United States Department of the Interior

U.S. GEOLOGICAL SURVEY
Pacific Islands Water Science Center
677 Ala Moana Blvd., Suite 415
Honolulu, Hawaii 96813

Phone: (808) 587-2400/Fax: (808) 587-2401

October 31, 2014

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Mr. Lawrence H. Miike, Hearings Officer
State of Hawai'i
Department of Land and Natural Resources
Commission on Water Resource Management
P.O. Box 621
Honolulu, Hawai'i 96809

Dear Mr. Miike:

Subject: Written testimony pertaining to USGS studies in East Maui Streams

The U.S. Geological Survey (USGS) published two reports in 2005 based on the results of our three-year cooperative study with the Commission on Water Resource Management (CWRM) to assess streamflow and stream-macrofauna characteristics in east Maui, Hawaii. The reports are:

Gingerich, S.B., 2005, Median and Low-Flow Characteristics for Streams under Natural and Diverted Conditions, Northeast Maui, Hawaii: Honolulu, HI, U.S. Geological Survey, Scientific Investigations Report 2004-5262, 72 p.

and

Gingerich, S.B. and Wolff, R.H., 2005, Effects of surface-water diversions on habitat availability for native macrofauna, northeast Maui, Hawaii: U.S. Geological Survey Scientific Investigations Report 2005-5213, 93 p.

The reports are available on the Internet at http://pubs.usgs.gov/sir/2004/5262/ and http://pubs.usgs.gov/sir/2005/5213/.

Diverted and Undiverted Streamflow Statistics

Median and low-flow statistics were estimated and are presented for continuous-record gaging sites and for other sites where various amounts of streamflow data are available, as well as for locations where no data are available. Records of daily mean flows were used to determine flow-duration, low-flow frequency, and base flow statistics for continuous-record stream-gaging stations in the study area following USGS established standard methods. Duration discharges of 50- and 95-percent were determined from total-flow and base-flow data for each continuous record. In order to compare streamflow records to each other, records were adjusted to concurrent periods, so that differences between the records were due to differences in climatic or drainage-basin characteristics and not to the fact that the records cover different times. The index-station method was used to adjust all of the streamflow records to a common period with the gaging station on West Wailuaiki Stream, which was chosen as the index station because of its record length (1914–2003) and favorable geographic location near the middle of the study area.

For the drainage basin of each continuous-record gaged site and selected ungaged sites, morphometric, geologic, soil, and rainfall characteristics were quantified using GIS techniques. Regression equations relating the streamflow statistics to basin characteristics of the gaged basins were developed using ordinary-least-squares regression analyses. Rainfall rate, maximum basin elevation, and the elongation ratio of the basin were the basin characteristics used in the final regression equations for 50-percent duration total flow and base flow. Rainfall rate and maximum basin elevation were used in the final regression equations for the 95-percent duration total flow and base flow. The proportion of the variation in the dependent variable that is explained by the independent variables (R^2) ranged from 94.9 to 75.3 percent, with the highest flows having the highest R^2. Standard errors of prediction ranged from 20.9 to 56.5 percent, with the highest flows having the lowest errors. The relative errors between observed and estimated flows ranged from 11 to 20 percent for the 50-percent duration total flow and from 29 to 56 percent for the 95-percent duration total flow and base flow.

The regression equations developed for this study were used to determine the 50-percent duration total flow, 50-percent duration base flow, 95-percent duration total flow, and 95-percent duration base flow at selected ungaged sites within the study area and at three gaging stations west of the study area using the appropriate basin characteristics. Estimated streamflow, prediction intervals, and standard errors were determined for 47 ungaged sites in the study area and four gaging stations west of the study area. Relative errors were determined for sites for which observed values of 95-percent duration discharge of total flow were available. East of Ke'anae Valley, the 95-percent duration discharge equation generally underestimated flow, and within and west of Ke'anae Valley, the equation generally overestimated flow.

Finally, most-reliable estimates of natural (undiverted) and diverted streamflow flow-duration statistics at gaged and ungaged sites on 21 streams in the study area were made using a combination of continuous-record gaging-station data, low-flow measurements, and values determined from the regression equations developed as part of this study. Average reduction in the low flow of streams due to diversions ranges from 55 to 60 percent.

Relating Streamflow to Habitat Availability

Five streams (Waikamoi, Honomanū, Wailuanui, Kopiliula, and Hanawī Streams) were chosen as representative streams for intensive study on the basis of several factors, including the amount of flow downstream of major surface-water diversions, stream terminus, impacts from human activities, existing hydrologic and biologic data, geographic location, and access. These five streams represent most of the range of hydrologic conditions encountered in the study area. On each of the five selected streams, representative reaches were selected immediately upstream of major diversions, midway to the coast, and near the coast.

This study focused on some of the native fish, snails, and shrimp species found in Hawaiian streams. Three of the five native fish species were observed in sufficient abundance for consideration in the study. The three fish species considered were the endemic gobies ʻalamoʻo and nōpili, and the indigenous goby nākea. The ʻakupa was not observed in abundances large enough to consider and the teardrop goby naniha was not observed during this study. The hīhīwai and ʻōpae abundances were also sufficient for consideration in the study.

Habitat selection models are widely used to evaluate habitat quality and predict effects of habitat alteration on animal populations. One habitat selection model for fish, the Physical Habitat Simulation System (PHABSIM) has been a basis for management decisions at hundreds of water projects in many countries, and similar approaches are widely used for managing terrestrial wildlife habitat. This model incorporates hydrology, stream morphology and microhabitat preferences to create relations between streamflow and habitat availability. PHABSIM simulates habitat/discharge relations for various species and life stages and allows quantitative habitat comparisons at different streamflows of interest.

A 300- to 500-ft length of channel was investigated at each of the intensively studied reaches on the five intensively studied streams to collect data that could be used for habitat modeling of the reaches. Each study reach was stratified at the level of three habitat types: riffle, run, and pool. The individual reach lengths were summed by habitat type and the proportion of each habitat type within the reach was calculated. Seven to ten transects were located randomly within each reach, with the number of transects per habitat type based on the proportion of the habitat type within the reach. Hydrological data were collected at 1-ft intervals along each transect to characterize hydraulic and geomorphologic conditions. At each interval, depth and velocity were measured and a substrate type was determined and the number and size of each species in a 1-ft by 2-ft area was noted. Additional habitat-related information including flow regime, potential channel width, active channel width, riparian density, canopy cover, and stream-bank substratum were recorded at each transect.

Overall hydrologic conditions in the study area were drier than normal during the period when stream reaches were intensively studied (7/30/02–7/23/03). Median daily streamflow at the U.S. Geological Survey gaging station on West Wailuaiki Stream during this period was 5.6 ft3/s, whereas long-term median daily streamflow (1914–2001) was 10 ft3/s. Most of the habitat and streamflow measurements were made during base-flow conditions, when all flow was diverted and only the flow gained downstream of the diversion was measured. Streamflow, measured at the time that habitat measurements were made, was below the estimated median total flow for each respective stream reach at 9 of the 15 sites and below the estimated median base flow at 6 of the 15 sites.

Intensive study and subsequent habitat modeling was limited to five reference streams of the 22 named streams flowing to the ocean in the study area. The effects of streamflow on habitat in the other streams were therefore estimated using information gathered using a variety of techniques including field reconnaissance, aerial digital photography of the streams, and geographic information system (GIS) analysis of stream and stream-basin characteristics.

The availability of aquatic habitat was estimated for diverted and undiverted conditions at the intensively studied stream sites using PHABSIM. Hydrologic data, collected over a range of low-flow discharges, were used to calibrate hydraulic models of selected transects across the streams. The models were then used to predict water depth and velocity (expressed as a Froude number, a combination of depth and velocity) over a range of discharges up to estimates of natural median streamflow. The biological importance of the stream hydraulic attributes was then assessed with the suitability criteria for each native species and life stage (adult and juvenile ʻalamoʻo, adult and juvenile nōpili, adult nākea, hīhīwai, and ʻōpae) developed as part of the study to produce a relation between discharge and habitat availability. The final output was expressed as a weighted habitat area of streambed for a representative stream reach.

PHABSIM model results were presented in plots showing the area of estimated usable bed habitat over a range of streamflow that includes the diverted and natural base-flow estimates. The results were also presented as habitat relative to natural conditions with 100 percent of natural habitat at natural median base flow and 0 percent of habitat at 0 streamflow. In general, the plots show a decrease in habitat for all species as streamflow is decreased from natural conditions. The exception is at Hanawi lower and middle sites, where the habitat amount available under diverted conditions is virtually the same as would be available under natural conditions. The results also indicate that only minor differences in habitat exist for the adult and juvenile nōpili, adult nākea, and hīhīwai. At most of the middle sites, more habitat is available for ʻōpae than for ʻalamoʻo at a given streamflow.

Several different measures were presented to show the relation between streamflow and habitat. The relative amount of habitat available at diverted conditions compared to expected natural conditions ranges from 0 percent at the Honomanū lower site, which is dry at diverted conditions, to about 100 percent at the Hanawi lower and middle sites, where Big Spring maintains steady streamflow. The diverted sites downstream of only one diversion have about 50 to 57 percent of their expected natural habitat, and the site downstream of two major diversions (Waikamoi middle-lower) has about 27 to 46 percent of expected natural habitat. ʻŌpae habitat for diverted conditions is as low as 40 percent at the Waikamoi middle-lower site to as much as 95 percent at the Hanawi middle site.

At six sites, a streamflow of about 1 ft^3/s will maintain 50 percent of the expected natural habitat and a streamflow of about 4 ft^3/s will maintain 90 percent of the expected natural habitat. At Kopiliula lower, about 2.6 ft^3/s is needed to maintain 50 percent of the expected natural habitat and about 7.6 ft^3/s is needed to maintain 90 percent of the expected natural habitat. For ʻōpae, greater than 50 percent of the expected natural habitat is already maintained at the diverted conditions. Streamflow of about 4 ft^3/s will maintain 90 percent of the expected natural ʻōpae habitat.

The relative amount of expected habitat available at 50 percent of natural median base flow ranges from 70 to 92 percent, and maintaining 90 percent of base flow results in 94 to 101 percent of expected natural habitat in the stream reaches. For ʻōpae, maintaining 50 percent of natural median base flow results in 82 to 92 percent of expected natural ʻōpae habitat, and flows at 90 percent of natural median base flow result in relative habitat of 97 to 99 percent of expected natural ʻōpae habitat.

Habitat-duration curves show the percentage of time that indicated habitat conditions would be equaled or exceeded and are based on the available estimates of flow duration at each stream reach developed earlier in the study for Q50 and Q95 of total flow and base flow.

The PHABSIM modeling results from the intensively studied streams were normalized to develop relations between the relative base flow in a stream at diverted conditions and the resulting amount of habitat available in the stream. The relations can be used to estimate relative habitat for diverted streams in the study area that were not intensively studied. The relations are valid for streams that are not dry. The model results indicate that the addition of even a small amount of water to a dry stream has a significant effect on the amount of habitat available.

The effects of streamflow on habitat in non-intensively studied streams was estimated using information gathered using a variety of techniques, including the use of the relation between streamflow diversion and habitat change and the field reconnaissance, aerial digital photography of the streams, and GIS analysis of stream and stream-basin characteristics. Estimates of the relative habitat range from 100 percent for stream sites with relatively small or no diversion to 0 percent for stream sites that are dry due to diversion. The maximum relative habitat at a stream site that is not dry is about 37 percent of expected natural habitat for ʻalamoʻo, nōpili, nākea, and hīhīwai and 58 percent of expected natural habitat for ʻōpae at the Haipuaʻena middle-lower site, where the base flow is about 10 percent of natural conditions.

Application of the Habitat-Study Results

After the release of the two reports, the USGS met with CWRM staff to provide additional support in using the results from the habitat study. The USGS prepared a table for discussion with example applications of the curves and data presented in the reports. This table is attached. This information is intended to provide relative estimates of the change in aquatic habitat due to surface-water diversions. Other factors of importance in determining whether a particular species will inhabit a stream reach include the available recruitment pool, food source, the presence of predatory alien species, and high flow events in the streams. Where "bottlenecks" prevent the upstream migration of species, care must be taken to consider if a particular species would be expected to inhabit a stream reach. The large waterfalls on many streams in the study area generally prevent the upstream migration of all but ʻōpae and ʻalamoʻo. Therefore, it is not appropriate to estimate habitat changes for the other species upstream of large waterfalls and usually not appropriate to estimate ʻōpae and ʻalamoʻo habitat downstream of the same large waterfalls. Dry stream reaches are "bottlenecks" to any species migration, and changes in habitat in upstream reaches are not relevant if the species cannot migrate upstream to inhabit these reaches.

As noted in the USGS report, many factors that affect the presence of native aquatic species in northeast Maui were beyond the scope of the study and not addressed, including:

1. What is the effect of alien species on the migration and living conditions of the native species?
2. What is the fate of animals upon reaching a dry stream reach during upstream migration?
3. At what rate and at what locations will native species population return to natural levels if diversions were removed?

4. Why were ʻōpae seen in abundance above the major diversions but ʻalamoʻo were not observed at all?
5. To what extent do native and alien species use the diversion ditches and tunnels for migration between streams?
6. What is the effect of taro loʻī on the migration and life cycle of native species?
7. What are the effects of stream diversions on native aquatic insect species?

This study was not designed to address these issues nor the other considerations for instream flow standards such as offstream uses, taro cultivation, or aesthetics. The mechanisms by which the various components of instream flow requirements are integrated and the relative importance they are assigned within the water-management decision process was beyond the scope of this study.

If you have any questions or would like more information about this study, please feel free to contact me at 587-2411 or by e-mail at sbginger@usgs.gov.

Sincerely,

Stephen B. Gingerich

Stephen B. Gingerich
Research Hydrologist

Attachment

Summary of median base flow and potential habitat at median base flow in diverted stream reaches, northeast Maui, Hawaii.

Percentages of target habitat restoration are hypothetical example applications of the study results for descriptive purposes only and do not imply endorsement by the U.S. Geological Survey or the Staff of the Commission on Water Resource Management

[ft^3/s, cubic foot per second, d.s.; downstream]

Stream reach	Median base flow remaining in stream (ft^3/s)		Minimum flow [17% natural median base flow] needed in stream to provide 50 percent of natural habitat (ft^3/s)	Minimum flow [25% natural median base flow] needed in stream to provide 60 percent of natural habitat (ft^3/s)	Minimum flow [36% natural median base flow] needed in stream to provide 70 percent of natural habitat (ft^3/s)	Minimum flow [48% natural median base flow] needed in stream to provide 80 percent of natural habitat (ft^3/s)	Minimum flow [64% natural median base flow] needed in stream to provide 90 percent of natural habitat (ft^3/s)	Comments
	Diverted conditions	Natural (undiverted) conditions						
Makapipi upper		1.3	0.22	0.33	0.47	0.62	0.83	losing stream
Hanawi upper		4.6						
directly d.s. of diversion	0	4.6	0.78	1.2	1.7	2.2	2.9	
middle	19	24	4.1	6.0	8.6	12	15	
lower	21	26	4.4	6.5	9.4	12	17	
Kapaula upper		2.8						
directly d.s. of diversion	0	2.8	0.48	0.70	1.0	1.3	1.8	
middle	2.1	5.1	0.87	1.3	1.8	2.4	3.3	
lower	2.6	5.7	0.97	1.4	2.1	2.7	3.6	
Waiaaka middle	0.77	0.77	0.13	0.19	0.28	0.37	0.49	
lower	1.1	1.1	0.19	0.28	0.40	0.53	0.70	
Paakea upper		0.90						
directly d.s. of diversion	0	0.90	0.15	0.23	0.32	0.43	0.58	
middle	3.8	4.7	0.80	1.2	1.7	2.3	3.0	
lower	4.6	5.5	0.94	1.4	2.0	2.6	3.5	
Waiohue upper		5.0						
directly d.s. of diversion	0	5.0	0.85	1.3	1.8	2.4	3.2	
middle	1.0	6.0	1.0	1.5	2.2	2.9	3.8	
lower	2.1	7.5	1.3	1.9	2.7	3.6	4.8	
Puakaa upper		1.1						
directly d.s. of diversion	0	1.1	0.19	0.28	0.40	0.53	0.70	
middle	1.1	2.2	0.37	0.55	0.79	1.1	1.4	
Kopiliula upper		5.0						
directly d.s. of diversion	0	5.0	0.85	1.3	1.8	2.4	3.2	
middle	1.2	6.5	1.1	1.6	2.3	3.1	4.2	
lower	2.8	9.5	1.6	2.4	3.4	4.6	6.1	
East Wailuaiki upper		5.8						
directly d.s. of diversion	0	5.8	0.99	1.5	2.1	2.8	3.7	
middle	1.0	6.8	1.2	1.7	2.4	3.3	4.4	
lower	1.5	7.2	1.2	1.8	2.6	3.5	4.6	
West Wailuaiki upper		6.0						
directly d.s. of diversion	0	6.0	1.0	1.5	2.2	2.9	3.8	
middle	0.80	6.8	1.2	1.7	2.4	3.3	4.4	
lower	1.2	7.2	1.2	1.8	2.6	3.5	4.6	

Summary of median base flow and potential habitat at median base flow in diverted stream reaches, northeast Maui, Hawaii.

Percentages of target habitat restoration are hypothetical example applications of the study results for descriptive purposes only and do not imply endorsement by the U.S. Geological Survey or the Staff of the Commission on Water Resource Management

[ft^3/s, cubic foot per second, d.s.; downstream]

	Median base flow remaining in stream (ft^3/s)		Minimum flow [17% natural median base flow] needed in stream to provide 50 percent of natural habitat (ft^3/s)	Minimum flow [25% natural median base flow] needed in stream to provide 60 percent of natural habitat (ft^3/s)	Minimum flow [36% natural median base flow] needed in stream to provide 70 percent of natural habitat (ft^3/s)	Minimum flow [48% natural median base flow] needed in stream to provide 80 percent of natural habitat (ft^3/s)	Minimum flow [64% natural median base flow] needed in stream to provide 90 percent of natural habitat (ft^3/s)	
Stream reach	Diverted conditions	Natural (undiverted) conditions						Comments
West Wailuanui upper		2.5						
directly d.s. of diversion	0	2.5	0.43	0.63	0.90	1.2	1.6	
East Wailuanui upper		2.0						
directly d.s. of diversion	0	2.0	0.34	0.50	0.72	0.96	1.3	
middle	1.0	6.1	1.0	1.5	2.2	2.9	3.9	
lower	1.1	6.7	1.1	1.7	2.4	3.2	4.3	second diversion
Waiokomilo upper		3.9						
directly d.s. of diversion	0	3.9	0.66	0.98	1.4	1.9	2.5	
middle	*3.7*	6.1	1.0	1.5	2.2	2.9	3.9	losing stream
lower	2.6	8.7	1.5	2.2	3.1	4.2	5.6	several diversions
Ohia lower (OL)	*4.7*	4.7	0.80	1.2	1.7	2.3	3.0	diversions, losing stream
Palauhulu upper		3.4						
directly d.s. of diversion	0	3.4	0.58	0.86	1.2	1.6	2.2	
middle	*5.9*	*9.3*	1.6	2.3	3.3	4.5	6.0	losing stream
lower	4.8	*11*	1.9	2.8	4.0	5.3	7.0	second diversion
Piinaau				no flow data; landslide also complicates estimates				
Nuaailua upper		0.28						
directly d.s. of diversion	0	0.28	0.05	0.07	0.10	0.13	0.18	
middle	2.2	2.5	0.43	0.63	0.90	1.2	1.6	
lower	7.1	7.4	1.3	1.9	2.7	3.6	4.7	
Honomanu upper		2.8						
directly d.s. of diversion	0	2.8	0.48	0.70	1.0	1.3	1.8	
middle	*3.8*	*6.7*	1.1	1.7	2.4	3.2	4.3	
lower	0	9.0	1.5	2.3	3.2	4.3	5.8	losing stream
Punalau middle	3.9	3.9	0.66	1.0	1.4	1.9	2.5	
directly d.s. of diversion	0	3.9	0.66	1.0	1.4	1.9	2.5	second diversion
lower	0.60	4.5	0.77	1.1	1.6	2.2	2.9	
Haipuaena upper		3.6						
directly d.s. of diversion	0	3.6	0.61	0.90	1.3	1.7	2.3	
middle-upper	0.80	4.3	0.73	1.1	1.5	2.1	2.8	
directly d.s. of diversion	0.00	4.3	0.73	1.1	1.5	2.1	2.8	second diversion
middle-lower	0.50	4.9	0.83	1.2	1.8	2.4	3.1	
lower	1.1	5.5	0.94	1.4	2.0	2.6	3.5	
Puohokamoa upper		6.4						
directly d.s. of diversion	0	6.4	1.1	1.6	2.3	3.1	4.1	
middle-upper	2.0	8.4	1.4	2.1	3.0	4.0	5.4	
directly d.s. of diversion	0.0	8.4	1.4	2.1	3.0	4.0	5.4	second diversion
middle-lower	1.1	10	1.7	2.5	3.6	4.8	6.4	
lower	2.1	11	1.9	2.8	4.0	5.3	7.0	

Summary of median base flow and potential habitat at median base flow in diverted stream reaches, northeast Maui, Hawaii.

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[ft^3/s, cubic foot per second, d.s.; downstream]

Stream reach	Median base flow remaining in stream (ft^3/s): Diverted conditions	Median base flow remaining in stream (ft^3/s): Natural (undiverted) conditions	Minimum flow [17% natural median base flow] needed in stream to provide 50 percent of natural habitat (ft^3/s)	Minimum flow [25% natural median base flow] needed in stream to provide 60 percent of natural habitat (ft^3/s)	Minimum flow [36% natural median base flow] needed in stream to provide 70 percent of natural habitat (ft^3/s)	Minimum flow [48% natural median base flow] needed in stream to provide 80 percent of natural habitat (ft^3/s)	Minimum flow [64% natural median base flow] needed in stream to provide 90 percent of natural habitat (ft^3/s)	Comments
Wahinepee middle	0.90	0.90	0.15	0.23	0.32	0.43	0.58	
lower	0.90	1.8	0.31	0.45	0.65	0.86	1.2	
Waikamoi upper		3.5						
directly d.s. of diversion	0	3.5	0.60	0.88	1.3	1.7	2.2	
Alo upper		1.5						
directly d.s. of diversion	0	1.5	0.26	0.38	0.54	0.72	0.96	
middle-upper	1.6	6.6	1.1	1.7	2.4	3.2	4.2	
directly d.s. of diversion	0	6.6	1.1	1.7	2.4	3.2	4.2	second diversion
middle-lower	0.20	6.7	1.1	1.7	2.4	3.2	4.3	
lower	0.20	7.0	1.2	1.8	2.5	3.4	4.5	losing stream
Kolea middle	2.5	2.5	0.43	0.63	0.90	1.2	1.6	reservoir
directly d.s. of diversion	0.0	2.5	0.43	0.63	0.90	1.2	1.6	
lower	0.9	3.4	0.58	0.85	1.2	1.6	2.2	lower diversion

	50 percent	60 percent	70 percent	80 percent	90 percent
Total flow needed past Koolau/Wailoa Ditch intakes	12	17	25	33	44
Historic flow in Wailoa Ditch at Honopou (1922-87)	Q99.998	Q99.997	Q99.995	Q99.988	Q99.969
# days with ditch flow lower	45 days	54 days	113 days	264 days	713 days

EXPLANATION

1. Diverted median base flow and natural median base flow from Tables 11 and 12 of Gingerich (2005) [base flow estimates in bold italic are considered maximums at sites downstream of unquantified but known losing reaches]

2. Minimum flows for selected habitat percentages determined from equation 3 of Gingerich and Wolff (2005) where y is desired habitat percentage and x is resulting base flow percentage [$y=100(1-(6.810\times10^{-5}(100-x)^2-3.200\times10^{-4}(100-x)))$]

3. Values in red are minimum flows needed to bypass diversion in order to maintain a target habitat (50%, 60%, 70%, 80%, or 90% of natural habitat)

4. Additional flow release at the diversion will be needed in losing streams in order to maintain the target habitat for the minimum flow (shown in red) at a site

5. Values in green indicate that additional flow is needed to account for additional diversion downstream of the Koolau/Wailoa diversion