

United States Department of the Interior



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Subject: Honouliuli National Historic Site Preliminary Hydrology Assessment (STAR #27864)

Executive Summary

Honouliuli National Historic Site (HONO) was founded in 2015 to “*conserve and interpret the largest and longest-used World War II incarceration site in the Hawaiian Islands.*” At the time of this report, the park is planning how the site will be accessed and facilitates need to support park resources and visitor experience. The park is not yet open to the public. Central to HONO planning needs is information on Honouliuli Tributary streamflow, which runs through Honouliuli Gluch in the center of HONO. This report presents a preliminary hydrologic assessment of Honouliuli Tributary using existing data from stream gages operated by the U.S. Geological Survey. The report also summarizes information from groundwater wells located within and adjacent to HONO.

Honouliuli Tributary is a moderately steep, ephemeral stream that flows naturally during rain events. At the upstream boundary of HONO, trans-basin diversion and subsequent irrigation releases from Waiahole Ditch augment low flow conditions in Honouliuli Tributary through HONO, providing more consistent baseflow through HONO than would otherwise occur. Waiahole ditch contributions are relatively small compared to natural flow that occurs during rainfall events and have little effect on flood flow conditions. An initial evaluation of flood risk at the site was conducted using regional regression relations through the USGS StreamStats program and a simplified modeling method to map flood inundation extent. The deep, steep gulch that Honouliuli Tributary flows through has little space for flood flows to expand laterally, and the inundation extent for the 0.2%-annual chance flood (i.e., 500-year flood) remains near the channel in the valley bottom. A more robust assessment of flood hazards should

be conducted if infrastructure is planned in or near the 0.2%-annual change floodplain identified in this study.

Introduction

Honouliuli National Historic Site (HONO) was founded in 2015 to preserve the 160-acre Honouliuli Internment Camp where civilian internees and prisoners of war were incarcerated during World War II. The site is located three miles north of Pearl Harbor in the deep gulch of Honouliuli Tributary. Currently, HONO is not open to the public and the park is developing comprehensive planning and management guidance to determine how visitors will access, use, and experience the historic site.

The HONO Foundation Document identified several data needs to inform the development and management of HONO (National Park Service, 2019). One such data gap pertains to the hydrology of Honouliuli Tributary and associated flood and erosional risk. Currently, the park has no information on timing and magnitude of annual floods, base flow conditions, and how the flow regime is affected by upstream water resource infrastructure. Understanding these basic hydrologic conditions is critical to park planning, as roads and other infrastructure should avoid being placed within the floodplain, culverts should be sized to convey high flows, and trails should not be placed on steep gulch slopes susceptible to severe erosion during Honouliuli Tributary floods.

In this report, we summarize the findings of a preliminary hydrologic assessment for Honouliuli Tributary based on existing datasets and make recommendations for future analyses and studies. We reviewed nearby stream gages operated by the United States Geologic Survey (USGS), documented upstream water resource infrastructure, including irrigation ditch release points, estimated the peak flow magnitude for different annual-chance floods, and predicted the inundation extent of the 0.2%-annual-chance flood (i.e., 500-year flood) using a low-complexity flood inundation mapping method.

Watershed characteristics

HONO is located on the leeward side of the island of O'ahu in the rain shadow. Most of the annual rainfall occurs in the fall and winter months from frontal storms that approach from the southwest (Rosa, 2017). Honouliuli Tributary runs southward through HONO and has a contributing watershed area of 4.8 mi² receiving on average 37.3 inches of precipitation a year (USGS, 2023). The total watershed relief is 2883 ft from the headwaters to the downstream park boundary (Figure 1). Honouliuli Tributary has a moderately steep gradient through HONO, with a slope of 0.026 ft/ft (i.e., 2.6%) based on elevation data extracted from a 2013 Light Detection and Ranging (LiDAR) survey along the tributary's channel centerline (Figure 2). The contributing watershed is composed mostly of forested landcover (50%), followed by shrublands (23%), cultivated crops (17%), grasslands (7%), and impervious/barren surfaces (3%) (USGS 2023). Land use in the contributing watershed has transitioned over the last century from large-scale sugarcane cultivation and cattle grazing at higher elevations to conservation areas and smaller agricultural plots and ranging operations (Rosa, 2017).

Honouliuli Tributary joins Honouliuli Stream downstream from HONO (Figure 1). The contributing watershed area of Honouliuli Tributary is approximately the same size as Honouliuli Stream at the confluence (4.8 mi² and 5.6 mi² for Honouliuli Tributary and Stream, respectively) and both watersheds receive approximately the same annual rainfall (USGS, 2023). In this sense, Honouliuli Tributary and

Streams are co-equal streams at their junction, despite one being called a “tributary” and the other being called a “stream”.

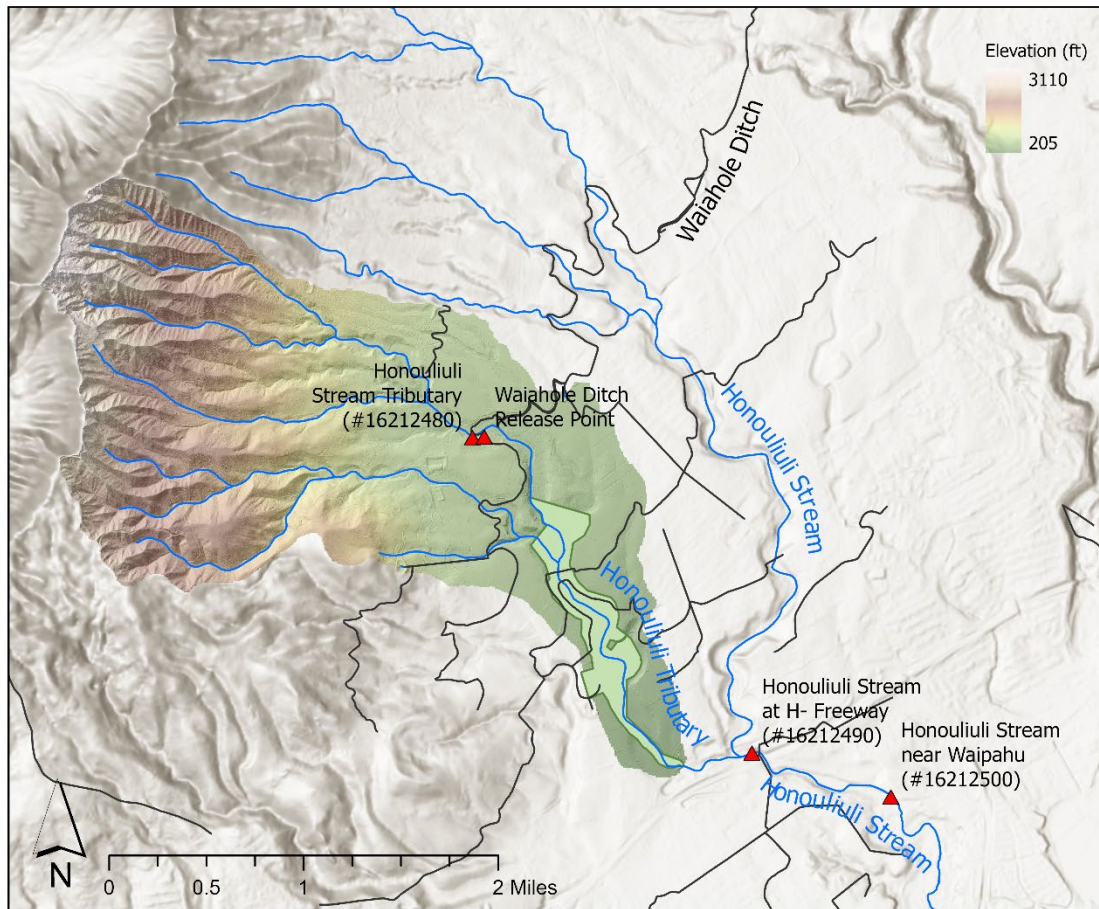


Figure 1. Location of HONO in relation to USGS stream gaging stations and the Waiahole Ditch release point into Honouliuli Tributary. Streams are shown as blue lines and ditches are shown as black lines. HONO park boundary is shown as a green polygon. Colored pixels show the elevation gradient of the Honouliuli Tributary watershed with elevation increasing from green to red colors.

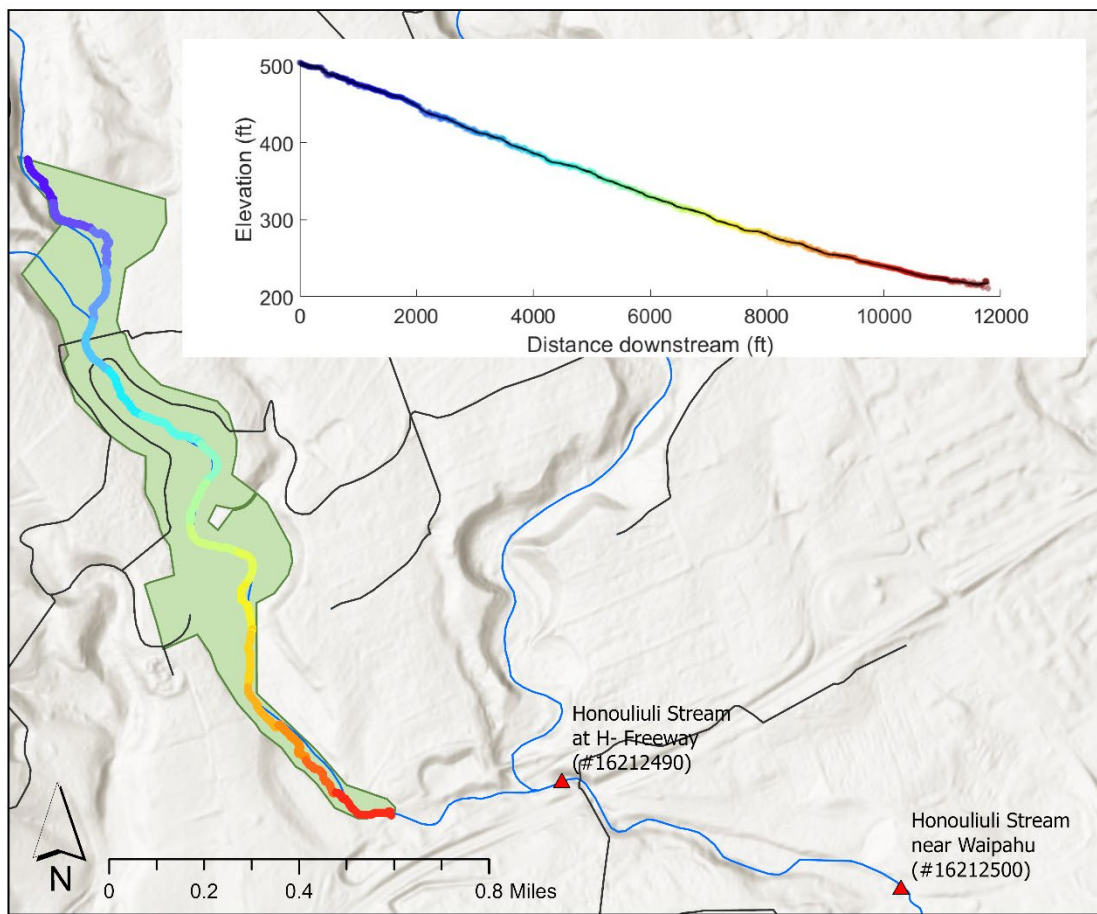


Figure 2. Longitudinal profile of Honouliuli Tributary through HONO. Main map shows Honouliuli Tributary through the park. The green polygon defines the park boundary and nearby USGS gages are shown as red triangles. Black lines are ditches and blue lines are streams. The longitudinal profile was calculated from elevation values extracted from a centerline along Honouliuli Tributary in HONO shown as colored points on the main map. Colored points along the channel centerline correlate to the downstream distance shown in the inset plot. Distance downstream increases from blue to red dots. Inset plot shows the longitudinal profile of Honouliuli Tributary through HONO based on elevations extracted from a DEM generated from a 2013 LiDAR survey along the channel centerline shown in the main map.

Surface water hydrology

Streamflow entering the upstream boundary of HONO is affected by natural runoff from the contributing watershed and irrigation releases from Waiahole Ditch into Honouliuli Tributary. The timing and magnitude of natural streamflow entering HONO was measured for 9 years between August 31, 2012 to November 23, 2021 at USGS gage Honouliuli Stream Tributary near Waipahu, Oahu, HI (#16212480; hereafter referred to as *Honouliuli Tributary gage*) (Figure 1). The gaging site was located directly upstream from the Waiahole Ditch release point, and therefore recorded natural inflow to HONO from the contributing watershed in the absence of additional inflow from Waiahole Ditch (Figure 1). The Honouliuli Tributary gage has since been discontinued because extensive vegetation encroachment in the usually-dry channel made maintaining a clean and consistent measurement location difficult (C. Yeung, *pers. comm.*, 6 March 2024).

Waiahole Ditch was initially constructed between 1913 to 1916 and additional collection tunnels were drilled from 1925 to 1935 to carry water from the windward to the leeward side of O'ahu for irrigation purposes (Figure 1). The Waiahole Ditch release point into Honouliuli Tributary is approximately 3,000 ft upstream of the northern park boundary but downstream from the Honouliuli Tributary gage (Figure 3). Waiahole Ditch releases into Honouliuli Tributary are not regularly measured, leaving a gap in our understanding of the low-flow seasonality through HONO. Additionally, there are several lateral ditches that cross the property that are also unmeasured (Figure 3).

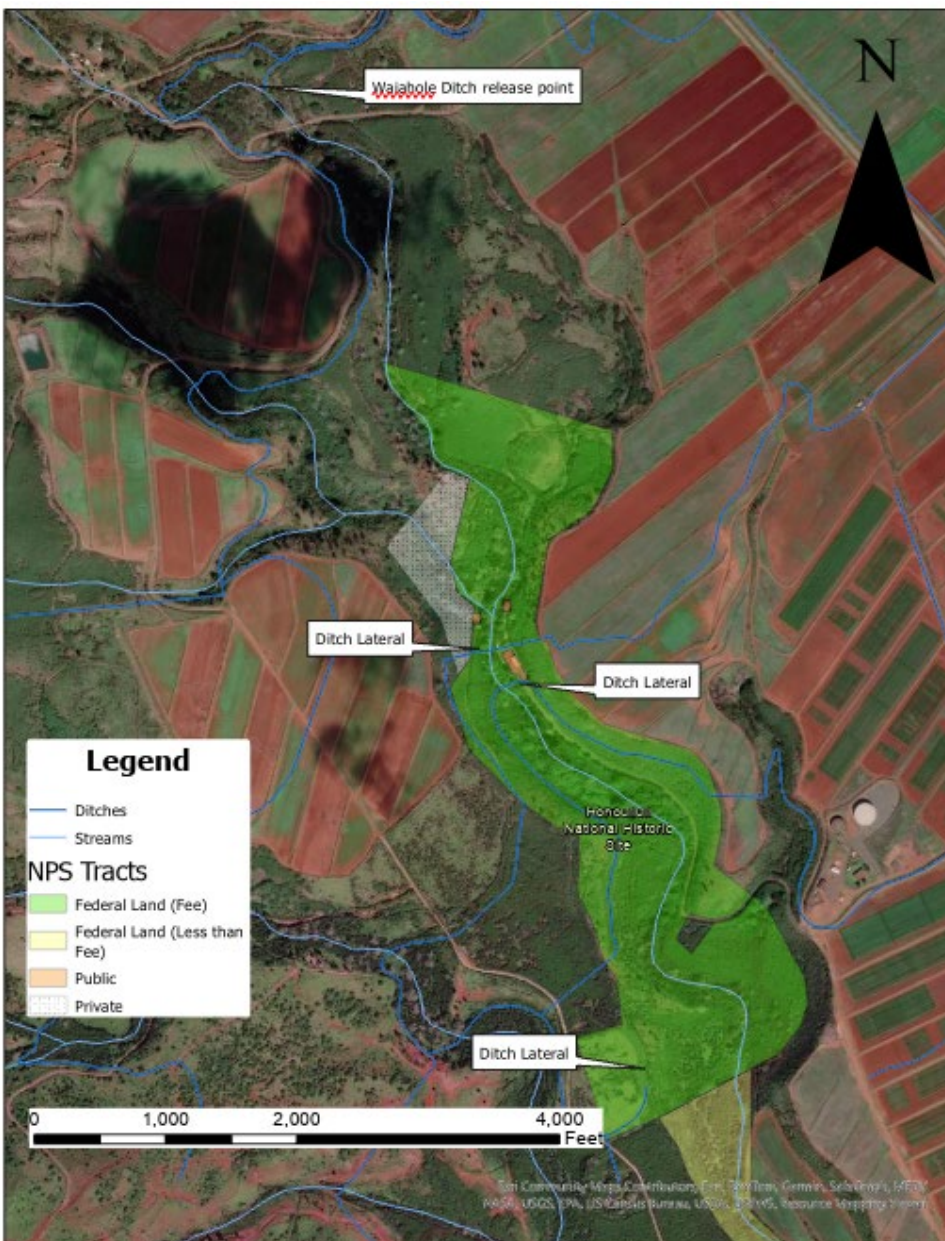


Figure 3. Location of Waiahole Ditch release point in relation to HONO boundary. HONO boundary is shown as a green polygon. Lateral ditches that intersect HONO are also shown.

The 9-year gaging record on Honouliuli Tributary indicates that the stream upstream of HONO is ephemeral and only flows naturally during rain events. Flow occurred during portions of just 3.8% of the

days within the record. Although flow was measured during every month, February averaged the most frequent flow (occurring on 2.3 days/year) while flow was least frequent in June (0.1 days/year) (Figure 4). Waiahole Ditch releases augment streamflow downstream from the Honouliuli Tributary gaging site. Two instantaneous discharge measurements on Honouliuli Tributary directly below the ditch release point were made on August 26 and August 31, 2015 (USGS gage #212407158035201). These measurements suggest that the ditch can release between 6 to 10 ft³/sec into Honouliuli Tributary, possibly enabling small flows to pass through HONO more commonly than what was observed during the 9-year gaging record at the Honouliuli Tributary gage.

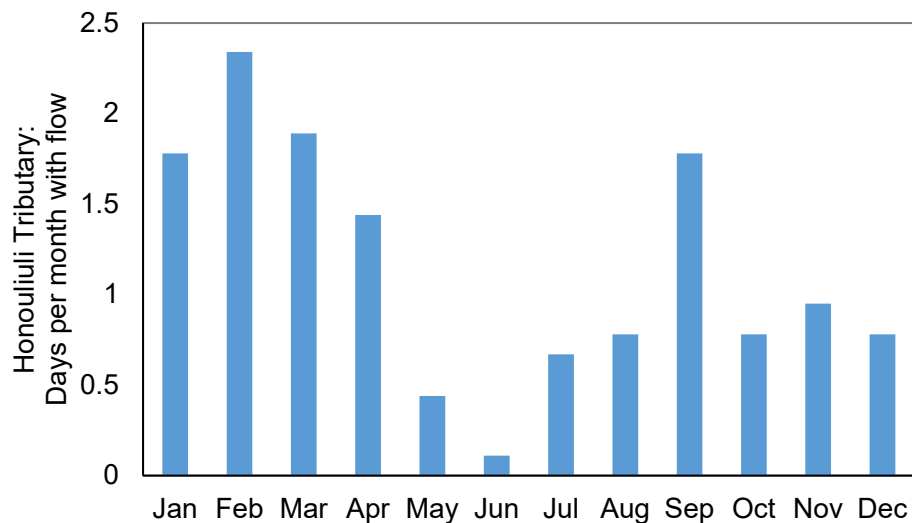


Figure 4. Average number of days per month that recorded non-zero flow at the Honouliuli Tributary gage, which operated upstream from HONO from 2012 to 2021.

Additional information about the timing and magnitude of Waiahole Ditch releases and low flow conditions through HONO can be inferred from the Honouliuli Stream at H-1 Freeway nr Waipahu gage (#16212490; hereafter referred to as *Honouliuli Stream gage*), which is located downstream from the confluence with Honouliuli Tributary (Figure 1). The Honouliuli Stream gage measures the cumulative effect of natural streamflow from the Honouliuli Stream and Honouliuli Tributary watersheds plus irrigation releases from Waiahole Ditch into Honouliuli Tributary. The complexity of the ditch system within the park and lack of available information about flows and operations makes it difficult to partition measured streamflow at the Honouliuli Stream gage into natural flow and ditch releases; however, the gaging records coupled with precipitation data can be used to infer which parts of the Honouliuli Stream hydrograph were likely influenced by ditch releases.

We assume during dry periods without precipitation, streamflow measured at the Honouliuli Stream gage is caused by Waiahole Ditch releases into Honouliuli Tributary. Waiahole Ditch releases may occur during rain events as well, but it's impossible to distinguish ditch flow from natural streamflow during these events without additional monitoring data from Waiahole Ditch. We used the PALEHUA rain gage located approximately 2 miles southwest of the watershed boundary and at a similar elevation as the upper Honouliuli Tributary watershed to identify periods in the Honouliuli Stream gage record where

streamflow was measured despite no measured rainfall for four or more consecutive days (Giambelluca et al., 2013; Figure 5a). We found that streamflow at the Honouliuli Stream gage was less than 4 ft³/sec when originating solely from Waiahole ditch releases and small releases occurred regularly throughout the year (Figure 5b, c). Streamflow in Honouliuli Tributary through HONO was likely greater than what was recorded at the Honouliuli Stream gage during ditch release events, because portions of the ditch release are lost to groundwater recharge in Honouliuli Tributary (Rosa, 2017). Thus, it is likely ditch releases create small, sporadic baseflow through HONO throughout the year.

Waiahole Ditch releases had little effect on streamflow during flood events in HONO. Little correlation and no seasonal patterns were detected between the 9-year overlap of continuous gaging records on Honouliuli Tributary and Honouliuli Stream from November 9, 2012 to November 23, 2021. However, when the hydrographs at both gages were partitioned into low and high flow periods, high-flow periods were strongly correlated while low-flow periods were not. Low-flow periods lacked correlation because Waiahole Ditch releases augmented streamflow at the Honouliuli Stream gage while having no effect on streamflow at the Honouliuli Tributary gage. During high-flow events, however, the amount of water released from Waiahole Ditch was small compared to the natural runoff, and the gages were correlated. The largest flow measured at the Honouliuli Tributary gage was 482 ft³/sec on October 14, 2013, and the largest flow during the overlapping period of record on the Honouliuli Stream gage was 611 ft³/sec which occurred, sensibly, one hour later. However, it is somewhat surprising that the Honouliuli Stream gage did not have a higher discharge, given that its watershed is nearly six times larger than that of the Honouliuli Tributary at the gaging site.

The Honouliuli Tributary stream gage operated for only 9 years and it appears floods during this period were modest compared to the regional long-term flood record. To evaluate how the short-term gaging record at Honouliuli Tributary fit into multidecadal streamflow, we compared the peak flow record at Honouliuli Tributary gage to a long-term peak flow gaging site operated since 1955 (Honouliuli Stream at Farrington Highway #16212500) located 1.2 miles downstream from the park and 0.8 miles below Honouliuli Stream gage. During the 9-year overlap period between gages, the largest flow at the longer record at Farrington Highway ranked only 20th out of 55 in its full record, with the peak flow in 1982 being six times greater than any flow recorded during the 9-year overlap. All other floods during the 9-year overlap were medium-to-low peak flows compared to the longer record (2012-2021; Figure 6). Therefore, it is reasonable to conclude that Honouliuli Tributary flooding can be more severe than what was recorded during the short-term gaging record.

The long-term peak flow record at Honouliuli Stream at Farrington Highway gage also revealed important insights about the timing of peak flows through HONO. The short nine-year record for peak annual flows at the Honouliuli Tributary gage suggested a bimodal seasonality, occurring in either late summer/fall or late winter. However, the longer flow record on Honouliuli Stream at Farrington Highway suggests that peak flows are apt to occur anytime October through March (Figure 7). Given the general similarity in watersheds and the greater reliability of longer records, it would be reasonable to expect peak flows in HONO to occur any time October through March.

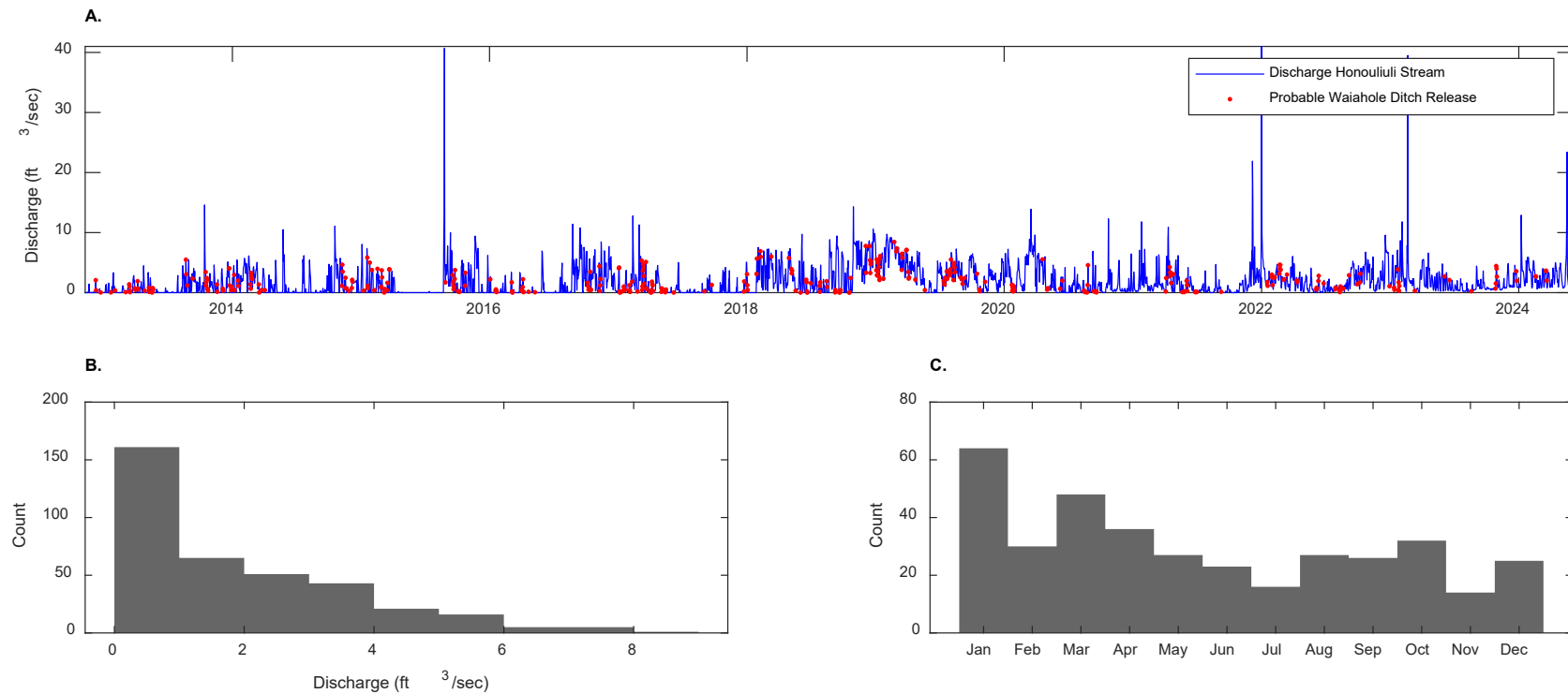


Figure 5. (A) Honouliuli Stream gage hydrograph shown as blue lines. Red dots show days where measured streamflow was likely caused by Waiahole Ditch releases. (B) Histogram of discharge measured at Honouliuli Stream gage during periods when streamflow was caused by Waiahole Ditch releases (i.e., discharge histogram of the red dots in A). (C) Histogram of the month when streamflow at Honouliuli Stream was caused by Waiahole Ditch releases (i.e., histogram of the month for red dots in A).

Honouliuli Tributary peak flow was greater than Honouliuli Stream at Farrington Highway peak flow in 6 of the 9 overlap years, which is odd given that the watershed for Honouliuli Stream at Farrington Highway gaging site is six times larger than the Honouliuli Tributary watershed (Figure 6). Possible explanations include that precipitation tends to be most extreme within the Tributary portion of the larger watershed, there is substantial infiltration and attenuation of streamflow as water flows downstream, or that there is enough error in the peak flow measurements to render the peak discharge estimates appreciably uncertain.

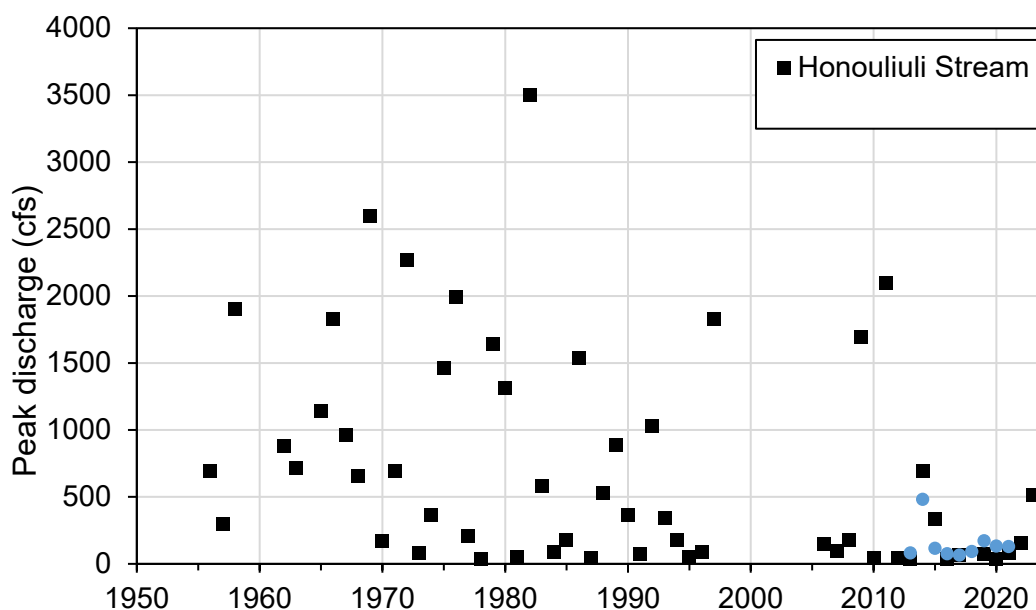


Figure 6. Peak annual discharges for Honouliuli Tributary (water years 2013-2021, blue circles) and Honouliuli Stream at gage #16212500 (water years 1956-2023, black squares). Note that the period of record for Honouliuli Tributary did not include any high flow years on the mainstem Stream, suggesting that its flows can get much higher than those in the measurement record.

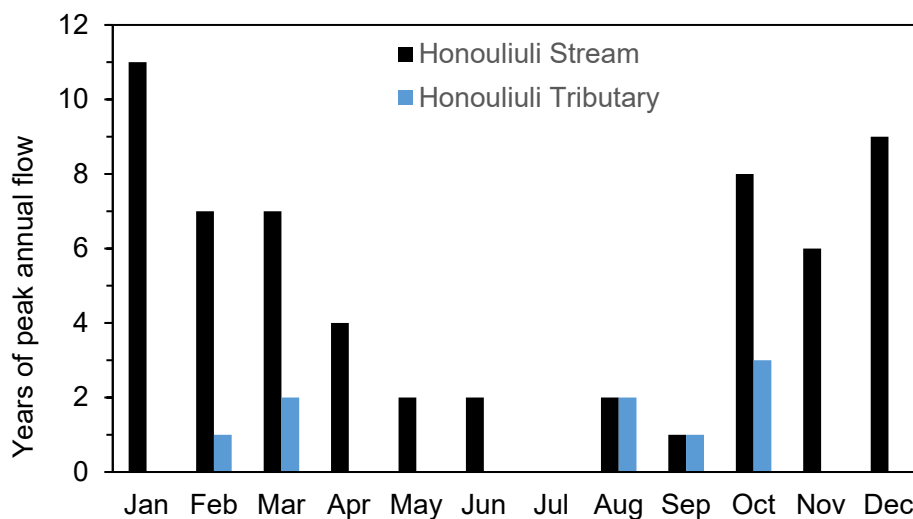


Figure 7. Month in which peak annual flows occurred for the Honouliuli Tributary gage (water years 2013-2021, blue) and at the longer peak flow gaging station on the Honouliuli Stream at Farrington Highway (1956-2023, black).

Estimating peak flow for annual exceedance probability floods – A regional regression approach

Flood risk was evaluated using a recently updated StreamStats methodology for the state of Hawaii, because the gaging record on Honouliuli Tributary was too short for a flood frequency analysis. StreamStats divides the state into ten regions of similar hydro-geomorphic basins using multivariate statistics and the widespread network of USGS gages (USGS, 2023). The Honouliuli Tributary lies within Region 3, whose regional regression equations were constructed from flow data from 43 USGS stream gages spanning the leeward side of O’ahu. To estimate peak flows for different annual-chance floods, the methodology uses multiple linear regression equations that incorporate watershed area, mean annual precipitation, and a soil permeability metric. Modeled peak flows have R^2 values of 0.83-0.87 when tested at gaged locations, demonstrating a strong foundation from which Honouliuli Tributary flows in HONO can be estimated.

Results suggest that the 50%-annual-chance flood (i.e., 2-year recurrence interval flood) on Honouliuli Tributary through the park is 185 ft³/sec, and the 0.2%-annual-chance flood (i.e., 500-year flood) peaks at 6580 ft³/sec (Table 1). These flows are driven by precipitation, which is predicted to peak at a daily intensity of 4.9 inches for the 50%-annual-chance flood and 15.6 inches for the 0.2%-annual-chance flood. A more detailed list of predicted precipitation intensities, flow frequencies, and flood discharges is reported in Table 1.

Table 1. Estimated peak flow and precipitation magnitudes for the Honouliuli Tributary watershed at the downstream boundary of HONO. Values estimated using USGS StreamStats (USGS 2023).

Recurrence Interval	Annual Chance Flood	Peak Discharge (cfs)	1-hr Max Ppt. (in)	24-hr Max Ppt. (in)
2-year	50%	185	1.6	4.9
5-year	20%	566	2.1	6.7
10-year	10%	991	2.5	8.0
25-year	4%	1780	3.0	9.8
100-year	1%	3540	3.8	12.5
500-year	0.2%	6580	4.7	15.6

Estimating flood risk – A simplified approach

The Federal Flood Risk Management Standard (FFRMS) require federal agencies to consider future flood risk to build more resilient infrastructure. FFRMS guidance proposes the 0.2%-annual-chance flood (i.e., 500-year flood) can be used in place of the commonly applied 1%-annual-chance flood (i.e., 100-year flood) to evaluate future flood risk and ensure infrastructure built within the floodplain is resilient to changing climate conditions. To evaluate flood risk in HONO, we developed a flood inundation map based on the 0.2%-annual-chance flood in Table 1 using a simplified flood inundation mapping method. The flood inundation map developed as part of this study should be used as a preliminary screening tool to evaluate whether planned or existing infrastructure is near the floodplain and determine whether a Floodplain Statement of Findings (FSOF) is needed for any proposed facilities projects. Additional analyses may be needed if the proposed infrastructure is within or near the inundation extent of the

0.2%-annual-chance flood to support a FSOE and guide infrastructure design. More information on NPS floodplain policy and guidance on creating a FSOE can be found on the NPS Water Resource Division, River's Program [Floodplain Policy and Compliance](#) SharePoint site.

Simplified flood inundation mapping methods are used to predict of flood inundation extent and depth in areas with limited data. These methods are a topographically driven alternative to traditional physics-based approaches that estimate flood risk using hydraulic models. While physics-based approaches are often needed to provide high precision and accuracy required for design of infrastructure projects, these models are data and resource intensive, and simplified methods can be used as a screening tool during the planning stage to help site infrastructure away from the floodplain.

Here, we use a low-complexity method call Height Above Nearest Drainage (HAND) in a probabilistic form presented by Diehl et al. (2021). The HAND method has been widely used in the literature to map flood inundation extents and is currently used in the National Water Model for flood forecasting (Zheng et al., 2018; Johnson et al., 2019). The probabilistic version of HAND (probHAND) incorporates uncertainty to produce probabilistic flood inundation maps and is particularly well-suited for areas with limited data, such as HONO. A general description of the probHAND method is described below; refer to Diehl et al. (2021) for a detailed description of the method.

The first step in the probHAND method is to develop a HAND model without considering uncertainty. First, we calculate the elevation difference between individual cells in a digital elevation model (DEM) and the nearest drainage using a sequence of geospatial functions (Zheng et al., 2018). The output of this step is a HAND layer where the value for every cell is the elevation above the nearest drainage, with drainages having a value of zero. In this study, we used a DEM derived from a 2013 LiDAR survey (NOAA, 2013). The HAND layer is used to extract information about the channel geometry at a flood stage (i.e., water depth) based on the inundated underlying topography. We then use a flow resistance equation (i.e., Manning's equation) to relate flood stage to discharge. This process is done repeatedly for flood stages ranging from 0.1 to 16 ft to develop synthetic rating curves that relate floods of different magnitudes to inundation extent.

There are several sources of uncertainty in the baseline HAND layer, including inaccuracies in the underlying topography, uncertainty in the flood stage associated with a given discharge, and the discharge magnitude for a given annual chance flood. The probHAND method incorporates these uncertainties by defining probability distributions for the channel geometry, channel slope, Manning's roughness, and annual chance discharge and re-running the analysis using a Monte Carlo approach. In this study, we use a normal distribution to assign uncertainty in each variable with a mean as defined by the baseline HAND model value and a standard deviation as defined below. The standard deviation for the channel area and slope was ± 0.1 and 0.3 times the original HAND model value, respectively. The standard deviation for the Manning's n value was a quarter of the average in-channel and floodplain roughness estimate for this system (i.e., 0.1 ± 0.025). The standard deviation for the 0.2%-annual-chance flood was based on the StreamStats average standard error for the regression analysis (6850 ± 2124 ft³/sec mean $\pm$ standard deviation). Finally, we randomly sampled from each variable distribution 1000 times and reran the HAND analysis to produce a probabilistic flood inundation map.

We used the most conservative boundary (i.e., 5% probability that the 0.2%-annual-chance flood will inundate the area) for purposes of defining the inundation extent for infrastructure siting and determining the applicability of NPS floodplain policy and compliance, as shown in Figure 8. Boundaries

for the 5% to 90% probability that the 0.2-annual-chance flood will inundate the area are shown in Appendix 1. Infrastructure planned within or near the inundation extent shown in Figure 8 is subjected to NPS Floodplain Policy and Compliance.

There was little difference between the inundation extents of the 0.2%-annual-chance flood among the probabilistic inundation boundaries in Appendix 1 Figure 1. The deep, steep gulch that Honouliuli Tributary flows through in HONO provides little space for flood flows to expand laterally and the steep gradient likely conveys water quickly through the park, meaning changes in discharge are mostly accommodated by changes in water depth and velocity with only relatively minor changes in inundation extent. For example, the uncertainty analysis suggested that flood stage can vary by 5.8 ft, yet the inundation extent only increases by 42% (Appendix 1 Figure 1), suggesting the probHAND method is relatively insensitive to the input parameter uncertainty in this setting. An important caveat, however, is that the probHAND method does not account for the localized effects of culverts and other in-channel structures on flood stage and inundation extent, including the impacts of sedimentation and other debris blocking culverts and/or low bridges during floods. If infrastructure is planned in or near the area shown to be inundated in Figure 8, additional analyses should be conducted to understand the effects of in-channel structures on flood depth, velocity, and extent.

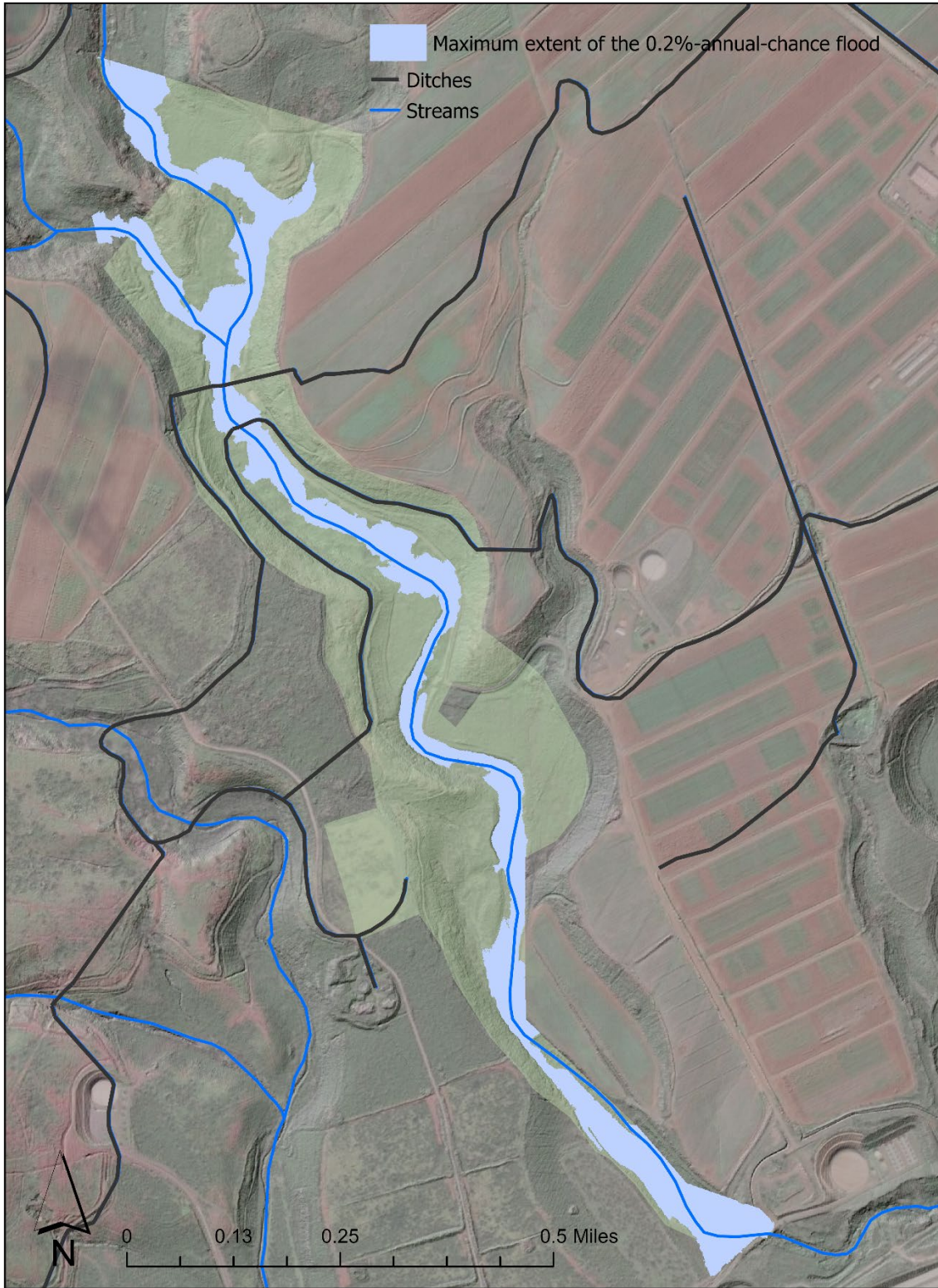


Figure 8. Light blue polygon shows the maximum inundation extent for the 0.2%-annual chance flood. HONO boundary is delineated as a transparent green polygon. Black lines are ditches and blue lines are streams. Infrastructure planned in or near the blue polygon is subjected to NPS floodplain policy and compliance.

Hillslope erosion in HONO gulch is destabilizing structures and deteriorating many archeological features (National Park Service, 2019). We identified areas prone to additional hillslope erosion during large floods by overlaying the maximum extent of the 0.2%-annual-chance flood in Figure 8 with a map of terrain slope derived from the 2013 LiDAR survey (Figure 9). Locations where the flood inundation extent, shown as the blue polygon, intersects steep slopes, shown as areas of dark brown, in Figure 9 are prone to erosion and hillslope instability during large floods. A field visit to these sites by a geotechnical engineer or geomorphologist may be warranted if trails, roads, or other infrastructure is placed in these areas.

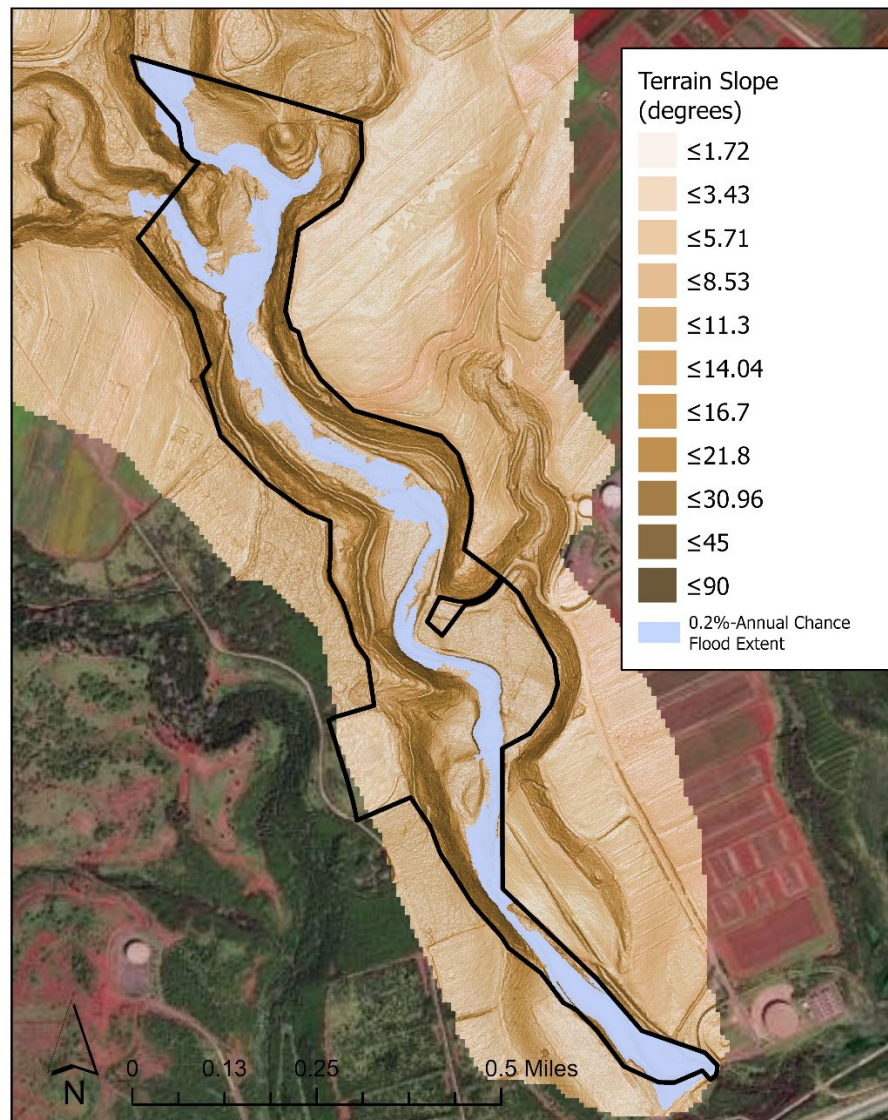


Figure 9. Maximum inundation extent for the 0.2%-annual chance flood (blue polygon) overlain on a map of terrain slope calculated from the 2013 LiDAR survey. HONO park boundary is shown as a black outline. The terrain slope gets steeper as colors moved from tan to dark brown. Areas where blue polygon intersects dark brown colors are site of potential hillslope instability during large floods.

Groundwater Well Inventory

Although the focus of this report is surface water hydrology, several groundwater wells also exist within or near HONO. This section provides a summary of groundwater wells in the area and information related to the well depth, production rates, and ownership.

There are four groundwater wells in HONO and several other wells near the park boundary (Figure 10). HONO_W_001 through HONO_W_004 are located within the park boundary and used by the Honolulu Board of Water Supply (BWS) for municipal water supply (Figure 10; Table 2). These wells are part of the Honouliuli II well field, which draws water from the Ewa-Kunia Aquifer System and have an authorized combined use of 4.48 million gallons per day (MGD) over a 12-month moving average. Water levels are not regularly monitored in the supply wells within HONO; however, the Honolulu BWS measured the water level in HONO_W_004 at 15 ft above sea level, or approximately 417 feet below ground. This level is consistent with other measurements taken in the area over the last decade. Water levels above sea level indicate that there is not a risk of saltwater intrusion, an important consideration if future water supplies rely on groundwater extraction.

Although the individual wells in HONO are not metered, the total water pumped from the Honouliuli II well field is monitored and managed by the state of Hawaii to limit overuse and saltwater intrusion. The Honouliuli II well field has averaged 5 MGD per day (the pumping limit for the well field) over the past 5 years. Under the current state regulations, the Ewa-Kunia Aquifer has the potential for more groundwater extraction if additional water supply is needed at the park. Close coordination with the State to determine the required permitting process will be needed if HONO intends to use groundwater from these wells.

Additionally, because these wells are active, there will be a surface presence of the wells in HONO consisting of well pads, electrical panels and transmission wires, pipelines, access roads, and security fencing. HONO staff should expect that BWS staff will require regular access to the wells for monitoring and maintenance, part replacements, facility upgrades, and emergency repairs. These activities could use large machinery that results in a permanent or temporary change of the existing surface facilities. Any NPS activity that may impact, encroach, or limit access to any of these features should be coordinated with the BWS as soon as possible.

	State ID 3-2303-003	Water Supply				
HONO_W_002	Honouliuli II-2; USGS 212342158034401; State ID 3-2303-004	Honolulu Board of Water Supply	Active	Supply	1/1/1989	555
HONO_W_003	Honouliuli II-3; USGS 212347158034301; State ID 3-2303-005	Honolulu Board of Water Supply	Active	Monitoring	3/1/1989	545
HONO_W_004	Honouliuli II-4; USGS 212347158034601; State ID 3-2303-006	Honolulu Board of Water Supply	Active	Supply	10/25/1989	535

Three additional wells are located just outside HONO boundary. One well is a deep monitoring well installed by the State of Hawaii and the USGS to study the risk of saltwater intrusion (Figure 10; Table 3). The other two wells were installed by Honolulu BWS for water supply (Figure 10; Table 3). Water supply well Honouliuli I-1 is located approximately 600 feet northeast of the park boundary and may be the artesian well drilled by James Campbell in 1879. Documented changes from artesian conditions to water levels several hundred feet below the surface could point to groundwater overuse and insufficient aquifer recharge from natural and agricultural sources. Further information about this issue and the State's management of groundwater can be found in the [Ewa Watershed Plan](#).

Table 3. Information on wells outside HONO park boundary.

Alternate IDs	Ownership	Status	Type	Depth (ft)
Honouliuli Deep Monitoring Well	USGS/State of Hawaii	Active	Monitoring	555
Honouliuli I-1	Honolulu Board of Water Supply	Active	Supply	625
Honouliuli I-2	Honolulu Board of Water Supply	Active	Supply	800

Conclusions and future questions

Honouliuli Tributary through HONO is a moderately steep stream with augmented low flows from Waiahole Ditch releases throughout the year. Analysis of the longer Honouliuli Stream discharge record suggests floods through HONO can be much larger than what was measured during the short 2012-2021 Honouliuli Tributary gage record. Floods likely occur between October to March.

Although the primary sources of streamflow entering HONO are natural inflow from the upstream watershed during rainfall events and Waiahole Ditch releases, the flow regime may be affected by

additional irrigation releases from several lateral ditches that cross the property and additional inflow from smaller drainages within the park boundary. The Honouliuli Tributary watershed area increases by 67% from the upstream to downstream park boundaries, and additional streamflow is likely supplied by smaller drainages that flow into Honouliuli Tributary within the park during rain events. To fully characterize the hydrology of Honouliuli Tributary through HONO, additional information about the lateral ditch system and smaller drainages within the park is needed. Additionally, little is known about Waiahole Ditch operations other than what can be inferred from publicly available data. It would be helpful to know whether Waiahole Ditch releases are metered, if uncontrolled water is allowed to overflow through a spillway during storm events, and what prompts a ditch release to occur.

Additional hydrologic and hydraulic analyses may be needed if infrastructure is planned in the area inundated by the 0.2%-annual-chance flood shown in Figure 8. A hydraulic model that incorporates in-channel structures and more detailed channel and floodplain topography is needed to refine flood depths and predict flood velocity for infrastructure design. The same hydraulic model can help the park evaluate whether existing culverts and bridges are properly sized to convey floodwaters in a future climate and identify sites that may be prone to bank or hillslope erosion during large floods.

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Appendix 1

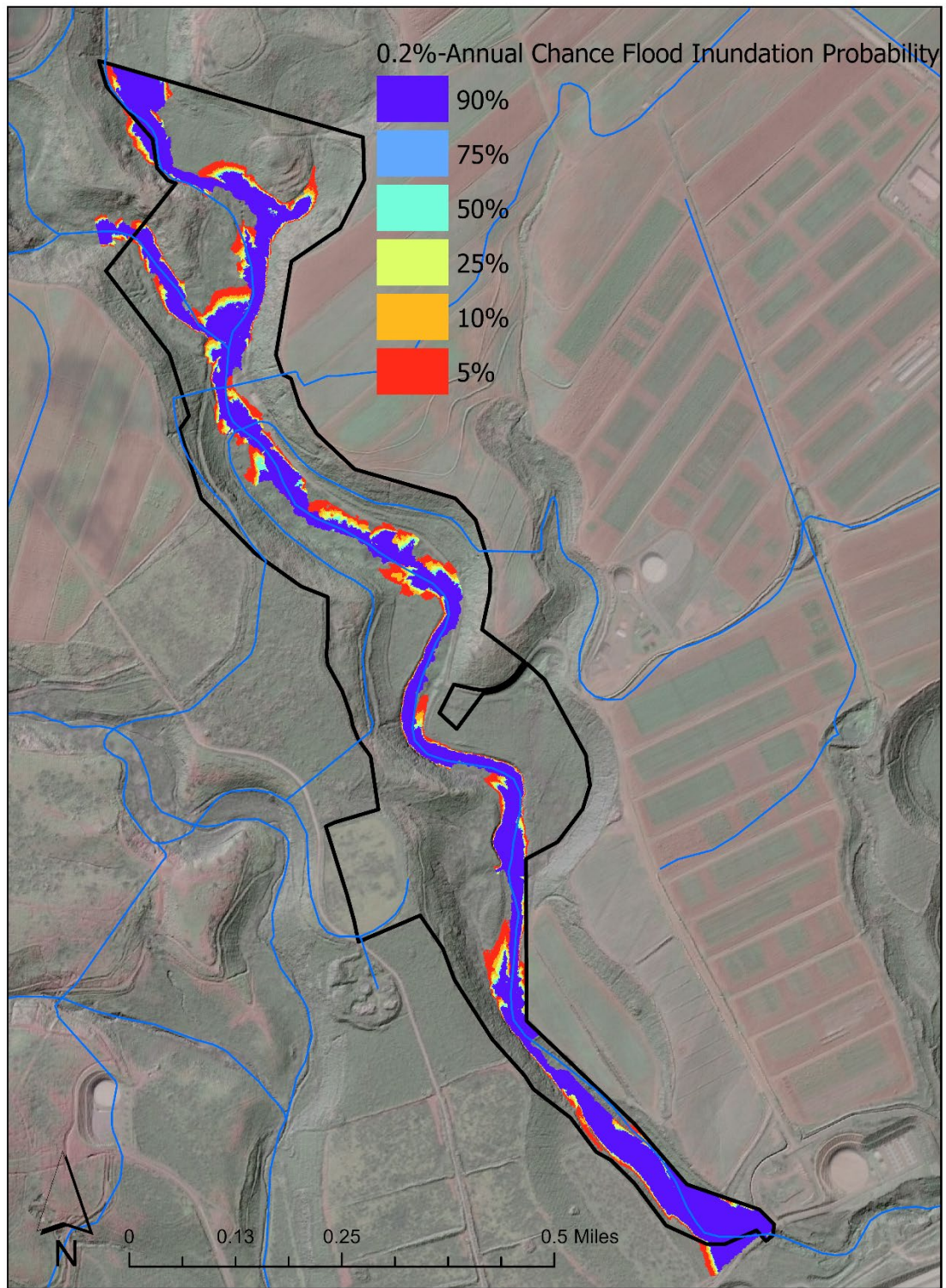


Figure 1. Inundation extent of the 0.2%-annual-chance flood. Colors indicate the probability that the 0.2%-annual-chance flood would inundate the area. Blue areas have a high probability of being inundated and inundation probability decreases as colors move from blue to red.