TOTAL MAXIMUM DAILY LOADS ESTIMATED FOR WAIMANALO STREAM
- ISLAND OF OAHU, HAWAII -

Prepared to U.S. Environmental Protection Agency Specifications
by the
Hawaii State Department of Health,
Environmental Planning Office
June Harrigan and Susan Burr

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Executive Summary

Waimanalo Stream is a 5.5-km long, highly altered, impaired waterbody located on the windward side of the island of Oahu, Hawaii. Sediments and nutrients from the watershed enter the stream at a rate faster than they can be assimilated and recycled. As a result, Waimanalo Stream is not meeting the State of Hawaii water quality criteria and its beneficial uses are not being maintained.

The Hawaii State Department of Health has determined the maximum amount of pollutants that can enter Waimanalo Stream without violating the State's Water Quality Standards, compiled in the Hawaii Administrative Rules, Chapter 11-54. This amount is called the Total Maximum Daily Load, or TMDL. Determining the TMDL is a process required by the US Environmental Protection Agency to ensure that all Americans have access to waters that are *fishable and swimmable*, which means that these surface waters support a balanced aquatic community, including any endangered species that may be present, and are safe for recreational uses.

The Department of Health collected water quality samples, assessed the biological integrity of the stream, conducted land-use surveys of the watershed, and analyzed data collected in-house and by contractors to determine the TMDLs for Waimanalo Stream. This complex set of data could not be synthesized into one simple number, and the process has resulted in 81 different TMDLs, 79 values for each of three parameters in five subwatersheds during both dry and rainy seasons at three different levels of flow (and one additional value in a subdrainage) (Table 10), and two values for habitat and biotic integrity . This complex matrix of numbers will make it easier to identify the most important pollution problems, implement specific measures to fix known problems, and monitor the success of these efforts.

Waimanalo Stream has many problems, including poor water quality, limited habitat, and altered flow regimes. The Department of Health recognizes that water quality will not improve without habitat and flow modifications, but has statutory authority over only water quality. The Department of Land and Natural Resources (DLNR) has primary authority for aquatic resource and water quantity management in Hawaii. The DLNR Division of Aquatic Resources and the Commission on Water Resources Management have the lead role in addressing these natural resource problems and setting in-stream standards for flows. Long-term improvements in the condition of Waimanalo Stream will only be achieved as a result of discussion and decision-making by a broadly-constituted stakeholder group. The present document represents an initial effort to describe pollutant-related problems and stimulate discussion on solutions, but a watershed management process that results in assignment of responsibility to a variety of public and private stakeholders is a necessary condition for stream improvement. This next step should occur during the implementation phase of the TMDL process.

In this document we discuss how the amounts of nutrients and sediments entering Waimanalo Stream must be reduced to the amount allowed by the TMDLs. We also recognize that the stream must be restored to the point at which it is able to recycle the nutrient load and reduce the transport of sediments. Once these goals are achieved, Waimanalo Stream will meet the State's Water Quality Standards.

The greatest opportunities for improvement exist in the middle sections of Waimanalo Watershed (see Figures 1-3), because these locations are exceeding the TMDLs by the greatest amount. However, load reduction is likely to be the most difficult here because of the contribution of pollutants from groundwater (Laws, 2000). Kahawai Stream Middle Subwatershed greatly exceeds the nutrient TMDLs

(nitrates and total dissolved phosphorus). Waimanalo Stream Middle Subwatershed exceeds the nitrate TMDLs to a great extent and the total dissolved phosphorus and total suspended sediment TMDLs to a lesser extent. The Waimanalo Stream Upper Subwatershed greatly exceeds the total dissolved phosphorus TMDL.

Best management practices (BMPs) for activities that potentially introduce pollutants into Waimanalo Stream, such as construction and maintenance of unpaved roads, fertilizer application in nurseries, stream diversions and return flows for taro cultivation, construction and use of hiking trails, operation of septic systems and cess pools, and disposal of waste from chicken coops must be developed and implemented in Waimanalo Watershed on a scale such that the pollutant loads are significantly reduced and the TMDLs are met. The habitat and vegetation characteristics of the stream must also be restored to the extent that the stream maintains some semblance of a naturally functioning ecosystem that recycles nutrients and retains some sediments, but not all. In-stream flow levels must also be increased by removal of channel-clogging vegetation and construction of low flow channels in order to increase the ability of the stream to assimilate sediments and nutrients. Pollutant-reducing BMPs, reasonable stream restoration, and an increase in base flow will bring Waimanalo Stream closer to its desired condition – a stream that meets the Water Quality Standards and is *fishable and swimmable*.

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Introduction

The Hawaii State Department of Health (HIDOH) has determined the Total Maximum Daily Load (TMDL) of pollutants allowable for Waimanalo Stream. The TMDLs are based upon the results of several studies and investigations conducted over the previous three years by government agencies, private contractors, and community groups (Smith, 1998; Kihara, 2000; Krupp, 2000; Laws, 2000; and Tomlinson and DeCarlo, 2000). Development of TMDLs is the first in a series of steps necessary to restore Waimanalo Stream such that it once again meets the criteria, objectives, and protected uses set forth in the Hawaii Administrative Rules (HAR), Chapter 11-54, Water Quality Standards (WQS).

Section 303(d) of the Federal Clean Water Act (CWA) [33 U.S.C. §1313(d), ELR Stat. FWPCA §303(d); see also 40 CFR 130.7] requires states to adopt a water quality standards-based approach to controlling sources of pollution in instances where application of technology-based standards has failed to bring State surface waters into compliance with State Water Quality Standards. The first step required of states under CWA §303(d) is development of the CWA §303(d) List of Water Quality-Limited Segments (List), which must be submitted to the U.S. Environmental Protection Agency (EPA) for approval by April 1st in successive even-numbered years (except for the year 2000, excluded to avoid confusion during EPA's process of developing a new TMDL rule, signed on July 11, 2000). TMDLs must be prepared for all waters on the List and approved by EPA. Federal regulations (40 CFR 130.6) and national policy (Perciasepe policy, August 1997) require TMDLs to be implemented through a mixture of regulatory and voluntary implementation approaches.

Waimanalo Stream, the subject of the present TMDL, is listed as an impaired waterbody on Hawaii's 1998 EPA-approved CWA 303(d) List (HIDOH, 1998). In order to prepare TMDLs for Waimanalo Stream, field measurements of pollutant concentrations and stream flows were conducted from February, 1999 to April, 2000 and used to compute the measured (observed) and expected pollutant load estimates and source load allocations reported below. Additional dry season concentration data collected by the HIDOH/Clean Water Branch (CWB) supplemented the data collected by Laws (2000) and were used to compute low flow and zero flow TMDLs as well as to provide a broader picture of baseline pollutant concentrations during the study period. These data exist as Excel documents and are listed as Tables 1-7 in the List of Tables (page 4). The files are available from the Environmental Planning Office.

Methods for estimating TMDLs add another dimension, that of surface flows, to the usual practice of evaluating water quality by measuring pollutant concentrations in water samples. The phrase "Total Maximum Daily Load" means that the weight of a pollutant entering an impaired waterbody per unit time (the daily load) is limited through application of permit conditions or "Best Management Practices" (BMPs) to that load that the waterbody can accept and still meet WQS (the maximum daily load). The "total" acceptable pollutant load must be allocated among all contributing sources, whether point or nonpoint sources or a combination of both. Next, load reductions are implemented where needed, and the same stations monitored to determine if the TMDL for a pollutant is being met. Several iterations of BMP implementation and TMDL monitoring may be needed to track changes in pollutant loading and transport over time; consequently, an adaptive management approach should be applied to TMDL implementation. The TMDLs presented in Section 5 are initial estimates, and represent pollution reduction targets for the first round of BMP design and installation along Waimanalo Stream.

Because TMDLs describe allowable pollutant delivery rates to an impaired waterbody from land, flows and pollutant concentrations should be measured simultaneously and the TMDLs described in the form of “fluxes.” For TMDL purposes, a flux is defined as the product of pollutant concentration times stream flow; the magnitude of the flux represents the weight of material passing by a particular location (station) per unit time. If stream flows are equal to zero, TMDLs are expressed as concentrations rather than fluxes. The primary goal of TMDL implementation is to reduce the delivery rate of material pollutants entering stream channels and either building up in stagnant waters or moving downstream in storm flows typical for the area to such a degree that Hawaii’s WQS are met.

The raw data tables, data summaries, and staff and contractors’ reports contain the details underlying estimation of TMDLs for Waimanalo Stream; these data tables and reports are listed in the “List of Tables” (page 4) and “List of Project Reports” (page 32). This document describes the environmental problem, summarizes findings of the various studies conducted, and explains the process for converting raw data into TMDLs for those material pollutants causing significant impairment of water quality in Waimanalo Stream, total suspended solids (TSS), total dissolved nitrogen (TDN), nitrate, and total dissolved phosphorus (TDP). Any pollutant for which a WQS has been promulgated, including temperature, may be the subject of a TMDL; however, HIDOH and EPA have determined that sediments and nutrients should be addressed first by Hawaii’s TMDL program. Excess loads of sediments and nutrients are frequently associated with land use activities (controllable sources) that cause erosion and loss of chemical fertilizers into adjacent waterbodies. Septic tank infiltration or other groundwater-born nutrient sources may also be responsible for elevated nutrient levels, especially during periods of low flow.

WQS extend beyond simple requirements to meet chemical criteria – the standards also include designated uses and antidegradation policies with respect to water quality that must be met. The functions and values of the chemical, physical, and biological aspects of streams are interdependent. Waters in relatively open channels with moderate flows have a greater likelihood of meeting the chemical criteria set forth in the WQS than streams with degraded habitat. Streams with severe habitat damage, including stream channels clogged by vegetation and extensive areas of stagnant pools, as evidenced in Waimanalo Stream, parts of which resemble a highly eutrophic wetland much more than a stream (Laws, 2000 and Tomlinson and DeCarlo, 2000), are unlikely to meet the chemical criteria. Although pollutant loadings can be reduced pursuant to the TMDL, vegetation clearing, riparian restoration, and flow modification may also be needed meet all WQS. Therefore, we have also established TMDLs for habitat and biotic integrity.

Contractors hired to assist with data collection and interpretation for the Waimanalo Stream TMDLs include Edward Laws, Ph.D. and Eric DeCarlo, Ph.D., University of Hawaii at Manoa (data collection and interpretation); Molly Kihara, UCLA graduate student (development of numerical model for estimating sediment delivery to Waimanalo Stream); and David Krupp, Windward Community College (streamside land use maps – a Geographic Information System project). Glen Fukunaga, Environmental Planning Office, prepared the preliminary land use report on Waimanalo Basin, and Gordon Smith, previously with the Environmental Planning Office, prepared the biological assessment of Waimanalo Stream. The HIDOH Clean Water Branch collected dry season data for pollutant concentrations along the stream.

Three different flow-based TMDLs (high, low, and zero) have been set for each of three pollutants (nitrate, TSS, and TDP) at five locations (Upper Kahawai, Upper Waimanalo, Middle Kahawai, Middle Waimanalo, and Lower Waimanalo) for each season (rainy and dry) (and an additional value for TSS in one subdrainage) – resulting in a total of 91 different TMDLs. However, no data were collected to enable computation of 12 of the TMDLs, reducing the total to 79 chemical TMDLs (see Table 10). Two additional TMDLs, one for habitat and one for biotic integrity, have also been established (see Table 11).

Minimum TMDL Elements

The following are eight minimum TMDL elements, suggested by EPA.

1. **Problem Definition**: Identify the waterbody, pollutants causing impairment, applicable WQS, and describe the environmental problem.

2. **Numeric Target Definition**: Discuss how the stream can assimilate the Total Maximum Daily Load (TMDL) of pollutants without violating the numeric WQS, narrative WQS, designated uses, and the CWA antidegradation policy. Discuss how the quantitative targets will address contamination in sediment and edible aquatic organisms and any health advisories that may be current in the area.

3. **Source Analysis and Estimation**: Estimate pollutant loads discharged into the waterbody from all sources, including natural background sources as well as land uses (i.e., agriculture and urban).

4. **Linkage Analysis**: Estimate the capacity of the waterbody to receive pollutants without exceeding WQS.

5. **Compute TMDLs and partition the loads among the contributing sources**: Establish standard operating procedures for these analyses.

6. **Margin of Safety Analysis:** Estimate explicit and implicit margins of safety in the TMDL calculations and discuss sources of error in the data collection methods and computations.

7. **Account for Seasonal Variations and Critical Conditions**: Estimate seasonal variations in pollutant loadings and discuss how selected TMDLs are sensitive to seasonal waterbody conditions, such that the TMDL will meet WQS in all seasons and under all critical conditions.

8. **Conduct a Public Participation Process**: Conduct public information meetings in Waimanalo, issue a public notice, and revise document based upon information received from the community.

This document satisfies the eight TMDL elements and is organized such that each section describes how each element is met. Obviously, collecting data and analyzing the results alone will not improve water quality. Improvements in the condition of Waimanalo Stream will only be achieved through discussion, decision-making, and implementation by a broadly-constituted stakeholder group. This TMDL report is the initial effort and can be the driving force needed to implement measures to improve the quality of Waimanalo Stream. A completed TMDL will give the Waimanalo community additional leverage to receive funding from the US EPA and other agencies. Planning, additional data collection, if needed, and implementation are the next steps for the stakeholders to undertake. HIDOH will, and federal and other state agencies should, participate as resources become available.

1. Problem Definition

Waimanalo Stream is a highly altered waterway that in many ways no longer functions as a stream (comment at public meeting of December 11, 2000). It is about 5.5 km in length, and located in the Koolaupoko District on the windward side of the island of Oahu, Hawaii (Figure 1). The stream is in the shape of the letter "Y," with the southeastern tributary identified as Kahawai Stream and the northwestern tributary, named Waimanalo Stream. Unless otherwise noted, the term "Waimanalo Stream" includes both Waimanalo and Kahawai tributaries. The stream water becomes brackish about one kilometer seaward of the confluence of the two tributaries, primarily where the flow has been channelized through the Bellows Field military base. TMDLs were calculated for only the perennial freshwater portions of Waimanalo Stream because this is the only portion of the stream that is included on Hawaii's 1988 List of Impaired Waterbodies. Although there are other potential sources of pollution to the estuarine portion of Waimanalo Stream and Waimanalo Bay, reducing the load of pollutants entering the freshwater portion of Waimanalo Stream should reduce the pollutant concentration in the estuarine portion of Waimanalo Stream and in Waimanalo Bay.

The Waimanalo drainage basin, about 16 km^2 in area, faces into the east-northeast tradewind flow (Figure 2). Moist tradewinds blowing across windward coastlines of Oahu ascend the eastern side of the Koolau mountains, generating orographic rainfall as the air cools at higher elevations and releases excess moisture in the form of trade wind showers, which may be intense at times. Less frequent but occasionally heavy rains are generated in Waimanalo when kona storms, including hurricanes, move north from the equator and strike the island. Although total rainfall in the Waimanalo basin has been below average for the past four years, there was sufficient rainfall to allow sampling of four rain events measuring 3.8-8.9 cm during the course of this study.

Primary land uses in the Waimanalo drainage basin include, from the mountains seaward, the upper forested conservation area, where development is prohibited because of the presence of steep slopes and potable water recharge areas; small agricultural operations, especially plant nurseries; residential neighborhoods; a golf course; and a military installation at Bellows Field. Many roads (both paved and unpaved), driveways, and stream crossings traverse the stream and watershed.

Waimanalo watershed has a proportionately high number of farm and household animals to residents, as compared to other watersheds on Oahu (Medeiros, 2000 and comment at public meeting of December 11, 2000), although some of the larger facilities (i.e., Meadow Gold dairy) are outside of the strict boundaries of Waimanalo watershed. Both animal wastes and inorganic chemical fertilizers contribute to the excess nutrient loads measured in surface waters, and are discharged into stream channels via both surface runoff and shallow groundwater flows. A small percentage of the homes in Waimanalo watershed are not connected to the sewer system and rely upon septic systems or cess pools to manage household wastewater. Septic system infiltration also contributes to the excess nutrient loads. Eroding roads, driveways, and bare road sides contribute excess sediments to the stream.

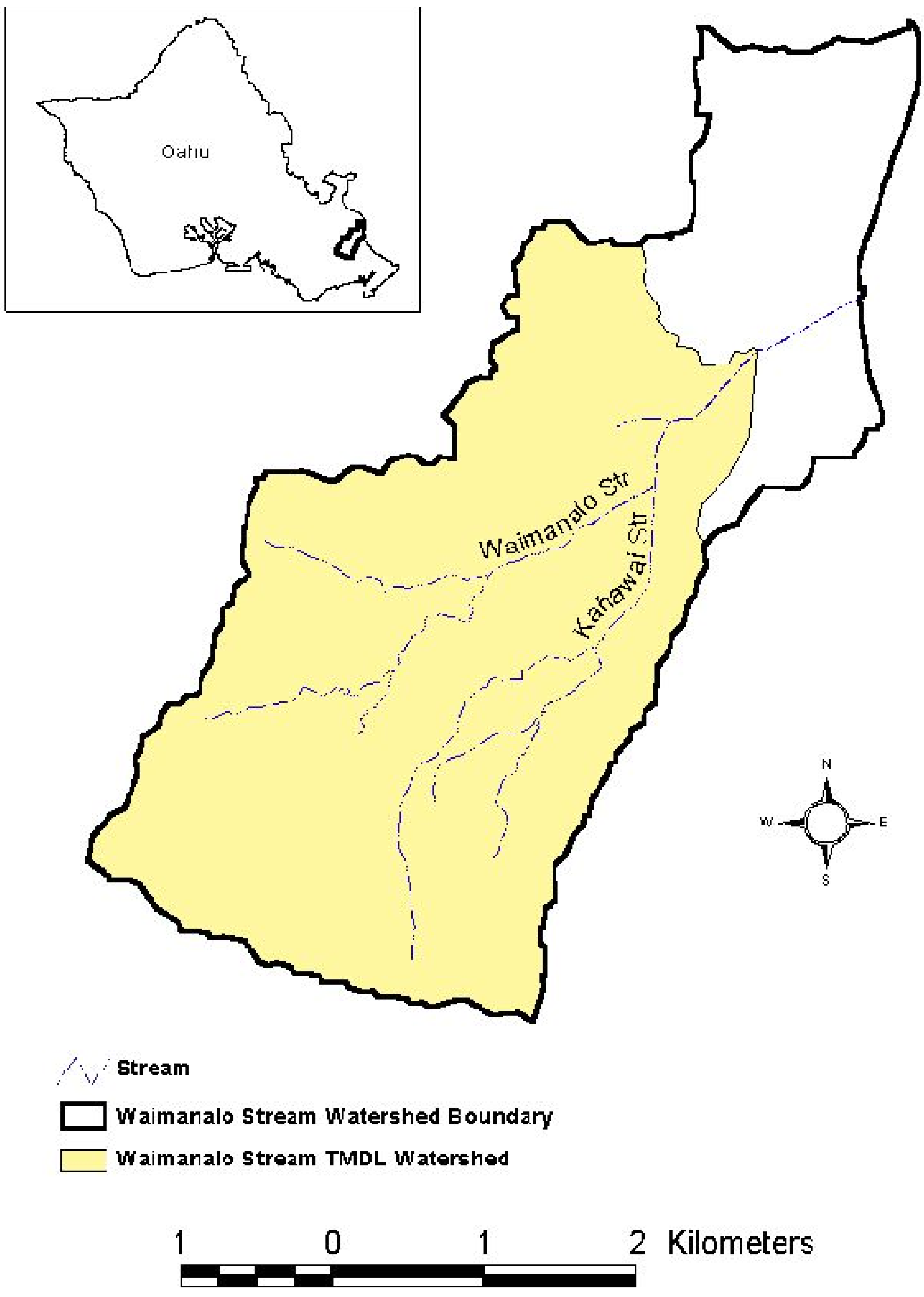

Figure 1. Map of Waimanalo watershed, Oahu (from Kihara, 2000).

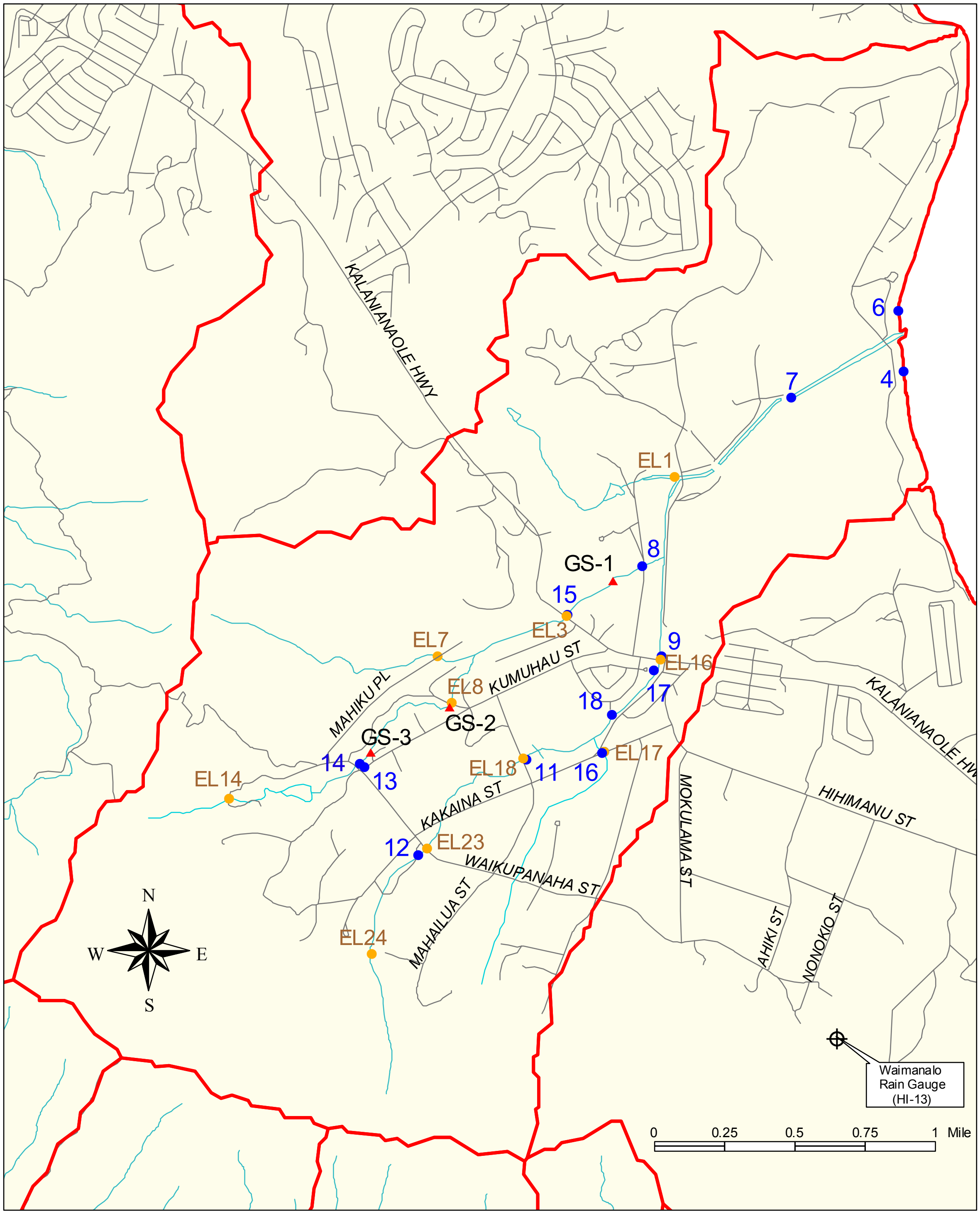

Figure 2.
Waimanalo Watershed
Sampling Stations

Bioassessment Monitoring Stations
Ed Laws' Sampling Stations
DOH Sampling Stations
Waimanalo Stream
Watershed Boundary

Department of Health EGIS 7.6.00

Waimanalo Stream is impaired primarily by sediments and nutrients (HIDOH, 1998). Stream channels have been heavily modified over time by a variety of flood control projects which, by removing trees and exposing stream channels to more light, have encouraged the growth of channel-clogging California grass and other vegetation that takes up water and traps sediments, converting extensive stream reaches from free-flowing waters to stagnant wetlands (Laws, 2000 and Tomlinson and DeCarlo, 2000). Historically, the natural wetlands that used to exist in the riparian zone in Bellows Field functioned to assimilate nutrients and trap sediments before the water discharged into the bay. During periods of very heavy rain, not experienced during the course of this project, significant quantities of vegetation are dislodged and carried seaward, often causing the stream to overflow at bridge crossings where channels tend to become blocked by tangled mats of vegetation. Heavy stream flows wash away the beach berm, depositing large amounts of sediments, vegetation, trash, and anything else washed off the land into Waimanalo Stream in the coastal waters. Although the stream acts as a sediment trap in typical low flow conditions, periodic major discharges of pollutants from land caused by the present pulsed flow system can significantly degrade the water quality in Waimanalo Bay for several weeks at a time. Waimanalo Bay is not listed on the CWA 303(d) List of Impaired Waterbodies, because it is assumed that most of the pollutants in the bay are transported there via Waimanalo Stream. Reducing the pollutant load of Waimanalo Stream should improve the water quality in Waimanalo Bay.

Waimanalo Stream likely has pollution problems that not addressed in this TMDL, beyond just nutrients and sediments. Chlorofluorocarbons, pesticides, temperature, heavy metals, petroleum-based hydrocarbons, and bacteria may also exceed acceptable levels in Waimanalo Stream. Potentially contaminated military sites, underground storage tanks, and periodic algal blooms are of concern to residents of Waimanalo (Glover, Waimanalo Resident, pers. comm.).

Krupp (2000) collected various types of geo-referenced data and created a Geographic Information System (GIS) for Waimanalo Stream (available from EPO upon request). His surveys found that just over one per cent of the streambed remains natural and over 42 per cent of the mapped stream is choked with dense growths of grass (California grass, usually), although his crew was unable to access and account for those sections of the stream that were the most overgrown (Table 8; see also Tables I-IV in Krupp (2000)). This information on bank conditions demonstrates the extent to which Waimanalo Stream has become altered.

The stream course has been so altered in some places that it has led to serious habitat and flooding problems. For example, during one sampling period at Station 1 in the Waimanalo Stream Tributary subwatershed, the water was flowing backwards while deep streams in the golf course fairways were pouring water into the tall California grass between the golf course and the stream. The drainage has been so altered by the golf course that no one stream course still exists, leading to serious flooding problems in the Saddle City area (comment at public meeting of December 11, 2000).

Laws (2000) determined the appropriate WQS to use (Table 9) to calculate each TMDL by analyzing the magnitude and duration of the observed storm events (Laws, 2000). The “Two Per Cent Recurrence” WQS was used to calculate the high flow TMDLs because the storm events measured occur about 2.5 per cent of the time. Hence, any criterion that is consistently violated during rains of this magnitude or greater constitutes a violation of the WQS. The Geometric Mean WQS was used to calculate the low flow and zero flow TMDLs, because these flow conditions are expected to occur the remaining 97.5 per cent of the time. The data are biased towards low flow because the four years preceding and during this sampling effort were unusually dry.

Table 8. Vegetation in or above the mapped portion of Waimanalo Stream, its tributaries, constructed drainages, and ditches (modified from Krupp (2000)).

TYPE OF GROWTH	TOTAL LENGTH OF SEGMENTS COMBINED (M)	PERCENT LENGTHS
clear	4,755	30
clear w/ orange sediment	13	<1
choked short grass	1,017	6
choked tall grass	4,247	27
canopy (clear)	2,244	14
choked and canopy	808	5
some vegetation	1,665	10
dirt filled	76	<1
thick bushes/shrubs	401	3
uncertain	759	5
Total	15,936	100

Table 9. Summary of Water Quality Standards for streams, listed in H.A.R. Chapter 11-54-05.2. "Inland Water Criteria."

Parameter	Geometric mean not to exceed the given value	Not to exceed the given value more than ten per cent of the time	Not to exceed the given value more than two per cent of the time
Total Nitrogen (μg N/L)	250.0* 180.0**	520.0* 380.0**	800.0* 600.0**
Nitrate + Nitrite Nitrogen (μg $[NO_3+NO_2]$-N/L)	70.0* 30.0**	180.0* 90.0**	300.0* 170.0**
Total Phosphorus (μg P/L)	50.0* 30.0**	100.0* 60.0**	150.0* 80.0**
Total Suspended Solids (mg/L)	20.0* 10.0**	50.0* 30.0**	80.0* 55.0**
Turbidity (N.T.U.)	5.0* 2.0**	15.0* 5.5**	25.0* 10.0**

[*] Rainy season - November 1 through April 30.
[**] Dry season - May 1 through October 31.

For the purposes of the TMDL program, “time” is defined as one year.

L = Liter
N.T.U. = Nephelometric Turbidity Units. A comparison of the intensity of light scattered by the sample under defined conditions with the intensity of light scattered by a standard reference suspension under the same conditions. The higher the intensity of scattered light, the higher the turbidity.
μg = microgram or 0.000001 grams

pH Units - shall not deviate more than 0.5 units from ambient conditions and shall not be lower than 5.5 nor higher than 8.0
Dissolved Oxygen - Not less than eighty per cent saturation, determined as a function of ambient water temperature.
Temperature - Shall not vary more than one degree Celsius from ambient conditions.
Specific Conductance - Not more than three hundred micromhos/centimeter.

Bottom criteria for streams:
Episodic deposits of flood-borne soil sediment shall not occur in quantities exceeding an equivalent thickness of five millimeters (0.20 inch) over hard bottoms twenty-four hours after a heavy rainstorm.
(A) Episodic deposits of flood-borne soil sediment shall not occur in quantities exceeding an equivalent thickness of ten millimeters (0.40 inch) over soft bottoms twenty-four hours after a heavy rainstorm.
(B) In soft bottom material in pool sections of streams, oxidation-reduction potential (EH) in the top ten centimeters (four inches) shall not be less than +100 millivolts.
(C) In soft bottom material in pool sections of streams, no more than fifty per cent of the grain size distribution of sediment shall be smaller than 0.125 millimeter (0.005 inch) in diameter.
(D) The director shall prescribe the appropriate parameters, measures, and criteria for monitoring stream bottom biological communities including their habitat, which may be affected by proposed actions. Permanent benchmark stations may be required where necessary for monitoring purposes. The water quality criteria for this subsection shall be deemed to be met if time series surveys of benchmark stations indicate no relative changes in the relevant biological communities, as noted by biological community indicators or by indicator organisms which may be applicable to the specific site.”

As mentioned above, these standards are representative of good quality waters in moderate flows in relatively natural, unclogged stream channels, a condition not achieved by Waimanalo Stream at present. Briefly stated, environmental problems in Waimanalo Stream were created over time by flow diversion, habitat damage, and stream channel modification. The Board of Water Supply’s wells and several privately-owned wells (legal and illegal) in Waimanalo watershed reduce the flow in Waimanalo Stream (comment at public meeting of December 11, 2000). Channelization and clearing of vegetation, especially trees that once shaded the stream and inhibited the growth of dense stands of the introduced California grass, land use activities that increase erosion and result in losses of soluble chemical fertilizers to the stream, and contaminated groundwater inflows have resulted in development of highly eutrophic conditions in the stream. The present system of large pulsed rather than small steady stream discharges has resulted in disproportionately severe water quality impacts to Waimanalo Bay after heavy rains in the basin. Regardless of how many BMPs are implemented for sediment and nutrient control, significant improvement in the water quality of Waimanalo Stream will be difficult to achieve unless in-stream standards for flows are set to increase the base flow and stream channels and riparian wetlands are at least partly restored to their natural form and function.

Despite its impaired condition, Waimanalo Stream is inhabited by a suite of endemic and indigenous aquatic species (see Section 5 – Biological Assessment) and there have been sightings of federally-listed endangered birds (stilts and coots) using the stream. Improving the quality of the water and habitat in Waimanalo Stream will improve the likelihood of survival of these species.

2. Numeric Target Definition

The WQS for streams, listed above, and estimated flow rates were used to calculate the TMDLs for Waimanalo Stream. For TMDL purposes, the WQS represent goals, or numeric targets, for water quality improvement projects that will be undertaken as a result of this study. When the TMDLs are met, the goal of achieving the WQS for Waimanalo Stream will also be met.

Waimanalo Stream is classified as a class 2 stream. According to H.A.R. Chapter 11-54-03(b)(2), "[T]the objective of class 2 waters is to protect their use for recreational purposes, the support and propagation of aquatic life, agricultural and industrial water supplies, shipping, and navigation. The uses to be protected in this class of waters are all uses compatible with the protection and propagation of fish, shellfish, and wildlife, and with recreation in and on these waters. These waters shall not act as receiving waters for any discharge which has not received the best degree of treatment or control compatible with the criteria established for this class." State WQS are also supported by the CWA antidegradation policy (40 CFR §131.12), which requires, in part, that "[E]existing instream water uses and the level of water quality necessary to protect the existing uses shall be maintained and protected."

Mitigation of contaminated sediments and contaminated tissues of edible stream organisms may also be addressed in a water quality standards-based approach to water pollution control. However, because the initial focus of the Waimanalo TMDL program is on control of sediment and nutrient loads entering the stream, we have not examined sediments or tissues of edible organisms for chemicals posing a possible public health risk. Samples collected by the US Geological Survey (USGS) in 1998 in other streams on Oahu that drain urban and agriculture areas, as part of the National Water-Quality Assessment (NAWQA) project, contained high concentrations of organochlorides, specifically chlordane, dieldrin, and DDT (Brasher and Anthony, 2000). Based upon the land use patterns in Waimanalo watershed, it is likely that the water quality of Waimanalo Stream will show similar evidence of urban and agriculture land use (Brasher, USGS NAWQA Project Leader, pers. comm.).

The purpose of the Waimanalo TMDL process conducted in 1999-2000 was to identify the magnitude and location of sediment and nutrient loads entering Waimanalo Stream in excess of those allowed by the WQS and accompanying antidegradation policy. The end result of the process is a set of allowable pollutant loads, that, when met, will bring Waimanalo Stream in compliance with the Water Quality Standards and restore the protected uses.

3. Source Analysis and Estimation

Current land uses along the streambanks were mapped and photographed by Krupp (Krupp, 2000). A CD-ROM containing these files is available upon request; file formats include ArcView, Microsoft

Word, and Excel. Kihara (elec. comm., 2000) delineated 18 different subwatersheds in Waimanalo Watershed using topographical data. We have consolidated these subwatersheds into six subwatersheds, which are based upon topography and appropriately-sited sampling locations with sufficient data to characterize the water quality of that subwatershed (Figure 3).

Waimanalo Stream Upper
Waimanalo Stream Middle
(including the subdrainage – Waimanalo Stream Middle Urban)
Waimanalo Stream Tributary
Kahawai Stream Upper
Kahawai Stream Middle
Waimanalo Stream Lower

No data were collected for the lowest subwatershed (Waimanalo Stream Lower) because it extends beyond the freshwater extent of the stream..

In his report, Laws concluded that 80-90 per cent of the nutrient and TSS load at Station 16 originates in the lower part of the Kahawai Stream Middle Subwatershed. Channel hardening and lack of riparian vegetation contributes to the poor functioning of the stream reach, and instead of nutrient and sediment recycling, these materials continue to be transported downstream. This result is different from what was found for Waimanalo Stream Middle Subwatershed, where the upper part accounts for 65-75 per cent of the nutrient and TSS load and the lower part of the subwatershed for only 25-35 per cent (Laws, 2000).

Pollutant loads enter Waimanalo Stream via both surface flow and subsurface flow. For example, most of the nitrate measured at Station 16 (Kahawai Stream Middle Subwatershed) is carried in groundwater flows (Laws, 2000).

For high flow conditions, load allocations are assigned to five different land use categories in each of five subwatersheds of Waimanalo Watershed. Loads are allocated in proportion to the acreage per land use in each subwatershed, given below. The land-use designations, are taken from Kihara's report (Kihara, 2001). In cases where *Water* is an existing land use, no allocation is made to water itself and that small portion of the allowable load is retained as an additional margin of safety (resulting in some allocations totaling less than 100%).

A. Waimanalo Stream Upper Subwatershed – Station 14
   Conservation – 77%
   Steep slope - 23%
B. Waimanalo Stream Middle Subwatershed – Station 3
   Agriculture – 32%
   Conservation – 49%
   Steep slope – 19%
C. Kahawai Stream Upper Subwatershed – Stations 23 and 24
   Agriculture – 21%
   Conservation – 25%
   Steep slope - 53%
D. Kahawai Stream Middle Subwatershed – Station 16
   Urban – 5%
   Agriculture – 75%

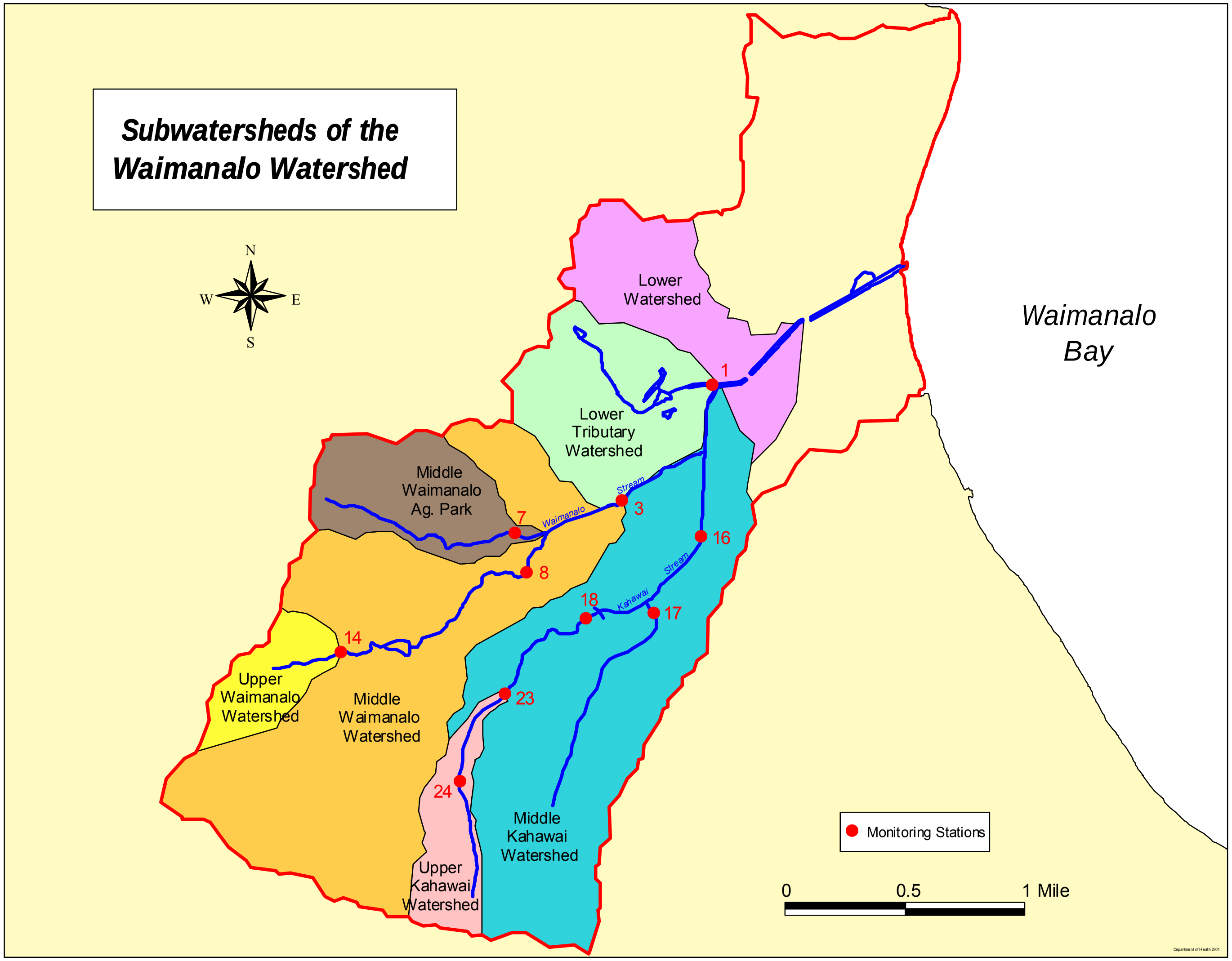

Figure 3. Subwatersheds of Waimanalo watershed (modified from Kihara, 2000).

Conservation – 7%
Steep slope - 13%

E. Waimanalo Stream Tributary Subwatershed– Station 1
Agriculture – 63%
Conservation – 35%

F. Waimanalo Stream Lower Subwatershed (was not sampled, TMDL was not developed)

For example, during the rainy season at a high flow condition in the Kahawai Stream Upper Subwatershed, 53 per cent (1644 µg/s) of the allowable nitrate load (3102 µg/s – see Table 10) entering the stream is allocated to lands with a slope greater than 100% because 53 per cent of the subwatershed is comprised of lands with steep slope. For nitrate, 776 µg/s is allocated to the conservation lands and 651 µg/s is allocated to agriculture lands. The same method may be used to compute source load allocations for the remaining subwatersheds and pollutants. (See Appendix A for another sample source load allocation and for the load allocation formula. Please note that there are 3-4 land use categories associated with each of the 79 TMDLs listed in Table 10, for a maximum of 79 x 4 = 316 load allocations. Specific allocations may be computed at the time of BMP design for selected subwatersheds, but were not calculated in this report for the sake of brevity). Sufficient BMPs must be developed and implemented on each land-use category for each subwatershed to reduce the load to that set by the TMDLs.

Additional sampling locations and land-use ground truthing would enable the loads to be more accurately allocated. However, these allocations provide a starting point for initial BMP implementation efforts. More precise load allocations may be desired when implementing the TMDL reductions in specific subwatersheds.

For low flow and zero flow conditions, the entire load is allocated to groundwater input, because we are assuming that groundwater is the sole contributor to the baseflow. Appropriately applied BMPs should be able to prevent pollutants from entering both the groundwater and surface flow.

4. Linkage Analysis

Five pollutants relevant to the Waimanalo Stream TMDL have numeric limits listed in H.A.R. Chapter 11-54-02(b)(1) – total suspended solids (TSS); dissolved nitrate; total dissolved nitrogen (TDN); total dissolved phosphorus (TDP), and turbidity. For reasons described below, TMDLs were not developed for TDN and turbidity.

The variation in TDN levels can be explained by the variations in nitrate levels, so we did not calculate separate TMDLs for TDN. Figure 4 shows the relationship between nitrate and TDN for the data collected in Waimanalo Stream. The correlation coefficient between nitrate and TDN is 0.87, which means that $(0.87)^2$ or 76 per cent of the variations in TDN levels is explained by variations in nitrates, an unsurprising result in oxidizing environments. Consequently, nitrate is a good surrogate indicator for TDN in Waimanalo Stream. Implementation of nitrate reduction BMPs will result in significant reduction of the TDN loads, most likely enough to result in compliance with the TDN WQS.

Likewise, variations in turbidity can be explained by variations in TSS. Figure 5 shows the relationship between turbidity and TSS for the data collected in Waimanalo Stream. The correlation coefficient

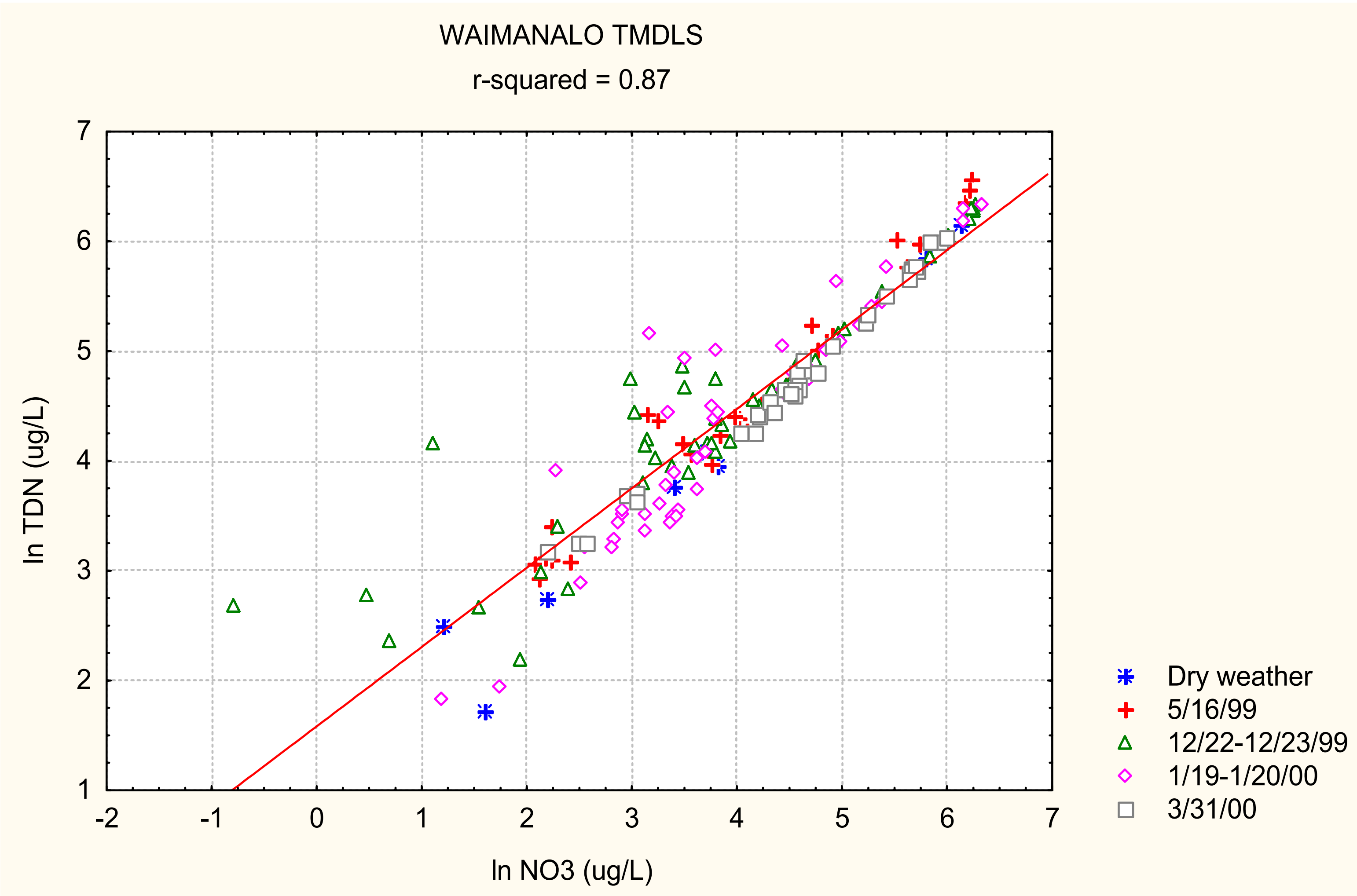

Figure 4. Relationship between NO_3 and TDN.

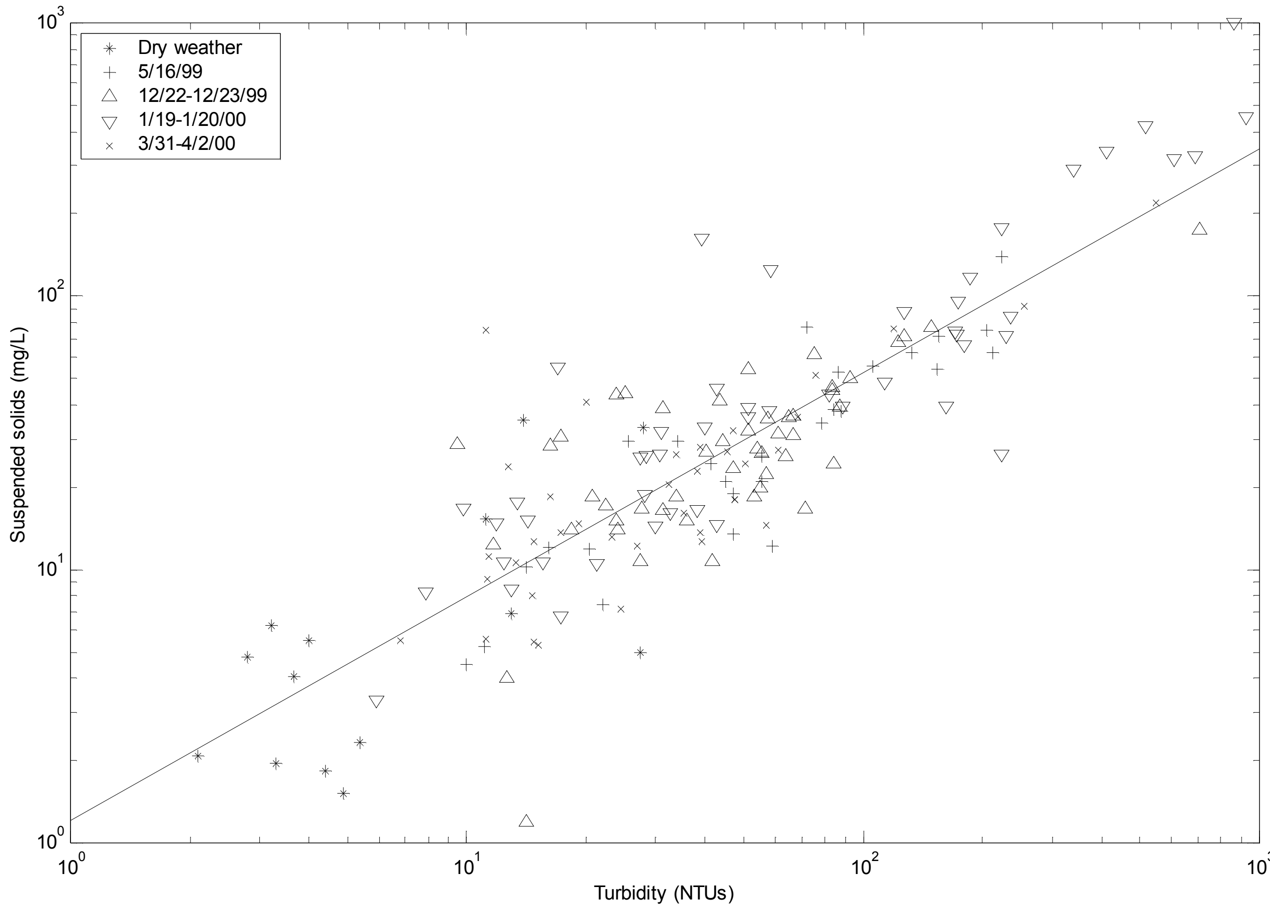

Figure 5. Relationship between turbidity and suspended solids (from Laws, 2000).

between turbidity and TSS is 0.86, so it is reasonable to view TSS as an appropriate surrogate for turbidity. However, even though turbidity and TSS are correlated, they are not measures of the same thing. Turbidity is also affected by the presence of colored dissolved substances that do not affect the

TSS measurement. A comparison of TSS and turbidity data shows that TSS levels associated with the turbidity standards appear to be lower than the TSS standards, so the TSS TMDL for high flows is set at 0.86 of the TSS WQS. Low flow and zero flow TSS TMDLs are based upon the uncorrected TSS WQS. In the future, all turbidity measurements will be taken in the field rather than measured in the laboratory because the laboratory data consistently underestimate the field results.

Many other water quality parameters were measured during the course of the study, and the results describe the broader picture of water quality in Waimanalo Stream; these data are compiled in Tables 1 and 2.

Natural stream systems have the ability to receive water with a certain concentration of pollutants and still deliver clean water to bays and the open ocean without violating water quality standards. A functioning stream system will cycle nutrients and filter contaminants from runoff. However, two conditions can cause this process to break down: too large a concentration of pollutants and a non-functioning stream system. Both of these conditions appear to exist in Waimanalo Stream.

Highly eutrophic low flow conditions, characterized by long water residence times in bright sunlight at elevated temperatures, excess dissolved nutrients, dense vegetation stands that trap sediments in the channels, and large swings in dissolved oxygen and pH caused by diurnal variations in photosynthesis of aquatic plants have caused many reaches in Waimanalo Stream to develop wetland characteristics (Laws, 2000 and Tomlinson and DeCarlo, 2000). Periodic heavy rains will clear out the channels temporarily, to the detriment of water quality in Waimanalo Bay.

When implemented in conjunction with stream improvement projects, the TMDLs will reduce the amount of sediments and nutrients being transported by Waimanalo Stream to a level such that the WQS are met. Full implementation of the TMDLs will most likely require both a reduction in the concentration of pollutants entering the stream and modification of flow and the streambank. Decisions must be made as to how to allocate potential funding towards pollution reduction and stream improvement efforts. Stream channels must be cleared of vegetation but shaded by bank vegetation, flood control basins should be built and riparian wetlands restored, and low flow channels constructed in order to reduce the eutrophic nature of this stream and increase its ability to transport nutrients and sediments downstream and into Waimanalo Bay in reasonable amounts that can be assimilated slowly over time.

5. Compute TMDLs and Partition the Loads Among Contributing Sources

Two independent arrays of sampling stations were established along the length of Waimanalo Stream. The first station array was established by the CWB and sampled from November, 1999 to April, 2000; the second array was established by Laws (2000) and his team of community assistants and sampled from February, 1999 to April, 2000 (see Figure 2). Not all of the CWB data include flow measurements; Laws' data contain simultaneous approximations of flow (obtained by non-automated methods) and concentration. Rainfall data were acquired from the Waimanalo sampling station (National Weather Service, station HI-13) (see Figure 2). Because the rain gage is located a considerable distance southeast of the Waimanalo Stream system, we used these data only as guidance for the amount of rainfall over the sampling stations, and relied on approximated flows to establish a flow range for the nitrate, TDP, and TSS TMDL computations. Figure 6 shows cumulative stream flow frequencies across the four storms sampled by Laws. The arrow marks the median flow value, 86 L/s.

The standard operating procedures selected for the Waimanalo TMDL computation minimize assumptions about the data and are based on comparisons of measured fluxes (observed) to water quality standards-based fluxes (expected). The geometric means of fluxes were computed for each station across the three storms sampled in the rainy season (rainy season-high flow fluxes), one storm sampled in the dry season (dry season-high flow fluxes), and for a limited number of non-rain events (dry season-low flow fluxes and rainy season-low flow fluxes). Concentration-based TMDLs were computed for a limited number of dry and rainy season-zero flow events. Steps in the procedure for reducing the grab samples and stream flow data are:

a. Multiply the water quality standard appropriate for the season for that pollutant (in µg/L or mg/L) by the flows (L/s) at each station; the result is the expected flux of pollutant passing that station in µg/s or mg/s for the same time as the observed flux was measured. For dry season- and rainy season-low flows, use the geometric mean water quality standard in effect at the "50% of the time" level; for rainy season-high flow, use the geometric mean standard in effect at the "2% of the time" level (see page 13 or H.A.R. Chapter 11-54-05.02(b)(1) for the table of stream criteria).
b. Compute the geometric means of the loads for each station across all sampling conditions. Establish TMDLs on a subwatershed basis in order to account for background loading conditions, allocate loads to specific land uses and sections of the watershed, allow upstream-downstream comparisons, and provide a clear sense of what levels of load reduction are needed in land areas adjacent to different reach areas.
c. In cases where flows equal zero, establish concentration-based TMDLs at the level of the WQS standard appropriate for the season, rainy or dry.
d. To determine the observed flux to be compared with the TMDL, multiply the pollutant concentration measured at each station (in µg/L or mg/L) by stream flow (in L/s); the result is the observed flux of pollutant passing that station in µg/s or mg/s at that time.

The method that HIDOH developed to calculate TMDLs for Waimanalo makes full use of the data collected but does not make unsupported assumptions. The calculations are simple, readily understandable, and can be related back to actual events in the watershed. However, it appears that this approach underestimates high flow event mean flows and loads and results in high flow TMDLs that are lower than those calculated from an approach based on application of event mean flows and fluxes estimated from flow models. Because the TMDLs are only accurate to within an order of magnitude, an appropriate scale for detecting improvement based upon BMP implementation, the difference in methodology will not be significant in practice. EPA accepts this method because it results in more environmentally protective TMDLs than those calculated using a modeling method. The end result is the same – when the TMDLs are implemented, Waimanalo Stream will meet the Water Quality Standards. (See Appendix B for a side-by-side comparison of DOH and EPA flow model high flow TMDL results).

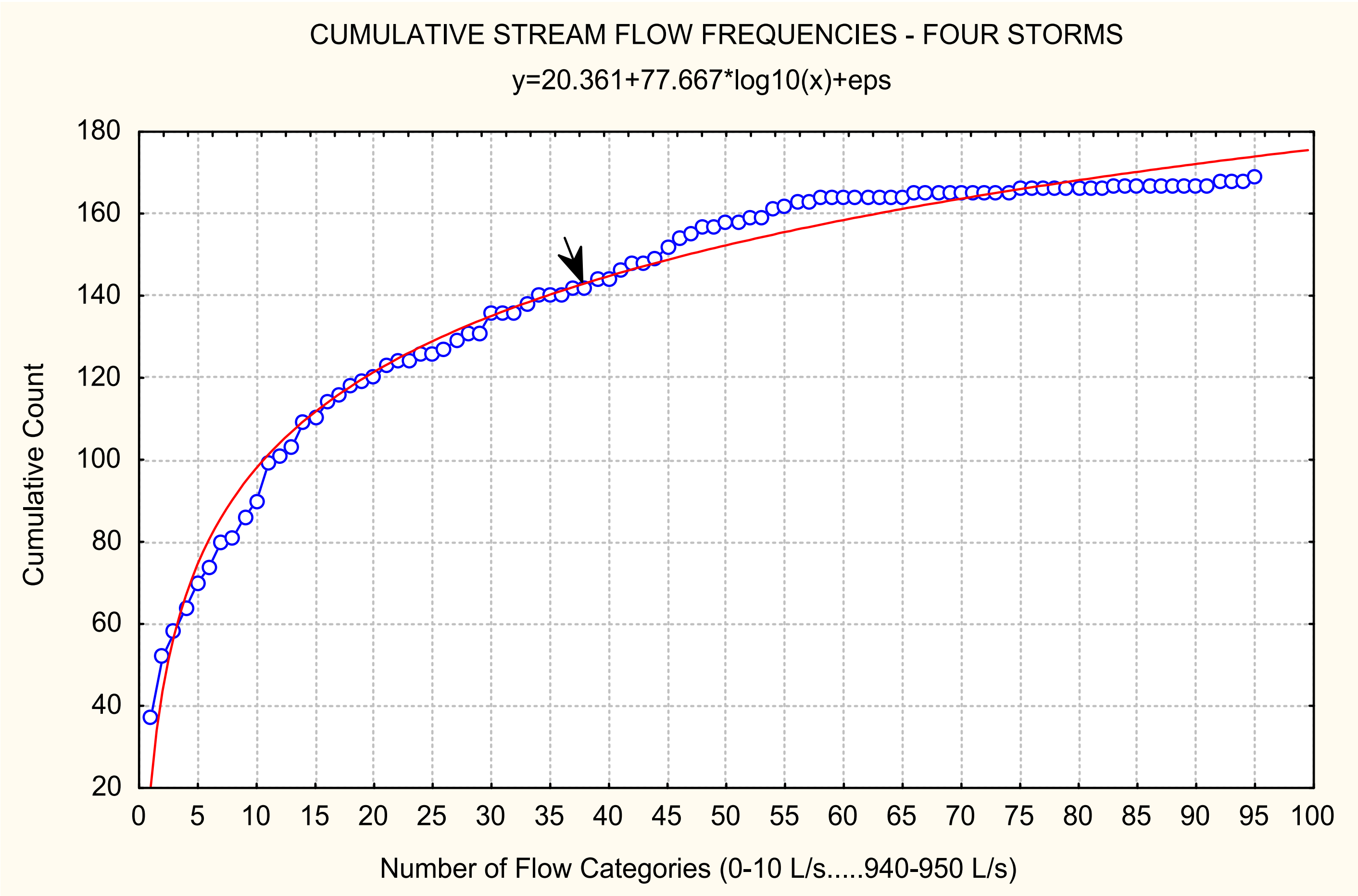

Figure 6. Cumulative stream flow frequencies across the four storms sampled by Laws. The arrow marks the median flow value, 86 L/s. Open circles represent data points; the solid line represents the logarithmic distribution curve. (n = 164 flow measurements)

The TMDLs for nitrate, TSS, and TDP are listed below (Table 10). HIDOH also established Habitat and Biotic Integrity TMDLs, described below (Table 11).

Figures 7a, 7b, and 7c depict the observed fluxes vs. the expected fluxes (TMDLs) for TSS, nitrate, and TDP, respectively at ten sampling locations on Waimanalo Stream.

Table 10. Waimanalo Stream TMDLs.

Critical Condition	Nitrate (µg/s) (rainy season)	Nitrate (µg/s) (dry season)	TSS (mg/s) (rainy season)	TSS (mg/s) (dry season)	TDP (µg/s) (rainy season)	TDP (µg/s) (dry season)
Upper Kahawai (measured at Stations 23 or 24)						
High flow	24,641	408	5,651	114	5,911	192
Low flow	112		32		80	
Zero flow	70.00 (µg/L)	30.00 (µg/L)	20.0 (mg/L)	10.0 (mg/L)	50.0 (µg/L)	30.0 (µg/L)
Upper Waimanalo (measured at Station 14)						
High flow	12,385	7,981	2,841	2,221	2,324	24
Low flow	735		210		525	
Zero flow	70.00 (µg/L)	30.00 (µg/L)	20.0 (mg/L)	10.0 (mg/L)	50.0 (µg/L)	30.0 (µg/L)
Kahawai above confluence (measured at Station 16)						
High flow	106,711	6,966	27,925	1,938	40,107	3,278
Low flow	4,340	690	1,240	230	3,100	690
Zero flow	70.00 (µg/L)	30.00 (µg/L)	20.0 (mg/L)	10.0 (mg/L)	50.0 (µg/L)	30.0 (µg/L)
Middle Waimanalo (measured at Station 3)						
High flow	103,414	16,152	23,716	4,494	39,811	7,601
Low flow	6,212	432	1,775	144	4,437	432
Zero flow	70.00 (µg/L)	30.00 (µg/L)	20.0 (mg/L)	10.0 (mg/L)	50.0 (µg/L)	30.0 (µg/L)
Lower Waimanalo Tributary (measured at Station 1)						
High flow	3,629	51	832	14.2	429	24.0
Low flow						
Zero flow	70.00 (µg/L)	30.00 (µg/L)	20.0 (mg/L)	10.0 (mg/L)	50.0 (µg/L)	30.0 (µg/L)
Middle Waimanalo Ag Park (measured at Station 7)						
High flow			124			

Rainy season = November 1 through April 30.
Dry season = May 1 through October 31.
Critical conditions:

High flow = Storm events
Low flow = Non-rain events
Zero flow = No flow (TMDL is based on the WQS concentration)

High flow TMDLs are set with 2% WQS.
Low and zero flow TMDLs are set with the Not To Exceed WQS.
Dry season-high flow TMDLs are based upon only one sampled storm.
TSS high flow TMDLs are set with 0.86*WQS because TSS/turbidity regression analysis shows that TSS levels associated with turbidity standards appear to be lower than the TSS standards.
Flow data were not collected at Station 1 during rainy season-low flow conditions, so those TMDLs cannot be set at this time.
Upper Kahawai TMDLs for rainy season-high flow and all zero flow conditions are based upon data collected at Station 24. Upper Kahawai TMDLs for rainy season-low flow and dry season-low flow are based upon data collected at Station 23.

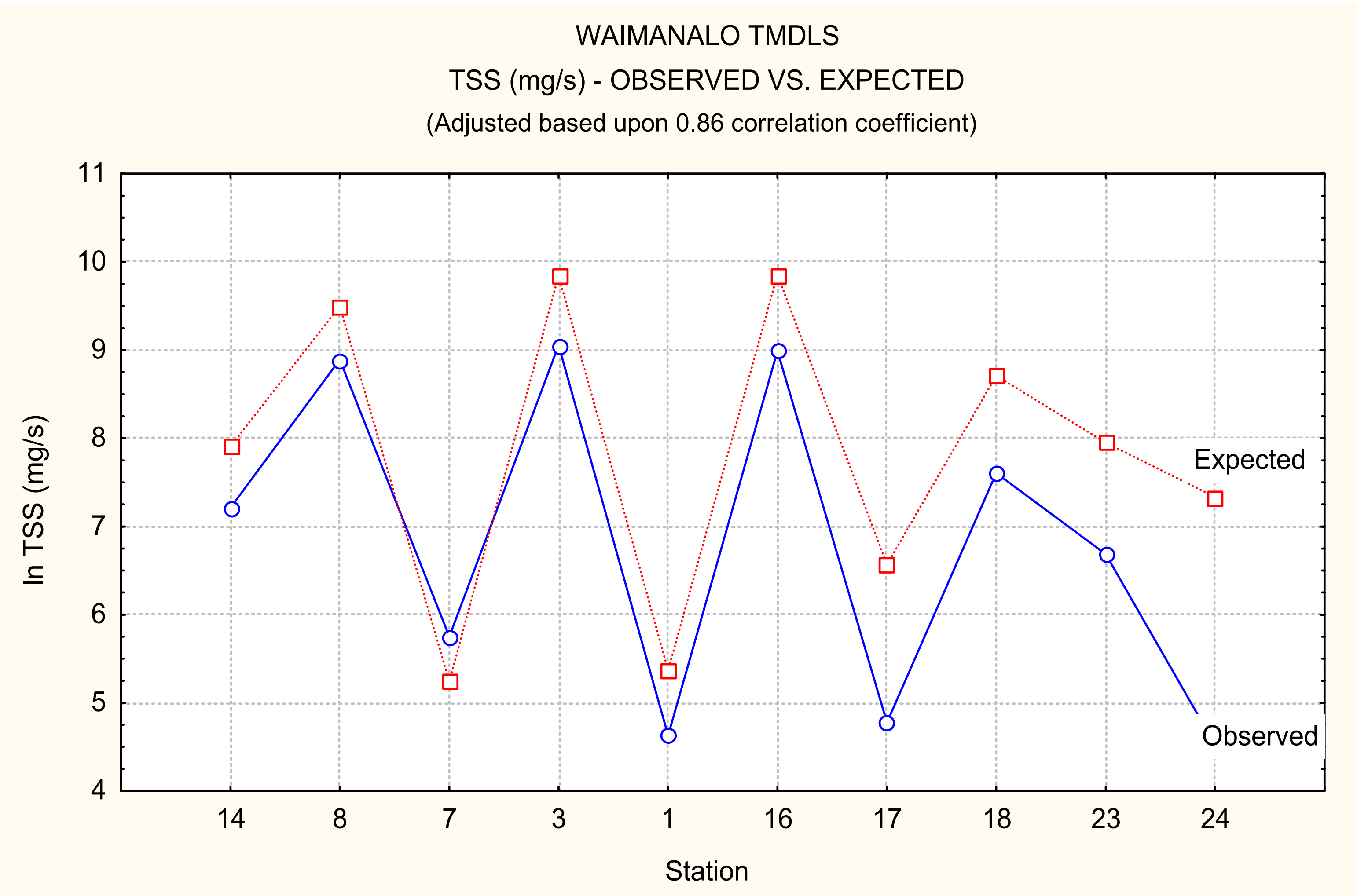

Figure 7(a): Stations are arranged to show the flow of water along Kahawai tributary in the seaward direction (stations 14 to 3) and along Waimanalo Stream in the seaward direction (stations 24 to 16). Station 1 is on a tributary that runs through a golf course. Expected TSS fluxes exceeded observed (measured) fluxes at all stations except station 7. TSS values have been adjusted by the 0.86 correlation coefficient (See Laws, 2000) and converted to natural logs.

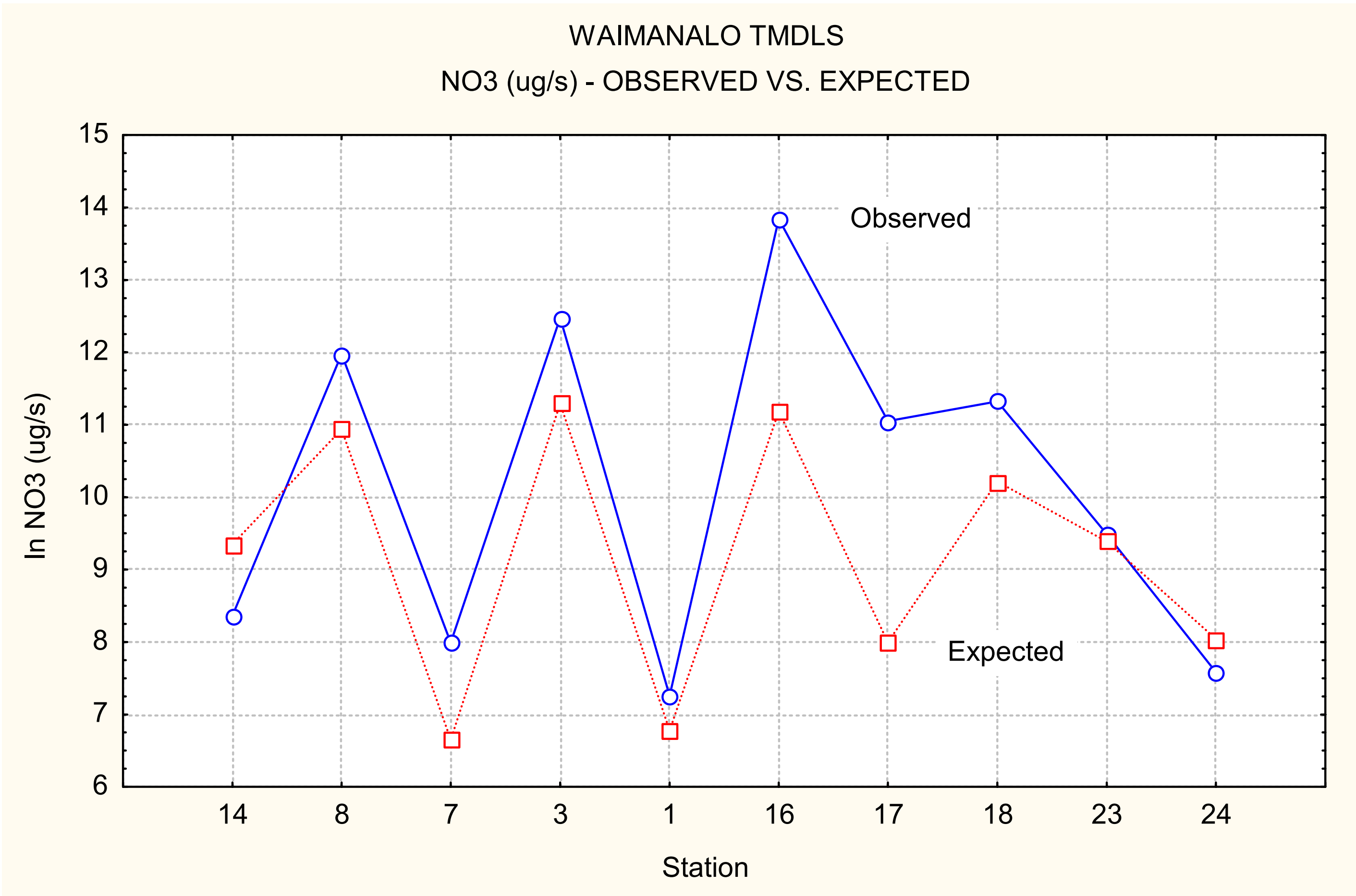

Figure 7(b). Observed NO_3 fluxes exceed expected fluxes at all but the upper watershed stations 14 and 24, indicating widespread excess nitrate loads in the lower, developed portions of the watershed. Nitrate values have been converted to natural logs.

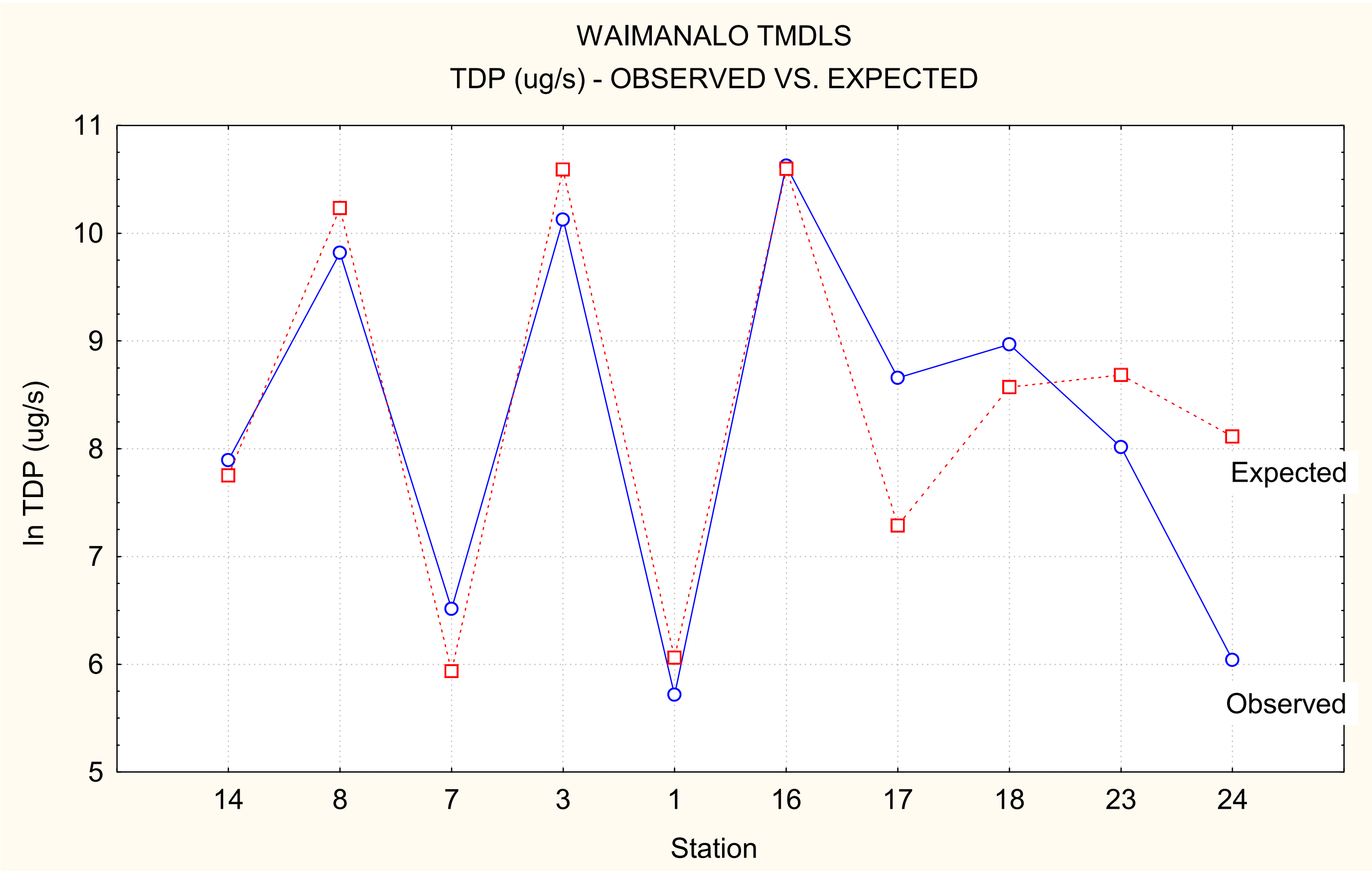

Figure 7(c): Observed TDP fluxes are significantly greater than expected fluxes only at station 17.

<u>Habitat and Biotic Integrity TMDLs:</u> The State of Hawaii is in the incipient stages of developing a biological assessment method to assesses the biotic integrity of streams. Because poor water quality in streams is often linked with habitat degradation, which leads to loss of biotic integrity, bioassessments play an important role in developing and implementing TMDLs for Hawaii's streams. Smith (1988) conducted a biological assessment of Waimanalo Stream and developed TMDLs for habitat and biotic integrity (Table 11). When the nutrient, sediment, habitat, and biotic integrity TMDLs are implemented, Waimanalo Stream should meet all of the WQS. The biological assessment for Waimanalo Stream can be found on EPO's web site (http://www.state.hi.us/health/eh/epo/index.htm). The discussion of the habitat characteristics in the report will be valuable when selecting appropriate implementation measures to alleviate the nutrient and sediment problems.

Three study sites were selected for an assessment of the biological and habitat integrity of Waimanalo Stream (see Figure 2). The lowest site, Site 1, 200 m above the Saddle City Bridge crossing, has been extensively altered by human activities. The middle site, Site 2, is near Laws' station 8, and the upper site, Site 3, is located just below Waikupanaha Road Bridge, at CWB stations 13 and 14.

Results at Site 1 depict a degraded stream reach that scored very low (13% of the habitat reference score), and was categorized as "non-supporting" for aquatic life uses. The very low score can be attributed to the cementing of the substrate with fine sand and silt. The author described the site as a "monotonous slow flowing shallow pool." The biological metrics scored at 40% of the reference scores because of large numbers of introduced species, such as tilapia, which are common in degraded habitats. The presence of native fish and crustaceans, however, resulted in a finding of a "moderately impaired" aquatic community at this location.

Because of the presence of riffle and pool habitat, Site 2 received a higher habitat metrics score, 40% of reference, but a large silt load and eroding bank sections kept the site in the category of "non-supporting" for aquatic life uses. The biological metrics score, 33% of reference, places this site just within the "moderately impaired" aquatic community category.

The Site 3 habitat score was 45% of reference, which still falls within the "non-supporting" category. Eroding bank sections, dense upper canopy, and areas of bare soil are all problems present at Site 3 that prevent the stream from supporting biotic integrity. The biological metrics score was 27% of reference, lowest of the three sites.

Results of the biological assessment are in agreement with observations by Laws (2000) that the Waimanalo Stream habitat is severely degraded, and that Site 2, in particular (Laws station 8), is impacted by sediment loads, although not to the level of station 7. The author concluded that the habitat provided by Waimanalo Stream is badly degraded, especially those characteristics that relate to soil erosion, siltation, and riparian vegetation. Findings from the biological assessment support findings of severe habitat damage reported by Laws (2000) and Tomlinson and DeCarlo (2000), and extend the pollutant transport studies to include detrimental effects of introduced species on native aquatic communities along the entire length of the stream.

The author presents biological and habitat scores for Waimanalo Stream in comparison with expected scores representing reference conditions, and draws a parallel with the definition of a TMDL as the sum of wasteload and load allocations plus a margin of safety (Table 11). If the biological and habitat target score ranges are defined as the expected load allocation, the actual stream scores as the observed sediment and nutrient-caused degradation, and the margin of error is identified by the use of target score ranges, then a TMDL model may be written in biological assessment terms as: TMDL = expected scores (load allocation) + expected score range (margin of safety). The TMDL is a numeric expression of the following narrative goal expressed in Smith (1998):

> *"Aquatic life uses shall be supported in Waimanalo Stream; the habitat characteristics shall be improved at least into the range of values indicating 'partially supporting' habitat, and the biological community shall be brought at least into the range corresponding to 'moderately impaired' as measured by the HSBI."*

Table 11. Waimanalo Stream Habitat and Biotic Integrity TMDLs (includes Margin of Safety).

Habitat TMDL	Biotic Integrity TMDL
50-75% of reference	30-70% of reference

Figure 8 depicts the observed vs. expected values (TMDLs) for habitat and biotic integrity at the three sampled locations on Waimanalo Stream.

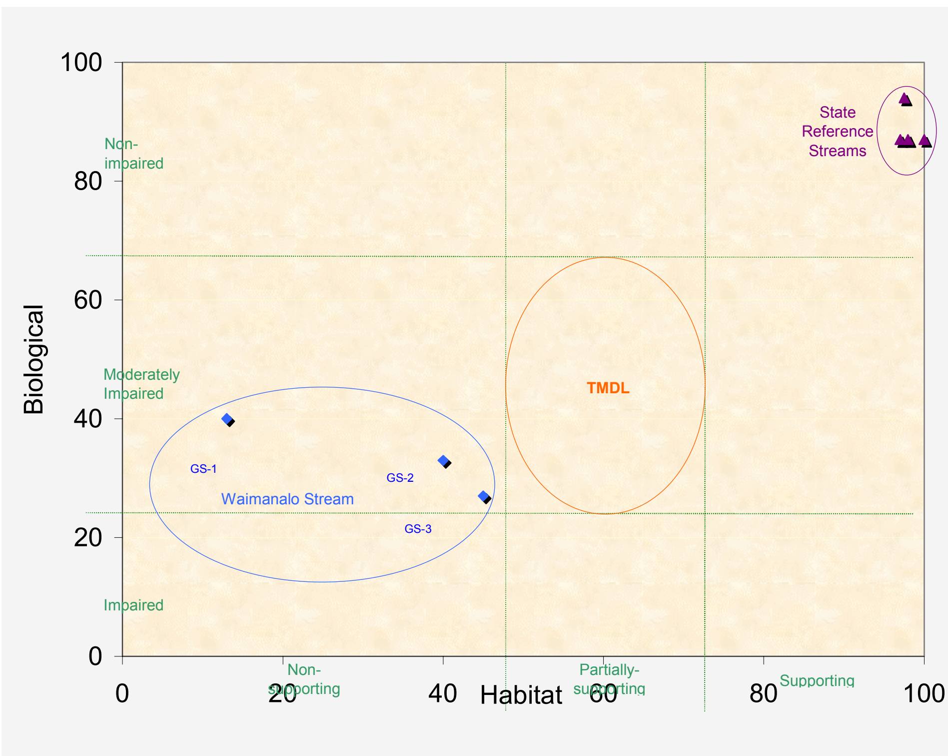

Figure 8. Observed, expected (TMDLs), and reference values for habitat and biotic integrity.

The end result of implementing the habitat and biotic integrity TMDLs will be an improvement of stream channels, reduction of sediment and nutrient loads, and reduction of introduced species impacts; similar results as are also expected through implementation of the flux-based TMDLs.

6. Margin of Safety Analysis

A margin of safety was built into each of the TMDLs through several conservative assumptions that are environmentally protective for Waimanalo Stream.

- Measurement errors have been accommodated by computing central tendencies (geometric means) across the storms sampled and by use of the WQS allowable for the season at the "2% of the time" value for the rainy season, and at the "50% of the time" value for the dry season.
- TMDLs were set for stations at which the limited high flow data indicated the WQS were being met, providing a margin of safety that helps to ensure that the TMDLs are set at levels that are expected to result in WQS attainment under the full range of high flow conditions.
- As discussed in Section 5, we selected the more conservative of two available calculation methods that results in more restrictive TMDLs for high flows.
- The TSS TMDLs were set as a function of the more restrictive turbidity standard, rather than the TSS standard itself.
- Habitat and biotic integrity TMDLs were established in addition to specific TMDLs for nutrients and sediments.
- The Land Use Boundary designations represent the most accurate land use information that was readily available to complete the TMDL. Preliminary sediment loading modeling results showed that sediment load contributions are not proportional to land use area, so the method to use land use percentages to allocate pollution loads (particularly sediment loads) may not be entirely accurate. However, by allocating loads proportionately to land use area, all types of land uses are held equally accountable – one type of use is not given a "license to pollute" while another is required to retain all of its pollutants.
- We assumed nutrients are conservative in the system, but it is likely that there is significant uptake and possibly long-term storage. Therefore, a margin of safety is added because the assimilative capacity of the system for nutrient inputs has been underestimated.

Sources of error in data collection and calculation methods include:

- A limited number of samples were collected, during a fairly dry year at the end of a four-year drought. Therefore, the TMDLs may not accurately reflect conditions that may occur in a more "normal" rainfall year.
- Flow was estimated using a basic non-automated methodology.
- The source allocations were made based upon Land Use Boundary maps produced by the State's Land Use Commission in May, 2000. These maps are representations for presentation purposes only and may not accurately reflect the actual on-the-ground land use.

Despite these known sources of errors, setting TMDLs with the WQS flux-based method represents a reasonable starting point for implementation. Subsequent monitoring during the implementation phase may be used to refine the TMDLs and should indicate whether or not BMPs are helping achieve better water quality. The present TMDLs should be regarded as initial, or interim, values.

7. Account for Seasonal Variations and Critical Conditions

Dry season conditions in Waimanalo Stream are characterized by highly eutrophic slow-moving flows or stagnant shallow pools in sections of the stream channels. When the flows were zero, pollutant fluxes could not be computed even though nutrient concentrations could be very high (sediments tend to settle to the bottom in shallow, still waters). In low flow conditions small amounts of pollutants continually introduced into the stream channels or regenerated in place will build up, then be washed downstream all at once during the larger rainfall events. Because of Hawaii's subtropical climate, conditions are fairly stable year round, except that maximum summer temperatures over unshaded channels with eutrophic low flows and minimum dissolved oxygen levels often reach levels unsuitable for survival of aquatic communities typical of the area.

Seasonal variation is accounted for by developing separate TMDLs for three different critical conditions (high, low, and zero flow) in each season (rainy and dry). Rainfall is more frequent in November through April (rainy season) than in May through October (dry season), although storms can occur at any time of the year. Rainy season conditions result in pulsed pollutant loads delivered downstream at distances and fluxes that are a function of stream flow, but drought years are not uncommon in Waimanalo, making low flow conditions the critical factor determining the magnitude of pollutant accumulation within the stream channels, and stream flow during storms the critical factor in determining the magnitude and rate of pollutant transport downstream.

8. Conduct a Public Participation Process

Members of the Waimanalo community helped collect the data that were used to develop the TMDLs for Waimanalo Stream. Community members will also be instrumental in developing the implementation plan. HIDOH used a draft version of this technical report as a launching point to initiate discussions with community leaders as to how best to get input from and involve the public in efforts to restore water quality in Waimanalo Stream. We requested comments and suggestions from the community leaders and public-at-large at this meeting, and have made appropriate revisions to this report based upon the input we received. These comments are summarized in Appendix C.

Finally, we have issued a public notice (February 5, 2001) soliciting official comments on this report, then we will prepare responses to comments and a final TMDL submittal for EPA approval. The final TMDL report and the comments received during the public notice period will be instrumental in developing future implementation plans. The implementation plans will need to include continued monitoring and mapping tasks. HIDOH will participate in TMDL completion as resources become available.

LIST OF PROJECT REPORTS AND REFERENCES

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Tomlinson, Michael and Eric DeCarlo (March, 2001). Final Report – Investigations of Waimanalo and Kaneohe Streams. Pp. 30.

Appendix A

Sample source load allocation:

Waimanalo Stream Middle Watershed at dry season-low flow conditions.
TMDL = 144 mg/s of TSS
70.6 mg/s allocated to conservation lands.
45.5 mg/s allocated to agriculture lands.
27.6 mg/s allocated to lands with slope>100%.
0.3 mg/s allocated to surface waters in the watershed.

Procedures to calculate additional source load allocations:

1. Determine TMDL for appropriate pollutant, location, critical flow condition, and season from Table 3.
2. Determine percentage of acreage of land use type for the subwatershed (page 12).
3. Multiply percentage of land use type by appropriate TMDL to obtain source load allocation.

SOURCE LOAD ALLOCATION = TMDL * LAND USE PERCENTAGE

Appendix B

Side-by-side comparison of rainy season-high flow TMDL results based upon HIDOH and EPA calculation methods.

Station/method	TSS TMDL (expected)	TSS Actual (observed)	TDP TMDL	TDP Actual	NO_3 TMDL	NO_3 Actual
3/DOH	23,716	9,796	25.1	39.8	103.4	298.7
3/EPA*	26,158	20,035	48.2	40.4	96.3	1,196
16/DOH	27,925	11,496	40.1	41.3	106.7	1,354
16/EPA*	31,304	29,201	68.3	82.5	136.5	6,393

* Also includes the one dry season-high flow event, which is not included in DOH figures.

Appendix C

WAIMANALO TMDL
COMMUNITY MEETING
December 11, 2000

-Meeting Summary-

1. Stream Vision – Waimanalo is not a stream at present.
2. The draft TMDL report divides the watersheds up differently than Ed Laws' report. How can we reconcile the differences? (Agreed to have a meeting to discuss on January 11, 2001).
3. Calculation methods for TMDLs are not fully supported by EPA, but results are the same as those from EPA's method. (EPA now fully supports HIDOH's method because it results in more environmentally protective TMDLs).
4. Report should emphasize the sampling station at the Agriculture Park. Runoff from roads is a sedimentation problem. The TMDL report does not mention roads or storm drains as contributing factors.
5. We have had dry years lately – how would more rain change results?
6. We don't have a good picture of watershed dysfunction, so it is hard to choose BMPs. Need to know why the watershed is *sick* before we can fix it.
7. How can the agencies and community groups coordinate within the watershed?
8. How is adaptive management being used? Use the Federal watershed management approach to develop uniform approaches.
9. Need to include Board of Water Supply in order to look at the whole picture.
10. The stream is missing the water.

Stream Visions

1. We need a community-driven approach to watershed management. (20 votes)
2. Prevent flooding, flows unclogged; sediment basins; no concrete. (9 votes)
3. Use a barrier to increase the groundwater table and stream flow. (8 votes)
4. Support native fish and wildlife. (6 votes).
5. Safe for cultural and recreational uses and for kids to play. (5 votes)
5. Unchannelized with wider flood plain. (5 votes)
5. Construct wetlands on Bellows Station. (5 votes)
5. Increase base flow; decrease flooding situations. (5 votes)
6. Clean water. (4 votes)
6. Control flooding without turning stream into a storm sewer. (4 votes)
7. Look like a natural stream before human contact. (0 votes)
7. Restore stream to high ecological status. (0 votes)