

**Water Circulation Modeling
and
Water Quality Monitoring/Modeling
For
Hilo Bay, Hawaii**

FINAL

Scope of Work

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General Background: In response to a request from the County of Hawaii to the U.S. Army Corps of Engineers, Honolulu District (POH), this scope of work was prepared with assistance from the U.S. Army Engineer Research and Development Center (ERDC), Coastal and Hydraulics Laboratory (CHL), to address numerical modeling of circulation, wave transformation, and water quality improvement in Hilo Bay. In a letter of request from the County of Hawaii to POH (dated 14 October 2004) Mayor Harry Kim indicated that Hilo Bay appears degraded to an undefined degree such that it does not provide a suitable environment for recreation and aesthetic enjoyment of the area. The initial focus of the numerical modeling will be to apply the appropriate models to assess various project alternatives to promote greater water circulation in Hilo Bay in order to improve water quality. Model results and predictions for up to five alternative plans will be fully documented in a technical report to facilitate selection of an appropriate course of action. Two of the alternatives to be considered are described in the attached January 2005, "Report on Water Quality Improvement to Hilo Bay, Hilo, Hawaii" that was provided in response to Mayor Kim's letter referenced above.

The criteria for assessing alternative plans in this study are determined by examining changes in wave, current circulation, water quality, and residence time, as well as by determining areas subject to stagnant or weak circulation or focused wave energy resulting from proposed construction. The initial modeling efforts will concentrate on

quantifying change in circulation and wave patterns with and without the alternatives in place for a range of forcing conditions. Multiple storms and non-storm conditions will be simulated.

The Coastal Inlets Research Program (CIRP) has developed the Inlet Modeling System (IMS) for simulating and predicting physical processes at and in the vicinity of coastal inlets and for coastal regions. The IMS is distributed within the Surfacewater Modeling System (SMS) interface developed by Brigham Young University (BYU). Hydrodynamic and Morphologic Steering Modules allow models to share information such that the combined processes of waves, currents, sediment transport, and morphology change can be simulated.

The proposed water circulation modeling will consist of three phases that encompass six technical tasks: 1) field data collection and assessment to include compilation of existing data, 2) development of circulation, wave, and water quality model grids, 3) development of forcing conditions for the models, 4) model validation, 5) model simulations, and 6) analysis and report preparation. The final product from these tasks is a set of calibrated hydrodynamic and wave models for the project site.

The models to be applied are as follows:

- 1) **Circulation Model – ADCIRC:** The ADCIRC hydrodynamic model simulates the circulation and water levels associated with both tides and storms. A two-dimensional depth-integrated (2DDI) version of ADCIRC will be applied. ADCIRC has been extensively applied in the Atlantic and Pacific Oceans (and world wide) to simulate circulation and associated storm surge and currents. (A finite element grid has been developed for the Hawaiian Islands by CIRP, and another project for the island of Oahu is currently underway.)

The ADCIRC hydrodynamic modeling will require the following components:

- a) Develop model grid to include recent bathymetry and shoreline data.
 - b) Calibrate and verify the circulation model to known wind conditions also including tidal constituent contributions for the project domain for 2- to 4-week simulation validation period. This will determine if the atmospheric input and tides are sufficient to drive the model or if additional assessment is needed.
 - c) Assist in the development/selection of alternative forcing conditions.
 - d) Model multiple storms and one non-storm period for each alternative.
 - e) Display circulation patterns via particle tracking.
- 2) **CH3D Hydrodynamic and Water Quality Transport Modeling:** The overall water quality of Hilo Bay is directly impacted by the inputs to the Bay via rivers, overland flow and point source discharges and the rate at which these inputs are diluted and flushed from the system. Increasing the circulation within Hilo Bay will decrease flushing time, which should result in improved water quality. In order to assess the degree of increased circulation and flushing for the structural alternatives being considered, a number of modeling conditions are required. These modeling

conditions will be performed using a combination of ADCIRC (Luettich et al. 1992) and CH3D (Chapman et al. 1996), in which ADCIRC water surface elevation and currents are used to derive boundary conditions for the near-field CH3D circulation and flushing simulations. CH3D is not part of the previously mentioned IMS suite of models, but is supported by the SMS interface.

The CH3D hydrodynamic modeling component will require the following tasks:

- a) Grid development to include recent bathymetry and shoreline data including structural alternatives within the grid.
- b) Development of fresh water inputs.
- c) 2DDI tidal calibration for the existing condition.
- d) 2DDI circulation and flushing alternative simulations using the existing and structural alternative grids.

- 3) **Wave Transformation Modeling – STWAVE:** STWAVE is a spectral wave model, which is capable of representing wave-current interaction, wave-wave interaction, wave-structure interaction and breaking (Smith et al. 1999). The ADCIRC and STWAVE models will be coupled to allow the interchange of radiation stresses from STWAVE to ADCIRC, and, wind-, and wave-generated currents from ADCIRC to STWAVE.

Application of STWAVE will require the following steps:

- a) Development of computational grid to simulate wave propagation.
- b) Verification of calculated waves by comparison to measurements.

Water Circulation Study Phases

An approach toward development of a hydrodynamic modeling system for this project is pursued in a phased process. Activities include identifying, assembling and assessing available data, field data collection, grid development, current and water level calibration/verification, and nearshore wave transformation. Phase 1 will be conducted first. Phases 2 and 3 can be conducted in parallel, after Phase 1 is completed.

Phase 1: Phase 1 involves the assembly of geographic, bathymetric, hydrodynamic (waves and circulation), fresh water inflow and meteorological data necessary to develop and calibrate the modeling system. An assessment of the quality of available data will aid in the specification of necessary additional field measurements. Field data collection is to include deployment of three wave/current gages and acquisition of water current profiles within Hilo Bay by use of a remotely controlled roving sensor. Tracer and drogoue studies will also be conducted as necessary to quantify surface currents throughout the bay. The gages will be deployed for a minimum of one month. The PDT will develop and calibrate the ADCIRC model for wind and tide forcing. Development of the numerical model grid will focus on coarse resolution in the deep ocean water, increased resolution around the island of Hawaii and highly detailed resolution in the nearshore regions of the project site. Any recent bathymetric data will be evaluated and incorporated into the model grid. Additional topographic and/or hydrographic survey

data acquisition is not part of this scope of work. The ADCIRC model will be validated via comparison to hourly water level measurements for Hilo Bay from a NOAA gauge available for a 14-year period from 1991 to the present day in addition to the site specific field data to be collected. Also a 4-year record exists for the same location, which contains 6-minute water level information from 2001 to the present day. ADCIRC simulations for Phase 1 can be submitted to the ERDC's High Performance Computing Center for faster turnaround.

Estimated Cost: \$ 115,000

Phase 2: A nested CH3D grid will be developed using shoreline and bathymetric data discussed in Phase 1 and including river inflow boundary locations and data. An example of a medium resolution nested CH3D grid for Hilo Bay is shown below, which includes the existing breakwater structure. The grid displays the SMS feature arcs, which define grid patches. A patch or group of patches can be modified to add or remove resolution, and change geographic features. However, a restriction of structured grid models such as CH3D requires that any row or column maintain the same number of segments throughout. The grid-patch generation method allows one to easily modify shorelines or structural features within the grid.

Depth-averaged tidal calibration of the baseline grid will be performed utilizing boundary water surface elevations derived from the ADCIRC simulations. The flushing efficiency resulting from the project design alternatives will be investigated for the selected storms and non-storm conditions. This relative flushing efficiency will be determined by comparing an initial and spatially constant tracer concentration, throughout Hilo Bay, with the resulting concentration at selected sites and times. It is envisioned that the worst-case scenario for flushing, thus the most appropriate for evaluating the relative flushing efficiency of the structural alternatives, will occur during non-storm, low/no river inflow periods that occur in summer and early fall.

Estimated Cost: \$ 40,000

Phase 3: A range of atmospheric and tidal forcing conditions will be established to simulate multiple storm and long-term non-storm conditions for all project alternatives. An STWAVE grid will be developed and calibrated for the study area. ADCIRC and STWAVE will be coupled for all events. Wind and pressure fields generated by a combination of National Center for Environmental Prediction (NCEP) and National Center for Atmospheric Research (NCAR) winds and pressures adjusted for local observations will be used as additional forcing conditions for the hydrodynamic model. The coupled ADCIRC/STWAVE model of all alternatives and events must presently be simulated on fast desktop computer workstations, which decreases the turnaround time for each simulation relative to simulations on the HPCC machines.

Estimated Cost: \$ 40,000

Water Quality Monitoring

Overview: Hilo Bay waters have been known to exceed state water quality standards since the late 1970s and were formally included on the US Environmental Protection Agency's (USEPA) 303(d) list of impaired waterbodies in 1998 (Koch et al. 2004). Parameters exceeding standards include turbidity, nutrients, and fecal bacterial indicators. The listing of Hilo Bay for nutrients and sediment has been determined solely by means of visual assessment and not by direct measurements of these parameters. To understand how Hilo Bay functions as an ecosystem, water quality and circulation data are needed for the Bay, as well as water quality and discharge data for the river draining into the Bay. UHH proposes to collect the baseline data on sediment and nutrient inputs to the Bay, and to assess the response of the Bay to these inputs under base and storm flow conditions. This information along with USACE circulation data will allow Hawai'i County to identify the best and most cost-effective remediation actions to improve Hilo Bay water quality.

Background: Reports are scarce and only one peer-reviewed paper exists for Hilo Bay (Silvius et al. 2005). Most water quality data for Hilo Bay are from consultant reports for Environmental Assessments (EA) and Environmental Impact Statements (EIS) from USACE evaluations, and Hawai'i Department of Health (HDOH) and the United States Geological Survey (USGS) monitoring (Silvius et al. 2005). However, these studies were not designed to evaluate how Hilo Bay operates under different conditions (i.e. baseflow vs. storms).

State of knowledge on Hilo Bay – Hilo Bay is considered a salt wedge estuary that is stratified with a freshwater surface layer existing up to a mile offshore (Dudley & Hallacher 1991). This stratification is most pronounced during wet season when surface runoff to Hilo Bay is high. The dense saline layer moves offshore at depth with the tide and the upper freshwater layer is pushed shorewards by easterly and northeasterly trade winds. There is minimal mixing between freshwaters and saltwater layers inside the breakwater because wave energy is low. Low wave energy also allows sediments carried by the rivers to settle out into the lower salty layer, where they may be transported back into the Bay with the incoming tide. Tidal velocities are probably too low to re-suspend bottom sediments, but suspended sediments will move in and out of Hilo Bay with the tide.

The Hilo Bay watershed has one of the highest precipitation rates on the Hawaiian Islands, ranging from 3 meters on the coast to 6 meters at the upper elevations annually (Juvik & Juvik 1998). Hence, it is no surprise that the amount of freshwater entering Hilo Bay is far greater than any other Hawaiian estuary. Surface waters are primarily discharged into Hilo Bay from the Wailoa and Wailuku Rivers. Wailoa River is a groundwater-fed flood-control channel that discharges into Waiakea Pond prior to entering Hilo Bay. Waiakea Pond is the single largest source of groundwater into Hilo Bay (M & E Pacific 1980). It is estimated that and 1.8 million cubic meters of groundwater enters the Bay in this area (M & E Pacific 1980). The Wailuku River is the largest perennial river in the state and the largest source of surface water to Hilo Bay.

The average flow of water from the Wailuku River into Hilo Bay is 1 million cubic meters (range: 40 thousand -7 billion cubic meters; M & E Pacific 1980). Surprisingly, little is known about the inputs of sediments and nutrients from these rivers. Currently, HDOH, in collaboration with USGS, are quantifying storm inputs of sediments and nutrients from Waiakea and Alenio gulches (both feed into Wailoa River) to Hilo Bay as a part of HDOH total daily maximum load (TMDL) program. Inputs of sediments and nutrients from the Wailuku River are currently being measured by UHH (Dr. Tracy Wiegner, Marine Science) and US Department of Agriculture Forest Service (Dr. Richard MacKenzie). Response of Hilo Bay to these inputs is unknown.

Much of the concern surrounding Hilo Bay’s water quality stems from the fact that Hilo Bay’s waters are not clear. High-relief drainage and intense rainfall in Hilo Bay’s watershed may contribute to naturally high sediment loads observed in the rivers during storms. It is suspected that the Wailuku River delivers the majority of sediments to Hilo Bay during storms and is the reason behind the poor water clarity in the Bay. Preliminary data from UHH has found that turbidity is 10 times higher in Wailuku River than Wailoa River during recent storms in October and November 2005 (Figure 1). Currently, it is not known how long the Bay’s waters stay turbid following a storm and whether these sediment inputs impact the ecosystem.

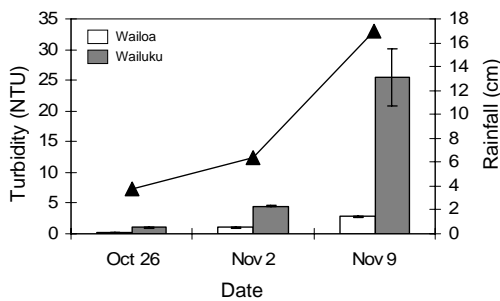


Figure 1. Comparison of average (\pm SD) turbidity values in the Wailoa and Wailuku Rivers in Hilo, HI over different rainfall amounts. Rainfall data was obtained from <http://www.prh.noaa.gov/hnl/pages/hiclimat.php>. Rainfall amounts were calculated using data from two days prior to sampling. Turbidity data were collected during MARE 350 class during Fall 2005 semester.

Another possible factor contributing to the low water clarity in Hilo Bay are algal blooms. Algal blooms result when nutrients are prevalent and their presence gives coastal waters a greenish tint. As previously mentioned, the USEPA 303(d) impaired listing for Hilo Bay for excessive nutrients was based solely on visual assessment. From these assessments, it was assumed

that Hilo Bay had high nutrient concentrations because the water had “a greenish tint”, resulting from suspected algal blooms (Silvius et al. 2005). Actual nutrient and chlorophyll a (chl a) data for Hilo Bay are scarce. Preliminary data from UHH indicates that nutrient concentrations are five times greater in the Wailoa than the Wailuku River (Figure 2), suggesting that Wailoa may be the primary surface water source of nutrients to Hilo Bay (MARE 350 unpublished data). The effect of these nutrient inputs to Hilo Bay has not been assessed to date.

The temporal scale over which the few turbidity and nutrient samples were

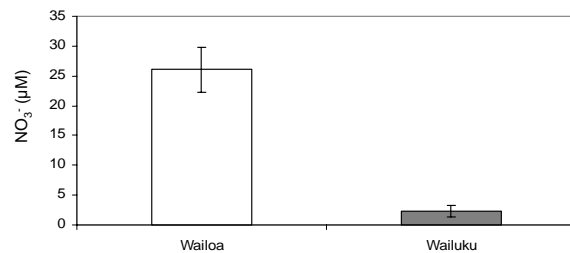


Figure 2. Comparison of average (\pm SD) nitrate concentrations in the Wailoa and Wailuku Rivers, Hilo, HI over October 19, October 26, November 2, and November 9. Data were collected by the MARE 350 class during Fall 2005 semester.

collected is inadequate to characterize the range of conditions experienced in Hilo Bay. It is assumed that inputs of sediments and nutrients to Hilo Bay are high during storms; however, these events have not been historically targeted. Current research efforts by UHH, HDOH, and USGS are beginning to quantify storm inputs of sediments and nutrients into Hilo Bay from the Wailuku River, Alenio Gulch, and Waiakea Gulch. Information on how Hilo Bay responds to storms over temporal and spatial scales is not known. Storm inputs of nutrients are thought to stimulate algal blooms; however, no direct measurements have verified this. Additionally, the importance of these algal blooms as a food source to higher trophic levels, like commercially and recreationally important fish, is unknown.

Overall, the Hilo Bay Restoration Plan recommends (Silvius et al. 2005):

- Identifying sources of sediments and nutrients to Hilo Bay from surface waters under base and storm flow conditions
- Collection of baseline chemical and ecological data to substantiate visual assessment of nutrients (making direct measurements of nutrient and chl a concentrations)
- Examining the response of algae in Hilo Bay to base and storm flow conditions
- “Scientific coordination to ensure that samples are continuously and constantly gathered, without interruptions or changes in protocols, and with much better spatial coverage than provided by” previous studies.

The study proposed below by UHH will begin to collect critical baseline data for Hilo Bay that is: 1) essential for understanding how the Bay functions under baseflow and storm conditions, 2) recommended by the Hilo Bay Restoration Plan, 3) needed to develop a successful and cost effective restoration plan, and 4) required to evaluate whether modification of the breakwater by USACE will improve Hilo Bay water quality.

Monitoring: Experimental Design: This study will specifically examine how storms affect water quality (sediments, nutrients, chl a) in Hilo Bay by comparing conditions in the Bay before and following a storm event over a one-year period. A similar design has been successfully used by Ringuet & Mackenzie (2005) to evaluate the effects of storms on water quality and algae in Southern Kaneohe Bay, Oahu.

Site Description: For this project, eight stations will be sampled for sediments, nutrients, and chl a (Figure 3). Two stations will be located in the freshwater portion of the Wailoa and Wailuku Rivers. These stations will be used to determine the amount of sediments and nutrients entering the Bay from surface waters. Four stations will be located inside of Hilo Bay. Two Hilo Bay stations will be located along a transect following the

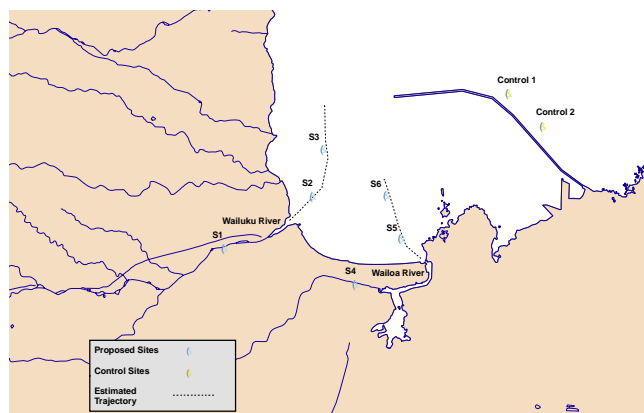


Figure 3. Proposed sampling stations in Hilo Bay.

Wailoa River plume (Figure 3). The other two Hilo Bay stations will be located along a transect following the Wailuku River plume (Figure 3). This transect will be on a slight angle to the northwest of the river's mouth because previous studies have shown that the Wailuku River plume is deflected northwest in Hilo Bay (Dudley & Hallacher 1991). Two control sites will be located outside of the Hilo Bay breakwater (Figure 3). Plumes from either river should not affect these control sites. Most of the proposed stations have been previously sampled by UHH through research and class projects (data shown in Figures 1 and 2).

Sampling Strategy: Water samples from the river and bay stations will be collected under base and storm flow conditions during the wet and dry season over a one-year period. Each station will be sampled for suspended sediments, nutrients, and chl a for five days during each season, under both base and storm flow conditions. This time frame was selected based on previous findings from Kaneohe Bay, where algae bloomed after three to five days following a storm (Ringuet & Mackenzie 2005). Because the focus of this study is to evaluate water quality in Hilo Bay before and after a storm, water samples will be collected from surface waters where river sediments and algae are most likely concentrated due to the Bay's stratification. For this study, storm conditions will be defined as when Hilo receives more than 5 cm of rain in 24 hours. This rainfall amount is based on current research Dr. Wiegner, who has found that 5 cm of rain corresponds to a rise in the Wailuku River by 1 m, which is the average stage height for a storm event based on historical USGS data. Rainfall data for Hilo Bay will be obtained from a NOAA website (<http://www.prh.noaa.gov/hln/pages/hiclimat.php>). Following a storm, all stations will be sampled for five consecutive days. Baseflow conditions will be defined as when Hilo receives less than 5 cm of rain over a period of five days prior to collection (Ringuet & Mackenzie 2005)

To estimate sediment and nutrient inputs to Hilo Bay from the Wailoa and Wailuku Rivers, water samples will be collected at the two river stations during base and storm flow conditions. For the Wailoa station, a depth integrated sampler will be used to collect all samples. Stage height and discharge for the Wailoa River will be measured using a staff gage and velocity meter, respectively. For the Wailuku River, a depth-integrated sampler will be used to collect water under base flow conditions and an automated storm sampler will be used to collect water during storms. A storm sampler has been installed on the Wailuku River near the USGS gage for current UHH research. Discharge for the Wailuku River will be calculated using stage height measured at the USGS gaging station and stage height-discharge relationship previously established by this agency. Concentration and discharge data will be used to calculate sediment and nutrient fluxes from the Wailoa and Wailuku Rivers to Hilo Bay under base and storm flow conditions.

Measurements: Parameters regulated by HDOH for estuarine water quality will be targeted for this study (HDOH 2004). Nutrients [total nitrogen (TN), ammonium (NH₄⁺), nitrate (NO₃⁻), total phosphorus (TP), phosphate (PO₄³⁻), dissolved silicon (H₄SiO₄), pH, turbidity, total suspended sediments (TSS), and chl a will be measured during the wet and dry season under base and storm flow conditions. Additionally, dissolved

organic carbon (DOC) and particulate carbon (PC) will be measured at the request of USACE for their eutrophication model. NH₄⁺ (USGS I-2525), NO₃⁻ (USEPA 353.4), TP (USGS I-4650-03), PO₄³⁻ (USEPA 365.5), and H₄SiO₄ (USEPA 366) will be measured using standard autoanalyzer methods. TN and DOC will be measured on a Shimadzu TOC-V CSH, TNM-1 following the recommendations by Sharp et al 2002. Turbidity will be measured on a Hach 2100P Turbidimeter. TSS will be measured using standard methods (APHA et al. 1995). PC will be analyzed on a CHN analyzer (Costech Analytical Technologies). Chl a will be measured using USEPA method 445.0. To characterize the conditions at each station when sampling, physiochemical parameters (salinity, conductivity, temperature, dissolved oxygen concentration, dissolved oxygen percent saturation, light penetration) will be measured using a YSI multi-parameter meter and a Li-Cor light meter, respectively. At the request of USACE, depth profiles for these physiochemical parameters will be measured at the six Hilo Bay stations. Meteorological data (rainfall, winds, waves, and tides) will also be obtained for the sampling dates.

Monitoring Outcomes: Essential baseline water quality data for Hilo Bay will be collected to complement circulation data being collected and numerical water quality models to be run USACE. This information will allow for a greater understanding of how Hilo Bay functions. With this understanding, appropriate restoration actions can be developed and implemented to improve Hilo Bay water quality.

Estimated Cost: \$66,000

Water Quality Modeling

Background: Design alternatives for the Hilo Bay breakwater will result in differing wave and circulation patterns. Depending on the point and non-point loadings to the bay, the alteration of the baseline flushing of the bay can result in varying degrees of water quality improvement. Water quality modeling techniques can be used to predict the concentration and persistence of various water quality parameters, such as dissolved oxygen.

Numerical models are widely used to study water quality issues. Among the water quality issues models have been used for include assessment the effectiveness of proposed remediation measures, determination of the impacts of different pollutant sources, distribution of substances in the water column and sediments, and impacts of changes in circulation upon water quality conditions. Models are used to look at the fate and transport of constituents such as nutrients, contaminants, salinity, temperature, algae, dissolved oxygen, and coliforms. More advanced models are capable of simulating living resources such as Submerged Aquatic Vegetation (SAV), zooplankton, and benthic invertebrates such as clams.

Levels of Water Quality Modeling: The level of water quality modeling required is dependent upon the problem being addressed. In some cases, the problem is a single constituent in the water column that can be modeled alone. Examples would be

temperature, salinity, or coliforms. These constituents are assumed to not be influenced by other parameters in the water column. In other cases a suite of constituents are required to address a water quality issue due to the interdependence of the constituents. An example of this would be dissolved oxygen which is impacted by processes such as algal production/respiration, nutrients, reaeration, and oxygen demanding substances in the water column and sediments.

All water quality modeling requires data. A time series of information is required for all boundaries (open water and tributary). In addition, flow and concentration (or load) information is required for all point source dischargers along with estimates for loadings originating in watershed that have direct contribution to the receiving water body. Finally, if the issue of concern, such as eutrophication or contaminants, involves sediments, then information on the chemical makeup of the sediments is required. All of this information can be obtained from a sampling program conducted in conjunction with the modeling study.

In many instances dissolved oxygen is the constituent of interest. It is often used as an indicator of the health of the system. Low dissolved oxygen levels result from a combination of poor circulation, oxygen demand in the water column exceeding reaeration, and excessive oxygen demand in the sediments. Low dissolved oxygen levels can have negative impacts upon living resources either by retarding their growth or by killing the creatures

Water quality modeling techniques can be used to determine the dissolved oxygen impact resulting from a change in circulation due to breakwater removal or relocation. Various levels of modeling effort are available to address these issues and are summarized below. Prior to selecting one approach over another it must be determined to what standard will the results be held by reviewing agencies and others.

1. Eutrophication – Involves the modeling of dissolved oxygen, algae, nutrients, and carbon. Realistic loads (observed or estimated) are required for **all major discharges** in the system. In addition, information on constituent concentrations are required for development of boundary conditions and for calibration. Sediment processes could either be specified or simulated with a sediment diagenesis model. This is the most involved approach in time and money and would provide the most defensible results provided there is an adequate data base for model development.
2. DO/BOD/SOD - Similar to number 1 except that all oxygen demand is specified as a Biochemical Oxygen Demand (BOD). Sediment Oxygen Demand (SOD) is specified as a constant rate and together with BOD are the only sinks for DO. Information is required on DO and BOD levels throughout the system for cursory model calibration. Information (observed or estimated) is required for all significant discharges. While less involved than level 1, this approach still requires some calibration. The results from this study are less

defensible as algae are left out and the impact of algal photosynthesis and respiration are omitted.

3. Residence Time - Not a measure of dissolved oxygen but a measure of the impact that circulation changes have on the time that water stays in a certain area. Assuming that oxygen demands are the same throughout the system, an increase in residence time would indicate a decrease in flushing and a decrease in DO. This is a very simplified approach relying heavily on inferences.

All of the above levels of model should indicate similar results as long as the water quality conditions are dominated by circulation. All three levels will require roughly the same level of effort for generating the hydrodynamics required to drive the water quality model.

Though not listed above, an additional option is not to model dissolved oxygen or water quality. Instead, evaluate hydrodynamic results and infer from them whether the conditions in the vicinity of the breakwater have changed. In this approach there is a pre-supposition that the conditions will not greatly change and that there are no strong gradients or plumes in the system. This approach is the simplest and cheapest but also the least defensible and should only be chosen if it is clear that the reviewing authority would accept such an approach.

Coliforms are also another water quality constituent of concern as their presence in elevated levels is taken as an indication of bacterial contamination and potentially pathogens. As such, excessive coliform levels result in restrictions for swimming, fishing, and shell fishing. Coliforms originate in the guts of warm blooded creatures. They typically enter water bodies as a result of runoff from the watershed or from wastewater treatment plants.

Coliforms can be modeled rather simplistically. There is no reproduction or generation in the water body. Once the coliforms are introduced into the water column they are removed at a specified rate. The rate can be independent of other constituents or a function of environmental constituents such as salinity.

Chemical contaminants in the form of metals, PCBs, and pesticides in the water column and sediments can degrade the water column and restrict the use. Typical sources of these contaminants are watershed loadings or sediment fluxes. As these contaminants are found in sediments they provide a persistent source to the water column and living resources. Modifications to circulation resulting from a breakwater removal or modification could lower the level in the water column if flushing is increased. However, the issue of the contaminated sediments would not be addressed by this measure and could require remediation or capping to limit the sediment source of contaminants.

Estimated Cost: \$109,000

Study Management

- 1) **Project Management:** CEPOH-PP-C shall assign a Project Manager (PM) to direct study efforts, maintain project milestone schedule and manage study funding. The PM shall establish a Project Delivery Team (PDT) comprised of POH, ERCD and non-Federal members as applicable. The PM will develop a Project Management Plan to serve as a guide for conduct of study tasks. A network of study activities will be established by the PM in the US Army Corps of Engineers' P2 scheduling software.
- 2) **Technical Management:** CEPOH-EC-T shall assign a Technical Manager (TM) to manage numerical model and field data collection efforts as well as provide regular updates of work progress to the PM. The TM shall coordinate accomplishment of the work tasks described in this scope of work with the Project Delivery Team (PDT) and attend PDT meetings upon request from the PM. CEPOH-EC-T shall participate in the in-progress meetings with the PDT, as required, and in general, keep the PM informed on the progress of work. Assume ten such meetings with the PDT, are necessary.

Estimated Cost: \$ 75,000

Deliverables

Water Circulation Modeling: The water circulation modeling will be completed over a 12 month period following notice to proceed. Amount for preparation of the draft final report includes labor costs for compilation and writing in addition to editing, publishing and printing costs. Amount for CHL travel outlined in the table below includes \$15K per person for up to two weeks in duration for site visit/field data collection. These costs include travel, labor and per diem for two ERDC staff members.

1. Monthly progress reports on the water circulation modeling will be provided.
2. Field data will be collected for a minimum of one month as described above. Field notes and raw data sets will be provided along with a detailed report of data acquisition, quality control and quality assurance.
3. Water circulation model will be calibrated to field data.
4. Water circulation will be quantified for existing conditions and five additional alternative plans.
5. The calibrated model for the project site and final Technical Report will be delivered following completion of Phase 3.

Water Quality Monitoring (work-in-kind): The following deliverables will be provided by UHH to the Honolulu District of the USACE:

1. Nutrient sample data in formats compatible with input to the proposed USACE water quality numerical models.
2. Draft and final report documenting nutrient sample collection, meteorological data for the sample collection periods (to include at a minimum rainfall, winds, waves and tides), description of sample concentration trends for each collection period, and summary/conclusion of sampling results.
3. Final deliverables will be provided to Honolulu District personnel within 12 months from the date of the notice to proceed.

Water Quality Modeling: The following water quality modeling deliverables will be provided:

1. Monthly progress reports on the water quality modeling will be provided.
2. Water quality modeling will be conducted for the parameters monitored by UHH as described in detail above.
3. Water quality models will be calibrated to the UHH monitoring data for existing conditions at Hilo Bay.
4. Water quality modeling will be conducted for five alternatives plans as investigated in the water circulation studies.
5. The calibrated model for the project site and final Technical Report will be delivered to the Honolulu District for distribution and future use.

Study Costs

	Cost (\$K)
Water Circulation Modeling	
Phase 1	115
Phase 2	40
Phase 3	40
Report	25
Travel (CHL)	30
Sub-total	250
Water Quality Monitoring (work-in-kind)	66
Water Quality Modeling	109
Technical Management	30
Project Management	45
Total	500K

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