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Phase 1 Inspection Report Kalihiwai Reservoir (KA-0024)

State of Hawaii Department of Land and Natural Resources

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Executive Summary

This report presents observations, conclusions, and recommendations drawn from a review of referenced data and analyses, information provided by the owner, and conditions observed during the Phase I Inspection of Kalihiwai Reservoir (KA-0024) performed on August 4, 2021. The purpose of the review and inspection was to assess the safety and adequacy of the dam against catastrophic failure of the major structural elements based on visual inspection and information available at the time of the review. Review of the pertinent documents, analyses, and instrumentation data included a review of the methods and assumptions, but not a detailed check of the calculations themselves. The condition assessment presented in this report is based only on visible features/areas of the dam on the day of the inspection.

Kalihiwai Reservoir is located within the north shore of the island of Kauai in Kalihiwai, Kauai County, Hawaii. It is situated in the mountains above the town of Kalihiwai. The reservoir is accessible by a dirt road accessed west from either Kahiliholo Road that runs south from the town of Kalihiwai or from the Kuhio Highway just south of Kilauea.

Kalihiwai Reservoir is classified by the Department of Land and Natural Resources (DLNR) as a HIGH hazard dam. The dam is classified as SMALL size with a maximum height of 20 feet and maximum storage capacity of 428 acre-feet.

The overall condition of the dam based on the 2021 Phase I Inspection is POOR. The POOR rating, as defined by the system used for the National Inventory of Dams (NID 2013) and adopted by the DLNR, is as follows:

> *POOR* – A dam safety deficiency is recognized for loading conditions, which may realistically occur. Remedial action is necessary. POOR may also be used when uncertainties exist as to the critical analysis parameters which identify a potential dam safety deficiency. Further investigations and studies are necessary.

The POOR rating was selected because there are identified existing dam safety deficiencies which have been documented for loading conditions expected during the life of the structure. Embankment stability evaluations (ARCADIS 2015; Meta Engineering 2017; Gannett Fleming 2021) indicate computed Factors of Safety (FOS) below accepted standards. In addition, the hydraulic capacity of the existing spillway structure is not sufficient to convey the probable maximum flood (PMF) event, which is the inflow design flood (IDF). It is required that the reservoir store the full PMF event (derived from the 24-hour PMP) or a spillway be constructed to pass the full PMF event with adequate residual freeboard based on the dam's high hazard potential, small size classification per Hawaii Administrative Rules (HAR) §13-190 [specifically HAR 13-190.1-4(c and d)]. Further, the DLNR issued a "Notice of Deficiency" (NOD) related to the condition of the mid-level outlet (also known as Outlet #2) and invoked a reservoir restriction that the pool be maintained at or below the invert of the mid-level outlet (stated to be gage height 10.2 in the NOD letter [2017]). The discharge capacity of the modified configuration of the mid-level outlet is unknown.

Alternatives for repairing, replacing, or removing the dam are currently in progress. The alternative study included geotechnical field investigations, hydrologic and geotechnical analyses and preliminary design (Gannett Fleming, 2020 and 2021). This Phase 1 dam safety review included review of data and analyses relevant to the existing condition of the dam. A technical review of proposed design or modifications is beyond the scope of this Phase 1 dam safety review. Based on review of the available data and analyses, as well as observations made during the 2021 Phase I Inspection, the following recommendations are provided for Kalihiwai Reservoir. These recommendations were developed assuming the dam is to remain in service as a HIGH hazard potential dam.

Priority 1 Recommendations

1. **Spillway Upgrades.** Based on past performance and the analyses summarized in the 2020 hydrologic analysis by Gannett Fleming (Gannett Fleming, 2020), it is understood that the existing

spillway has insufficient capacity to pass the Probable Maximum Flood (PMF), which is the required Inflow Design Flood (IDF) for a High Hazard dam. The spillway should be modified to increase its capacity to safely pass the PMF while maintaining sufficient freeboard in accordance with Hawaii Administrative Rules (HAR) §13-190 [specifically HAR 13-190.1-4(c and d)].

2. **Embankment Slope Stability Analysis and Stabilization.** Based on the analyses presented in the 2020 and 2021 geotechnical evaluations performed by Gannett Fleming (Gannett Fleming, 2020 and 2021), the existing embankment does not meet current stability requirements for a High Hazard dam based on long-term steady-state conditions and requires stabilization modifications. Post-earthquake stability analyses have not been performed for the current embankment configuration and should be evaluated. In addition, only the maximum embankment section was analyzed (Gannett Fleming 2020). Other sections of the embankment alignment should also be evaluated that may have a more critical combination of steep slopes and weak layers. The stabilization design should incorporate a seepage collection system (see also Priority 1 Recommendation 5) and consider incorporating modifications to or abandonment of the irrigation/siphon ditch that runs along the downstream embankment toe.

3. **Mid-Level Outlet (Outlet #2) Modifications.** The HDPE conduits currently installed at the mid-level outlet (also referred to as Outlet #2) should be modified to a more permanent and robust structure with known invert elevation and discharge capacity either as a separate outlet with upstream control or incorporated as part of a spillway modification. In the interim, the elevation and correlated staff gage height of this outlet and the restricted pool level should be confirmed by survey. See also Priority 2 Recommendation 4.

4. **Maintain Proactive Vegetation Maintenance.** Vegetation maintenance has significantly improved since years past. Vegetation maintenance of the upstream and downstream embankment slope (including groins and toe areas), outlet works area, and spillway (including crest section and discharge channel) should continue to be improved. Seepage along the downstream toe continues to be a dam safety concern and proactive maintenance of vegetation is critical for effective monitoring of seepage on and downstream of the embankment.

    a. It is recommended that mowing operations on the embankment slopes use a reel or rotary mower to cut the grass but leave the roots, instead of a flail mower or tiller that can uproot the vegetation. An even grass cover with shallow roots, cut short to allow for inspection, provides some erosion resistance while not leading to deep root systems that could damage the embankment and lead to seepage pathways.

    b. Tree stumps on the embankment slope should be completely removed (i.e., root ball included) to limit preferential seepage pathways along root systems through the embankment and/or foundation and properly backfilled with compacted fill to avoid open depressions within the embankment.

    c. Backfill and monitor existing depressions due to tree removal along the embankment crest and slope for changing conditions.

    d. Continue to remove excessive vegetation and debris from the spillway crest section and discharge channel to allow free flow through the channel.

    e. Maintain short vegetation at the location of the staff gage (or move staff gage to an alternate location not prone to vegetation cover – see also Priority 2 Recommendation 3)

5. **Develop a Plan for Collecting, Measuring and Monitoring Seepage**. Based on past performance, seepage is judged to be a concern when the reservoir is operating with a full normal storage. Existing seepage areas at the toe of the embankment should be monitored regularly for changing conditions such as increase in flows, muddy flows, and turbidity or sediment in the discharge. Seepage should be kept clear of vegetation and regularly monitored as part of the routine inspections for developing changes such as increase in seepage flow, cloudy or muddy seepage flow, or discharge of soil particles. Observations made during inspections should be noted on the daily and monthly activity logs, as appropriate. Reservoir level should always be noted at the time of

the observations. Consideration should be given to using photographs at set vantage points for visual monitoring of changes in seepage during monthly inspections. In addition, the source of ponded water downstream of the toe should be investigated. The installation of a seepage filter and collection system in the embankment should be considered.

Priority 2 Recommendations

1. **Perform Tabletop Training Exercise.** It is understood that a tabletop exercise was performed in 2015. It is recommended a tabletop exercise be performed every 5 years. Perform a tabletop exercise with emergency response personnel to exercise the plan. The objective of the EAP exercise is to familiarize key stake holders with the EAP, provide a training opportunity for those stakeholders, and help identify areas where the EAP could be improved. The EAP exercise should begin with a brief orientation session that includes an overview of the DLNR dam safety program, a brief dam safety overview presentation by the facilitator, and a familiarization site tour of the dam site and key downstream areas of concern.
2. **Evaluate the Erosion/Scour Potential of the Upstream Slope, Spillway, and Mid-Level Outlet (Outlet #2).** An assessment should be made of the spillway crest, approach channel, and discharge channel related to erosion and scour potential and the need for riprap or other revetment to minimize the potential for erosion, scour and/or headcutting. A similar scour evaluation should be performed of the mid-level outlet, currently serving as the control for normal pool, to determine if riprap or other revetment is required for the mid-level outlet channel. A wave-runup and erosion analysis should be performed to evaluate the need for riprap armoring of the upstream slope.
3. **Improve Staff Gage.** Reservoir levels are currently monitored using a staff gage located near the right abutment. Vegetation makes reading the staff gage difficult. Consider moving the staff gage or improve vegetation management to allow accurate readings. The staff gage should also extend to the top of the embankment crest. Maintain calibration between the manual staff gage and the digital reservoir level sensor. At the time of the 2021 Phase 1 inspection, there was an approximately 18-inch discrepancy between the two gages.
4. **Update O&M Manual.** Update the 2018 O&M Manual as follows:
    a. Document the correlated gage height and elevations of key dam features. Review and update pertinent data listed in the O&M Manual including elevation, correlated staff gage height, and dimensions of key structures for accuracy and consistency with other documents, such as the 2022 EAP (see also Priority 2 Recommendation 6).
    b. There is an apparent discrepancy regarding the staff gage height of the maximum allowed restricted reservoir level (reported as 7 ft, 10.2 ft, and 11.6 ft in various documents and discussions) and which physical feature (e.g. mid-level outlet conduit invert/springline) and elevation to which the restricted-level gage height correlates. Verify accurate staff gage height of the mid-level outlet and the corresponding staff gage height of the restricted reservoir level.
    c. Include a copy of the daily log form in the manual.
    d. Include a map showing locations of known, monitored seepage areas and all instrumentation including flumes, recently installed piezometers, and reservoir gages. The map should be a full-page or sized to be clearly legible.
    e. Include the well installation log of piezometers indicating completion details such zones of anulus backfill and key elevations (top of casing, bottom of well, and screen interval).
    f. Include reading and recording piezometer levels as part of the monthly logs.
    g. Clarify the current responsible dam operator. According to the 2018 O&M Manual, Jack Gushiken currently serves as the Dam Operator and Tripp McCallister serves as the Back-up Operator. However, based on discussions during the Phase 1 inspection, it was stated that Mr. McCallister is the primary operator and Mr. Gushiken is now a volunteer assistant.

h. Remove reference to maintenance and inspection of the "floodgate/flood gate" which is understood to reference the gate structure previously located at the mid-level outlet (Outlet #2) that was removed in 2018.

i. Include general visual observations of the embankment, mid-level outlet entrance, and spillway entrance under the routine/daily inspections. Monthly inspections should consist of a more thorough walk/inspection of the upstream and downstream slopes, abutment areas, and toe areas.

5. **Update the EAP.** At the time of publication of this Phase 1 Report, the latest EAP is dated July 2022. A few revisions are recommended for the next regular update of the EAP. Spillway and outlet discharge capacity curves and impoundment capacity (storage) curves should be included. It is suggested that the Key Elevations table, which lists both the surveyed Mean Sea Level elevation and staff gage height, be revised for the intake invert of the low-level outlet works to indicate a staff gage height "<0" rather than "0", so as not to confuse the listed elevation of 375.1 as the correlation between staff gage height and MSL elevation (the documented correlated staff gage height 0 is elevation 377.4). Correct the top-of-dam staff gage height in the Key Elevations table. Delete reference to the removed Outlet #2 (mid-level outlet) gate structure throughout the document. Verify by survey any key elevations listed in the table that are noted as being estimated. It is also suggested that the site-specific guide for determining an event level (Section VIII Emergency Detection) be revised to indicate appropriate site-specific thresholds for seepage flow quantities at known seepage locations.

6. **Access to Inlet.** Consider obtaining an easement from the property owner on whose land the inlet structure lies to allow unrestricted access for inlet operation.

7. **Locate Construction Photos**. Original design documents and construction as-built drawings of Kalihiwai Reservoir are reportedly not available. However, the Dam Operator (Mr. Gushiken) indicated he believes there are some limited photos from original construction. If located, these construction photos should be filed with DLNR as they can be very helpful in understanding subsurface conditions of the embankment and foundation.

Table ES-1 summarizes the dam's compliance with the DLNR Dam Safety Rules (i.e., HAR §13-190 and Hawaii Revised Statutes [HRS] §179D) based on review of the available data, observations from the most recent annual visual dam safety inspection completed in 2015, and observations and findings of this 2021 Phase I Inspection.

Table ES-1: Compliance with DLNR Dam Safety Rules

DLNR Requirement	Authority	Compliance
Embankment Slopes Not Steeper than 2.5H:1V	HAR §13-190.1-4	No (1)
Minimum Embankment Crest Width of 10 feet	HAR §13-190.1-4	Yes
Earthen Spillway Constructed in Natural Ground	HAR §13-190.1-4	Yes
Low Level Outlet for Draining Reservoir	HAR §13-190.1-4	Yes
Stability Analysis (significant and high hazard potential)	HAR §13-190.1-4	Yes (2)
Spillway Safely Passes Appropriate IDF	HAR §13-190.1-4	No (3)
Meets Minimum Residual Freeboard during Peak Spillway Flow associated with IDF	HAR §13-190.1-4	No (3)
Operations and Maintenance (O&M) Plan	HAR §13-190.1-40.1	Yes
Inspection and Monitoring Program	HAR §13-190.1-40.1	Yes
Emergency Action Plan (EAP) [including initiation and response]	HAR §13-190.1-42	Yes
Physical Access to Dam Features	HRS §179D-30	Yes
Maintain Records (modifications/improvements, O&M, etc.)	HRS §179D-30	Yes

Notes:

1. The downstream slope varies from 2H:1V to 0.6H:1V. Recent slope stability analyses indicate that the steady-state stability of the downstream slope does not meet current recommended Factor of Safety (FOS) standards and embankment stability modifications have been recommended. Refer to *Priority 1, Recommendation 2*.
2. Refer to Section 2.10.2 for a discussion on the slope stability analyses performed for the embankment dam. A stability analysis performed by Gannett Fleming (2021) resulted in factors of safety less than minimum criteria for the steady-state condition. Refer to *Priority 1, Recommendation 2*.
3. Refer to Section 2.10.1 for a discussion on the hydrologic and hydraulic evaluations performed for the dam site. The current spillway capacity is insufficient to convey the IDF and requires modifications. Refer to *Priority 1, Recommendation.*

1. Introduction

This report documents the Phase I Inspection for Kalihiwai Reservoir. Kalihiwai Reservoir is owned by Kalihiwai Ridge Community Association (KRCA), and leased by the Porter Irrigation Company. The dam is under the jurisdiction of State of Hawaii Department of Land and Natural Resources (DLNR) as State Dam KA-0024. The inspection was performed in accordance with the DLNR Guidelines for Safety Inspections of Dams (DLNR Guidelines) (1992) and includes a site inspection, review of the available data and analyses, and review of reservoir operations as they pertain to dam safety.

The purpose of the review and inspection was to assess the safety or adequacy of the dam against catastrophic failure of the major structural elements based on visual inspection and information available at the time of the review. Safety herein is restricted to a discussion of the adequacy of the major structural and control features against catastrophic failure. Review of the pertinent documents, analyses, and instrumentation data included a review of the methods and assumptions, and not a detailed check of the calculations themselves.

2. Site Information

2.1 Site Location and Purpose

Kalihiwai Reservoir is located within the north shore of the island of Kauai in Kalihiwai, Kauai County, Hawaii. It is situated in the mountains above the town of Kalihiwai. The approximate longitudinal and latitudinal coordinates are –159.432378 and 22.187054, respectively. A vicinity and location map for Kalihiwai Reservoir is shown on Figure 1. Aerial and site plans of the dam and its appurtenant structures are shown on Figures 2 and 3, respectively. The reservoir is accessible by a dirt road accessed west from either Kahiliholo Road that runs south from the town of Kalihiwai or from the Kuhio Highway just south of Kilauea.

Kalihiwai Reservoir is thought to be constructed in the 1920s for use of irrigating downstream sugar cane fields. Kalihiwai Reservoir is currently utilized for storage and distribution of water for irrigation and fire repression, wildlife, flood detention (reportedly for Kalihiwai Ridge Phase 2 Development), and for use by the KRCA residents for recreational fishing.

2.2 Pertinent Data Summary

This section provides an overview of pertinent data regarding the physical characteristics of the dam and appurtenant structures. Table 2-1 summarizes the pertinent data of the dam site. More detailed descriptions of the features are included in subsequent sections of this report.

Table 2-1: Pertinent Data Summary Table

General Information	Description / Value [1]
1. Name	Kalihiwai
2. National Inventory of Dams (NID)	HI 00024
3. State ID	KA-0024
4. State	Hawaii
5. County	Kauai
6. Latitude	22.187054° North
7. Longitude	159.432378° West
8. Tax Map Key	(4) 5-2-022:003
9. Current Hazard Classification	High
10. Size Classification	Small
11. Stream	TR-Kalihiwai River
12. Year Constructed	1920
13. Modifications in last 10 years	• Mid-level outlet (Outlet #2) replaced with two 24-inch HDPE culverts (2020) • Slope stability scarp on downstream slope repaired (2020) • Gravel added to crest and graded access road (2020)
Dam Embankment	**Description / Value [1]**
1. Type	Earthen
2. Crest Elevation	396 ft (Esaki 2013 as documented in 2022 EAP) 394.8 to 397.2 (Gannet Fleming 2021) [2]
3. Crest Length	950 ft
4. Minimum Crest Width	15 ft
5. Maximum Dam Height	20 ft
6. Upstream Slope	2.0H:1V [2]
7. Downstream Slope	0.6H:1V to 2.0H:1V [2]
Drainage Basin	**Description / Value [1]**
1. Area of Drainage Basin	0.32 Square Miles
2. Downstream Description:	Heavily Vegetated
Reservoir	**Description / Value [1]**
1. Storage Capacity at Restricted Pool[3]	53.5 acre-feet[2] (at Elevation 387 feet)
2. Normal Storage Capacity [at Spillway Crest]	278 acre-feet (reference Elevation not reported but presumed to correspond to Elevation 391.5 feet)
3. Maximum Storage Capacity [at Dam Crest]	428 acre-feet (reference Elevation not reported) 242 acre-feet[2] (at Elevation 395 feet)
4. Normal Surface Area	22 acres[2] (at El. 387)[3] 23 acres (reference Elevation not reported but presumed to correspond to Normal pool El. 391.5)
5. Surface Area at Spillway Crest (Elevation 391.5 feet)	Unknown
6. Maximum Surface Area (Elevation 395 feet)	31.8 acres[2]
Outlet Works	**Description / Value [1]**

Outlet #1 (Low Level Outlet and Primary Water Supply Line)	
1. Location	Through embankment, near right abutment
2. Intake Structure	24-inch line through the embankment into an 18-inch line that tees to two 12-inch lines which flow through filters and back to an 18-inch line. Controlled downstream at Plantation.
a. Intake Invert Elevation	375.1 ft (2022 EAP, unknown elevation source)
b. Control Location	Downstream at Plantation.
3. Discharge Conduits	Metal pipe
a. Length	Unknown
b. Dimension	24 inches
4. Outlet Structure	None
a. Outlet Invert Elevation	374.5 ft (Esaki 2014 as documented in 2022 EAP)
b. Energy Dissipation	None
5. Discharge Channel	Irrigation ditch
6. Discharge Capacity	Unknown
Outlet #2 (Mid-Level Outlet) (3)	Mid-Level Outlet gate structure was removed in 2018. The uncontrolled mid-level outlet now serves as the primary spillway controlling normal reservoir level.
1. Location	Left abutment
2. Intake Structure	None. Boulders placed upstream of conduits.
a. Intake Invert Elevation (3)	387.6 ft (per 2022 EAP estimated based on reference to old/removed outlet structure).
b. Control Location	Uncontrolled
3. Discharge Conduits	
a. Length	~ 25 ft
b. Dimension	2 x 24” diameter HDPE pipes
4. Outlet Structure	None
a. Outlet Invert Elevation	N/A
b. Energy Dissipation	N/A
5. Discharge Channel	Earthen
6. Discharge Capacity	Unknown
Spillway	**Description / Value (1)**
a. Description	Earthen channel
b. Location	Left of left abutment
c. Control Section Type	Uncontrolled gravel- and concrete-lined control section
d. Control Section Dimensions	55 feet wide (2)
e. Control Section Elevation	391.6 ft (KMT 2016 as documented in 2022 EAP)
f. Energy Dissipation	None
g. Discharge Channel Length	332 ft (narrows to a 14-ft-wide channel downstream of control section)
h. Discharge Capacity	Unknown
Inlet Works	**Description / Value**
1. Reservoir Inlet	Kalihiwai Ditch inflow (4 ft wide trapezoidal dirt channel) and drainage area estimated at 0.32 sq miles conveyed through Pohakuhonu Stream (4)
Management	**Description / Value**

1. Owner	Kalihiwai Ridge Community Association (5)
2. Purpose	Irrigation and recreational fishing
3. Contact Information	President of Kalihiwai Ridge Community Association Jean-Michel Gabet c/o Certified Management 4-1579 Kuhio Highway, #102A Kapaa, HI 96746

Notes:

1. Reported descriptions/values are as listed on the DLNR data sheet for the dam (DLNR 2015) unless otherwise noted.
2. Information referenced from the 2021 Gannett Fleming Draft Design Report (Gannett Fleming 2021). Storage capacity information was reportedly estimated from available topography data and indicated smaller storage volumes at similar elevations reported in the DLNR database.
3. Outlet #2, also referred to as the Mid-Level Outlet, was modified following the 2018 flood event. The concrete control structure was removed and replaced with uncontrolled HDPE conduits with unknown invert elevation. This outlet now serves as primary reservoir level control. Reference to “Normal Pool” versus “Restricted Pool” elevation and gage height is inconsistent in recent documents. Restricted reservoir level is reported to be in reference to this outlet with uncertain elevation and inconsistent reference to correlated staff gage height. See Priority 1 Recommendation 3 and Priority 2 Recommendation 4.
4. It was reported during the 2021 Phase 1 inspection that there are a total of three (3) inlets into the reservoir. The location of the third inlet (in addition to the Kalihiwai Ditch and natural stream) was unable to be confirmed. It is possible additional grading from recent residential development conveys additional runoff into the reservoir for flood detention.
5. KRCA is the dam Owner. There are two easement owners: Bridgewater Irrigation, LLC and Porter Irrigation Company.
6. Staff Gage Height 0 = Elevation 377.4 ft MSL according to the 2022 EAP.

2.3 Hazard and Size Classification

Kalihiwai Reservoir is classified as a HIGH hazard potential dam due to the possibility for downstream impacts associated with a failure of the dam. A breach inundation study with reservoir level near the maximum capacity (listed in the study as 428 acre-feet) was performed by the Pacific Disaster Center assuming the dam fails by piping originating halfway up the dam face, under sunny-day conditions (PDC 2016). The inundation zone included a total of 23 parcels and an estimated population at risk of 1. The dam is classified as SMALL size with a maximum height of 20 feet and maximum storage capacity of 428 acre-feet with the reservoir at the dam crest elevation. These classifications are in accordance with the Hawaii Administrative Rules for Dams and Reservoirs (2012), referred to hereafter as HAR §13-190 and the Hawaii Revised Statutes for Dams and Reservoirs (2019), referred to hereafter as HRS §179D. Hazard potential and size classification definitions based on HAR §13-190 and HRS §179D are provided in Appendix A.

2.4 Construction History

Kalihiwai Reservoir was constructed in approximately 1920 for the purpose of providing irrigation water. Original design documents and construction as-built drawings of Kalihiwai Reservoir are not available. However, the Dam Operator (Jack Gushiken) indicated he believes there are some limited photos from construction. If located, these construction photos should be filed with DLNR as they can be very helpful in understanding subsurface conditions of the embankment and foundation.

The DLNR issued a Notice of Dam Safety Deficiency (NOD) in May 2013 with a follow up letter in 2017 related to the condition of the mid-level outlet works. The dam overtopped by several inches in 2018, which prompted the removal of the mid-level outlet gate as an emergency intervention to increase discharge capacity. The overtopping also prompted repairs of the embankment crest and downstream slope along the right embankment segment. Recent modifications to the embankment and its appurtenant structures also include installing two ungated 24-inch-diameter high density polyethylene (HDPE) pipes at the location of the mid-level outlet.

2.5 Site Description

The primary features of Kalihiwai Reservoir consist of an embankment dam; an unlined spillway located at the left[1] abutment of the dam; a low-level outlet works; and an uncontrolled secondary (mid-level) outlet works. Aerial and site plans of the dam and its appurtenant structures are shown on Figures 2 and 3, respectively.

The reservoir receives inflows from the Kalihiwai Ditch and surface runoff from the surrounding 0.32 square mile watershed drainage area upstream of the dam. Based on the 2021 Gannett Fleming Draft Final Design Report, the reservoir has a surface area of approximately 22 acres and storage capacity of approximately 53.5 acre-feet at a restricted operating pool elevation of 387.6 feet, which is approximately 4 feet below the spillway crest (elevation 391.5 feet). The reservoir has a maximum surface area of 31.8 acres and reservoir storage capacity of 242 acre-feet with the reservoir at the dam crest (reference elevation 395 feet). It should be noted that these values are not reflected in DLNR records. Discharges from the reservoir flow into the Kalihiwai River.

Original drawings of the dam are not available. Renderings based on surface topography have been developed in available reports (e.g., Gannett Fleming 2021).

2.5.1 Embankment Dam

Kalihiwai Reservoir is a compacted earthfill embankment with a crest elevation of approximately 396 feet, crest length of 950 feet, minimum crest width of 15 feet, and a maximum height of 20 feet. The embankment consists of two segments as shown in Photo 2-1. A site plan and typical cross-section of the embankment dam is shown on Figure 4.

The embankment crest consists of a single lane, graveled access road, as shown in Photo 2-2 below. There is some uncertainty in the embankment crest elevation. The 2022 EAP and 2018 O&M Manual list the embankment crest elevation as 396 feet while the 2021 Gannett Fleming Draft Final Design Report lists the embankment crest elevation as 394.8 feet to 397.2 feet. The upstream embankment slope is approximately 2 horizontal to 1 vertical (2H:1V) and is grass covered, as shown in Photo 2-3 and Photo 2-4. The downstream embankment slope varies from approximately 0.6H:1V to 2H:1V. There were portions of the downstream slope with were near vertical, most prominently along the upper portion of the left embankment downstream slope. The downstream slope is grass covered as shown in Photo 2-5. However, a few portions of the downstream slope and toe were densely vegetated with taller grass and the toe portion of the right downstream embankment segment was exposed and includes a seepage collection ditch. Debris from previous vegetation removal was also present on the downstream slope. Erosion control matting was observed on the downstream embankment slope near the right abutment as shown in Photo 2-6.

[1] Left and right as used in this document are from the vantage of looking downstream.

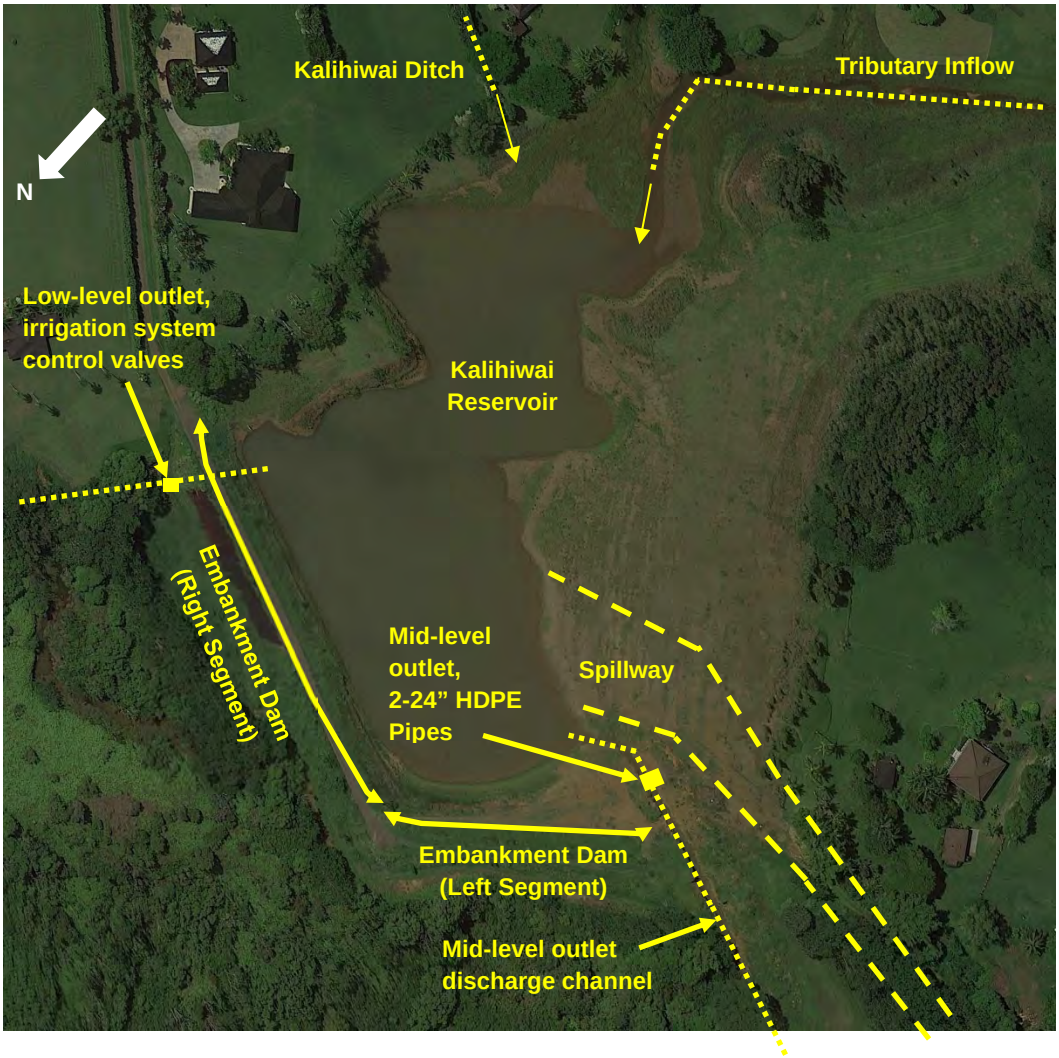


Photo 2-1: Aerial View of Dam and Appurtenant Structures

Photo 2-2: Embankment Crest looking Right

Photo 2-3: Upstream Embankment Slope, Looking Left from Near Right Abutment

Photo 2-4: Upstream Embankment Slope, Looking Right from Middle of Embankment

Photo 2-5: Downstream Embankment Slope: (a) Looking Right from near Middle of Right Embankment and (b) Looking Left from near Middle of Left Embankment

Photo 2-6: Erosion Mat along Downstream Embankment Slope. Looking towards Right Abutment

2.5.2 Spillway

The spillway is located at the left abutment of the embankment and consists of an uncontrolled trapezoidal shaped earthen section with a control elevation of 391.5 feet and an approximate bottom width of 55 feet at the control section narrowing to a width of approximately 14 feet along the discharge channel. The spillway is uncontrolled and transitions to a steeper trapezoidal section prior to discharging to the floodplain of the Kalihiwai River.

Photo 2-7: Spillway Approach (looking upstream towards reservoir)

Photo 2-8: Spillway Discharge Channel (looking downstream)

Photo 2-9: Lower Portion of Spillway Discharge Channel

2.5.3 Outlet Works

Low-level outlet control from the reservoir is located near the right abutment and is used to distribute reservoir water to the downstream irrigation system (Outlet #1). The low-level outlet consists of a 24-inch diameter line through the embankment into an 18-inch diameter line that T's into two 12-inch diameter lines which flow through filters and back to an 18-inch diameter line. A valve structure is located at the downstream embankment toe but remains in the open position. Flow is controlled further downstream at an existing plantation.

Photo 2-10: Low Level Outlet Works Valve at Downstream Embankment Toe (Outlet #1)

The mid-level outlet works (Outlet #2) historically consisted of an approximately 30-inch diameter corrugated metal pipe (CMP) with an upstream slide gate located near the left abutment. The mid-level outlet gate structure was removed during the flood of 2018 to increase discharge capacity and replaced in 2020 with two ungated 24-inch diameter HDPE pipes which discharge to an unlined channel.

Photo 2-11: Mid-level Outlet (Outlet #2)

2.5.4 Inlet Works

Inflow to the reservoir is from (1) the Kalihiwai Irrigation Ditch and (2) from Pohakuhonu Stream, a natural tributary from the surrounding drainage area which measures 0.32 square miles. The Kalihiwai Irrigation Ditch is reportedly 4 feet wide unlined ditch and inflow from the Kalihiwai Ditch is controlled by a wooden slide gate structure. The inlet works was not inspected during the 2021 Phase I inspection and it was reportedly closed. When operating, flow into the reservoir is measured through a Parshall Flume at the inlet and recorded in the daily logbook. It was reported during the 2021 Phase 1 inspection that there are

a total of three (3) inlets into the reservoir. The location of the third inlet (in addition to the Kalihiwai Ditch and natural stream) was unable to be confirmed. It is possible grading from recent residential development conveys additional runoff into the reservoir for flood detention.

2.6 Operations and Maintenance

The current operations and maintenance (O&M) manual for Kalihiwai Reservoir on record with DLNR is dated August 2018 and was prepared following the modifications/removed of the mid-level outlet. The 2018 O&M manual outlines the operation, inspection, monitoring, and maintenance activities for the dam and its appurtenant structures. Emergency procedures are outlined in the Emergency Action Plan (EAP) dated July 26, 2022, which is also on file with the DLNR. Information presented in this section is based on review of the 2018 O&M manual and 2022 EAP, as well as discussions with the dam owner's representative at the time of the 2021 Phase I Inspection.

2.6.1 Normal Operation

Kallihiwai Reservoir is owned by the Kalihiwai Ridge Community Association. There are two easement owners, Porter Irrigation and Bridgewater Irrigation, who serve as the operators for the facility. According to the 2018 O&M Manual, Jack Gushiken (Porter Irrigation) currently serves as the Dam Operator and Tripp McCallister serves as the Back-up Operator. However, based on discussions during the 2021 Phase 1 inspection, it was stated that Tripp McCallister is the primary operator and Jack is a volunteer assistant.

Daily operations include visuals surveillance and instrumentation monitoring (see Section 2.7) and any adjustments necessary to maintain the target water level. Mr. Gushiken visits the site daily and keeps a logbook of the following daily readings: rainfall, intake flow, staff gage reservoir level, outlet flow, seepage, estimate of any spillway flow, and general remarks regarding gate operations, maintenance activities, and unusual conditions. Mr. McCallister visits the site twice a week or as needed. The daily log contained in the logbook is submitted to DLNR on a monthly basis.

Under the restricted reservoir operations, inflow from the Kalihiwai Ditch diversion is normally closed and therefore, the only inflow is from the natural drainage area. Inflow from the natural drainage area was reported to have increased since recent residential development in the area and therefore the reservoir fills more rapidly during rainfall events.

Outflow is released for purposes of irrigation via the low-level outlet works (Outlet #1). Under current restricted operating conditions, the reservoir level is generally kept between elevation 387 to 388 feet (gage height 9.6 to 10.6), which is near the invert of the mid-level outlet, approximately 8 to 9 feet below the embankment crest of 395 feet MSL. The 2018 O&M Manual indicates a maximum target reservoir at staff gage height 11.6 ft, which appears to be in contradiction to the 2017 NOD letter indicating a restricted reservoir level of gage height 10.2 ft. It was also notable that discussions during the 2021 Phase 1 inspection referenced a restricted reservoir level of 7 ft and the logbook reviewed during the site inspection listed reservoir levels between 5'6" and 7'4", which did not appear to directly correlate with the range of levels marked on the staff gage.

Embankment maintenance of the Kalihiwai Reservoir has generally consisted of mowing grass, removal of woody vegetation from the embankment and toe areas and maintaining access roads/paths. These maintenance activities are performed approximately every two months. The upstream embankment slope had recently been mowed; however, the equipment used appeared to have uprooted portions of the grass cover (see Photo 2-1) leaving loose debris over potentially bare earth for much of the slope. It is recommended that mowing operations on the embankment slopes instead use a reel or rotary mower to cut the grass but leave the roots intact. An even grass cover with shallow roots, cut short to allow for inspection, provides some erosion resistance while not leading to deep root systems that could damage the embankment and lead to seepage pathways. Woody vegetation, including brush and trees, should be completely removed from the embankment including the root ball and properly backfilled.

The slopes are relatively steep and appear to have experienced erosion in the past. The embankment overtopped in 2018 and slope repairs were reportedly completed including placing localized backfill in the area of a slump that occurred in the downstream slope and placing a turf reinforcement mat.

The dam operators indicated exercising/operating the low-level outlet (Outlet #1) valve is performed regularly at the downstream plantation. The low level outlet valve(s) that are located at the downstream embankment toe are not known to have been operated for several decades and remain in the open position.

2.6.2 Flood Operation

In the event of heavy rainfall storms or floods, the inflows to the reservoir from the Kalihiwai Ditch are diverted and the low-level outlet works are fully opened. Flow is passively discharged from the mid-level outlet channel and upon further rise in reservoir level, through the spillway. The maximum discharge capacity of all existing flood passage features (low level outlet, mid-level outlet and spillway) is unknown under the current configuration. The maximum discharge capacity of the spillway is estimated to be approximately 2,412 cubic feet per second with the reservoir at the peak reservoir elevation of 393.9 feet (Gannett Fleming, 2021).

In accordance with the 2018 O&M Manual, the site should be inspected at 3- to 4-hour intervals during “very rainy” conditions until the reservoir level has stabilized, as the reservoir levels are known to rise quickly. The owners and operators of Kalihiwai Reservoir indicate that the large rocks located upstream of the mid-level outlet would be removed in advance of a predicted inflow event to increase the overall capacity of the mid-level outlet if needed.

2.6.3 Emergency Procedures

The most recent EAP for Kalihiwai Reservoir on file with the DLNR at the time of publication of this Phase 1 report is dated July 26, 2022. If an emergency situation is detected, the EAP would be implemented. The 2022 EAP indicates that it is the responsibility of the dam owner and/or dam owner’s representative to inspect, monitor, and operate the dam; detect an unusual or emergency situation; determine the notification level for the situation; notify the appropriate agencies by activating the EAP; and monitor or remediate the situation. According to the EAP, the two main contacts for the dam owner are Jack Gushiken and Tripp McCallister. Tripp McCallister lives within about a 5-minute response time of the site.

The dam and its appurtenant structures are located within the south shore of the island of Kauai in Kalaheo, Kauai County, Hawaii. It is situated in the mountains above the town of Kalaheo. Access to the dam site is by traveling north on Kuhio Highway, Highway 56, from the town of Kapaa, turning left on Kahiliholo Road, near mile marker 24. The reservoir is on the west side of the road and a locked gate must be opened to access the dam, or a short walk can be made to access the dam. A member of KRCA is required to assist in unlocking the gate and locating the dam. A secondary access is also available but requires access through private property on the left end of the reservoir. A four-wheel-drive vehicle is necessary to reach the site during adverse weather conditions.

Equipment for emergency intervention is located off site but available to mobilize to the property. The EAP lists locally available resources for heavy equipment service and rental, sand and gravel supply, ready-mix concrete supply, sand bags, pumps, diving contractor, lighting, generator, piping, geotextile, and siphon.

Mr. McCallister participates in DLNR dam safety training when offered. At the time of the 2021 Phase 1 inspection, the last EAP exercise was reportedly held in 2016.

2.6.4 Assessment of O&M Procedures

This section is a general assessment of the operational procedures, ongoing maintenance, and training and dam safety knowledge of the operator(s). Any recommended additions or changes related to operation and maintenance items are included in the Executive Summary and Section 4.3.

The following operation and maintenance items are relevant for continued safe operation of the dam:

- Maintain vegetation control on the downstream slope of the embankment, at the outlet works, and at the spillway to facilitate visual surveillance. Use rotary or reel mowers to maintain a low grass cover.

- Improve vegetation control at the location of the staff gage to facilitate accurate readings and maintain reservoir staff gage for legibility of markings.
- Keep spillway approach channel, control section, and discharge channel free of debris.
- Maintain embankment crest at uniform height and maintain a gravel cover.
- Perform regular inspections of the embankment, mid-level outlet and the spillway.
- Perform maintenance and exercising of the low-level outlet works valves.
- Monitor the seepage flows along the downstream slope for any developing changes.
- Maintain primary access route to the dam.
- Participate in periodic EAP and dam safety training for the owner and operator.
- Consider storing equipment and material on site for emergency intervention.
- Be apprised of predicted significant storms for advance warning and reservoir lowering.

2.7 Monitoring and Performance History

Visual surveillance and instrumentation monitoring activities for Kalihiwai Reservoir are regularly performed by the owners and DLNR representatives. Information presented in this section is based on review of the previous inspection reports, as well as discussions with the dam owner representatives at the time of the 2021 Phase I Inspection. This section also summarizes the performance history of the dam and its appurtenant structures based on previous inspections and the status of previous recommendations resulting from those inspections.

2.7.1 Visual Surveillance

Daily observations are performed by driving along the embankment crest and toe and driving to the spillway control section. Daily observations include inspections of reservoir level, embankment crest and slopes, spillway, and outlets. Observations include inspecting the embankment crest for depressions, inspecting the downstream slope for bulges or wet spots, and inspecting the downstream toe area for seepage. Mr. Gushiken visits the site daily and keeps a logbook of the following daily readings: rainfall, intake flow, staff gage reservoir level, outlet flow, seepage, estimate of any spillway flow, and general remarks regarding gate operations, maintenance activities, and unusual conditions. Mr. McCallister visits the site twice a week or as needed. The daily log contained in the logbook is submitted to DLNR on a monthly basis. Any unusual observations noted by the dam operator should be reported immediately to the DLNR.

It is recommended that the O&M Manual clarify that daily inspections include general observations of the embankment, mid-level outlet entrance, and spillway entrance. Monthly inspections should consist of a more thorough walk/inspection of the upstream and downstream slopes, abutment areas, and toe areas. *See Priority 2 Recommendation 5*.

In accordance with the 2018 O&M Manual, the site should be inspected at 3- to 4-hour intervals during “very rainy” conditions until the reservoir level has stabilized, as the reservoir levels are known to rise quickly.

Periodic inspections are completed by the DLNR using a visual inspection checklist titled “Dam Safety Inspection Sheet” similar to that provided in Appendix C. See Section 2.8 for a summary of documented DLNR inspections.

2.7.2 Instrumentation Monitoring

Instrumentation present at the dam site include the following:

- A manual reservoir staff gage located near the upstream toe near the right abutment.

- A digital automated staff gage is located near the manual staff gage.
- Two piezometers located within the embankment (PZ-1 and PZ-2) that were installed during geotechnical investigations in 2014-2015, however, these are not regularly monitored and it is unknown if they are currently functional.
- Two additional open standpipe monitoring wells were installed in borings GF-3 and GF-5 as part of geotechnical investigations in 2020 to monitor groundwater levels in the dam embankment and to perform falling head tests.
- A Parshall flume located at the reservoir inlet.
- A flume located at the downstream toe of the right embankment segment (left end of right embankment section).

At the time of the 2021 Phase 1 inspection, the piezometers were not being regularly recorded and data was not available for review. However, some historical monitoring data is available in the 2021 Gannett Fleming report. Based on historic data from two of the piezometers, piezometer levels show correlation with water levels in the reservoir. Piezometers PZ-1 and PZ-2 are shown in Photo 2-15.

The reservoir staff gage and automated staff gage are used to measure the pool elevation. The staff gage consists of water level markings spaced at quarter-foot increments painted on the downstream side of white boards installed within the reservoir, as shown in Photo 2-13. The automated staff gage consists of an automated data acquisition system that provides real-time reservoir monitoring and is shown in Photo 2-14.

Photo 2-12: Location of Manual and Automated Staff Gages Near Right Abutment

Photo 2-13: Close-up of Manual Reservoir Staff Gage Near Right Abutment

Photo 2-14: Close-up of Automated Staff Gage Near Right Abutment

Photo 2-15: Piezometers: (a) PZ-1 Located near Middle of Right Embankment Toe and (b) PZ-2 Located near Middle of Right Embankment Crest

The inlet was closed as part of the normal operations under the restricted reservoir level and therefore the inlet flume was not being actively monitored. The flume located at the downstream toe of the right embankment segment is measured as part of the routine/daily inspections and recorded on the daily log. The flume reportedly flows in the range of 5 to 10 gallons per minute (gpm) under the restricted pool level and up to about 20 gpm under previously normal operating conditions. It was noted that the logbook for the month of July 2021 references a seepage volume of 10,000 gallons per minute (labeled as the S-1 location in the daily log), which was stated to be a data entry error. It was recorded to be about 10 gpm for the month of June 2021 and was estimated to be approximately 2 gpm at the time of the 2021 Phase 1 inspection.

Photo 2-16: Flume to Monitor Seepage at Downstream Toe of Right Embankment Segment

2.7.3 Performance History and Status of Previous Recommendations

The dam has reportedly overtopped in the 1970s, which prompted lowering of the spillway crest. The embankment overtopped again by several inches in 2018 causing a slump of the downstream slope,

limited damage to the crest, and removal of the mid-level outlet gate structure as an emergency intervention to increase discharge capacity. The downstream toe of the right embankment has a history of seepage which continues to be monitored and has caused some erosion along the toe. There are also reports of seepage exiting above the embankment toe along the right embankment segment, particularly in areas that had slumped following the 2018 overtopping event.

Inspections of the dam and reservoir appurtenant structures has occurred consistently since 2006 and are indicated below:

- September 2000 (DLNR)
- March 20, 2006 (USACE/DLNR)
- November 2006 (USACE/DLNR)
- October 4, 2007 (Kleinfelder)
- August 12, 2008 (DLNR)
- July 20, 2010 (DLNR)
- November 4, 2010 (DLNR to inspect vegetation clearing)
- May 1, 2012 (DLNR)
- April 16, 2014 (DLNR)
- January 13, 2015 (DLNR)

The most recent visual dam safety inspection was performed on January 13, 2015 by the DLNR. The most recent Phase I inspection was performed on October 4, 2007 (also reported as September 27, 2007) by Kleinfelder (Report Dated April 2009). The overall condition of the dam was reported as POOR. POOR was defined as “a potential dam safety deficiency is clearly recognized for normal loading conditions. Immediate actions to resolve the deficiency are recommended; reservoir restrictions may be necessary until problem resolution”.

Reasons for the POOR rating included the following:

- Heavy vegetation covered most of the dam. The upstream and downstream slopes were steep with some undercutting of the crest on the downstream slope.
- There was rutting and possible sinkholes on the dam crest.
- There was heavy vegetation in the approach and exit channels of both the spillway and outlet works.
- An Emergency Action Plan (EAP) had been developed and submitted to DLNR, however, the EAP is in poor condition and requires a number of improvements.
- An Operations and Maintenance (O&M) manual had not been prepared.
- There had been discussion between owners of the dam and residents that live along the shore of the reservoir concerning the safe level for the reservoir. The dam has a history of seepage and it has been reported that the dam has overtopped in the past. It is questionable if keeping the reservoir full is a safe operating level.

The most recent visual dam safety inspection was performed on January 13, 2015 by DLNR and the following deficiencies were noted that led to the facility being placed on a “Level 1 Emergency Status.”

- Areas of bare earth
- Areas of severe cutting/rutting/erosion of the downstream slope – the vertical slope deemed a hazard with potential for further erosion.
- History of overtopping
- Compromised condition of the mid-level outlet (Outlet #2)

Table 2-3 summarizes recommendations provided in the 2009 Phase I Visual Inspection Report Review (Kleinfelder 2009), recommendations made during the most recent DLNR inspection, and the current status of all outstanding recommendations.

Table 2-2: Status of Previous Recommendations

Recommendations from 2009 Phase I Inspection Review and 2015 DLNR Inspection	Status
Priority 1, Recommendation 1. Clear the vegetation and stumps from the slopes, toe and abutment areas, outlet channel and spillway to allow for a more thorough inspection. Check for seepage once the slopes and toe have been cleared. Refer to FEMA Manual 534 – Impact of plants on Earthen Dams for guidance on vegetation removal. This manual is available on the FEMA website.	**Ongoing.** Clearing performed in 2010 identified the ditch that runs along the downstream toe of the left embankment segment. By 2015 most of the large trees and woody vegetation had been cleared. Areas of severe erosion and near vertical slopes were exposed. Vegetation maintenance has improved from years past and allowed better monitoring of seepage, erosion, and slope stability, which continue to be a concern at the site. Vegetation maintenance should be continued as recommended in Priority 1 Recommendation 4.
Priority 1, Recommendation 2. Investigate the sinkholes along the slopes and on the crest to determine if they are signs of embankment instability or piping.	**Partially completed.** Several depressions/potholes were observed in 2007 and it was uncertain whether they were sinkholes or just a result of rutting. Similar depressions were not observed in subsequent DLNR inspections and may have been filled in or regraded. Depressions were observed during the 2021 Phase 1 Inspection along the crest and upper portions of the slopes which appeared to be and were reported to be a result of removing large vegetation that had not been backfilled. These areas should continue to be monitored. as recommended in Priority 1, Recommendation 4c.
Priority 1, Recommendation 3. Perform a stability analysis to evaluate the steep upstream and downstream slopes of the dam. The majority of the downstream slope is vertical and should be reshaped.	**Completed.** Gannett Fleming (2021) performed seepage and slope stability evaluations. The results indicate that the existing embankment does not meet current accepted Factors of Safety (FOS) for steady state conditions and buttress fill and a toe drain collection system have been recommended.
Priority 1, Recommendation 4. Perform a hydrologic and hydraulic study. This study should be performed to determine if the existing spillway is capable of passing the inflow design flood and what modifications, if any, are necessary.	**Completed.** Hydrologic/hydraulic evaluations were completed by Gannett Fleming in 2020/2021 as part of the rehabilitation designs for the dam. The results of the hydrologic/hydraulic analysis indicates that the existing spillway is not capable of conveying the IDF and spillway modifications have been recommended (Gannett Fleming, 2021)
Priority 1, Recommendation 5. Monitor and measure seepage. Seepage is of major concern when the reservoir if full. Seepage area at the toe should be monitored regularly for changing conditions such as higher flows, muddy flows, and turbidity or sediment in the discharge. A seepage measuring and monitoring device such as a V-notch weir or Parshall flume should be installed. Piezometers should be installed to monitor seepage through the embankment. The installation of a drainage system in the embankment should be considered.	**Partially completed.** A flume has been installed at the downstream toe of the right embankment to help quantify seepage estimates. Additional piezometers have been installed but are not part of the active monitoring program. A formalized seepage monitoring and collection system has been recommended as part of the 2021 rehabilitation designs (Gannett Fleming, 2021). This recommendation is re-issued as Priority 1, Recommendation 5 and Priority 2, Recommendation 4.

Recommendations from 2009 Phase I Inspection Review and 2015 DLNR Inspection	Status
Priority 1, Recommendation 6. Determine the source of the ponded water just beyond the downstream toe, and further investigate the source.	**Incomplete.** This recommendation should be considered part of the overall seepage monitoring and collection system for the reservoir and is included as part of Priority 1, Recommendation 5.
Priority 1, Recommendation 7. Establish and maintain a safe pool operating level.	**Partially complete.** The uncontrolled mid-level outlet that was installed in 2020 provides a safe operating pool for the reservoir. However, the elevation and capacity of the mid-level outlet should be confirmed. See Priority 1, Recommendation 3 and Priority 2, Recommendation 4.
Priority 1, Recommendation 8. Backfill and compact the ditch at the downstream toe of the dam. The ditch is cutting the toe of the dam and could cause embankment instability.	**Partially complete.** The ditch has been exposed by vegetation removal in the past; however, re-growth of vegetation is continuing to occur. Per the November 2010 DLNR Informal Inspection, the ditch used to take flows from the siphon in the Kalihiwai gulch and convey it towards the [low level] outlet. The old siphon is no longer in existence and there may not be much use for the ditch except to divert overflow from the [mid-level] outlet. It is recommended that this ditch be modified/replaced as part of embankment stabilization and a formalized seepage collection system. See Priority 1, Recommendation 2 and Priority 2, Recommendation 4.
Priority 1, Recommendation 9. Update the Emergency Action Plan. Updates to the EAP should be done in accordance with the EAP Presentation at Day 2 of the 2008 Dam Safety Seminars. Some items that should be added include; list of roles and responsibilities, guidance for determining emergency levels, flow chart of who is to be notified during emergencies, emergency service contacts, list of persons responsible for review and maintenance of the EAP, an event log, a dam emergency situation report, list of resources for equipment, labor and materials that are available, location and vicinity maps, and pertinent data for the dam and reservoir.	**Partially complete.** The most recent EAP available for review is dated July 2022 which included several updates since this 2007 recommendation. The EAP should be regularly updated as required by State of Hawaii statues. Priority 2, Recommendation 5 includes a few minor improvements to the EAP to be incorporated at the next regular update.
Priority 1, Recommendation 10. Develop an operations and maintenance manual for the dam.	**Partially complete.** An O&M Manual was developed for the site in 2018 and is on file with the DLNR. Priority 2, Recommendation 4 provides several recommendations for updates to the manual.
Priority 1, Recommendation 11. Maintain a log of visits, operations, and maintenance at the dam.	**Complete.** The Dam Operator maintains a daily log of operations, instrument readings, and maintenance activities. The log is submitted to the DLNR monthly.
Priority 2, Recommendation 1. Add riprap to the upstream slope and to the spillway crest, approach and outlet channels. Riprap should be designed by an engineer to withstand wave erosion or velocities as appropriate.	**Incomplete.** Riprap or other revetment has not been provided on the upstream embankment slope and/or emergency spillway crest. This recommendation is re-issued as Priority 2, Recommendation 2.
Priority 2, Recommendation 2. Add numbers to the staff gage to monitor the pool level.	**Complete.** Staff gage numbers in quarter-foot increments are shown on the staff gage. However, vegetation makes it difficult to read lower elevations. See Priority 2, Recommendation 3.
Priority 2, Recommendation 3. Regrade the crest to remove the ruts.	**Complete.** Re-grading of the crest to remove existing ruts and place a gravel cover was reported to have been partially

Recommendations from 2009 Phase I Inspection Review and 2015 DLNR Inspection	Status
	completed as part of regular maintenance activities. Limited rutting was observed during the 2021 Phase 1 inspection. However, depressions that resulted from removal of large vegetation/trees were observed on the site and require backfill/monitoring. See Priority 1, Recommendation 4).
Priority 1, DLNR 2015 Inspection. Repair the gate and tunnel at the Mid-level outlet structure (Outlet #2).	**Partially complete.** The gate and tunnel were removed in 2018 and replaced with an excavated open channel and twin 24-inch diameter HDPE culverts in 2020. A rock check structure within the approach to the culverts maintains the reservoir pool elevation and is uncontrolled. The earthen channel has steep side slopes and is unlined. Elevations and capacity of the modified configuration is unknown. This recommendation is re-issued as Priority 1, Recommendation 3.

2.8 Geology

The island of Kauai is the fourth largest of the eight major islands of the Hawaiian Archipelago and covers approximately 550 square miles. Kauai is also the oldest of the major islands with the oldest rock dating 5.72 million years ago. The bulk of Kauai was formed by discharge of basaltic lavas (which make up the Waimea Canyon volcanic series) from an area near the current center of the island. Following depositions of the Waimea Canyon series, the island has been subject to a long period of intense weathering, which has both chemically and physically altered the rock forming the island, creating a very deep soil profile and the large erosional features of the island. Beginning approximately 1.4 million years ago, the Koloa phase of volcanic activity occurred on the island and continued until the late Pleistocene or early Holocene era. (Stearns 1985 and MacDonald et al. 1960).

Kalihiwai Reservoir is situated in the northeastern quarter of the island of Kauai in the Hanalei District. The geologic deposits underlying the reservoir site consist of basalt flows of the Koloa series. These flows were discharged from vents in the area. Very deep soils (generally extending to depths of over 100 feet) have been developed by the in-situ weathering of the basaltic lava flows. Weathering of basaltic igneous rock under the rainfall and temperature conditions common to much of Kauai has resulted in leaching of silica and silicates from the soil and rock, leaving behind deposits rich in iron and aluminum oxides and giving the soil its characteristic red color.

The Natural Resource Conservation Service (NRCS) has mapped soils in the area as Pooku silty clay. Thus, the embankment is assumed to be founded on silty clay.

2.9 Seismicity

A site-specific seismic hazard study has not been performed for the site. However, Gannett Fleming performed a screening level seismic hazard analysis in support of determining seismic inputs for a simplified liquefaction triggering assessment for the dam. Results of the peak ground accelerations from the Gannett Fleming study are presented in Table 2-3.

The USGS Earthquake Hazards Program provides estimated seismic loading for the Hawaiian Islands in the Hawaii 1998 version (v1.0x). The USGS released a new seismic model for the Hawaiian islands in December of 2021 that is not yet incorporated into the earthquake hazards program, but the data for the updated seismic characterization was available at the time of this report (Rukstales et al. 2021). Table 2-3 summarizes the estimated peak ground acceleration (PGA) for various return periods at the dam site based on the new seismic model released in December of 2021. The PGA values presented in the table

are bedrock accelerations based on the National Earthquake Hazards Reduction Program (NEHRP) Site Class B/C boundary, which is associated with a shear wave velocity averaged over the top 30 meters of ground (V_{s30}) of 760 meters per second. Magnitude (M) deaggregation data is not yet available for the 2021 seismic model. A state-wide seismic hazard assessment (SHA) is currently underway for Hawaii, and it is expected to be published before the end of 2022. This updated SHA should be used for seismic characterization as discussed in Section 2.10.2.

Table 2-3: Summary of Peak Ground Accelerations

Return Period (years)	PGA (g)[1]	PGA Site Class B/C from USGS NSHMP (g)[2]	PGA Site Class E from NGA-W2 Amplification Factor (NEHRP Amplification Factor)[2]
2,475	0.07	0.09	0.16-0.32 (0.24)
5,000	0.11	0.13	0.22-0.39 (0.30)
10,000	0.16	0.18	0.27-0.47 (0.34)

1. Rukstales et al., 2021
2. Gannett Fleming, 2021

2.10 Supporting Analyses

The following references were reviewed in the development of this report:

- Flow Simulation, Reservoir Dam-Break Flooding (October 2006)
- AquaTechnix, Kalihiwai Reservoir Bathymetry Study (2009)
- Kleinfelder, Phase I Visual Inspection Report (April 2009)
- ARCADIS, Seepage and Stability Evaluation of Northeast Embankment (March 2015)
- Pacific Disaster Center, Individual Assessment Report, Kalihiwai Reservoir (April 2016)
- Gannett Fleming, Kalihiwai Reservoir Dam Rehabilitation Draft Final Design Report (March 2021)

Technical reviews were performed of the analyses on record with the DLNR for the site as part of this 2021 Phase 1 dam safety review. Available analyses included slope stability evaluations (ARCADIS, 2015; Gannett Fleming, 2021), hydrology and hydraulic evaluations (Gannett Fleming 2020), bathymetry evaluations (AquaTechnix, 2009) and dam breach modelling (Flow Simulation, 2006; Pacific Disaster Center, 2016). Alternatives for repairing, replacing, or removing the dam are currently in progress. The alternative study included geotechnical field investigations, hydrologic and geotechnical analyses and preliminary design (Gannett Fleming, 2020 and 2021). This Phase 1 dam safety review included review of data and analyses relevant to the existing condition of the dam. A technical review of proposed design or modifications, and analyses related to modification design, is beyond the scope of this Phase 1 dam safety review.

AECOM reviewed analyses, which included a review of the methodology, parameters, and general reasonableness of results, but did not include a detailed check of the calculations. Review summaries of the available hydrology/hydraulic and slope stability evaluations relevant to the existing condition of the dam are presented below.

2.10.1 Hydrology and Hydraulics

The contributing watershed area for Kalihiwai Reservoir is approximately 0.32 square miles based on USGS digital elevation model data. The estimated 24-hour probable maximum precipitation (PMP) depth was previously estimated to be 49 inches, and the estimated 100-year, 24-hour precipitation depth of 19 inches for this watershed (Kleinfelder, 2009).

The reservoir has a reported history of storm events that have exceeded the conveyance capacity of the spillway leading to overtopping of the embankment, including once in the 1970's and again in April 2018 during record setting rainfall. Prior to the April 2018 flood event, Kalihiwai Reservoir had two gated outlets. Outlet #1 feeds into a pipe system and ultimately provides water to a downstream fire suppression system. Outlet #2 (mid-level outlet) discharges downstream of the embankment and ultimately into the Kalihiwai River. During the April 2018 overtopping event, emergency intervention was taken to remove the gate structure and excavate a bypass channel at the location of outlet #2. This action increased the overall discharge capacity out of the reservoir.

Hydrology and hydraulics evaluations were completed as part of the dam rehabilitation design performed by Gannett Fleming (Gannett Fleming, 2021). The DLNR Guidelines (1992) and HAR §13-190 (2012) provide guidance on the inflow design flood (IDF) that spillways should safely pass based on the hazard potential and size classification of the dam, as well as freeboard requirements during the IDF. For Kalihiwai Reservoir, which is classified as a HIGH hazard potential, SMALL size dam, the IDF is the Probable Maximum Flood (PMF). The 2020 Gannett Fleming study analyzed the 24-hour duration PMF event and the 100-year frequency, 24-hour duration storm events for comparison. The peak 24-hour duration PMF inflow to the reservoir is 3,624 cubic feet per second (cfs) and the peak 100-year frequency, 24-hour duration inflow is 1,386 cfs.

The reservoir area-capacity curve, spillway discharge curve, and maximum outlet rating curve that were developed for reservoir routing evaluations are provided in the 2021 Gannett Fleming rehabilitation design report.

Hydrologic and hydraulic evaluations were performed in 2020 by Gannett Fleming as part of preliminary dam and spillway rehabilitation design for Kalihiwai Reservoir. The hydrologic analysis was performed using HEC-HMS version 4.3 software and following procedures outlined in National Engineering Handbook Part 630.

Pertinent data was summarized from the 2020 Gannett Fleming hydrologic evaluations as shown in Table 2-4.

Table 2-4: Hydrologic and Hydraulic Evaluation Results

Storm Event	Scenario	Peak Inflow (cfs)	Peak Outflow (cfs)	Peak Reservoir Elevation (ft)	Freeboard (ft)
PMF (24-hour Duration PMP)	Existing	3,624	2,412	393.9	1.1
100-year Event (24-hour Duration storm)	Existing	1,386	712	389.2	5.8

Gannett Fleming (Gannett Fleming, 2021) also performed wave runup and wind setup calculations for the reservoir. The analysis indicates that a minimum of 2.52 feet of freeboard should be provided.

The hydrologic evaluations undertaken appear to be reasonable for the reservoir and consistent with current accepted engineering best practices.

Based on review of the hydrologic and hydraulic analyses, the existing spillway does not have the capacity to pass the IDF. Spillway modifications are required to pass the IDF (Priority 1 Recommendation 1).

2.10.2 Slope Stability

Gannett Fleming completed slope stability evaluations for the existing Kalihiwai Reservoir embankment as part of developing rehabilitation designs for the dam embankment to verify compliance with HAR §13-190. The slope stability analyses are summarized below:

- A subsurface exploration was conducted by Gannett Fleming in January 2020. The exploration program included borehole drilling and sampling through the dam embankment and foundation, monitoring well installation, field permeability testing, and soil laboratory testing. Four vertical borings (GF-1, and GF-3 through GF-5) were drilled by Geolabs, Inc. between January 9 and January 16, 2020 at different locations of the dam embankment, and eight test pits (TP-1 through TP-8) were excavated on January 8, 2020. Open standpipe monitoring wells were installed in borings GF-3 and GF-5 to monitor groundwater levels in the dam embankment and to perform falling head tests.
- Laboratory testing of soil samples collected during the subsurface exploration was completed by Geolabs, Inc. located in Honolulu, Hawaii, and included particle size analysis, water content, unit weight, Atterberg limits, soil dispersion test, standard Proctor, and consolidated undrained triaxial shear strength testing.
- The stratigraphy of the dam embankment and its foundation was determined in the vicinity of borings GF-4 and GF-5 since these borings were drilled in the east side of the dam, where the existing embankment exhibits its maximum height. Soil samples indicate the embankment and foundation soils are similar in color and texture making it difficult to identify the embankment-foundation contact.
  - The upper stratum includes the top portion of the existing dam embankment materials. This stratum is comprised by elastic silt (MH) and silty sand (SM) of high plasticity, with varying gravel content. The Plasticity Index (PI) of the soils ranged from 24 to 37. The SPT N-values ranged from 0 (weight of hammer) to 4 blows per foot (bpf), with an average of 2 bpf indicating that the material is very soft to soft.
  - The middle layer is comprised by non-plastic sandy silt (ML) and non-plastic fine silty sand (SM) with gravel, occasionally weathered. The SPT N-values varied from 1 to 8 bpf, with an average of 4 bpf indicating that material is very loose to loose. It was judged that the embankment-foundation contact is at an indeterminate elevation within this zone.
  - The bottom foundation layer investigated was comprised by elastic silt (MH) and fat clay (CH) with little to no sand. One sample of silty sand (SM) with a PI of 30 was identified in GF-5. In general, the PI of the soils ranged from 9 to 56, and the SPT N-values ranged from 3 to 20 bpf, with an average of 10 bpf. The SPT N-values indicate the materials range from soft to very stiff. Dispersion tests indicate that these soils are non-dispersive.
  - No bedrock was encountered to the depths investigated during the geotechnical investigations (down to elevation 346).
- Shear strengths were estimated based on laboratory shear strength testing, empirical correlations with blow count data, and published values for similar materials. Piezometric conditions were estimated based on seepage analyses and water level readings in wells.
- Slope stability analyses were performed to determine the factor of safety of the dam embankment slopes for current conditions. Long-term steady state and rapid drawdown conditions were analyzed for the downstream and upstream slopes, respectively, of the current dam embankment at the steepest section (Sta. 10+34, current station 1+46). Post-earthquake analysis of the existing embankment was not performed. Slope stability was analyzed using SLOPE/W Version 10.2.0.

Table 2-5: Existing Dam Embankment Slope Stability

Analysis Conditions	Factor of Safety	
	Required Minimum[1]	STA 1+46 Section
Long Term Steady State - Downstream	1.5	Global: 1.4 Upper slope: 1.0
Rapid Drawdown - Upstream	1.3	1.6

1. U.S. Army Corps of Engineers (USACE). Slope Stability, EM 1110-2-1902. 2003 as referenced in HAR §13-190.

The results indicate that the downstream slope does not meet minimum safety factor criterion for long-term steady state conditions, while the current embankment upstream slope meets minimum factor of safety for rapid drawdown conditions. HAR §13-190 also requires seismic analysis, which have not been performed for the existing embankment. Liquefaction analyses performed in support of potential embankment rehabilitation indicate portions of the embankment or foundation may lose strength as a result of seismic loadings analyzed. Therefore, post-earthquake stability of the existing embankment should also be performed. In addition, only the maximum embankment section was analyzed. Other sections of the embankment alignment should also be evaluated that may have a more critical combination of steep slopes and weak layers.

3. Site Inspection

A site inspection was performed on the morning of August 4, 2021. The weather conditions during the visit were overcast with drizzling rain. Table 3-1 lists the participants at the site inspection. The reservoir is typically operated between gage height 5.5 and 7.5 feet based on monthly logs. At the time of the inspection, the reservoir pool level was reported to be at approximately gage height 7 feet, but this could not be confirmed with the staff gage located within the reservoir near the right abutment due to the lower section of the gage being obscured with vegetation (Photo B-42). In addition, it was reported that the automated digital staff gage was reading approximately 18 inches lower than the staff gage (5.5 feet). The reservoir level appeared to be less than 6 inches above the invert of mid-level outlet HDPE conduits.

Visible portions of the reservoir, embankment dam, spillway, and outlet works were inspected during the site visit. Photos from the inspection are provided in Appendix B. The inspection checklist is provided in Appendix C. A site plan showing the photo locations is presented on Figure 5. This section discusses the physical condition and general observations of the dam and its appurtenant structures.

The recommendations identified below related to the site inspection (Priority 1, Recommendations 1, 3 through 5 and Priority 2, Recommendations 2, 4 and 6) are included in Section 4.3.

Table 3-1: August 4, 2021 Site Inspection Participants

Name	Organization
Jennifer Williams, PE	AECOM
Christina Bennetts, PE	AECOM
Noah Wong, PE	AECOM
Carty Chang, PE	DNLR
Kristen Akamine	DLNR
Jesse Colandrea, PE	DLNR
Edwin Matsuda, PE	DLNR
Tripp McCallister	Porter Irrigation (Operator)
Jack Gushiken	Porter Irrigation (Former Operator)

Makaala Kaaumoana	KRCA
Maggie Lea	KRCA

3.1 Embankment Dam

The embankment dam was observed by walking the upstream slope above the reservoir level, the embankment crest, the downstream slope and toe, and the abutments.

Approximately 10 to 13 vertical feet of the upstream slope was visible above waterline at the time of the inspection. The visible portion of the upstream slope was grass covered and was in satisfactory condition. Photos B-3 through B-10 show the upstream embankment slope. The following observations of the upstream slope were noted during the inspection:

- Average slope was about 2H:1V.
- No signs of sinkholes, slumps, depressions, or cracks were observed.
- No riprap armoring is present on the upstream slope. However, no signs of wave-induced erosion were visible.
- Vegetation on the upstream slope of the right embankment segment had recently been cut with a flail mower, which left a cover of mulched grass. The loose mulched grass may have obscured smaller depressions or cracks. (Photo B-3 through B-6).
- A thick grass cover was present on the upper portion of the upstream slope of the left embankment segment making visual inspection on those portions of the slope difficult (Photo B-6 through B-10). The lower portion of the upstream slope (along and below the access road) has been mowed with areas of bare earth. *It is recommended that the vegetation maintenance of the upstream embankment slope continue to be improved (Priority 1, Recommendation 4).*

The embankment crest consists of a graveled access road and was in fair condition. Photos B-11 through B-14 show the embankment crest. Although portions of the crest were grass covered with shallow rutting that will need periodic maintenance to maintain a uniform surface, the current condition did not warrant recommended corrective action, with the exception noted below. The following observations of the embankment crest were noted during the inspection:

- The crest width is approximately 15-30 feet, which is wider than the minimum crest width required by HAR §13-190 (2012). The crest consists of an approximately 15-foot-wide single lane, graveled access road with grass shoulders spanning the crest.
- The crest appeared mostly uniform with minor isolated ruts. No cracking or signs of instability were noted. The crest and crest shoulders appeared in good alignment.
- There was a depression noted along the upstream shoulder of the crest near the right abutment (right embankment segment). The depression measured approximately 5 feet in diameter and 18 inches deep (Photo B-12). The depression was reportedly a result of brush removal that had not been backfilled. *It is recommended to backfill and monitor existing depressions due to tree removal along the embankment crest and slope for changing conditions (Priority 1, Recommendation 4c).*

The downstream embankment slope varies from approximately 0.6H:1V to 2H:1V from the dam crest to the toe, however, there were portions of the downstream slope with were near vertical, most prominently along the upper portion of the left embankment downstream slope. The upper portion of the downstream slope is primarily grass covered with varying types and amounts of vegetation cover including tall grasses, bushes, shrubs, and tree stumps. Some portions of the downstream slope were covered with a turf reinforcement matting. The downstream slope was in fair condition. Photos B-16 through B-29 show the downstream slope and toe area. The following observations of the downstream slope were noted during the inspection:

- Portions of the downstream embankment slope (right embankment segment) have been covered with a erosion control mat that has been exposed in some locations. The mat is not keyed in and appears to be in fair condition. It is understood that the mat was placed following some localized regrading and fill placement along the right embankment to repair slumping and erosion that occurred following the 2018 overtopping event. The materials and methods used to regrade and compact the slope backfill are unknown.
- Portions of the downstream embankment slope are steeper than 2.5H:1V and is therefore steeper than the steepest slope allowed by HAR §13-190 (DLNR 2012). Slope stability analyses recently conducted (Gannett Fleming, 2021) indicate that embankment modifications are required in order meet minimum stability FOS.
- While it is recognized that vegetation maintenance has drastically improved along the downstream slope in the last 10 years, there were still isolated areas of large shrubs, bushes, and tree stumps observed, primarily on the downstream slope near the dogleg in the alignment, (Photos B-16 through B-18) that made visual inspection and observation difficult. *It is recommended that the vegetation maintenance of the downstream embankment slope continue to be improved (Priority 1, Recommendation 4).*
- Ponded water and potential seepage were noted at the downstream toe of the embankment. This water is generally measured through a flume and visually monitored. The ponded water was discolored, but no “bubbling” or signs of active seepage or sediment transport was visually detected. *It is recommended that existing seepage areas at the toe of the embankment should be monitored regularly for changing conditions such as increase in flows, muddy flows, and turbidity or sediment in the discharge. Seepage should be kept clear of vegetation and regularly monitored as part of the routine inspections for developing changes such as increase in seepage flow, cloudy or muddy seepage flow, or discharge of soil particles. Observations made during inspections should be noted on the daily and monthly activity logs, as appropriate. Reservoir level should always be noted at the time of the observations. Consideration should be given to using photographs at set vantage points for visual monitoring of changes in seepage during monthly inspections. In addition, the source of ponded water downstream of the toe should be investigated. The installation of a seepage filter and collection system in the embankment should be considered (Priority 1, Recommendation 5).*

The embankment abutments were in satisfactory condition (Photos B-22, B-23, B-29, B-32, B-33, B-34 and B-36). The left side of the embankment abuts with the mid-level outlet (Photo B-33 and B-34). The right abutment ties into the natural surrounding ground (B-22 and B-23). The following observations of the abutments were noted during the inspection:

- The abutments are well-maintained and substantially free of vegetation making visual inspection and observation feasible.

3.2 Spillway

The spillway is located left of the mid-level outlet in native ground and consists of an approximately 50-foot-wide uncontrolled earthen trapezoidal-shaped control section, that narrows to a 14-foot-wide trapezoidal shaped earthen discharge channel. The spillway channel is about 330 feet long, and it narrows in the lower portion of the channel before discharging to the Kalihiwai River. Photos B-36 to B-40 show the condition of the spillway. The physical condition of the spillway appeared in satisfactory condition. It is apparent regular vegetation control and erosion monitoring is required to maintain a satisfactory condition. *Capacity of the spillway is inadequate to pass the IDF and therefore requires modification in accordance with Hawaii Administrative Rules (HAR) §13-190 [specifically HAR 13-190.1-4(c and d)] (Priority 1, Recommendation 1)*. The erosion and headcutting potential of the spillway is unknown and should be evaluated. The following observations of the spillway were noted during the inspection:

- The spillway approach channel was grass-covered and appeared well maintained and free of obstructing vegetation (Photo B-36).

- The spillway discharge channel was generally bare earth along the invert with brush and trees along the side slopes. The channel appeared generally well maintained and free of obstructing vegetation (Photo B-37 to B-39).
- There was a drop-off along the discharge channel that did not allow inspection further downstream (Photo B-40).

3.3 Outlet Works

3.3.1 Low-level Outlet

Photo B-29 shows the low-level outlet valve located at the downstream embankment toe near the right abutment. The intake was submerged and not visible. The valves located at the downstream embankment have not been operated since the 1970s (based on recollection of dam operators) and remain in the open position. All operation of the low level outlet occurs at the downstream plantation, which was not visited during the 2021 Phase 1 inspection. The downstream valves are reportedly operated periodically without issue. There is no known internal inspection of the conduit that extends through the embankment at the right abutment. No active embankment/foundation seepage was observed in the vicinity of the outlet valves. The low-level outlet was in fair condition

3.3.2 Mid-level Outlet

A mid-level outlet is located near the left abutment of the dam. The outlet currently consists of two 24-inch diameter HDPE pipes that are uncontrolled. A rock check dam located upstream of the culverts serves as the control structure from the reservoir. Water was flowing through the mid-level outlet during the 2021 Phase I inspection. The two 24-inch HDPE pipes replaced a previously-existing gated 30-inch corrugated metal pipe (CMP) outlet. The elevation of the rock check dam and 24-inch HDPE pipe inverts as well as the relative hydraulic capacity of the outlet is unknown. *It is recommended that additional information (control elevation and pipe invert elevations) about the mid-level outlet be collected through a survey of the area (Priority 1, Recommendation 3).* Photos B-30 to B-35 show the mid-level outlet and discharge channel. The mid-level outlet was in fair condition. The following observations of the mid-level outlet were noted during the inspection:

- Entrance to the outlet was generally unobstructed upstream of the rock check dam.
- The HDPE pipes appeared free from obstruction. The right HDPE pipe appears to have experienced some deflection but appears currently functional with no signs of collapse along its alignment.
- The unlined outlet channel was in fair condition. Minor sloughing has occurred along the channel, primarily along the left channel slope. *It is recommended to assess the mid-level outlet and discharge channel for erosion and scour potential and the need for riprap or other revetment to minimize the potential for erosion, scour and/or headcutting (Priority 2, Recommendation 2).*

3.4 Inlet Works

The inlet works was not inspected during the 2021 Phase I inspection and it was reportedly closed. Therefore the condition of the inlet works is unknown. During the Phase I inspection, it was reported that access to the inlet works structure is limited*. It is recommended to consider obtaining an easement from the property owner on whose land the inlet structure lies to allow unrestricted access for inlet operation (Priority 2, Recommendation 6).*

4. Conclusions and Recommendations

4.1 Overall Condition of the Dam

The overall condition of the dam based on the 2021 Phase I dam safety review is POOR. A condition of POOR is defined as follows: A dam safety deficiency is recognized for loading conditions which may realistically occur. Remedial action is necessary. POOR may also be used when uncertainties exist as to critical analysis parameters which identify a potential dam safety deficiency. Further investigations and studies are necessary.

An overall condition rating of POOR is assigned because there are identified existing dam safety deficiencies which have been documented for loading conditions expected during the life of the structure. Embankment stability evaluations (ARCADIS 2015; Meta Engineering 2017; Gannett Fleming 2021) indicate computed Factors of Safety (FOS) below accepted standards. In addition, the hydraulic capacity of the existing spillway structure is not sufficient to convey the required Inflow Design Flood (IDF). Further, the DLNR issued a “Notice of Deficiency” (NOD) related to the condition of the mid-level outlet (also known as Outlet #2) and invoked a reservoir restriction that the pool be maintained at or below the invert of the mid-level outlet (stated to be gage height 10.2 in the NOD letter [2017]). The discharge capacity of the modified configuration of the mid-level outlet is unknown.

Alternatives for repairing, replacing, or removing the dam are currently in progress. The alternative study included geotechnical field investigations, hydrologic and geotechnical analyses and preliminary design (Gannett Fleming, 2020 and 2021). This Phase 1 dam safety review included review of data and analyses relevant to the existing condition of the dam. A technical review of proposed design or modifications is beyond the scope of this Phase 1 dam safety review. Based on review of the available data and analyses, as well as observations made during the 2021 Phase I Inspection, recommendations were developed (see Section 4.3) for Kalihiwai Reservoir. These recommendations were developed assuming the dam is to remain in service as a HIGH hazard potential dam.

At the time of the 2021 Phase I Inspection, the upstream embankment slope was in fair to satisfactory condition and the downstream embankment slope was in fair condition. The upstream slope was well-maintained and generally clear of woody vegetation. While it is evident that vegetation control has drastically improved in the last 10 years, areas of the downstream slope and the area near the toe seepage collection ditch need additional vegetation control and/or grading to facilitate proper inspection, seepage collection, and access.

The spillway approach channel was in satisfactory condition, was vegetated with grass and some short shrubs, and appeared well maintained. The spillway control section and upper discharge channel were in satisfactory condition and appeared generally unobstructed from vegetation. However, the capacity of the spillway is insufficient to pass the IDF and required upgrades.

The mid-level outlet appears to be in fair to satisfactory condition however the capacity of the existing system is unknown and should be evaluated.

Recommendations related to the overall condition and assessment of the dam are provided in Section 4.3 below.

There appeared to be no immediate threat to the safety of the dam at the time of the inspection under normal loading conditions. No assurance can be made regarding the dam’s condition after this date. Subsequent adverse weather and other factors may affect the dam’s condition.

4.2 Compliance with DLNR Dam Safety Rules

Table 4-1 summarizes the dam’s compliance with the DLNR Dam Safety Rules (i.e., HAR §13-190 [2012] and HRS §179D [2019]) based on review of the available data, observations from the most recent annual visual dam safety inspection completed in 2015, and observations and findings of this 2021 Phase I Inspection.

Table 4-1: Compliance with DLNR Dam Safety Rules

DLNR Requirement	Authority	Compliance
Embankment Slopes Not Steeper than 2.5H:1V	HAR §13-190.1-4	No (1)
Minimum Embankment Crest Width of 10 feet	HAR §13-190.1-4	Yes
Earthen Spillway Constructed in Natural Ground	HAR §13-190.1-4	Yes
Low Level Outlet for Draining Reservoir	HAR §13-190.1-4	Yes
Stability Analysis (significant and high hazard potential)	HAR §13-190.1-4	Yes (2)
Spillway Safely Passes Appropriate IDF	HAR §13-190.1-4	No (3)
Meets Minimum Residual Freeboard during Peak Spillway Flow associated with IDF	HAR §13-190.1-4	No (3)
Operations and Maintenance (O&M) Plan	HAR §13-190.1-40.1	Yes
Inspection and Monitoring Program	HAR §13-190.1-40.1	Yes
Emergency Action Plan (EAP) [including initiation and response]	HAR §13-190.1-42	Yes
Physical Access to Dam Features	HRS §179D-30	Yes
Maintain Records (modifications/improvements, O&M, etc.)	HRS §179D-30	Yes

Notes:

1. The downstream slope varies from 2H:1V to 0.6H:1V. Recent slope stability analyses indicate that the steady-state stability of the downstream slope does not meet current recommended Factor of Safety (FOS) standards and embankment stability modifications have been recommended. Refer to *Priority 1, Recommendation 2.*
2. Refer to Section 2.10.2 for a discussion on the slope stability analyses performed for the embankment dam. A stability analysis performed by Gannett Fleming (2021) resulted in factors of safety less than minimum criteria for the steady-state condition. Refer to *Priority 1, Recommendation 2.*
3. Refer to Section 2.10.1 for a discussion on the hydrologic and hydraulic evaluations performed for the dam site. The current spillway capacity is insufficient to convey the IDF and requires modifications. Refer to *Priority 1, Recommendation 1*.

4.3 Recommendations

Based on review of the available data and analyses, as well as observations made during the site inspection, the following recommendations are provided for Kalihiwai Reservoir:

Priority 1 Recommendations

1. **Spillway Upgrades.** Based on past performance and the analyses summarized in the 2020 hydrologic analysis by Gannett Fleming (Gannett Fleming, 2020), it is understood that the existing spillway has insufficient capacity to pass the Probable Maximum Flood (PMF), which is the required Inflow Design Flood (IDF) for a High Hazard dam. The spillway should be modified to increase its

capacity to safely pass the PMF while maintaining sufficient freeboard in accordance with Hawaii Administrative Rules (HAR) §13-190 [specifically HAR 13-190.1-4(c and d)].

2. **Embankment Slope Stability Analysis and Stabilization.** Based on the analyses presented in the 2020 and 2021 geotechnical evaluations performed by Gannett Fleming (Gannett Fleming, 2020 and 2021), the existing embankment does not meet current stability requirements for a High Hazard dam based on long-term steady-state conditions and requires stabilization modifications. Post-earthquake stability analyses have not been performed for the current embankment configuration and should be evaluated. In addition, only the maximum embankment section was analyzed (Gannett Fleming 2020). Other sections of the embankment alignment should also be evaluated that may have a more critical combination of steep slopes and weak layers. The stabilization design should incorporate a seepage collection system (see also Priority 1 Recommendation 5) and consider incorporating modifications to or abandonment of the irrigation/siphon ditch that runs along the downstream embankment toe.

3. **Mid-Level Outlet (Outlet #2) Modifications.** The HDPE conduits currently installed at the mid-level outlet (also referred to as Outlet #2) should be modified to a more permanent and robust structure with known invert elevation and discharge capacity either as a separate outlet with upstream control or incorporated as part of a spillway modification. In the interim, the elevation and correlated staff gage height of this outlet and the restricted pool level should be confirmed by survey. See also Priority 2 Recommendation 4.

4. **Maintain Proactive Vegetation Maintenance.** Vegetation maintenance has significantly improved since years past. Vegetation maintenance of the upstream and downstream embankment slope (including groins and toe areas), outlet works area, and spillway (including crest section and discharge channel) should continue to be improved. Seepage along the downstream toe continues to be a dam safety concern and proactive maintenance of vegetation is critical for effective monitoring of seepage on and downstream of the embankment.

    a. It is recommended that mowing operations on the embankment slopes use a reel or rotary mower to cut the grass but leave the roots, instead of a flail mower or tiller that can uproot the vegetation. An even grass cover with shallow roots, cut short to allow for inspection, provides some erosion resistance while not leading to deep root systems that could damage the embankment and lead to seepage pathways.

    b. Tree stumps on the embankment slope should be completely removed (i.e., root ball included) to limit preferential seepage pathways along root systems through the embankment and/or foundation and properly backfilled with compacted fill to avoid open depressions within the embankment.

    c. Backfill and monitor existing depressions due to tree removal along the embankment crest and slope for changing conditions.

    d. Continue to remove excessive vegetation and debris from the spillway crest section and discharge channel to allow free flow through the channel.

    e. Maintain short vegetation at the location of the staff gage (or move staff gage to an alternate location not prone to vegetation cover – see also Priority 2 Recommendation 3)

5. **Develop a Plan for Collecting, Measuring and Monitoring Seepage**. Based on past performance, seepage is judged to be a concern when the reservoir is operating with a full normal storage. Existing seepage areas at the toe of the embankment should be monitored regularly for changing conditions such as increase in flows, muddy flows, and turbidity or sediment in the discharge. Seepage should be kept clear of vegetation and regularly monitored as part of the routine inspections for developing changes such as increase in seepage flow, cloudy or muddy seepage flow, or discharge of soil particles. Observations made during inspections should be noted on the daily and monthly activity logs, as appropriate. Reservoir level should always be noted at the time of the observations. Consideration should be given to using photographs at set vantage points for visual monitoring of changes in seepage during monthly inspections. In addition, the source of

ponded water downstream of the toe should be investigated. The installation of a seepage filter and collection system in the embankment should be considered.

Priority 2 Recommendations

1. **Perform Tabletop Training Exercise.** It is understood that a tabletop exercise was performed in 2015. It is recommended a tabletop exercise be performed every 5 years. Perform a tabletop exercise with emergency response personnel to exercise the plan. The objective of the EAP exercise is to familiarize key stake holders with the EAP, provide a training opportunity for those stakeholders, and help identify areas where the EAP could be improved. The EAP exercise should begin with a brief orientation session that includes an overview of the DLNR dam safety program, a brief dam safety overview presentation by the facilitator, and a familiarization site tour of the dam site and key downstream areas of concern.
2. **Evaluate the Erosion/Scour Potential of the Upstream Slope, Spillway, and Mid-Level Outlet (Outlet #2).** An assessment should be made of the spillway crest, approach channel, and discharge channel related to erosion and scour potential and the need for riprap or other revetment to minimize the potential for erosion, scour and/or headcutting. A similar scour evaluation should be performed of the mid-level outlet, currently serving as the control for normal pool, to determine if riprap or other revetment is required for the mid-level outlet channel. A wave-runup and erosion analysis should be performed to evaluate the need for riprap armoring of the upstream slope.
3. **Improve Staff Gage.** Reservoir levels are currently monitored using a staff gage located near the right abutment. Vegetation makes reading the staff gage difficult. Consider moving the staff gage or improve vegetation management to allow accurate readings. The staff gage should also extend to the top of the embankment crest. Maintain calibration between the manual staff gage and the automated digital staff gage. At the time of the 2021 Phase 1 inspection, there was an approximately 18-inch discrepancy between the two gages.
4. **Update O&M Manual.** Update the 2018 O&M Manual as follows:
    a. Document the correlated gage height and elevations of key dam features. Review and update pertinent data listed in the O&M Manual including elevation, correlated staff gage height, and dimensions of key structures for accuracy and consistency with other documents, such as the 2022 EAP (see also Priority 2 Recommendation 6).
    b. There is an apparent discrepancy regarding the staff gage height of the maximum allowed restricted reservoir level (reported as 7 ft, 10.2 ft, and 11.6 ft in various documents and discussions) and which physical feature (e.g. mid-level outlet conduit invert/springline) and elevation to which the restricted-level gage height correlates. Verify accurate staff gage height of the mid-level outlet and the corresponding staff gage height of the restricted reservoir level.
    c. Include a copy of the daily log form in the manual.
    d. Include a map showing locations of known, monitored seepage areas and all instrumentation including flumes, recently installed piezometers, and reservoir gages. The map should be a full-page or sized to be clearly legible.
    e. Include the well installation log of piezometers indicating completion details such zones of anulus backfill and key elevations (top of casing, bottom of well, and screen interval).
    f. Include reading and recording piezometer levels as part of the monthly logs.
    g. Clarify the current responsible dam operator. According to the 2018 O&M Manual, Jack Gushiken currently serves as the Dam Operator and Tripp McCallister serves as the Back-up Operator. However, based on discussions during the Phase 1 inspection, it was stated that Mr. McCallister is the primary operator and Mr. Gushiken is now a volunteer assistant.
    h. Remove reference to maintenance and inspection of the “floodgate/flood gate” which is understood to reference the gate structure previously located at the mid-level outlet (Outlet #2) that was removed in 2018.

i. Include general visual observations of the embankment, mid-level outlet entrance, and spillway entrance under the routine/daily inspections. Monthly inspections should consist of a more thorough walk/inspection of the upstream and downstream slopes, abutment areas, and toe areas.

5. **Update the EAP.** At the time of publication of this Phase 1 Report, the latest EAP is dated July 2022. A few revisions are recommended for the next regular update of the EAP. Spillway and outlet discharge capacity curves and impoundment capacity (storage) curves should be included. It is suggested that the Key Elevations table, which lists both the surveyed Mean Sea Level elevation and staff gage height, be revised for the intake invert of the low-level outlet works to indicate a staff gage height "<0" rather than "0", so as not to confuse the listed elevation of 375.1 as the correlation between staff gage height and MSL elevation (the documented correlated staff gage height 0 is elevation 377.4). Correct the top-of-dam staff gage height in the Key Elevations table. Delete reference to the removed Outlet #2 (mid-level outlet) gate structure throughout the document. Verify by survey any key elevations listed in the table that are noted as being estimated. It is also suggested that the site-specific guide for determining an event level (Section VIII Emergency Detection) be revised to indicate appropriate site-specific thresholds for seepage flow quantities at known seepage locations.

6. **Access to Inlet.** Consider obtaining an easement from the property owner on whose land the inlet structure lies to allow unrestricted access for inlet operation.

7. **Locate Construction Photos**. Original design documents and construction as-built drawings of Kalihiwai Reservoir are reportedly not available. However, the Dam Operator (Mr. Gushiken) indicated he believes there are some limited photos from original construction. If located, these construction photos should be filed with DLNR as they can be very helpful in understanding subsurface conditions of the embankment and foundation.

5. Limitations

In this report, the term "safety" is interpreted to be restricted specifically to major structural and control features in regard to their adequacy against catastrophic failure due to natural or operational events. No consideration is given herein to public safety aspects related to voluntary occupancy or use of reservoir features in such manner as to result in personal mishaps. The contents of this report are presented to satisfy the requirements of a Phase I Inspection as outlined in the DLNR's Guidelines for Safety Inspection of Dams (1992). Reuse of this document for any other purposes, in part or in whole, is at the sole risk of the user.

This report presents observations, conclusions, and recommendations drawn from a review of referenced analyses and data, information provided by the owner, and conditions observed during the site inspection. The purpose of the review and inspection was to assess the safety or adequacy of the dam against catastrophic failure of the major structural elements during normal operations or unusual or extreme events based on visual inspection and information available at the time of the review. Review of the pertinent documents, analyses, and instrumentation data included a review of the methods and assumptions, and not a detailed check of the calculations themselves. The condition assessment presented in this report is based only on visible features/areas of the dam on the day of inspection. This inspection does not relieve the owner/operator from their responsibility to conduct routine inspections, maintenance, repairs, modifications, monitoring, documentation, and/or investigative studies. The conclusions and professional opinions presented herein were developed in accordance with generally accepted engineering principles and practices at the time and location the services were provided. AECOM makes no other warranty, either expressed or implied.

6. References

The following list of references were used for data review and citations in the development of this Phase 1 Inspection report

AquaTechnix, LLC. *Kalihiwai Reservoir Bathymetry Study*. Prepared for Kalihiwai Ridge Community Association, 2009.

ARCADIS, Kalihiwai Reservoir – Seepage and Stability Evaluation of Northeast Embankment. March 2, 2015.

Flow Simulation, LLC. *Final Report, Simulations of Kalihiwai Reservoir Dam-Break Flooding*. Prepared for Kalihiwai Ridge Community Association, October 17, 2006.

Gannett Fleming. *Kalihiwai Reservoir and Reservoir – Hydrologic & Hydraulic Analysis*. Technical Memorandum prepared for Kalihiwai Ridge Community Association. April 2020.

Gannett Fleming. *Kalihiwai Reservoir Dam Rehabilitation Draft Final Design Report, Kalihiwai Reservoir, Kauai, Hawaii, National Inventory of Dams ID: HI00024, Hawaii Dam ID: KA-0024*. Prepared for Kalihiwai Ridge Community Association, March 2021.

Gannett Fleming. *Kalihiwai Reservoir Removal Final Design Report, Kalihiwai Reservoir, Kauai, Hawaii, National Inventory of Dams ID: HI00024, Hawaii Dam ID: KA-0024*. Prepared for Kalihiwai Ridge Community Association, April 2022.

Emergency Action Plan (EAP) for Kalihiwai Reservoir State ID # KA-0024. Kalihiwai, Kauai, Kauai. Revised October 31, 2021.

Kleinfelder. *Phase I Visual Inspection Report Kalihiwai Reservoir, Kalihiwai, Kauai County, Hawaii, NID HI-00024*. Prepared for State of Hawaii Department of Land and Natural Resources (DLNR), April 2009.

Pacific Disaster Center. *Individual Assessment Report - Kalihiwai Reservoir*. Oahu : DLNR, April, 2016..

Rukstales, K.S., Shumway, A.M., and Petersen, M.D., (Rukstales et al.), Data Release for the 2021 Update of the U.S. National Seismic Hazard Model for Hawaii, U.S. Geological Survey data release, https://doi.org/10.5066/P91V4SDT. December 2021.

State of Hawaii, Department of Land and Natural Resources (DLNR), *Guidelines for Safety Inspection of Dams,* Report R92, December 1992.

State of Hawaii, Department of Land and Natural Resources (DLNR), *Hawaii Administrative Rules*, Chapter 13-190.01 “Dams and Reservoirs,” November 2012.

State of Hawaii, Department of Land and Natural Resources (DLNR), *Kalihiwai Reservoir (KA-0024), Dam Safety Inspection Report,* August 8, 2008.

State of Hawaii, Department of Land and Natural Resources (DLNR), *Kalihiwai REservoir (KA-0024), Dam Safety Inspection Report,* July 20, 2010.

State of Hawaii, Department of Land and Natural Resources (DLNR), *Kalihiwai Reservoir (KA-0024), Dam Safety Inspection Report,* May 1, 2012.

State of Hawaii, Department of Land and Natural Resources (DLNR), *Kalihiwai Reservoir (KA-0024), Dam Safety Inspection Report,* April 16, 2014.

State of Hawaii, Department of Land and Natural Resources (DLNR), *Kalihiwai Reservoir (KA-0024), Dam Safety Inspection Report,* January 13, 2015.

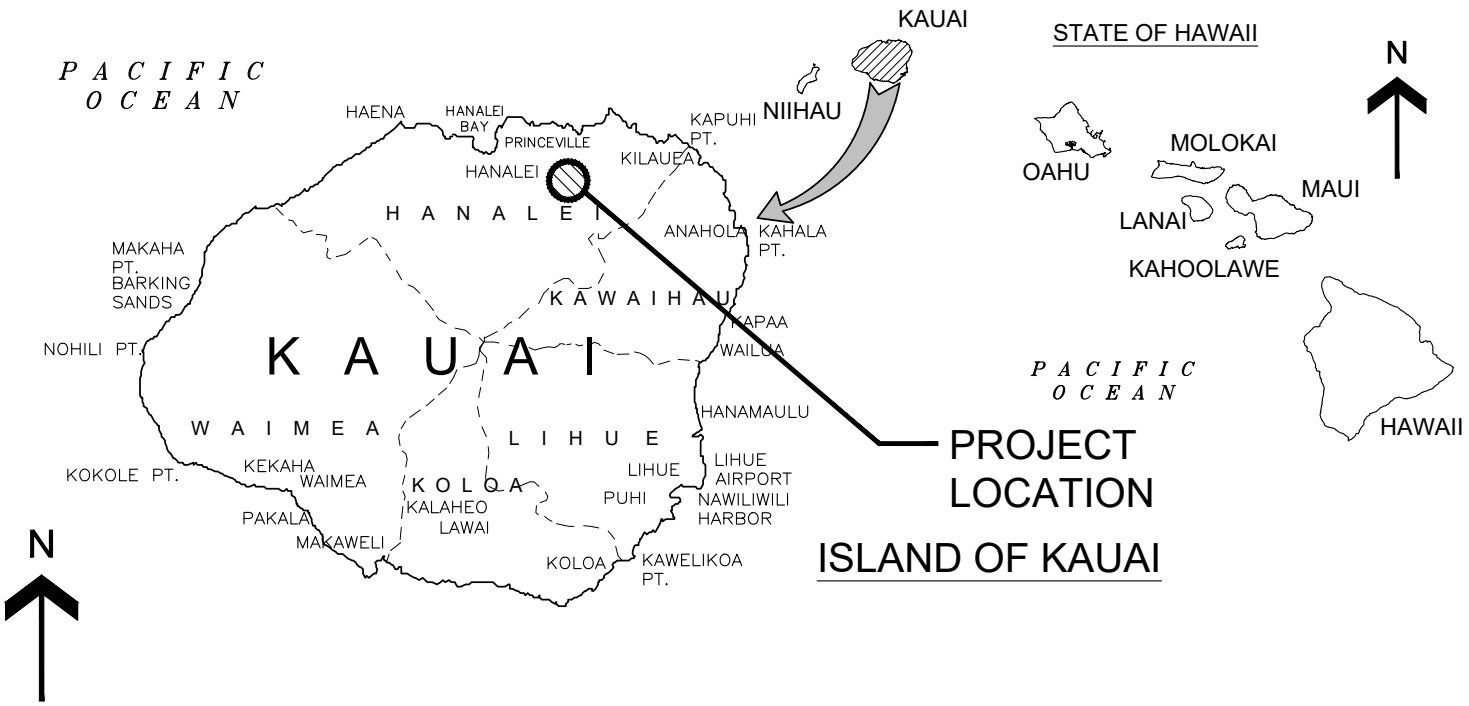
State of Hawaii, Department of Land and Natural Resources (DLNR), *Kalihiwai Reservoir (KA-0024), Kauai, Notice of Dam Safety Deficiency, 2017 Follow Up.* August 24, 2017.

State of Hawaii, Department of Land and Natural Resources (DLNR), *Hawaii Revised Statutes*, Title 12 "Conservation and Resources," 179D "Dams and Reservoirs," 2019.

National Weather Service (NWS). *Rainfall-Frequency Atlas for the Hawaiian Islands*. 1962.

U.S. Geological Survey (USGS), Earthquake Hazards Program, Hawaii 1998 edition (v1.0.x).

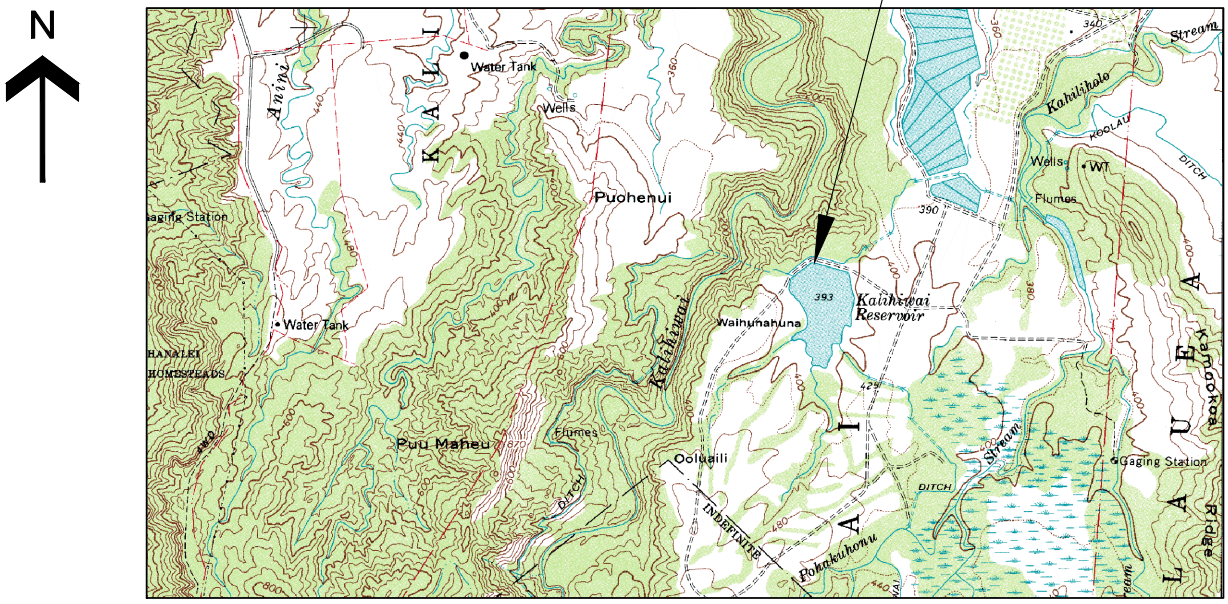
Figures



VICINITY MAP

NOT TO SCALE

PROJECT SITE
KALIHIWAI RESERVOIR



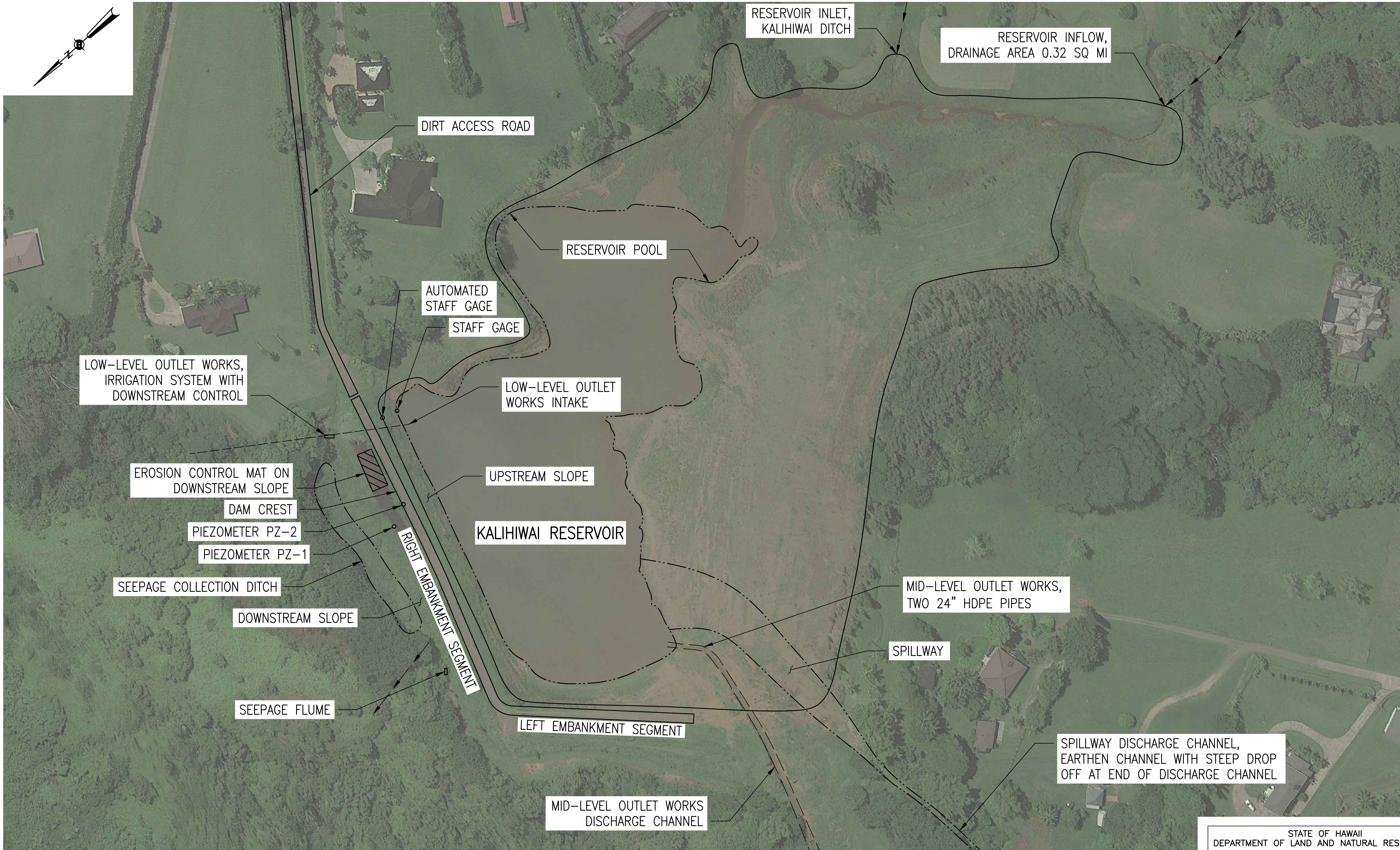
LOCATION MAP

SCALE: 1" = 3000'

NOTE:
1. LOCATION MAP FROM UNITED STATES GEOLOGICAL SURVEY (USGS) QUADRANGLE TOPOGRAPHIC MAPS.

AECOM
1001 BISHOP ST, SUITE 1600, HONOLULU, HAWAII 96813

FIGURE 1
VICINITY AND LOCATION MAPS
DAM INSPECTION REPORT
KALIHIWAI RESERVOIR
PHASE 1 DAM INSPECTION
Kauai, Hawaii
SEPTEMBER 2022



NOTES:

1. NORTH DIRECTION IS APPROXIMATE.
2. SCALE IS APPROXIMATE.
3. AERIAL PHOTO FROM GOOGLE EARTH, MAY 2019.
4. FIGURE SHOULD NOT BE USED AS A REPRESENTATION OF TRUE DIMENSIONS.

OWNER INFORMATION:

OWNER: CG UTILITIES LLC, KALIHIWAI RIDGE COMMUNITY ASSOCIATION
TAX MAP KEY NUMBER: (4) 5-2-022:003

KALIHIWAI RESERVOIR AERIAL PLAN

APPROXIMATE SCALE: 1" = 150'

0 150 300 450
SCALE FEET

STATE OF HAWAII
DEPARTMENT OF LAND AND NATURAL RESOURCES

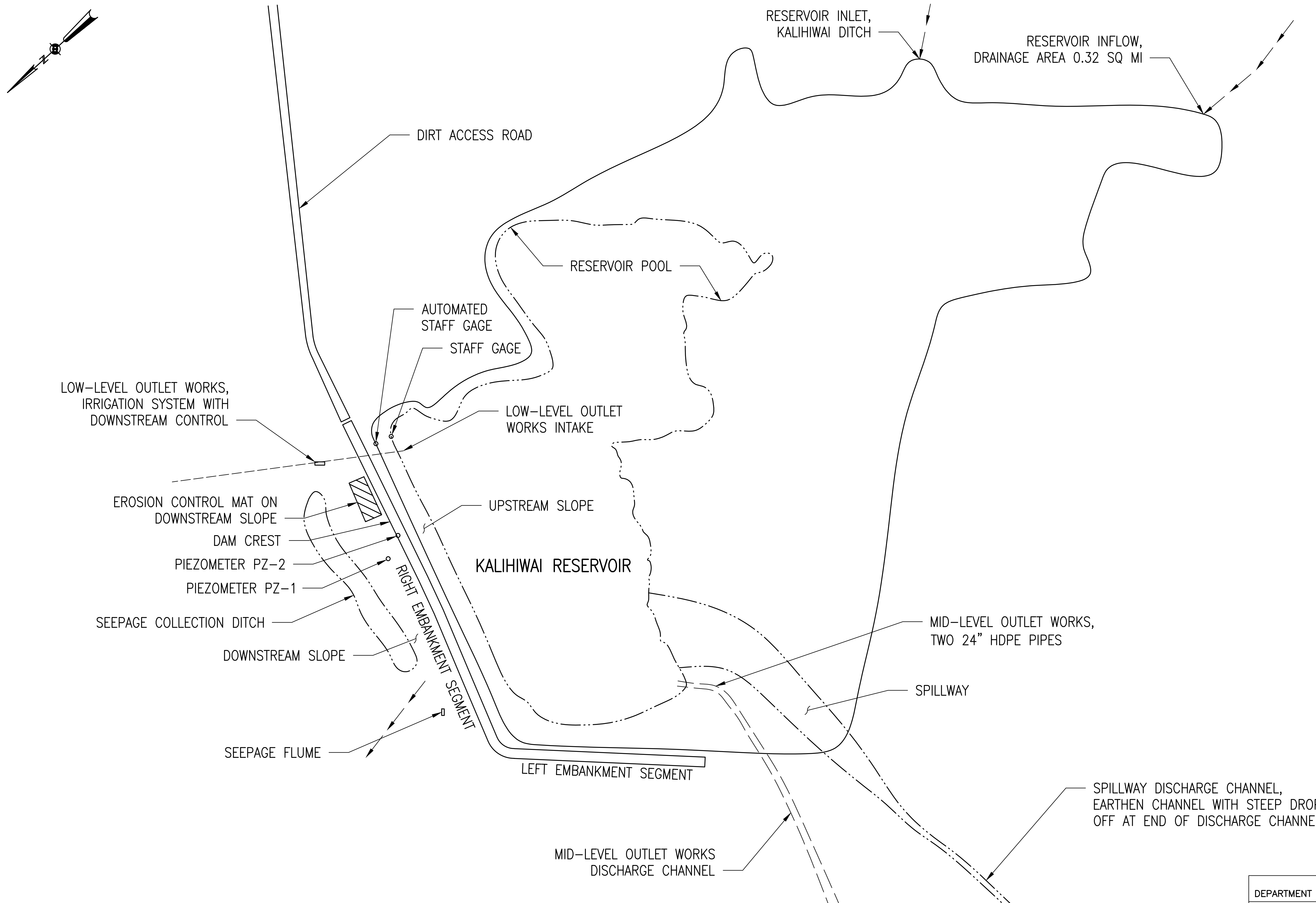
KALIHIWAI RESERVOIR
PHASE 1 DAM INSPECTION
KAUAI, HAWAII

AERIAL PLAN

AECOM
1001 BISHOP ST, SUITE 1600, HONOLULU, HAWAII 96813

FIGURE 2

DATE: SEPTEMBER 2022



NOTES:

1. NORTH DIRECTION IS APPROXIMATE.
2. SCALE IS APPROXIMATE.
3. FIGURE SHOULD NOT BE USED AS A REPRESENTATION OF TRUE DIMENSIONS.

OWNER INFORMATION:

OWNER: CG UTILITIES LLC, KALIHIWAI RIDGE COMMUNITY ASSOCIATION
TAX MAP KEY NUMBER: (4) 5-2-022:003

KALIHIWAI RESERVOIR SITE PLAN

APPROXIMATE SCALE: 1" = 150'

STATE OF HAWAII
DEPARTMENT OF LAND AND NATURAL RESOURCES

KALIHIWAI RESERVOIR
PHASE 1 DAM INSPECTION
KAUAI, HAWAII

SITE PLAN

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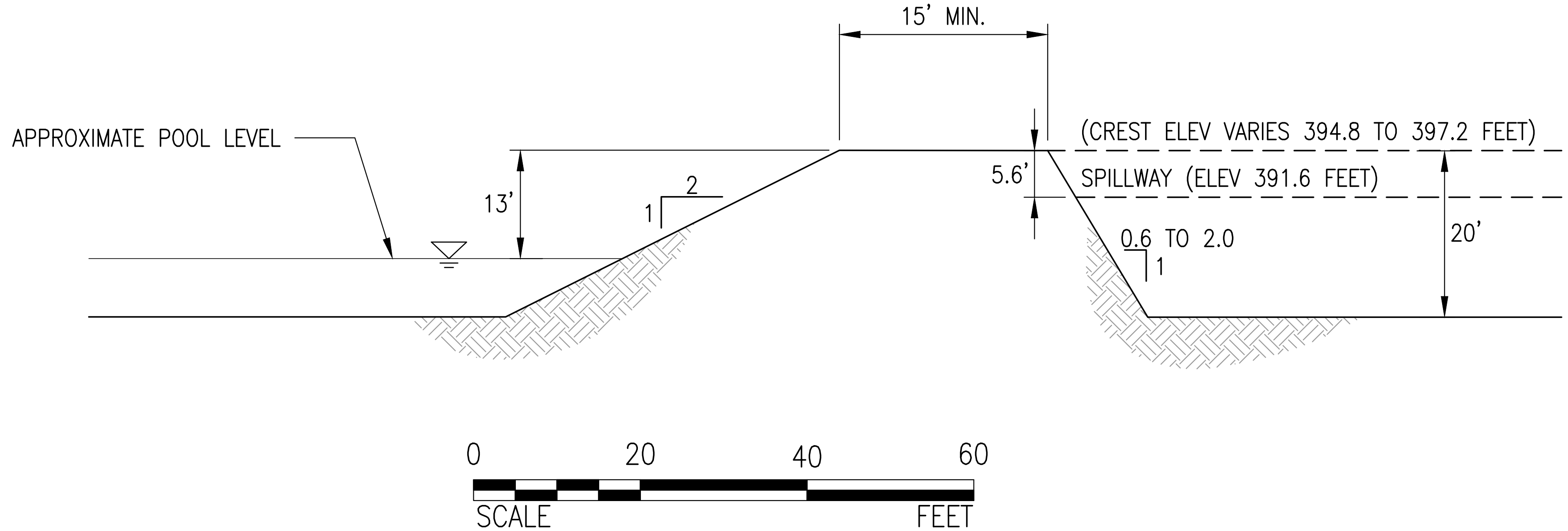
1001 BISHOP ST. SUITE 1600, HONOLULU, HAWAII 96813

FIGURE 3

DATE: SEPTEMBER 2022



KALIHIWAI RESERVOIR CROSS SECTION

APPROXIMATE SCALE: 1" = 20'

STATE OF HAWAII
DEPARTMENT OF LAND AND NATURAL RESOURCES

KALIHIWAI RESERVOIR
PHASE 1 DAM INSPECTION
KAUAI, HAWAII

CROSS SECTION

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1001 BISHOP ST. SUITE 1600, HONOLULU, HAWAII 96813

FIGURE 4

DATE: SEPTEMBER 2022

NOTES:

1. NORTH DIRECTION IS APPROXIMATE.
2. SCALE IS APPROXIMATE.
3. AERIAL PHOTO FROM GOOGLE EARTH, MAY 2019.

Legend:

(12) PHOTO LOCATION AND VIEWING DIRECTION

KALIHIWAI RESERVOIR PHOTO LOCATIONS

APPROXIMATE SCALE: 1" = 150'

0 150 300 450

SCALE FEET

STATE OF HAWAII
DEPARTMENT OF LAND AND NATURAL RESOURCES

KALIHIWAI RESERVOIR
PHASE 1 DAM INSPECTION
KAUAI, HAWAII

PHOTO LOCATIONS

AECOM
1001 BISHOP ST, SUITE 1600, HONOLULU, HAWAII 96813

FIGURE 5

DATE: SEPTEMBER 2022

Appendix A Definitions

Hazard Potential Classification

In accordance with the Hawaii Administrative Rules (HAR) §13-190 and Hawaii Revised Statutes [HRS] §179D), a dam system is classified based on its hazard potential. “Hazard potential” means the possible adverse incremental consequences that result from the release of water or stored contents due to the failure of the dam or reservoir or operational failures of the dam, reservoir, or appurtenances. The hazard potential classification of a dam or reservoir shall not reflect in any way on the current condition of the dam or reservoir and its appurtenant works, including the dam’s or reservoir’s safety, structural integrity, or flood routing capacity. These classifications are as described below:

Low Hazard Potential

“Low hazard” means a dam’s or reservoir’s failure will result in no probable loss of human life and low economic loss or environmental loss, or both. Economic losses are principally limited to the owner’s property.

Significant Hazard Potential

“Significant hazard” means a dam’s or reservoir’s failure will result in no probable loss of human life but can cause major economic loss, environmental damage, disruption of lifeline facilities, or impact other concerns. Significant hazard potential classification dams or reservoirs are often located in predominantly rural or agricultural areas but could be located in areas with population and significant infrastructure.

High Hazard Potential

“High hazard” means a dam’s or reservoir’s failure will result in probable loss of human life.

Size Classification

In accordance with the DLNR Guidelines for Safety Inspections of Dams (1992), a dam system is classified based on its height and potential storage capacity. Size classification may be determined by either storage or height, whichever gives the larger size category.

Category	Storage (acre-feet)	Height (feet)
Small	Between 50 and 1000	Between 25 and 40
Intermediate	Between 1000 and 50000	Between 40 and 100
Large	Greater than 50000	Greater than 100

Overall Condition Classification of Dam

In a system similar to the National Inventory of Dams (NID 2013), when the following terms are capitalized, they denote and shall be used to describe the overall classification of the dam as follows:

SATISFACTORY – No existing or potential dam safety deficiencies are recognized. Acceptable performance is expected under all loading conditions (static, hydrologic, seismic), in accordance with the applicable regulatory criteria or tolerable risk guidelines.

FAIR – No existing dam deficiencies are recognized for normal loading conditions. Rare or extreme hydrologic and/or seismic events may result in a dam safety deficiency. Risk may be in the range to take further action.

POOR – A dam safety deficiency is recognized for loading conditions which may realistically occur. Remedial action is necessary. POOR may also be used when uncertainties exist as to critical analysis

parameters which identify a potential dam safety deficiency. Further investigations and studies are necessary.

UNSATISFACTORY – A dam safety deficiency is recognized that requires immediate or emergency remedial action for problem resolution.

Condition Rating Criteria

In a system similar to the U.S. Department of the Interior, Bureau of Reclamation Safety Evaluation of Existing Dams (SEED 1995), the terms satisfactory, fair, poor, and unsatisfactory are used in a general sense when describing the structural condition and the operational adequacy of the equipment for a dam or reservoir and its appurtenant works during the visual inspection. In addition, the term unknown may be utilized as applicable.

Satisfactory – Expected to fulfill intended function.

Fair – Expected to fulfill intended function, but maintenance or other actions are recommended.

Poor – May not fulfill intended function; maintenance, repairs, or other actions are necessary.

Unsatisfactory – Is not expected to fulfill intended function; repair, replacement, or modification is necessary.

Unknown – Not visible, not accessible, not inspected, or unable to determine the condition rating based on the observation taken.

Recommendation Listing

Recommendations shall be written concisely and identify the specific actions to be taken. The first word in the recommendation should be an action word (i.e., “Prepare”, “Perform”, or “Submit”). The recommendations shall be prioritized and numbered to provide easy reference. Dam Safety recommendations shall be grouped, listed or categorized similar to the U.S. Department of the Interior, Bureau of Reclamation Manual - Directives and Standards - Review/Examination Program for High- and Significant-Hazard Dams (July 1998 FAC 01-07) as follows:

Priority 1 Recommendations: Priority 1 Recommendations involve the correction of severe deficiencies where action is required to ensure the structural safety, operational integrity of a facility, and that may threaten the safety of the dam. May also include studies or investigations required to verify the safety of a dam or reservoir facility.

Priority 2 Recommendations: Priority 2 Recommendations where action is needed or required to prevent or reduce further damage or impair operation and/or improve or enhance the O&M of the facility, that do not appear to threaten the safety of the dam.

Dam Height

Dam Height referenced in this report is assumed to mean the maximum value of dam height, structural height, and hydraulic height as defined below, unless stated otherwise. However, the State of Hawaii, DLNR regulates based on hydraulic height unless the hydraulic height is not available, in which case the dam height is used. As defined below, “the lowest point in the original streambed” is equivalent to the downstream toe of the embankment.

Dam Height – Height of the dam, in feet to the nearest foot, which is defined as the vertical distance between the lowest point on the embankment crest and the lowest point in the original streambed, or the lowest point of the outside limit of the barrier if it is not across a stream channel or watercourse.

Structural Height – Structural height of the dam, in feet to the nearest foot, which is defined as the vertical distance between the lowest point of the excavated foundation to the top of the dam. Top of dam refers to the parapet wall and not the embankment crest.

Hydraulic Height – Hydraulic height of the dam, in feet to the nearest foot, which is defined as the vertical distance between the maximum design water level and the lowest point in the original streambed, or the lowest point of the outside limit of the barrier if it is not across a stream channel or watercourse.

Appendix B Site Inspection Photos

Photo B-1: Reservoir from Embankment Crest

Photo B-2: Reservoir from Embankment Crest

Photo B-3: Cleared Upstream Embankment Slope, Right Embankment Segment (looking left near middle of embankment)

Photo B-4: Cleared Upstream Embankment Slope, Right Embankment Segment (looking right from near middle of embankment)

Photo B-5: Upstream Embankment Slope (looking right from near left end of right embankment segment)

Photo B-6: Upstream Embankment Slope, Left Embankment Segment (looking left from near dog-leg)

Photo B-7: Upstream Embankment Slope, Left Embankment Segment (looking right from near middle of left embankment segment)

Photo B-8: Upstream Embankment Slope, Left Embankment Segment (looking left)

Photo B-9: Upstream Embankment Slope, Left Embankment Segment (looking right from near left abutment)

Photo B-10: Lower Portion of Upstream Embankment Slope, Left Embankment Segment (looking right from near left abutment)

Photo B-11: Embankment Crest (looking left from near right abutment)

Photo B-12: Depression in Dam Crest on Right Embankment Segment (reportedly from brush removal)

Photo B-13: Embankment Crest on Right Embankment Segment (looking left toward dog-leg in alignment)

Photo B-14: Embankment Crest (looking left from near middle of left embankment segment)

Photo B-15: Downstream Left Abutment of Left Embankment Segment (looking left).

Photo B-16: Downstream Embankment Slope, Left Embankment Segment (looking left from near middle of left embankment segment).

Photo B-17: Downstream Embankment Slope, Right Embankment Segment (looking right from near dog-leg)

Photo B-18: Downstream Embankment Slope, Right Embankment Segment (looking left toward dog-leg in embankment)

Photo B-19: Piezometer PZ-1 at Downstream Embankment Slope, Right Embankment Segment (looking right)

Photo B-20: Downstream Embankment Slope, Right Embankment Segment (looking right from near middle of right embankment segment)

Photo B-21: Downstream Embankment Slope and Slope Erosion Protection, Right Embankment Segment (looking left from near right abutment).

Photo B-22: Downstream Slope, Right Embankment Segment (looking right near right abutment).

Photo B-23: Downstream Right Abutment of Right Embankment Segment (looking right).

Photo B-24: Seepage Flume (S-1) at Downstream Toe of Right Embankment Segment (looking upstream and slightly right at left end of right embankment segment).

Photo B-25: Area of Seepage along Downstream Toe of Right Embankment Segment (looking downstream from Seepage Flume)

Photo B-26: Downstream Embankment Toe (cleared for inspection, looking left toward left end of right embankment segment)

Photo B-27: Seepage Collection Ditch along Downstream Toe of Right Embankment Segment (looking toward left end of right embankment segment)

Photo B-28: Seepage Collection Ditch along Downstream Toe of Right Embankment Segment (looking right)

Photo B-29: Low-level Outlet Works (near downstream toe of right abutment)

Photo B-30: Mid-level Outlet Structure (Two 24-inch Diameter HDPE Culverts)

Photo B-31: Mid-level Outlet Channel and Pipes

Photo B-32: Approach to Mid-level Outlet Near Left Abutment (Standing Above Two 24-inch Diameter HDPE Culverts)

Photo B-33: Rock Control Section to Mid-level Outlet Near Left Abutment

Photo B-34: Mid-level Outlet Channel (looking downstream)

Photo B-35: Downstream portion of the mid-level outlet channel (looking upstream)

Photo B-36: Spillway Approach (looking upstream)

Photo B-37: Spillway Channel (looking downstream)

Photo B-38: Spillway Channel (Transition to narrow section, looking upstream)

Photo B-39: Spillway Channel (narrow channel section, looking upstream)

Photo B-40: Spillway Channel (Transition to Steep Section, looking downstream)

Photo B-41: Digital Reservoir Gage (upstream shoulder of embankment crest near right abutment of right embankment segment)

Photo B-42: Reservoir and Staff Gage

Appendix C Site Inspection Checklist

Dam ID: KA-0024
Kalihiwai Reservoir

Inspection No:
Date: August 4, 2021

STATE OF HAWAII - DLNR
DAM SAFETY INSPECTION VISIT

Owner Name: **Kalihiwai Ridge Community Association (KRCA)**

Persons present at inspection:	*Affiliation:*
Jennifer Williams	AECOM
Christina Bennetts	AECOM
Noah Wong	AECOM
Tripp McCallister	Porter Irrigation (Operator)
Jack Gushiken	Porter Irrigation (Former Operator)
Makaala Kaaumoana	KRCA
Maggie Lea	KRCA
Carty Chang	DLNR
Kristen Akamine	DLNR
Edwin Matsuda	DLNR
Jesse Colandrea	DLNR

Weather: ☐ Rain previous day ☐ Rainy ☐ Drizzle / Mist ☐ Cloudy/Overcast ☑ Partly Cloudy ☐ Sunny ☐ Dry

Time: Inspection commenced at 8:00 am. Weather conditions were partly cloudy and warm. The temperature was 80°F.

1. Questions for Owner's Representative:

	Yes	No	Unknown	Comments
Modifications / Improvements	☑	☐	☐	Mid-level outlet (Outlet #2) replaced with two 24-inch HDPE culverts, slope stability scarp on downstream slope repaired, Gravel added to crest and graded access road (2020)
Recent Incidents?	☑	☐	☐	Overtopping event in April 2018 causing slope stability scarp on downstream slope.
Emergency Action Plan (last update)	☑	☐	☐	Dated October 31, 2021.
Operation & Maintenance Manual	☑	☐	☐	Dated August 2018. Needs update.
Maintain Insp/Maintenance Logbook	☑	☐	☐	The primary operator Tripp McCallister visits the site twice a week or as needed. The former operator Jack Gushiken visits the site daily and serves as a back-up operator. Maintenance is performed every two months and typically includes controlling vegetation on embankment using an excavator.
Notice of Deficiency	☑	☐	☐	Restricted on August 24, 2017 to the invert of the mid-level outlet, which was stated to be gage height 10.2 feet.
Remediation plan	☑	☐	☐	Gannett Flemming currently performing rehabilitation designs for the dam.

Notes: According to 2022 EAP

	Elevation	**Staff Gage**	**Sensor Gage**
Top of Dam Crest Elev.	**396 ft**	**N/A**	**N/A**
Spillway Invert Elev.	**391.6 ft**	**14.2**	**N/A**
Normal operating level	**387.6 ft**	**10.2**	**N/A**

Outlet invert (Downstream)	**374.5 ft**	**N/A**	**N/A**
CURRENT RESTRICTION Elev.	**387.6 ft**	**10.2**	**N/A**
Water level during inspection	**384.4 ft**	**7 ft**	**N/A**

2. Reservoir:

☑ Satisfactory ☐ Fair ☐ Poor ☐ Unsatisfactory ☐ Unknown

Typical Operation ☐ Spillway always flowing ☐ Kept Empty ☑ Other: Reservoir typically maintained at or below restricted pool.

Physical Staff Gage: Yes Description: Wooden board painted with black numbering located near right abutment (Photo B-42).

Electronic Gage: Yes Data logger make/model: 1.5ft difference between staff gage and automated staff gage

Reservoir is currently operating at or below restricted gage height of 10.2 feet. Reservoir was restricted on August 24, 2017 because of collapse of the mid-level outlet.

Reservoir staff gage does not extend to top of embankment crest.

☑ a. Extend staff gage to embankment crest to monitor and measure elevated reservoir levels.

3. Inflow Works:

☐ Satisfactory ☐ Fair ☐ Poor ☐ Unsatisfactory ☑ Unknown

☑ The inflow works was not inspected

Drainage area: 0.32 square miles

Inflow number 1: Kalihiwai Irrigation Ditch. Reportedly 4ft wide unlined ditch. Inflow controlled by controlled by a wooden slide gate structure located off property and is reportedly closed. Consider obtaining an easement from the property owner on whose land the inlet structure lies to allow unrestricted access for inlet operation. A Parshall flume is reportedly located at the reservoir inlet.

4. Upstream Slope:

☑ Satisfactory ☐ Fair ☐ Poor ☐ Unsatisfactory ☐ Unknown

Typical Slope (+/- H:V): 2H:1V

Slope Protection: ☑ None ☐ Dumped Rock ☐ Fitted Rip Rap ☐ Grouted Rip Rap ☐ Liner ☐ Other:

☐ Defect in Protection: Description: Upstream slope was grass/vegetated covered. Average slope was about 2H:1V. No signs of sinkholes, slumps, depressions, or cracks were observed on upstream slope. Vegetation on the upstream slope of the right embankment segment had recently been cut with a flail mower, which left a cover of mulched grass (Photos B-3 to B-6).

Erosion: ☐ Loose soil w/ little vegetation ☐ Rut (<6") ☐ Gully (>6" deep) ☐ Not Visible ☑ None Observed

Cracks: ☐ Parallel with crest ☐ Perpendicular to crest ☐ Slide visible ☐ Not Visible ☑ None Observed

Sinkholes: ☐ Observed (#; size): ☐ Not Visible ☑ None Observed

Vegetation: ☐ None ☑ Low Ground Cover ☑ Bushes or Tall Grass ☐ Trees # Few ☐ <6" ☑ >6" & <20" ☐ >20"

A thick grass cover was present on the upper portion of the upstream slope of the left embankment segment making visual inspection on those portions of the slope difficult (Photo B-6 through B-10).

Debris from previous vegetation removal obscures slope (Photos B-3 to B-6). The lower portion of the upstream slope (along and below the access road) has been mowed with areas of bare earth.

☑ a. Clear high vegetation and maintain low to enable easy visual inspection.

☐ b. Remove trees from dam embankment, per FEMA manual. Routinely monitor the damaged area for signs of settlement and seepage.

☑ c. Remove debris from previous vegetation removal to allow for adequate visual surveillance of upstream embankment slope.

☐ d.

5. Crest: ☐ Satisfactory ☑ Fair ☐ Poor ☐ Unsatisfactory ☐ Unknown

Approximate Crest Width (+/- ft): 15 to 30 feet (variable)

Access: ☐ None ☐ Walking Path ☑ Roadway, Surface / Width / Usage: 15-foot-wide gravel access road with grass shoulders spanning crest (Photos B-11 through B-14).

Erosion: ☐ Loose soil w/ little vegetation ☑ Rut (<6") ☐ Gully (>6" deep) ☐ Not Visible ☐ None Observed

Cracks: ☐ Parallel with crest ☐ Perpendicular to crest ☐ Slide visible ☐ Not Visible ☑ None Observed

Sinkholes: ☑ Observed (#; size): 1 depression approimxately 5ft diameter, 18in deep ☐ Not Visible ☐ None Observed

Vegetation: ☑ None ☑ Low Ground Cover ☑ Bushes or Tall Grass ☐ Trees #_____ ☐ <6" ☐ >6" & <20" ☐ >20"

Although portions of the crest were grass covered with shallow rutting that will need periodic maintenance to maintain a uniform surface. (Photos B-11 and B-14).

☐ a. Clear high vegetation and maintain low to enable easy visual inspection.

☐ b. Remove trees from dam embankment, per FEMA manual. Routinely monitor the damaged area for signs of settlement and seepage.

☐ c. _____

☐ d. _____

6. Downstream Slope: ☐ Satisfactory ☑ Fair ☐ Poor ☐ Unsatisfactory ☐ Unknown

Typical Slope (+/- H:V): 0.6H:1V to 2H:1V

Slope Protection: ☑ None ☐ Dumped Rock ☐ Fitted Rip Rap ☐ Grouted Rip Rap ☐ Other: _____

☐ Defect in Protection: Description: Downstream slope is grass-covered.

Erosion: ☐ Loose soil w/ little vegetation ☐ Rut (<6") ☐ Gully (>6" deep) ☐ Not Visible ☑ None Observed

Cracks: ☐ Parallel with crest ☐ Perpendicular to crest ☐ Slide visible ☐ Not Visible ☑ None Observed

Sinkholes: ☐ Observed (#; size): _____ ☐ Not Visible ☑ None Observed

Vegetation: ☐ None ☑ Low Ground Cover ☑ Bushes or Tall Grass ☑ Trees # Few ☑ <6" ☐ >6" & <20" ☐ >20"

Seepage: Seep Spot Number 1: Description: _____
☐ Green Vegetation ☐ Wet / Muddy ☑ Ponding Water ☐ Flowing ☐ Not Visible ☑ None Observed
Water Clarity: ☐ Clear ☐ Some particles ☐ Muddy ☐ Other: _____

Seep Spot Number 2: Description: _____
☐ Green Vegetation ☐ Wet / Muddy ☐ Ponding Water ☐ Flowing ☐ Not Visible ☑ None Observed
Water Clarity: ☐ Clear ☐ Some particles ☐ Muddy ☐ Other: _____

Generally well-maintained grass cover. However, few portions of the downstream slope and toe were densely vegetated with taller grass and the toe portion of the right downstream embankment segment was exposed. Debris from previous vegetation removal was also present on the downstream slope. Photos B-16 through B-29 show the downstream slope and toe areas.

Portions of the downstream slope with were near vertical, most prominently along the upper portion of the left embankment downstream slope.

Portions of the downstream embankment slope (right embankment segment) have been covered with a erosion control mat that has been exposed in some locations. The mat is not keyed in and appears to be in fair condition.

There were isolated areas of large shrubs, bushes, and tree stumps observed, primarily on the downstream slope near the dogleg in the alignment

☑ a. Clear high vegetation and maintain low to enable easy visual inspection.

☐ b. Remove trees from dam embankment, per FEMA manual. Routinely monitor the damaged area for signs of settlement and seepage.

☑ c. Seepage/Ponding water was observed. Monitor and conduct further investigation to locate the source of water and extent of any possible hazardous or developing condition.

☑ d. The slope was very steep, further study is required to verify slope stability. Slope stability analyses performed by Gannett Fleming 2021.

☑ e. Remove debris from previous vegetation removal to allow for adequate visual surveillance of downstream embankment slope.

7. Abutment: ☑ Satisfactory ☐ Fair ☐ Poor ☐ Unsatisfactory ☐ Unknown

Erosion: ☐ Loose soil w/ little vegetation ☐ Rut (<6") ☐ Gully (>6" deep) ☐ Not Visible ☑ None Observed

Cracks: ☐ Parallel with crest ☐ Perpendicular to crest ☐ Slide visible ☐ Not Visible ☑ None Observed

Vegetation: ☐ None ☑ Low Ground Cover ☐ Bushes or Tall Grass ☐ Trees #_____ ☐ <6" ☐ >6" & <20" ☐ >20"

Seepage: ☐ Description: _____
☐ Green Vegetation ☐ Wet / Muddy ☐ Ponding Water ☐ Flowing ☐ Not Visible ☑ None Observed
Water Clarity: ☐ Clear ☐ Some particles ☐ Muddy ☐ Other: _____

Bare soil in some areas.

☐ a. Clear high vegetation and maintain low to enable easy visual inspection.

☐ b. Remove trees from dam embankment, per FEMA manual. Routinely monitor the damaged area for signs of settlement and seepage.

☐ c. Seepage/Ponding water was observed. Monitor and conduct further investigation to locate the source of water and extent of any possible hazardous or developing condition.

☐ d. _____

☐ e. _____

8. Toe: ☐ Satisfactory ☐ Fair ☑ Poor ☐ Unsatisfactory ☐ Unknown

Vegetation: ☐ None ☑ Low Ground Cover ☑ Bushes or Tall Grass ☑ Trees # Few ☑ <6" ☑ >6" & <20" ☐ >20"

Seepage: Seep Spot Number 1: Description: Seepage Collection Ditch along right embankment downstream slope toe.
☐ Green Vegetation ☑ Wet / Muddy ☑ Ponding Water ☐ Flowing ☐ Not Visible ☐ None Observed
Water Clarity: ☑ Clear ☐ Some particles ☐ Muddy ☐ Other: _____

Seep Spot Number 2: Description: _____
☐ Green Vegetation ☐ Wet / Muddy ☐ Ponding Water ☐ Flowing ☐ Not Visible ☑ None Observed
Water Clarity: ☐ Clear ☐ Some particles ☐ Muddy ☐ Other: _____

Ponded water and potential seepage were noted at the downstream toe of the embankment. This water is generally measured through a flume and visually monitored. The ponded water was discolored, but no "bubbling" or signs of active seepage or sediment transport was visually detected. (See Photos B-24, B-25, B-27 and B-28). Seepage flume shown in Photo B-24. Seepage flow was estimated to be 2gpm at the time of inspection. Seepage was recorded to be 10gpm for the month of June 2021.

☑ a. Clear high vegetation and maintain low to enable easy visual inspection. Remove trees 20 feet from toe.

☐ b. Remove trees from dam embankment, per FEMA manual. Routinely monitor the damaged area for signs of settlement and seepage.

☑ c. Seepage/Ponding water was observed. Monitor and conduct further investigation to locate the source of water and extent of any possible hazardous or developing condition.

☑ d. Based on past performance, seepage is judged to be a concern when the reservoir is operating with a full normal storage. Existing seepage areas at the toe of the embankment should be monitored regularly for changing conditions such as increase in flows, muddy flows, and turbidity or sediment in the discharge. Develop plan for monitoring seepage.

☐ e. _____

9a. Outlet Works #1: Low-Level Outlet ☐ Satisfactory ☑ Fair ☐ Poor ☐ Unsatisfactory ☐ Unknown

Last Video Inspection: No known interior camera inspection of low-level outlet conduit.

Culvert / Pipe:

Size: The low-level outlet consists of a 24-inch diameter line through the embankment into an 18-inch diameter line that T's into two 12-inch diameter lines which flow through filters and back to an 18-inch diameter line (Photo B-29). Valve structure is located at the downstream embankment toe but remains in the open position. Flow is controlled further downstream at an existing plantation.

Culvert: ☐ Concrete ☐ Masonry ☐ Unlined Bare Earth ☐ Other N/A

Pipe: ☐ DIP ☐ Corrugated Metal ☐ PVC ☐ HDPE ☐ Concrete ☑ Other metal.

Control Type: ☐ Gate ☐ Valve ☑ Other butterfly valves.

Location: ☐ Control on Upstream side ☑ Control on Downstream side

Seepage: Description:

☐ Green Vegetation ☐ Wet / Muddy ☐ Ponding Water ☐ Flowing ☐ Not Visible ☑ None Observed

Water Clarity: ☐ Clear ☐ Some particles ☐ Muddy ☐ Other:

Valves located at the downstream embankment have not been operated since the 1970s (based on recollection of dam operators) and remain in the open position. All operation of the low level outlet occurs at the downstream plantation, which was not visited during the 2021 Phase 1 inspection.

No active embankment/foundation seepage was observed in the vicinity of the outlet valves.

☐ a. Downstream outlet under water. Recommend reconfigure so water flows away from outlet and outlet can be inspected / monitored for seepage.

☐ b. Seepage/Ponding water was observed. Conduct further investigation to locate the source of water and extent of any possible hazardous or developing condition.

☐ c. Seepage was observed flowing and particles were observed to be removed by the flow. Take immediate action to stop the loss of soil. Conduct further investigation to determine the underlining cause and take corrective action. Monitor the area. Failures caused by seepage/piping along the outlet conduit are very common and potentially be a dangerous situation.

☐ d. Were not visible due to high grass and bush vegetation. Clear high vegetation and maintain low to enable easy visual inspection.

☑ e. Recommend moving control to upstream side.

☑ f. Recommend conducting outlet video inspection to verify physical condition of the conduit.

9b. Outlet Works #2: Mid-Level Outlet ☐ Satisfactory ☑ Fair ☐ Poor ☐ Unsatisfactory ☐ Unknown

Last Video Inspection: N/A.

Culvert / Pipe:

Size: Mid-level outlet consists of two ungated 24-inch diameter HDPE pipes which discharge to an unlined channel. A rock check dam located upstream of the culverts serves as the control structure from the reservoir. Photos B-30 to B-35 show the mid-level outlet and discharge channel

Culvert: ☐ Concrete ☐ Masonry ☐ Unlined Bare Earth ☐ Other

Pipe: ☐ DIP ☐ Corrugated Metal ☐ PVC ☑ HDPE ☐ Concrete ☐ Other

Control Type: ☐ Gate ☐ Valve ☑ Other Uncontrolled.

Location: ☐ Control on Upstream side ☐ Control on Downstream side

Seepage: Description:

☐ Green Vegetation ☐ Wet / Muddy ☐ Ponding Water ☐ Flowing ☐ Not Visible ☑ None Observed

Water Clarity: ☐ Clear ☐ Some particles ☐ Muddy ☐ Other:

The HDPE pipes appeared free from obstruction. The right HDPE pipe appears to have experienced some deflection but appears currently functional with no signs of collapse along its alignment.

The unlined outlet channel was in fair condition. Minor sloughing has occurred along the channel, primarily along the left channel slope.

☐ a. Downstream outlet under water. Recommend reconfigure so water flows away from outlet and outlet can be inspected / monitored for seepage.

☐ b. Seepage/Ponding water was observed. Conduct further investigation to locate the source of water and extent of any possible hazardous or developing condition.

☐ c. Seepage was observed flowing and particles were observed to be removed by the flow. Take immediate action to stop the loss of soil. Conduct further investigation to determine the underlining cause and take corrective action. Monitor the area. Failures caused by seepage/piping along the outlet conduit are very common and potentially be a dangerous situation.

☐ d. Were not visible due to high grass and bush vegetation. Clear high vegetation and maintain low to enable easy visual inspection.

☐ e. Recommend moving control to upstream side.

☐ f. Recommend conducting outlet video inspection to verify physical condition of the conduit.

☑ g. It is recommended that additional information (control elevation and pipe invert elevations) about the mid-level outlet be collected through a survey of the area.

☑ h. It is recommended to assess the mid-level outlet and discharge channel for erosion and scour potential and the need for riprap or other revetment to minimize the potential for erosion, scour and/or headcutting.

☑ i. The HDPE conduits currently installed at the mid-level outlet should be modified to a more permanent and robust structure with known invert elevation and discharge capacity either as a separate outlet with upstream control or incorporated as part of a spillway modification.

10. Spillway: ☑ Satisfactory ☐ Fair ☐ Poor ☐ Unsatisfactory ☐ Unknown

Dimension: 55ft wide control section. Narrows to approximately 14ft wide along spillway discharge channel. The spillway channel is about 330 feet long, and it narrows in the lower portion of the channel before discharging to the Kalihiwai River.

Photos B-36 to B-40 show the condition of the spillway

Type: ☐ None ☐ Culvert/Pipe ☑ Channel ☐ Other _____

Spillway Protection: ☐ None ☑ Grass ☐ Dumped Rock ☐ Fitted Rip Rap ☐ Grouted Rip Rap ☐ Concrete

☑ Defect in Protection: Description: Spillway approach was mostly grass covered and clear of obstructing vegetation but had Some bare soil areas. Spillway discharge channel was mostly bare soil.

Erosion: ☐ Headcut ☐ Scour / Gully ☑ Not Observed ☐ Other: _____

Vegetation: ☐ None ☑ Low Ground Cover ☐ Bushes or Tall Grass ☐ Trees #__ ☐ <6" ☐ >6" & <20" ☐ >20"

Approach: ☑ Clear ☐ High Veg. ☐ Trees ☐ Other: _____

Downstream channel: ☑ Clear ☐ High Veg. ☐ Trees ☐ Other: _____

Pass IDF: ☐ Yes ☑ No, Overtop ☑ H&H Analyses: Date: April 2020

The existing spillway has insufficient capacity to pass the Probable Maximum Flood (PMF), which is the required Inflow Design Flood (IDF) for a High Hazard dam (Gannett 2020). The spillway should be modified to increase its capacity to safely pass the PMF while maintaining sufficient freeboard in accordance with Hawaii Administrative Rules (HAR) §13-190 [specifically HAR 13-190.1-4(c and d)].

☐ a. Slope protection needs maintenance or repair. Description: _____

☐ b. The spillway approach was blocked. Clear approach.

☐ c. Severe scour erosion was observed which requires maintenance and/or repair.

☐ d. A headcut was observed. Action required to prevent this problem from moving upstream.

☐ e. Trees in or near the spillway channel and approach. Take corrective action to remove the trees and repair the damaged area.

☐ f. Unclear if spillway is adequately sized. Spillway should pass the probable maximum flood. Verify spillway capacity and take corrective action as required.

11. Additional Comments:

1. This inspection sheet is intended to be a supplement to the 2021 Phase I Inspection Report and not a standalone document. Refer to the Phase I Inspection Report for full descriptions of the site assessment.

2. Instrumentation at the dam site includes one reservoir staff gage consisting of wooden boards painted white with black numbering located near right abutment, and an automated staff gage located on the embankment crest near the right abutment. Reservoir water level measured daily by operator. Two piezometers located within the embankment (PZ-1 and PZ-2) that were installed during geotechnical investigations in 2014-2015, however, these are not regularly monitored and it is unknown if they are currently functional. A Parshall flume is located at the reservoir inlet. A seepage flume is located at the downstream toe of the right embankment segment. Two additional open standpipe monitoring wells were installed in borings GF-3 and GF-5 as part of geotechnical investigations in 2020 to monitor groundwater levels in the dam embankment and to perform falling head tests.

3. Reservoir is maintained at or below restricted pool level. Low-level outlet works and mid-level outlet works are kept open.

All regulated dams and reservoirs shall comply with
Hawaii Revised Statures Chapter 179D, titled “Dams and Reservoirs”; and
Hawaii Administrative Rules, Title 13, Chapter 190.1, titled “Dams and Reservoirs”.

Below is a brief listing of the minimum requirements:

Regulatory Requirements	
Requirement	**Authority**
Embankment slopes not steeper than 2.5H:1V	HAR 13-190.1-4
Minimum crest width 10-ft	HAR 13-190.1-4
Spillway in natural ground	HAR 13-190.1-4
Low level outlet for draining reservoir	HAR 13-190.1-4
Stability analysis (High/Significant)	HAR 13-190.1-4
Spillway pass appropriate Inflow Design Flood (H&H)	HAR 13-190.1-4
Meet Freeboard requirements (H&H)	HAR 13-190.1-4
Operations & Maintenance Plan	HAR 13-190.1-40.1
Conduct inspections	HAR 13-190.1-40.1
Emergency Action Plan (including initiation and response)	HAR 13-190.1-42
Physical Access to Dam Features	HRS 179D-30
Maintain records (improvements, O&M, etc.)	HRS 179D-30
Good Standing – Certificate to impound	HRS 179D-30, HAR 13-190.1-50 to 52

All improvements should/may/shall be required to meet additional requirements to be consistent with current standard of practice for Dam Safety.

Appendix D Phase I Inventory Data

Inventory Data	Existing (in database)	Current (as inspected)	Indicate if update required (Yes/No)	Notes (comment on uncertainties, critical items, or to update)
nid_id	HI00024			
state_id	KA-0024			
dam_name	KALIHIWAI RESERVOIR			
other_dam_name				
status	Active			
island	Kauai			
county	Kauai			
state	HI			
longitude	-159.432378			
latitude	22.187054			
private_dam_on_fed_prop	FALSE			
watershed	Kalihiwai			
TMK	(4) 5-2-022:003			
TMK2				
dam_type	Earthen			
dam_purpose	Irrigation	Irrigation and Recreation	Yes	Based on 2021 Phase I Inspection
stream_name	TR-KALIHIWAI RIVER			
nearest_city	KALIHIWAI			
nearest_city_distance	2			
dam_designer				
year_completed	1920			
year_last_modified		2020	Yes	•Mid-level outlet (Outlet #2) replaced with two 24-inch HDPE culverts (2020) •Slope stability scarp on downstream slope repaired (2020) •Gravel added to crest and graded access road (2020)
size	Small			
volume				
dam_length	950			
dam_height	20			
hazard	High			
structural_height	25			
hydraulic_height	20			
maximum_storage	428	428 ac-ft (reference El. Not reported) 242 ac-ft (at El. 395)	Yes	Based on the 2021 Gannet Fleming Design Report.
normal_storage	278	278 ac-ft (reference El. Not reported but presumed to correpond to El. 391.5)	Yes	Based on the 2021 Gannet Fleming Design Report.

Inventory Data	Existing (in database)	Current (as inspected)	Indicate if update required (Yes/No)	Notes (comment on uncertainties, critical items, or to update)
surface_area	23	22 acres	Yes	•22 acres at El. 387 based on the 2021 Gannet Fleming Design Report. •23 acres (reference Elevation not reported but presumed to correspond to Normal pool El. 391.5)
drainage_area	0.32			
spillway_type	Channel	Earthen Channel	Yes	Based on the 2015 DLNR Final Inspection Report.
spillway_control	Uncontrolled	Uncontrolled		Based on the 2015 DLNR Final Inspection Report.
spillway_width	14	55 ft (narrows to a 14-ft-wide channel downstream of control section)		Based on the 2021 Gannet Fleming Design Report.
spillway_max_discharge		2,412 CFS	Yes	Based on the 2021 Gannet Fleming Design Report.
spillway_protection	Bare Soil	Gravel and concrete-lined control section		Based on the 2015 DLNR Final Inspection Report.
spillway_length	332	332 ft		Based on the 2015 DLNR Final Inspection Report.
spillway_wall_height	0			
outlet_type	Upstream Control	1) Low-level outlet to irrigation system with downstream control 2) Mid-level outlet, uncontrolled	Yes	Based on 2021 Phase I Inspection. Main outlet consists of 24-in line through embankement into an 18-in line that T's to 2-12-in lines which flow through filters and then back into an 18-in line. Mid-level out let consists of 2-24 in HDPE pipes.
ogee_present	FALSE			
outlet_access	On Dam Crest	1) Through embankment, near right abutment 2) Left abutment	Yes	Based on 2021 Phase I Inspection.
outlet_max_discharge				
outlet_control_location	Upstream - Throwaway Gate	1) Controlled downstrem at Plantation 2) Uncontrolled	Yes	Based on 2021 Phase I Inspection.
outlet_size	36 in	1) 24 inches 2) 2 x 24" diameter HDPE pipes	Yes	Based on the 2015 DLNR Final Inspection Report and 2021 Phase I Inspection.
staff_gage_level	15	10.2 ft per gage	Yes	Restricted staff gage level as of June 28, 2017.
min_crest_width	15			
upstream_slope_grade	30	2.0H:1V		Based on the 2021 Gannet Fleming Design Report.
upstream_protection	Bare Soil	Grassed		Based on the 2015 DLNR Final Inspection Report.
downstream_slope_grade	22	0.6H:1V to 2.0H:1V		Based on the 2021 Gannet Fleming Design Report.
downstream_protection	Vegetation	Bare earth		Based on the 2015 DLNR Final Inspection Report.
waterbodytype	State Regulated Dam			
last_inspection_date	8/4/2021			
inspection_frequency	2			

Inventory Data	Existing (in database)	Current (as inspected)	Indicate if update required (Yes/No)	Notes (comment on uncertainties, critical items, or to update)
hazard_analysis_date	6/1/2009			
eap	TRUE			
eap_date	2/22/2022 12:22			
eap_createdby	Kauai Kalihiwai			
OnlineEAP	Y			
OnlineEAPDate	2/22/2022 12:22			
certificate_to_impound_date				
district_code	2			
district_name	2nd Congressional District			
representative	Kai Kahele			
party	Democratic			
electronic_gauge_url				
top_of_crest		15 (L) to 30 (r) - ft wide varies	Yes	Based on 2021 Phase I Inspection
spillway_crest				
operating_level		7 ft per gage	Yes	Based on 2021 Phase I Inspection
dam_former_name				
state_reg_agency	DLNR			
core	X			
foundation	U			
section				
nid_height	25			
nid_storage	428			
number_of_locks	0			
length_of_locks	0			
width_of_locks	0			
fed_funding				
fed_design				
fed_construction				
fed_regulatory				
fed_inspection				
fed_operation				
fed_owner				
fed_other				
source_agency	HI			
submit_date				
url_address	https://dams.hawaii.gov/DamInformation.aspx?id=731D0908-04A9-456E-8771-A76576E4DDB4			
ConditionAssessment	POOR			

Inventory Data	Existing (in database)	Current (as inspected)	Indicate if update required (Yes/No)	Notes (comment on uncertainties, critical items, or to update)
ConditionAssessmentDate	8/1/2008	8/4/21	Yes	Based on 2021 Phase I Inspection
ConditionAssessmentDetail				
DataOwner				
EnforcementAuthority	TRUE			
InspectionAuthority	TRUE			
JurisdictionalDam	TRUE			
NumSeparateStructures				
OtherStructureID				
OutletGates				
PermittingAuthority	TRUE			
RecordID	14763			
dam_type_nid	RE			
size_nid	S			
hazard_nid	H			
dam_status_description	Active			
spillway_type_nid	U			
outlet_type_nid	U			
watershed_description	Kalihiwai			
access_surface_description	Unpaved	Grassed / 15-ft for access	Yes	Based on the 2015 DLNR Final Inspection Report.
access_method_description	4x4 (wet conditions only)	Vehicle access	No	Based on the 2018 DLNR Final Inspection Report.
om_onfile	FALSE			
om_date				
hhreport_onfile	FALSE			
hhreport_date				
stabilityreport_onfile	FALSE			
stabilityreport_date				
level_restriction				
last_nod_date				
PMF_level				
Flood100yr				
Owner_Type	P	P		Kalihiwai Ridge Community Associateion is the dam Owner. There ar etwo easement owners: Birdgewater irrigation, LLC and Porter Irrigation Company

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