O’ahu Coastal Communities Evacuation Planning Project

PHASE 2

Final Report

September 2019

Prepared for:

City and County of Honolulu
Department of Emergency Management

Prepared by:

TETRA TECH

This report was funded in part through grants from the Federal Highway Administration and Federal Transit Administration, U.S. Department of Transportation. The views and opinions of the agency expressed herein do not necessarily state or reflect those of the U.S. Department of Transportation.

Prepared by the City and County of Honolulu Department of Emergency Management in Cooperation with the Oahu Metropolitan Planning Organization and the United States Department of Transportation.

This report was funded in part through grants from the Federal Highway Administration and Federal Transit Administration, U.S. Department of Transportation. The views and opinions of the agency expressed herein do not necessarily state or reflect those of the U.S. Department of Transportation.

Prepared by the City and County of Honolulu Department of Emergency Management in Cooperation with the Oahu Metropolitan Planning Organization and the United States Department of Transportation.

EXECUTIVE SUMMARY

The Oahu Coastal Communities Evacuation Project is a critical preparedness effort for the residents and visitors of Oahu, which will result in much needed tsunami evacuation routes, signage and designated Safe Sites correlated with updated tsunami modeling. In fall 2017, Tetra Tech, Inc. was contracted by the City and County of Honolulu's (City) Department of Emergency Management (DEM) to complete Phase 2 of this effort. Phase 1 of the project had been completed in 2015 under contract with a consulting team led by Atkins, and Phase 2 was designed to complete tsunami evacuation routing and Safe Site identification for the southern coast of Oahu which was not addressed in Phase 1. The Phase 2 project area included:

- Hanauma Bay
- Hawaii Kai
- Wailupe
- Kahala
- Diamond Head
- Waikiki
- Downtown Honolulu
- Ke'ehi Lagoon
- Pearl Harbor East/West:
  - Includes Waipahu, Pearl City, Aiea
- Pearl Harbor Mouth:
  - Includes Honolulu Airport, Hickam
- Ewa Beach

In contrast with Phase 1, which analyzed evacuating some of the less densely populated areas of Oahu and addressed associated issues with limited Safe Sites, unpaved evacuation routes and private property, the Phase 2 project area was comprised primarily of high-density areas with paved public roads. However, while many of the issues from Phase 1 were avoided, other complexities emerged. One of the Phase 2 challenges evident from the outset was the high volume of residents, visitors and tourists in areas such as Waikiki and Downtown Honolulu, with a limited number of potential evacuation routes. While this proved not to be an issue for pedestrian evacuation, vehicular evacuation will be significantly impacted depending upon traffic volumes. Offsetting this issue was the large number of high-rise structures that were potentially suitable for vertical evacuation and would reduce the number of evacuees leaving the area.

To assist the City in promoting vertical evacuation, Phase 2 included the design and development of an engineering evaluation tool to serve as the basis for a future Tsunami-Safe Vertical Evacuation Program. This Engineering Assessment Tool was developed by Tetra Tech's Team subcontractor Degenkolb Engineers in close coordination with the Hawaii Earthquake and Tsunami Advisory Committee (HETAC).

The Tetra Tech Team worked closely with DEM and the HETAC to develop and revise the Engineering Assessment Tool based upon new international tsunami engineering design standards. This included the selection and assessment of two (2) City-owned high-rise structures within the tsunami inundation area as beta tests. While the Engineering Assessment Tool was received favorably, the HETAC requested additional beta tests, which were added and funded under a subsequent change order and scope modification before the tool was finalized and accepted by DEM and the HETAC.

Additionally, whereas Phase 1 did not include contractor support to develop an installation-ready signage implementation plan, Phase 2 included geocoded sign placements supported by mapping and pictures of each location with digital representations of installed signs, either on existing poles or recommended installation sites. This is a significant outcome from Phase 2 of the project because it allows the City to immediately begin sign installation as funding permits. In-house efforts by DEM to develop a similar installation plan for Phase 1 signage utilizing volunteer support had proven to be extremely manpower intensive and an inefficient usage of DEM staff time. To take advantage of economies of scale and available resources, Tetra Tech was tasked through a change order and scope modification to also develop an implementation plan for Phase 1. As part of this effort, Tetra Tech created a unified database of signage locations, including geocoded locations, installation instructions, supporting maps and pictures.

As with Phase 1, a major component of Phase 2 was the identification and selection of Safe Sites to be used as a place of refuge during a Tsunami event. Rather than shelters, such as would be used in a hurricane, most Safe Sites are more aptly described as gathering places with large areas for parking where those with nowhere else to go could congregate and wait for an all-clear. In the event of a significant tsunami, pre-identification of Safe Sites allows DEM to focus support services and resources for impacted populations, especially those with access or functional needs.

Throughout the project, Tetra Tech worked with DEM to engage stakeholders and the public. This included presentations and information gathering sessions with the public during Tsunami Awareness Month, as well as targeted meetings with specific stakeholder groups, such as representatives from adjacent military installations and most of the high-rise hotel and resort complexes within the Phase 2 study area. These outreach efforts were instrumental in selection of Safe Sites, as well as the identification of volunteer facilities for the final 2 beta-tests of the Engineering Assessment Tool. Of particular note was the engagement of the HETAC, which received regular briefings on the project from DEM as well as targeted presentations and various time during the development process. Their assistance and input was integral to ensuring the Engineering Assessment Tool appropriately addresses the needs of the City and a future Tsunami-Safe Vertical Evacuation Program.

As a culminating task, Tetra Tech worked closely with DEM to develop approved language describing project outcomes, such as evacuation routes, signage and safe sites for dissemination and future outreach efforts. In doing so, Tetra Tech and DEM looked to balance the nuances of the project and terminology while ensuring consistent and simplified messaging that will be easily understood not only by local residents, but by visitors with limited exposure to existing tsunami plans and signage. Once the English verbiage was approved, Tetra Tech utilized a DEM-approved vendor for translation of the outreach material into 14 additional languages in order to maximize coverage of the potentially impacted populations. The translated languages included:

- Chinese (Simplified)
- Chinese (Traditional)
- Chuukese
- Hawaiian
- Ilocano
- Japanese
- Korean
- Marshallese
- Pohnpeian
- Samoan
- Tagalog
- Thai
- Tongan
- Vietnamese

While Phase 2 identified some residual needs, including additional policy development and public buy-in for a Tsunami-Safe Vertical Evacuation Program, it met initial project goals and, through subsequent change orders, was able to unify Phase 1 and 2 outcomes with implementable next steps which will result in island-wide tsunami evacuation routes, signage and designated Safe Sites.

CONTENTS

GAPS, NEEDS AND CAPACITY ANALYSIS

As Phase 2 of an overarching project, Tetra Tech was directed by DEM to be as consistent as possible with the methodologies and assumptions utilized in Phase 1. However, in some cases, due to the availability of data, passage of time, or fundamental differences in the challenges related to each project area, Tetra Tech identified changes that were either required or recommended for the betterment of the project. In these cases DEM was consulted or advised. Foundational methodologies and assumptions used for the Gap Analysis and Needs Assessment are detailed in the Phase 1 Final Report.

GAP ANALYSIS

The following assumptions were utilized in developing the Gap Analysis, which is included as data files on the Project thumb drive.

- In most cases conservative estimates were utilized with deliberately inflated safety margins.
- Behavioral Study utilized in Phase 1 provided many of the underlying assumptions.
- Utilized available modeling for tsunami inundation, consistent with Phase 1 including the Tsunami Evacuation Zone (TEZ) and the addition of the Extreme Tsunami Evacuation Zone (XTEZ).
- Tourist populations were apportioned across the hotel layer using GIS analysis.
- Ran scenarios to determine the worst case population impacts (XTEZ + TEZ + Tourists and Visitors) for Day/Night Weekday and Day/Night Weekend scenarios to determine worst case population impact scenarios.
- Worst Case Scenarios appeared to be at night when most people were home.
- Increased vehicle evacuation usage rate from 70% to 80% for safety margin.

Route Group	Analysis Neighborhood	Total Impacted Population including Visitors in Max Impact Scenario	Population Using Vehicles to Evacuate in Max Impact Scenario	Vehicles Using Safe Site in Max Impact Scenario
1	Hawaii Kai	2,605	2,176	145
2	Hawaii Kai	5	4	0
3	Hawaii Kai	4,154	3,417	227
4	Hawaii Kai	958	804	53
5	Hawaii Kai	2,246	1,854	124

Route Group	Analysis Neighborhood	Total Impacted Population including Visitors in Max Impact Scenario	Population Using Vehicles to Evacuate in Max Impact Scenario	Vehicles Using Safe Site in Max Impact Scenario
6.01	Hawaii Kai	1,524	1,261	86
6.02	Hawaii Kai	1,066	865	57
7.01	Hawaii Kai	2,388	1,970	130
7.02	Hawaii Kai	6,304	5,124	341
8.01	Hawaii Kai	2,441	1,981	131
8.02	Hawaii Kai	2,732	2,198	146
9.01	Diamond Head / Waikiki	1,113	903	60
9.02	Diamond Head / Waikiki	1,211	970	64
10.01	Diamond Head / Waikiki	244	199	14
10.02	Diamond Head / Waikiki	2,481	2,041	135
11	Diamond Head / Waikiki	1,861	1,524	102
12	Diamond Head / Waikiki	2,306	1,913	127
13	Diamond Head / Waikiki	3,853	3,198	311
14	Diamond Head / Waikiki	2,456	1,994	133
15	Diamond Head / Waikiki	2,307	1,858	182
16	Diamond Head / Waikiki	3,086	2,528	4,558
17	Diamond Head / Waikiki	1,836	1,490	101
18	Diamond Head / Waikiki	12,843	10,051	2,361

Route Group	Analysis Neighborhood	Total Impacted Population including Visitors in Max Impact Scenario	Population Using Vehicles to Evacuate in Max Impact Scenario	Vehicles Using Safe Site in Max Impact Scenario
19	Diamond Head / Waikiki	18,273	14,632	1,305
20	Diamond Head / Waikiki	8,386	6,608	442
21	Diamond Head / Waikiki	4,832	3,684	251
22	Diamond Head / Waikiki	15,511	12,603	2,504
23	Diamond Head / Waikiki	7,490	6,108	880
24	Downtown	1,203	983	65
25	Downtown	4,685	3,852	514
26	Downtown	1,235	1,024	108
27	Downtown	10,426	8,507	568
28	Downtown	5,169	4,120	276
29	Downtown	6,705	5,365	358
30	Hickam / Moanalua	4,386	3,394	259
31	Hickam / Moanalua	283	235	15
32	Hickam / Moanalua	793	667	44
33	Hickam / Moanalua	2,255	1,770	116
34	Hickam / Moanalua	901	742	93
35	Hickam / Moanalua	1,675	1,338	89
36	Pearl City	748	627	41

Route Group	Analysis Neighborhood	Total Impacted Population including Visitors in Max Impact Scenario	Population Using Vehicles to Evacuate in Max Impact Scenario	Vehicles Using Safe Site in Max Impact Scenario
37	Pearl City	2,322	1,825	143
38	Pearl City	4,793	4,052	270
39	Pearl City	34	26	2
40	Pearl City	942	757	51
41	Pearl City	1,789	1,443	97
42	Pearl City	2,029	1,589	106
TOTALS		**168,885**	**136,274**	**18,185**

Capacity Analysis

Tetra Tech conducted an initial analysis of the Phase 2 Project Area for Safe Site capacity extending 1 mile from the XTEZ boundary. This analysis initially focused on public facilities but for some evacuation routes no adequate Safe Sites were determined and the search area was extended to 2 miles from the XTEZ. However, in consultation with DEM, it was determined that facilities more than 1 mile from the XTEZ boundary were not optimal and the analysis was rerun to include private property. The resulting analysis is included as a consolidated spreadsheet on the Project thumb drive.

Safe Sites and Evacuation Routes

Building upon the Gaps, Needs and Capacity Analysis, Tetra Tech started with a list of hundreds of potential Safe Sites within 2 miles of the Extreme Tsunami Evacuation Zone (XTEZ). Initial focus was on publicly owned properties, but expanded to private locations in some instances.

Safe Site Selection

Tetra Tech worked with DEM, stakeholders, and the public to cull the list down to a workable number. This involved removing unsuitable locations such as gun ranges, hospitals, and other sensitive areas. In addition, an effort was made to avoid locations that might otherwise be utilized during an evacuation. While in most cases the capacity analysis indicated sufficient capacity for all evacuating vehicles, there is a finite limit to how many Safe Sites can be supported by the City. Final selection of Safe Sites was determined by the City.

Map	Community	Selected Safe Sites
Route 1	Hawaii Kai	Kalama Valley Community Park
Route 2	Hawaii Kai	Koko Head District Park
Route 3	Hawaii Kai	Koko Head District Park
Route 4	Hawaii Kai	Kaiser High School
Route 5	Hawaii Kai	Kamilo Iki Community Park
Route 6.1	Hawaii Kai	Kamilo Iki Neighborhood Park
Route 6.2*	Hawaii Kai	Kamilonui Place
Route 7.1*	Hawaii Kai	Kaluanui Road
Route 7.2	Hawaii Kai	Hahaione Valley Neighborhood Park
Route 8.1*	Hawaii Kai	Hawaii Kai Retirement Community
Route 8.2	Hawaii Kai	Kuliouou Neighborhood Park
Route 9.1*	Diamond Head/Waikiki	Puamamane Street
Route 9.2*	Diamond Head/Waikiki	Anolani Street and Haleola Street
Route 10.1*	Diamond Head/Waikiki	Hawaii Loa Ridge
Route 10.2	Diamond Head/Waikiki	Wailupe Valley Neighborhood Park
Route 11*	Diamond Head/Waikiki	Hao Street
Route 12	Diamond Head/Waikiki	Laukahi Slopes Mini Park and Kamole Mini Park
Route 13	Diamond Head/Waikiki	Kalani High School (not including Field)

Map	Community	Selected Safe Sites
Route 14	Diamond Head/Waikiki	Kahala Mall
Route 15	Diamond Head/Waikiki	Kilauea District Park
Route 16	Diamond Head/Waikiki	Kapiolani Community College & Kapaolono Community Park
Route 17	Diamond Head/Waikiki	Liholiho Elementary School & Kaimuki Community Park
Route 18	Diamond Head/Waikiki	Crane Community Park & Kanewai Community Park
Route 19	Diamond Head/Waikiki	University of Hawaii Manoa & Kuhio Elementary School
Route 20	Diamond Head/Waikiki	Kamanele Park & MidPacific Institute
Route 21	Diamond Head/Waikiki	Cartwright Neighborhood Park & Makiki District Park
Route 22	Diamond Head/Waikiki	Queen Kaahumanu Elementary School & Roosevelt High School
Route 23	Diamond Head/Waikiki	Hanahauoli School & Makiki Street Mini Park
Route 24	Downtown	Thomas Square
Route 25	Downtown	Dole Community Park
Route 26	Downtown	Central Middle School & Kamamalu Playground
Route 27	Downtown	Kauluwela Community Park & Lanakila District Park
Route 28	Downtown	Kalakaua District Park & Kalihi Middle School
Route 29	Downtown	Kamehameha Shopping Center & Kapalama Elementary School
Route 30	Hickam/Moanalua	Moanalua High School
Route 31	Hickam/Moanalua	Moanalua Community Park & Moanalua Middle School
Route 32	Hickam/Moanalua	Ala Puumalu Community Park
Route 33	Hickam/Moanalua	Pearl Harbor Kai & Pearl Harbor Elementary Schools
Route 34	Hickam/Moanalua	Battleship Cove Playground & Ford Island Landing Park
Route 35	Hickam/Moanalua	Radford High School & Makalapa Elementary School
Route 36	Pearl City	Pearlridge Center & Aiea High School
Route 37	Pearl City	Pearlridge Community Park & Pearlridge Elementary School
Route 38	Pearl City	Waimano Shopping Center & Pacheco Neighborhood Park
Route 39	Pearl City	Pearl Highlands Shopping Center & Leeward Community College
Route 40	Pearl City	Waipahu High School & Waipahu District Park

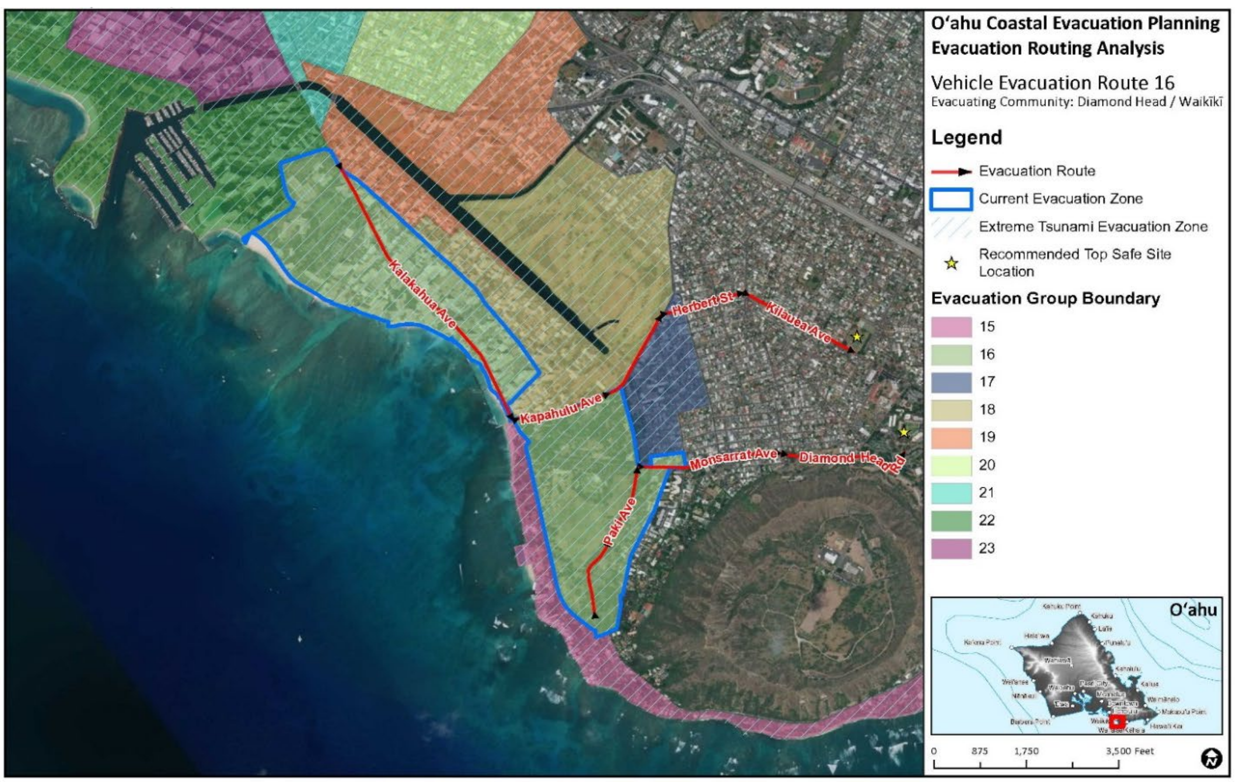
Map	Community	Selected Safe Sites
Route 41	Pearl City	Waipahu Intermediate School & Hans L'Orange Neighborhood Park
Route 42	Pearl City	Waipahu Town Center & Don Quixote Waipahu

*Streets and Private Gated Property

EVACUATION ROUTES

Once Safe Sites had been selected, Tetra Tech finalized evacuation routes for each area. As in Phase 1, priority was given to avoiding left hand turns when possible, and utilizing major streets with the most capacity. However, while in most cases distances to the boundary of the XTEZ were short, each route was plotted to continue to an identified Safe Site (See Figure 1). In some cases evacuation routes converged due to a limited number of potential routes before diverging to continue on to an identified Safe Site. As a result, it was decided in consultation with DEM that assigning specific Safe Sites to individual households or locations would not be feasible.

Figure 1: Evacuation Route Format



SIGNAGE IMPLEMENTATION PLAN

Under the original scope of work for Phase 2, Tetra Tech developed a signage implementation plan for Phase 2 evacuation routes. This included geocoded sign placements supported by mapping and pictures of each location with digital representations of installed signs, either on existing poles or recommended installation sites. As a result of a scope modification and additional funding Tetra Tech also developed an implementation plan for Phase 1.

For each evacuation route in both phases, an attribute and installation file was created in Microsoft Excel® listing the following characteristics:

- Unique Sign ID
- Project Phase
- Route
- Sequence in Route
- Sign Label
- Sign Direction
- Existing Post or New
- Street Name
- Instructions to Driver
- Community
- Latitude/Longitude
- Sign 1 – 4
- Assigned Safe Site
- Comments

Consistent with City requirements for installation, an accompanying map of each evacuation route with numbered sign placements was developed showing each sign along the evacuation route (See Figure 2). Additional maps were developed for each sign showing a closer view of the immediate area (See Figure 3) and finally a street-level photograph was taken by a Tetra Tech Field Team or pulled from Google Street View when available (See Figure 4). The Street view includes superimposed digital renderings of the exact signs to be installed at each location, either on an existing post or a suggested location for a new post. Each street view also includes the coordinates of the post as well as an oversized directional arrow indicating North on a compass heading.

In some cases, when signs appear on both sides of the street, such as when indicating exiting or entering the tsunami inundation area, the direction of the street view is oriented towards the direction of evacuation and the other sign is shown reversed and translucent as appropriate for its position and orientation (See Figure 5).

Figure 2: Implementation Plan – Full Route

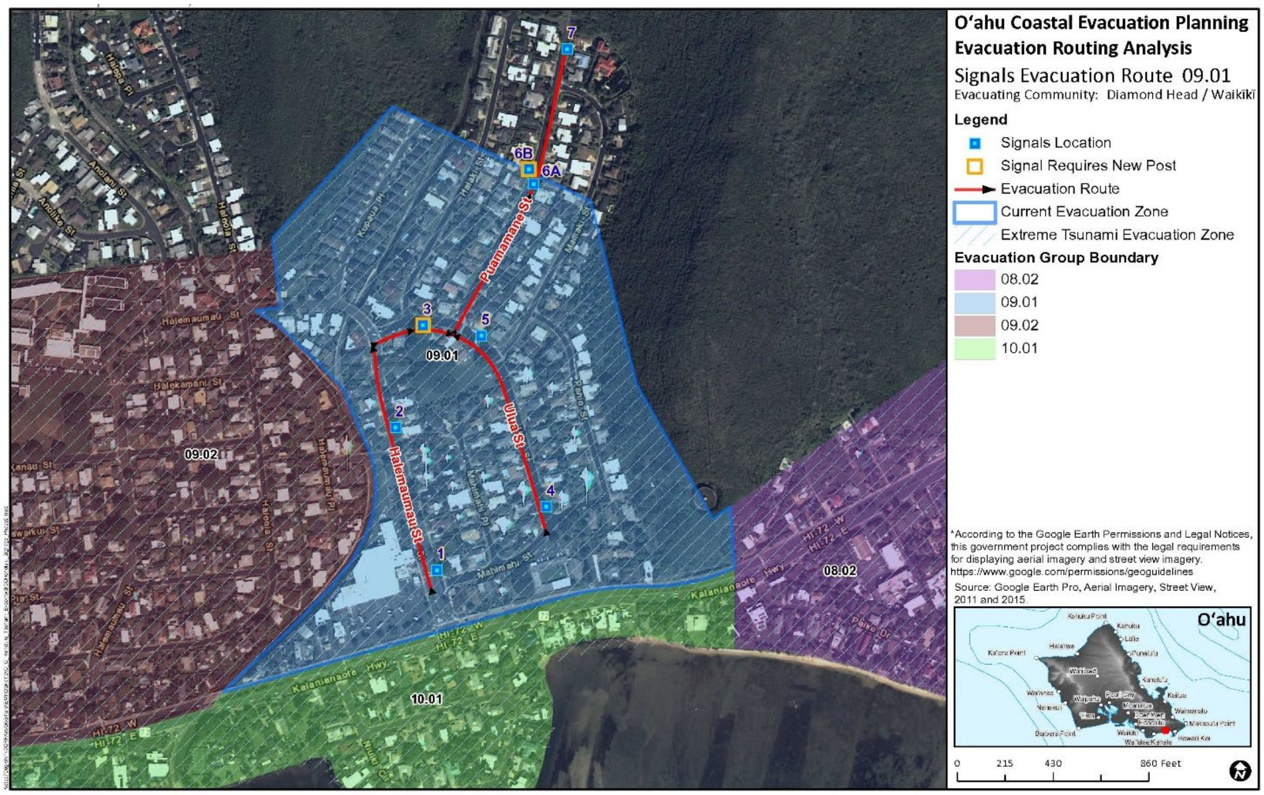


Figure 3: Implementation Plan – Sign Specific Map

Figure 4: Implementation Plan – Street View

Figure 5: Implementation Plan – Street View Double Sign

Tsunami-Ready Engineering Assessment Tool

In support of the Tsunami-Ready Engineering Assessment Tool, Tetra Tech provided overarching support and coordination with DEM and HETAC, while Degenkolb Engineers provided engineering expertise and technical development. The tool represents a multi-phased approach to assessing a structure, thereby providing early indication if a structure is not likely to have a favorable outcome and limiting potentially expensive engineering analysis. Structures that proceed to the second level of analysis undergo a detailed analysis resulting in identification of specific vulnerabilities. Rather than a simple pass/fail, this approach identifies potentially correctable deficiencies so that structures that cannot currently be certified can identify potential retrofits for certification at a later date.

Tsunami Design Standards

The Tsunami-Ready program leverages the recently-published national standard ASCE 7-16, which includes provisions for Tsunami Loads and Effects on building structures, by developing an evaluation criteria to screen and evaluate buildings which may be viable for tsunami vertical evacuation. The tool assumes the screening and evaluation procedures would be implemented by a qualified structural engineer familiar with evaluation standards for existing buildings. Therefore, the evaluation procedures are developed similar to ASCE 41– Seismic Evaluation and Retrofit of Existing Buildings to take advantage of the familiarity of an existing evaluation procedure.

Phase 1 – Initial Screening

The Initial Screening is intended to be the first step in the Tsunami-Ready evaluation procedure. The screening is similar to the Tier 1 evaluation of ASCE 41 and considers key physical features of a building and its site and aggregate the results to help building owners or other stakeholders decide whether to pursue a Detailed Evaluation.

A checklist-based screening procedure was developed to identify which features are favorable, unfavorable, or likely to be not feasible in terms of tsunami-safe performance while considering the magnitude of impact these features hold. Buildings which receive mostly favorable rankings, without any marked as not feasible, would be more likely to pass the Detailed Evaluation phase and worth the increased level of evaluation in Phase 2. The identifying features are based on ASCE 7-16 Chapter 6 combined with professional experience and input from the HETAC.

PHASE 2 – DETAILED EVALUATION

The Detailed Evaluation phase is developed to further evaluate buildings after a positive Initial Screening outcome. This evaluation requires detailed calculations, performed by a qualified structural engineer, to demonstrate the building can resist the tsunami loads and effects and ultimately validates whether the building meets tsunami-safe performance.

The methodology implements ASCE 7-16 Chapter 6 provisions on existing buildings for the Detailed Evaluation. The performance objective remains the same as it is set in ASCE 7-16 for new buildings, but some of the requirements are relaxed to account for the shorter lifespan of existing buildings and to waive some provisions that may be too onerous and prohibit many buildings from becoming tsunami shelters. The modifications to ASCE 7 provisions are documented in the Detailed Evaluation procedure.

BETA TESTING

The Initial Screening and Detailed Evaluation procedures were refined through beta tests of a total of four buildings (Frank Fasi Municipal Building and Marin Tower in Honolulu; and, two beach-front hotels in Waikiki, identified as "Building C" and "Building D" due to their owner's request for confidentiality). The focus of the beta testing is to validate the Initial Screening and Detailed Evaluation methodology and acceptance criteria. It should be emphasized that both the Initial Screening and Detailed Evaluation performed for the beta tests are neither complete nor comprehensive. They are intended to serve as *examples*, but *not* to fully validate whether the subject buildings are Tsunami-Ready.

HETAC INTEGRATION

The evaluation procedures and the results of the beta testing were presented to the HETAC during the development of the methodology during webinar briefings on 11/21/2017 and 7/17/2019. The input and feedback provided by HETAC have been incorporated into the finalized procedures contained herein. A final copy of the PowerPoint presentation slides covering the Tsunami-Ready evaluation methodology has been provided.

IMPLEMENTATION

The Tsunami-Ready evaluation methodology is based on, but not identical to the ASCE 7 provisions. Some provisions of ASCE 7 may be relaxed or waived in Tsunami-Ready evaluation, as those may prevent building owners from pursuing certification under this program. Some examples of onerous provisions include the peer review and site-specific tsunami inundation analysis as these requirements may increase cost and complexity beyond retaining a qualified structural engineer to carry out the evaluation. DEM should ultimately decide, along with HETAC, which of the provisions are modified to better encourage adoption and support of the program for building owners.

DEM may also wish to require building owners to file a “Notice of Intent” to apply for the Tsunami-Ready certification. This will allow DEM and HETAC to meet with the building owners to identify any major potential issues, including the site-specific inundation analysis and the peer review requirements, and set up intermediate review milestones prior to the building owner obtaining the engineering services. This can help prevent “surprises” along the course of the evaluation.

DEM may also wish to establish minimum qualification requirements for the structural engineer in responsible charge of a Tsunami-Ready evaluation. In addition to requiring the evaluating engineer be a licensed structural engineer, DEM may impose minimum years of relevant engineering experience. A similar approach is utilized by the US Resiliency Council (USRC) for certifying Rating Professionals and Rating Reviewers. Similar requirements could be adopted by DEM.

STAKEHOLDER AND PUBLIC OUTREACH

Throughout the project, Tetra Tech worked with DEM to engage stakeholders and the public. As a culminating task, Tetra Tech worked closely with DEM to develop approved language describing project outcomes, such as evacuation routes, signage and safe sites for dissemination and future outreach efforts. Once the English verbiage was approved, Tetra Tech utilized a DEM-approved vendor to have the outreach material translated into 14 additional languages in order to maximize coverage of the potentially impacted populations. The translated languages included:

- Chinese (Simplified)
- Chinese (Traditional)
- Chuukese
- Hawaiian
- Ilocano
- Japanese
- Korean
- Marshallese
- Pohnpeian
- Samoan
- Tagalog
- Thai
- Tongan
- Vietnamese