per second, averaging 3,600 feet in 15 minutes.
- People ages 65 or older can walk on average three feet per second averaging 2,700 feet in 15 minutes.
- The preferred strategy can provide refuge for 2,000 people.

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- Tyree Wilde, National Oceanic and Atmospheric Administration, NOAA
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