State of Hawaii
DEPARTMENT OF LAND AND NATURAL RESOURCES
Engineering Division
Honolulu, Hawaii 96813

November 10, 2022

Board of Land and Natural Resources
State of Hawaii
Honolulu, Hawaii

Request Approval of Variance of Hawaii Administrative Rules Title 13, Subtitle 7, Chapter 190.1, Section 13-190.1-4 (3); Spillway constructed in natural ground, for Kehalani Offsite Retention Basin (MA-0141), Maui.

Dam Owners: RCFC Kehalani, LLC
2005 Main Street
Wailuku, HI 96793
Legal Landowner: Heona Investments, LLC,

Location: Waikapu, Maui
Tax Map Key: (2) 3-5-0028:001

Background on Variance Request

The Kehalani Offsite Storm Water Retention Basin was constructed in 2003 to store storm water runoff from the Kehalani Mauka project site in Wailuku to meet County of Maui post-development stormwater requirements. The County standard required storage of incremental post-development stormwater volume for a 100-year, 24 hour storm. The basin was formed by excavation and construction of a dam. An overflow spillway was designed to allow volumes in excess of the storage to be directed to Waikapu stream via a trapezoidal concrete channel. In addition to the overflow spillway, a pump system was installed to drain the basin after storm events. The pump system is capable of pumping 37,000 gallons per minute or approximately 53 million gallons per day. The pump system has a backup emergency generator to run the system in the event power is lost.

The Kehalani Offsite Storm Water Retention Basin is currently classified as a small, high hazard potential dam, as a failure of the dam could result in loss of human life. We believe that the basin may have originally been designated low hazard prior to construction, for which the inflow design flood would have resulted from the 100-year, 24-hour storm. A design review by the Department of Land and Natural Resources (Department) in December 2008 expressed concern as to the dam spillway's capacity to pass one-half of the Probable Maximum Flood (PMF) event, the standard at the time for small high hazard dams. On February 20th, 2012, new Dam and Reservoir Administrative Rules went into effect which changed the inflow design flood to the full PMF for high hazard dams, regardless of size.

Beginning in 2010, WEST Consultants (WEST) conducted hydrologic and hydraulic analyses which found that the existing spillway is not able to pass the required flood event, the PMF, with adequate freeboard. WEST then studied multiple different alternatives that would either divert flow upstream of the facility, expand the existing spillway, or include a new auxiliary spillway in order to pass the design flood. However, constraints such as a limited right of way, impacts to adjacent landowners, and County requirements for stormwater storage narrowed the options and led to the recommendation to construct a new auxiliary spillway over the existing east embankment.

Designing a spillway over the manmade embankment portion of the dam is normally not desired as it introduces additional potential failure modes. Therefore, the Department's Dam Safety Administrative Rules minimum design requirements for regulated dams stipulates that earthen spillways be constructed in natural ground.

Although the proposed spillway design does not meet the Department's minimum design requirements, it will allow safe passage of the PMF design storm and dam safety mitigative features will be incorporated into the new secondary spillway design to address dam safety concerns and minimize risks. The original spillway will remain unaltered as originally designed and will act as the primary (initial) spillway.

Therefore, a variance is being requested to allow the secondary spillway design to be constructed over the existing dam embankment. The conceptual design of the spillway has been developed by the owner's engineer to help visualize the anticipated scope and extent of the proposed spillway at the dam site.

Conceptual Design Overview

The conceptual design is a concrete auxiliary spillway constructed in the east embankment, as shown in Figure 1. The existing spillway will remain in place and allow evacuation of flows exceeding the existing storage volume and pump capacity. The auxiliary spillway would only be activated during extremely rare storm events. The conceptual spillway design includes a spillway crest at the existing embankment elevation. A parapet wall, not part of the variance request, will ensure that adequate freeboard is maintained during the PMF event.

Hydraulic modeling analyses using the conservative assumptions required by the Department (reservoir full to the spillway crest elevation at the beginning of simulations even though the basin is normally dry, neglecting existing large pump capacity to evacuate the reservoir) were conducted to show that construction of the new spillway would allow for flows above the capacity of the existing spillway to be conveyed safely away from the structure.

A dam safety permit application for the final spillway design improvements would be required to be submitted to the Department for review and approval by the Board of Land and Natural Resources (Board). Prior to bringing the dam safety permit to the Board for approval, the dam safety program will review the application to ensure that current standards of practice and mitigative design features are incorporated to minimize the potential risk of a spillway or dam failure.

Figure 1. Key elements of Conceptual Design for remediation to Kehalani Retention Basin (note parapet wall is not part of the variance request but necessary to add freeboard for wind waves per DLNR requirements)

Legal Authority
HRS Chapter 179D- 6(b) 1-6 General Powers and duties of the board of land and natural resources

§179D-6 General powers and duties of the board of land and natural resources.

(b) The board shall administer the dam and reservoir safety program established by this chapter. In carrying out this chapter, the board shall cooperate, advise, consult, contract, and enter into cooperative agreements with the United States government or any of its agencies, other state agencies, and the county governments or any of their agencies. In the performance of its duties, the board shall:

(1) Establish by rules adopted under chapter 91, policies, requirements, or standards governing the design, construction, operation, maintenance, enlargement, alteration, repair, removal, and inspection of dams, reservoirs, and appurtenant works for the protection of life and property from structural failure of dams and reservoirs.

(5) Require the owners to apply for, and obtain from the board written approval of plans and specifications on the construction of any new dam or reservoir or the enlargement of any dam or reservoir prior to commencement of any work;

(6) Require the owners to file an application and secure the written approval of the board before commencing the repair, alteration, or removal of a dam or reservoir, including the alteration or removal of a dam or reservoir so that it no longer constitutes a dam or reservoir as defined in this chapter. Repairs shall not be deemed to apply to routine maintenance not affecting the safety of the structure.

Hawaii Administrative Rules Title 13 Chapter 190.1, Section 4(3)

§13-190.1-4 <u>Minimum design requirements.</u> (a) Regulated dams and reservoirs shall incorporate the following minimum design requirements:
(1) Embankment slopes that are not steeper than 2.5 horizontal to 1 vertical unless a specific design for a steeper slope shows that the embankment is stable and capable of being safely maintained;
(2) An embankment crest that has a minimum width of ten feet;
(3) Earthen spillways that are constructed in natural ground; and
(4) A low-level outlet shall be designed to drain the reservoir by gravity flow.

<u>Recommendations</u>

That the Board of Land and Natural Resources approve the following:

1. Authorize a Variance of Hawaii Administrative Rules Title 13, Subtitle 7, Chapter 190.1, Section 13-190.1-4 (3) for spillway improvements to be allowed to be constructed over the dam embankment at the Kehalani Offsite Retention Basin (MA-0141) on the island of Maui.

2. Authorize the dam safety program staff to work with the owner on the extent and application of the approved variance.

Respectfully submitted,

CARTY S. CHANG
Chief Engineer

APPROVED FOR SUBMITTAL:

SUZANNE D. CASE, Chairperson
Board of Land and Natural Resources

Attachment:

A. Memorandum: *2D Hydraulic Modeling of Pre- and Post-Kehalani Retention Basin – Updated Manning's n*, Dated June 21, 2021

WEST Consultants, Inc. MEMORANDUM

TO: Eric Matsuda, P.E., SSFM International

FROM: Martin Teal, P.E.

DATE: June 21, 2021

SUBJECT: 2D Hydraulic Modeling of Pre- and Post Kehalani Retention Basin – Updated Manning's *n*

The purpose of this memorandum is to summarize the hydrologic and hydraulic analysis of Waikapu Stream during the Probable Maximum Flood (PMF) event. WEST developed a pre-project conditions model in which flows from Waikapu Stream were added to the existing model and the drainage channel from the Kehalani development, Kehalani Basin, and spillway were removed. The pre-project modeling results were then compared with results from the Kehalani basin with the 1,000-foot auxiliary spillway preliminary design (project) conditions. Results generally show only small increases in maximum depth with the spillway in place, leading to the conclusion that addition of an auxiliary spillway is a feasible alternative to pass the PMF and meet dam safety regulations.

1. Background

As summarized in the memorandum of January 12, 2017, subbasin 4 was split into two subbasins, 4A and 4B (depicted in Figure 1) and modeled in HEC-HMS to determine the outflow hydrographs at the valley mouths. These hydrographs were then used as boundary condition inflows to a two-dimensional (2D) hydraulic model and are used in the current study. The following sections describe the methodologies used to compute flows and develop the 2D model.

2. Hydrologic Input

The PMF flow for the Waikapu Stream drainage basin was computed using the HEC-HMS (HMS) hydrologic modeling software. The Probable Maximum Precipitation (PMP) was developed and used as input in the HEC-HMS model in order to generate the PMF. The results from the hydrologic model were used as input to the 2D hydraulic model to examine the hydraulic impact of Waikapu Stream on flooding near to and downstream of the Kehalani Basin.

The same procedures, parameters, and data described in the "Kehalani Retention Basin Hydrologic Analysis" report were used to delineate the Waikapu Stream subbasin and determine the curve number, impervious percentage, and lag time. Likewise, the area-weighted PMP and distribution for the basin were developed using the same methodology and storm pattern as used in the previous HMS models. The peak modeled outflow from the subbasin is 22,200 cubic feet per second (cfs). The input hyetograph for the effective precipitation applied to the HEC-RAS model was the same one as used in the previous study.

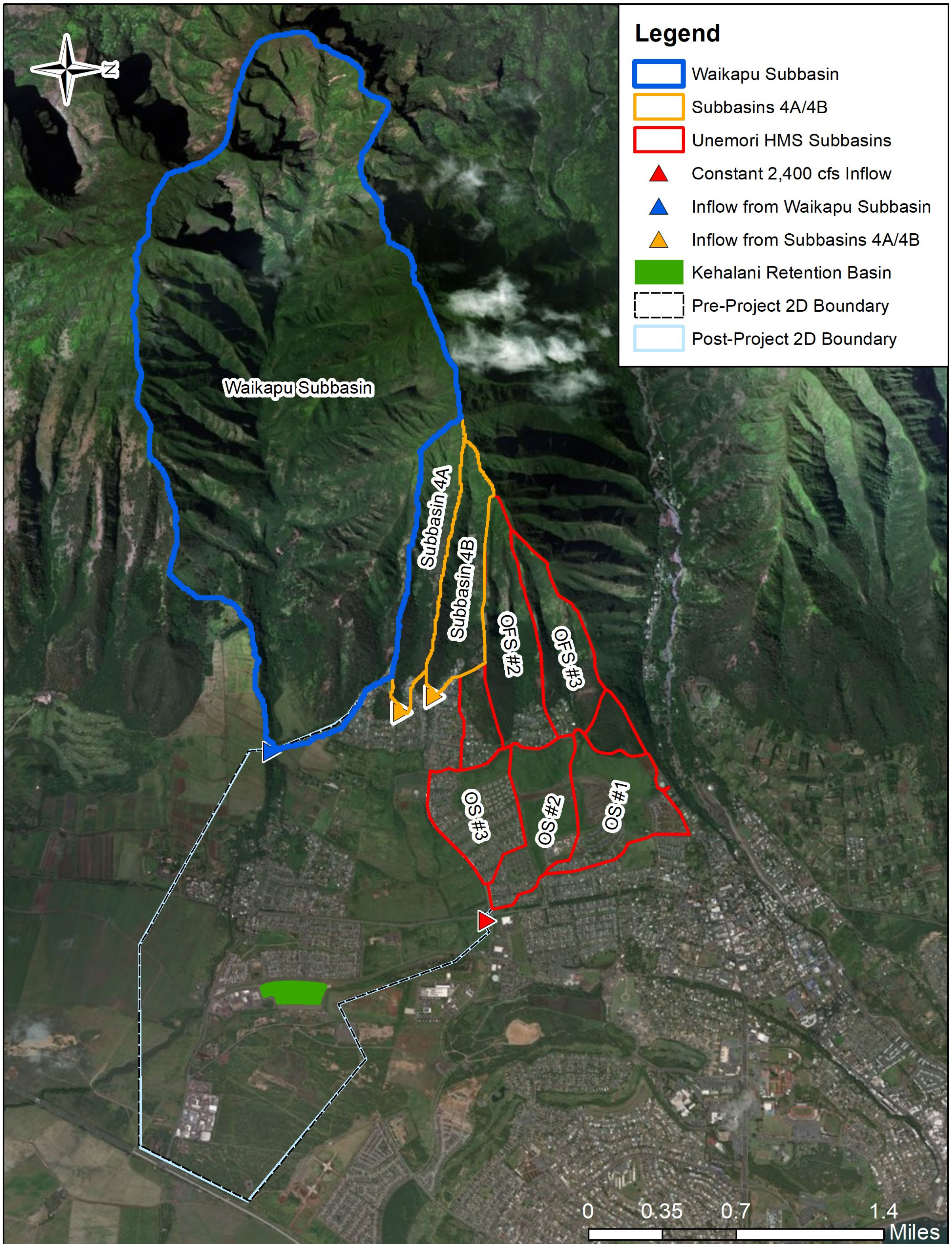

Figure 1. Model Schematic Showing HEC-RAS 2D Boundaries, HEC-HMS Subbasins, Retention Basins, and Model Inflow Locations.

3. 2D Hydraulic Model

Figure 1 shows a schematic of the model layout and includes the Waikapu Stream HMS subbasin, the 2D model boundaries for pre-project and project conditions, the inflow locations, and the relative position of the Unemori subbasins used in previous analyses.

Mr. Tom Ochwat of the County of Maui Department of Water Supply provided 2-foot contours based on LiDAR elevation data collected by the County in 2005, and these were used to develop the base terrain for the 2D HEC-RAS hydraulic model.

The pre-project 2D grid was extended to include Waikapu Stream along the south side and makai of Kehalani Retention Basin to Honoapiilani Highway. The project 2D grid was also extended makai of Kehalani Retention Basin to Honoapiilani Highway to evaluate and compare flooding extents with pre-project conditions. A nominal cell size of 50 feet was used for both pre-project and project models. Break lines were added to provide definition and place cell faces along high ground.

Land use data were obtained from the National Land Cover Database Hawaiian Zone Land Cover Layer (USGS, 2003) and clipped to the extents of the model domain. The various land use classes were consolidated into six land cover types and visually checked for accuracy using aerial imagery. Street polygons were created manually with a width of 30 feet, based on centerline data available from the Maui County GIS Division (Maui County, 2012), and merged with the other land use data. Manning's *n* values used to model surface roughness were assigned to land use categories as follows:

- Open water – 0.04
- Streets – 0.02
- Developed – 0.08
- Evergreen forest – 0.1
- Grass (short grass) – 0.038
- Cultivated soils – 0.035

Manning's *n* values were assigned using guidance from the United States Environmental Protection Agency "Storm Water Management Model Reference Manual Vol 1 – Hydrology" (EPA, 2016), Chow (1959), and FLO-2D Reference Manual (2019). The "streets" value of 0.02 is characteristic of smooth surfaces such as concrete, asphalt, gravel, or bare soil. The "developed" value of 0.08 is a combination of very high roughness due to buildings and other obstructions and lower roughness for open areas, front yards, etc. The "evergreen forest" is characteristic of woods with light underbrush. The "cultivated soils" layer is based on a residue cover of ≤20 percent. The land cover shapefile was added to the HEC-RAS model and associated with the terrain layer and model geometry. The Waikapu Stream Manning's *n* value for the channel (0.065) was obtained from the FEMA effective hydraulic model and was used to override the land cover data specified above along the channel only. Figure 2 shows the land use types underlying the 2D grid.

In addition to the previously-described effective rainfall hyetograph, which was applied uniformly over the grid, four boundary inflows (shown in Figure 1) were applied to the project model:

1. Flows originating in the two subbasins mauka of the Wailuku Heights development (4A and 4B) were input to the 2D grid at the outlet locations as two separate time series hydrographs.
2. Flow originating in the Kehalani Development is conveyed to the Kehalani Retention Basin via an open channel. A previous study determined that inflows from the development are limited to the actual capacity of the off-site drainage system (in particular, the culvert passing under Kuikahi Drive), which was not designed to contain the PMF. The peak flow conveyed by the culvert is approximately 2,400 cfs; this was applied as a constant boundary flow to the 2D grid at the request of the reviewers, though it is very conservative in terms of the total volume conveyed to Kehalani Retention Basin over the course of the PMF event.

3. Per DLNR policy (personal communication with John Dawley, January 10, 2014), the basin water surface was assumed at spillway level at the beginning of the simulation. In order to fill the Kehalani Basin in the 2D model prior to rainfall runoff, a boundary inflow was connected directly to the basin and a small inflow hydrograph input before the start of the simulated PMF event, filling the basin to the spillway elevation.

The effective rainfall hyetograph was also applied uniformly over the grid for the pre-project conditions, and three boundary inflows (shown in Figure 1) were applied to the pre-project model:

1. Flows originating in the two subbasins mauka of the Wailuku Heights development (4A and 4B) were input to the 2D grid at the outlet locations as two separate time series hydrographs.
2. Flow originating from the Waikapu Stream subbasin.

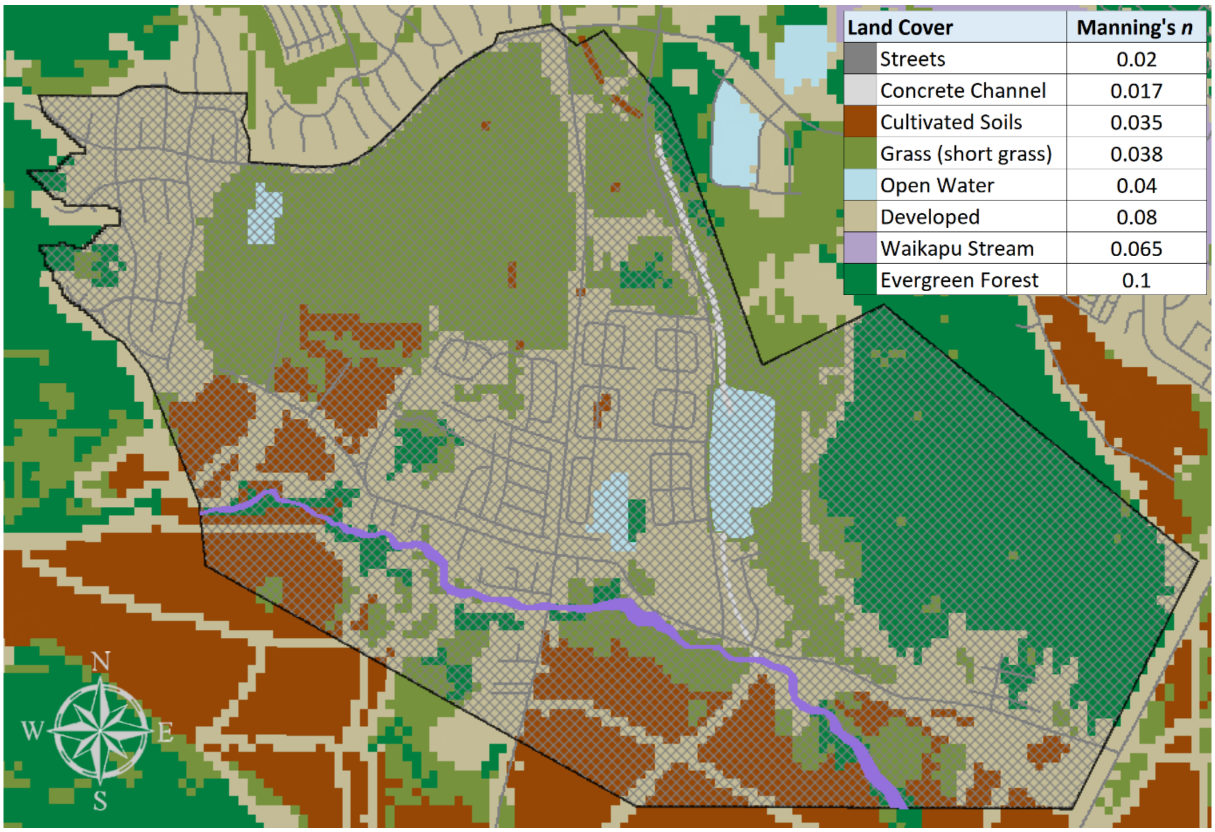

Figure 2. Land Cover and Manning's *n* Data Used with HEC-RAS 2D Model.

Boundary condition lines with normal depth relationships and friction slopes matching the terrain were included at downstream edges of the 2D grid to prevent water from ponding for both pre-project and project models. Both the pre-project and project 2D models were run with a time step of one second using the St. Venant (Full Momentum) equations, consistent with the previous modeling.

Figure 3 shows the maximum depth difference between pre-project and project conditions, in which pre-project depths were subtracted from project depths. Positive numbers in Figure 3 indicate that project depths are greater than pre-project depths.

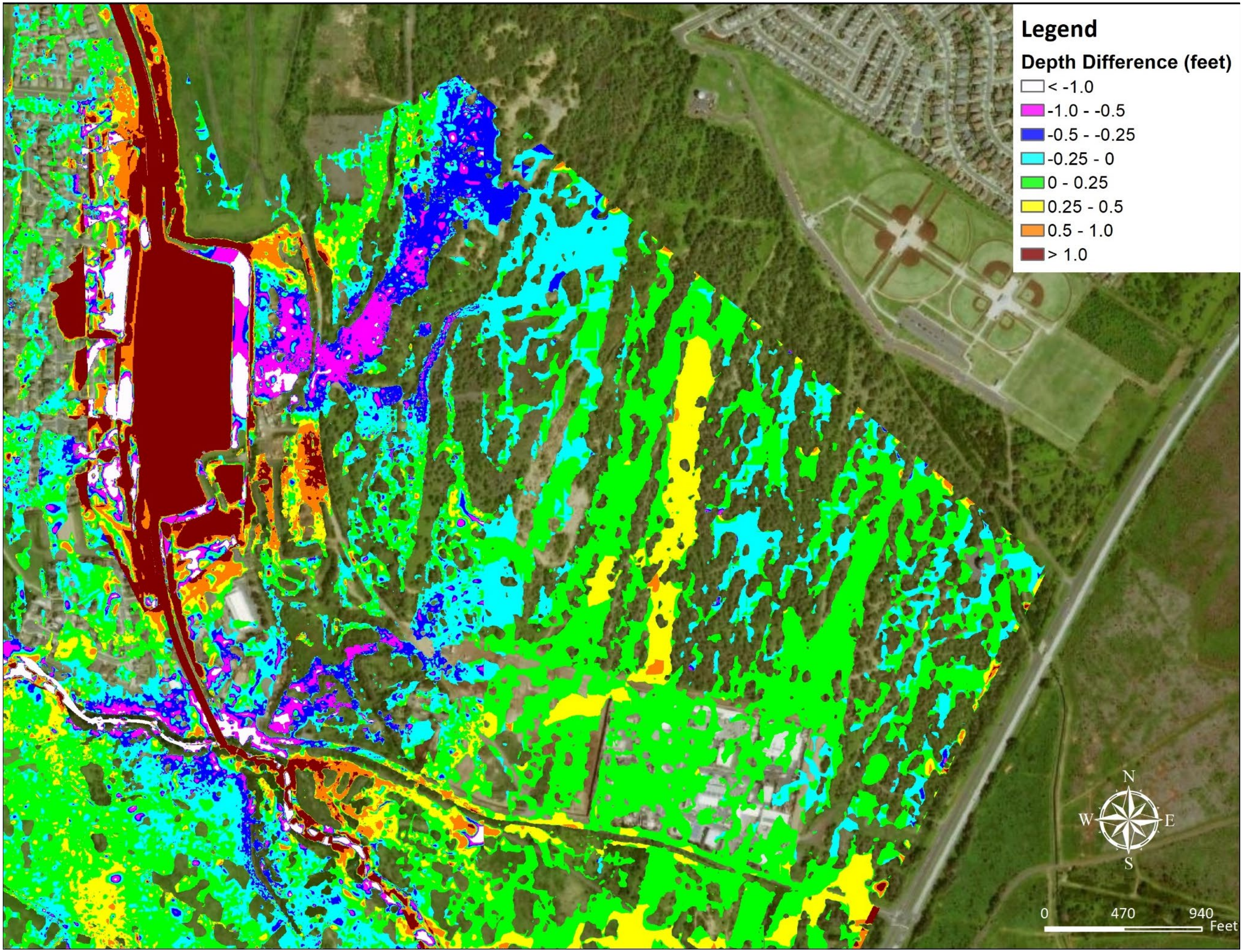

Figure 3. Depth Difference between Project and Pre-project (Positive Values Indicate Project Depths are Greater than Pre-project Depths)

Figure 3 shows that greater depths are generally expected for project conditions. Given that Figure 3 shows the differences in maximum depths, nine locations were chosen makai of Kehalani Basin to compare the PMF inundation impacts of pre-project and project conditions throughout the simulation. Figure 4 shows the nine different locations where the computed depths were compared. Figures 5 through 13 show comparisons of the depth results between pre-project and project conditions at each of the nine locations (note that the vertical scale varies between figures). The figures show that overall higher depths are observed under project conditions for locations 1 through 6 (Figures 5-10). However, it should also be noted that under project conditions the basin is full at the beginning of the simulation so that the primary spillway activates immediately and the capacity is quickly exceeded. This can be seen in the figures as the rising limb of the project hydrograph is steeper and/or arrives earlier in many locations. Figures 11 and 13 show depth results at locations 7 and 9, in which the max depth at the peak for pre-project conditions is higher than project conditions by approximately 0.04 feet and 0.64 feet, respectively. Figure 12 shows the depth results for location 8, which shows that slightly higher depths are observed under pre-project conditions. The hydraulic analysis results show that more flooding is observed on the makai side of Kehalani basin under pre-project conditions and more flooding is observed on the makai side of the primary spillway under project conditions. Flow going over the auxiliary spillway (Figure 4) is approximately 2,000 cfs, and approximately 1,200 cfs overtops the primary spillway along the makai side.

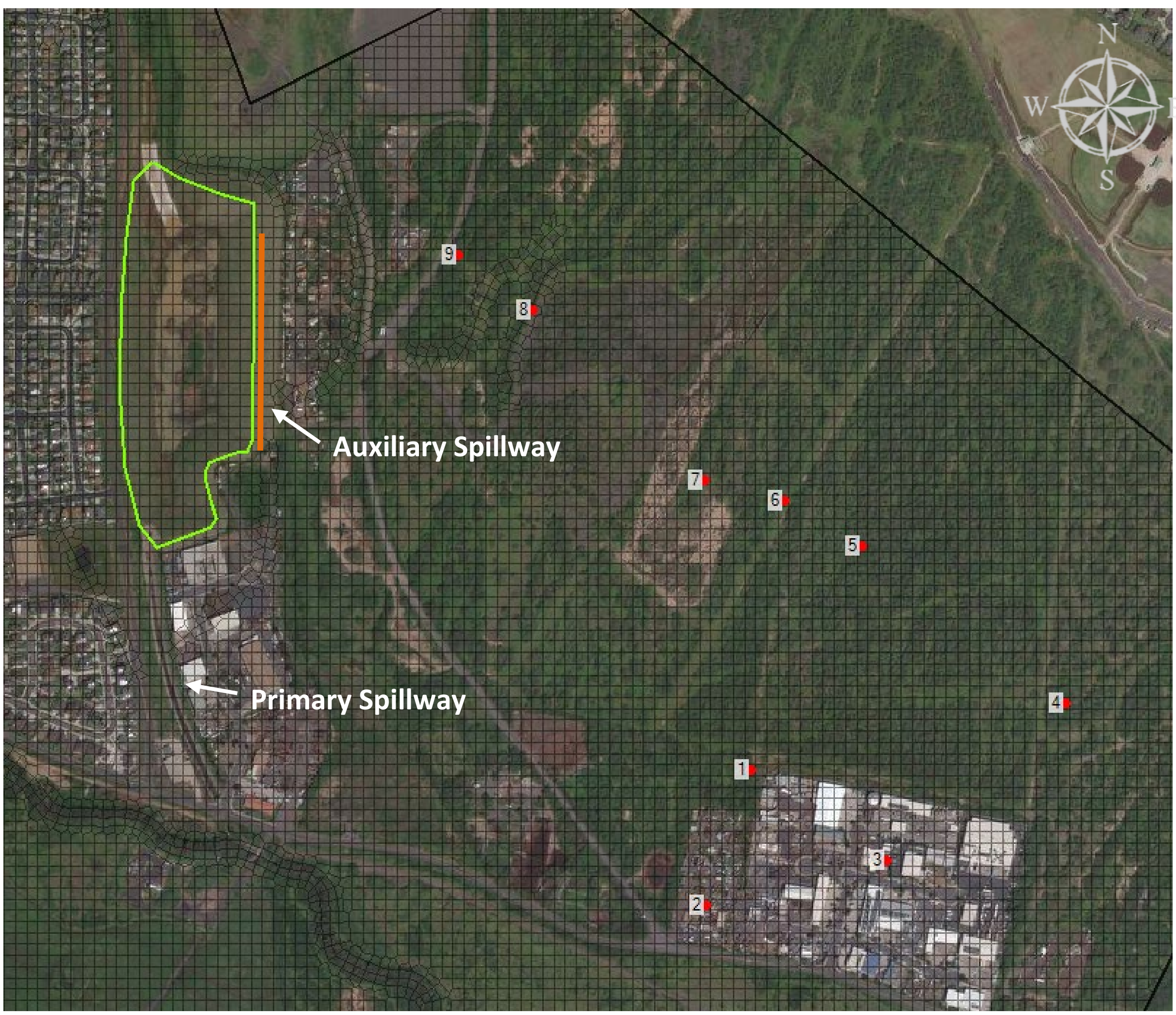

Figure 4. Depth Results Comparison at Nine Locations Makai of Kehalani Basin

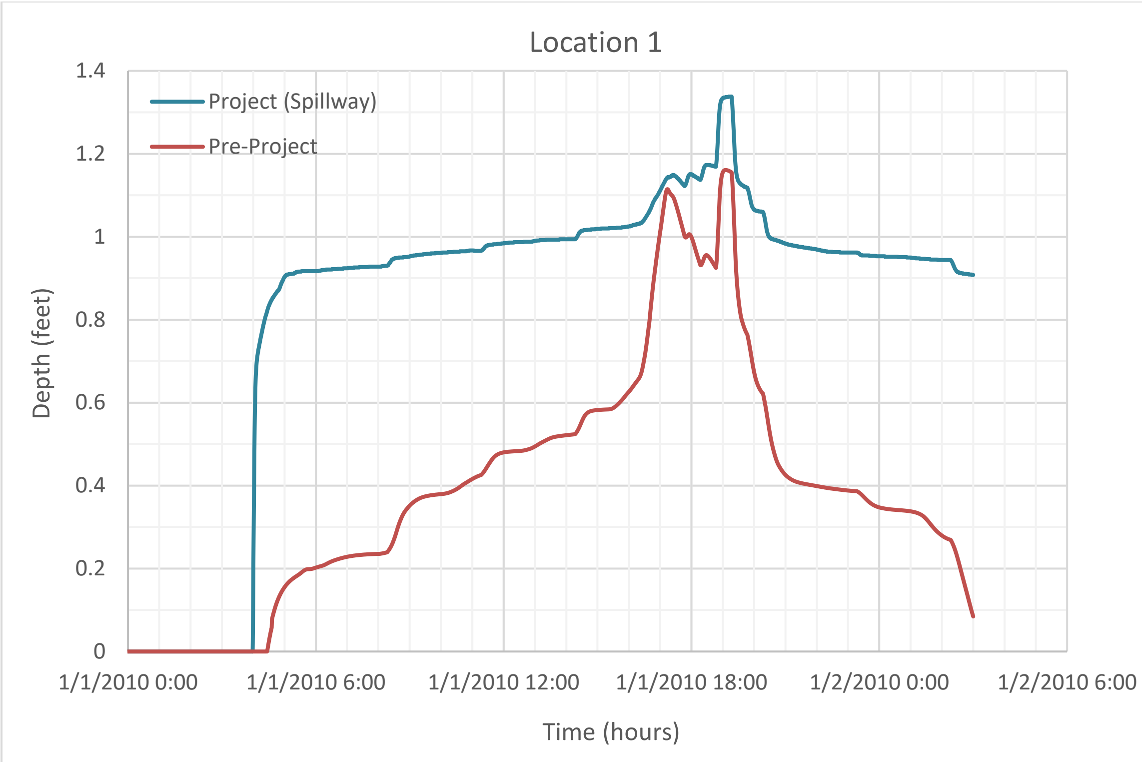

Figure 5. Depth Results Comparison of Pre-project and Project Conditions at Location 1

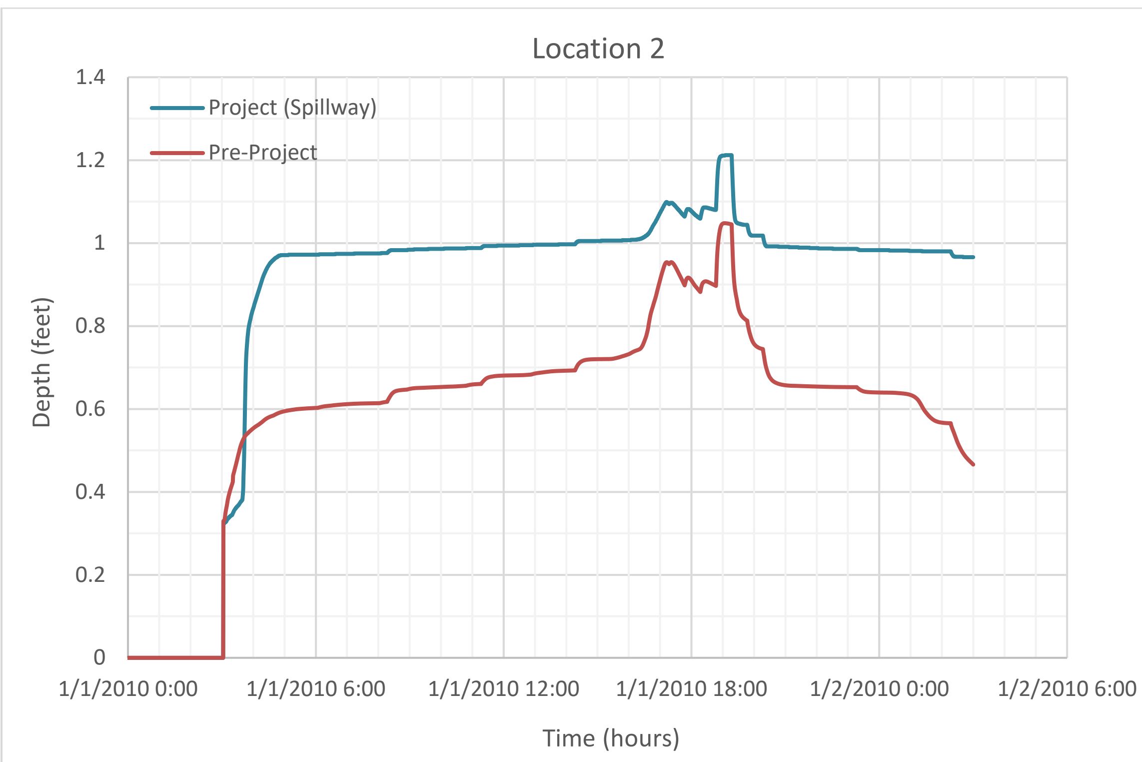

Figure 6. Depth Results Comparison of Pre-project and Project Conditions at Location 2

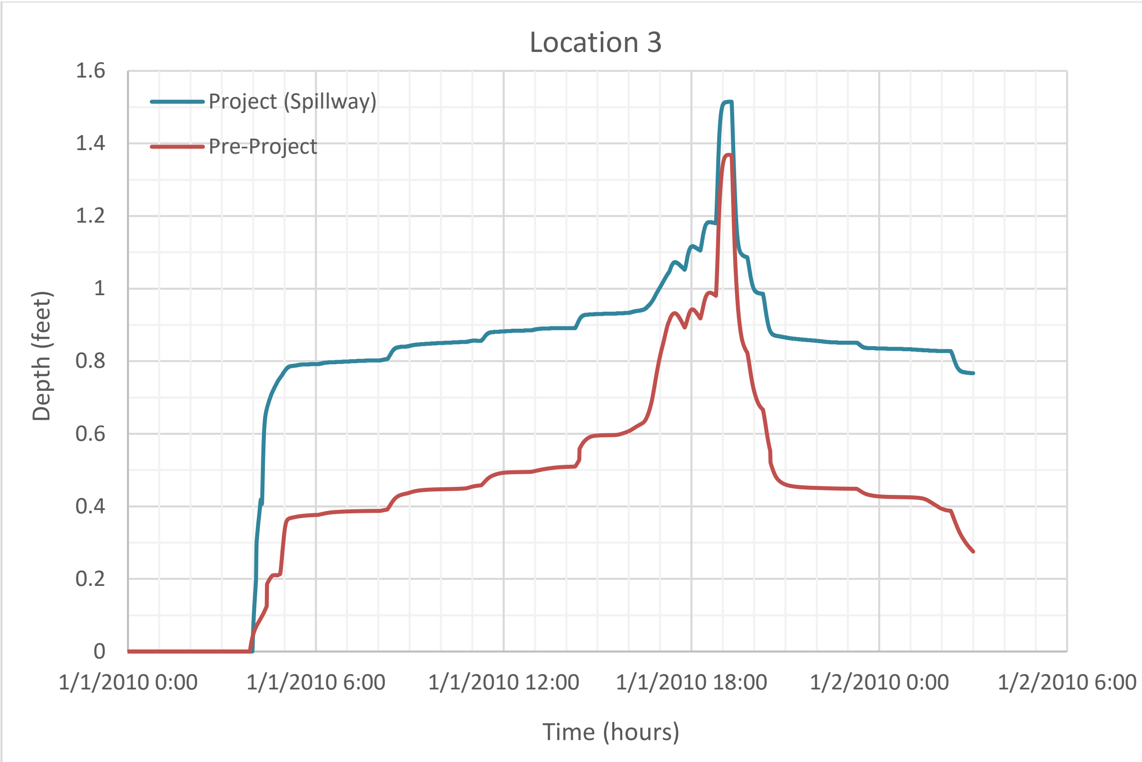

Figure 7. Depth Results Comparison of Pre-project and Project Conditions at Location 3

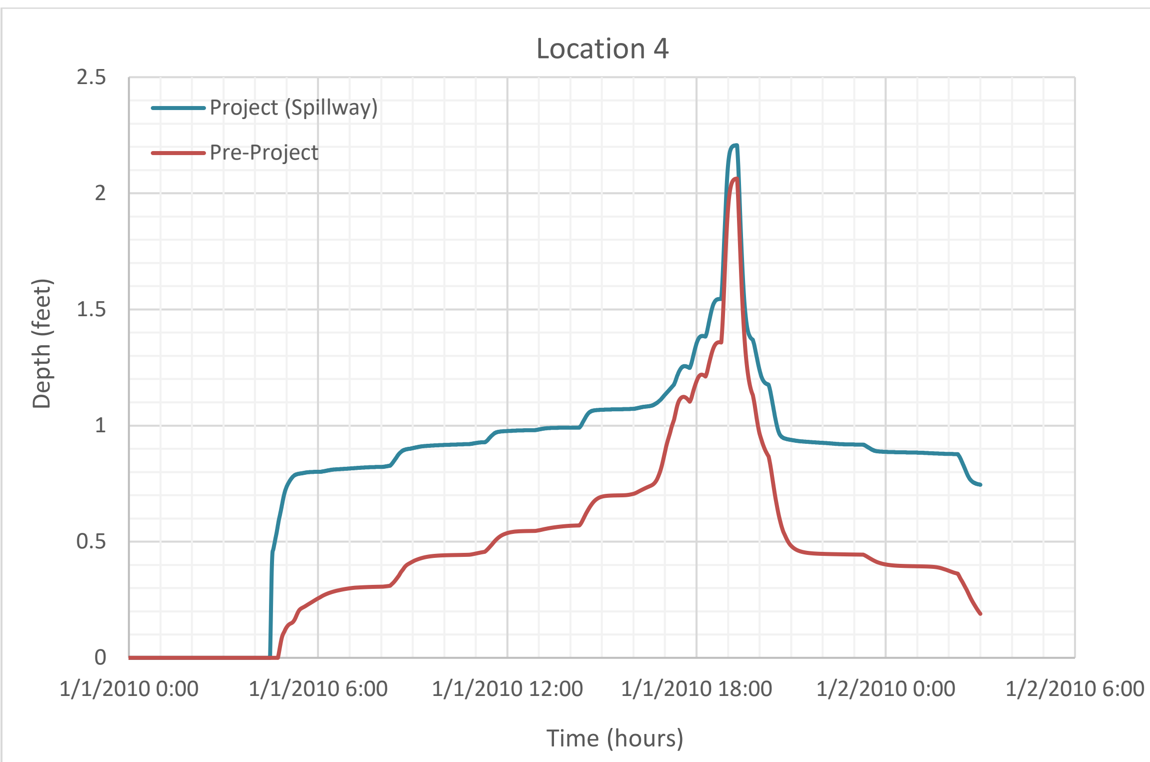

Figure 8. Depth Results Comparison of Pre-project and Project Conditions at Location 4

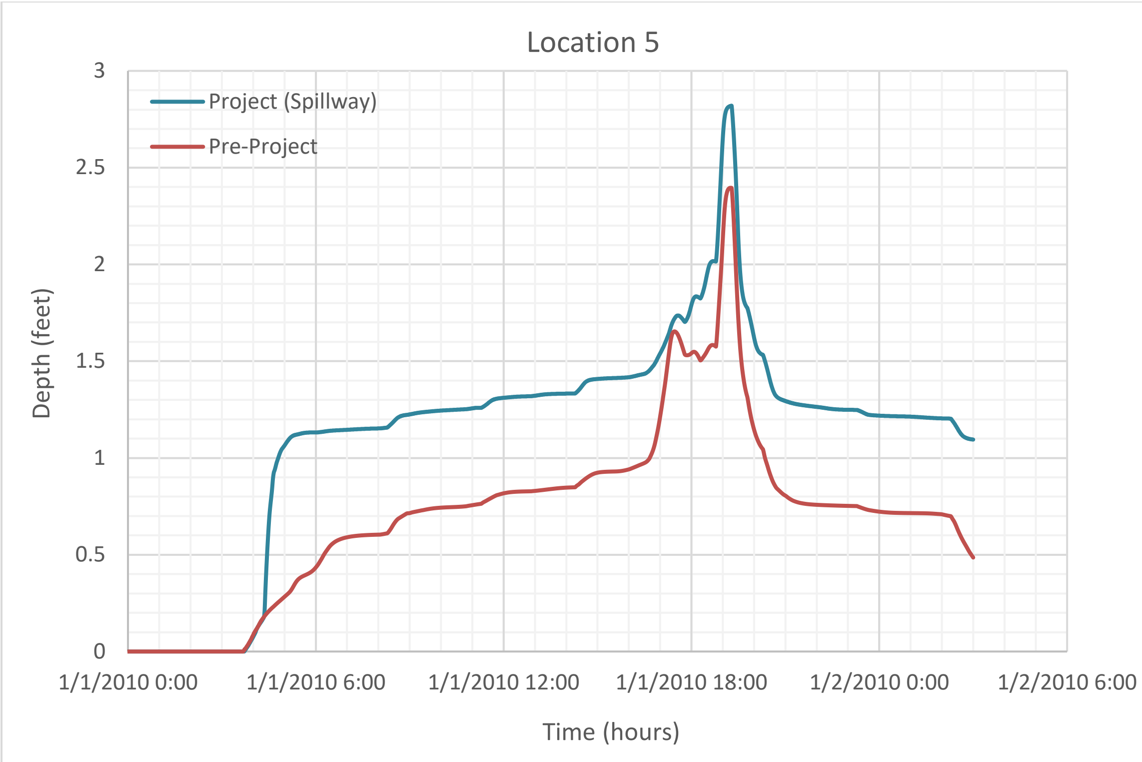

Figure 9. Depth Results Comparison of Pre-project and Project Conditions at Location 5

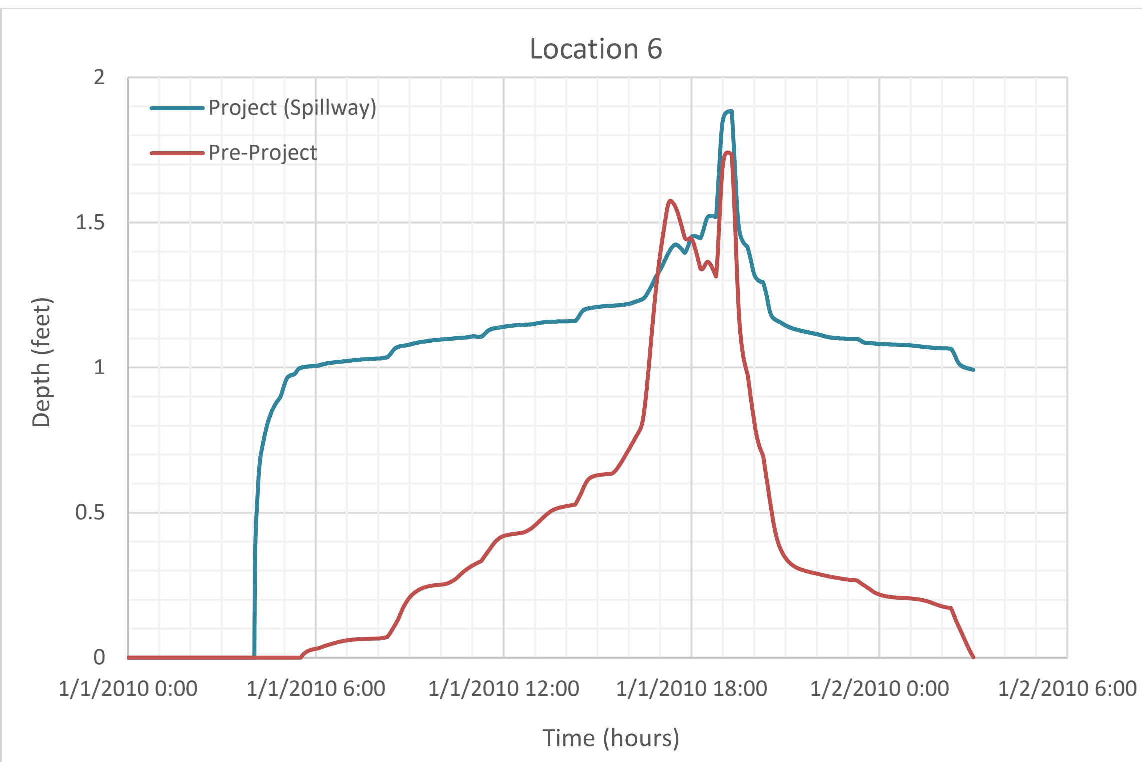

Figure 10. Depth Results Comparison of Pre-project and Project Conditions at Location 6

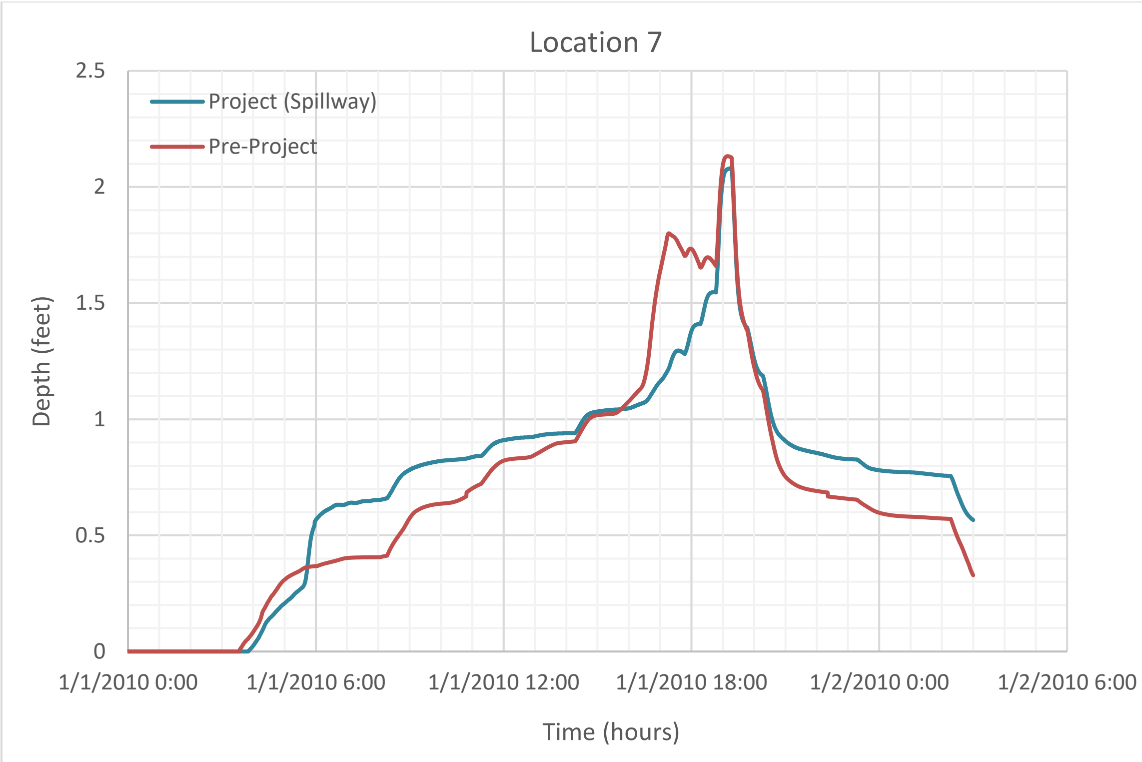

Figure 11. Depth Results Comparison of Pre-project and Project Conditions at Location 7

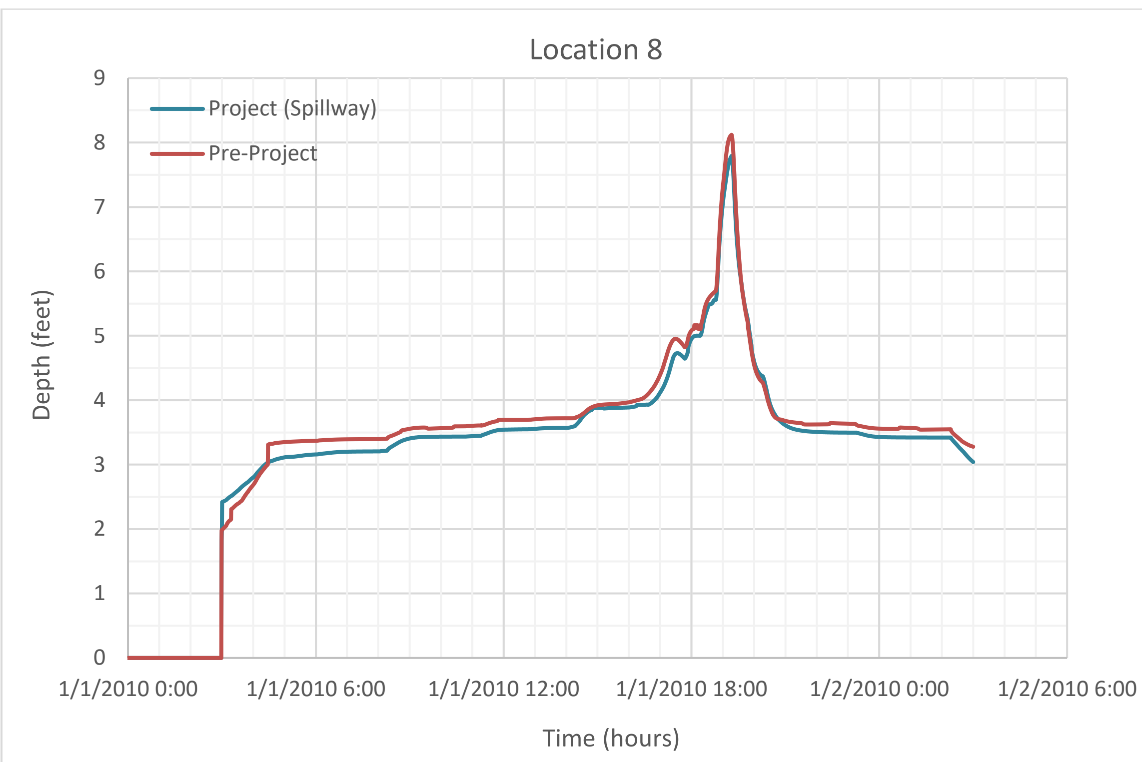

Figure 12. Depth Results Comparison of Pre-project and Project Conditions at Location 8

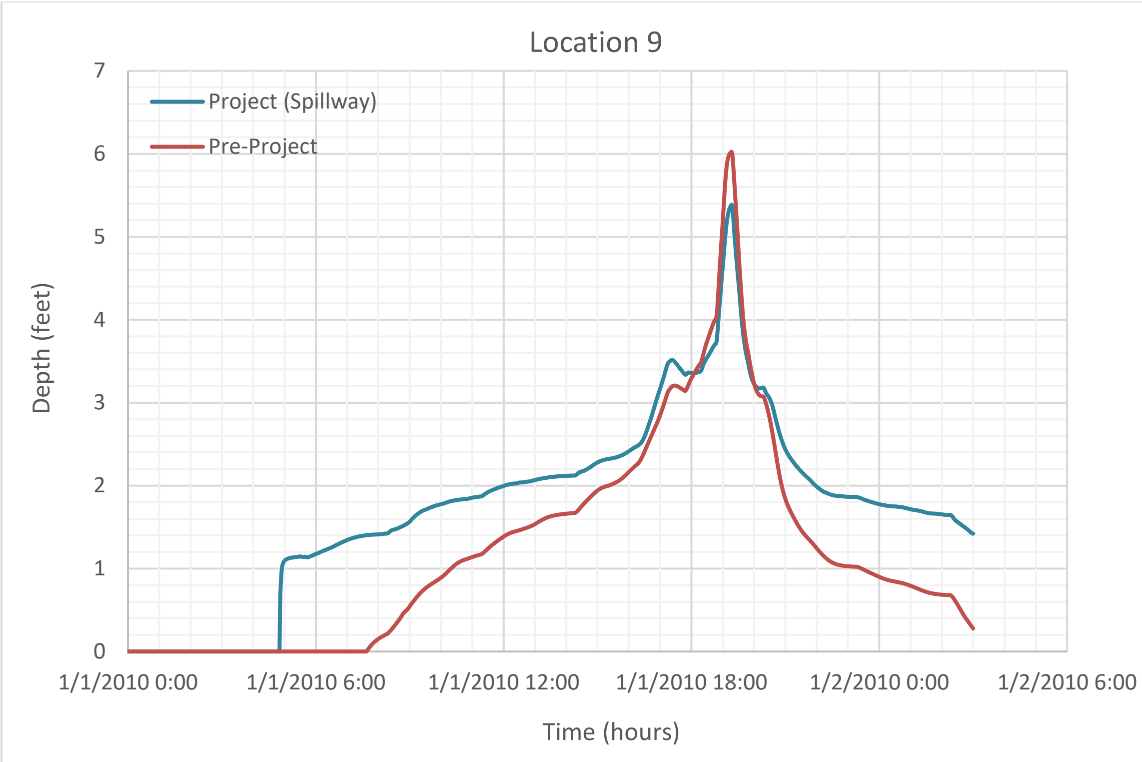

Figure 13. Depth Results Comparison of Pre-project and Project Conditions at Location 9

4. Conclusions and Recommendations

The results show that the overtopping of Kehalani Basin with the auxiliary spillway in place, and the basin full at the beginning of the simulation, increases the depth of inundation makai of the primary spillway in many locations when compared to pre-project conditions. Results at locations 1 through 6 (Figures 5 through 10) generally show small increases in maximum depth, one-half foot or less, and larger flow volumes (corresponding to the area under each hydrograph) due to water leaving the basin over the primary spillway. These results lead to the conclusion that addition of an auxiliary spillway is a feasible alternative to pass the PMF and meet dam safety regulations.

Refinement of the spillway design, varying parameters such as the crest elevation, spillway length, etc. may change the results downstream of the basin. The basin's release capacity should be optimized such that the impact to the makai side due to the increased releases is reduced as much as possible. Depending on the computed depth increases, purchase of land and/or flooding easements may still be necessary.

5. References

Chow, Ven Te (Chow, 1959). Open-Channel Hydraulics. McGraw-Hill, New York, 1959.

FLO-2D Software, Inc. (2019). FLO-2D Reference Manual. Build No. 19 2019. Nutrioso, AZ

Maui County (Maui County, 2012). Roads and Road Names for the Islands of Maui, Molokai and Lanai. Maui County Geographical Information Systems Division, Department of Management.

United States Environmental Protection Agency (EPA, 2016). Storm Water Management Model Reference Manual Vol 1 – Hydrology. January 2016.

United States Geological Survey (USGS, 2003). National Land Cover Database Hawaiian Zone Land Cover Layer, United States Geological Survey, Multi-Resolution Land Characteristics (MRLC) Consortium, Sioux Falls, SD.

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April 30, 2022

Signature *Expiration Date of License*