O'ahu Coastal Communities Evacuation Planning Project

Plan Design Enable

Final Report

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Prepared for:

Department of Emergency Management

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In November of 2012, The City and County of Honolulu Department of Emergency Management (DEM) hired a team comprised of Atkins, North America Inc.; Group 70 International, Inc.; Solutions Pacific, LLC; Martin and Chock, Inc.; and the University of Hawaii Sea Grant Program to prepare work products to assist rural communities throughout the Island of O'ahu to prepare for possible distantly-spawned tsunami events. Atkins and the rest of the team was selected in a competitive bid process. The roles of each firm in the overall conduct of the project is as follows:

- Atkins was the overall team leader and with its national evacuation expertise was tasked with developing the evacuation routes, vulnerability analysis and signage plans required by the contract;
- Group 70 was designated as the local firm lead to coordinate the activities of the other local firms that comprised the team as well as taking the lead on conducting the field work and determining the refuges that would be suitable for use during a tsunami event;
- Solutions Pacific, another local firm, was charged with collecting and analyzing behavioral data for its use in the vulnerability assessment, as well as leveraging its extensive local contacts to gather any other relevant local information needed by the team;
- Martin and Chock, a prominent local engineering and design firm, was tasked to be the physical sciences lead for the project, given that tsunamis are a physical phenomenon, they were instrumental in obtaining modeling and other data to support the vulnerability analysis portion of the project; and
- University of Hawaii Sea Grant Program was instrumental in developing the technical and public information needed to interact with local government officials and the public at the end of the overall project.

Hereafter, the collective group of firms above will be referenced as the Team.

Initially the contract specifically addressed the communities of Waianae, Nanakuli, Ewa Beach, Haleiwa/Waialua, Hauula, and Waimanalo and was to address the evacuation zone delineated in 2010. However by December of 2012, in consultation with DEM it became apparent that additional communities would need to be added to the area of study and that a much more severe tsunami scenario was becoming evident for the project's planning endeavors. Therefore, the project was expanded to include the communities of Makaha, Maili, Iroquois Point, Kailua and Kaneohe; although ultimately the scope of the study included all North Shore and Windward communities from Kaena Point to Mokapuu Point, and all Leeward and Ewa Communities from Kaena Point to Iroquois Point.

In addition to the expansion of the communities to be included in the study area, a new tsunami threat, named the Greater Aleutian Tsunami (GAT) scenario greatly expanded the vulnerability area to be considered for evacuation under the project. The GAT is a scenario caused by a magnitude 9 earthquake in the Mid-Aleutian Trench that would spawn a much more extreme tsunami wave and inundation area than that for the 2010 event. Although the GAT was considered to be a one in approximately 2,500 year event, it still warranted that the project consider it in its planning considerations, assumptions and processes. The GAT became the new standard and basis for all project work thereafter.

In December, 2012, the Team met with the following Emergency Preparedness Committees (EPC) to discuss the project and to gather information regarding the local procedures and other actions undertaken by the EPCs relative to the tsunami threat. The Team met with the EPCs in Kailua, Ewa Beach, Hauula, the entire North Shore, Project 52 and others from the Waianae Coast communities, and Kaheohe.

By January of 2013, the project team was provided very early access to the preliminary GAT scenario model data that was prepared by Dr. Kwok Fai Cheung, and immediately it set about determining which refuge facilities would not be subject to inundation in that scenario **(See GA Tsunami.zip in OAHU Coastal Communities Evac\!FINAL\Shapefiles in box)**. With that hazard specific modeling data, the team also began developing its behavioral analysis results **(See Draft Behavior Study.pdf in OAHU Coastal Communities Evac\!FINAL in box)**, conducting field work to verify refuge, community specific and other important ground truth information **(See Community Summaries-Final.pdf in OAHU Coastal Communities Evac\!FINAL in box)**; as well as delineating a new evacuation/inundation zone for the new scenario **(See Evac_Zone_10-GAT.zip in OAHU Coastal Communities Evac\!FINAL\Shapefiles in box)**.

Behavioral Assumptions Used in Study

As mentioned above Solutions Pacific performed an island-wide behavioral survey and analysis for another emergency management related project that focused on the public's responses to hurricanes and tsunamis. The study captured the variations in behavioral responses seen at different locations on the island. Therefore, the study results reflected the nuanced differences in the public response to tsunamis based on specific locations recognizing that locations and the demographic compositions of the public in that area would have a great deal of influence on their reactions to the tsunami threat. Solutions Pacific for the purposes of this study reanalyzed this previously collected data to conform to the specific needs of this particular project and prepared a study report with those findings. The behavioral report can be found at **(See Draft Behavior Study.pdf in OAHU Coastal Communities Evac\!FINAL in box).**

From the reanalysis results the Team used the following basic behavioral assumptions in performing their own efforts under the contract scope of work:

1. For the 2010 tsunami scenario, the study assumed a 100% participation rate in the Tsunami Evacuation Zone (TEZ) – this assumption, although it would probably not be realized in a actual tsunami event, was used in order to <u>allow all evacuees in that zone ample time to clear the inundation area and get to nearby safe locations</u>;

2. For the 2010 tsunami scenario, the study assumed the stated local participation rate for the immediate fringe area later generally designated the Extreme Tsunami Evacuation Zone (XTEZ);
3. For the GAT scenario, the study assumed a 100% participation rate in both the TEZ and XTEZ – again this assumption, although it would probably not be realized in a real tsunami event, was used in order to allow all evacuees in that zone ample time to clear the inundation area;
4. Generally, the Team assumed that slightly more than 20% of evacuating households would seek refuges for their safe destination, vis a vis going to friends and family or hotels/motels; and
5. Generally, approximately 85% of households would use one or more of their available vehicles to evacuate. The remaining percentages would flee on foot, use mass transit, or double up with other households.

Most of these behavioral assumptions were used knowing full well that the bias was toward overestimating vulnerable populations and clearance times and other estimates, which for public safety purposes is not only acceptable, it is preferred. These overestimates ensure that all decisions are based on information that slightly overstates the hazard and its impacts in order to safeguard the lives of the evacuating public.

Refuge Identification, Investigation and Selection

During this period, the Team began to investigate appropriate facilities and areas for use as refuges in both scenarios (2010 and GAT). Rather early on in the process, the Team recommended, and DEM accepted, that in order to reduce the likelihood of confusion in the populace, it would be preferable to have a single refuge for both scenarios. This would negate the possibility of evacuees seeking refuge at facilities that would be vulnerable in a GAT scenario because they were used to using that location for the more frequent and likely 2010 events. The Team began mapping and assessing the list of existing refuges identified by DEM for the 2010 scenario, and depending on their location, either retained or removed those facilities from the viable refuge list for the project.

Facility	Address	Community	Notes
Aina Koa Neighborhood Park	1331 Aina Koa Ave	Honolulu	3
Asing Community Park	91-1450 Renton Rd	Ewa Beach	1
Ewa Mahiko District Park	Renton Road	Ewa Beach	1
Herbert K. Pililaau Community Park	85-166 Plantation Rd	Waianae	2
Kahala Community Park	4495 Pahoa Ave	Honolulu	3
Kahuku District Park	56-170 Pualalea Street	Kahuku	2
Kailua District Park	21 South Kainalu Dr	Kailua	2
Kaimuki Community Park	3521 Waialae Ave	Honolulu	3
Kalakaua District Park	720 McNeil St	Honolulu	3
Kaneohe District Park	45-660 Keaahala Road	Kaneohe	1
Kilauea District Park	4109 Kilauea Avenue	Honolulu	3

Facility	Address	Community	Notes
Kokohead District Park	423 Kaumakani St	Honolulu	3
Kuliouou Neighborhood Park	501 Kuliouou Rd	Honolulu	3
Makaha Community Park	84-730 Manuku St	Waianae	1
Makakilo Community Park	92-1440 Makakilo Drive	Kapolei	1
Makiki District Park	1527 Keeaumoku St	Honolulu	3
Manoa Valley District Park	2721 Kaaipu Avenue	Honolulu	3
McCully District Park	831 Pumehana St	Honolulu	3
Nanakuli High & Inter School	89-980 Nanakuli Ave	Waianae	1
Niu Valley Middle School	310 Halemaumau St	Honolulu	3
Patsy T. Mink Central Oahu Regional Park	94-801 Kamehameha Hwy	Waipahu	1
Waialua High & Intermediate School	67-160 Farrington Highway	Waialua	1
Waianae Elementary School	85-220 McArthur St	Waianae	2
Wailupe Community Park	939 Hind luka Dr	Honolulu	3
Waimanalo District Park	41-415 Hihimanu Street	Waimanalo	1
Wilson Community Park	4901 Kilauea Avenue	Honolulu	3
1 = Viable for consideration in study 2 = Not viable, not considered for use in study 3 = Unknown viability, not in immediate study area			

Table 1: Existing DEM Refuge Facilities

The Team also considered facilities named or recommended by the local EPCs, some of which are listed below.

Facility	Address	Community	Notes
LDS Church	66-1009 Kaukonahua Rd	Waialua	2
Kawailoa Rd	Kawailoa Rd	Haleiwa	1
Opaeula and Twin Bridge Roads	Opaeula & Twin Bridge Roads	Haleiwa	1
Field adjacent Intelsat Paumalu Teleport	Comsat Rd	Sunset Beach	1
Kahuku District Park	56-170 Pualalea St	Kahuku	2
Kahuku Elementary	56-170 Pualalea St	Kahuku	2
Kahuku HS & Intermediate	Kamehameha Hwy	Kahuku	2
Hauula Kai Shopping Center	54-223 Kamehameha Hwy	Hauula	2
Elaine Chang property	54-230 Kam Hwy	Hauula	1
Hauula LDS Mauka Chapel	55-75 Hauula Homestead Rd	Hauula	1
Emergency Container Land	Hauula Homestead Rd	Hauula	1
Kailua Elementary	315 Kuulei Rd., , HI 967	Kailua	2
Kailua Intermediate	145 S Kainalu Dr	Kailua	2
Kalaheo High School	730 Iliaina St	Kailua	1
Lanikai Elementary	140 Alala Rd	Kailua	2
Christ Church Uniting Disciple	1300 Kailua Rd	Kailua	1
Pohakupu Mini Park	Ulumalu St	Kailua	1
Faith Baptist Church	1230 Kailua Road	Kailua	1
United Methodist Church	1110 Kailua Rd	Kailua	2
St. John Lutheran Church	1004 Kailua Rd	Kailua	2

Facility	Address	Community	Notes
Mid Pacific County Club	266 Kaelepulu Dr	Kailua	1
LDS Church Kailua	1461 Kanapauu Drive	Kailua	1
Le Jardin Academy	917 Kalanianaole Hwy	Kailua	1
Keaunui Community Park	Keaunui Dr	Ewa Beach	1
Kroc Salvation Army Center	91-3257 Kualaka'i Parkway	Ewa Beach	1
Notes 1 = Viable for consideration in study 2 = Not viable, not considered for use in study			

Table 2: Some Recommeded EPC Refuge Facilities

Also associated as part of this process was the determination of what areas were indeed safe and suitable for refuging. As mentioned above, the Team was provided early access to output from Dr. Kwok Fai Cheung's model results showing the extents and depths of inland flooding caused by the new GAT scenario. O'ahu Digital Elevation Models (DEMs), twenty foot contour data from the State, elevation data from Google Earth Pro were combined with GIS representations of Dr. Cheung's model output to create new shapefiles that established the most inland extent of GAT inundation. These maps **(See GA Tsunami.zip in OAHU Coastal Communities Evac\!FINAL\Shapefiles in box)** not only served as the basis for determining which refuge sites were ultimately safe from the impacts of a GAT scenario, but also for developing the vulnerable population and refuge demand figures discussed below.

Unfortunately, many of the DEM and EPC recommended facilities although very appropriate for a normal 2010 scenario would be inundated in a GAT scenario. The team further did an extensive survey of many other facilities throughout the study area that were probably outside the GAT inundation zone.

Once the entire inventory of refuge locations were identified by the Team in the study area, Group 70 conducted site visits with GPS to verify coordinate locations and elevations. They also used aerial imagery and GIS to establish vehicle parking locations, determine their capacities and establish other likely services that may be on site for use by evacuees. Nonetheless the entire Team met on numerous occasions to select and discuss the refuge options throughout the study area. Finally, the refuges seen as viable in both the 2010 and GAT scenarios were mapped and included in a refuge atlas entitled, Oahu Coastal Evacuation Planning Refuge Capacity Analysis **(See Refuge Cap Analysis-Final.pdf in OAHU Coastal Communities Evac\!FINAL in box)**. This atlas contains all the facilities assessed by the team and deemed as viable for use as a refuge (for all documents and shapefiles herein, the Refuge Number relates to the specific page in this atlas where the facility is featured). However, not all of the refuges included in the Atlas were ultimately used; that is, had evacuating populations or areas assigned to them as part of the evacuation route and signage plans. These "unused" facilities are nonetheless appropriate for use in both tsunami evacuation scenarios and could be used as backup or alternate facilities.

With respect to the selection criteria used in establishing the facilities deemed appropriate for use in all tsunami scenarios, the following items were considered:

1. Emphasis on using already existing refuges/shelters or co-location with those facilities – these types of locations would allow an easier transition to long term sheltering in case a tsunami actually destroyed residences and businesses;
2. Encouraged use of public owned facilities (either the City and County of Honolulu, the State of Hawaii, etc.), over the use of private property – that was to simplify the pre-event arrangements for their use;
3. The site had to have ample parking to justify its use, relative to the immediate local need (i.e., if a larger refuge could handle all local refuge demand relative to a smaller site, the more substantial facility would be used) – to minimize the number of overall sites used for refuging;
4. Where possible, refuge locations were selected to be strategic to the area and populations around them – this seeks to ensure that most evacuees in an area would be encouraged to evacuate to local locations rather than attempt to travel long distances to reach their safe destinations; and
5. Where possible, choose locations that would limit the likelihood of post-tsunami isolation – to minimize the likelihood that a single road washout would make long-term post-event resupply at a refuge site difficult or impossible.

Regarding the determination of parking spaces at each refuge facility and their mapping, the following standards were used:

1. For hardstand (paved) parking spaces, parking capacities were based on an assumption that each vehicle sent to that location would need 350 ft^2; and
2. For field parking, each vehicle would need 1,000 ft^2 in order to allow for travel lanes and to account for the general disorder caused by not having lines and other pre-event guidance for where vehicles should park.

The Team recognizes that these per vehicle assumptions have resulted in underestimating the parking capacity at each refuge location. Nonetheless these parking figures were used again to favor public safety and ensure that the population designated to use each facility could in fact be accommodated, with some allowance for additional vehicles if needed.

All locations deemed as suitable for use as refuges for this study (either with assigned populations or as potential sites) were mapped in GIS and can be found at **TS_Refuges_FINAL.zip in OAHU Coastal Communities Evac\!FINAL\Shapefiles in box.** The numbers displayed in the refuge location polygon, as well as the accompanying attribute table coincide with the page number of the Oahu Coastal Evacuation Planning Refuge Capacity Analysis atlas referenced above.

Vulnerable Population and Refuge Demand Figures

The draft evacuation limit shapefiles developed from Dr. Cheung's model output by the Team were provided to DEM for vetting purposes and for their own efforts to transform the inundation limits into evacuation zones for the GAT scenario. By September 2014, DEM had developed new evacuation zones to supplement those for a normal event, and named them the Extreme Tsunami Evacuation Zone (XTEZ) and Tsunami Evacuation Zone (TEZ) respectively. The new XTEZ boundary was even more inclusive than the Team's evacuation limits in that it included an additional 200 foot buffer area to the periphery of the previously developed evacuation zone.

The Team then used the new XTEZ in the identified study area and conformed all previous work to the new boundary, including reconfiguring the existing refuge assignment areas to fit the new XTEZ. In addition, the vulnerable population and refuge demand figures were recalculated in accordance with the new zone. With the dissemination of the XTEZ, all final work products prepared by the project Team conform to these new boundaries.

The Team combined the behavioral characteristics discussed above with U.S. Census figures from 2010 to develop vulnerable population and refuge figures. Once the existing (TEZ) and proposed (XTEZ) evacuation areas were developed using the model output from Kwok Fai Cheung's model, U.S. Census data to the Block level was superimposed onto those zones. Those Census Blocks that straddled the evacuation zones (i.e., TEZ, XTEZ, or outside) were further subdivided so that all data boundaries conformed to one another **(See Evac_Zone_10-GAT.zip in OAHU Coastal Communities Evac\!FINAL\Shapefiles in box)**. For those subdivided U.S. Census Blocks, aerial imagery was used to segregate the homes therein into their appropriate evacuation zone.

Once the 2010 base populations for each evacuation zone were developed, those figures were extrapolated to 2015 numbers by determining the annualized growth rate from 2000 to 2010 Census count. Those figures were then combined with the behavioral assumption percentages to develop the vulnerable population figures prepared as part of this report.

Also included with the vulnerable permanent resident populations are those from the various tourist facilities throughout Oahu. These tourist figures also encompass the seasonal units as identified in the U.S. Census data. The hotel/motel tourist unit estimates were developed from State of Hawaii databases (Department of Business, Economic Development and Tourism (DBEDT), as well as from other public and private sources, Hawaii Revealed Blue Book, Frommers). Therefore, these figures include tourist numbers for hotels and motels, condominiums, and vacation rental by owners (VRBO).

The vulnerable population figures are available at **Vulnerable Pop Figures 2015-Final.docx in OAHU Coastal Communities Evac\!FINAL** in box, whereas the refuge demand data is titled **Refuge Pops_Final.docx** at the same location. The refuge population/demand document details the number of vehicles and people that are expected to use each designated refuge from each of their assigned refuge areas. This table also relates those figures for high (i.e., weekends, evenings and nights) and low (i.e., weekday daytime) demand periods, as well as against the vehicle refuge parking capacity. As mentioned above these vulnerable population and shelter demand estimates for both scenarios are probably higher than the figures that will actually be realized during an actual event. Nonetheless, this overestimate is to ensure that all tsunami protective action decisions are based on data that will maximize public safety.

Evacuation Route Determination and Signage

In establishing the evacuation routes and developing a supporting signage plan, The Team discussed and developed an approach that further leveraged the work already done for the refuges. The basic tenet of this methodology was that each refuge would have a designated portion of the evacuation zones (See Figure 1 below) and its own dedicated route(s) (See Figure 2 below). The permanent residences and tourist units in each designated refuge area would follow on a unique route to their assigned refuge locations. Furthermore the signage plan would directly support the assigned refuge area and designated route concept.

Using the parking capacity developed for each refuge site, the TEZ and XTEZ Census Blocks were further divided into assigned refuge areas **(See Refuge_Blocks_FINAL.zip in OAHU Coastal Communities Evac\!FINAL\Shapefiles in box)** so that the number of allocated homes and tourist units therein would not exceed the number of parking spaces at the refuge location. Once each refuge was provided with an assigned refuge area, the following precepts with respect to routing were applied:

1. Where possible, evacuation routes would not cross one another in conveying traffic from the assigned refuge areas to the designated refuge locations;
2. The trip to refuge would be kept to as short a distance as possible;
3. Tried to maximize the use of right hand turns along the route;
4. Where possible, tried to capitalize on normal directions of traffic flow; and
5. Routes would convey traffic mauka as quickly as possible.

Evacuation Routes (**See EvacRoutes_FINAL.zip in OAHU Coastal Communities Evac\!FINAL\Shapefiles in box)** and signage only pertain to those evacuation trips going to refuge, all other traffic to different locations (i.e., friend and family) were assumed to know and employ their own routing to get to their alternate destinations.

For the placement and type of signage the following measures were utilized:

1. To minimize the number of signs placed on the highway, signage was placed only at strategic locations along the route to the refuge, namely where turns occurred, or where the directed course of travel is different than a normal direction of movement. Therefore, signage pointing in a normal and obvious direction of travel was avoided since it was assumed that evacuees going to refuges would go that direction anyway;

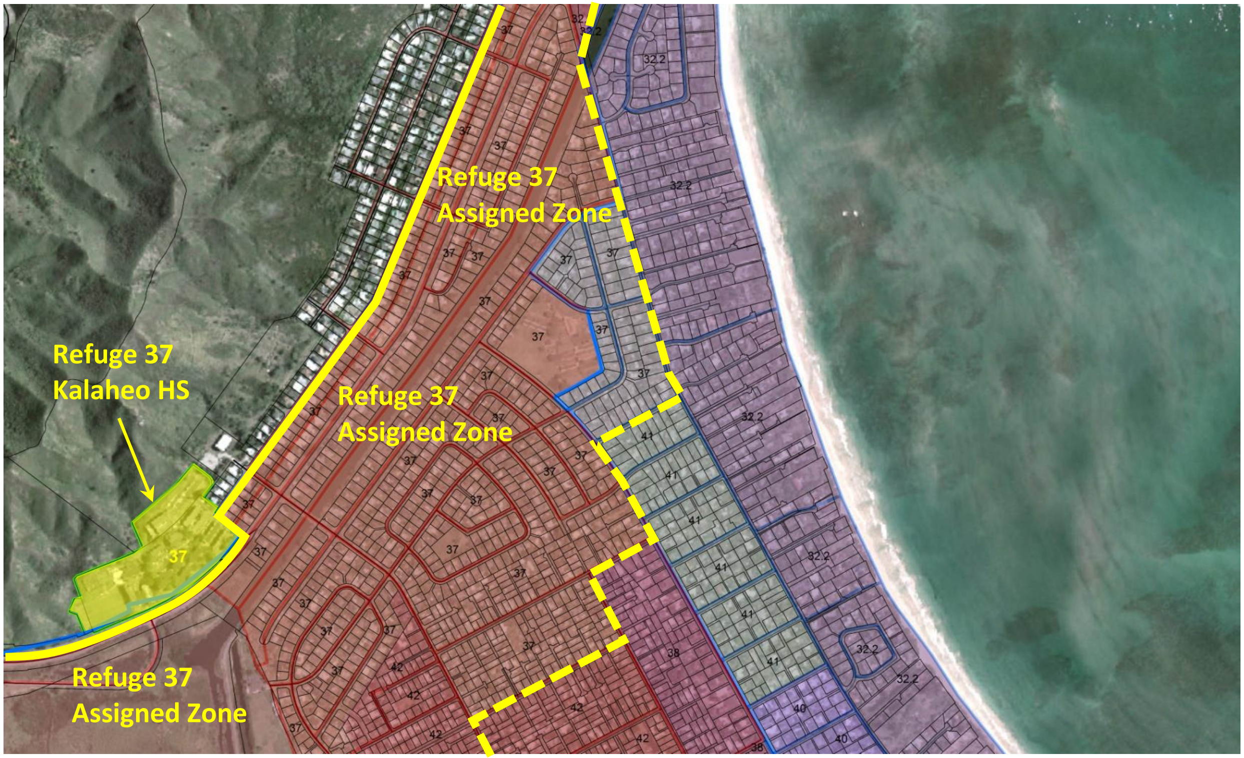

Figure 1: Refuge Assignment Area

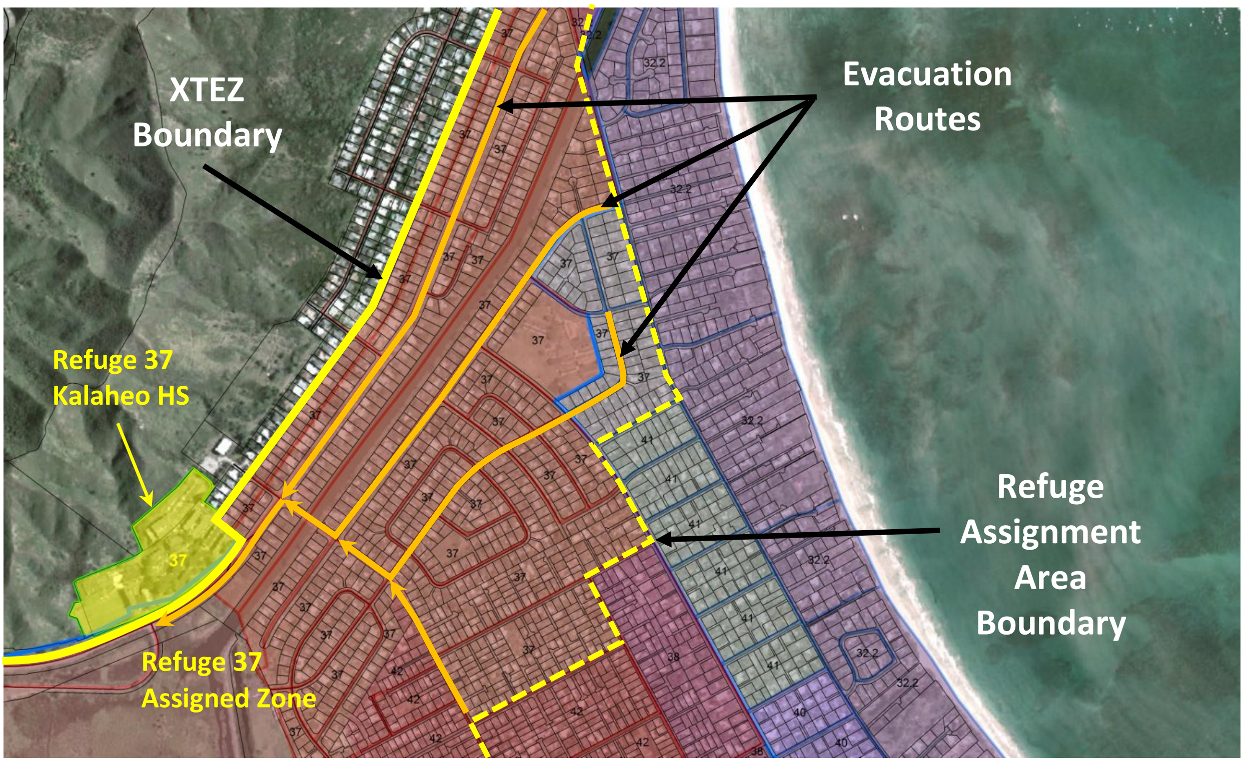

Figure 2: Designated Evacuation Routes

2. Where possible, tried to maximize using already emplaced vertical infrastructure (e.g., existing signs, light posts, etc.) to mount signs; and
3. Although all posted signage is directional in nature, most directional arrows include text with clarifying information (e.g., name of destination refuge, approaching turn directions, etc.).

The signage GIS file is at **Signage_FINAL.zip in OAHU Coastal Communities Evac\!FINAL\Shapefiles** in box. The display convention for the sign is, the red dot indicates the location of the post or stanchion on which the sign is mounted, the black line indicates the orientation of the face of the sign and the arrow shows the specific guidance or instruction provided by the sign (See Figure 3 below).

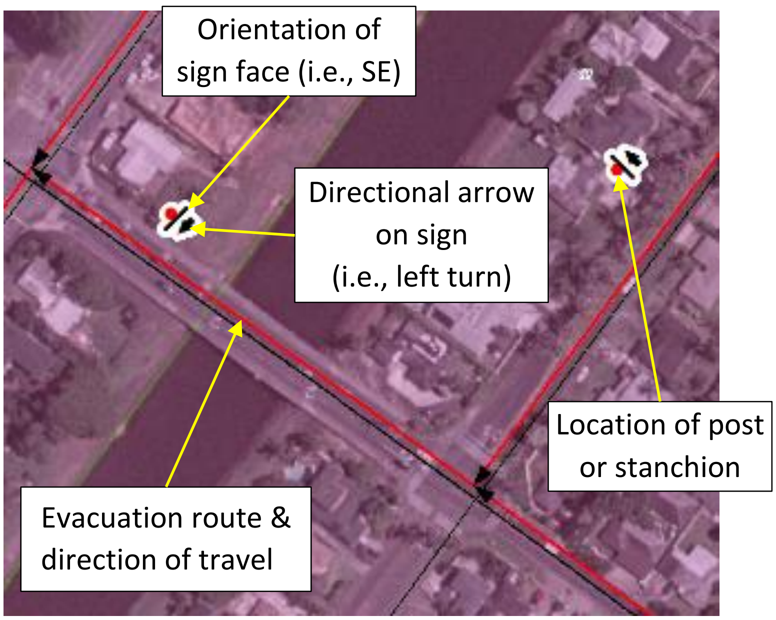

Figure 3: Signage Symbol Explanation

<u>Clearance Time Determinations</u>

Once evacuation routes were designated and mapped **(See EvacRoutes_FINAL.zip in OAHU Coastal Communities Evac\!FINAL\Shapefiles in box)**, Atkins determined clearance times for each refuge and its accompanying assigned refuge zone. Each evacuation route was subdivided into route segments with the termini situated at intersections, or at locations where significant changes in roadway characteristics (e.g., increase in number of lanes, etc.) warranted a method for differentiating one portion of roadway from the next. Each route segment was then assigned a directional service volume, which is a value that represents how many vehicles per hour can be conveyed along that portion of the transportation network in each direction. Using the number of lanes, roadway type (e.g., limited access, divided, undivided, etc.), responsible agency (i.e., federal, state, or local), surrounding land uses (e.g., urban, rural, etc.) and other physical attributes, an hourly Level of Service (LOS) was assigned to each and every section of evacuation roadway on Oahu.

Each refuge and assigned refuge area, as well as its supporting evacuation routes were the analyzed to determine which roadway segments would likely be the bottlenecks for those specific evacuation trips. These bottlenecks, which usually coincide with intersections, or other areas where roadway capacity are constrained relative to traffic demand, are the primary determinant of the clearance time for that refuge facility and assigned zone.

Once the likely bottlenecks are identified, those roadway segments are loaded with evacuation traffic, represented by the number of vehicles using that section of roadway for evacuation. In determining the evacuation traffic, both those vehicles passing through the link with the express purpose of travelling to the designated refuge and those driving through to other destinations (e.g., friends and family, etc.) were included in the calculations.

In addition to these evacuating trips, these bottlenecks were further burdened with those trips not specifically involved with the evacuation, also known as background traffic. Background traffic will certainly occur concurrently with evacuation trips, since even non-evacuating people will need to travel on the same roadways simultaneously, especially in urbanized areas where tsunami evacuations may coincide with normal rush hours or other daily activities. To factor in background traffic, the peak, measured, directional, hourly traffic volume was used to ensure that clearance time calculations were based on the worst-case, but realistic scenario (i.e., a tsunami evacuation occurring simultaneously with a weekday rush hour event). These peak hour background traffic figures were obtained from the Hawaii Department of Transportation, Highways Division Planning Branch 2009 Traffic Station Mapbook.

Simplistically the equation for calculating clearance times is represented thusly:

$$\frac{\text{Evacuating Trips to Refuge + Evacuating Trips to Other Locations + Background Traffic}}{\text{Hourly Directional Service Volume}}$$

This simple schematic equation is further complicated by the inclusion of a loading curve (to factor in a two hour public mobilization time), time-stepped attenuation of the hourly directional service volume (to represent the reduction in throughput caused by increasing traffic congestion and turbulence) and diminution of background traffic (traffic will naturally decrease as the forecast event arrival time draws near).

For the purposes of this study, a clearance time is defined as the time it takes to clear all vehicles that will use a bottleneck segment during an evacuation, beginning from when the first evacuating vehicle enters the roadway until the last evacuating vehicle reaches a point of assumed safety. Therefore, a clearance time includes:

1. time for the bottleneck to gradually experience escalating traffic volumes as a result of natural variability in how quickly people will prepare to evacuate, and/or travel to the bottleneck (also known as mobilization, or loading time);
2. the amount of time the bottleneck will need to operate at peak assumed capacity in order to process all of the vehicle demand caused by the evacuation order (also known as queuing delay time); and
3. The travel time from the bottleneck to a point of relative safety, in this case to the nearest assigned refuge.

Clearance time is not the time that any one vehicle will need to get from the point of origin (the evacuating household or tourist unit) to the final safe destination (the assigned refuge). Those vehicles starting their evacuation trips early, before the bottleneck segments begin to experience saturation flow, will take a normal amount of time to reach their destination. Whereas vehicles leaving later in relation to when the evacuation order was issued, will experience much longer commute times to their assigned refuges, especially once those same bottlenecks become overloaded by their evacuation vehicle demand.

A table with clearance times for each refuge with assigned evacuation areas is located at **Clearance Times-Final.docx in OAHU Coastal Communities Evac\!FINAL** in box. DEM provided guidance that approximately four hours would be the maximum amount of response/evacuation time allowed by a GAT scenario seismic event. Given that goal, most vehicles from the assigned refuge areas can easily reach their associated refuge within that particular timeframe. Some locations however, exceed the four hour threshold, but unfortunately those times cannot be avoided given the current roadway network, or refuging options/locations.

Table 3 below documents those difficult bottlenecks, which arise primarily because they are situated on the only corridors in the area that can be used by all parties to reach any safe destination (i.e., refuges or other) and because an overwhelming number of vehicles at any of these bottlenecks are heading toward locations other than refuges. Therefore these bottlenecks identified below may potentially exceed the stated four hour window, regardless of whether refuge bound vehicles are routed through them or not. In fact, in two cases cited below (i.e., Refuges 11 and 17), the evacuating vehicles designated to travel to their assigned refuges are routed on alternate roadways, Pa’akea Rd and Kaukonahua Rd respectively to avoid these problem roadway segments.

Those evacuees travelling to their assigned refuges through all of the other critical bottlenecks cited above must be encouraged to leave as early as possible. Their arrival at these critical roadway segments must occur before the vehicles further up the Wai’anae Coast and the Windward Coast, and going to all other destinations, can arrive at these locations and overwhelm their capacity.

Refuge No.	Refuge Location	Refuge Name	Bottleneck location	TEZ Number of Vehicles Evacuating	XTEZ Number of Vehicles Evacuating	TEZ Clearance Time in Hours	XTEZ Clearance Time in Hours
[1]				[2]	[2][3]	[4]	[4]
10	Nanakuli	Nanakuli HS & IS	via Farrington Hwy @ Helelua St	6,461	7,910	6.0	6.9
11	Ma'ili	Pu'u O Hulu CP etc	via Farrington Hwy [5]	4,918	5,961	4.4	5.9
17	Waialua	Dole Plantation Facilities	via Kamehameha Hwy @ Weed Circle [6]	4,524	4,932	5.8	6.8
22	Ka'a'awa	Kualoa Ranch	Kamehameha Hwy @ Kualoa Regional Park	3,796	4,342	5.2	6.2
24	Waiahole	Waiahole ES & IS	Kamehameha Hwy @ Waiahole Valley Rd	4,067	4,838	5.4	6.8
25	Waihee	Senator Fong's Garden	Kamehameha Hwy @ Pulama Rd	3,927	4,683	5.8	7.4
26	Kahalu'u	Kahalu'u ES/ Mini Park/ Key Project	Kamehameha Hwy @ Waihee Rd	4,108	5,158	5.9	7.8
28	He'eia	Ahuimanu ES & Community Park	Kamehameha Hwy @ Hui Iwa St	3,904	4,794	5.7	7.6

[1] Refuge Number corresponds with the page number for that refuge in the Oahu Coastal Evacuation Planning Refuge Capacity Analysis atlas.

[2] Maximum total number of local evacuating vehicles traveling through bottleneck, regardless of destination (i.e., refuge vs. out of sector).

[3] XTEZ figures include TEZ evacuating vehicles.

[4] At peak (rush) hour, regardless of time of day.

[5] Figures Include vehicles going to refuge (11.1-11.4), as well as vehicles leaving Makaha, Wai'anae and Ma'ili. This route was not chosen in favor of sending evacuees to Pa'akea/Hakimo/Lualualei Naval Road refuges using alternate routes because of excessive clearance times at this roadway segment.

[6] Figures Include vehicles going to refuge (17), as well as vehicles leaving Waialua, Hale'iwa and Mokuleia. This route was not chosen in favor of sending evacuees to Dole Plantation refuge using Kaukonahua Rd because of excessive clearance times at this roadway segment.

Table 3: Critical Bottleneck Clearance Times

Public Outreach

Through the latter part of November and early December 2014, The University of Hawaii Sea Grant Program, in concert with DEM conducted public hearings throughout O'ahu to explain the technical aspects of the new GAT scenario and to present the new Extreme Tsunami Evacuation Zone (ETEZ). In addition to the communities with active EPCs, and those in the project's study area, public meetings were also held in the localities not included in the project such a Kapolei, Hawaii Kai, Waikiki and others. Furthermore, in February of 2015, Atkins, again in concert with DEM, conducted detailed working meetings with the EPCs to discuss the specifics of the refuging, routing and signage plans prepared for their communities. Not only were these meetings an opportunity to hear first-hand the particular measures that the project was proposing for their jurisdictions, they also allowed the EPCs an occasion to provide further guidance and feedback before the project's work products were finalized. These follow on EPC meetings were conducted in Kailua, Hau'ula, Makaha, 'Ewa Beach, Kane'ohe and Waimanalo. The updated presentations which were prepared and delivered to the respective EPCs, each community with its own PowerPoint file, can be found in the subdirectory **OAHU Coastal Communities Evac\!FINAL\EPC Presentations** in box.

Recommended Actions

1. All traffic from Iroquois Point must be diverted to Iroquois Ave/ 12th St/West Lock Rd/Iroquois Rd. N Rd westbound from 12 St to Ft Weaver Rd must be blocked to disallow any vehicles from getting onto Ft Weaver Rd south of Iroquois Rd.
2. The fence that blocks the roadway near 87 Mohihi St should be removed and the road continued through to allow through passage on Mohihi Street all the way to Lualualei Naval Rd.
3. Develop another emergency bypass road that connects Lualualei Naval Road with Haleakala Ave to allow vehicles in western Nanakuli to bypass the worst congested roadway link on the Waianae Coast to get to the Nanakuli HS & IS refuge. Nanakuli HS & IS refuge is underutilized and evacuees will have to seek refuge along roadways in the open because there is no way they will be able to reach the Nanakuli HS & IS refuge in under the four hour timeframe.
4. Ensure that all Wai'anae Coast Emergency Access Route (WCEAR) roadways are opened and are available to accommodate evacuation traffic.
5. Ensure that the gates on either side of Cane Haul Road in Haleiwa are opened prior to the initiation of any tsunami evacuation.
6. Especially in the XTEZ scenario, more of the population at large must be convinced to seek local refuge than currently is evident in the behavioral surveys. Too many evacuees are going to try and commute to distant destinations (according to our current behavioral surveys), rather than go to local refuges. These "exiting" vehicles increase clearance times that extend well beyond the three to four hours available in the XTEZ scenario. This is especially true for the

Wai’anae Coast near Nanakuli, Weed Circle for the North Shore and the Kam Highway from Ka’a’awa to Waiahole for the Windward Coast.

7. Consider developing a separate siren signal to be deployed one hour before the forecast arrival time of the tsunami to warn those evacuees still in stuck in traffic queues to abandon their vehicles and start walking mauka as quickly as possible.
8. Consider adopting policies that gas stations in the TEZ and XTEZ and along designated evacuation routes will be directed to cease fuelling operations so that their vehicle queues do not cause an additional impediment to traffic flow during an evacuation.
9. Where possible, all field parking at refuge facilities identified through this effort should have curb cuts with gates to allow vehicles to smoothly transition from parking lots and pavement over curbs and onto the field parking areas.

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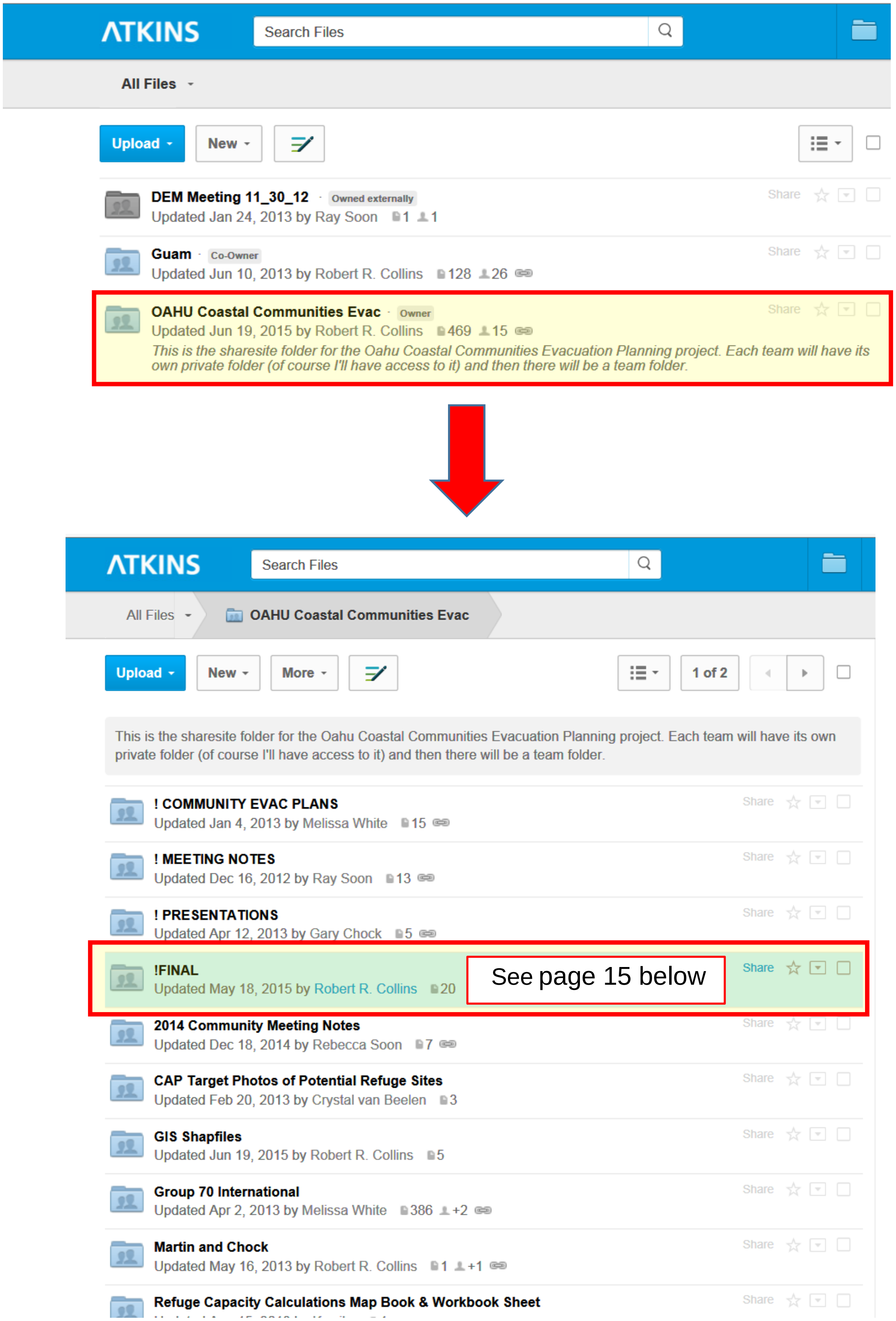

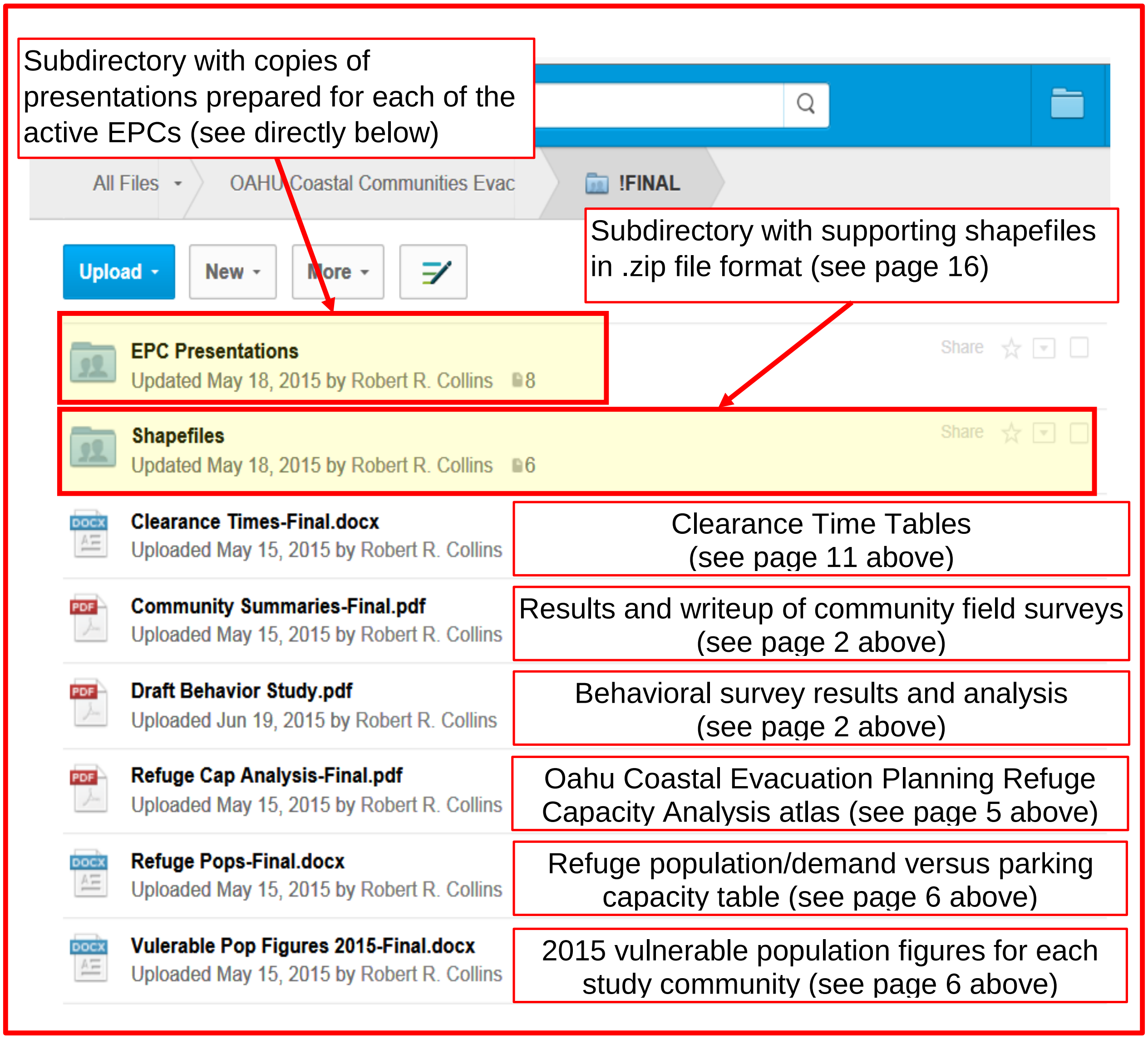
Subdirectory with copies of presentations prepared for each of the active EPCs (see directly below)
All Files
OAHU Coastal Communities Evac
!FINAL
Subdirectory with supporting shapefiles in .zip file format (see page 16)
Upload
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EPC Presentations
Updated May 18, 2015 by Robert R. Collins 8
Share
Shapefiles
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Clearance Time Tables (see page 11 above)
Community Summaries-Final.pdf
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Results and writeup of community field surveys (see page 2 above)
Draft Behavior Study.pdf
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Behavioral survey results and analysis (see page 2 above)
Refuge Cap Analysis-Final.pdf
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Oahu Coastal Evacuation Planning Refuge Capacity Analysis atlas (see page 5 above)
Refuge Pops-Final.docx
Uploaded May 15, 2015 by Robert R. Collins
Refuge population/demand versus parking capacity table (see page 6 above)
Vulerable Pop Figures 2015-Final.docx
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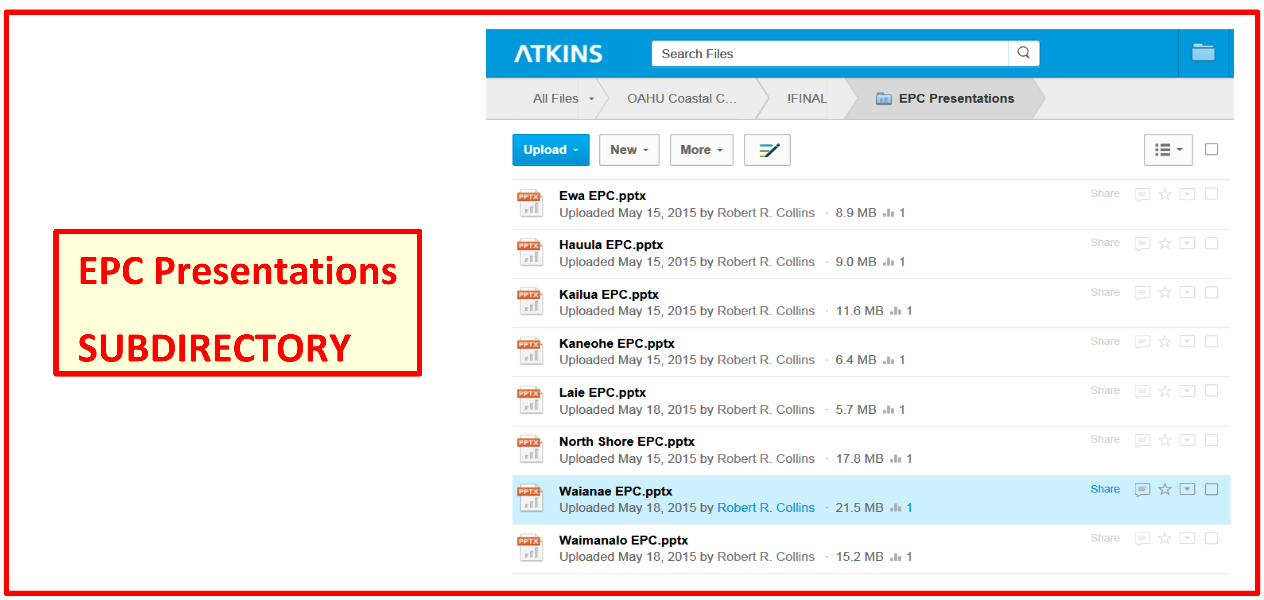
2015 vulnerable population figures for each study community (see page 6 above)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Shapefiles

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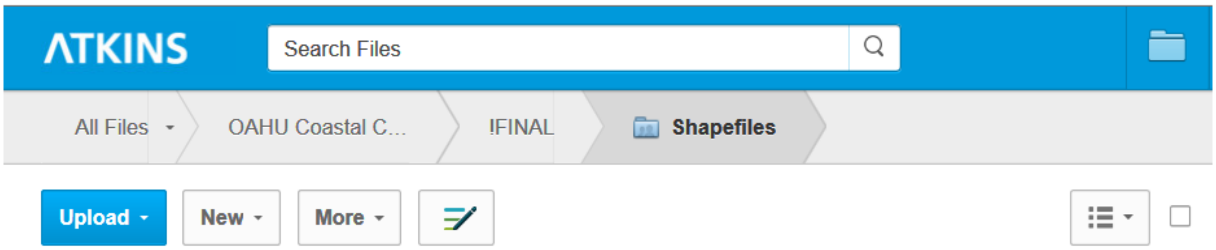

File	Description
EvacRoutes_FINAL.zip Uploaded May 15, 2015 by Robert R. Collins	Evacuation route shapefiles (see page 7 above)
Evac_Zone_10-GAT.zip Uploaded Jun 19, 2015 by Robert R. Collins	2010 and GAT evacuation limits submitted by the Team (see page 6 above)
GA Tsunami.zip Uploaded Jun 19, 2015 by Robert R. Collins	Original GAT inundation limit shapefiles from Dr. Cheung's model (see page 2 & 4 above)
Refuge_Blocks_FINAL.zip Uploaded May 18, 2015 by Robert R. Collins	Refuge Assignment Area shapefiles established from XTEZ (see page 7 above)
Signage_FINAL.zip Uploaded May 15, 2015 by Robert R. Collins	Signage plan shapefiles (see page 9 above)
TS_Refuges_FINAL.zip Uploaded May 15, 2015 by Robert R. Collins	Listing of all refuges considered viable for both tsunami scenarios (see page 6 above)