Instream Flow Standard Assessment Summary

East Maui Hydrologic Units:
Hoʻolawa (6035), Waipiʻo (6036), Hoalua (6038), Hānawana (6039), Kailua (6040), Nailiiliihaele (6041), Puehu (6042), Oopuola (6043), Kaaiea (6044), Punaluʻu (6045), Kōlea (6046)

October 2020 **PR-2020-16**

State of Hawaiʻi
Department of Land and Natural Resources
Commission on Water Resource Management

Contents

1. Overview

In 2001, 27 petitions to amend the interim instream flow standard (IIFS) were filed with the Commission on Water Resource Management (Commission). In 2008, six IIFS were established by Commission staff recommendation on streams in the Honopou, Hanehoi, Piʻinaʻau, Waiokamilo, Wailuanui hydrologic units. In 2010, staff recommended additional IIFS on streams in the Waikamoi, Puohokamoa, Haipuaena, Punalau, Honomanū, West Wailuaiki, East Wailuaiki, Kopiliula, Waiohue, Paʻakea, Kapaula, Hānawī hydrologic units. Following a contested case hearing which addressed the IIFS for all 27 petitions (subsequently determined to be 24 individual streams), the Commission issued its final Decision & Order (D&O) in 2018[1]. The D&O established measurable IIFS for 21 of the 24 streams, with Ohia (not diverted by East Maui Irrigation) and the streams in Waiaaka and Wahinepeʻe (too small) determined to not need amended IIFS. The Commission first evaluated each stream individually, assessing their flow characteristics, instream uses, habitat restoration potential for fish and other stream animals, recreational opportunities, associated traditional and customary practices, and scenic values. The Commission then looked at all of the affected streams in an integrated manner with consideration for the overall ecological ramifications of the decision and used those factors to align instream flow standards with public trust responsibilities. This decision evaluated the availability of water from all sources, including that from non-petitioned streams, in its balance of instream and non-instream uses. The Commission's expectation is that restoring flows to streams that are spread out geographically will: 1) provide greater protection against localized habitat disruptions; 2) produce a wider benefit to estuarine and near-shore marine species; and 3) result in improved comprehensive ecosystem function across the entire East Maui watershed. The Commission's intent in the 2018 D&O was to ensure that a sufficient amount of water is available to support the cultivation of diversified agricultural crops on the lands designated as important agricultural lands (IAL) in central Maui. Their best estimate is that the water available from the petitioned and non-petitioned streams (including those outside of the license area) would provide for about 90% of the irrigation needs for 23,000 acres of IAL. It is the Commission's belief that improvements in irrigation system efficiency (reductions in the 20% system loss), will make up for the 10% of water not available due to the 2018 D&O.

This document is meant to provide a summary of information used to evaluate hydrological data and instream uses for the surface water hydrologic units of Hoʻolawa (6035), Waipiʻo (6036), Hoalua (6038), Hānawana (6039), Kailua (6040), Nailiiliihaele (6041), Puehu (6042), Oopuola (6043), Kaaiea (6044), Punaluʻu (6045), Kōlea (6046). The hydrologic units for these streams in East Maui vary substantially by size, geology, rainfall, and land cover (Table 1). The geology and water resources are heavily influenced by the post-erosional Kula Volcanic Series and the rejuvenation Hāna Volcanic Series which overlie the highly permeable Volcanics of the shield building phase, which is exposed only in heavily incised valleys. The Kula Series is composed of ash deposits and aa flows which form perched water bodies. Streams with low maximum elevations, small drainage areas, and low mean annual rainfall (e.g., Mokupapa, Waipiʻo, Hānawana, Puehu, Punaluʻu) are considered intermittent in some or all portions of the stream. Many of the streams end in terminal waterfalls which restrict the recruitment of juvenile amphidromous species to those with climbing abilities (e.g, *Awaous stamineus, Lentipes concolor, Sicyopterus stimpsoni, Neritina granosa, Atyoida bisulcata*). A number of inland waterfalls, some with natural overhanging basalt formations, further restrict the upstream migration of native amphidromous species (e.g., Hoʻolawa, Nailiiliihaele). Poor reach diversity, a lack of shallow waters, and minimal

[1] https://files.hawaii.gov/dlnr/cwrm/cch/cchma1301/CCHMA1301-20180620-CWRM.pdf

baseflow limits the availability of habitat under natural flow conditions. The larger perennial streams in this area have historic continuous record data at approximately the 1,250-foot elevation which monitored natural flow conditions (e.g., Hoʻolawa, Kailua, Nailiiliihaele, Oopuola, Kaaiea). Most of the watersheds are covered in evergreen forest or grassland dominated by alien species, with pastureland dominating the lower elevation agricultural zones. The area is part of the Huelo census tract that has a total population of 2,173 people (U.S. Census Bureau, 2018).

Table 1. General topographic features of non-petitioned streams in the East Maui license Area, Maui. (Source: Atlas of Hawaiian Watersheds and their Aquatic Resources, 2008)

Hydrologic Unit	Drainage Area (mi^2)	Mean Annual Rainfall (in)	Maximum Elevation (ft)	Length of longest stream (mi)	Terminal Waterfall	Inland Waterfall Barrier	Reach Diversity Rating (of 10)	Shallow Waters Rating (of 10)	Size Rating (of 10)
Hoʻolawa	3.58	148	3510	9.37	No	Yes	4	0	2
Mokupapa	0.39	76	700	2.09	Yes	No	n/a	n/a	n/a
Waipiʻo	0.58	105	1530	3.12	Yes	No	3	0	1
Hoalua	1.23	153	3530	7.03	No	No	3	0	1
Hānawana	0.58	121	1540	2.75	Yes	No	1	0	1
Kailua	4.9	197	6550	8.73	Yes	Yes	5	1	2
Nailiilihaele	4.67	177	5210	10.6	Yes	Yes	5	0	3
Puehu	0.49	127	1680	2.94	Yes	No	n/a	n/a	n/a
Oopuola	1.06	152	2060	3.41	No	Yes	3	1	2
Kaaiea	0.92	190	2720	5.61	Yes	No	n/a	n/a	n/a
Punaluʻu	0.20	128	1190	1.62	Yes	No	n/a	n/a	n/a
Kōlea	0.62	149	1860	2.96	Yes	No	2	0	1

2. Background

Current Instream Flow Standard

The current interim instream flow standard (IFS) for streams in East Maui was established by way of Hawaii Administrative Rules (HAR) §13-169-44, which, in pertinent part, reads as follows:

> Interim instream flow standards for East Maui. The Interim Instream Flow Standard for all streams on East Maui, as adopted by the commission on water resource management on June 15, 1988, shall be that amount of water flowing in each stream on the effective date of this standard, and as that flow may naturally vary throughout the year and from year to year without further amounts of water being diverted offstream through new or expanded diversions, and under the stream conditions existing on the effective date of the standard.

The current interim IFS became effective on October 8, 1988. Since streamflow was not measured on that date; the current interim IFS is not a measurable value.

Instream Flow Standards

Under the State Water Code (Code), Chapter 174C, Hawaii Revised Statutes (HRS), the Commission has the responsibility of establishing IFS on a stream-by-stream basis whenever necessary to protect the public interest in the waters of the State. Early in its history, the Commission recognized the complexity of establishing IFS for the State's estimated 376 perennial streams and instead set interim IFS at "status quo" levels. These interim IFS were defined as the amount of water flowing in each stream (with consideration for the natural variability in stream flow and conditions) at the time the administrative rules governing them were adopted in 1988 and 1989.

The Hawai‘i Supreme Court, upon reviewing the Waiāhole Ditch Contested Case Decision and Order, held that such "status quo" interim IFS were not adequate to protect streams and required the Commission to take immediate steps to assess stream flow characteristics and develop quantitative interim IFS for affected Windward O‘ahu streams, as well as other streams statewide. The Hawai‘i Supreme Court also emphasized that "instream flow standards serve as the primary mechanism by which the Commission is to discharge its duty to protect and promote the entire range of public trust purposes dependent upon instream flows."

To the casual observer, IFS may appear relatively simple to establish upon a basic review of the Code provisions. However, the complex nature of IFS becomes apparent upon further review of the individual components that comprise surface water hydrology, instream uses, noninstream uses, and their interrelationships. The Commission has the distinct responsibility of weighing competing uses for a limited resource in a legal realm that is continuing to evolve. The following illustration (Figure 1) was developed to illustrate the wide range of information, in relation to hydrology, instream uses, and noninstream uses that should be addressed in conducting a comprehensive IFS assessment.

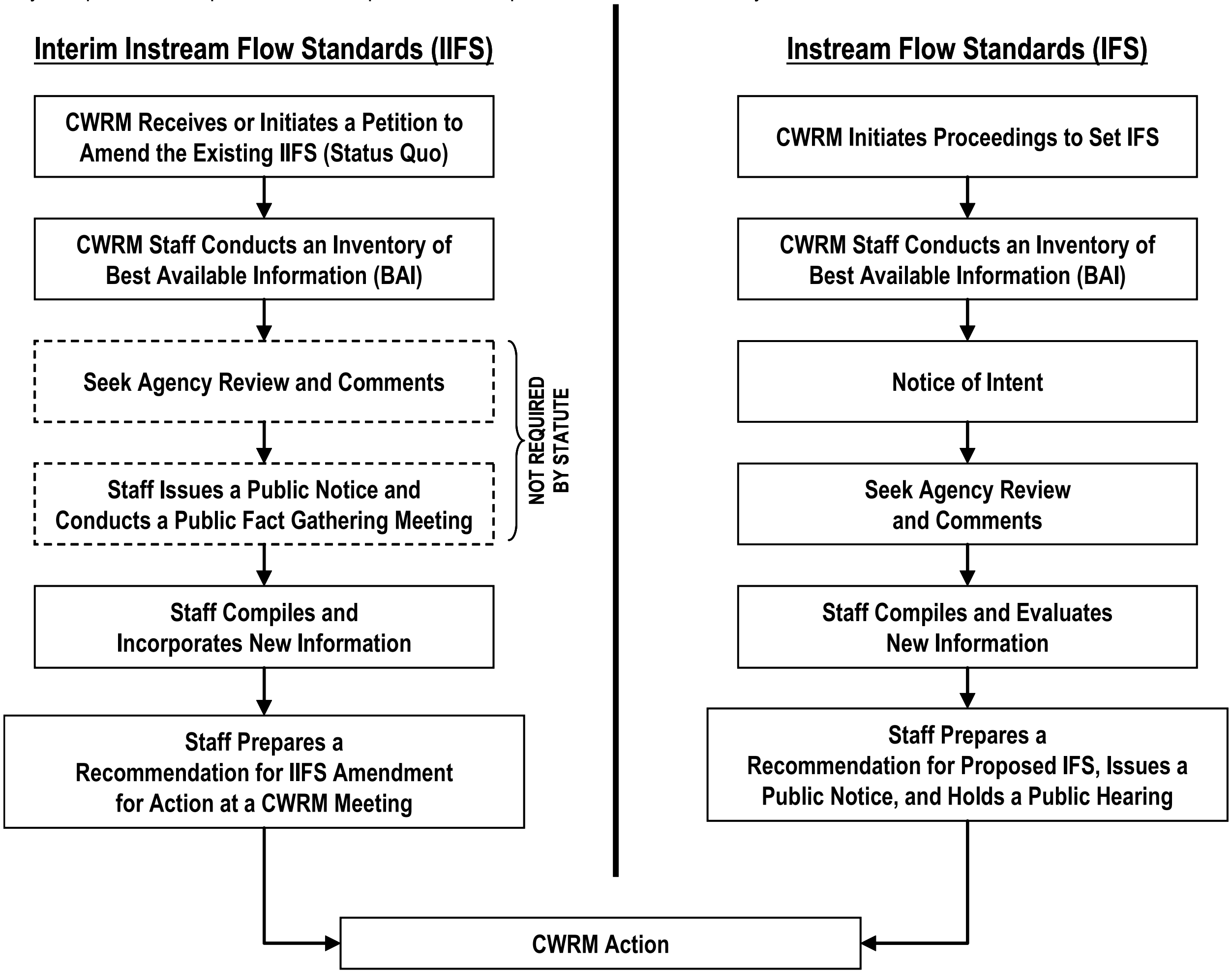
Figure 1. Information to consider in setting measurable instream flow standards.

Interim Instream Flow Standard Process

The Code provides for a process to amend an interim IFS in order to protect the public interest pending the establishment of a permanent IFS. The Code, at §174C-71(2), describes this process including the role of the Commission to "weigh the importance of the present or potential instream values with the importance of the present or potential uses of water for noninstream purposes, including the economic impact of restricting such uses."

Recognizing the complexity of establishing measurable IFS, while cognizant of the Hawai‘i Supreme Court's mandate to designate interim IFS based on best available information under the Waiāhole Combined Contested Case, the Commission at its December 13, 2006 meeting adopted a process for staff to develop interim IFS. Under this adopted process (reflected in the left column of Figure 2), the Commission staff conducts a preliminary inventory of best available information upon receipt of a petition to amend an existing interim IFS. The Commission staff shall then seek agency review and comments on the compiled information (compiled in an Instream Flow Standard Assessment Report) in conjunction with issuing a public notice for a public fact gathering meeting.

Figure 1. Simplified representation of the interim instream flow standard and permanent instream flow standard processes. Keys steps of the adopted interim IFS process are depicted in the left column by the boxes drawn with dotted lines.



Instream Flow Standard Assessment Report

The Instream Flow Standard Assessment Report (IFSAR) is a compilation of the hydrology, instream uses, and noninstream uses related to a specific stream and its respective surface water hydrologic unit. The report is organized in much the same way as the elements of IFS are depicted in Figure 1. The purpose of the IFSAR is to present the best available information for a given hydrologic unit. This information is used to determine the interim IFS recommendations, which is compiled as a separate report. The IFSAR is intended to act as a living document that should be updated and revised as necessary, thus also serving as a stand-alone document in the event that the Commission receives a subsequent petition solely for the respective hydrologic unit.

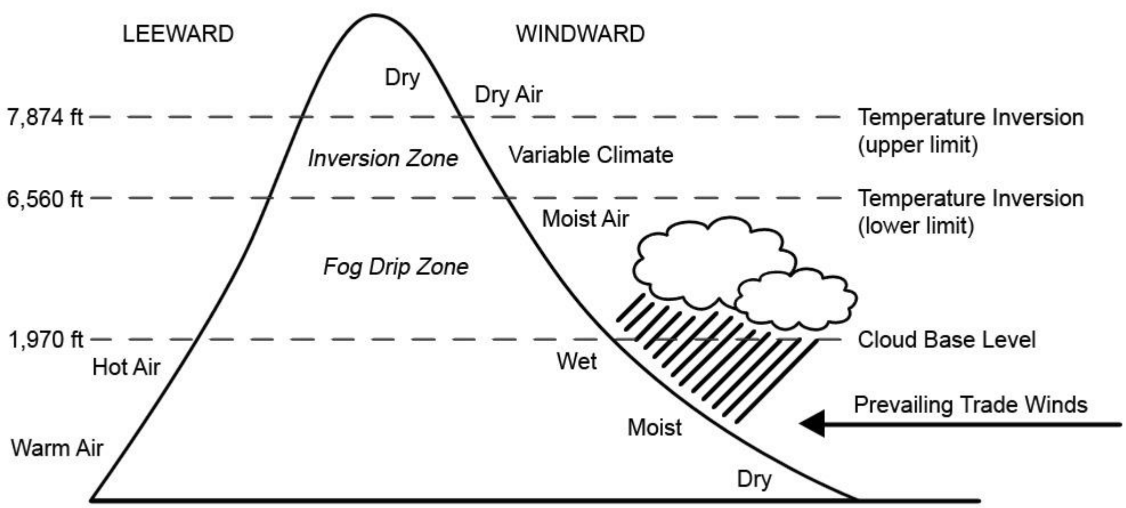
Each report begins with an introduction of the subject hydrologic unit and the current IFS status. Then summarizes the various hydrologic unit characteristics that, both directly and indirectly, impact surface water resources. It contains a summary of all available hydrologic information, and then summarizes the best available information for the nine instream uses as defined by the Code. Including public trust uses of water not covered in other sections. Noninstream uses are then summarized. Maps are provided to help illustrate information presented within the section's text or tables.

3. Characteristics of East Maui Hydrologic Units

Rainfall

Haleakalā is the driving force influencing the distribution of rainfall in East Maui, with rainfall affected by the orographic[2] effect and the rainshadow effect (Figure 3). Orographic precipitation occurs when the prevailing northeasterly trade winds lift warm air up the windward side of the mountains into higher elevations where cooler temperatures persist. As moist air cools, water condenses and the air mass releases precipitation. As a result, frequent and heavy rainfall is observed on the windward mountain slopes. The temperature inversion zone, the range of elevations where temperature increases with elevation, typically extends from 6,560 feet to 7,874 feet. This region is identified by a layer of moist air below and dry air above (Giambelluca and Nullet, 1992). The fog drip zone occurs below the elevation where cloud height is restricted by the temperature inversion (Sholl et al., 2002). Fog drip is a result of cloud-water droplets impacting vegetation (Scholl et al., 2002) and can contribute significantly to groundwater recharge. Above the inversion zone, the air is dry and the sky is frequently clear (absence of clouds) with high solar radiation, creating an arid atmosphere with little rainfall. This region is found in the higher elevations on Haleakalā.

Figure 2. Orographic precipitation in the presence of mountains higher than 6,000 feet.



Haleakalā, as the tallest peak (10,023 feet a.s.l) on Maui, influences the elevational distribution of moisture around the island. The steep gradient around the island forces moisture-laden air to rapidly rise in elevation (over 3,000 feet) in a short distance, resulting in a rapid release of rainfall. The maximum elevation of each hydrologic unit influences the amount of fog drip contributing to its water budget. Hydrologic units in East Maui receive a substantial orographic rainfall, contributing to higher rainfall in the 2,000 to 6,000-foot elevations (Giambelluca and Nullet, 1992; Figure 4). Hydrologic units that have maximum elevations below this have much less rainfall, fog drip, and groundwater recharge contributing to its water budget. Above 2,000 feet, rainfall is highest usually during the months of March and April.

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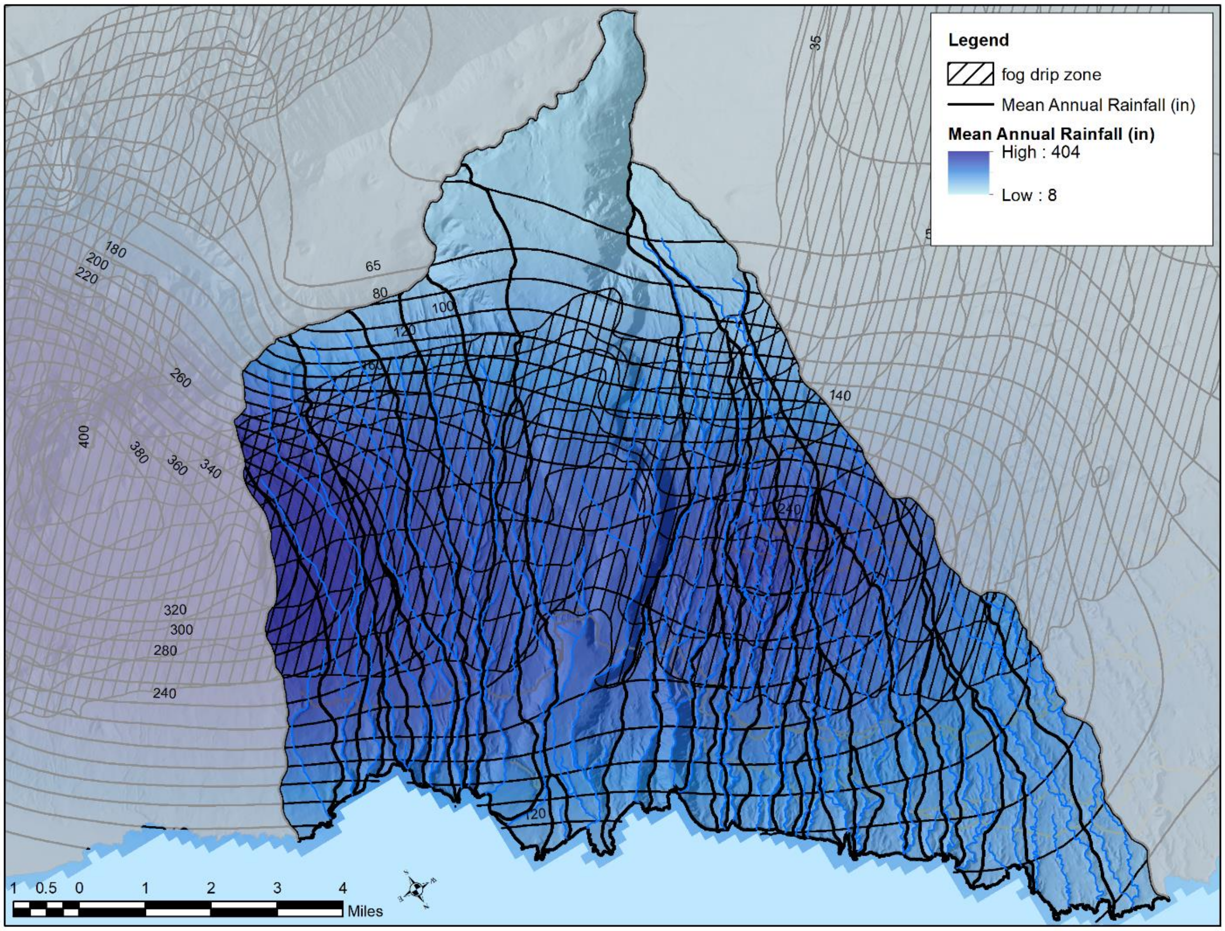
[2] Orographic refers to influences of mountains and mountain ranges on airflow, but also used to describe effects on other meteorological quantities such as temperature, humidity, or precipitation distribution.

The spatial distribution of water-budget components for the Island of Maui is available from USGS[3]. The water-budget components were computed by a water-budget model for a scenario representative of average climate conditions (1978–2007 rainfall) and 2010 land cover. The model was developed for estimating groundwater recharge and other water-budget components for each subarea of the model. The model subareas were generated using Esri ArcGIS software by intersecting (merging) multiple spatial data sets that characterize the spatial distribution of rainfall, fog interception, irrigation, reference evapotranspiration, direct runoff, soil type, and land cover. These water budget components are summarized for the non-petitioned hydrologic units in East Maui in Table 2.

Figure 3. Mean annual rainfall (in), mean annual rainfall isohyets (in), and zone of fog drip for hydrologic units in the East Maui license area. (Source: Giambelluca et al., 2013)



The hydrologic units with maximum elevations below the fog drip zone had no fog drip contributions to the water budget (e.g., Mokupapa, Waipiʻo, Hānawana, Puehu, Punaluʻu, Kōlea). These units also have minimal surface runoff. The hydrologic units with substantial runoff were Hoʻolawa, Kailua, Nailiiliihaele.

[3]Johnson, A.G., Engott, J.A., Bassiouni, Rotzoll, K. (2014). Spatially distributed groundwater recharge estimated using a water-budget model for the Island of Maui, Hawaiʻi, 1978-2007. US Geological Survey SIR 2014-5168.

Table 2. Mean annual water budget components (in millions of gallons, mg) for current (1978-2007) climate conditions by hydrologic unit for non-petitioned streams in the East Maui License Area, Maui. (Source: Johnson et al. 2014)

Hydrologic unit	Rainfall (mg)	Fog Drip (mg)	Runoff (mg)	Evapotranspiration (mg)	Recharge (mg)
Hoʻolawa	12120.3	760.7	4106.2	4328.7	4459.3
Mokupapa*	947.6	0.0	101.9	570.7	281.5
Waipiʻo	2849	0.0	518.2	1445.4	912.0
Hoalua	4561.1	129.2	1592.4	1592.0	1504.8
Hānawana	2006.5	0.0	523.5	855.6	635.9
Kailua	18499.0	2353.3	10293.5	3949.1	6605.5
Nailiilihaele	13576.0	932.0	6964.1	3126.8	4590.1
Puehu	1370.0	0.0	484.8	589.6	294.8
Oopuola	4169.2	13.8	1867.9	1285.5	1028.1
Kaaiea	5946	405.4	2734.2	1258.6	2326.9
Punaluʻu	869.7	0.0	309.7	333.6	225.8
Kōlea	2755.4	0.0	1125.9	832.8	795.5

*Mokupapa is located within the Ho'olawa hydrologic unit, but it's data were analyzed separately

Geology

Surface geology influences the rate and movement of groundwater infiltration and its influence on surface flow. In East Maui, the geology is composed of three types: the late phase rejuvenation Hāna Volcanics, the late phase Kula Volcanics, and the shield-building phase of the Honomanū Volcanics. The Kula Volcanics is composed of progressive layers of ash and lava which increase the lateral movement of groundwater (Gingerich, 1999a[4]). Kula volcanics are composed of mainly aa flows (lava characterized by jagged, sharp surfaces with massive, relatively dense interior) poured out at progressively longer intervals so that numerous valleys were cut between the younger lava flows. The older flows are massive, aggregating 2,000 feet thick on the summit and thin toward the isthmus where they are only about 50 feet thick. In the eastern end of Haleakalā near Nāhiku, perched high-level groundwater[5] is held up by the relatively low permeability[6] Kula volcanics and associated weathered soils and ash beds (Gingerich, 1999b[7]). A small area near the heads of the larger hydrologic units includes geologic formations (weathered cinders, spatter, and pumice) originally built along fissures by firefountains (sprays of gases carrying magma from vents, spewing up to several hundred feet high, producing "spatter") at the source of the lava flows, forming a few perched spring water systems. The Honomanū volcanic series, which predates the Kula volcanics, forms the basement of the entire Haleakalā mountain to an unknown depth below sea level (Figure 5). They are predominantly pahoehoe flows (lava characterized by a smooth or ropy surface with variable interior, including lava tubes and other voids), ranging from 10 to 75 feet thick and are very vesicular. The Honomanū basalts are extremely permeable and yield water freely (Stearns and MacDonald, 1942). Only in heavily incised watersheds with low-elevation channels near the mouth of streams is the Honomanū volcanic series exposed, generally resulting in streams that lose flow to groundwater recharge and an estuarine environment. Erosion of the overlying surface geology by incising stream channels exposes more resistive layers. In watersheds with Volcanics, as the eroding

[4] Gingerich, S.B. (1999a). Ground water and surface water in the Haʻikū Area, East Maui. U.S. Geological Survey Water Resources Investigations Report, 98-4142.
[5] Perched water is water confined by an impermeable or slowly permeable layer, thus accumulating in a perched water table above the general regional water table. It is generally near-surface, and may supply springs.
[6] Permeability is the ease with which water passes through material. It is a factor in determining whether precipitation runs off on the surface or descends into the ground.
[7] Gingerich, S.B. (1999b). Ground-water Occurrence and Contributions to Streamflow, Northeast Maui, Hawaii. U.S. Geological Survey Water-Resources Investigations Report 99-4090.

nickpoint shifts upstream, inland waterfalls are generated, reforming an inland barrier to upstream migration (Figure 6).

Table 3. Area and percentage of surface geologic features for each non-petitioned hydrologic unit in the East Maui license Area, Maui. (Source: Sherrod et al, 2007)

Stream	Hāna Volcanics (50-140 kya)	Percent of Unit	Kula Volcanics (140-780/950 kya)	Percent of Unit	Honomanū Basalt (950-1,300 kya)	Percent of Unit
Hoʻolawa	1.358	28.2	3.433	71.4	0.018	0.3
Waipiʻo	0.0	0.0	0.969	95.3	0.048	4.7
Hoalua	0.263	21.5	0.907	74.0	0.055	4.5
Hānawana	0.125	19.4	0.485	75.1	0.035	5.4
Kailua	3.073	59.1	2.107	40.5	0.017	0.3
Nailiilihaele	0.465	13.2	3.052	86.4	0.015	0.4
Puehu	0.0	0.0	0.342	96.6	0.012	3.4
Oopuola	0.0	0.0	1.180	96.2	0.044	3.6
Kaaiea	0.0	0.0	1.113	97.5	0.029	2.5
Punaluʻu	0.0	0.0	0.199	90.1	0.020	9.9
Kōlea	0.0	0.0	0.665	95.0	0.035	5.0

Figure 4. Surface geology and waterfalls of hydrologic units in the East Maui License Area, Maui. (Source: Sherrod et al., 2007)

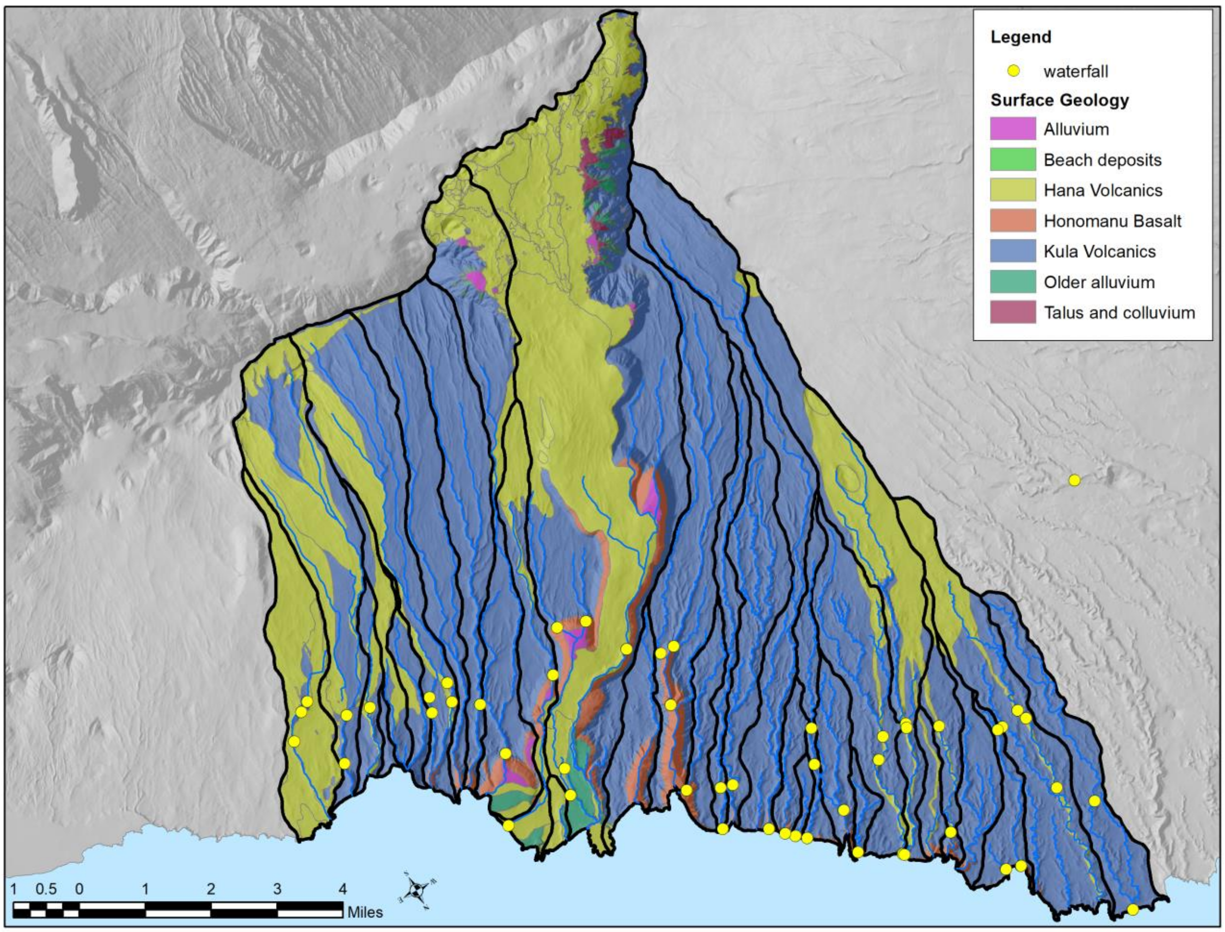
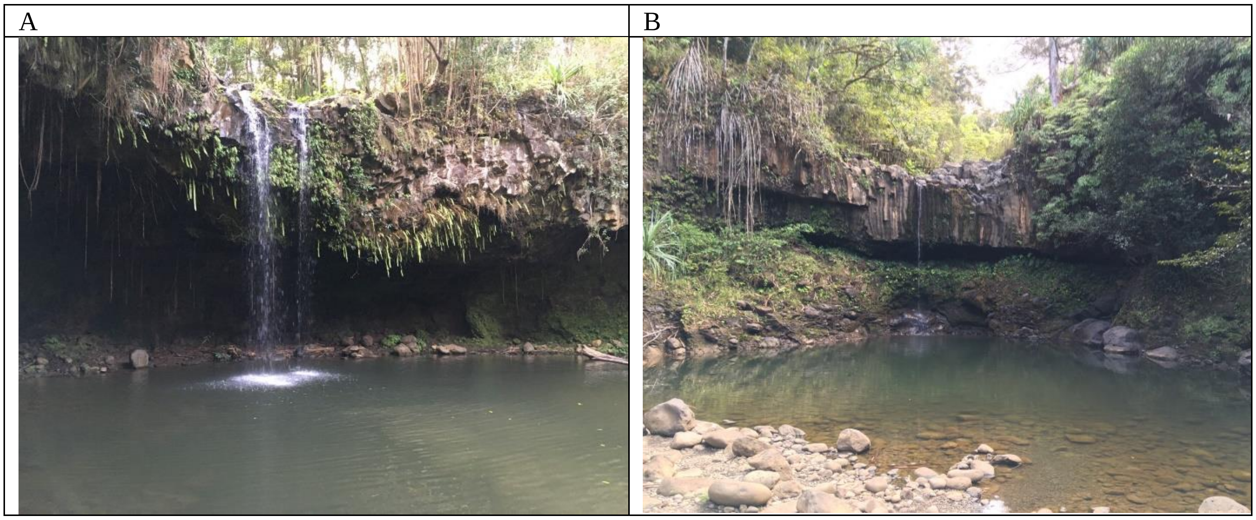


Figure 6. Example of naturally exposed overhanging Hāna volcanics at the 600-foot elevation forming a barrier to upstream migration in Hoʻolawaliilii (A) and Hoʻolawanui (B).



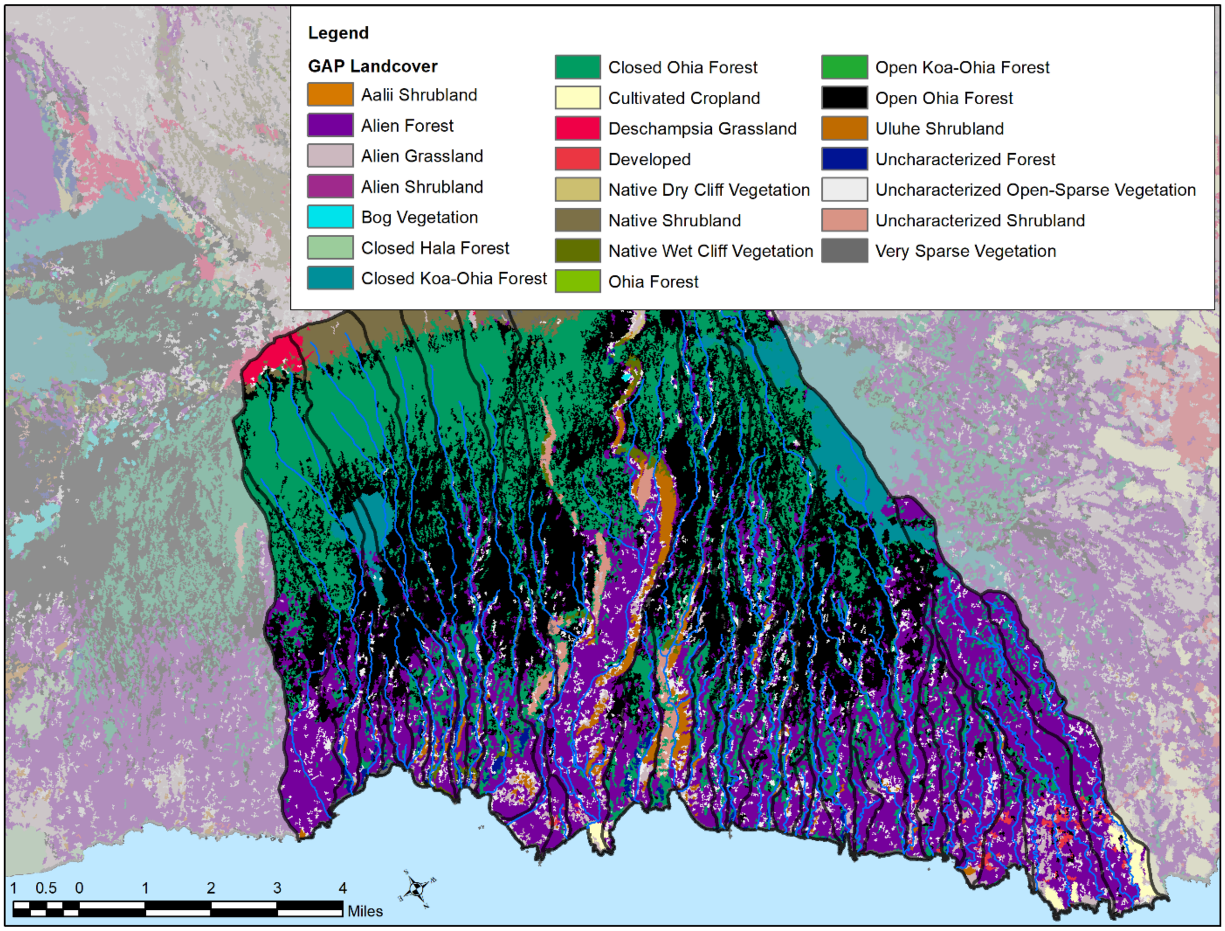
Land Cover

Land cover for the hydrologic units in East Maui is represented by a 30-meter Landsat satellite dataset developed by the Hawaii Gap Analysis Program (HI-GAP). This program mapped the National Vegetation Classification System (NVCS) associations for each type of vegetation, using ground-truthing for validation (Figure 7).

Based on the land cover classification system, the land cover in each East Maui hydrologic unit is influenced by its maximum elevation, with larger units that have greater maximum elevations consisting of forested wetland, evergreen forest, and scrub wetland, particularly in elevations above 2000 feet. The lower elevations are made up of developed land or pasture. Alien forest makes up much of the vegetation, especially along streams in the lower elevations; with closed ʻōhiʻa forest, closed koa-ʻōhiʻa forest or open ʻōhiʻa forest, limited to higher elevations.

At lower elevations (i.e., below the forest reserve), riparian vegetation is dominated by non-native, often highly invasive species. The riparian vegetation of streams that pass through lower elevation agriculturally-zoned lands in the non-petitioned stream is dominated by highly invasive species which disrupt the food-web of freshwater ecosystems by: 1) increasing carbon inputs (e.g., leaves, fruit); 2) increasing coarse woody debris (e.g., bamboo, hau bush); 3) occluding the stream canopy (i.e., reducing algal growth); and 4) altering the channel the flow of water in the channel. This is particularly true in the agriculturally-zone regions of Honopou, Hoʻolawa, Hanehoi, Waipiʻo, Hoalua, Hānawana, Kailua, Nailiilihaele, Puehu, Oopuola, Kaaiea, Punaluʻu, and Makapipi.

Figure 7. Hawaii GAP land cover classes in East Maui license area, Maui. (Source: USGS, 2001).



4. Hydrology

The Commission, under the State Water Code, is tasked with establishing instream flow standards by weighing "the importance of the present or potential instream values with the importance of the present or potential uses of water for noninstream purposes, including the economic impact of restricting such uses." While the Code outlines the instream and offstream uses to be weighed, it assumes that hydrological conditions will also be weighed as part of this equation. The complexity lies in the variability of local surface water conditions that are dependent upon a wide range of factors, including rainfall, geology, and human impacts, as well as the availability of such information. The following is a summary of general hydrology and specific hydrologic characteristics for watersheds in East Maui.

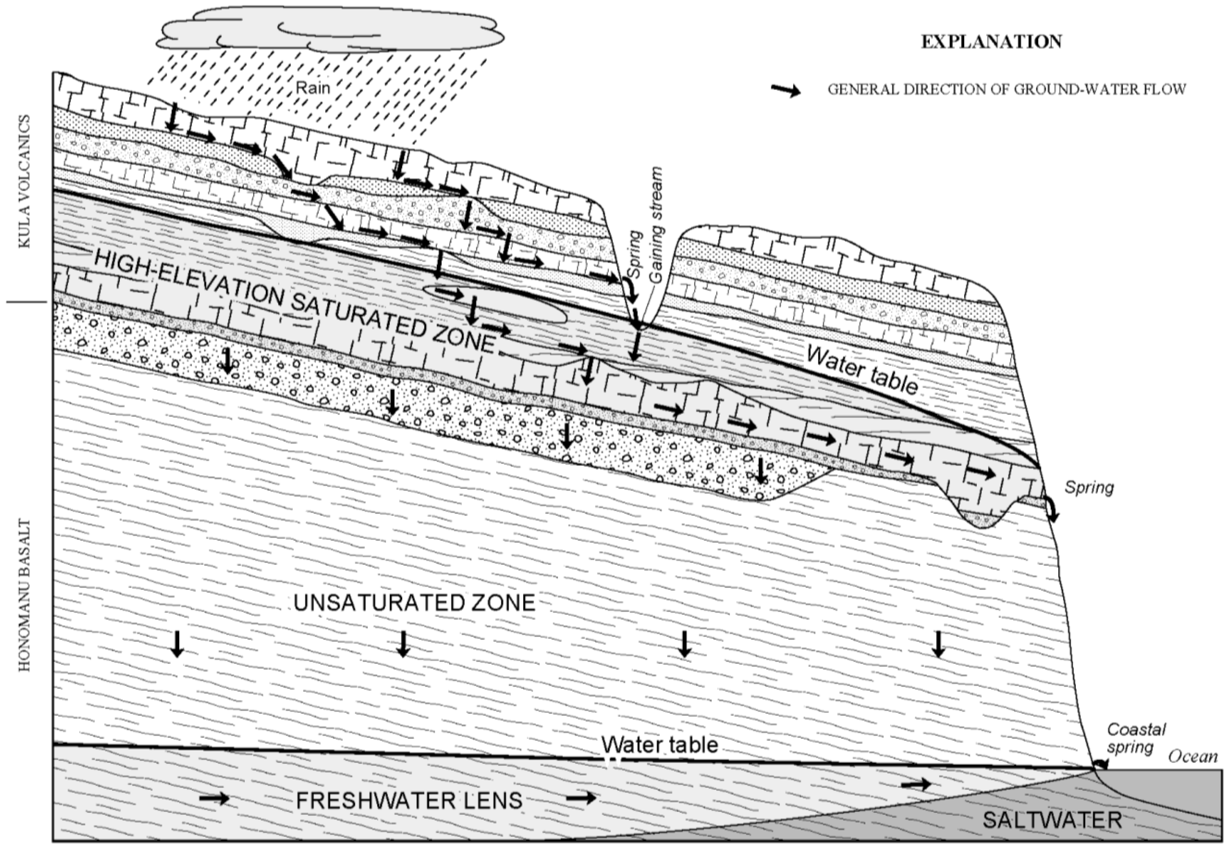
Groundwater

Groundwater is an important component of streamflow as it constitutes the base flow[8] of Hawaiian streams. In Hawai'i, groundwater is replenished by recharge from rainfall, fog drip, and irrigation water that percolate through the plant root zone to the subsurface rock. Recharge can be captured in three major groundwater systems: 1) fresh water-lens system; 2) dike-impounded system; and 3) perched system. The fresh water basal aquifer provides the most important sources of ground water. It includes a lens-shaped layer of fresh water, an intermediate transition zone of brackish water, and underlying salt water. The Ghyben-Herzberg principle describes the displacement of higher density saltwater by lower density fresh water in an aquifer for a condition where two fluids do not mix and the freshwater flow is primarily horizontal. In such a situation, for every one foot above sea level of freshwater, there are approximately 40 feet of freshwater below sea level. Thus, a vertically extensive fresh water-lens system can extend several hundreds of feet below mean sea level. By contrast, a dike-impounded system is found in rift zones or a caldera where low-permeability dikes compartmentalize areas of permeable volcanic rocks, forming high-level water bodies. On Maui, dikes impound water to as high as 3,300 feet above mean sea level. A perched system is found in areas where low-permeability rocks impede the downward movement of percolated water sufficiently to allow a water body to form in the unsaturated zone above the lowest water table (Gingerich and Oki, 2000[9]). The water-bearing properties of various rock structures largly depends on their composition, and therefore their permeability. Where a dike complex exists, 100 or more dikes per mile, occupying 5% or more of the rock, is not uncommon and can hold substantial quantities of water in the permeable layers between the dikes.

A general overview of the ground water occurrence, movement, and interactions with surface water in East Maui is described in Gingerich (1999b) and illustrated in Figure 8. Groundwater is found at high elevation saturated zones not present near the coast due to erosion that has removed the low-permeability layers formed by the Kula Volcanics. USGS[10] has estimated the rate of groundwater recharge for the island of Maui, and in the East Maui license area, recharge is primarily in the higher elevations where rainfall and fog drip are greatest (Figure 9).

[8] Base flow is the water that enters a stream from persistent, slowly varying sources (such as the seepage of ground water), and maintains stream flow between water-input events (i.e., it is the flow that remains in a stream in times of little or no rainfall).
[9] Gingerich, S.B., Oki, D.S. (2000). Ground water in Hawaii. U.S. Geological Survey Fact Sheet 126-00.
[10] Johnson, A.G., Engott, J.A., Bassiouni, M., Rotzoll, K. (2014). Spatiall distributed groundwater recharge estimated using a water-budget model for the Island of Maui, Hawai'i, 1978-2007.

Figure 8. Diagram illustrating the ground water system west of Ke'anae Valley, northeast Maui, Hawai'i. Arrows indicate general direction of ground water flow (Source: Gingerich, 1999b).



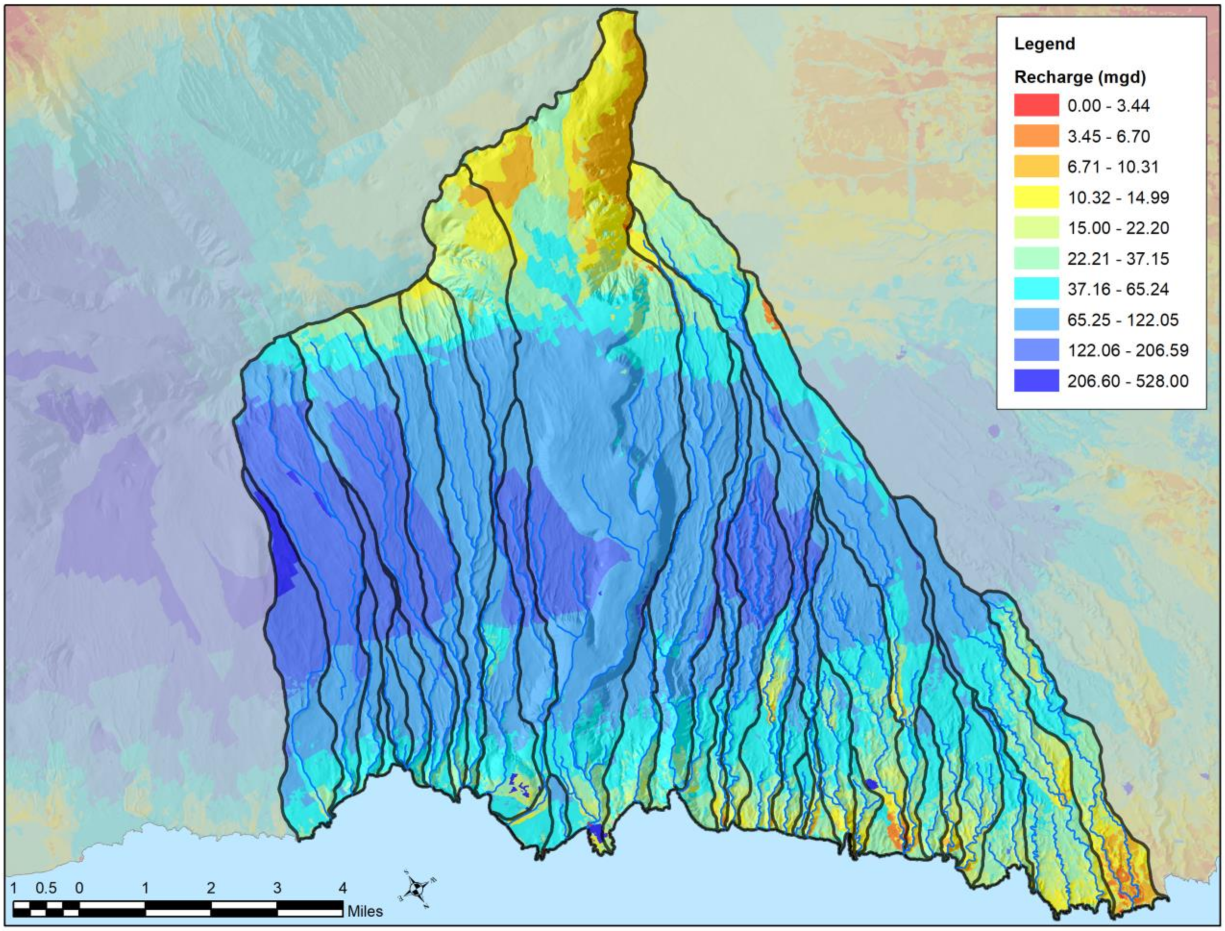
Streams in Hawai'i

Streamflow consists of: 1) direct surface runoff in the form of overland flow and subsurface flow that rapidly returns infiltrated water to the stream; 2) groundwater discharge in the form of base flow; 3) water returned from streambank storage; 4) rain that falls directly on streams; and 5) additional water, including excess irrigation water discharged into streams by humans (Oki, 2003). The amount of runoff and groundwater that contribute to total streamflow is dependent on the different components of the hydrologic cycle, as well as man-made structures such as diversions and other stream channel alterations (e.g. channelizations and dams).

Streams in Hawai'i can either gain or lose water at different locations depending on the geohydrologic conditions. A stream gains water when the groundwater table is above the streambed. When the water table is below the streambed, the stream can lose water. Another way that groundwater influences streamflow is through springs. A spring is formed when a geologic structure (e.g., fault or fracture) or a topographic feature (e.g., side of a hill or a valley) intersects groundwater either at or below the water table. This regularly occurs in East Maui where the stream channel has incised through the Kula volcanics series and exposed lateral flowing water. Figure 8 illustrates a valley that has been incised into a high-level water table, resulting in ground water discharges that contribute directly to streamflow and springs that contribute to streamflow. Springs can discharge groundwater onto the land surface, directly into the stream, or into the ocean.

The USGS has monitored streamflow continuously at dozens of stations throughout East Maui, although there are only four currently active monitoring stations (with funding to support two more from the Commission on Water Resource Management to be installed in federal fiscal year 2021).

Figure 9. Mean daily groundwater recharge in hydrologic units of the East Maui License area, Maui. (Source: USGS, 2015).



Streamflow Characteristics

One of the most common statistics used to characterize streamflow is the median value of flow in a particular time period. This statistic is also referred to as the total flow at 50 percent exceedance probability, or the flow that is equaled or exceeded 50 percent of the time (TFQ_{50}). The longer the time period that is used to determine the median flow value, the more representative the value is of conditions in the stream. Median flow is typically lower than the mean or average flow because of the bias in higher flows, especially during floods, present when calculating the mean flow[11]. The flow at the 90 percent exceedence probability (TFQ_{90}) is commonly used to characterize low flows in a stream. In Hawai‘i, the baseflow (BF) is usually exceeded less than 90 percent of the time, and in many cases less than 70 percent of the time (Oki, 2004[12]). The Commission on Water Resource Management funds several long-term continuous stream flow monitoring stations currently in operation including on Honopou (USGS station 16587000), on West Wailuaiki (USGS station 16518000), and Hānawī (USGS station 16508000) streams.

[11] Streamflow tends to have a positively skewed distribution.
[12] Oki, D.S. (2004). Trends in Streamflow characteristics at Long-Term Gaging Stations, Hawaii. U.S. Geological Survey Scientific Investigations Report 2004-5080.

Using record extension techniques, flow duration values for the current (1984-2013) climate period at discontinued stations in the East Maui license area were developed by USGS[13] (Table 4).

Table 4. Selected natural low-flow duration discharge exceedance values for the current (1984-2013) climate period in the East Maui license area, Maui. (Source: Cheng, 2016) [Flows are in cubic feet per second (million gallons per day)]

station ID	stream name	drainage area (mi²)	elevation (ft)	discharge (Q) for a selected percentage (xx) discharge was equaled or exceeded			
				Q_{50}	Q_{70}	Q_{90}	Q_{95}
16586000	Hoʻolawaliilii Stream	0.62	1250	3.6 (2.3)	2.7 (1.8)	1.7 (1.1)	1.4 (0.9)
16585000	Hoʻolawanui Stream	1.34	1230	4.4 (2.8)	2.6 (1.7)	1.4 (0.9)	1.0 (0.7)
16577000	Kailua Stream	2.42	1310	7.8 (5.0)	4.2 (2.7)	2.0 (1.3)	1.4 (0.90)
16570000	Nailiilihaele Stream	3.69	1280	14 (9.0)	8.6 (5.6)	4.6 (3.0)	3.6 (2.3)
16566000	Oopuola Stream	0.25	1205	0.95 (0.61)	0.50 (0.32)	0.26 (0.17)	0.18 (0.12)
16565000	Kaaiea Stream	0.68	1310	2.4 (1.6)	1.3 (0.84)	0.69 (0.45)	0.52 (0.34)
16557000	Alo	0.47	1248	2.5 (1.62)	1.3 (0.84)	0.69 (0.45)	0.53 (0.34)
16552800	Waikamoi	2.50	4487	0.12 (0.08)	0.05 (0.03)	0.02 (0.01)	--
16527000	Honomanū	2.94	1840	4.9 (3.17)	2.6 (1.68)	1.1 (0.71)	0.73 (0.47)
16524000	Honomanū	2.54	2900	1.6 (1.03)	0.76 (0.49)	0.32 (0.21)	0.23 (0.15)
16520000	East Wailuanui	0.53	1310	3.1 (2.00)	1.7 (1.10)	0.91 (0.59)	0.65 (0.42)
16519000	West Wailuanui	5.06	1245	3.8 (2.46)	2.2 (1.42)	1.1 (0.71)	0.75 (0.48)
16518000	West Wailuaiki	3.59	1550	8.9 (5.75)	5.2 (3.36)	2.8 (1.81)	2.2 (1.42)
16517000	East Wailuaiki	3.14	1340	7.7 (4.98)	4.6 (2.97)	2.8 (1.81)	2.1 (1.36)
16516000	Kopiliula	3.56	1290	6.6 (4.27)	3.8 (2.46)	2.4 (1.55)	2.1 (1.36)
16515000	Waiohue	0.74	1320	5.2 (3.36)	3.9 (2.52)	2.9 (1.87)	2.5 (1.62)
16513000	Waiaaka	0.08	650	0.80 (0.52)	0.68 (0.44)	0.54 (0.35)	0.50 (0.32)
16510000	Kapaula	1.35	1350	4.3 (2.78)	2.3 (1.49)	1.3 (0.84)	0.98 (0.63)
16508000	Hānawī	3.29	1318	6.2 4.01)	3.9 (2.52)	2.6 (1.68)	2.2 (1.42)

Groundwater-Surface Water Interactions

Stream channels that incise geologically young substrates expose high-elevation water bodies (e.g., dikes, perched layers) that generate spring flow which contribute to gains in the baseflow of streams. Particularly, in East Maui, stream channel incision exposes the lateral flow of water from the Kula Volcanics representing a high-elevation saturated zone. The USGS estimated baseflow gains in East Maui streams downstream of diversion structures in Gingerich (1999a,b) and Gingerich (2005[14]).

Below the Wailoa Ditch on Hoʻolawanui Stream, the stream gains 0.39 cfs (0.25 mgd) to the 600 ft elevation above the Lowrie Ditch. The Lowrie Ditch at the 590 ft elevation does not divert 100% of baseflow, and there is a gain of 0.27 cfs (0.18 mgd) down to the Haiku Ditch at the 450 ft elevation. From the 420 ft elevation below the Haiku Ditch to the 15 ft elevation, the stream gains 0.30 cfs (0.19 mgd). Below the Wailoa Ditch on Hoʻolawaliilii Stream, the stream gains 0.82 cfs (0.53 mgd) to the 620 ft elevation above the Lowrie Ditch. The Lowrie Ditch at the 590 ft elevation does not divert 100% of

[13]Cheng, C.L. (2016). Low-flow characteristics for streams on the islands of Kauaʻi, Oʻahu, Molokaʻi, Maui, and Hawaiʻi, State of Hawaiʻi. U.S. Geological Survey Scientific Investigations Report 2016-5103.
[14] Gingerich, S.B. (2005). Median and low-flow characteristics for streams under natural and diverted conditions, Northeast Maui, Hawaii. U.S. Geological Survey Scientific Investigations Report 2004-5262.

baseflow, and there is a gain of 0.28 cfs (0.18 mgd) down to the Haiku Ditch at the 450 ft elevation. Using these measurements, Gingerich (1999b) estimated a cumulative streamflow gain of 0.96 cfs (0.62 mgd) in baseflow in addition to the upstream runoff. Similar downstream gains in flow were measured in Kailua, Nailiilihaele, Oopuola, Kaaiea, Waikamoi, Puohokamoa, Haipuaena, Honomanū, Waiokamilo, Wailuanui, West and East Wailuaiki, Kopiliula, Waiohue, Pa‘akea, Waiaaka, Kapaula, and Hānawī (Gingerich, 1999b). In areas where Honomanū basalt is exposed near the coast (e.g., in Hoalua, Oopuola, Honomanū, Nua‘ailua, Pi‘ina‘au, Waiokamilo, West and East Wailuaiki), stream reaches lose flow to groundwater recharge in those areas.

Additional streamflow estimates by the USGS, measurements by Commission staff or measurements by the USGS at ungagged locations are provided in Table 5.

Table 5. Selected flow estimates and measurements at ungagged locations on non-petitioned streams of the East Maui License Area, Maui. (Source: field verification surveys, except where noted) [Flows are in cubic feet per second, cfs]

			regression estimates[1,2]			
stream name	drainage area (mi^2)	elevation (ft)	TFQ_{50}	BFQ_{50}	Measurements	notes
Ho‘olawa	3.10	460			0.45 on 10/23/2020	Perennial
Ho‘olawaliilii					0.23 on 10/29/2020	Perennial
Ho‘olawanui					0.05 on 10/29/2020	Perennial
East Mokupapa	0.06	650	0.17	0.10	0.033 on 10/10/07	Intermittent
West Mokupapa	<0.01	650			dry on 10/4/07	Intermittent
Waipi‘o	0.45	517	2.9	2.0	0.13 on 10/4/07	Intermittent
West Waipi‘o	0.30	554			0.007 on 10/10/07; dry on 10/29/20	Intermittent
East Waipi‘o	0.07	765			0.044 on 10/10/07	Intermittent
Hoalua	1.10	639	4.3	2.5	0.4 on 10/16/20	Intermittent
Hānawana	0.31	724	2.2	1.4	1.39 on 10/4/07; 1.3 on 8/8/11	Intermittent
Pa	0.21	724	1.3	0.80	0.044 on 10/18/07	Intermittent
Punalu‘u	0.14	663	0.86	0.55	0.55 on 10/16/07	Intermittent
West Kōlea	0.10	1270	0.47	0.25	1.53 on 10/31/07	Perennial
East Kōlea	0.07	1240	0.33	0.16	0.92 on 10/31/07	Perennial
Kōlea[1]	0.51	525	3.6	2.5	0.4 on 10/16/20	Perennial

[1]from Gingerich (2005)

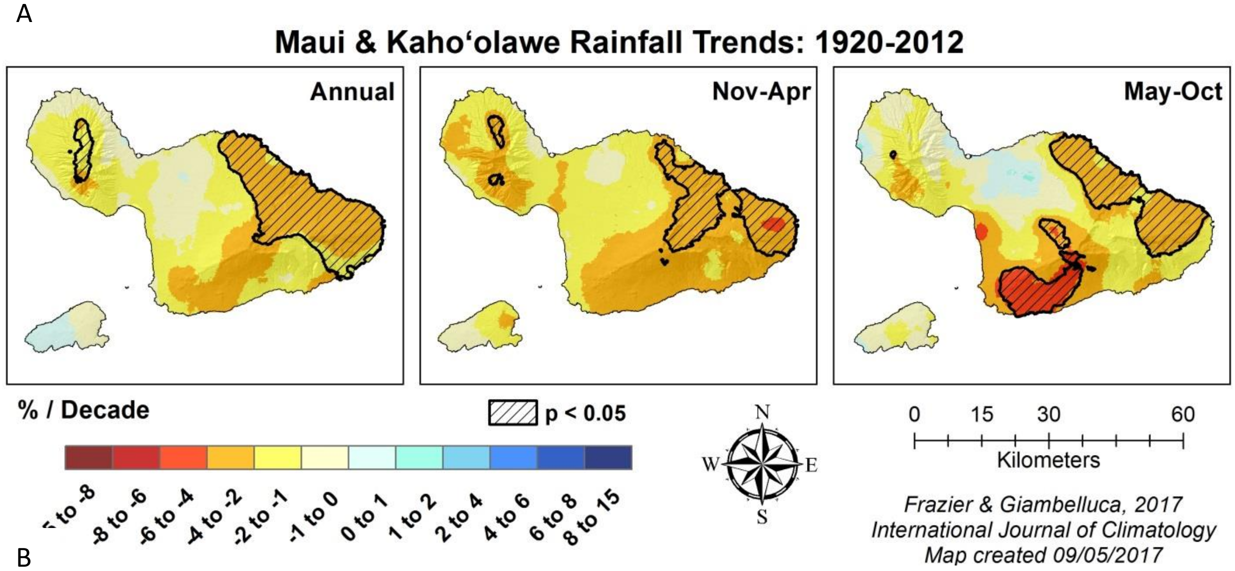
[2]regression estimates extended beyond the region they were developed and using data potentially outside of the original range of values may have errors different from those accepted in the original study

Long-term trends in rainfall and streamflow

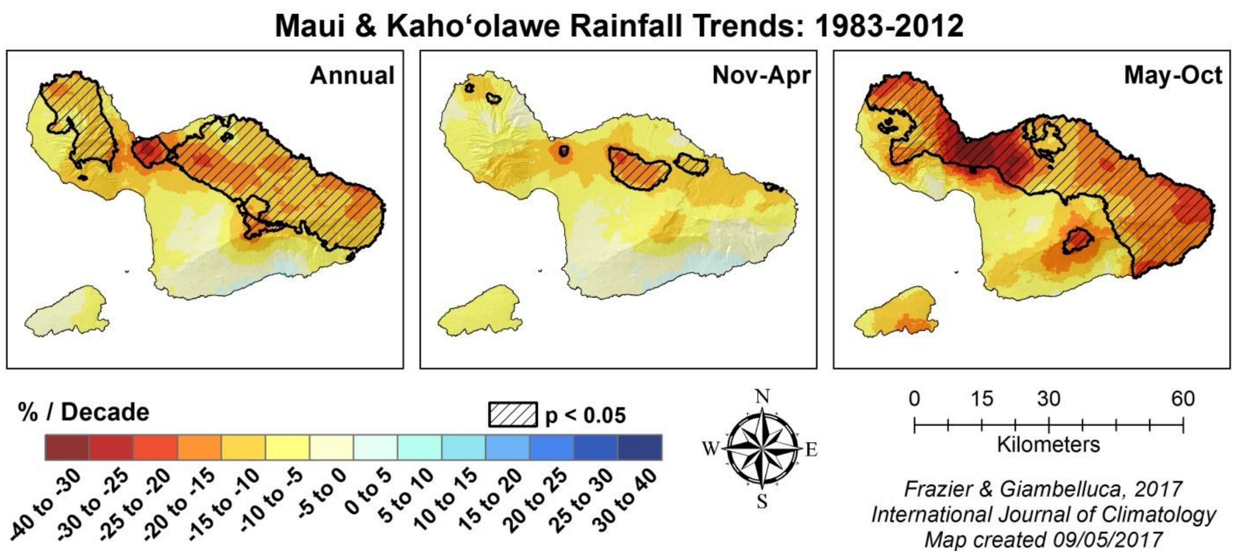
The climate has profound influences on the hydrologic cycle and in the Hawaiian Islands, shifting climate patterns have resulted in an overall decline in rainfall and streamflow. Rainfall trends are driven by large-scale oceanic and atmospheric global circulation patterns including large-scale modes of natural variability such as the El Nino Southern Oscillation and the Pacific Decadal Oscillation, as well as more localized temperature, moisture, and wind patterns (Frazier and Giambelluca, 2017; Frazier et al, 2018). Using monthly rainfall maps, Frazier and Giambelluca (2017) identified regions that have experienced significant ($p<0.05$) long-term decline in annual, dry season, and wet season rainfall from 1920 to 2012 and from 1983 to 2012. On Maui, much of the windward side of Haleakalā has experienced a significant decline in annual and seasonal rainfall from 1920 to 2012, and for most of the island from 1983-2012 (Figure 10).

Figure 10. Annual, wet season (Nov-Apr) and dry season (May-Oct) rainfall trends for the 1920-2012 (A) and 1983-2012 (B) periods, Maui. Hashed line areas represent significant trend over the period. (with permission from Frazier and Giambelluca, 2017)

A



B



5. Maintenance of Fish and Wildlife Habitat

When people in Hawai‘i consider the protection of instream flows for the maintenance of fish habitat, their thoughts generally focus on just a handful of native species including five native fishes (four gobies and one eleotrid), two snails, one shrimp, and one prawn. Table 6 below identifies commonly mentioned native stream animals of Hawai‘i.

Table 6. List of commonly mentioned native stream organisms. (Source: State of Hawai‘i, Division of Aquatic Resources, 1993)

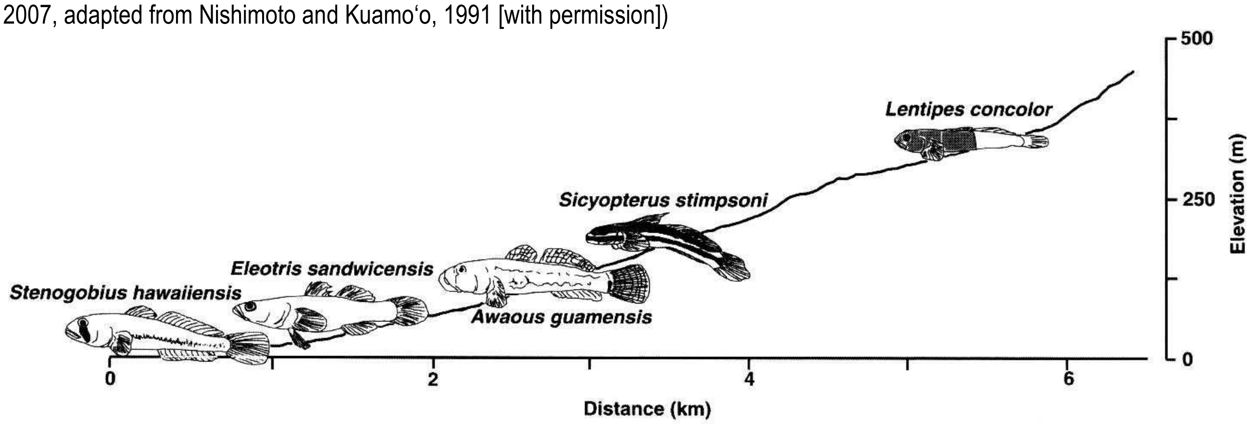
Scientific Name	Hawaiian Name	Type
Awaous stamineus	‘O‘opu nakea	Goby
Lentipes concolor	‘O‘opu hi‘ukole (alamo‘o)	Goby
Sicyopterus stimpsoni	‘O‘opu nopili	Goby
Stenogobius hawaiiensis	‘O‘opu naniha	Goby
Eleotris sandwicensis	‘O‘opu akupa (okuhe)	Eleotrid
Atyoida bisulcata	‘Opae kala‘ole	Shrimp
Macrobrachium grandimanus	‘Opae ‘oeha‘a	Prawn
Neritina granosa	Hihiwai	Snail
Neritina vespertina	Hapawai	Snail

Hawai‘i’s native stream animals have amphidromous life cycles (Ego, 1956) meaning that they spend their larval stages in the ocean (salt water), then return to freshwater streams to spend their adult stage and reproduce. Newly hatched fish larvae are carried downstream to the ocean where they become part of the planktonic pool in the open ocean. The larvae remain at sea from a few weeks to a few months, eventually migrating back into a fresh water stream as juvenile *hinana*, or postlarvae (Radtke et al., 1988). Once back in the stream, the distribution of the five native fish species are largely dictated by each species’ ability to traverse waterfalls (Nishimoto and Kuamoo, 1991). This ability to climb is made possible by a fused pelvic fin which forms a suction disk. *Eleotris sandwicensis* lacks fused pelvic fins and is mostly found in lower stream reaches. *Stenogobius hawaiiensis* has fused pelvic fins, but lacks the musculature necessary for climbing (Nishimoto and Kuamoo, 1997). *Awaous stamineus* and *Sicyopterus stimpsoni* are capable of ascending moderately high waterfalls (less than ~60 feet) (Fitzsimons and Nishimoto, 1990), while *Lentipes concolor* has the greatest climbing ability and has been observed at elevations higher than 3,000 feet (Fitzsimons and Nishimoto, 1990) and above waterfalls more than 900 feet in vertical height (Englund and Filbert, 1997).

Thus, the geology and topography of a stream influences the longitudinal gradient of species assemblage. Figure 11 illustrates the elevational profile of these native fresh water fishes. The presence, abundance, and distribution of species follows a distribution pattern that varies with the type of stream. Larger streams on older islands with terminal estuaries support all five species of fish, while narrow, steep gradient, boulder and bedrock-dominated streams with a terminal waterfall may only support a single species (*Lentipes concolor*). Further, in streams with high terminal waterfalls, *L. concolor* may only recruit to a short distance inland from the stream mouth when they encounter suitable habitat (McRae, 2007). Not all streams can support suitable habitat at all times. Streams that only flow in response to rainfall (ephemeral streams), or streams that naturally have reaches without baseflow (intermittent streams), or streams that lack suitable substrate, gradient, or riparian vegetation, may not support sufficient habitat to sustain a viable population (McRae, 2007).

The maintenance, or restoration, of stream habitat requires an understanding of, and the relationships among, the various components that impact fish and wildlife habitat, and ultimately, the overall viability of a desired set of species. These components include, but are not limited to, species distribution and diversity, species abundance, predation and competition among native species, similar impacts by alien species, obstacles to migration, water quality, and streamflow. The Commission does not intend to delve into the biological complexities of Hawaiian streams, but rather to present basic evidence that conveys the general health of the subject stream. The biological aspects of Hawai'i's streams have an extensive history, and there is a wealth of knowledge, which continues to grow and improve.

Figure 11. Elevational profile of a terminal-estuary stream on the Big Island of Hawai'i (Hakalau Stream). (Source: McRae, 2007, adapted from Nishimoto and Kuamo'o, 1991 [with permission])



Parham (2019) modeled total habitat units for each stream based on stream surveys conducted in 2017 and 2018 and analyzed the consequences of the IIFS established by the CWRM 2018 Decision & Order on habitat (Table 7). Division of Aquatic Resources (DAR) has also summarized the presence of native biota stream by stream, which helps visualize the natural distribution of species (Table 8).

Table 7. Total modeled habitat units (m^2) and percentage of total in East Maui under natural and 2018 Decision & Order (D & O) IIFS values for the original 24 petitioned streams and the 12 non-petitioned streams.

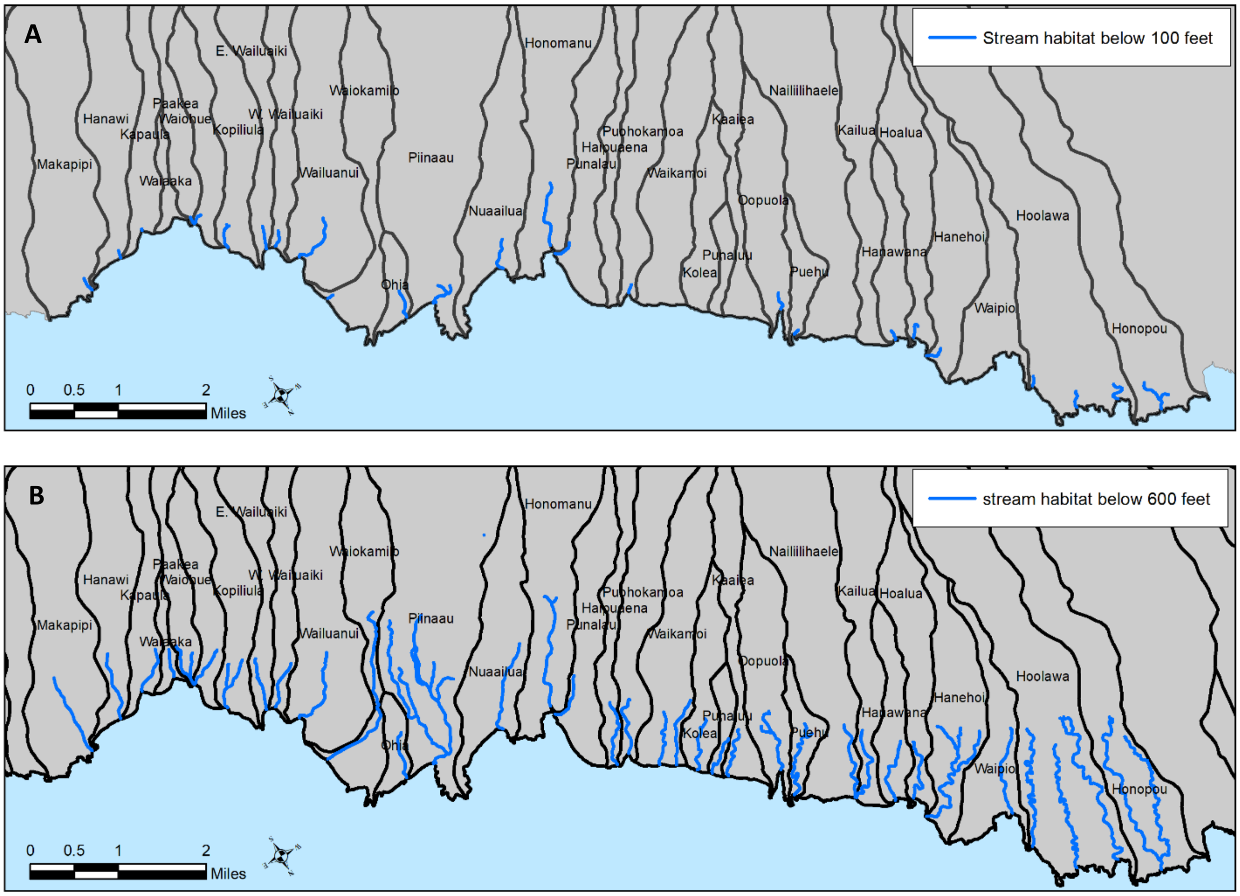
Scenario	24 Petitioned Streams	12 non-petitioned streams	total
Natural Conditions	1,392,812 (66.0%)	717,242 (34.0%)	2,110,054 (100.0%)
2018 D & O IIFS	1,075,132 (51.0%)	94,092 (4.5%)	1,169,224 (55.5%)

The available habitat that can be colonized by recruiting amphidromous species in East Maui varies with stream size, which is primarily a function of drainage area, rainfall, and geology. The length of stream that supports various assemblages of species can be differentiated by the elevation of the stream reach and the presence of waterfalls, as identified in Figure 12. The 24 petitioned East Maui streams in the license area account for 4.786 miles of potential low elevation (<100 feet above sea level) stream habitat (82.0%) while the other 12 non-petitioned streams represent 1.048 miles of potential low elevation stream habitat (18.0%). Similarly, of the available potential stream habitat including mid-elevation (<600 feet above sea level) reaches, the 24 petitioned streams account for 27.392 miles (73.8%) and the 12 non-petitioned streams account for 9.702 miles (26.2%), assuming the naturally occurring substrate and streamflow in all reaches can support freshwater biota.

Table 8. Total modeled habitat units, percent of total habitat units in license area streams, and presence of native stream biota by stream in East Maui.

stream	Habitat Units	Percent of Total	*Eleotris sandwicensis*	*Stenogobius hawaiiensis*	*Awaous stamineus*	*Sicyopterus stimpsoni*	*Lentipes concolor*	*Neritina granosa*	*Neritina vespertinus*	*Macro grandimanus*	*Atyoida bisulcata*
Makapipi	24,288	1.2%	X		X	X	X	X			X
Hānawī	126,408	6.0%	X	X	X	X	X	X			X
Kapaula	25,418	1.2%									
Waiaaka	0	0.0%									
Paʻakea	17,270	0.8%									
Waiohue	18,459	0.9%	X	X	X	X	X	X	X	X	X
Kopiliula	80,507	3.8%	X		X		X	X			X
E. Wailuaiki	60,737	2.9%	X		X		X	X			X
W. Wailuaiki	38,754	1.8%									X
Wailuanui	46,240	2.2%	X								X
Waiokamilo	37,792	1.8%									X
Piʻinaʻau	349,196	16.5%	X	X	X	X	X	X	X	X	X
Nuaʻailua	54,106	2.6%			X						X
Honomanū	108,859	5.2%									X
Punalau	14,527	0.7%			X	X	X				X
Haipuaena	40,496	1.9%					X				X
Puhokamoa	189,132	9.0%			X	X	X				X
Waihinepee	0	0.0%									
Waikamoi	40,068	1.9%									X
Kōlea	5,940	0.3%									
Punaluʻu	0	0.0%									
Kaaiea	28,013	1.3%									X
Oopuola	20,616	1.0%									
Puehu	0	0.0%									
Nailiilihaele	275,924	13.1%									X
Kailua	130,209	6.2%				X					X
Hānawana	2,633	0.1%									
Hoalua	24,959	1.2%									
Hanehoi	28,009	1.3%									
Waipiʻo	3,211	0.2%									
Mokupapa	0	0.0%									
Hoʻolawa	225,737	10.7%									X
Honopou	92,546	4.4%	X		X	X	X				

Figure 12. Stream reach lengths in the East Maui license area that would support low-elevation freshwater species (below 100 feet in elevation) (A) and mid-elevation freshwater species (below 600 feet in elevation) (B) as identified in Figure 11.



DAR Atlas of Hawaiian Watersheds

The State of Hawai‘i Division of Aquatic Resources (DAR) maintains a compilation of best available information relating to stream habitat and freshwater biota in the *Atlas of Hawaiian Watersheds and Their Aquatic Resources* for each of five major islands in the state (Kaua‘i, Hawai‘i, O‘ahu, Molokai, and Maui). Each atlas describes watershed and stream features, distribution and abundance of stream animals and insect species, and stream habitat use and availability. Based on these data, a watershed and biological rating is assigned to each stream to allow for easy comparison with other streams on the same island and across the state. The data presented in the atlases are collected from various sources, and much of the stream biota data are from stream surveys conducted by DAR. Currently, efforts have been focused on updating the atlases with more recent stream survey data collected statewide, and developing up-to-date reports for Commission use in interim IFS recommendations. A summary of the findings is provided in Table 9.

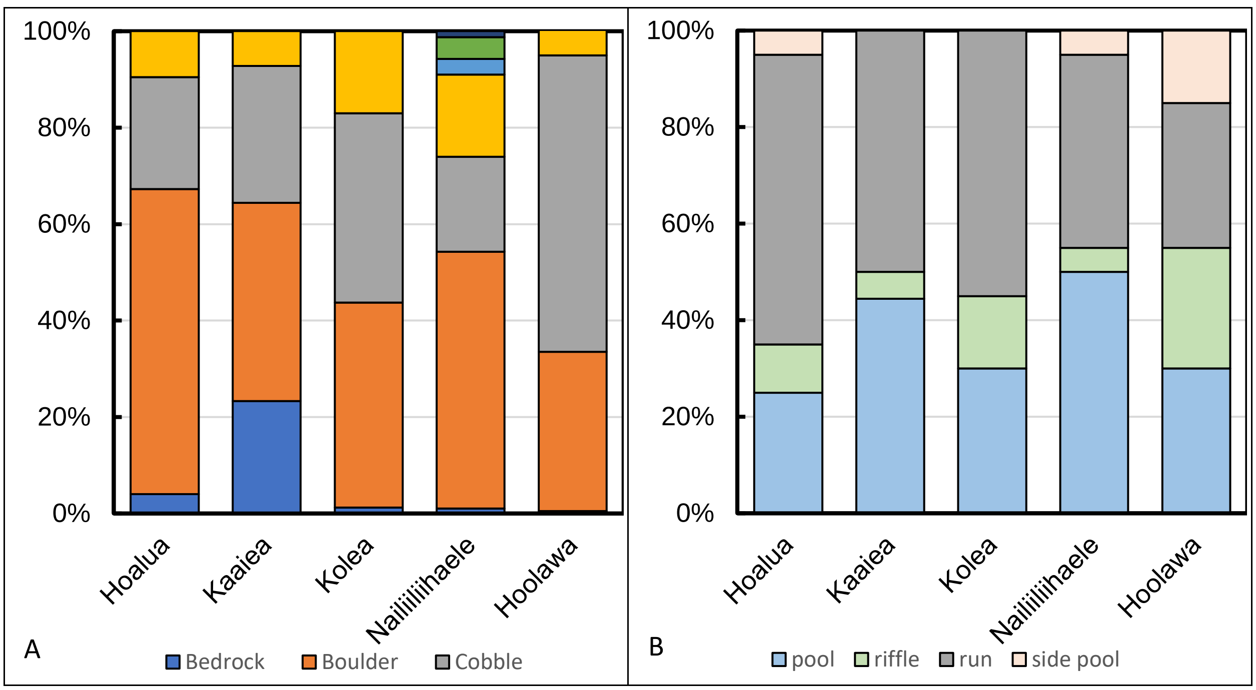
Table 9. DAR Atlas of Hawaiian Watersheds rankings for streams in the East Maui License Area, Maui. (ranking based on 10 > 9 > 8 > 7…..1 > 0) [NR = not ranked; blank, no watershed recognized**)**

Stream	Land Cover	Shallow Water	Stewardship	Size	Wetness	Reach Diversity	Native Species	Introduced Genera	Overall
Honopou	8	1	3	2	5	4	7	6	5
Hoʻolawa	10	0	5	2	6	4	2	10	6
Mokupapa									
Waipiʻo	9	0	4	1	5	3	NR	NR	NR
Hanehoi	9	0	5	2	6	4	1	6	4
Hoalua	10	0	6	1	7	3	NR	NR	NR
Hānawana	9	0	3	1	5	1	NR	NR	NR
Kailua	10	1	7	2	7	5	2	10	7
Nailiilihaele	10	0	6	3	8	5	NR	NR	6
Puehu									
Oopuola	9	1	5	2	7	3	NR	NR	NR
Kaaiea	9	0	5	1	7	3	NR	NR	NR
Punaluʻu									
Kōlea	9	0	5	1	6	2	NR	NR	NR
Waikamoi	9	0	8	2	5	5	2	8	6
Waihinepee									
Puhokamoa	10	0	6	2	9	5	3	10	7
Haipuaena	10	0	7	1	9	4	3	9	7
Punalau	10	0	6	1	8	2	2	9	6
Honomanū	9	0	7	2	8	6	7	9	8
Nuaʻailua	9	1	6	1	8	3	8	9	8
Piʻinaʻau	8	1	8	4	6	6	10	7	9
Ohia	8	0	3	1	6	0	3	9	5
Waiokamilo	9	0	5	1	8	5	2	8	5
Wailuanui	7	1	8	2	5	4	9	9	8
W. Wailuaiki	9	0	7	2	7	4	8	8	8
E. Wailuaiki	10	0	7	2	7	4	7	9	8
Kopiliula	10	0	7	2	7	5	8	9	8
Waiohue	10	0	6	1	10	2	10	9	8
Paʻakea	9	0	3	2	9	3	8	8	6
Waiaaka									
Kapaula	9	0	4	1	10	2	NR	NR	5
Hānawī	10	0	6	2	8	5	9	9	9
Makapipi	10	0	6	1	9	5	7	8	8

Recent Habitat and Biota Surveys

Staff from the Commission and the Division of Aquatic Resources have surveyed many of the streams in the East Maui license area for habitat and freshwater biota. Recent interest in the habitat available in the non-petitioned streams as well as the temporary (since the closure of HC&S in 2016) discontinuation of the lower elevation ditches (e.g., Spreckels Ditch at various elevations, Center Ditch at the 450 foot elevation, Lowrie Ditch at the 250 foot elevation, and the Haiku Ditch at more recently the150 foot elevation) prompted an analysis of the effects of four years of continuous flow from the mid-elevation reaches to the ocean. Many of the non-petitioned license area streams end in terminal waterfalls, limiting access to the terminal reaches. Thus, surveys focused on mid-elevation reaches at about the 150- to 250-foot elevation to assess habitat and recruitment of climbing species: *L. concolor*, *A. stamineus*, *S stimpsoni*, and *A. bisulcata*. Five streams were surveyed represented a range of sizes and stream flow conditions: Kōlea, Kaaiea, Nailiiliihaele, Hoalua, and Hoʻolawa. Each reach survey consisted of 20 point-quadrat biota and habitat surveys[15]. The suitability of each reach for each species was based on the composite suitability as determined by the Froude suitability (substrate), the depth suitability, and the velocity suitability, as detailed in Gingerich and Wolff (2005[16]) for East Maui Streams. General habitat data are provided in Figure 14, and the combined total area of weighted usable habitat per 1000 linear feet of stream reach provided in Figure 15. Despite the presence of substantial amounts of habitat, only 2 *A. bisulcata* were observed among all surveys (in Nailiiliihaele Stream).

Figure 14. Percent of total surveyed area by substrate (A) and habitat classification (B) for five non-petitioned streams in the East Maui license area at the 250 foot elevation.



[15] Higashi, G.R. and Nishimoto, R.T. (2007). The Point Quadrat Method: A Rapid Assessment of Hawaiian Streams. In: N.L. Evenhuis & J.M. Fitzsimons, Biology of Hawaiian Streams and Estuaries. Bishop Museum Bulletin in Cultural and Environmental Studies 3: 305-312.

[16] Gingerich, S.B., Wolff, R.H. (2005). Effects of surface-water diversion on habitat availability for native macrofauna, Northeast Maui, Hawaii. U.S. Geological Survey Scientific IUnvestigations Report, 2005-5213.

Figure 15. Area (ft²) of weighted usable habitat per 1,000 feet of stream by species for five non-petitioned streams in the East Maui license area at the 250-foot elevation.

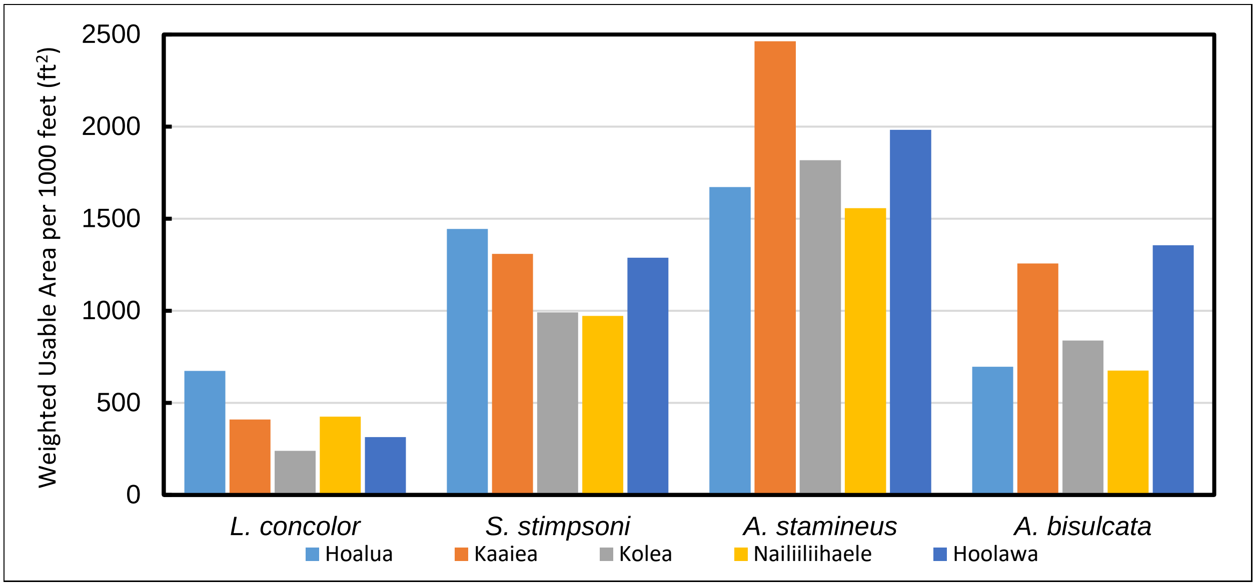
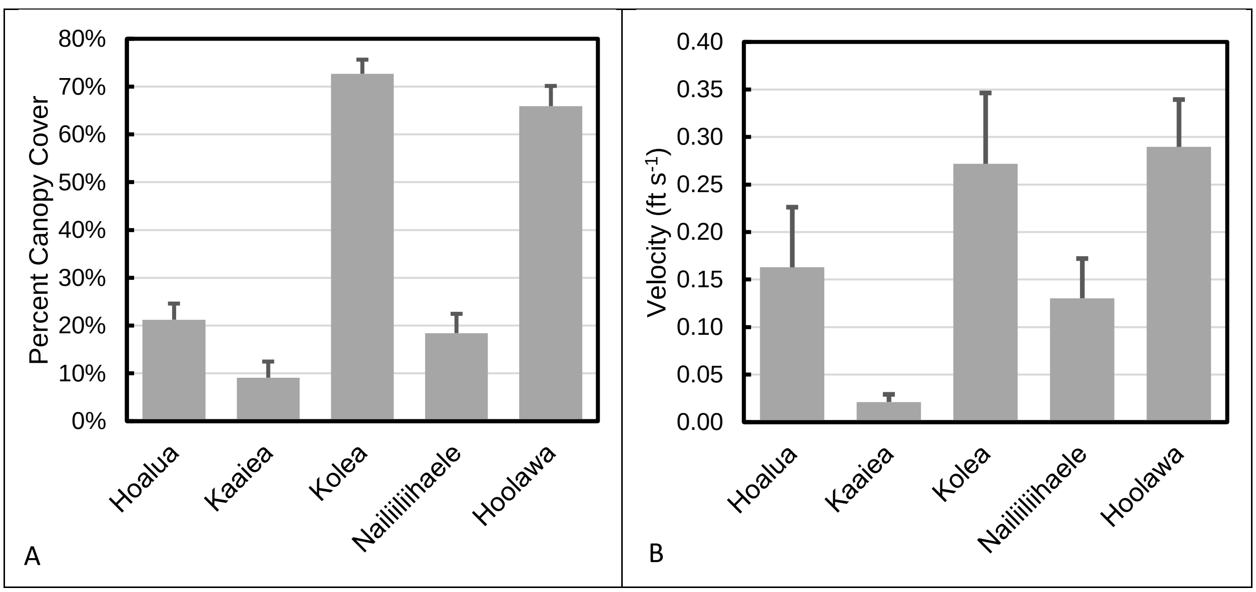


Figure 16. Mean (±standard error) (A) percent canopy cover and (B) velocity measured in the surveyed reach



Differences in the availability of habitat were largely due to the suitability of the surveyed reach to support each species. For example, some areas were ideal for supporting *A. stamineus* while others were more suitable for supporting *S. stimpsoni*, simply based on the depth, substrate, and velocity.

Implications of Diversion Structures to Upstream Migration and Larval Entrainment

Diversion structures and their intakes have the possibility to affect the recruitment of amphidromous species whose juvenile stage (*hinana*) migrate upstream from the ocean to suitable habitat for their adult lives. Such recruitment is dependent on the habitat quality and availability above the diversion to support species. In streams with no quality habitat or where upstream migration is affected by natural barriers (e.g., inland waterfalls), there is no recruitment and therefore no effect of the diversion on upstream migration. Likewise, in such streams where there is no natural recruitment to a particular reach, there are no reproductive adults that would produce larvae for entrainment downstream. The impact of a diversion on recruitment or entrainment is dependent on the species of interest, the elevation of the reach and diversion, habitat quality (i.e., riparian vegetation, substrate, habitat type), and interactions with non-native species (e.g., disease transmission, predation, competition). Streams with terminal waterfalls are not going to support the recruitment of *S. hawaiiensis* or *E. sandwicensis*. Large inland waterfalls are going to restrict the recruitment of *A. stamineus* and *N. granosa*. Closed canopies due to the dominance of non-native riparian vegetation (e.g., bamboo, albezia, hau bush, java plum, guava) will reduce the availability of algae as a food resource, increase carbon and nitrogen inputs from leaf litter and fruit production, increase runoff and sediment in the stream, and restrict the movement of species through the stream, all of which contribute to poor habitat quality. This is common in: Kōlea (bamboo, guava), Kaaiea (bamboo, guava), Oopuola (albezia, java plum, hau bush), Nailiiliihaele (bamboo), Kailua, (hau bush), Waipiʻo (hau bush, guava), and Hoʻolawa (guava, java plum). Thus, the non-petitioned streams support limited to no recruitment or reproduction and existing diversions have minimal impact on the life-history of native aquatic biota.

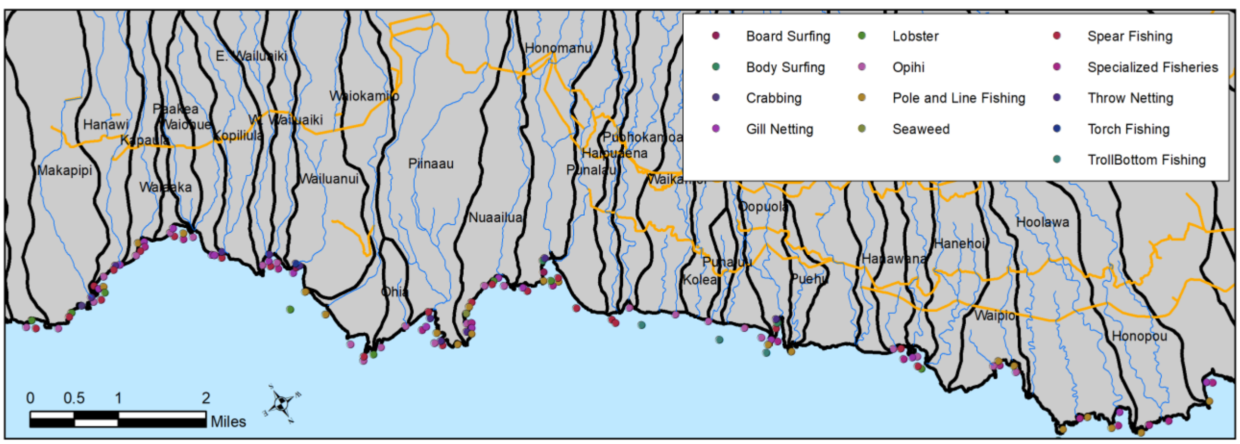
6. Outdoor Recreational Activities

Water-related recreation is an integral part of life in Hawaiʻi. Though beaches may attract more users, the value of maintaining streamflow is important to sustaining recreational opportunities for residents and tourists alike. Streams are often utilized for water-based activities, such as boating, fishing, and swimming, while offering added value to land-based activities such as camping, hiking, and hunting. Growing attention to environmental issues worldwide has increased awareness of stream and watershed protection and expanded opportunities for the study of nature; however, this must be weighed in conjunction with the growth of the eco-tourism industry and the burdens that are placed on Hawaiʻi's natural resources.

The Hawaiʻi Stream Assessment identified recreational opportunities in each hydrologic unit and did not recommend any of the non-petitioned streams for protection based on recreational values (National Park Service, 1990). Only Piʻinaʻau, Waiohue, and Hānawī streams were listed as candidate streams for protection based on their recreational resources in East Maui.

Since changes to streamflow and stream configurations have raised concerns regarding their impact to on-shore and near-shore activities, the Commission has also attempted to identify these various activities in relation to streamflow. A 1981 Hawaiʻi Resource Atlas, prepared by the State of Hawaiʻi Department of Transportation's Harbors Division, inventoried coral reefs and coastal recreational activities. Looking at available data, activities identified in the immediate vicinity of each stream, including ʻopihi collecting, gill netting, and pole and line fishing (Figure 13).

Figure 13. Coastal resources identified in the East Maui license area, Maui.



7. Hawaiʻi Stream Assessment Rankings

One of the earliest statewide stream assessments was undertaken by the Commission in cooperation with the National Park Service's Hawaiʻi Cooperative Park Service Unit. The 1990 Hawaiʻi Stream Assessment (HSA) brought together a wide range of stakeholders to research and evaluate numerous stream-related attributes (e.g., hydrology, diversions, gaging, channelizations, hydroelectric uses, special areas, etc.). The HSA specifically focused on the inventory and assessment of four resource categories: 1) aquatic; 2) riparian; 3) cultural; and 4) recreational. Though no field work was conducted in its preparation, the HSA involved considerable research and analysis of existing studies and reports. The data were evaluated according to predefined criteria and each stream received one of five ranks (outstanding, substantial, moderate, limited, and unknown). Based on the stream rankings, the HSA offered six different approaches to identifying candidate streams for protection: streams with outstanding resources (aquatic, riparian, cultural or recreational), streams with diverse or "blue ribbon" resources, streams with high quality natural resources.

Due to the broad scope of the HSA inventory and assessment, it continues to provide a valuable information base for the Commission's Stream Protection and Management Program and will continue to be referred to. The only streams that the HSA recommended being listed as candidate streams for protection in the East Maui License Area are Piʻinaʻau, Waiohue, and Hānawī (Table 10).

Table 10. Hawai'i Stream Assessment summary rankings for streams in the East Maui License Area, Maui. (ranking based on 4 > 3 > 2 > 1 > 0) [n/a = not assessed by the HSA**)**

Stream	Aquatics	Riparian	Cultural	Recreational	Diversity of Resources	Blue Ribbon Resources
Hoʻolawa	1	0	3	3		
Waipiʻo	0	0	0	0		
Hanehoi	0	0	0	0		
Hoalua	0	0	3	0		
Hānawana	0	0	3	2		
Kailua	2	0	3	3		
Nailiilihaele	1	0	0	2		
Puehu	0	0	0	0		
Oopuola	0	0	0	3		
Kaaiea	0	0	0	3		
Punaluʻu	n/a	n/a	n/a	n/a		
Kōlea	0	0	0	0		
Waikamoi	1	3	0	3		
Waihinepee	n/a	n/a	n/a	n/a		
Puhokamoa	1	3	0	3		
Haipuaena	1	0	0	2		
Punalau	1	0	0	0		
Honomanū	1	4	0	4		
Nuaʻailua	1	0	0	3		
Piʻinaʻau	4	4	0	4	AqRpRc	AqCu
ʻŌhiʻa	0	0	3	3		
Waiokamilo	0	0	0	4		
Wailuanui	4	3	3	4		
W. Wailuaiki	2	3	0	4		
E. Wailuaiki	2	4	0	4		
Kopiliula	2	4	0	3		
Waiohue	4	0	0	4	RcAq	Aq
Paʻakea	2	0	0	3		
Waiaaka	0	0	0	3		
Kapaula	1	0	0	3		
Hānawī	4	4	0	4	AqRpRc	AqRc
Makapipi	4	0	4	3		

8. Assessment of Noninstream Uses

Maui County DWS Upcountry Municipal System

There are five separate water systems operated by Maui County Department of Water Supply (Maui DWS) in East Maui: two groundwater systems and three surface water systems. The Upcountry Maui (sometimes referred to as Makawao or Kamole Weir) system is supported by water from the Kamole Weir on EMI's Wailoa Ditch, which supports the Kamole Weir surface water treatment facility (WTF). The Olinda (Upper Kula system) and Piiholo (Lower Kula system) surface water treatment facilities also serve the Upcountry region.

Kamole Weir WTF is Maui's largest surface water treatment plant, receiving water from the Wailoa Ditch, which supplements the primary groundwater sources (Haʻikū and Kuapakalua wells) for the region. This system also serves as backup in the event of pump failure or drought. The Kamole Weir WTF produces approximately 3.6 mgd, but is capable of producing 8 mgd at maximum capacity. The Kamole Weir WTF supplies water to approximately 6,571 water service connections and is capable of providing water to the entire Upcountry region (9,708 connections) if necessary. Maui DWS Upper Kula system is served by water diverted from Haipuaena and Waikamoi Streams; and Maui DWS Lower Kula is served by water diverted from Honomanū, Haipuaena, and Waikamoi Streams. Maui DWS themselves divert the streams for the Upper and Lower Kula systems; it is only the Makawao system whose source is the EMI system.

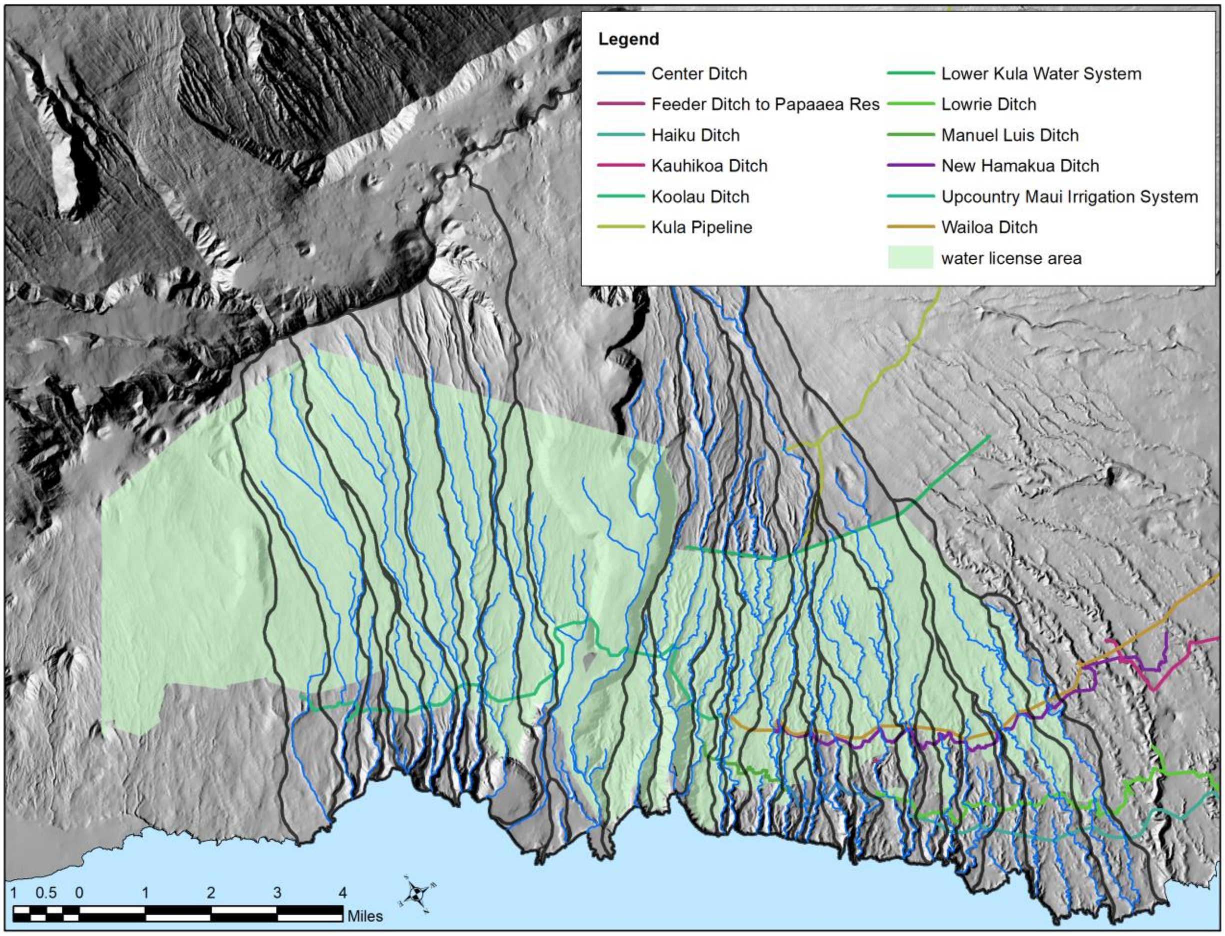
Agricultural Uses

Under the State Water Code, noninstream uses are defined as "water that is diverted or removed from its stream channel…and includes the use of stream water outside of the channel for domestic, agricultural, and industrial purposes." Article XI, Section 3 of the State Constitution states: "The State shall conserve and protect agricultural lands, promote diversified agriculture, increase agricultural self-sufficiency and assure the availability of agriculturally sustainable lands." Water is crucial to agriculture and agricultural sustainability. Article XI, Section 3 also states, "Lands identified by the State as important agricultural lands needed to fulfill the purposes above shall not be reclassified by the State or rezoned by its political subdivisions without meeting the standards and criteria established by the legislature and approved by a two-thirds vote of the body responsible for the reclassification or rezoning action." It is the availability of water that allows for the designation of Important Agricultural Lands.

East Maui Irrigation System

In total, the EMI system consists of 388 separate intakes, 24 miles of ditch, 50 miles of tunnel, twelve inverted siphons, and numerous small feeders, dams, intakes, pipes, and flumes. Supporting infrastructure includes 62 miles of private roads and 15 miles of telephone lines. The system primarily captures surface water from multiple watersheds in east Maui with a combined area of approximately 56,000 acres, of which 18,000 acres are owned by EMI, and the rest by the State of Hawaiʻi (Figure 13).

Figure 13. East Maui Irrigation system and State of Hawaiʻi East Maui Water License Area.



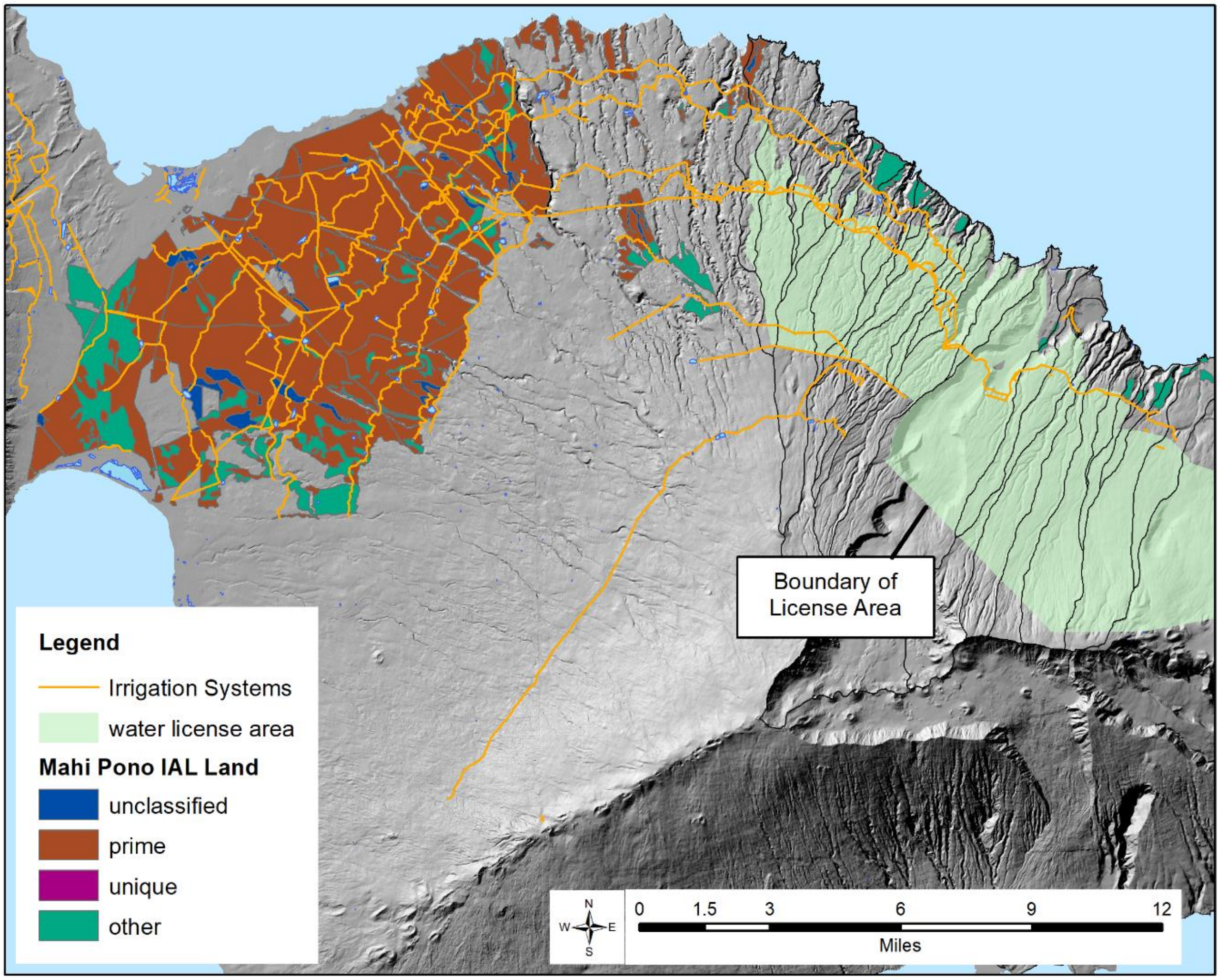
Utilization of Important Agricultural Lands

In 1977, the Agricultural Lands of Importance to the State of Hawaiʻi inventory was completed by the State Department of Agriculture (HDOA), with the assistance of the Soil Conservation Service (SCS), U.S. Department of Agriculture, and the University of Hawaiʻi College of Tropical Agriculture and Human Resources. Three classes of important agricultural lands (IAL) were established for Hawaiʻi in conjunction with the SCS in an effort to inventory prime agricultural lands nationwide (Figure). Hawaiʻi's effort resulted in the classification system of lands as: 1) Prime agricultural land; 2) Unique agricultural land; and 3) Other important agricultural land. Each classification was based on specific criteria such as soil characteristics, slope, flood frequency, and water supply. The IAL was intended to serve as a long-term planning guidance for land use decisions related to important agricultural lands.

Table 11. Agricultural Lands of Importance to the State of Hawaiʻi owned by Mahi Pono (formerly owned by Alexander & Baldwin) in the central valley, Maui. (Source: State of Hawaiʻi, Office of Planning, 2015g)

Type	Square miles	Acres
Prime land	2.851	1824.6
Unique land	53.377	34161.3
Unclassified land	0.01	6.4
Other lands	10.832	6932.5

Figure 14. Important Agricultural Lands (IAL) owned by Mahi Pono fed by the East Maui Irrigation System



Irrigation Needs of Diversified Agriculture

The State of Hawai'i Department of Agriculture uses a baseline irrigation rate of 3,400 gallons per acre per day (gad) to calculate the irrigation water demand for diversified agriculture. While this average may be applicable across a broad range of soil and climate conditions using particular irrigation practices with some crops, it does not help in the estimation of the actual water demands for crops frown in the field.

The Commission funded the development of a GIS-based software program the utilizes the state of Irrigation Water Requirement Estimation Decision Support System, IWREDSS. IWREDSS is an ArcGIS-based numerical simulation model that estimates irrigation requirements (IRR) and water budget components for different crops grown in the Hawaiian environment. The model accounts for different irrigation application systems (e.g., drip, sprinkler, flood), and water application practices (e.g., field capacity versus fixed depth). Model input parameters include rainfall, evaporation, soil water holding capacities, depth of water table, and various crop water management parameters including length of growing season, crop coefficient[17], rooting depth, and crop evapotranspiration. Overall, the model is an appropriate and practical tool that can be used to assess the IRR of crops in Hawai'i.

Understanding that water demand is highly site, weather, application, and crop dependent, IWREDSS can still provide a useful approximation of water needs. The simulation estimated that the IRR for various crops proposed for the central valley grown on TMK 2-3-8-003-005 (a randomly chosen parcel) ranges from 2250-3100 gallons per acre per day, depending on the drought scenario (Table 12). The model calculates IRR based on long-term rainfall records available at the weather stations located nearest to the fields. Thus, the estimated IRR represents an average value for given drought scenarios as opposed to average or wet year conditions. However, the estimated IRR for the relative drought year frequencies could be extrapolated to represent the highest demand scenarios. Alternatively, water demand per tree can be used based on the number of trees planted.

In the Commission's 2018 D&O, a balance of instream uses and sufficient water to meet non-instream agricultural and municipal needs was met. Based on long-term median flow estimates of water availability as well as the supply of water from non-petitioned streams, the Commission estimated that approximately 110.6 cfs (71.5 mgd) would be the median flow available for non-instream uses after 10.5 cfs were used by Maui DWS at the Kamole WTP and Kula Agricultural Park (total median diverted flow of 121.1 cfs). The Draft EIS for the East Maui Water Lease[18] estimated that approximately 142.8 cfs (92.32 mgd) could be diverted while maintaining the interim IFS for use on the 22,254 acres of land designated as IAL. Based on the IRR values for proposed crops (Table 12), this should be sufficient to meet the irrigation needs of the proposed diversified agricultural plan. Additional acreage (up to 36,000 acres are available) is also likely to be developed into pasture or row crops with variable water requirements.

Table 12. Mean drip irrigation demand estimates for various crops grown in central Maui based on IWREDSS scenarios modeled using the trickle drip irrigation method given a 10 ft depth to water table. Irrigation Requirement (IRR) value in gallons per acre per day.

	estimated irrigation demand (gallons/acre/day) for a given drought frequency			
crops	1 in 2 (50%)	1 in 5 (20%)	1 in 10 (10%)	1 in 20 (5%)
citrus	2258	2407	2474	2524
avocado	2516	2773	2891	2980
sweet potatos	2738	2927	3010	3073
coffee	2514	2741	2843	2921

Current Agricultural Demands

Water from the EMI ditch system was used historically for sugarcane cultivation, domestic water supply, and small diversified agriculture. In 2016, Alexander and Baldwin closed the HC&S sugar plantation. Following the closure, irrigation demand dropped to approximately 20 mgd, as Alexander and Baldwin transitioned to a diversified agricultural plan, with 6 to 8 mgd used by Maui DWS, 1 mgd used by HC&S's cattle operation, 2 mgd used for bioenergy crops, and 6 mgd used to maintain reservoirs for fire protection. The EMI system also services Maui DWS at Kamole Weir and the Kula Agricultural Park

[17] Crop coefficient is an empirically derived dimensionless number that relates potential evapotranspiration to the crop evapotranspiration. The coefficient is crop-specific.
[18] http://oeqc2.doh.hawaii.gov/EA_EIS_Library/2019-09-23-MA-DEIS-East-Maui-Water-Lease.pdf

which services diversified agricultural needs. In 2018, the land owned by HC&S and EMI were sold by Alexander and Baldwin to Mahi Pono, a new diversified agricultural company, who also purchased a 50% stake in East Maui Irrigation Co. Currently, the transition to a larger diversified agriculture operation is ramping up with water demands increasing as more acerage is planted. Mahi Pono began planting orchard crops and growing diversified agricultural crops in 2018, with increased production each year (Table 13).

Table 13. Crop category, acreage, estimated irrigation demand, and water demand by crop in the 2019 Farm Plan proposed by Mahi Pono for 2020.

Crop Category	Acreage	Year to be planted	Irrigation Demand (gad)	Crop Water Demand (mgd)
Lemon	125	2019/2020	2407	0.301
Lime	800	2019/2020	2407	1.926
Mandarins	400	2020	2407	0.963
Orange	350	2019/2020	2407	0.842
Coffee	350	2020	2741	0.959
Community Farm Project	650	2020	3400	2.210
Cover crops	400	2019	2000	0.800
Sweet Potato	470	2019	2927	1.376
Nursery	510	TBD		
Row Crops	430	TBD		
Avocado	275	2019/2020	2773	0.763
Macadamia nut	1000	2019/2020	300	0.300
Dragon Fruit	25	2020	522	0.013
Guava	20	2019/2020	625	0.013
Lilikoi	35	2019	18	0.001
Papaya	15	2020	8690	0.130
White Pineapple	3	2019	3037	0.009
Total	5858			10.6

9. Indicators of Successful Conservation of Streams

The Commission has the responsibility of establishing IFS on a stream-by-stream basis whenever necessary to protect the public interest in the waters of the State. Early in its history, the Commission recognized the complexity of establishing IFS for the State's estimated 376 perennial streams. Based on a number of criteria, including the Hawai‘i Stream Assessment, the recommendations prepared by the Stream Protection and Management Task Force, petitions to the amend the IIFS, and complaints filed with the Commission related to conflicting water usage, the Commission has a prioritization process for establishing IIFS statewide.

When it comes to a regional management strategy for protecting instream uses, while providing for the reasonable and beneficial uses of water, the Commission relies upon the expertise of Commission staff, other Divisions within the Department of Land and Natural Resources, the US Geological Survey, the US Fish and Wildlife Service, and scientists from the University of Hawai‘i and elsewhere. Successful management of biota requires an understanding of life-history characteristics, metapopulation dynamics (i.e., source-sink populations, alpha and beta diversity), and knowledge of the habitat potential in each stream. Some streams may naturally provide better conditions for successful survival, reproduction, and recruitment than others. Simply managing for population density or biodiversity for a given stream reach may not be appropriate. Like many marine species, stochastic events within the marine environment lead to high mortality. In addition to this, amphidromous species experience high mortality as free-embryos migrate to the ocean once they hatch. Thus, biological, hydrological, geomorphic, and anthropogenic factors along the stream channel may affect survival. For example, naturally occurring mid-reach plunge pools, side pools, and backwater eddies are abundant in East Maui stream reaches, but result in low velocity habitats which increases mortality of free-embryos. These pools also support introduced poecilid fishes that prey upon free-embryos as well as transfer parasitic diseases to recruiting juveniles and adults.

In the 2018 D&O, the Commission's expectation is that restoring flows to streams that are spread out geographically will: 1) provide greater protection against localized habitat disruptions; 2) produce a wider benefit to estuarine and near-shore marine species; and 3) result in improved comprehensive ecosystem function across the entire East Maui license area. To this extent, the 2018 D&O fully restored streams spread out across the entire breadth of the license area, with particular attention to streams that support populations of all five endemic freshwater fishes such as Honomanū, Pi‘ina‘au, West Wailuaiki, and Waiohue. Streams of smaller size, streams with terminal waterfalls, and streams that had limited habitat value, were given lower priority.

Streams recognized with substantial riparian value that support traditional and customary gathering practices, instream recreational value, and aesthetic value were also prioritized with restoration. Without substantial investment in the management of invasive riparian vegetation along with the removal of aquatic invasive species, it is unlikely that flow restoration in these streams will substantially affect the broader meta population of native aquatic species.

Thus, successful freshwater ecosystem management does not necessitate full or partial restoration of all streams. Rather a focus on the restoration of specific streams that provide the greatest reproductive potential which serve as source populations for other streams. Management must also consider the maintenance of stream vegetation and the control of non-native aquatic species.