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Assessment and Protection Plan for the Nawiliwili Watershed: Phase 3–Restoration and Protection Plan

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The proposed plan covers the nine elements required by the U.S. Environmental Protection Agency for watershed-based plans that are developed or implemented with Section 319 funds to address requirments of Section 303(d) of the federal Clean Water Act for listed waters. The elements include identification of the causes that will need to be controlled to achieve contaminant load reductions; an estimate of the load reductions expected for the management measures described in the plan; a description of the nonpoint-source (NPS) management measures that will need to be implemented to achieve the load reductions; an estimate of the amounts of needed technical and financial assistance, associated costs, and resources; an information and education component for the public; a schedule for implementing NPS management measures identified in the plan; a description of interim measurable milestones for determining whether NPS management measures are being implemented; a set of criteria that can be used to determine whether loading reductions are being achieved; and a monitoring component to evaluate the effectiveness of the implementation efforts over time.

Section 1 of this report contains an introduction, provides some background information, and covers water quality problems and sources of contaminants in the watershed. In addition, the status and severity of the water quality problems of Nawiliwili Bay and major streams are assessed. Section 2 introduces a proposed structure for the management of the watershed restoration plan. A new entity, the Nawiliwili Watershed Restoration Office, will manage and supervise all restoration activities and also be responsible for integrating the efforts of watershed stakeholders. These stakeholders include watershed residents; landowners; commercial, industrial, and agricultural businesses; community groups; schools and academic institutions; and county, state, and federal agencies. Efforts of all parties need to be synchronized toward implementing a holistic watershed management program using the plan proposed here as a guiding framework.

Section 3 covers the basis for the development of the restoration activities for the Nawiliwili Watershed. Community concerns and priorities were used to identify goals for the remediation and protection of the watershed. The goals include (1) improving water quality in the Nawiliwili Watershed to the point where it meets both state and federal standards, thereby allowing for the de-listing of the impaired segments from the 303(d) list, (2) enhancing current instream flows, (3) enhancing the biological integrity of waterways, and (4) enhancing the sustainability of the watershed. This section also discusses specific cleanup goals for various Nawiliwili Watershed basins. The goals are derived based on each basin’s characteristics, especially regarding land use and cover. In addition, Section 3 covers strategies developed for use as a guideline in achieving these goals. The strategies concern (1) managing storm water runoff and water quality, (2) enforcing current water quality

polices and regulations, (3) revising these policies and regulations, (4) integrating the ahupuaʻa concept with modern watershed management, (5) controlling invasive and non-native plant and animal species, (6) encouraging collaboration between various county and state agencies, (7) developing and implementing education and outreach programs, and (8) developing a water budget for the watershed.

Section 4 introduces specific restoration activities, including (1) developing and implementing education and outreach programs, (2) preventing soil erosion from agricultural lands, (3) implementing capital improvement projects, (4) controlling non-native and invasive plant and animal species, (5) eliminating cesspools, (6) developing a water budget for the watershed, (7) implementing low-impact development practices, (8) protecting and restoring habitats, (9) dredging sandbars in Hulēʻia Basin and moving the boat mooring area, and (10) coordinating with total maximum daily load studies.

Section 5 assesses the expected load reductions for nutrients and sediment in the Nawiliwili Watershed based on suggested remediation strategies, which is generally referred to as best management practices (BMPs). The first step was to use a model to estimate streamflow and baseline sediment and nutrient loads. Then the reductions were estimated based on a comparison of new estimated annual loadings derived from the model based on suggested BMPs. The section also emphasizes limitations of the modeling results, which can be categorized as those inherent to the model itself and those due to the input data quality and degree of completeness. One major difficulty was the absence of gaged streamflow stations for the Nawiliwili Watershed.

Section 6 emphasizes field water quality monitoring as an integral part of the restoration and protection plan of the Nawiliwili Watershed. The objective of monitoring is to assess pre-restoration conditions and the progress of various restoration and protection strategies. The design of specific remediation activities might require installing new monitoring equipment and collecting data from state and federal sources. This section also covers collected data management, sampling procedures and protocols, overall watershed assessment, and a quality assurance program for data collection and management.

Section 7 deals with restoration plan evaluation and includes a list of measures for evaluating plan success, a schedule for plan implementation, and criteria for success of load-reduction strategies. Monitoring, community involvement, and the overall supervisory role of the Restoration Office are the major controlling factors for success of the plan.

Section 8 deals with periodic revision of the restoration plan, and Section 9 sets priorities regarding proposed restoration measures. In general, the project can roughly be grouped into overlapping issues dealing with nutrient and sediment load reduction, water resource assessment and management, and education. Education is a corner stone of the protection plan, which depends to great extend on community and visitors' good will and participation. Topping the list of priorities is the implementation of erosion and nutrient control measures. Preparation of a water budget and setting of instream flows are also high on the list due to the need for these in any successful restoration effort.

Finally, Section 10 discusses the economic implications of the Nawiliwili Watershed restoration plan. Economic impacts of the plan include potential expenditures in the areas of agriculture, recreation and tourism, and households. In addition, since all three areas have direct and indirect connections to other sectors of the economy, these changes will reverberate throughout the economy of Kaua'i. This section covers the cost of restoration versus expected benefits, the economy of Kaua'i and the Nawiliwili Watershed area, the cost of remediation efforts, and potential sources of funding for the restoration and protection plan.

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1. INTRODUCTION

This three-phase study was aimed at assessing the status of the Nawiliwili Watershed on Kaua'i, Hawai'i, and developing a plan for its future protection. Phase 1 was concerned with validating and documenting existing environmental data (Furness et al., 2002). Phase 2 was aimed at identifying current sources of pollution and contamination in the watershed (El-Kadi et al., 2003). Finally, Phase 3 dealt with developing a restoration and protection plan for the watershed. The Phase 3 results are presented in this volume.

1.1. Elements of the Nawiliwili Watershed-Based Plan

As required by the U.S. Environmental Protection Agency (USEPA), watershed-based plans that are developed or implemented with Section 319 funds to address 303(d) listed waters must include at least the nine elements listed below. These elements are covered in this report, although not within any single section. The continuity of information necessitates the structure of the report in this way. The elements and the section(s) in which they appear are as follows:

1. An identification of the causes and sources or groups of similar sources that will need to be controlled to achieve the load reductions estimated in this watershed-based plan [*Section 1*]
2. An estimate of the load reductions expected for the management measures described under element (3) below [*Section 5*]
3. A description of the nonpoint-source (NPS) management measures that will need to be implemented to achieve the load reductions estimated under element 2 above and an identification (using a map or a description) of the critical areas in which those measures will need to be implemented [*Sections 3 and 4*]
4. An estimate of the amounts of technical and financial assistance needed, associated costs, and/or the sources and authorities that will be relied upon, to implement this plan [*Sections 2 and 10*]
5. An information/education component that will be used to enhance public understanding of the project and encourage the public's early and continued participation in selecting and designing the NPS management measures that will be implemented [*Section 4*]
6. A schedule that is reasonably expeditious for implementing NPS management measures identified in this plan [*Section 7*]
7. A description of interim measurable milestones for determining whether NPS management measures or other control actions are being implemented [*Section 7*]
8. A set of criteria that can be used to determine whether loading reductions are being achieved over time and whether substantial progress is being made toward attaining water quality standards and, if not, the criteria for determining whether this watershed-based plan needs to be revised; or, if an NPS TMDL has been established, whether it needs to be revised [*Section 7*]
9. A monitoring component to evaluate the effectiveness of the implementation efforts over time, as measured against the criteria established under element 8 above [*Section 6*]

1.2. Nawiliwili Watershed

The report of the first phase of this study (Furness et al., 2002) provided details about Nawiliwili Watershed's historical land-use changes and hydrology. The following summary is based on that report.

Nawiliwili Bay is fed by three main streams: Hulēʻia Stream, Puali Stream, and Nawiliwili Stream (Figure 1[1]). Major changes have occurred in the Nawiliwili Watershed throughout geologic and historical times, including uses of land, harbor construction, industrialization, and development. Several hundred years ago the flood plain of the Hulēʻia River was simply used for growing taro. Water that was diverted to flood the taro patches ultimately returned to the same watershed. Many taro fields were eventually converted to rice fields around 1860. Soon after, the sugar plantations came in and land use changed again. After World War II, the sugarcane fields on the Rice property were converted to ranches. More drastic changes took place around the 1930s when Nawiliwili Bay was dredged and the land was reclaimed, or filled in, to build the harbor and the breakwater wall. As time passed, Līhuʻe developed into a commercial district. The Kauaʻi Surf Hotel was built and subsequently grew, evolved, and changed to the Kauaʻi Westin Hotel, and then to the Kauaʻi Marriott Hotel. During the time of the hotel expansion, two streams that flowed into Kalapakī Bay were diverted under the hotel, and now they discharge into Nawiliwili Stream. A sewage treatment facility and golf course were placed near the hotel at Kauaʻi Lagoons.

In accordance with section 303(d) of the federal Clean Water Act, Nawiliwili Bay, Nawiliwili Stream, and Hulēʻia Stream are currently listed by the Hawaiʻi Department of Health (HDOH) as water bodies in which water quality is impaired by excessive turbidity. Nawiliwili Bay is also listed as being impaired by excessive nutrients, enterococci, and chlorophyll a. The impaired status of these waters requires that HDOH establish total maximum daily loads (TMDLs). Such values are essential in estimating the required reduction in existing pollutant loads in order to attain water quality standards for each water body.

To fulfill this requirement for Nawiliwili and Hulēʻia Streams, as well as to determine if stream-based pollutant load reductions would be sufficient for attaining nutrient and turbidity standards in Nawiliwili Bay, HDOH is currently developing TMDLs for nutrient and sediment loads in Nawiliwili, Hulēʻia, Papakōlea (a tributary of Hulēʻia), and Puali Streams. After these TMDLs are approved by USEPA, HDOH will coordinate the development of a TMDL implementation plan that identifies specific measures for reducing pollutant loads and improving water quality in these stream basins.

Many of the streams in the Nawiliwili Watershed drain into and can cause pollution conditions in Nawiliwili Bay. Streams, harbor sites, and beaches are used by residents and by tourists for kayaking, swimming, and other recreational activities. In this regard, Kalapakī Beach is a primary swimming area in Nawiliwili Bay.

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[1] GIS map obtained from the Internet site of the Hawaiʻi Statewide GIS Program: *www.hawaii.gov/dbedt/gis/*.

1.3. Water Quality Problems and Sources of Contaminants

An objective of Phase 1 of this study was to utilize sources of existing information to assess sources and levels of pollutants believed to be present in the watershed. In Phase 2, ten primary sites and four alternative sites were chosen for sampling. Water quality parameters measured were turbidity, salinity, temperature, nitrate and phosphate, and fecal indicator bacteria. Data collected over about a year were used to determine point- and nonpoint-source contributions of nutrients and bacteria. They were also used to determine whether the water within the watershed met water quality standards for the above parameters or if it represented a health hazard. Hydrological models were also used in assessing contributions of point and nonpoint sources of contamination in the watershed. The following subsections summarize the condition of the watershed and various streams in the area, as described in the Phase 1 report by Furness et al. (2002) and in the Phase 2 report by El-Kadi et al. (2003).

1.3.1. Nawiliwili Bay

Nawiliwili Bay is subjected to accidental sewage, chemical, fertilizer, and oil/gasoline spills. Storm drains and other drainage facilities have been built to discharge stormwater directly into the stream. These types of drainage facilities are designed for “maximum efficiency of conveyance.” As a result, stormwater or runoff from a facility, such as the chemical spill that occurred in the industrial area of Līhu‘e in 1993, will find its way to Nawiliwili Bay via these natural pathways.

Fairly extensive potential sources of pollution were identified in Phase 1 of this study. This type of information may provide guidelines for choosing data-collection sites and a strategy for sampling-scheme design, in addition to identifying the location of best management practices (BMPs) for controlling NPS pollution. Absence of baseline data has been emphasized by various local and state agencies. HDOH’s current TMDL studies, although conducted for a different purpose, may provide public information that could be useful in assessing the health of the Nawiliwili Watershed. Since more baseline data are being made available, we now have the opportunity to look at changes and trends in the watershed. In some cases, a rationale used in environmental impact statements is that if an area is already highly impacted, a new development cannot possibly affect the area any further. Among the many benefits of having baseline data is that such a rationale would be eliminated.

The first phase of this study identified sediment, nutrient, and bacterial-contamination problems in the watershed and bay. Sediment sources include agricultural lands, construction sites, channels, a quarry, and urban areas. Nutrients originate from agricultural lands, golf courses, cesspools, forested areas, urban areas, and wastewater treatment spills. Bacterial contamination originates from cesspools, forested areas, urban areas, and wastewater treatment spills. There is a chance that other chemicals from varius sources are also present. The focus for this study, however, is on the pollutants identified by HDOH in its 303(d) list.

1.3.2. Nawiliwili Stream

Many pollutants appear to be concentrated in the box culvert by Duke's Restaurant, which is located near the mouth of Nawiliwili Stream. Bacterial counts at the culvert are consistently some of the highest in the watershed. The wastewater treatment facilities near the stream are deteriorating and in much need of repair. On occasion, spills of sewage effluent from the Līhuʻe Wastewater Treatment Plant flow into the stream running through the golf course at Kauaʻi Lagoons and then into the diversion under the Kauaʻi Marriott Hotel, before being finally discharged through the box culvert into Nawiliwili Stream. Pollutants can end up in the estuary located at the mouth of Nawiliwili Stream and Kalapakī Beach area, which is home to many endangered water birds. A storm drain located in a parking lot above the culvert catches the runoff from activities in the lot.

Drainage manuals for county projects and for large landowners' development projects are out of date, and streams remain the avenue for drainage. Diversions, pumping, and channel alteration, as well as an increase in the area of impervious surfaces, affect the amount of water flowing into the bay via these drainageways. Nutrients, petrochemicals, and sediments are potential contaminants that can be transported by the runoff.

1.3.3. Puali Stream

If current urbanization practices continue, it is likely that the condition in Puali Stream will become similar to that in Nawiliwili Stream. Golf course irrigation recharge and runoff may have been influencing nutrient levels. Many alterations have been made to Puali Stream. These include two culverted sections, of which one has a cement weir that crosses the channel. Excessive sedimentation and the overgrowth of hau cause water stagnation. In the pool in front of the culvert, Tahitian prawns, crayfish, and poeciliids were noted. On the other side of the culvert, the stream was fenced in. Farther downstream behind a residential housing development (Halelani Villages) in Puhi, Puali Stream's channel was artificially realigned. The banks are nearly vertical, and the stream channel looks like a ditch. Nearby, the construction of a residential development (Halemalu Village) is underway. This new development is not far from the banks of Puali Stream. Drainage facilities for these developments can be the source of stormwater into the stream.

Reservoir Haiku 4B was constructed right on the stream channel at the confluence of Puali and Halehaka around 1930. This reservoir may be the reason why Puali is not the most turbid stream in the watershed. There is also a chance that the reservoir is removing the natural bed load and filtering out sediment. A bioassessment of the stream provided by Kido (1999) indicated that, although native species were present, they were found in small quantities and were often outnumbered by alien species such as the Tahitian prawn *Macrobrachium lar*. The survey, which also looked into habitat availability, found Puali Stream to be severely degraded with excessive sedimentation and erosion.

Additional problems related to Puali Stream may be caused by the operation of a sewage treatment plant uphill from the stream and a landfill site on one of its tributaries. The landfill was operated between 1973 and 1991. There may be a need for a study of Puali

Stream to analyze fish tissues and sediments for the bioaccumulation of toxins, similar to the fish tissue sampling for Nawiliwili Stream conducted by the U.S. Geological Survey (USGS) for PISCES and the Nawiliwili Bay Watershed Council. Although no toxic or hazardous waste was recorded as being deposited in Puali Stream, illegal dumping may have occurred. In the nearby groundwater, there is a probable nutrient problem due to irrigation recharge.

Puali Stream enters the ocean at Niumalu near a beach park and canoe club. This is near the small-boat harbor and is the launching point for three kayak tour companies. This area is highly used by boaters, paddlers, crabbers, and tourists. It is very shallow (1 to 4 feet), and the bottom is covered with fine silt. Cesspools are common in the area and are potential sources of contamination.

1.3.4. Hulēʻia Stream

Problems of the Hulēʻia Stream include water diversions that are difficult to account for. Excess flows and tremendous spikes in turbidity have been recorded after rain events. Parts of the stream basin are now used for cattle ranching, an activity that can generate sediment loads which find their way into the stream during storm events. Another source of sediment is the nearby quarry, which has been listed as a sediment contributor in a number of reports from HDOH (e.g., Hawaiʻi State, DOH, 1990).

Bacterial contamination may be caused by the nearby cesspool at Niumalu and to a much lesser extent by recreational activities in the stream. High bacterial counts may also be linked to ranching activity in the vicinity. Pigs in the area are a cause of sediment and bacterial contamination. They are also a suspected source of leptospirosis, one of the public's biggest health concerns.

Studies found that Hulēʻia Stream, in general, had the best biological integrity of the streams in the Nawiliwili Watershed, yet no native aquatic species were found near bridge crossings (Kido, 1999). The rating of "best in the watershed" only means that multiple native species were found somewhere in the stream, some recruitment is taking place, and there is some habitat availability. However, when compared with reference streams, Hulēʻia Stream ranked poorly.

Hulēʻia Stream is by far the largest source of freshwater input into Nawiliwili Bay. This stream is culturally significant for being the location of ʻAlekoko Fishpond as well as many other fishponds (now gone). Additionally, Hulēʻia Stream once was the water source for the staple food (taro) of the Hawaiian population. There is saltwater influence in this stream for over 2 miles upstream. The lower part is important as an estuarine environment and nursery ground for many marine fish and crustacean species. It is also important as a water bird habitat because many of our endangered water birds can be found in this portion of the stream. Unfortunately, the red mangrove accidentally introduced 50 or so years ago is thriving and is prolific along the banks as far up as the saltwater influence is present. The mangrove may contribute a significant amount of organic material to the stream, thereby increasing turbidity and nutrient concentrations. Additionally, the massive amount of roots extending from this plant into the stream may slow flows and trap sediment.

Papakōlea Stream, a tributary of Hulēʻia Stream, winds its way through the Hulēʻia National Wildlife Refuge before discharging into Hulēʻia Stream. Studies completed by the Nawiliwili Bay Watershed Council indicate that Papakōlea is the most turbid stream in the watershed. Kido's (1999) assessment of Papakōlea Stream categorizes it as severely degraded. Preliminary results of a more recent study reveal that the sites assessed in the Nawiliwili Watershed (including Papakōlea) were impaired in terms of flow regimes, habitat structure, channel sedimentation, riparian characteristics, bank stability, and substrate availability (Kido, 2002b).

During our site visits, we saw evidence of sedimentation problems caused by feral pigs at the lower Papakōlea site in the wildlife refuge. Other sources of contamination include abandoned objects and trash.

1.4. Severity of Water Quality Problem

During Phase 2 of this study, field data collected for about a year at a number of sampling sites were used to assess the status of surface-water bodies in the watershed. The sampling sites are described in detail in El-Kadi et al. (2003). The ten primary sites, numbered 1 through 10, are shown in Figure 2, and their general locations are given below.

Site 1. Nawiliwili Stream. This site is located just above the Suemori residence in Rice Camp.

Site 2. Marriott Culvert. This site represents stream water and storm-drain discharge originating from north of Nawiliwili Stream, including drainage from the golf course area. Water passes under th e Kauaʻi Marriott Hotel before being discharged into Nawiliwili Stream near Duke's Restaurant.

Site 3. Pine Trees. This site is located where the mouth of Nawiliwili Stream enters the south end of Kalapakī Beach.

Site 4. Kalapakī Beach. This site represents the center of Kalapakī Beach.

Site 5. Seaflite Jetty. This sampling site is located at the Nawiliwili Harbor jetty in Nawiliwili Bay and represents the area formerly used by Seaflite Jetty for landing.

Site 6. Papalinahoa Stream. This sampling site represents the mouth of a small stream near the Kauaʻi Sugar Storage Facility.

Site 7. Small Boat Harbor. This site is located in Nawiliwili Harbor near the small boat harbor where some sources of pollution from boats are suspected.

Site 8. Puali Stream. This site is located at the intake of water for an area resident's irrigation system.

Site 9. Papakōlea Stream. This site is located under the bridge on Hulemalu Road.

Site 10. Hulēʻia Stream. This sampling site represents that part of Hulēʻia Stream upstream of ʻAlekoko Fishpond.

Data was also collected from four other sites. Although each of the four sites is very close to a respective primary site, the data can be useful because the different collection days would reflect other rainfall conditions. These four sites, designated as "alternative sites," are shown in Figure 2, and their general locations are given below.

Site 1A. Nawiliwili Stream Alternative Site. This site is located about 100 m downstream of Site 1.

Site 8A. Puali Stream Alternative Site. This site is located about 30 m upstream of Site 8.

Site 9A. Papakōlea Alternative Site. This site is located about 100 m downstream of Site 9.

Site 10A. Hulēʻia Alternative Site. This site is located about 30 m downstream of Site 10.

An assessment of turbidity data indicated that five of ten sites have a 60% probability for turbidity to be at or to exceed a suggested standard of 5 nephelometric turbidity units (NTU). The Papakōlea Stream site has the highest sediment level and the Nawiliwili Stream site the second highest. These results emphasize the significance of sediment load originating from agricultural land-use districts that feed the two sites. Here it is important to distinguish between lands that are merely within the agricultural land-use district (which may be unused and unmanaged) and lands that are currently used for agricultural production. Up-to-date maps are not available; however, our visits to the area actually confirm that the area upstream from the Papakōlea sampling site (Figure 3) is mostly unmanaged agricultural land. The banks of Papakōlea Stream are very steep, causing erosion problems. In the stream is a large accumulation of sediment, which might be contributing to the high bacterial count at this site. There is a need to assess the condition from the area upstream of the sampling site to the headwaters. Papakōlea Stream could definitely benefit from BMP implementation, such as a riparian buffer zone. Cleanup of debris in the area—which includes metal scraps, junked cars, iron roofing, and construction waste—is required.

There is an 80% probability for phosphate concentrations at the ten primary sites to be at or to exceed the level of 0.01 mg/l suggested by this study. The Marriott Culvert and Pine Trees sites are the two highest in phosphate contamination. In addition, seven of the ten sites have an 80% probability for nitrate concentrations to be at or to exceed the suggested level of 0.1 mg/l. The Nawiliwili Stream and Marriott Culvert sites have the highest nitrate contamination potential, most likely due to various sources, including waste spills (see Subsection 1.3.2).

The HEC-1 model was used for estimating flow hydrographs of streams in the Nawiliwili Watershed in El-Kadi et al. (2003). Lack of appropriate data for calibration limited our effort in constructing a comprehensive model. The hydrograph data were used to estimate order of magnitude nutrient loads to streams and to Nawiliwili Bay. Additional modeling efforts are described in Section 5 of this report.

Groundwater models in El-Kadi et al. (2003) provided estimates for total nitrate loads from the deeper aquifer to the rivers and streams in the South Līhuʻe area. The groundwater model MODFLOW was used in modeling water flow in the South Līhuʻe area, while the model MT3DMS was used in modeling the transport of nitrate, which is treated as a conservative dissolved chemical. The modeling package Groundwater Modeling System was used as the working environment for MODFLOW and MT3DMS. Among the streams in the Nawiliwili area, Hulēʻia Stream received the largest nitrate load, about 28 kg/yr. Other streams in the area received negligible chemical loads. The estimated values are most likely higher than the actual values, since our simulations overestimated the concentrations in the aquifer. It can thus be assumed that contributions from the deeper aquifer are a negligible part of the contaminant load to the steams and the bay. However, the lack of data for the near-surface zones made it difficult to assess contributions from such a zone on water quality of the bay.

The study by El-Kadi et al. (2003) estimated nutrient and sediment loads from surface water to the streams and Nawiliwili Bay. For nitrate, Nawiliwili Stream had the highest load, followed by Puali and Papakōlea Streams. The nitrate load per unit acre was highest at Puali Stream and second highest at Nawiliwili Stream. The Hulēʻia Stream and Nawiliwili Stream sites received the highest loads of phosphate, but the Nawiliwili site alone ranked highest in terms of phosphate load per unit acre. Estimated loads to Nawiliwili Bay were on the order of 6 and 2 tons/yr for nitrate and phosphate, respectively. The load estimates provided in this study should be used as a guide only, due to a number of limitations, including the lack of hydrograph data for calibration. However, the results can still be useful, for example, in assessing the relative success of strategies aimed at reducing nutrient loss to streams and Nawiliwili Bay. We recommend elaborate hydrologic studies, based on rainfall storms, be conducted to estimate stream hydrographs at various sampling sites. The concurrent TMDL studies can be useful in this regard.

In Section 5 of this report, a detailed modeling scheme of streamflow output from the watershed is used. The results (see Section 5) estimated values of 43 and 12 tons/yr for total nitrogen and phosphorous yields, respectively, which are higher than the values described above. The higher values are most likely more accurate, considering the level of modeling adopted. However, model limitations, including the absence of data for calibration, still put severe restrictions on such estimates.

The Universal Soil Loss Equation (USLE) was used in El-Kadi et al. (2003) to estimate the potential sediment loads from the Nawiliwili Watershed. The estimations were made for three sub-basins of the watershed: Hulēʻia, Puali, and Nawiliwili. For each basin, the maximum estimated load was 23 tons/acre/yr and the most likely value was less than 1 ton/acre/yr. The generally acceptable maximum is 5 tons/acre/yr, with much lower values recommended, depending on the soil type. Section 5 of El-Kadi et al. (2003) qualitatively describes erosion problems in the Nawiliwili Watershed, which indicates that most likely our estimates are low. The website of the National Resources Conservation Service (NRCS) (*http://www.nrcs.usda.gov/technical/land/meta/ m5058.html*) provides estimates for the loss from fields on Kauaʻi in the range of 3 to 5 tons/acre/yr, which falls between the most likely and the maximum values.

In Section 5 of this report, the same USLE is used but within a more detailed modeling scheme of streamflow output from the watershed. The results estimated an average sediment load of 0.53 ton/acre/yr, based on values ranging between about 0.2 and 1.1 tons/acre/yr. Again, these values are lower that what the NRCS identifies for Kauaʻi.

The results of El-Kadi et al. (2003) showed a significant correlation between turbidity and phosphate concentration in open waters. Although no evidence that a strong correlation between sediment load and turbidity exists, the data suggest that sediment might be the main avenue for phosphate contamination. Phosphate is adsorbed by soils and is carried to stream and ocean waters as particulate bound. In contrast, the negative correlation between turbidity and nitrate concentration indicates that sediment is not a significant avenue for nitrate contamination. Nitrate is introduced to streams and the ocean in dissolved form by means of surface and subsurface water flows. Additional analysis of sediment generation is needed to confirm these conclusions.

High turbidity seems to be triggered when the daily rainfall rate ranges from 2 to 3 inches. The high sediment load after the major storm of May 13, 2002 demonstrated the vulnerability of the watershed to rainfall, in terms of sediment loads; hence there is an urgent need to develop strategies to reduce such loads from various sources.

Most water samples obtained from stream sites greatly exceeded the current USEPA recreational water quality standards for fecal coliform (200 CFU/100 ml) and enterococci (33 CFU/100 ml) (Figures 4 and 5). At six sites (two on Nawiliwili Stream and one each at Marriott Culvert, Pine Trees, Papakōlea Stream and Papalinahoa Stream), the geometric mean concentration was above 1,000 CFU/100 ml for fecal coliform. At seven sites (the same five sites plus Puali and Papakōlea Streams), the geometric mean concentration for enterococci was at or exceeded 1,000 CFU/100 ml. Site 1 (Nawiliwili Stream) had the highest geometric mean concentrations for both fecal coliform (7,1740 CFU/100 ml) and enterococci (2,914 CFU/100 ml). Site 2, Marriott Culvert, had respective geometric mean concentrations of 4,915 CFU/100 ml for fecal coliform and 1,939 CFU/100 ml for enterococci.

At Site 4 (Kalapakī Beach), the geometric mean concentrations of fecal coliform (11 CFU/100 ml) and enterococci (14 CFU/100 ml) were below current USEPA standards. On the other hand, the concentrations of enterococci exceeded the state of Hawaiʻi's standard of 7 CFU/100 ml for marine waters. The sample collected on May 14, 2002 was characterized by elevated concentrations of fecal coliform (22,400 CFU/100 ml) and enterococci (14,800 CFU/100 ml). The water quality data from Site 5 (Seaflite Jetty) revealed elevated concentrations of fecal coliform (372 and 404 CFU/100 ml) and enterococci (232 and 348 CFU/100 ml) only for two rainy-day events.

Exceeding the EPA standards for bacterial indicators should be carefully assessed because it appears, as with the case for results previously obtained for O‘ahu, that the sources of fecal bacteria on Kaua‘i are environmental in nature. Overland and subsurface flows wash the fecal bacteria from the soil into streams. It seems thus that it is not possible to use such indicators as evidence for reducing levels of bacteria through management decisions. Moreover, it has been concluded that the concentrations of fecal indicator bacteria are not related to health risks from sewage contamination (Hardina and Fujioka, 1991). As mentioned earlier, USEPA standards for assessing water quality based on concentrations of fecal coliforms and enterococci were exceeded at most of the study sites. Thus, more reliable fecal indicators, such as *Clostridium perfringens* and FRNA coliphages, are needed. More studies are needed to verify the use of FRNA coliphages. The U.S. Food and Drug Administration (*http://vm.cfsan.fda.gov/~mow/chap11.html*) indicates that *C. perfringens* might not be a good indicator of sewage discharge. However, Fujioka and Shizumura (1985) showed that *C. perfringens* is better than fecal bacteria as an indicator of sewage contamination in streams in Hawai‘i. HDOH is using Fujioka's *C. perfringens* water quality standards to determine when waters are contaminated with sewage. Until completely reliable indicators are identified, it seems sanitary surveys and bacterial source tracking may provide the only definitive answers for assessing sewage contamination. However, the difficulty is that sanitary surveys alone cannot detect underground leakage from a sewage source.

Nearly all of the sampling sites contained low numbers of *C. perfringens*, indicating that the streams in the Nawiliwili Watershed are not being directly contaminated with sewage discharge. The only exception was the Pine Trees site, where the recommended standard of 50 CFU *C. perfringens*/100 ml was exceeded.

Papakōlea Stream had the highest concentration of FRNA coliphages, and this was taken as evidence of cesspool contamination. Since some water samples from Nawiliwili, Papalinahoa, and Puali Streams contained elevated levels of FRNA coliphages and low levels of *C. perfringens*, we concluded that these streams are being occasionally contaminated with cesspool wastes.

The results of this study suggest that environmental sources of fecal coliform, which are present in soil, may be sources of somatic coliphages. However, additional studies are recommended to confirm this conclusion. In addition, genotyping FRNA coliphages to determine human from animal sources is another tool that can be used to assess the sources of contamination.

2. RESTORATION PLAN MANAGEMENT

This section describes a proposed management structure needed to implement the Nawiliwili Watershed Restoration and Protection Plan. The plan itself is described in the following sections, including goals, strategies, monitoring, and economic considerations.

We propose the establishment of a new entity, the Nawiliwili Watershed Restoration Office, with a structure similar to that proposed for the Kailua Protection Plan (Tetra Tech Em Inc., 2003). The office will manage and supervise all restoration activities and also be responsible for integrating the efforts of watershed stakeholders, who are concerned about its health and welfare. These stakeholders include watershed residents; landowners; commercial, industrial, and agricultural businesses; community groups; schools and academic institutions; and county, state, and federal agencies. The efforts of all parties need to be synchronized toward implementing a holistic watershed management program using the plan proposed here as a guiding framework.

The office operation will be supervised by a core group that includes representatives from HDOH, Kaua‘i County, Hawai‘i Department of Land and Natural Resources (HDLNR), and an advisory stakeholder group. Also, as suggested for the Kailua Protection Plan, partners should include other government and private entities, in particular, USEPA, U.S. Fish and Wildlife Service (USFWS), U.S. Department of Agriculture (USDA), Hawai‘i Department of Transportation (HDOT), academic institutions, and the private sector. Cooperation should be established with volunteer groups from the community, schools, and nongovernmental organizations. Roles and responsibilities should be clearly set through interagency agreements defining the leading agencies or organizations, based on the nature of the implementation action.

Overall program management and coordination would be provided by the proposed Nawiliwili Watershed Restoration Office, whose main function will be to achieve the goals of the restoration plan through the strategies described in this report and to monitor plan progress. An organization chart for the restoration office showing the core group, partners, and volunteers is provided in Figure 6. The organization of this office may change and evolve over time as the restoration program becomes established and attracts more participants and resources. A guiding principle for this implementation program, however, should be ensuring that all interested individuals or organizations be allowed to join. Subsection 3.3.5 describes in detail the importance of the role of the community in plan implementation. Members of the community should be represented in both the core group and volunteer activities.

3. WATER QUALITY GOALS AND STRATEGIES FOR THE NAWILIWILI WATERSHED

3.1. Water Quality Goals

This section sets the basis for the development of restoration activities for the Nawiliwili Watershed. Community concerns and priorities were used to identify goals for remediation and protection of the watershed. Strategies and actions to reach these goals and desired outcomes were then developed.

Under the federal Clean Water Act, the State of Hawaii has identified Nawiliwili Bay, Nawiliwili Stream, and Hulē‘ia Stream as water-quality-limited segments. Puali Stream is currently under consideration. By definition, a water-quality-limited segment is a water body that cannot reasonably be expected to attain or maintain state water quality standards without additional action to control nonpoint sources of pollution. Additionally, the Nawiliwili Watershed has been identified as a category 1 watershed, which is a watershed in need of restoration. Hawai'i's 303(d) listings include Nawiliwili Bay and Nawiliwili Stream for turbidity and nutrients and Hulē'ia Stream for turbidity.

The proposed Nawiliwili Watershed Restoration and Protection Plan is aimed at ensuring that all water bodies meet both state and federal water quality standards and thus can be removed from the 303(d) list. The goals outlined in this section include improving water quality, not just maintaining it. The plan will seek not only to meet state and federally mandated goals but also to include community aspirations. Community input is the corner stone of this plan.

The following is a list of Nawiliwili Watershed water quality goals defined by community members and other agencies concerned with the health and well-being of the watershed and bay.

Goal A. Improve water quality in the Nawiliwili Watershed to the point where it meets both state and federal standards, thereby allowing for the de-listing of the impaired segments from the 303(d) list

Federal and state agencies are responsible for setting standards and funding projects to help remediate problems responsible for impaired water quality. On the other hand, county agencies are focused on maintaining current water quality conditions. While this is an acceptable practice if the water quality meets state standards, it is not an ideal practice for impaired conditions. The county does recognize this deficiency, however. It is recommended that agencies from all governmental sectors work together to improve water quality.

Goal B. Enhance current instream flows

Streams in the Nawiliwili Watershed suffer from a variety of alterations to their natural flow regimes. Some streams are periodically inundated with stormwater runoff volumes, causing an unnaturally large increase in flow, while other streams are dewatered due to irrigation and other diversions. There may also be additional flow volumes present due to diversions that deliver water from other watersheds. The community desires that a more natural flow regime be established by returning water to dewatered streams and reducing stormwater runoff volumes in other streams by implementing appropriate management measures, such as establishing retention ponds. The preparation of a water budget is the essential first step to understanding the flow of water in and out of the watershed. Current and potential instream and out-of-stream uses will need to be weighed to determine the most important use of the water. It may be established at that point that instream flows need to be set. Enhancing instream flows has been a community concern for many years, and this concern has been addressed during meetings of the Nawiliwili Bay Watershed

Council on numerous occasions. The state's Supreme Court has also recognized the importance of restoring instream flows by its Waihole Ditch ruling.

Goal C. Enhance biological integrity of waterways

Native aquatic macrofauna have nearly been eliminated from the Nawiliwili Watershed as a result of increased runoff volumes and pollutant loads, loss of habitat, and increased recruitment barriers. Barriers include physical structures such as step-type culverts and diversions, as well as unnatural biological conditions that include introduced predatory populations such as bass. The native migratory species in Hawaiʻi streams also have cultural significance. It is of great importance that the biological integrity of these streams be restored.

Goal D. Enhance sustainability of the watershed

Watershed sustainability covers many issues but can be grouped into three main areas: environmental, economic, and social. For such a watershed, resources (such as freshwater) must regenerate at a rate that meets or exceeds the rate of use. Additionally, pollutant loads should not exceed the capacity of the environment to process such pollutants. Economic stability can only be achieved if practices to protect resources are developed. Resource availability must not only meet current needs but must also provide for future generations. Substitutes for nonrenewable resources, such as water recycling, must also be developed.

Sustainability-related goals mandate that the Nawiliwili streams and bay be fishable and swimmable without presenting a health risk. These goals reinforce the provisions of the Clean Water Act, i.e., protecting the propagation of fish, shellfish, and wildlife and safeguarding recreation in and on the water, wherever attainable. Fishing and family recreation are important to members of the Nawiliwili community and are at the core of a sustainable watershed.

3.2. Specific Goals for Various Nawiliwili Watershed Basins

To achieve the overall water quality goals, it is imperative to identify specific objectives for each basin, based on each basin's characteristics, especially regarding land use and cover. Meetings of the research team with community members, nongovernment organizations, and government agencies resulted in developing the following objectives for each basin. The objectives reflect the overall goals for the watershed, while targeting specific areas of importance within each basin as discussed in Subsection 1.2. Figures 7, 8, and 9 are land use/land cover (LULC) maps for the Nawiliwili, Puali, and Hulēʻia Basins, the main basins of the watershed. Table 1 lists the areas served by each LULC and their percentages of each basin's area. According to the state's website, these maps are based on manual interpretation of the 1970s and 1980s aerial photography and land-use maps and surveys. Obviously, these maps need updating, but as discussed below, they still show the LULC disparities of the respective basins.

3.2.1. Nawiliwili Stream Basin

The total area of the Nawiliwili Stream Basin is 16.22 km^2 or 17.24% of the total watershed area of 94.11 km^2 (Table 1). LULC is roughly equally divided among urban, agricultural, and forest lands, at about 34%, 38%, and 27% of the basin's area, respectively. Thirty-nine percent of the urban area is in residential use and the rest is in commercial and other urban uses. It is clear that this basin is the most urbanized of all basins, thus reducing contamination due to urban storm runoff and cesspool use should be among the water quality goals of this basin. The goals are:

1. Reduce pollutant loads and volume of urban stormwater runoff conveyed within the storm drain system and discharged into Nawiliwili Stream by use of appropriate management practices, such as constructed wetlands and retention ponds.
2. Eliminate any increase in runoff volume due to new development by requiring on-site detention and processing.
3. Identify the current level of impervious cover and reduce it by a feasible and appropriate amount. Levels of urbanization characterized by 8% to 12% impervious cover have adverse impacts on habitat quality and the overall health of streams (Haub and Hoenig, 1999; Haub, 2002).
4. Provide educational opportunities for community members, landowners, and other stakeholders.
5. Improve habitat for native aquatic species.
6. Reduce bacterial pollutant loads from cesspools, underground storage tanks, and other sources.

3.2.2. Hulēʻia Stream Basin

The total area of the Hulēʻia Stream Basin, the largest of all basins, is 72.55 km^2 or 77.1% of the total area of the watershed (Table 1). Most of the basin (94%) is covered by agricultural and forest lands, at about 51% and 43% of the total area, respectively. The remaining area includes shrub and brush rangeland (4%). The water quality goals for this basin are mostly related to agricultural, forest, and range lands. Urban land use is very limited (less than 1%), and any land-use restriction regarding urbanization, if adopted, can be relatively easy to apply. The goals are:

1. Reduce pollutant loads attributed to runoff from agricultural practices, forest lands, and mining operations.
2. Identify current level of impervious cover and restrict it to 12% for new developments, if possible.
3. Provide educational opportunities for community members, eco-tour groups, landowners, and other stakeholders.
4. Restore habitat for native aquatic species.
5. Enhance instream flows to at least 50% of base flow.
6. Restore ʻAlekoko Fishpond for educational, cultural, and historical values.

Papakōlea Stream is a tributary of Hulēʻia Stream. Most of its basin is covered by agricultural land, but a small urban area is situated at the boundary with Puali Stream Basin (Figure 9). The specific water quality goals for this stream are:

1. Reduce pollutant loads and volume (especially sediment) from conservation and agricultural areas.
2. Identify current level of impervious cover and restrict it to 12%, if possible.
3. Provide educational and outreach opportunities for community members, eco-tour groups, landowners, and other stakeholders.
4. Improve and enhance habitat for native aquatic species.
5. Reduce bacterial loads from cesspools and other sources.
6. Identify and enhance appropriate instream flow.

3.2.3. Puali Stream Basin

The total area of the Puali Stream Basin, the smallest of the three basins, is 5.34 km^2, which is less than 6% of the total area of the watershed (Table 1). The basin is covered by agricultural, forest, and urban lands at about 60%, 25%, and 16% of the total area, respectively. The water quality goals mirror those for the Nawiliwili Basin, especially considering that the Puali Stream Basin is rapidly moving toward more urbanization. The goals are:

1. Reduce pollutant loads and volume of stormwater runoff from residential, commercial, and industrial areas, as well as from golf courses and roadways.
2. Eliminate increase in runoff volume from new developments by requiring on-site processing and detention.
3. Identify the current level of impervious cover and restrict or reduce it to around 12%, if possible.
4. Provide educational opportunities to community members, landowners, and other stakeholders.
5. Enhance habitat for native aquatic species.
6. Identify and enhance appropriate instream flow.

3.3. Strategies for Improving Water Quality in the Nawiliwili Watershed

A list of strategies was developed to use as a guideline for achieving the goals listed above. These strategies provide a variety of methods that can be applied to help improve water quality within the Nawiliwili Watershed. It should be noted that there are overlaps regarding what the strategies can achieve toward the goals listed above. Strategies 2 and 3 address all four goals (A, B, C, and D); Strategy 4 addresses Goals A and D; Strategy 5 mainly addresses Goal C, but also overlaps with Goals A and D; Strategy 6 addresses all four goals; Strategy 7 addresses Goals A and D; and Strategy 8 specifically targets Goal B, but also addresses the other three goals.

3.3.1. Strategy 1 — Manage Stormwater Runoff and Water Quality

The percentage of impervious cover in a basin can be used—to a great extent—in assessing its degree of urbanization. An increase in impervious cover affects the hydrology of the basin by decreasing infiltration and the subsequent subsurface recharge. Changes in basin hydrology and riparian vegetation are important factors that affect instream aquatic habitat conditions. Both factors can be directly linked to the degree of urbanization or the percentage of impervious cover. Impacts on habitat quality, which in turn affect aquatic biota, begin to occur at relatively low levels of urbanization characterized by 8% to 12% impervious cover (Haub and Hoenig, 2002). It is important to first determine these levels for the Nawiliwili Watershed because such percentages are not known with certainty. It has been suggested that the degradation of biological conditions is affected more by physical changes to the stream corridor than by chemical water quality constituents because metal concentrations do not usually exceed water quality standards until urbanization reaches the 45% impervious cover range (May et al., 1997). It may not be possible to maintain biodiversity and predevelopment hydrologic conditions at a level above 25% total impervious cover (Haub and Hoenig, 2002).

Changes to hydrology that affect aquatic habitat and biota may be exacerbated by traditional stormwater management practices. The purpose of such practices is to remove the runoff from the site as quickly as possible by collecting the runoff via gutters into the storm drain system and then rapidly discharging it into the stream. This is an important practice on roads and highways for safety, flood control, and property protection, but water quality and habitat protection should also be factors in stormwater management. There are many approaches to integrate stormwater management practices with provisions for habitat protection, water quality, and water quantity. These methods are formally known as best management practices (BMPs) and are necessary for a sustainable plan that addresses all elements. The use of BMPs for stormwater runoff must also be supported by the drainage policies and regulations that are in place. Both public and institutional education can also provide benefits for stormwater management.

Unabated urban stormwater runoff that is discharged at rapid velocities and high volumes has been identified as a priority concern in the Nawiliwili Watershed. Increasing the degree of urbanization can cause irreversible damage to aquatic habitat and biota (May et al., 1997). However, with careful planning and focused goals, including community participation, it can be avoided.

Section 4 covers specific restoration activities for the Nawiliwili Watershed and includes measures for stormwater management through the use of BMPs, better site-design practices (BSDPs), policy changes, and education and outreach programs. It should be suggested, however, that the use of any one of these practices by itself might not be sufficient to achieve the desired results. Instead, a combination of activities and BMPs would be more successful at reducing runoff volumes and pollutant loads.

Extensive technologies are available for stormwater BMPs and BSDPs. General information is included here; however, only certain designs may be appropriate or feasible for use in the Nawiliwili Watershed. One of the difficulties in applying many of these practices is that they are designed for implementation at the inception of land developments. When an area has already been developed or is already highly urbanized, current stormwater management practices need to be retrofitted and hence can be more costly. This is what the Nawiliwili Watershed is faced with, especially in the Nawiliwili Stream Basin.

In developing areas, controlling runoff and the associated pollutants is a major objective of watershed management. Educating the public is a necessary step toward watershed protection against illegal waste disposal. Enforcing regulations pertinent to the storage of contaminants in sensitive areas is also essential. Finally, BMPs can be used on-site to remove runoff pollutant loads or at least to reduce them to acceptable levels. Examples include natural drainage swales, detention basins, ponds, and constructed wetlands. Village Homes, a residential community in Davis, California, is an example of a development that has been very successful, not only for its desirability but also for its on-site runoff detention and processing. This development can be used as a model for innovative stormwater management practices and BSDPs for future residential developments in the Nawiliwili Watershed.

BSDPs differ from BMPs. BSDPs have the potential to prevent pollutants and runoff volumes from reaching waterways, whereas BMPs help treat runoff and reduce pollutant loads. BSDPs are referred to as low-impact development (LID) strategies, due to the inherent nature of their design. Depending on their design, BSDPs can protect a watershed by conserving its natural features and resources, by using low-impact site-design techniques, by reducing impervious land cover, or by utilizing natural features for stormwater management (see Georgia Stormwater Management Manual [Atlanta Regional Commission and Georgia Department of Natural Resources, Environmental Protection Division, 2001]). Conservation of natural features and resources includes preserving undisturbed natural areas and riparian buffers, as well as avoiding flood plains and steep slopes. Low-impact site-design techniques include fitting the design to the terrain, locating development away from sensitive areas, reducing the limits of grading and clearing, utilizing open spaces, and considering creative development design. Reducing impervious cover can be accomplished by reducing the widths and lengths of roads, reducing building and parking footprints (building up instead of out), reducing setbacks and frontages, using fewer or alternative cul-de-sacs, creating parking lot stormwater "islands," and using pervious pavers. The utilization of natural drainage features includes the use of buffers and undisturbed areas, vegetated swales, and other natural drainageways (excluding streams). In doing so, natural features will replace curb, gutter, and storm drain systems, rooftop draining to pervious areas, and even landscape irrigation by rooftop runoff.

By using preventive measures, land developers can save costs up front, while state and county agencies can avoid costs that would have been incurred from remediating problems due to poor site design. Implementing preventive measures has other benefits that include increased property values, expanded open space for parks and recreation, protected habitat, and improved aesthetic value.

Descriptions of a general stormwater BMPs that may be appropriate for use in the Nawiliwili Watershed are included below. The use of a specific BMP depends on the type of land use. In many cases it may be necessary to design a creative BMP to meet the requirements of a specific site. A future study should be conducted to determine the feasibility, cost, and effectiveness of each BMP through site evaluations and through a series of demonstrations or test projects.

BMPs can be broken down into structural and non-structural practices. Non-structural practices are relatively affordable and offer preventative benefits. These include the preservation of open spaces and naturally vegetated areas, which can help reduce erosion and allow for natural infiltration and evapotranspiration processes. Retaining or establishing riparian buffers can reduce pollutant loads by slowing flows, trapping sediment, and encouraging natural infiltration processes. Structural BMPs are designed to treat the first flush of stormwater runoff. They can be grouped into four types: sources control BMPs, source filtration BMPs, regional detention and treatment systems, and pollution prevention practices. Some of these practices are described below.

Bioretention areas. Bioretention areas are shallow vegetated depressions that can be used to intercept and treat runoff from parking lots and rooftops. They function through promoting the infiltration and evapotranspiration processes. Bioretention areas can include other components, such as filter strips which help trap particulates before ponding and infiltration occur. Underground perforated pipes can optionally be used to discharge water after infiltration.

Catch basin inserts. Catch basin inserts, which include vortexes and larger devices, can be used to intercept runoff from parking lots, roadways, and other appropriate locations. The inserts remove trash, large debris, and course sediment. Optionally, they can be fitted with absorbent material to filter out oil and grease. Catch basin inserts should not be substituted for other reliable BMPs; instead, they should be used as part of a treatment train in combination with other BMPs.

Erosion control mats/blankets. Erosion control mats can be used on gradual to steep slopes to temporarily reduce erosion while facilitating vegetation establishment. These mats usually consist of some type of netting and an organic matrix that provides moisture for the retention of seeds. The netting becomes intertwined with the growing roots to reinforce the site and reduce soil loss. The mat is usually biodegradable and therefore disintegrates at some time after vegetation has been established. Long-term soil stabilization is actually provided by the established vegetation.

Construction BMPs. Construction BMPs provide protection against potential pollution problems associated with construction sites. These BMPs fall into several different categories, including stabilization, runoff diversion, waste and material management, velocity reduction, and sediment traps or filters. Stabilization BMPs may include erosion control mats and geotextiles, filter strips, planting, retention of natural features, and mulching. Waste and material management include controls for storing, using, spilling, and cleaning up a pollutant. Runoff diversion includes BMPs such as check dams, swales, and temporary stream crossings to reduce the amount of sediment that is discharged to natural water bodies. Velocity reduction reduces erosion by slowing flows with roughened surfaces and protecting the outlets. Sediment filters and traps help retain sediment on or near the site to reduce the chances of its inclusion in runoff.

Constructed wetlands. Constructed wetlands can be used as final step in a treatment train or in cases where it may not be feasible to treat stormwater close to the source. Wetlands can be used to treat large drainage areas and can provide both storage and treatment benefits. Treatment occurs through both settling and uptake from plants. Wetlands can provide habitat for wildlife and aesthetic benefits in addition to improving water quality by removing petroleum hydrocarbons, bacteria, nutrients, dissolved metals, and settleable solids. A variety of constructed wetland technologies are available for different types of applications. These include extended detention wetlands, pocket wetlands, elbow wetlands, and modular wetlands.

Detention basins. Detention basins can be used for temporary impoundment of stormwater during large storms to reduce the peak rate of discharge. They are used to control water quantity but have limited water quality benefits. Detention basins can also be multi-functional, with large ones used as parks, soccer fields, or other recreational facilities.

Filter strips. Filter strips are densely vegetated land areas that can be used to intercept runoff from parking lots and roadways (or other impervious areas), settle out particulates, promote infiltration, and reduce the volume of runoff entering streams. Filter strips can also be incorporated into riparian buffer zones for pretreatment purposes and for reducing runoff velocities.

Grass channels. Grass channels are wide, shallow channels that can be used in place of curb and gutter drains, especially alongside roads. In grass channels runoff is conveyed slowly, thereby promoting infiltration and reducing stormwater volumes. Additionally, grass channels service to provide some contaminant removal by allowing particulates to settle out.

Pervious pavers. Pervious pavers consist of porous concrete or modular porous paver systems that are structured with voids (like a hollow tile) which can be filled with sand or turf. Pervious pavers are used to reduce impervious cover. The pavers are installed over a gravel bed to provide storage and allow runoff to infiltrate into the soil bed below. Examples include pedestrian walkways, parking areas, and residential driveways.

Riparian buffers. Riparian buffers can be used near environmentally sensitive streams where natural buffer systems have been removed or minimized. Buffer zones can help prevent pollutant loads from reaching streams by reducing flow velocities, promoting infiltration, trapping sediment, removing pollutants, and taking up nutrients. Riparian buffers also help preserve wildlife habitats and can provide additional aesthetic benefits.

Rain gardens. Rain gardens are similar to bioretention areas. They can be designed as a shallow depression in residential yards to collect sheet flow runoff and promote infiltration. They also promote evapotranspiration through the use of flood- and drought-resistant plants. This type of BMP can be implemented at the household level.

Sand filters. A sand filter is typically a multi-chamber structure that can be used to treat runoff from impervious areas, such as parking lots. Runoff is diverted to off-line sediment chambers for the removal of fine and coarse sediment. Water is then collected in underground pipes and finally discharged into a stream or optionally exfiltrated into surrounding permeable soils.

Vegetated swales. Vegetated swales are wide channels that can be used instead of concrete-lined channels or underground pipes in areas where stormwater conveyance is required. In the process of storage and conveyance, particulates are allowed to settle out, infiltration is promoted, and stormwater volume is reduced.

3.3.2. Strategy 2 — Enforce Current Water Quality Policies and Regulations, and Strategy 3 — Review and Revise Current Water Quality Policies and Regulations

The Water Quality Management Plan for the County of Kauaʻi (KRP Information Services, 1993) as well as Phase 1 and Phase 2 of this study point to unabated stormwater runoff as one of the biggest contributing factors in polluting the waterways of the Nawiliwili Watershed. The Nawiliwili Watershed is not unique; it shares the same problem experienced in many other watersheds across the country. Many counties around the United States, however, are making use of available technologies to abate the problem. Western Washington is one of the leaders of sustainable development, which has been achieved mainly through changes to the laws and policies, along with active community participation. In some instances, laws were changed as a result of lawsuits demanding such changes. Stormwater management manuals were designed to reflect the new policies, and implementation followed. An important factor in the effectiveness of such policies is enforcement. Violations are swiftly dealt with through lawsuits.

The report for Phase 1 of this study indicated that many of Kauaʻi's policies, laws, and manuals were outdated. An example is the Storm Drainage Standards for Kauaʻi County, dated 1972. With an increasing population, a recent burst in development, and pressure from local community groups, it became apparent that these documents needed to be updated. The Storm Water Runoff System Manual for the County of Kauaʻi is now available. There have been some positive revisions to the drainage manual, such as the requirement of detention basins for projects of a certain size. Unfortunately, however, many policies are still outdated with respect to new technologies that are currently available. Therefore, many policies still do not reflect current water quality goals.

Bill 2003, ordinance 778, which accompanies the Storm Water Runoff System Manual, states:

> The Storm Water Runoff System Manual was developed incorporating residents' concerns and State and Federal clean water regulations regarding: (1) the maintenance of predevelopment flow rates from developments to mitigate an increase in storm runoff as a result of construction of structures, roadways, and other impermeable surfaces; (2) the minimization of pollutants being drained into streams, rivers and natural watercourses by providing water quality provisions and regulating illicit discharges as required by 40 CFR Parts 9, 122, 123 and 124 of the National Pollutant Discharge Elimination System, Phase II ("NPDES"), as amended; and (3) the minimization of pollutants being drained into streams,

rivers and natural watercourses by providing best management practices and regulating illicit discharges for erosion and sedimentation control for construction work as required by State Water Quality Regulations and NPDES Permit.

The purpose of the ordinance is to replace the outdated drainage standards with the new Storm Water Runoff System Manual.

However, in subsection 3.2, Basic Principles of the Storm Water Runoff System Manual, the very first statement is "a. Natural Drainage Ways shall be used for storm runoff drainage ways wherever possible."

This seems to be a direct contradiction to the reasons stated for adopting the manual (#1 and #2 above) if the natural drainage way of choice (stream) continues to be used. However, if the term "natural drainage ways" was more clearly defined to exclude streams but include swales, buffer systems, and other "natural" options, peak flows and velocities could be reduced substantially. The Storm Water Runoff System Manual would then be more consistent with its purpose.

The manual also states that storm drainage facilities shall be designed to require the least amount of maintenance as determined by the Engineer and reviewed by the County Engineer. Cost effectiveness seems the motivation behind such a principle. However, this may discourage the use of BMPs that are more environmentally friendly, such as catch basins with sumps or catch basin inserts that could significantly reduce the amount of pollutants reaching natural drainage ways and ultimately Nawiliwili Bay. The lack of funds for the maintenance of BMPs may be a major limiting factor in the ability to improve water quality.

Because the revised Storm Water Runoff System Manual is designed to address new developments, no amendments address the correction of old problems, such as the contribution of pollutants entrained in stormwater runoff that is currently being discharged by the existing infrastructure. Such problems are responsible for many of the water quality issues that the Nawiliwili Watershed faces today. Moreover, because the Storm Water Runoff System Manual is designed to maintain the current water quality of a watershed, it does not address the problem that many watersheds, including Nawiliwili, do not currently meet the water quality standards and thus are placed on the 303(d) list by USEPA and HDOH. So the real problem of improving water quality is not addressed at all.

However, Kaua‘i County does have a Water Quality Management Plan, dated 1993, which not only identifies sources of pollution but also offers some sound advice (KRP Information Services, 1993). For example, the plan states that to be effective, stormwater management should be planned for an entire drainage basin, not simply for individual sites, because responsible coordinated solutions for individual developments in the absence of basin-wide plans are difficult to achieve, particularly since current practices are based on traditional drainage concepts. This means existing developments using traditional drainage practices may rapidly create large runoff volumes such that downstream developing areas would not be able to use collection system management techniques without significant (and perhaps unacceptable) costs. In other words, current practices do not account for cumulative impacts, so if downstream developments cannot accommodate the additional runoff, the ultimate solution of discharging it into natural drainage ways such as streams becomes the solution.

The plan is also aimed at establishing management structures necessary to implement the control strategies effectively, efficiently, and equitably (KRP Information Services, 1993). However, it seems that the plan has not been fully implemented at this time. The County of Kauaʻi recognizes this problem as stated in the Kauaʻi General Plan:

> A key concern is the long-term organizational structure for watershed management. Each restoration project will draw upon a network of government and community-based organizations. But it is unclear which agency or organization will accept responsibility and be funded to coordinate restoration and management over the long term, or how such an agency would function within the existing management network.

The ahupuaʻa concept may be of use to elicit cooperation between government agencies, nongovernment organizations, and community members. Although it may seem difficult to achieve, cooperation between all agencies (county and state) is necessary for the long-term management of a watershed. Increasing the number of responsible parties could result in a synergistic effect.

As discussed earlier, it is possible to reduce pollutant loads in the Nawiliwili Watershed by not allowing the discharge of any runoff into streams, a practice that is currently allowed and encouraged by the Storm Water Runoff Systems Manual. This can be achieved following the example of counties like Olympia, Washington (Green Cove), that developed detailed manuals that include low-impact development standards (LIDS), policies, and ordinances that would work equally well for the Nawiliwili Watershed. Achieving this success requires a more comprehensive manual for the detention, treatment, and reuse of stormwater runoff through the use of BMPs and BSDPs.

A comprehensive policy revision for the County of Kauaʻi would thus include the adoption of LIDS that consist of stormwater management practices. It should also include a provision concerning reduction of impervious surface coverage, street design, open-space plans, native revegetation, zoning densities, and lot sizes. These policies would protect property and accommodate growth yet maintain the water quality and aesthetic qualities of the watershed. In some instances it may require only accommodating limited growth in order to preserve and protect existing habitats (Haub, 2002). The ultimate objective would be to improve the quality of life that makes this island attractive to visitors and residents, without adversely affecting the local economy. Basins can be designated as sensitive, impacted, moderately impacted, and intact, then the most appropriate goals can be assigned for each basin. Ordinances to adopt LIDS and perhaps interim standards may be required as part of a policy revision. Another source for model ordinances that protect local resources is the USEPA website *http://www.epa.gov/owow/nps/ordinance/*that links to the Local Government Environmental Assistance Network.

One issue that the County of Kauaʻi and the Nawiliwili Watershed region are faced with, even in the event of policy changes, is that many of the developments currently taking place (or planned for the near future) were approved up to 25 years ago. In the master plan for these developments, antiquated drainage policies may have been in place. Now that these approved developments are in progress, they most likely are using these old policies. Some of the repercussions of using old policies and traditional stormwater management practices are discussed below (example 2). Since the Kaua'i General Plan includes the plans for many new developments, it would be wise to review the approval of the developments with respect to the old drainage policies when it comes time for actual permitting. Otherwise, a perfect plan for watershed restoration may be developed in vain because the pre-approved developments would legally be using inadequate and outdated policies.

The source of this problem can (probably) be traced to the Hawai'i State Water Code, in which Section 174C-71 discusses the protection of instream uses. Part 3 states that stream channels shall be protected from alterations wherever practicable to provide for fishery, wildlife, recreational, aesthetic, scenic, and other beneficial instream uses. Then in Part A it states that "the commission shall require persons to obtain a permit from the commission prior to undertaking a stream channel alteration." Further, Part B emphasizes that "projects which commenced construction or projects reviewed and approved by the appropriate federal, state or county agency prior to July 1, 1987, shall not be affected by this part." With very little space left for development in some of the watershed's smaller basins, it would be wise to re-evaluate this policy, considering the repercussions. Many other counties have faced the same types of problems. Andy Haub of the Olympia Department of Public Works identified building relationships with the community, based on environmental goals as the most important tool for improving water quality and combating these types of problems, especially during times of transition involving policy changes. In doing so, it may be possible to obtain voluntary cooperation with respect to the implementation of appropriate BMPs and the limited use of streams for the discharge of runoff.

In 2002, while completing Phase 1 of this project, the County of Kaua'i Department of Public Works was contacted. The staff indicated that policies were in place to protect areas that provide water quality benefits (such as wetlands) and to prevent disturbing natural drainage features and vegetation. Two examples are introduced below to illustrate some problems with the current policies and their enforcement. The first example concerns a development that followed the guidelines in the Storm Water Runoff Systems Manual. However, the development nullified the purpose of the drainage ordinance to maintain predevelopment runoff volumes and flow rates and minimize pollutants entering waterways. The second example demonstrates how current policies are not working properly.

Recently, a local landowner violated a grading ordinance that resulted in impairing the quality of a local water body (Pila'a) and destroying some of the reef. According to *The Garden Island* newspaper, "Soong indicated the county's penalties—$1,000 or imprisonment not to exceed 30 days, or both for each offense—were not powerful enough incentives to prevent violations of the county's grading ordinance" (March 13, 2003).
However, the violation lead to a lawsuit that resulted in the HDLNR calling for nearly $5.9 million in fines (*The Garden Island*, August 23, 2003). The results of this locally publicized lawsuit made an impact on Kaua'i by sending a warning to potential violators. A contested case hearing may result in a different fine because currently there are no laws in Hawai'i that address damaging a coral reef. This is a perfect example of why laws need to be updated and

put in place. It is noted that the lawsuit ultimately stopped the degradation of water quality, even though the policy itself was inadequate to prevent it. As a result, the Kaua‘i Department of Public Works has been criticized by many Kaua‘i residents for not acting quickly enough in cases like this one where un-permitted grading, grubbing, or other county laws are being violated. Senator Gary Hooser is now asking for a state performance and management audit of the county department (*The Garden Island*, September 23, 2003). The county’s actions could give the impression that policy violations have little or no consequences.

The second example concerns a 4-ft-diameter storm drain that was built to discharge runoff from the Schuller Homes subdivision in Puhi into Puali Stream. Although an energy dissipator, a BMP, has been used to slow the water velocity, the discharge is still actively eroding the stream banks. There is an increase in runoff volume from the project and an increase in pollutants, including the illicit discharge of pollutants being drained into the stream (Figure 10). The last time (July 2003) an HDOH research team was in this area, someone was dumping what appeared to be white paint into the storm drain system; of course, it subsequently drained into the stream. Plastic bags, bottles and wrappers were all present at the storm drain outfall in the stream. The point is that because the suggested BMP is not effective in mitigating pollution or maintaining predevelopment flow volume, the current policy is not working to meet its own stated purpose.

Kaua‘i’s current policies may not reflect the changes that are necessary to make the Nawiliwili Watershed sustainable or to make the waterways comply with the Clean Water Act. The current practice of voluntary action on behalf of the county and landowners has proved to be inadequate to keep the water quality in the Nawiliwili Watershed from exceeding standards set forth by the state government. Therefore, the recommendation offered by the inhabitants of the Nawiliwili Watershed is to find a mechanism for the enforcement of existing policies. It is also recommended to expand or change policies to include the implementation of more and better BMPs not only to maintain water quality but also to improve it. It is prudent for the County of Kaua‘i to recognize and authorize watershed councils or neighborhood boards in participating in the development of natural resource conservation plans. Finally, there is a need for more coordinated effort between state and county agencies. In the past, the division of responsibility has led to serious problems (KRP Information Services, 1993).

3.3.3. Strategy 4 — Integrate the Ahupua‘a Concept with Modern Watershed Management

It has been recommended by the Ahupua‘a Action Alliance, Hawai‘i that the ahupua‘a system be adopted as the legal framework for planning and resource management in Hawai‘i. This is also a goal of the Nawiliwili Bay Watershed Council, whose members feel that Hawaiian traditional and cultural practices and all related activities should be included in the goals of the community. The ahupua‘a concept has been long considered and advocated as an alternative approach to watershed management. A holistic approach such as this would contribute to the overall sustainability of the watershed. The integration of the ahupua‘a concept into modern watershed management is an attempt to reconnect man, nature, and government. The hope is that when one recognizes one’s place in the watershed as a steward, it removes the attitude that the watershed is one’s own resource to take from but the government's responsibility to protect. This attitude can then be replaced with the idea that the watershed will be a resource for all of its residents as long as its residents make responsible decisions.

Mike Kido, along with Bruce Wilcox of the Center for Conservation Research and Training, wrote a paper entitled "The Hawaiian ahupuaʻa: Modern lessons from a traditional watershed management system." Kido, also with the UH Hawaii Stream Research Center presented this approach at the annual Conservation Conference in Honolulu as well as at other venues. The abstract is included below to provide background information on how and why this concept could contribute to the restoration and maintenance of water quality in the Nawiliwili Watershed:

> The Ahupuaʻa, a traditional Hawaiian land/resource management concept that revolved around a practical understanding of ecological watershed-to-sea connections, was at the core of the economic, cultural, and socio-political system in pre-contact Hawaiʻi. Contemporary definition and understanding of this traditional concept defies conventional western paradigms of science and resource management even though the sustainable use of natural resources is the common goal of both approaches. In the Ahupuaʻa, however, human impact on the environment was tempered by a long tradition of ecological understanding and respect for both living and non-living entities. A growing movement in Hawaiʻi is struggling to revive these ideas and values so as to integrate them into a modern management context; however, their transdisciplinary character represents a significant challenge to conventional western approaches to research, resource management, and perceptions of human-nature relationship. We discuss two such ideas historically associated with the Ahupuaʻa whose value for practical application to current resource management problems in Hawaiʻi is becoming increasingly apparent. One, "Pono" provides responsible guidance for human-interactions as well as sustainable resource use and is a concept applicable to the practical challenges of working with local communities on restoration and management projects in their watersheds. The other idea is that of the maintenance of the functional unity of land and water (including sea) ecosystems that was critical to the health of an Ahupuaʻa. The delinking of these ecosystems coupled with the loss of traditional guidance is manifest today in dwindling fisheries levels that threaten Hawaiʻi lifestyles and values.

3.3.4. Strategy 5 — Control Invasive and Non-native Species

Invasive plant and animal species pose a threat to not only all of Hawaiʻi's watersheds and water resources, but also the tourism-based economy, agriculture, health, and quality of life. Habitat destruction and the introduction of alien species have been the predominant cause of biodiversity loss in Hawaiʻi for over a century. More native species have been eliminated from Hawaiʻi than anywhere else in the United States (KISC, 2003). Native species comprise only a small portion the species composition in the Nawiliwili Watershed. This area is named Nawiliwili because at one time native wiliwili trees were abundant. Now, less than a handful of these trees have been identified in the watershed. Non-native and invasive vines, trees, shrubs, and grasses are instead the dominant populations. On a tour led by one of the local kayak companies on the Hulēʻia River, a single plant (moa) and a single wiliwili tree were pointed out as the only native species in the area.

Biological assessments conducted in Nawiliwili Watershed streams accounted for six native fish species: *Awaous guamensis*, *Sicyopterus stimpsoni*, *Stenogobius hawaiiensis*, *Eleotris sandwicensis*, *Kuhlia sanvicensis*, and *Mugil cephalus*. This diversity was only recorded at low elevations in Hulēʻia Stream. Only *A. guamensis* has been recorded in Papakōlea and Puali Streams. Nawiliwili Stream is, to great extent, devoid of native species. Other native invertebrates such as *Macrobrachium grandimanus* and *Atyoida bisulcata* have been recorded in Hulēʻia Stream, but *A. bisulcata* has not been seen there since 1995 (Mike Kido, personal communication, 2003). None of these species are found mauka of Halfway Bridge. One cause of impaired biological integrity within the stream itself may be the presence of alien predatory species. According to William S. Devick (personal communication, 2004), there were several waves of introductions of alien species going back to the 1800s when Asian immigrants brought turtles, carp, and other species with them for food. There was a time when Hawaiʻi streams were considered "depauperate" and various species were introduced to improve the quality of life in Hawaiʻi as well as the populations available for food and recreation. Tucanare were first introduced in 1957, but it is believed that it was not until nine years later that they became established. Over the last century more than 70 aquatic species have been introduced, and over half of them have since become established (Yamamoto and Tagawa, 2000).

Large-mouth bass were first introduced in 1856 on the island of Hawaiʻi. Small-mouth bass were introduced by the Hawaiʻi Division of Fish and Game in 1953 and have since thrived in Hawaiʻi stream environments (Yamamoto and Tagawa, 2000). According to Don Heacock (personal communication, 2004), they were first introduced into the Wailua River on Kauaʻi to promote recreational freshwater fishing in 1959. Because bass are top predators, Heacock is concerned that the carrying capacity of our waterways is being reduced. It is also believed that small-mouth bass represent the greatest threat to Hawaiʻi's native amphidromous species. Voracious predators like bass limit recruitment of migratory fish. It is possible that other non-native species such as tilapia may also be competing for resources.

The red mangrove *Rhizophora mangle* is an invasive species that is actively spreading in the Nawiliwili Watershed. Hulēʻia estuary and ʻAlekoko Fishpond have been inundated with mangrove. The rock walls of the fishpond are being torn apart by the mangrove roots, and the estuary itself seems to be shrinking in size as the mangrove closes in. According to some local residents, the wall of the fishpond was still clearly visible in the 1980s, but now it is completely obscured by the mangrove. It is uncertain whether the mangrove is providing any water quality or aquatic habitat benefits. In fact, the introduced mangrove appears to facilitate the establishment of opportunistic exotics such as the Samoan crab while concurrently enhancing local species richness (Demopoulos, 2003). In Hawaiʻi, the mangrove may slow flows and trap sediment, thereby increasing its own propagation success and in the process choke ʻAlekoko Fishpond. Although mangroves may provide many water quality benefits in their native environment, in Hawaiʻi they tend to encroach upon habitat used by native water birds and migratory shorebirds. Upstream in the Hulēʻia estuary, hau dominates where the tidal influence wanes and there is more usable habitat for native water birds as the mangrove becomes less abundant. Therefore, controlling the spread of mangroves and removing some of their existing range are necessary for the protection of native species (David Smith, personal communication, 2003). In order to control the spread, it may be useful to develop public interest for mangrove uses such as firewood, mulch, and building or crafting material. In this manner, harvesting could be encouraged. In the meantime, floating booms or other devices could be used to trap propagules and control further spreading. The Kaua‘i Invasive Species Committee (KISC) has planned the mapping of mangrove populations for monitoring purposes. As more information becomes available regarding the extent of the problem, it may be determined that more immediate action is needed. This can include the complete removal of the mangrove from the estuary. The method that has been used in Hawai‘i is to first kill the trees with Garlon 4/JBL biodegradable crop oil mixture and then pull them out by the roots using a backhoe and bulldozer (David Smith, personal communication, 2003). Due to the location and extent of the problem, the U.S. Army Corps of Engineers may need to be brought in to conduct a project of this magnitude.

Invasive species can contribute to the degradation of water quality in a number of ways. Some non-native trees found along the banks of streams in the Nawiliwili Watershed are either allelopathic (eucalyptus) or are so dominant that no other species can grow as understory (strawberry guava). This type of environment may not provide the proper buffer systems necessary to slow surface flows, remove suspended solids, and allow for proper infiltration. The removal of this type of monotypic forest and the introduction of some native plants may restore some of the natural infiltration processes, thereby improving water quality. Re-establishing adequate riparian buffer zones with the appropriate species is one of the restoration projects suggested for the Nawiliwili Watershed. On another front, community planting/reforestation days offer educational opportunities that have additional value.

Finally, it must be mentioned that feral ungulates that are not native to the Nawiliwili Watershed, such as pigs, negatively impact water quality. In mauka areas of the watershed they destroy habitat by removing some of the remaining native vegetation, making way for more aggressive species. They also directly affect water quality by causing erosion and other sediment contributions by routing in soil near stream banks. Additionally, pigs are responsible for creating some health risks. Their routing and wallowing create a breeding habitat for mosquitoes. Pigs may also be partly responsible for the spread of leptospirosis, one of the biggest health concerns among community members using the watershed for recreation purposes. A control plan for pigs may include allowing/encouraging more pig hunting in mauka sections of the watershed. Limiting the pig populations may help reduce water quality impacts.

Fencing is another option for controlling pigs. A priority site for pig fencing is the Hulē‘ia National Wildlife Refuge. Don Heacock is already working with the refuge manager, who offered to supply the fencing material. What is needed are manpower and support. Partnering with NBWC, this activity could easily be put together as a community work-day project. Funding from the Native Plant Initiative through the National Fish and Wildlife Foundation grant program can be obtained for the project (Don Heacock, personal communication, 2004). The National Tropical Botanical Gardens may supply some rare and endangered Hawaiian Mesic forest plants to plant in the refuge after the pigs have been fenced out (Don Heacock, personal communication, 2004).

Monitoring and control programs for invasive species are essential restoration activities for the Nawiliwili Watershed. Eradicating incipient species, controlling the spread of established invasive populations, and preventing the entry of new invasive species, are the goals of KISC. This local organization is a voluntary partnership of government agencies, private and non-profit organizations, and concerned individuals working to eliminate or control the most-threatening invasive plant and animal species in order to preserve Kaua'i's native biodiversity and minimize adverse ecologic, economic, and social impacts (KISC, 2003). KISC intends to supplement existing and emerging programs through partnerships with other organizations and aims to assist in the coordination of island-wide efforts. The group holds annual workshops to re-evaluate objectives and priority listings of targeted invasive plants and animals. Currently, *Miconia calvescens* is the top priority for the committee. This species is not currently affecting the Nawiliwili Watershed, but it is hopeful that KISC will eliminate its potential threat. KISC also maintains maps of known locations of targeted species, along with annotations on population structure, fertility, and history of control efforts. KISC will be a valuable resource and partner for restoration projects that take place in the Nawiliwili Watershed.

3.3.5. Strategy 6 — Encourage Collaboration Among Various Agencies

It has been long recognized that collaboration among government agencies, nongovernment organizations, and community members is critical for the success of watershed management. The Kaua'i General Plan[2] states, "A key concern is the long-term organizational structure for watershed management. Each restoration project should draw upon a network of government and community based organizations. But it is unclear which agency or organization will accept responsibility and be funded to coordinate restoration and management over the long-term, or how such an agency would function within the existing framework." Instead, it may be necessary to take a regional or basin-wide approach to watershed planning and management in order to provide a broader framework in which the efforts of various agencies and organizations can be integrated. According to the 1993 Water Quality Plan for the County of Kaua'i, "to be effective, storm water management should be planned for an entire drainage basin, not simply for individual sites because responsible coordinated solutions for individual developments in the absence of basin-wide plans are difficult to achieve, particularly since current practices are based on traditional drainage practices" (KRP Information Services, 1993).

The preparation and writing of the Nawiliwili Watershed Restoration and Protection Plan has already started using this "watershed" approach. Numerous agencies and individuals from many different sectors have been encouraged to participate in identifying restoration activities for this plan. This process has already begun to facilitate participation and

[2] The County of Kaua'i Planning Department is responsible for the *General Plan for the County of Kaua'i*. According to Bill 1957, Draft 2, Ordinance 753, which adopted the Kaua'i General Plan, the purpose of the plan is as follows: "The General Plan states the County's vision for Kaua'i and establishes strategies for achieving that vision. The strategies are expressed in terms of policies and implementing actions. They may be augmented and changed as new strategies are developed. The General Plan is a direction-setting policy document. It is not intended to be regulatory. It is intended to be a guide for future amendments to land regulations and to be considered in reviewing specific zoning amendments and development applications."

collaboration to some extent. Building relationships and encouraging cooperation can have a synergistic effect by maximizing human resources that already have a role in watershed restoration, minimizing project overlap, and thereby maximizing cost effectiveness. Collaboration also encourages the flow of information. The implementation of restoration activities will require continued cooperation in order for the plan to be successful. More collaborative effort will lead to better solutions, to efficient use of resources, and to a greater sense of community responsibility.

Community involvement is also a critical component of watershed planning, decision-making, and management. Community members can be a source of manpower, ideas, personal knowledge of the watershed, and motivational strength. Community-based organizations, such as watershed councils and neighborhood boards, can provide additional support to government agencies in the planning and decision-making processes. Community participation and support could be more successful if community-based organizations were recognized by the County of Kaua‘i and given a leading role in the planning process. A key element is to derive continuous community input from watershed councils or neighborhood boards that provide a vehicle for the flow of information through ongoing meetings. In this way the community stays involved throughout the planning and implementation processes, making revisions wherever necessary. It is worth mentioning again that one of most effective tools for implementing successful watershed restoration plans is the strong relationships between community members and government agencies, based on common environmental goals. Giving community members the power to make a difference reinforces a strong sense of community and unity, which can perpetuate itself in the attitudes of individuals from both the private and public sectors.

3.3.6. Strategy 7 — Develop and Implement Education and Outreach Programs

The purpose of a watershed education program is to increase awareness of watershed conditions and provide opportunities that allow community members to participate in the solution. Education is one of the most powerful tools to enhance environmental conditions and reduce pollutant loads. Ideally, education can lead to prevention. If water quality degradation is prevented, then restoring water quality will no longer be an issue. For education to be effective, it must begin at an early age. In this way it can be ensured that the principles of watershed protection and pollution prevention are brought forward into future generations. Resource management must first be introduced to children who still have fresh, open minds. Simple concepts like stewardship can teach children that they are responsible for their actions within the watershed. Students who learn how watershed dynamics work may realize that making responsible decisions can improve the condition of the watershed. Education programs should begin in elementary schools and continue throughout middle and high schools.

Community education and outreach programs can be an effective way to spread awareness about watershed issues, but it is a difficult task to reach the adult generation. On a small island it would seem that the community would be more connected to the environment, like their ancestors were, but this is not necessarily the case. Absence of interest is based on the difficult economic conditions and the lack of time to think about their place in the watershed. Frustration with economic conditions has led to blaming government agencies for the exploitation of resources and the degradation of water quality. Education programs intend to change this attitude. It is time for community members to take control of their resources and be a part of the solution.

Education programs for children, as recommended above, can help in reaching the adult population as well. Children who bring new values home can inspire a change in their parents. In addition, adult education and outreach programs, if correctly designed, can be effective tools for many community members who care about their resources but may not know enough about how to help or how they can participate. In many cases, educational opportunities have not been available or designed to reflect community needs and technical backgrounds. In some cases, even basic knowledge of hydrology is absent, so a suitable education program should be designed to satisfy such a need. According to Alabama's "how to" guide for urban watershed management, "the most effective education programs connect people with the resource through hands-on activities that allow education to lead to structured outcomes that turn education into action. If individuals see how changes in their behavior will make a difference and if that difference can be achieved fairly quickly people are more likely to take additional actions as success builds upon success" (Center for Environmental Research and Service, Troy State University, 2000).

This generation has gotten used to pointing out problems without identifying solutions. Presenting solutions offers hope, and involving individuals in the solution returns ownership of (and responsibility for) the resources to the community. Solutions and educational opportunities can be offered via local television programs, eco-tours, or community-participation projects such as beach cleanup days and storm drain stenciling. Projects like these can give the community the feeling that they can make a difference and that solutions are not so far out of reach. A memorable experience can lead to the passing on of information, the perpetuation of education. When government agencies sponsor these activities, it provides them an opportunity to build new relationships with community members. Counties that have been successful in restoring their watersheds have found that building relationships with community members based on environmental goals can be one of the most effective ways to improve environmental conditions.

A watershed education program should not only increase general public awareness but should also include more technical education and support targeted at specific groups such as landscapers, developers, contactors, eco-tour companies, small businesses in industrial areas, restaurants, and resorts. Businesses that participate in eco-friendly activities could use their "watershed-friendly" practices as part of their promotional material. The Bellevue, Washington, community formed a group called the "Business Partners for Clean Water" (City of Bellevue, 1993). Forming a similar group may be a good way to involve many of the small businesses that operate in the Nawiliwili Watershed.

Successful education programs give individuals the tools to make changes and the opportunity to see those changes come to fruition. Numerous restoration activities that provide educational opportunities for the community have been identified for the Nawiliwili Watershed and will be discussed in more detail in Subsection 4.3.

3.3.7. Strategy 8 — Develop a Water Budget for the Watershed

A water budget can give watershed planners and managers a better idea of how to plan for water use. A water budget is an accounting of all of the inflows, outflows, and changes of storage within a system. Inflows and outflows may include water from tributaries, ditches, irrigation diversions, and other inputs. Water that may be flowing out of a source watershed into an entirely different basin also needs to be accounted for. Irrigation systems and groundwater withdrawals change natural flow patterns. In the absence of a water budget, studies that monitor water quality are forced to assume that the water flows from the mountains to the sea. This has many implications for studies that are trying to determine the source and amount of pollutants present in a watershed, when it is unclear how much water is coming from other watersheds and whether it is carrying pollutants. Conclusions that are drawn from these types of studies may give an inaccurate picture of what is really occurring. Dewatering streams reduces the amount of flow available to dilute pollutants, thus increasing pollutant concentrations. It also reduces the amount of energy available for transporting sediment, thus causing more settling of fine sediments. This is not to say by any means that dilution is the solution, but natural flow regimes may provide for better water quality. It is obvious then that water quantity can also affect water quality.

The Nawiliwili Watershed is not alone when it comes to alterations in natural flow regimes. The entire island's water system has become a complex network of inter-connected ditches, irrigations systems, diversions, flumes, and reservoirs. The engineering of these systems is very complicated. When the sugar industry was emerging, massive quantities of water were needed to irrigate the crop. In some regions, there was little water available locally, so it was brought in from elsewhere. This required the building of a complex network of irrigation systems that still exist today. However, very little sugarcane is still being grown, and yet water is still flowing through these systems. There is a lack of knowledge regarding the condition of these systems, regarding whether they are operational or not, and regarding the volumes of water diverted to other watersheds. Most of the systems are privately owned by large landowners (former plantation owners), and the information has not been made public.

A water budget may be prepared by first consulting the Commission on Water Resource Management's (CWRM) database. According to the State Water Code, CWRM is responsible for the registration of all diversion works within or outside of a water management area. A field survey would need to be conducted to verify the information contained in the database. Also, large landowners would need to be consulted to determine if all of the diversion works have been accounted for. Their cooperation is essential to the accounting process. Landowners may also keep records of flow rates, the condition of the irrigation system, and the frequency of operator-induced flow changes, including shutting a diversion off during a storm. Other useful information that could be obtained from landowners includes their future plans for water use.

If there are no plans for the water that is flowing in the irrigation systems, it may be determined that there is no longer a need to divert the water. If this is the case, then a petition may be filed with CWRM to amend interim instream flow standards or to establish instream flow standards. According to the State Water Code, "In considering a petition to adopt an interim instream flow standard, the commission shall weigh the importance of the present or potential instream values with the importance of the present or potential uses of water for noninstream purposes, including the economic impact of restricting such uses" (Hawaiʻi State, 2003). The benefits of setting values for instream flows and returning some of the water may include recruitment of native fish, restoration of habitat, dilution of some contaminants, and increasing stream flushing capacity.

Specific sites where instream flows need to be restored include the following (Don Heacock, personal communication, 2004):

1. Puali and Halehaka Streams in Puhi Industrial Park — reservoir Haiku 4B needs to be relocated off the stream channel for physical and chemical reasons.
2. Papalinahoa Stream — below Ulu Ko subdivision where the stream has dried up for a reason to be investigated.
3. Hulēʻia Stream — below the major weir that dewaters the river and takes water to Poipu.
4. Nawiliwili Stream, which receives water from the south fork of Wailua River; an action that was done at the time of the construction of the Līhuʻe sugar mill.

If there are plans to use the water, based on the out-of-stream use, CWRM may determine whether it is economically viable to return any of the water. Some out-of-stream uses that are currently being considered include the treatment of surface water for drinking. In areas of the watershed where a proposed new development is required to provide a drinking water supply, many of the wells are low-producing. As an alternative, a suggestion is to use irrigation water to flood-irrigate some upstream areas in order to recharge the aquifer in hope of increasing well production. It is a concern among watershed councils that inappropriate planning measures could be taken if the water budget has not been prepared before the implementation of any plan. This is because it is uncertain how any of the subsequent steps could be taken or how successful they would be without first preparing the water budget. The preparation of this essential document could answer many of the questions remaining about appropriate planning for water use.

4. RESTORATION ACTIVITIES FOR THE NAWILIWILI WATERSHED

4.1. Education and Outreach

Table 2 outlines proposed education and outreach activities for the restoration of the Nawiliwili Watershed and lists the suggested participants, including government agencies, nongovernment organizations, businesses, community groups, and individuals. The proposed plan guarantees a broad base of participation in preparing the educational material and in targeting a diverse audience. Details are provided below.

4.1.1. Education Programs in Schools

As discussed earlier (Subsection 3.3.6), it is imperative to develop education programs that target school children at a young age. The objective is to reach a group that is open-minded and willing to participate. Concepts like stewardship and resource management have a better chance of reaching future generations. Education programs targeting school children could integrate watershed management principles into science and social studies curriculums. Lessons in resources management can easily be adjusted to address education standards required by the Hawai‘i Department of Education (HDOE).

One of the topics that should be included in a watershed education program is the ‘ahupua‘a concept. Students would be made aware that the watershed is a community resource and that its care is part of their responsibility. This lesson would teach stewardship by reconnecting students with their resources. Hands-on activities would provide students the opportunity to make a visible difference in a short period of time and are more likely to motivate them to offer more help.

A watershed curriculum would integrate the subject matter into the areas of science, social studies, ethics, history, health, statistics, and writing. However, a hands-on component would comprise a large portion of this curriculum. Many educators have stated that students who are academically challenged in areas such as science may excel when given the opportunity to participate in a hands-on project. According to school officials, Hawai‘i’s schools need more resources for education in the sciences. A cooperative effort between HDOH and HDOE may prove to be beneficial for both parties.

There are several different approaches to introducing watershed concepts through a curriculum at schools. The first is to introduce short lessons as part of a larger science or social studies curriculum by including service projects such as water quality monitoring and native tree planting, as discussed below. Another way is to offer a complete curriculum devoted to watershed science, such as the online curriculum that Pat Cockett of Kaua‘i High School developed and uses in his classroom (*www2.Hawaii.edu/~pcockett/index.htm*).

A cooperative partnership between HDOH and HDOE was established about six years ago for school watershed education projects. Kaua‘i High School is the only school in the Nawiliwili Watershed that has taken advantage of this partnership. The purpose of this partnership is to develop standards-based units that teach students to use scientific methods through scientific inquiry. These methods are then used to address issues that communities face, such as NPS pollution and developing or identifying possible next-step actions.

The development of Cockett’s online curriculum was supported by this partnership. It is important that, after he retires from teaching at Kaua‘i High School, this curriculum continues to be utilized to ensure watershed education and stewardship in future years. It is important that the Nawiliwili Watershed Restoration Office be in contact with Kaua‘i High School from year to year to ensure that this curriculum is still being offered. Also, the restoration office should offer to help train a new teacher to utilize this curriculum and offer support and other resources (especially if the new teacher is unfamiliar with watershed concepts).

Additionally, the established partnership should be fully utilized and expanded so that units can be developed and implemented at Wilcox Elementary School and Chiefess Kamakahelei Middle School. These units can then be adapted, promoted, and utilized at Island School and Kaua‘i Community College.

Some concerns may be raised about whether data collected by students are usable. The data should not be used as a part of detailed technical analysis, but it can be used to identify general obvious trends or obvious pollution sources. If a general negative trend is identified, then a specialist can investigate the situation and collect data for technical purposes at that time. The program itself is intended to increase awareness about streams and water resources.

Five schools are located in the Nawiliwili Watershed, including Wilcox Elementary School, Chiefess Kamakahelei Middle School, Kaua‘i High School, Kaua‘i Community College, and Island School (private; all grades). Colleges and private schools may have more freedom to include these types of activities in their curriculums. There is also a growing number of children involved in alternative learning programs such as home or online schooling. One community member suggested that a watershed curriculum be made available to these children because many are lacking hands-on activities. It has also been suggested that a professional trained in conducting voluntary action programs, monitoring, or stream ecology be funded and tasked to take groups or individual alternative learners into the field for these types of activities. In fact, it may be necessary to create a volunteer coordinator/public education position within HDLNR to facilitate many of the projects that are described in this report. That person could act as an educator for schools, lead community work projects, take youth groups into the field, and assist in the coordination of volunteers for restoration activities.

A concern identified by community members at one of our meetings was the lack of environmental youth activities for children, especially teenagers. Although activities such as stream monitoring and cleanup can be part of a school curriculum, they could also be extracurricular activities. Engaging youth groups as well as school children in these types of activities may also relieve some social concerns, such as drug abuse and underage drinking. One possible outlet for these activities could be the county Department of Parks and Recreation. The department could sponsor stream-monitoring activities to involve students of alternative schooling and interested youth groups.

An entire curriculum devoted to watershed science may be more successful than conventional science classes at teaching scientific concepts while increasing awareness about watershed dynamics and pollution prevention. The visual assessment protocol monitoring activity described above could supplement existing curriculums or be included into newly developed ones. As previously mentioned, a watershed curriculum would include topics from all areas of science, including biological, physical, chemical, and ecological disciplines. Other topics that would be included are Hawaiian heritage and management (ahupua‘a), policy, stewardship, and ethics. One of the most important components, however, would be the hands-on experience. Portions of this curriculum could be implemented at all grade levels and could be offered at all schools in the watershed. The inclusion of watershed principles in school curriculums could ultimately be very effective in fostering a whole future generation of watershed stewards.

A watershed curriculum could easily be developed with the many resources that are already available, including Cockett's curriculum, which is specific to the Nawiliwili Watershed. The implementation of a watershed curriculum would entail approaching science and social studies teachers. It may be necessary to approach DOE at a higher level in order to incorporate these concepts into curriculums at all grade levels in all schools.

4.1.2. Expansion of Native Tree Planting on Hulēʻia National Wildlife Refuge

Don Heacock takes boy scouts every year to the Hulēʻia National Wildlife Refuge and helps them plant native trees, an activity which provides a combination of education and BMP implementation. Kō, alaheʻe and wiliwili are all planted in the forested area of the refuge. As mentioned before, wiliwili trees were once abundant in this area. However, most of the lowland forests now consist of non-native species, and what portion of native species still exists in these areas is currently uncertain. Native trees that are planted in the refuge have a better chance of survival due to the lack of goats that populate the land on the Kipu Kai side of Hulēʻia River. Trees planted in the refuge two years ago are already reaching heights of 15 feet. With the cooperation of the Hulēʻia National Wildlife Refuge and the U.S. Fish and Wildlife Service, Heacock hopes for more participation by every scout troop and school group in the Nawiliwili Watershed in future years. Since the refuge is set aside as public land for the restoration of native plant species and for providing a habitat for endangered water birds, it could feasibly serve to house and safeguard a native forest for years to come.

4.1.3. ʻAlekoko Fishpond as Educational Research Center

ʻAlekoko Fishpond is considered one of the most important cultural resources of the Nawiliwili Watershed and the island of Kauaʻi. It is an educational gem awaiting restoration and use. Although the fishpond is currently privately owned, restoration is feasible if federal or local community funds can be obtained to purchase the fishpond. The only way the community could take over the responsibility of restoring and managing the fishpond is through federal condemnation proceedings that allow for its purchase at an affordable price. Related to its purchase is a community concern as to who would be responsible for taking on a restoration and management effort of this magnitude. There is the possibility of placing the fishpond in a public land trust.

After purchase, the fishpond could be restored and used as an educational resource for the entire island. An educational center and living laboratory could be established to serve the schools, the community, and visitors through workshops on local history, science, and aquaculture. A living laboratory for fish production could provide hands-on experience for students and farmers. The restoration of ʻAlekoko Fishpond would be the result of the community adopting ahupuaʻa principles, reconnecting themselves to their resources, and giving back to the community.

The Nawiliwili Bay Watershed Council hosted several meetings in 2000 and 2001 to discuss the vision for ʻAlekoko Fishpond. The community's input was used to develop the following slightly modified mission/vision statement and goals (Don Heacock, personal communication, 2004). At this time there is no actual plan for implementation, but the statements below may be used as a guideline for future restoration activities for the fishpond.

MISSION/VISION:

To restore the ecological, archeological, and cultural resources and community management of ʻAlekoko Fishpond in order for it to function as an aquaculture demonstration, training, education, and research center for the production of fish, shellfish, and limu and for cultural enrichment and environmental education.

GOALS:

- *To establish a community-based organization to manage the restoration and maintenance of ʻAlekoko Fishpond. It may be necessary to establish a 501(c) 3 like "Malama Na ʻAlekoko" to become the legal owner and manager of the fishpond.*
- *To seek funding for the purchase of ʻAlekoko Fishpond. Possible sources: Trust for Public Lands, a nationwide campaign for donors/contributors, Pew and other foundations, NOAA/National Estuarine Research Program, EPA/Five Star Program; others. Last resort — state condemnation process.*
- *To establish baseline biological, physical, and chemical characteristics of the fishpond.*
- *To eradicate red mangrove from the fishpond, and to establish a long-term control program.*
- *To restore the fishpond wall and makaha gates.*
- *To re-establish aquaculture production in the fishpond as a community-based cultural activity to generate funds to restore and maintain the fishpond.*
- *To establish native and non-invasive introduced plants that will promote food and habitat for endangered Hawaiʻi water birds.*
- *To establish environmental education interpretive displays about ʻAlekoko Fishpond; about the native vegetation, fishes, and water birds that use the fishpond; and about native Hawaiian values and traditional management practices (e.g., ahupuaʻa model).*
- *To establish a partnership or memorandum of understanding (MOU) with USFWS to better create and manage an endangered water bird habitat in and adjacent to the fishpond, including taro loʻi.*
- *To establish a volunteer docent training program/kupuna program that will take visitors on cultural/ecological tours of the fishpond, focusing on its legends, form and function, natural history, and archeological resources.*

- *To develop an aquaculture training, education, and research center focusing on traditional Hawaiian aquaculture practices integrated with appropriate technology focused on building sustainable watershed communities.*
- *Establish an MOU among KCC, Kaua‘i High School, King Kaumualii and Chiefess Kamakahelei Middle School, and other educational institutions, to make ‘Alekoko a regional or island-wide center for aquaculture training, environmental education, and cultural enrichment.*

4.1.4. Low-Impact Development Strategies Videotape/Workshop

LID strategies are attractive methods of preventing pollutant loads from reaching streams and other water bodies. Subsection 4.7 covers these concepts in more depth. For educational and outreach purposes, a workshop could be conducted and a videotape produced to explain LID concepts. The target audience for the video would include county agency personnel, architects, contractors, self-help housing office staff, and individuals who are hoping to design and build a home. The video and workshop could be promoted by county permitting offices. Viewing the video or attending the workshop could be optional, or it could be made mandatory by requiring its viewing before permits are given. This way, architects, contractors and new homebuilders are given alternatives to traditional high-impact construction methods before the finalization of their plans. By knowing various options and cost advantages, homebuilders and others perhaps would choose to utilize LID concepts by incorporating them into the design and construction of their homes.

Kaua‘i faces some unique problems with regard to residential real estate, due to shortages of available land and single-family homes, which have driven the prices to record levels in the past one or two years. The increase in demand for real estate and vacant land has also increased the demand for building and landscaping supplies, promoting the opening of a Home Depot store in the Nawiliwili Watershed. The opening of such a store will encourage even more residential building and renovations. One of the competitive advantages of shopping at Home Depot is that they offer free weekend workshops on home improvement projects such as laying tile and installing faucets. One avenue for educating individual homebuilders could be to through Home Depot workshops based on sustainable development concepts for single-family homes. Some LID strategy topics that could be covered are reusing non-potable water for landscaping, xeriscaping, using pervious pavements, and planting rain gardens.

Targets of education programs should also be government agencies, contractors, landscapers, and other parties involved in both commercial and residential construction projects. We recommend the appointment of highly trained, certified LID, and erosion and sediment control specialists by these agencies for the island of Kaua‘i. A specialist of this sort could be a source of information for all construction-oriented groups. Workshops or videotapes outlining LID strategies should be made available for training purposes.

4.1.5. Ahupuaʻa Videotape

A panel of experts could be invited to speak to Kauaʻi residents and government agency personnel about ahupuaʻa concepts and how to integrate them into modern watershed management. The workshop could be videotaped by students in a communications class or hoʻike for airing on local access television to provide further educational opportunities.

4.1.6. Education Program for Eco-tour Guides and Boat Captains

Another avenue for education is through the eco-tour industry, which may reach a different yet still important target audience. Many eco-tour companies operate their businesses in the Nawiliwili Watershed, offering kayaking, hiking, swimming, all-terrain-vehicle (ATV) riding, and tube riding. Concerns about these types of activities include allowing tourists to go into areas closed off to the general local population, water pollution due to sunscreen and insect repellent use, increase in trash, stream bank erosion, and non-native species dispersion.

Although eco-tourism may account for some negative impacts to water quality, it also presents an opportunity to potentially educate a broader audience that would include not only local residents but also off-island visitors. A workshop and videotape could be developed to address the concerns that have been raised. Here again, the videotape could be produced by students in a communications or videotape production class. The workshop could be voluntary but preferably required during the permitting process of all new eco-tour guides and boat captains. A suggestion is to have HDLNR's Division of Boating and Ocean Recreation (DOBOR) adjust the permitting process for tour operators, thereby providing an avenue for implementation. The tour operator could have new hires view the videotape and sign a statement that would be submitted to DOBOR annually with the permit renewal application.

Workshop topics would include identification of native and non-native species (both plants and animals), general watershed facts such as where the water flows and what types of pollutants it carries, conservation techniques, and the history of irrigation systems. Considering that the tour guides would continually be visiting the watershed, including the remote areas, it would be useful if they were to keep a field journal. Workshops would inform them about useful information to enter in a journal, such as changes in hydrological conditions, vegetation, and any incidences of leptospirosis or other illnesses.

Eco-tour guides should be able to clearly describe the condition of the visited sites in easy-to-understand terms. In addition to elaborating on the condition of the watershed, they would probably be able to offer solutions for problems and, given an opportunity, to solicit visitors' help in restoring watershed conditions. Permitting agencies like DOBOR could make attending the workshop a requirement for tour operators. Permitting could also be an avenue to derive funding to keep some of these projects going. Tour companies should be urged (perhaps through incentives) to offer discounted rates to local residents and school groups for environmental educational tours.

This education strategy could be successful because most guides choose these jobs because they love the outdoors and they appreciate Kaua‘i's resources. They often work extra hours to clean up trash and maintain trails. Properly educating guides could reduce impacts to the watershed and may also help to restore water quality. Furthermore, through these guides Kaua‘i's history and natural status could be properly presented to visitors who will carry this information back home. Often times, historical and natural facts are misrepresented when uninformed guides make up stories or species names and pass them on to naive visitors. Misrepresentation of facts is certainly unacceptable, especially with the availability of accurate information that helps in restoration and protection efforts.

In many of the world's developing countries, like Costa Rica, volunteer research tours are offered to interested vacationing parties who actually pay money to participate in the efforts. This idea could be incorporated into any number of the tours that are already offered on Kaua‘i. Ideas for such a tour would include an educational nature walk followed by activities such as native planting, invasive species removal, water quality monitoring, visual assessments, or sharing of ideas for future restoration. This type of tour is fun and effective, and it can be profitable while simultaneously helping to restore the watershed.

4.1.7. Educational Plaques

Another way to target visitors is by placing signs or plaques in heavily frequented areas. The Kaua‘i Marriott, the Harbor Mall, and the cruise ship industry attract or bring large numbers of visitors into the Nawiliwili Watershed everyday. Free shuttles are offered to cruise ship passengers to access the beach and shops at Kalapakī. The Harbor Mall and the Kaua‘i Marriott both have property adjacent to Nawiliwili Stream. Visitors stop on the bridge to peer into the stream. What they see is a turbid estuary frequented by Hawaiian water birds. The area is choked with water hyacinth and tilapia, which is probably the dominant fish species there. One of the authors of this report (M. Mira) often answers tourists' questions about the species that are present and whether the estuary is a popular fishing spot. It could be beneficial to have plaques posted along the edges of the stream and estuary to identify water birds, fish and plants, and even monk seals that pull up for a nap. Other topics that could be included on the plaques include the history of Nawiliwili Stream and Bay, public health issues, and the status of restoration activities, such as water quality monitoring. The benefits of these plaques, including the promotion of the island's points of attraction, would greatly exceed their nominal costs. It was suggested that the plaques could even be made by local students. The Kaua‘i Marriott, which offers an educational tour through its native plant garden, is currently working on posting plaques near the native and endangered plants on its property.

Additional plaques could be placed in areas where BMPs have been implemented and are working (e.g., the vegetated swale around Wal-Mart). These BMPs can offer educational opportunities to the public as well as to future developers. The posted plaques could describe the BMP, its purpose, and even its success rate. The plaque sites could be visited during field trips as part of LID workshops.

4.1.8. Storm Drain Stenciling Projects

Storm drain stenciling is an important tool to educate the public about the adverse effects of dumping contaminants into the storm drain system. The stencil itself is only one part of the educational process. The Department of Transportation puts plastic plaques on storm drains to provide information on where the waste goes. However, getting schools and community groups out on the road to actually apply paint to the stencil reinforces the message carried by the sign. During field trips, students often find stenciling storm drains a memorable experience that can be shared with others, multiplying the educational effect of just posting the sign or stenciling the sidewalk.

4.1.9. Education Program from NRCS

The topic of educational opportunities for reducing water quality impacts from agricultural land is covered in more detail in Subsection 4.2, which covers agricultural BMPs. The NRCS offers information and education for farmers and ranchers on everything from reducing erosion on agricultural roads to cost-sharing programs that are available to reduce impacts from farming and ranching operations. One activity that the local NRCS office envisions is a "working farm" where its suggested BMPs are in place to reduce sediment loads. The working farm could be a model for other farmers to learn about implementing these practices, their function, and their expected results. The working farm would be like a classroom or a lab where tours are given to educate others about agricultural BMPs. Since a large portion of the Nawiliwili Watershed is farmland and ranchland, such a working farm has the potential to reduce impacts from thousand of acres. NRCS staff has recognized an increase in the use of their services over the past few years, which suggests that an educational activity such as the working farm has the potential to reach many farmers in this watershed.

4.2. Prevention of Soil Erosion and Sedimentation from Agricultural Lands

A large portion of the Nawiliwili Watershed is comprised of agricultural land. Some of this land is being actively farmed and ranched, while other parts are just lying fallow. ATV riding and eco-tours have become growing businesses on agricultural land. Intensive agriculture, such as sugarcane, caused periodic disturbances of soil during harvesting and tilling activities, but ranching and other permanent crop agriculture may be improving water quality by reducing the frequency of these disturbances. However, soil from agricultural roads is subject to erosion and can end up in streams and waterways if not properly managed. ATV riding and other activities that have mottos like "let's get dirty" exacerbate erosion by dislodging sediment from roads with their 4-wheeling vehicles.

This section discusses restoration projects which address erosion from agricultural roads as well as solutions to sedimentation caused by cattle. The NRCS office on Kaua'i offers an extensive list of BMPs available to farmers, ranchers, and others needing soil conservation advice. These resources are also available as an online BMP encyclopedia[3] to anyone who has Internet access. Table 3 summaries proposed activities to prevent soil erosion from agricultural lands. Details of such activities are provided below.

4.2.1. Promote Videotapes Produced by Soil and Water Conservation Districts

In a partnership with Grove Farm and Kaua'i Coffee Company, the East and West Kaua'i Soil and Water Conservation Districts (SWCDs) recently completed a project, "Demonstration and Training in Critical Area Stabilization Techniques on Agricultural Roads and Unprotected Waterways." The project, funded in part by a 319 (h) grant, produced five educational videotapes that explained different methods of erosion control for agricultural roads on Kaua'i. The videotapes also documented demonstration BMP projects that were implemented. In each scenario, a conservation problem was presented with several options for a solution. Then the solution that was chosen for the Kaua'i site was implemented and lessons learned from the project were then shared. Many of the projects took place in the Nawiliwili Watershed on Grove Farm land. BMPs were tailored for the area, and locally available materials were recycled for use in some of the projects.

The videos demonstrated many options that are available to agricultural land leasers/operators to divert water from their roads before it can cause erosion. Of course, once the water is diverted from the road, sediment filtering or settling is required before the water can be safely discharged into a waterway. The use of filter strips and energy dissipaters to slow the velocity of runoff are examples of possible solutions shown by the videos. The videos also include information for stabilizing roads with slopes using honeycomb matrix and/or geotextile mats as well as vegetation. These videos offer valuable information for farmers, tour company operators, or other individuals about erosion control practices that could reduce water quality impacts. An example of a project is described in the next section.

4.2.2. Expand Use of Conveyor Belt Water Bars to Prevent Erosion

One very simple project that was demonstrated in the videos described above seemed to stand out in the mind of one NRCS staff member. Making use of locally available materials, this project involved the use of a protruding water bar that was adapted specifically for the Nawiliwili Watershed. The BMP, previously used on forest roads on the mainland, called for the use of cut tires. For Kaua'i, a conveyor belt from the old sugar mill was substituted for the tires. Recycling old materials is not only environmentally friendly but also cost effective. The belt was nailed to a pressure-treated Albesia board provided by a local tree farmer. The protruding water bar was then placed at a 35° to 45° angle to the road to ensure the swift movement of water from the road. Once the water moves off the road, it can go into a roadside ditch, filter strip, or other outlet. Since the water spends less time on the road, there is less chance for sheet and rill erosion. Potential locations for the expanded use

[3] See for example, National Watershed Manual, National Soil Survey Handbook, which can be found at *www.nrcs.usda.gov/technical/references*. Additional conservation information for farmers and ranchers can be found at *www.nrcs.gov/patners/for_farmers.htm*.

of water bars include the areas along Kalepa Ridge, across from the Humane Society, and south of Halfway Bridge.

Since the projects from the video were conducted on Kauaʻi—more specifically in the Nawiliwili Watershed—they offer solutions for road erosion and maintenance issues and proof of their potential success on the local level. The video emphasizes that the use of any suggestions or information offered by NRCS are strictly on a voluntary basis. For farmers and ranchers, funding for the implementation of these practices is often the limiting constraint. According to the Kauaʻi NRCS office, however, there seems to be an increasing number of farmers and ranchers implementing these practices.

4.2.3. Locate Water Troughs for Cattle Away From Streams

Another practice to reduce sediment inputs to streams from agricultural lands is to place water troughs at a distance of about 30 m (100 ft) from the stream. It has been shown that this practice can keep cattle out of the stream up to 90% of the time. Keeping cattle out of the streams could also reduce bank erosion and cattle-related bacterial problems. A pilot project should be conducted by one of the ranchers in the Nawiliwili Watershed to determine the effectiveness of this activity. Suggested locations would be within large ranches such as the Rice Ranch. According to Jon Schlegel, who could not be more specific, some ranches are already using this practice while others are in the planning and implementation stages. A program should be initiated to provide continued support and education to ranchers during the planning and implementation stages.

4.2.4. Develop a "Working Farm" to Demonstrate BMP Implementation

A partnership could be formed between NRCS and a local farmer or rancher who has successfully implemented BMPs on his/her property. This person's property would function like a classroom or laboratory where tours or training workshops could be held to demonstrate BMP implementation and their ability to reduce erosion and sediment loads. Any lessons learned or design modifications made for local applications can be offered as a part of the tour or workshop.

4.2.5. Update Land-Use Maps

Updated information is crucial for the development of future plans for the watershed and the implementation of BMPs. Because currently available land-use maps for the watershed are outdated, they cannot provide the information necessary for devising recommendations to solve problems caused by specific land uses. For example, it is not possible to distinguish between active agricultural lands and unused or unmanaged lands that are merely within an agricultural land-use district (see Subsection 1.3). Obviously, pollutant loads associated with each use can differ, leading to possible errors in identifying sources of such pollutants and in defining solutions for reducing pollutant loads. Updating land-use maps would require helicopter or airplane time to take the necessary photos. Partnerships that are formed as a result of activities listed in this restoration plan can help in defining creative ways to share costs and simultaneously accomplish multiple tasks. Other groups who use airtime for their projects, such as KISC, may be able to share airtime and the associated costs.

4.2.6. Promote Water Recycling and Conservation Practices

The East and West Kaua'i SWCDs offer awards to individuals or groups for adopting innovative water conservation practices to irrigate crops without the use of county water. One of the winners, Gary Ueunten, uses rainwater runoff that flows by gravity from his roof to irrigate his five-acre farm. This method can also be used for landscape irrigation or in koi fish culturing. Publishing the winners' methods in the local paper educates the public on creative techniques for recycling water and reducing runoff.

In Hawai'i, a combination of a growing population and limited water resources is reducing the availability and quality of drinking water supplies. There are also environmental problems and financial costs resulting from the disposal of wastewater. Hence increasing the safe use of recycled water can address all these problems. HDOH has long been an advocate for water reuse as long as it does not compromise public health and our valuable water resources (Hawai'i State, DOH, 2002.) Its guidelines for the treatment and reuse of recycled water are intended to (1) protect public health and avoid public nuisance; (2) prevent environmental degradation of aquifers and/or surface waters; (3) delineate specific recycled water application with recycled water quality treatment; (4) facilitate use of recycled water in greater amounts; and (5) facilitate acceleration of planning, design, permitting, and implementation of water reclamation projects. The means to reach these objectives are documented (Hawai'i State, DOH, 2002). For example, the first objective is realized through reducing concentrations of pathogenic bacteria, parasites, and enteric viruses in the recycled water; controlling chemical constituents in the recycled water; and/or limiting public exposure (contact, inhalation, ingestion) to the recycled water.

An example of water reuse in the Nawiliwili Watershed concerns Kaua'i Lagoons, which uses up to 1.2 mgd of R-2 water from the Lihue Waste Water Treatment Plant for golf course irrigation. According to the Kaua'i Division of Wastewater, the current average reuse is about 1 mgd. Six injection wells are currently being drilled for emergency overages. Until the drilling is completed, no comment about what currently happens to spills will be made by the division. However, cases have been documented for spills that have found their way to Nawiliwili Bay via streams and diversions.

There is a 10-year contract with Kaua'i Lagoons, and at this time there are no plans for any reuse of additional effluent as the treatment plant reaches capacity. Moreover, there are no known plans to build new golf courses. There is a need to create a task force to determine use for the additional recycled water as the plant reaches capacity.

Obviously, there is a need to increase the use of recycled water. Such uses will have to conform to guidelines for the treatment and use of recycled water (see Hawai'i State, DOH, 2002). Restrictions include suitability of the type of recycled water for specific uses, as listed in Table 4. In the table, uses are divided into irrigation, supply to impoundments, and supply to other uses for recycled water types R-1, R-2, and R-3. These types are defined as follows:

- R-1 water — significant reduction in viral and bacterial pathogens
- R-2 water — disinfected secondary-23 recycled water, which means secondary treatment with disinfection to achieve a median fecal coliform limit of 23 per 100 ml based on the last seven days for which analyses were completed
- R-3 water — undisinfected secondary recycled water

Application of recycled water over an aquifer that is used as a domestic water supply is restricted to the deficit water budget. According to HDOH, although increasing the use of water recycled from municipal wastewater can greatly assist in meeting the water requirements of the state, the practice must be limited to areas that can safely accept the applied wastewater without adversely affecting potable aquifers (Hawai‘i State, DOH, 2002). Criteria for acceptability not only include acceptable concentration levels of constituents and microbiologic parameters, but also hydrogeologic suitability of an area to receive such waters. In many areas, the highly permeable nature of soils and lavas permits rapid percolation of applied water into the aquifers.

For the Nawiliwili Watershed, specific actions to encourage recycling include (1) promoting and supporting current recycling efforts, (2) offering incentives such as awards and tax or other types of credits, (3) producing and distributing a pamphlet that offers water recycling projects and ideas, and (4) launching an educational campaign to use gray water for landscape irrigation. Some of these ideas could be incorporated into the educational opportunities for architects, plumbers, contractors, home-builders, and do-it-yourselfers.

4.2.7. Provide Solutions for ATV Riding and Eco-tour Erosion

ATV riding and eco-tours are emerging industries that are operating on former agricultural land. Since these tours take place on privately owned land, their activities are somewhat unregulated. Part of the ATV riding experience is to get as dirty as possible by driving through the dirt and mud found along the roads. The use of ATVs on a regular basis is no doubt exacerbating the already-present erosion problem. When the tours began, the operator needed to build a road that would go under Halfway Bridge in order to avoid highway driving and ensure the safety of the riders. According to a farmer who leases land in this area, the ATV tour company cut a steep road with a backhoe near the bridge (Figure 11), resulting in a somewhat unstable road with an erosion problem near Hulēʻia Bridge. Although the road appears to be fairly stable, no BMPs are currently in place to mitigate the active erosion that is taking place. The runoff from these roads is concentrated in a fairly specific area that could be targeted as a site for a restoration project.

As discussed in Subsection 4.1.6, the tour companies need to be educated about the impacts that can be associated with their activities and also about preventing such impacts. The SWCD videotapes are appropriate educational tools for this purpose. In fact, the third videotape discusses some BMPs that could work for this specific area, including the use of roadside ditches to transport water away from the road. Effort should be made to ensure that only clean water is discharged into streams. Erosion control mats could be used while establishing vegetation to further reduce erosion. The use of filter strips or a small sediment basin lined with geotextile mats could further reduce the amount of sediment reaching Hulēʻia Stream. Another videotape discusses ways to stabilize steep road banks. In addition, a self-monitoring program may need to be developed. Designing and implementing an appropriate program will ultimately make tour companies responsible for their actions.

Kauaʻi ATV Tours was contacted to see if it would be willing to participate in area restoration programs, and it showed interest. It seems the company is willing to protect the environment, but it was obvious that it is uninformed about the impacts of its activities and could benefit from learning about cost-effective solutions to reduce erosion. A non-confrontational approach that emphasizes cooperation should facilitate the best results with this and other comparisons. In addition, the road itself has been built on Grove Farm property, so the company would also need to be involved if a restoration project were to take place.

4.3. Capital Improvements

A network of gutters and storm drains captures urban stormwater runoff from the general Līhuʻe area and then discharges it at various points along the streams in the Nawiliwili Watershed. Pollutants in stormwater runoff may include metals, sediment, oil and grease, trash, nutrients, and bacteria. It is challenging to come up with solutions to prevent this runoff because of the way it is currently discharged. Additionally, in the Nawiliwili basin, high development densities make it difficult to locate the space needed to implement structural BMPs aimed at treating this polluted runoff. A growing number of new developments are implementing BMPs from the beginning of their project, thereby eliminating the effects of runoff discharged to streams. However, existing infrastructures that discharge to streams need to be retrofitted with appropriate structural BMPs in order to mitigate the pollution associated with traditional stormwater management techniques. This section focuses on capital improvements and other BMPs that may be used to treat urban polluted runoff.

Capital improvements represent a very expensive restoration activity, due to failure to recognize the need for BMPs before the existing infrastructures were built. Retrofitting creates design challenges as well as financial challenges. However, it has been recognized that NPS pollution from runoff is contributing a significant amount of pollutants to the waterways in the Nawiliwili Watershed.

Activities discussed in this subsection are not intended to solve all problems. Each activity is suggested as a part of a treatment train to reduce, but not necessarily eliminate, pollutant loads. The activities will require site visits and evaluations prior to their implementation. Areas that are mostly urbanized and densely developed would primarily benefit from these BMPs. Therefore, it may be challenging to find sites to locate BMPs that take up a fair amount of space, such as constructed wetlands and detention basins. If space is not available, the solution would involve diverting runoff so that it can be treated at another location. In some cases, this may require locating a BMP upstream from the outfall and would require the use of a pump. It is possible in some instances to use a hydroelectric generator to cover some energy needed for pumping. Wetlands should be designed in a site-specific way, incorporating community involvement in the implementation process. Community workdays can provide cost benefits, educational benefits, and a sense of ownership to those involved.

Recently, the County of Kauaʻi applied for a grant under the USEPA's Brownfields Economic Development Initiative. Possible uses for the grant include an environmental survey of polluted lands on Kauaʻi. Beth Tokioka, head of the county's Office of Economic Development, stated that the department, with the help of a consultant, would be accepting public input on the identification and prioritization of island properties (*The Garden Island*, December 3, 2003). For the cleanup of these properties in the future, grants and low-interest loans may be secured. It is possible to identify a polluted parcel for potential use, after restoration, as a site for a BMP. It is necessary to partner with the County of Kauaʻi or at least to find out more about the Brownfields projects for possible collaboration.

Table 5 summarizes activities for capital improvements, and details are provided below.

4.3.1. Catch Basin Inserts

Catch basin inserts are supplementary BMPs designed to trap some pollutants that are entrained in stormwater runoff. There are many different designs for catch basin inserts, but the basic one is that of a basket or a tray that filters runoff (Figure 12). Coarse sediment, trash, and other debris are caught by the basket. A filter medium can be optionally used to provide additional pollutant removal capabilities. However, this BMP is costly and requires a fair amount of monitoring and maintenance, and its capacity to adequately remove pollutants is uncertain. Therefore, catch basin inserts are not suggested as substitutes for constructed wetlands, swales, and detention basins. Instead, it is suggested that catch basin inserts be used as a pretreatment device in a treatment train. Catch basin inserts have been successfully used in other counties to address trash TMDLs.

Most roads in the Nawiliwili Watershed are fitted with curb and gutter catch basins to convey stormwater away from the roads. Unfortunately, most of this stormwater is then discharged directly into streams. Implementing a basin insert program necessitates identifying the location of all storm drain outfalls in the Nawiliwili Watershed by reviewing both HDOT and Kauaʻi County plans. Additionally, the number of catch basins and the amount of impervious area associated with each outfall need to be determined. This preliminary evaluation is also necessary for the design of any constructed wetlands that will intercept water from these outfalls. The next step is to develop a criterion for fitting certain catch basins with inserts, based on ease of site access, severity of problem in the area, and other factors. Another consideration is deciding whether absorbent insert liners should be added for the removal of oil and grease.

The installation of catch basin inserts can be fairly labor intensive. Community work groups could be involved in the installation and maintenance of the inserts. In 2002, NBWC conducted a demonstration project to install and monitor 25 inserts in the Līhuʻe area. During this project the community was involved in both the installation and maintenance of the inserts. Due to the limited scope of the project, monitoring was minimal. There was no testing in the receiving stream to determine if pollutant levels decreased after the installation of the inserts. Additionally, no data were collected to determine the size of the impervious area serviced by each catch basin insert or the estimated volume of water that flowed through the absorbent sock material. No rainfall data (duration, intensity, or number of storms) were recorded. The inserts were not monitored consistently but, rather, at random time intervals instead of after each storm event. Therefore, it is believed that not enough data were collected to determine the effectiveness of this BMP in the Nawiliwili Watershed, which was not the purpose of the demonstration project. Another pilot project is therefore recommended to determine the effectiveness of this supplemental BMP. The inserts are still in place and could be reused to carry out this project and thereby reduce costs.

However, it was visibly obvious that the NBWC project inserts were removing some pollutants. Trash, coarse sediment, and coarse organic material were the most abundant items collected by the inserts during the course of the project. Additionally, some of the absorbent socks were analyzed for their ability to remove pollutants such as oil and grease and polyaromatic hydrocarbons. Entrapment of these pollutants in the absorbent material obviously indicates a reduction in pollutant loads entering Nawiliwili Stream and Nawiliwili Bay (Babcock, 2002).

The Nawiliwili Small Boat Harbor could also benefit from the use of catch basin inserts in at least two catch basins near the boat washing area (Figure 13). Catch basin inserts could be installed to catch pollutants, such as detergents generated from boat washing and maintenance activities. Other potential pollutants associated with boating activities include anti-fouling paint particulates from sanding, fuels, waxes, and trash. A tent is currently required for maintenance activities to minimize the spread of toxic particulates; however, excess particulates that make their way into the storm drains could be intercepted by the catch basin inserts. Since the small boat harbor is a relatively small contained area, it would be fairly simple to install and monitor a handful of catch basin inserts.

The Glover Halfway Bridge rock quarry holds an NPDES permit for discharges through one of the outfalls to Kamoʻoloa and Kuʻia Streams. However, the frequent washing of cement trucks in the parking lot on the plateau above Hulēʻia Stream is an activity that is not covered by the NPDES permit. Although a small number of cement basins collect some of the runoff from the trucks, there is a chance that sediment and cement from the trucks make their way into Hulēʻia Stream. Downstream land users have voiced several complaints that the sediment is affecting their activities. On several different occasions, research teams were unable to finish sampling because the white silt resulting from washing the trucks had inundated the stream near this location. On low-flow days, this activity has a more noticeable effect. Simply moving the truck-washing activity farther away from the stream may provide benefits. However, a more effective solution is the installation of a sump or catch basin fitted with catch basin inserts to reduce this pollutant load. Again, this type of BMP is very effective, considering that the source is well defined.

Additionally, it is recommended that an independent water quality monitoring program be implemented at this site. Only two discharges have been reported from the Glover Halfway Bridge quarry facility in the last ten years. This information is not consistent with reports from attendees of our restoration plan meetings who have complained to HDOH about other incidents. Additionally, the last inspection date of this facility is not known with certainty. A more comprehensive review of the NPDES files for the Halfway Bridge quarry operation is needed.

The permit renewal process for the quarry will begin in 2004 for the 2005 permit. The community should actively participate in this process, by first obtaining accurate and complete information from the NPDES files through discussion with Glover personnel. It may be necessary to consult with HDOH's Clean Water Branch personnel about the permitting process and other particulars in order to prepare questions and make suggestions about permitting conditions for the upcoming renewal.

4.3.2. Constructed Stormwater Wetlands

Natural wetlands have been studied for the pollutant-removal capabilities that enable them to improve water quality. Constructed wetland technology is based on the same ecological principles that make natural wetlands successful. Constructed wetlands are a good example of sustainable wastewater treatment. Just like their natural counterparts, constructed wetlands are able to break down a variety of compounds while filtering out others. They remove pollutants through not only biological processes but also chemical and physical processes. Chemical and physical processes may include sediment adsorption, filtration, or volatilization. Sedimentation is the primary mechanism for the removal of suspended solids, heavy metals, and particulate nitrogen. Metals and hydrocarbons may then be removed by adsorption onto the settled or suspended solids. Microbial activity helps to remove nitrogen and organic material (USEPA, 1999).

Constructed wetlands provide multiple benefits. Besides being one of the most reliable BMPs for their ability to treat pollutants and improve water quality, constructed wetlands can also control runoff volume by storing it in a shallow basin. By controlling the runoff volume, stream bank erosion caused by runoff from peak storms can be reduced. Constructed wetlands can therefore improve the downstream habitat. By enhancing diverse vegetation they can provide additional wildlife habitat and aesthetic values in urban areas. Constructed wetlands, which can be easily integrated into the landscape, can be used as an educational tool, such as a community-adopted project. Constructed wetlands require minimal maintenance and little energy inputs, and they are generally less expensive than conventional systems (Ocean Arks, 2002).

There are, of course, some drawbacks to constructed wetlands. It is possible that invasive species, whose spread is difficult to control, can become established in wetlands. Also, wetlands may increase the temperature of the water that is returned to natural systems, causing potential harm to sensitive fish species (USEPA, 1999). Another drawback is the mosquitoes that may breed in ponding areas, but there are fish and plants that can help control this problem. In the Nawiliwili basin, the potential location of wetlands may be far enough away from residential areas to limit this public health concern. Ample groundwater or another source of base flow is required to sustain the wetland vegetation. Additionally, appropriate vegetation for Hawaiʻi environments will need to be determined. Constructed wetlands also require some maintenance and monitoring. During the first year of establishing a wetland, it should be inspected after storm events to ensure that it is functioning and detaining the runoff volumes. The wetland plants should also be monitored, and they may also require some maintenance (USEPA, 1999).

The biggest drawback to constructed wetlands is that they require large areas of open space and are therefore subject to land availability. Due to this constraint, they are not always feasible solutions in already-developed, densely populated urban areas. There are, however, a few potential sites for their development in the Nawiliwili basin, which are discussed below, in addition to those that can be identified at a later time through careful survey of the watershed.

The volume of a wetland is determined by the quantity of runoff generated by 90% of the runoff-producing storms (USEPA, 1999). Watershed imperviousness also affects runoff volumes. Therefore, the preliminary surveys suggested in Subsection 4.3.1 are also essential here. Models can be used to estimate volumes of runoff based on water budget considerations. At this point it may be determined if a constructed wetland is an appropriate or feasible option for the treatment of stormwater at the outfall locations. Specialized organizations, such as Ocean Arks and Natural Systems Hawaii, can participate in the design and construction due to their experience in Hawaiʻi environments.

Although a more complete survey of the watershed needs to be conducted, we have already identified some potential sites, which are described below (see Figure 14). A more complete survey would include obtaining county documentation of the number of storm drains and outlets in the area as well as the impervious area serviced by these storm drains. Once this information is retrieved, it will be possible to calculate water runoff volumes, and to identify the necessary size of the structures and assess their overall appropriateness. It should also be realized that the sites listed below are merely suggestions and that the actual selection and construction are beyond the scope of this report. Appropriate negotiation with owners is needed, leading preferably to cooperative partnership.

Site 1. Rice Street ditch (Figure 15) is a long, wide ditch that captures runoff from Rice Street and other impervious locations in that general area. Dense vegetation such as guinea grass is already established in the ditch. The end of the ditch discharges to an impressive energy dissipater on a steep slope that leads to Nawiliwili Stream, the final point of discharge. The ditch itself is large enough to possibly endure modifications required to build a constructed wetland. Detailed site inspection would be needed to determine the impervious area associated with this outfall and to ascertain if there is ample base flow to sustain wetland vegetation. This site potentially captures runoff from a large impervious area.

Site 2. Kalena Street site (Figure 16) is a 2- to 3-ft drainage pipe and culvert with a much smaller energy dissipater at the end. This site is upstream from the Rice Street ditch site. Adjacent to this Nawiliwili Stream outfall is an old abandoned plantation camp house that is extremely over-grown. This site is a little harder to access than the Rice Street ditch, but the adjacent land parcel may be large enough to build a constructed wetland. Land ownership would need to be determined. The site collects runoff from both state and county roads.

Site 3. Līhu‘e mill site is an area adjacent to the newly widened Kuhio Highway mauka of the Līhu‘e sugar mill. The land is owned by Grove Farm. Runoff from a portion of Kuhio Highway that starts at Ahukini Road is discharged into a narrow concrete-lined channel, before heading into an area of rip-rap, then under the road through a 5- to 6-ft culvert, and ultimately into Nawiliwili Stream (Figure 17). A constructed wetland built on the mauka side of the road could potentially interrupt and treat this runoff before it is discharged into Nawiliwili Stream.

Site 4. Industrial area golf course site is just downstream of the Lihue Industrial Area that was identified in Phase 1 as the source of a chemical spill. At a minimum, runoff from this industrial area is discharged through a culvert into “Kalapaki” Stream (Figure 14). Runoff may be associated with an even bigger area, but that has yet to be determined. Due to the number of toxic chemicals and hydrocarbons that are stored and used in this industrial area, the potential for contamination of Nawiliwili Bay is a grave concern. Downstream of the culvert, it is apparent by visual inspection that the water is polluted. The valley and stream banks are used like a “dump,” where old equipment is being stored and the stream water itself runs whitish-gray. This stream, which is too small to show up on formal maps, goes through an adjacent golf course and the Kaua‘i Marriott Hotel property, diverts under the hotel, and finally discharges into Kalapaki Bay. A constructed wetland can be built in the area where the golf-cart path crosses the stream on property believed to be owned by A&B. Although this area is small, it represents quite a big risk due to the concentration of pollutants stored in the industrial area and should therefore be a priority for treatment.

Site 5. Marriott luau grounds lot site is located in a valley on the far side of the Marriott Hotel property in a public access parking lot (Figure 18). A cooperative partnership with Marriott would be needed, and members of Marriott management have already expressed their desire to collaborate in feasible restoration projects.

Runoff from a large parking lot above this site, in addition to that from two streams, is currently diverted under the hotel and discharged into Nawiliwili Stream. One of the two streams captures overflow from the nearby wastewater treatment plant when accidental spills occur. Some of this runoff could be diverted for treatment in a constructed wetland. There is an additional site upstream from this site on A&B property that may also be suitable for a constructed wetland. This location has the most potential for being a community project that can be used as an educational tool. According to Marriott staff, some other proposals are currently being discussed for this site, including an extension of the parking lot. If the parking lot extension is approved, Marriott is not opposed to considering pervious pavements as an option.

Site 6. Halemalu subdivision site is located on Puali Stream near the new Schuller Homes subdivision. A 3- to 4-ft culvert discharges runoff from the subdivision into Puali Stream (Figure 19). There does not seem to be much space available at this location, so creative design techniques would need to be applied.

The six sites listed above only represent a portion of the potential sites in the Nawiliwili Watershed. It will be necessary to conduct stormwater monitoring at the outfalls to determine target pollutants at each and to identify which outfalls are priorities for treatment. Using these variables, it may be determined that the six sites would instead benefit from the use of a detention basin as an alternative to a constructed wetland. The County of Kauaʻi's new Storm Water System Manual currently requires implementation of detention basins for projects that exceed two acres in size in order to detain the increased runoff volume and maintain predevelopment discharge levels. These detention basins can be multipurpose, serving both recreational and drainage uses (County of Kauaʻi, 2001). Detention basins are being implemented at the new police station (Figure 20, a–b). It is promising to see that these and other BMPs are being successfully implemented at new development sites (Figure 20, c–d). The Storm Water System Manual also encourages the use of vegetated swales and grass channels for stormwater conveyance. Continued support for the implementation of these practices is recommended.

4.4. Control of Non-native and Invasive Species

Table 6 summarizes activities for control of non-native and invasive species. Details are provided in the following subsections.

4.4.1. Form Partnership With KISC

As described in Subsection 3.4, KISC aims to supplement existing and emerging programs through partnerships with various groups and to assist in the coordination of island-wide efforts. It holds workshops to re-evaluate the objectives and priority listings of targeted invasive plants and animals. It maintains maps of known locations of targeted species, along with annotations on population structure, fertility, and history of control efforts (KISC, 2003). KISC would be a valuable resource and partner for restoration projects by reducing costs, increasing the flow of information, reducing project overlap, and energizing the effort to implement the restoration activities.

4.4.2. Develop Monitoring and Control Program for Mangrove

The mangrove *Rhizophora mangle* is currently on KISC's priority list of targeted invasive species because it is encroaching on habitat used by native water birds and migratory shore birds along the Hulēʻia River. It is also destroying ʻAlekoko Fishpond, an important cultural and potential educational resource. KISC has some tentative plans to map its distribution to define the extent of the problem and propose an action plan. It is important to collaborate with KISC during this part of the project, especially at the initial design stages.

Others concerned about the spread of the mangrove include personnel of the Hulēʻia National Wildlife Refuge and the U.S. Fish and Wildlife Service.

An action plan would include controlling this invasive species and monitoring the progress of the effort. It is feasible to ask kayak tour companies that use the Hulēʻia River to participate in the monitoring effort. Control methods may include using floating booms to trap floating propagules. Community volunteers and school groups may be able to assist in control efforts by removing seedlings in newly populated areas. To encourage harvesting by the public, an effort should be directed toward promoting the use of mangroves as firewood and as crafting materials.

The removal of mangrove from Hulēʻia estuary is a major task. Removal methods that have been employed on Oʻahu include the use of Garlon 4/JBL biodegradable crop oil mixture to first kill the mangrove. The roots are then removed with a backhoe or bulldozer. The feasibility of this project would need to be determined as it will be extremely costly to conduct a project of this magnitude. Additionally, because ʻAlekoko Fishpond is an important cultural site, extra care would need to be taken in order to minimize any further damage to it. This project will only be possible if strong partnerships are formed with HDLNR, USFWS, KISC, and other historical preservation groups.

4.4.3. Develop Community Work Days Program

The most effective education programs connect people with resources through hands-on activities that allow people to see their results in a short period of time. Community work days are sometimes attractive because they offers individuals a chance to visit areas that are usually off-limits to the general public. Community work days can involve successful restoration activities that provide educational opportunities as well. Controlling invasive species generally require high-level manpower, and community volunteers can increase the efficiency and the effectiveness of the control strategy. A number of locations along the banks of Puali, Hulēʻia, Nawiliwili, and Papakolea Streams could benefit from the removal of non-native and invasive plant species.

The re-introduction of native vegetation and non-invasive species is a part of invasive species control that is rarely discussed, despite their potential role in water quality enhancement. Planting trees and shrubs is an activity that allows community volunteers to see the results of their efforts, thereby motivating them to take additional measures to build upon their successes.

4.4.4. Develop a Plan to Encourage Hunting

Feral ungulate populations such as pigs and goats are responsible for contributing sediment loads to waterways, thereby impacting water quality. Pigs are also responsible for destroying habitat and native species that could provide water quality benefits, thus providing an opportunity for more aggressive invasive species to spread. The Hawaiʻi Division of Forestry and Wildlife (HDOFAW) is concerned about the role of pigs in the destruction of habitat and native species. It is possible to reduce the impact of feral ungulates by encouraging recreational hunting, which is supported by HDOFAW as a way of keeping pig populations in check.

Hunting is currently limited on Kauaʻi because private landowners deny the general public access to hunting grounds, giving liability as the main reason. A comprehensive plan that includes the regulation of this activity may be a beneficial way to help reduce the pig population in the watershed. At the same time, it could help minimize illegal hunting activities and ease the liability concerns. Additional benefits include encouraging the participation of an underrepresented island group in restoration activities for the Nawiliwili Watershed and addressing public health concerns regarding leptospirosis.

4.5. Elimination of Cesspool Contamination

Phases 1 and 2 of this study identified cesspools as a source of contamination in the Nawiliwili Watershed. Although the construction of cesspools has been restricted since August 1991, areas that were developed prior to 1990 continue to use cesspools. It is possible that new systems are still being constructed. It is strongly recommended that cesspools be eliminated and that the existing sewer line be expanded to accommodate the areas using cesspools. Septic tanks should be allowed to replace cesspools in isolated areas or in cases for which the costs are excessive. Additionally, constructed wetlands can be designed to treat septic waste from individual lots. As of April 2000, the USEPA has banned all large-capacity cesspools, and April 2005 is the deadline to close all existing ones. This ruling will remove sources near Nawiliwili Bay, namely, the Kalapaki and Niumalu county parks cesspools, which are very close to the water's edge. According to Harold Yee of HDOH, Kauaʻi County has already applied for loans to eliminate this type of cesspool. If it is determined that connecting to the existing sewer line is not feasible, then alternative solutions will have to be determined before closure of the cesspools. As suggested earlier, one solution is the use of constructed wetlands. There are many sources of information available on the treatment of wastewater by constructed wetlands, including case studies of the Ocean Arks' Tyson Chicken Study[4].

An educational pamphlet could be produced to inform the residents of areas with cesspools about proper and timely cesspool maintenance. The pamphlet could also cover the advantages of converting to septic systems or alternative wastewater treatment systems. In fact, it is possible that new residents do not even realize their parcels are serviced by cesspools. The newly digitized database of parcels with cesspools could be used to identify residents to whom the pamphlet should be sent. Cost-sharing or tax-saving and other incentives to ease the financial burden of conversion could be offered.

At present, the Līhuʻe Wastewater Treatment Plant, which has a capacity of 2.5 mgd, is operating at approximately 1.2 mgd. How much additional load would be placed on the treatment plant by accommodating the areas that currently use cesspools would have to be

[4] *www.oceanarkes.org/restorer/pdf/ocean_arks_restorer_brochure_page1.pdf*
www.oceanarkes.org/restorer/pdf/ocean_arks_restorer_brochure_page2.pdf
www.oceanarkes.org/restorer/pdf/ocean_arks_restorer_brochure_page3.pdf
www.oceanarkes.org/restorer/pdf/ocean_arks_restorer_brochure_page4.pdf

determined. Additionally, the load for previously planned developments that may have already been promised some of the present capacity need to be taken into account. Furthermore, according to the Kaua‘i General Plan, a 400-unit resort planned for Nawiliwili Running Waters is lacking a water supply and sewer capacity. So, there is a chance that the treatment plant would have to expand its capacity in the near future to accommodate the additional loads.

A summary of activities for cesspool elimination in the Nawiliwili Watershed is provided in Table 7. It has been suggested by community members that a wastewater/sanitary survey be conducted before any of cesspools are eliminated. The survey would help in assessing contamination that is currently being contributed by cesspools. Guidelines for performing a sanitary survey can be obtained from the HDOH. Obstacles to completing a sanitary survey include the lack of resources and trained personnel. The first step of the survey process would be to identify land units (parcels) that currently use cesspools. The HDOH Wastewater Branch has these records stored on cards. We digitized the records for parcels located within the Nawiliwili Watershed (see Figure 21). The watershed has 470 parcels that use cesspools. Unfortunately, the information compiled so far does not include the size of each cesspool or the number of cesspools within each parcel. In Section 9, the information is used to estimate the cost of replacing the cesspools with septic tanks.

4.6. Water Budget for the Watershed

To develop a successful restoration plan, it is important to have an accurate accounting of all water flows into and out of the Nawiliwili Watershed. It is necessary to consult with both CWRM and the large landowners in the Nawiliwili Watershed to obtain an updated inventory of the streams and diversions. Information needed about diversions includes ownership, location, direction, and amount of flows. Current and planned water use is also vital information. Available information include the work by Timbol and Maciolek (1978) who surveyed Kaua‘i’s streams in the 1970s. A gross water budget for the Grove Farm ditch system is presented in the Hawai‘i Water Resources Protection Plan (Hawai‘i State, CWRM, 1990). Water budget calculations for Kaua‘i are found in Shade (1995). Some of the available information was presented in the Phase 1 report for this study (Furness et al., 2002). However, an updated inventory of streams and their base flows is another important component of a water budget.

According to CWRM, there is a database of stream diversions, but not all of the diversion works were verified. Therefore, it is essential that field surveys be conducted to verify all diversion works and record flow volumes. The database itself is not currently available to the public because it is still under construction. However, a geographic information system (GIS) layer that contains such information as the registered users of the diversion works could be obtained from CWRM. Since many of the users did not submit diverged amounts, the field survey could be used to determine flows and thereby supplement and update the database.

The preparation of a water budget is a priority issue for NBWC because inappropriate plans or decisions could be made without having an accurate accounting of the water. A summary of needed activities is shown in Table 8. Collection of information for a water budget should include the following components:

- Accurate inventory of all of the diversion works, including
  - How much water is flowing in the diversion
  - Where the water is going to come from
  - Which diversion works are defunct or in need of repair
  - Why the water is being diverted
    - Current water use
    - Whether there are future plans for the water (e.g., treated for drinking/developments)
- Ownership of the diversion works
- Whether the diversion is permanent or if the amount or direction can be changed, and how often changes occur
- Accurate inventory of all streams, including their respective base flows

The preparation of a water budget is an important element of the watershed's restoration, especially in light of the many ongoing studies. The results of some monitoring studies may need to be re-evaluated using accurate flow data. In doing so, estimates of pollutant loads can be more accurate. The need to set instream flows might arise based on accurate instream and out-of-stream uses. Benefits of enhanced instream flows include reducing pollutant concentrations, increasing recruitment of native fish, and hastening habitat restoration.

4.7. Low-Impact Development Strategies

This subsection focuses on LID strategies and integrated management practices that could be used in the Nawiliwili Watershed. Only general ideas are included. A comprehensive manual for LID strategies that specifically target the Nawiliwili Watershed and the County of Kaua'i should be produced. A national LID design manual is available for use in development planning. A summary of activities for LID is provided in Table 9, and details are provided below.

4.7.1. Definition of LID

The following definition of LID was taking from the Low Impact Development Center's website (*http://www.lid-stormwater.net/intro/background.htm#1*):

> Low Impact Development (LID) is an innovative stormwater management approach with a basic principle that is modeled after nature: manage rainfall at the source using uniformly distributed decentralized micro-scale controls. LID's goal is to mimic a site's predevelopment hydrology by using design techniques that infiltrate, filter, store, evaporate, and detain runoff close to its source. Techniques are based on the premise that stormwater management should not be seen as stormwater disposal. Instead of conveying and managing / treating stormwater in large, costly end-of-pipe facilities located at the bottom of drainage areas, LID addresses stormwater through small, cost-effective landscape features located at the lot level. These landscape features, known as Integrated Management Practices (IMPs), are the building blocks of LID. Almost all components of the urban environment have the potential to serve as

> an IMP. This includes not only open space, but also rooftops, streetscapes, parking lots, sidewalks, and medians. LID is a versatile approach that can be applied equally well to new development, urban retrofits, and redevelopment / revitalization projects.
>
> Development of LID principles began with the introduction of bioretention technology in Prince George's County, Maryland, in the mid-1980s. LID was pioneered to help Prince George's County address the growing economic and environmental limitations of conventional stormwater management practices. LID allows for greater development potential with less environmental impacts through the use of smarter designs and advanced technologies that achieve a better balance between conservation, growth, ecosystem protection, and public health / quality of life.

LID strategies could be incorporated into guidelines used by the County of Kaua'i Department of Public Works and could be adopted through ordinances. The Department of Public Works has already incorporated some BSDPs, such as the use of detention basins, into the Storm Water Runoff System Manual. Application of these practices can be seen in the construction of the new police station and the recently completed Home Depot. Some model ordinances for the adoption of LID strategies can be found in a paper, entitled "Low Impact Development Strategy for Green Cove Basin: A Case Study in Regulatory Protection of Aquatic Habitat in Urbanizing Watersheds," at the following website: *http://www.psat.wa.gov/Programs/LID/Green_Cove.pdf*. The goal of establishing these regulations is to ensure that new development proceeds in a manner that protects environmentally sensitive areas.

4.7.2. LID Strategies and Techniques

LID strategies and better site-design practices and techniques that could be used in the Nawiliwili Watershed are presented below.

4.7.2.1. Basin Designations

Strategies used in the Green Cove study include adopting appropriate policies based on goals for basins with different designations. Depending on its habitat condition, each basin is designated as sensitive, impacted, moderately impacted, or intact. For example, in basins where the habitat is still intact, a higher priority is given to the goal of preserving the habitat. Also, the goal of accommodating growth, using LID strategies, is a priority in regions where the habitat is degraded. In the Nawailiwili Watershed, Hulē'ia could be designated a sensitive drainage basin and Nawiliwili and Puali could be designated as impacted basins.

4.7.2.2. Zoning Density

In the Green Cove case study, interim standards were adopted to limit development densities. A maximum density of four housing units per acre within the city limits was used. The idea was to have a larger lot size and less impervious cover. Lot sizes may also need to be considered in this category. This strategy goes hand-in-hand with the preservation of open space. For Kaua'i, it may be necessary to determine if limiting development densities would be beneficial. It may be difficult to weigh the environmental benefits of this strategy against the cost of real estate. Additionally, space is already a limiting factor in the Nawiliwili Stream Basin. Restrictions on zoning densities may only be useful in basins with emerging populations, such as in the Puali and Hulēʻia basins.

4.7.2.3. Tree, Forest, and Open Space Protection

Hawaiʻi's forests are intimately connected with watershed health. Forests act like a sponge, soaking up water to deliver to streams and aquifers and to provide a stable watershed. The tall canopy of the forest blocks out the sun, minimizing water loss through evapotranspiration, and the dense understory prevents erosion by anchoring the soils. Forests also reduce peak streamflows and sustain low streamflows by helping to control the speed at which the water percolates underground (Nature Conservancy, 2003). In urban areas, the value of open space can be measured not only by its water quality benefits but also by its aesthetic value. In addition, open space can provide recreational areas, such as parks.

The first Polynesian settlers (the early Hawaiians) took great care to protect the upland forests. However, by the time Captain Cook arrived, the lowland forests had already been altered for extensive agriculture (taro loi) and aquaculture (fishponds). By the mid-19th century, hundreds of thousands of goats and cattle roamed the islands unchecked, causing extensive damage to the upland forests. In 1903 the territorial legislature created the forest reserve system in response to this damage. At that time, it was recognized that if the damage continued, there would be no water left to support the emerging sugarcane-growing industry. As a result, a private and public partnership was formed to invest in a massive reforestation effort. The Hawaiʻi State Legislature recognized the 100th anniversary of the formation of the Hawaiʻi's forest reserve system by declaring 2003 as the Year of the Hawaiian Forest. Unfortunately, over the years, public investment has diminished such that the forest reserves face massive budget shortfalls. Additionally, with over half of Hawaiʻi's native rain forests already gone, concerned agencies are left without resources to battle invasive species and feral animals and to deal with other critical problems. The success of any attempt at massive reforestation will require the partnership of private enterprises and government agencies (Nature Conservancy, 2003).

Many U.S. counties have begun to once again recognize the vital functions of forested areas and their impact on the health of a watershed and have adopted tree planting as a strategy to protect watersheds. Because most of the natural forested area in the Nawiliwili Watershed was eliminated before the beginning of the sugarcane era, a policy of reforestation or tree planting is needed. The existing forested areas in this watershed consist mostly of non-native vegetation. They should be replanted with native and non-invasive species to improve the health of the watershed. Trees could also be replanted in areas that have been significantly altered due to development.

In the Green Cove case study, tree retention requirements were set at a density of 60 trees per acre for areas with buildings. For the Nawiliwili Watershed, beneficial tree densities would have to be determined before they can be set. In the past, incentives were offered for the utilization of native vegetation for landscaping, but there was a lack of native plants for large projects. There are now some producers on Kaua‘i, including the Waipa Foundation, that are striving to furnish a larger supply of native plants for such projects.

Tree protection activity would include the establishment of riparian buffer zones. Some of the invasive and non-native species could be removed and more appropriate vegetation re-established. Establishing riparian buffer zones and protecting existing riparian zones help in trapping sediment and particulates, in slowing flows, and in increasing percolation.

In the Nawiliwili Watershed, some stream segments, especially the Puali Stream, completely lack riparian buffers (Figure 22). Streams flow through ditches in industrial areas and across housing developments where there are only dirt hills separating houses from the stream. In some cases, streams flow across golf courses, which only have an overfertilized turf as a buffer zone. “Kalapaki” Stream, which runs through the Kaua‘i Marriott parking lot, lacks a buffer zone in some places but exhibits a non-native monotypic riparian zone in others. Re-establishing buffer zones in areas where they are currently absent or impaired could provide great water quality benefits for these stream segments. A first step would be to identify appropriate native plants for each project. The Hawai‘i Plant Materials Center may be a valuable resource for plant selection.

The Kaua‘i Marriott staff has begun to stabilize the hotel area’s stream banks through replanting. The grounds department staff expressed their desire to cooperate in a community project to replant more riparian vegetation along the banks, making the Kaua‘i Marriott a valuable partner for such an effort.

Specific actions for the Nawiliwili Watershed include:

1. Identifying areas suitable for establishing buffer zones replanted with primarily native plants (xeriscaping). A list of possible sites follow (Figure 3):

    a. Puali Stream and Halehaka Stream as they run through Puhi in the “fenced in” area and behind the Schuller Homes subdivision
    b. Kaua‘i Marriott Hotel parking lot
    c. Spring-fed perennial ‘Alekoko Stream on the Hulē‘ia National Wildlife Refuge, an area that is heavily damaged by pigs
    d. Papakōlea Stream, upstream from Hulemalu Bridge where junked cars and metal debris need to be removed
    e. An area just downstream of Halfway Bridge where a local farmer leases about 15 acres from Grove Farm. It is already planted with a number of different species of native trees, along with native hibiscus and other shrubs and non-native hardwoods such as mahogany (Figure 23). This property edges up to Hulē‘ia Stream and one of its tributaries. It may be beneficial to support the farmer’s efforts and help expand the plantings. There may be an opportunity for a riparian buffer restoration demonstration project here as well. The farmer has been working with Dr. David Bernie of the National Tropical Botanical Gardens who is helping with plant selection. His vision is to ultimately have

an eco-park with native trees and hardwoods that can be shared with visitors and the community.

2. Identifying native and non-invasive plants that could be used for riparian buffer zone restoration. According to Laura Crago of Bishop Museum, the museum has just finished a document entitled “Riparian Plant Restoration: A Management Tool for Habitat Restoration in Hawai‘i.” It is an interactive plant key designed as a tool to assist managers of riparian restoration projects in selecting native plants appropriate for their out-planting site. It includes a compilation of information from current restoration projects and a comprehensive literature research with guidance from engineers, hydrologists, botanists, soil scientists, and conservation biologists. The key is a model based on 37 species (34 native, 3 Polynesian introduced) commonly used in current streamside restoration projects. Basically, the program walks the site manager through a series of questions about a restoration site while narrowing down a list of plants based on his or her responses. The document is located online at *http://hbs.bishopmuseum.org/botany/riparian/*. Detailed instructions are provided to run the key.

3. Carrying out riparian-buffer and bank-stabilization restoration and demonstration projects with the help of community volunteers

4.7.2.4. Stormwater Management Standards

A comprehensive review of the Storm Water Runoff System Manual for the County of Kaua‘i may need to be undertaken to determine if revisions are necessary in order to achieve water quality goals identified by this report and also mandated by the State of Hawai‘i. The goal behind the stormwater management standards is to disallow additional stormwater runoff from new developments. In other words, post-development runoff releases must be equal to or less than pre-development levels. Although Kaua‘i County has an ordinance stating this as its purpose, techniques used to achieve this goal fall short of accomplishing it. Additional techniques can include minimizing impervious surfaces (as will be explained in Subsection 4.7.2.6) and maximizing infiltration and evapotranspiration. The desired results could require new ordinances as well as stricter enforcement of current regulations.

4.7.2.5. Grading Restrictions

Kaua‘i has already suffered from many grading and grubbing problems, and recent blatant violations have drawn the public’s attention to inadequacies in the current regulations. The County of Kaua‘i is now addressing this problem. However, the island’s water quality may benefit from some additional modifications to such regulations. In the Green Cove case study, the county adopted interim standards where grading was seasonally restricted to protect water quality and preserve soil-infiltration capacity. Another strategy is to limit grading areas to certain footprints, so that natural features and forested areas are left undisturbed during a development. Grading should only take place where actual structures will be built. By using these techniques, developers can save on grading and landscaping costs while providing benefits for water quality.

4.7.2.6. Minimizing/Reducing Impervious Surface Cover

Scientists at the University of Washington showed that impacts to stream habitat quality begin to occur at very low development densities that includes impervious area covering 8% to 12% of the total area (Haub and Hoenig, 1999). Increased urbanization also negatively impacts stream biota and eventually leads to water quality impairment. These problems have already occurred in the Nawiliwili Watershed, and it certainly beneficial to reduce the degree of urbanization. It is necessary to first determine the current percentage of impervious surface cover in each basin to assess the severity of the problem. Nawiliwili and Puali basins are presumed to exceed the 8% to 12% estimate, while Hulēʻia and Papakōlea basins are not as highly urbanized (see Subsection 3.2). Obviously, reducing existing impervious cover is much more difficult than restricting it for new developments. A series of activities to minimize the effects of impervious surfaces may have to be implemented to complement reduction efforts.

To reduce the percentage of impervious area, products such as pervious pavements could be utilized in parking lots and on driveways and walkways. Also, green roofing could be implemented, such that a significant portion of water is absorbed by the soil and plants, leading to a reduction in runoff. Evapotranspiration processes reduce not only runoff but also the effects of thermal radiation, creating a cooling effect. In some instances this can lead to a reduction in energy consumption.

It seems little or no green roofing has been done in Hawaiʻi. The Bishop Museum database mentioned above could probably identify plants for use in a green roof project. A demonstration project to identify the best plants may be initiated. A good source of information about the subject is *www.greenroofs.org*, where announcements for conferences and classes are posted.

In new developments, a technique for decreasing the size of impervious areas is to reduce the size of building footprints by constructing two-story houses instead of sprawling single-story units.

Many roads in residential areas of the Nawiliwili Watershed are wider than some of the main thoroughfares. Wide roads may not be necessary in residential developments with minimal traffic. Maximum widths could be set for roadways to minimize impervious areas. The use of cul-de-sacs should be also minimized. However, when necessary, their design should include "stormwater islands" to reduce the impacts of impervious cover.

Road width is a topic that has come up in many community meetings. In a recent Na Leo o Kauaʻi meeting in the Līhuʻe district, it was mentioned that an ordinance would be adopted to require all new developments to provide wider roads to fulfill parking needs. Before that happens, it would be beneficial to educate the community at these meetings about the effects of wider roads on water quality. Also, it would be necessary to provide alternative solutions and stress the added benefits of narrow roads, such as reduced speed. Alternative parking areas would also need to be provided, preferably with the use of pervious paving materials.

4.7.2.7. Utilization of Natural Features (excluding streams) for Stormwater Management

The utilization of natural features can provide many benefits for improving water quality and aesthetic value. However, it is necessary to provide clear definitions concerning the terms "natural features" and "natural drainageways". It is a common practice to use natural drainageways, such as streams, for stormwater management. The natural features discussed here that offer water quality benefits include vegetated swales, open grass channels, filter strips, extended detention wetlands, and green roofs. Utilizing these drainage features can reduce velocities of runoff, allow for some infiltration and pollutant removal, and contribute to the goal of maintaining pre-development stormwater releases. Stormwater can also be spread out in buffer areas, such as filter strips that have been left intact or have been built for this specific purpose. Rooftops should always drain to pervious areas and never directly connect to the storm drain system. In addition to reducing runoff by decreasing impervious surface coverage, green roofs can provide temperature control.

Grass channels and vegetated swales are already being successfully utilized in the Nawiliwili Watershed (Figure 24). Grass channels are present along many of the roadways, and vegetated swales are found around the Wal-Mart parking lot. The Līhu‘e Airport uses many of these practices, and many public and government facilities (parks, stadiums, police and fire stations, state and county buildings, airports) already utilize and promote these practices.

Another example of natural drainage features is native plant landscapes, which is already present in many government facilities. These native plants use less water because of their adaptation to Hawai‘i's environment. Displaying plaques that describe the native plants and their benefits can enhance the expansion of this practice. A recent community-based project to beautify the airport gateway has been very successful. Unfortunately for that specific project, at the time very few native plants were used, due mostly to the lack of such plants for large projects of this size. Since then, native plant production has increased and their use increased. For example, because more native plants became available and their cost began to drop, the Kaua‘i Marriott was able to utilize more native plants in their landscaping. The grounds supervisor established a native and endangered Hawaiian plant garden on the hotel property where educational tours are provided for visitors to see the plants. The hotel management is aiming at increasing the use of native plants, which will be beneficial for both the environment and for their guests' experience. Incentives could be offered to resorts to encourage this practice, which also provides an educational benefit to visitors.

Specific projects would include:

1. Compiling a list of Kaua‘i sources for native plants and the respective plants and numbers. It may be necessary to compare the list with Bishop Museum's list of appropriate plants for riparian restoration.

2. Obtaining similar lists compiled by government and other entities—including Home Depot, Kauaʻi Police Department, Department of Water, and Kukui Grove— that have native plants on display around their buildings.

3. Constructing a native plant garden for educational and demonstration purposes. It could be established on the grounds of one of the hotels or resorts. A possibility would be to expand the very small native garden at the Kauaʻi Marriott. Other possible locations include Kukui Grove or Puakea golf course on Puali Stream. Individual projects may be implemented and maintained by employees with assistance from school groups or community volunteers.

4. Offering incentives, including special funds to allow larger projects to receive subsidies to purchase plants. Free consultation and landscaping design could be provided with the purchase of native plants.

4.7.2.8. Education

Another important component in the adoption of LID strategies is education (this topic is discussed in more detail in Subsection 4.1). Several different groups should be targeted for education on the topic of LID strategies, including county personnel, architects, contractors, small business people, and the general public. In order to encourage education, policy makers should be urged to attend specialized conferences such as "Putting the LID on Stormwater Management," which was held in Maryland in 2004. A dialogue has already been started with USEPA to facilitate education on sustainable urban planning by bringing a LID strategy specialist to Kauaʻi to give a workshop for the target group. One potential speaker is Andy Haub from the Department of Public Works in Olympia, Washington, but many others could be just as effective. Although this may be a one-time workshop or seminar, it could be filmed and aired on the community access TV station, Hoʻike, in order to reach a wider audience.

4.7.2.9. Partnership with Agencies and other Communities

The ability to produce a marketable development has been one of the considerations of using LID strategies. In Davis, California, Village Homes was successful in producing a marketable development that has since appreciated in value, proving its economic worth as well as its sustainability. Affordable housing for Kauaʻi residents has been a growing concern. With the cost of land at an all-time high, it is difficult for agencies to fund self-help housing projects that are desperately needed. The Nawiliwili Watershed could host a model sustainable community for Kauaʻi residents. A functioning sustainable residential community could be designed and developed with perhaps the help of its future residents, by teaming up with HUD, a willing developer, an engineering graduate student, and a LID specialist. A "no release" policy would be required for this community, such that the project would be required to process its runoff on-site. This could be a very successful and rewarding project for Kauaʻi.

A Habitat for Humanity functioning sustainable residential community could be designed and developed with perhaps the help of its future residents, involving community members directly in the building process of self-help homes for low-income residents. The director of the Kauaʻi office of this organization expressed an interest in participating in such a project, which would help the community and the environment. Community members would participate in the project and be educated about innovative techniques to reduce environmental impacts while solving some of the social and economic issues on Kauaʻi. The resulting community could be a model for others. Currently, there are no plans for Habitat for Humanity to build in the Nawiliwili Watershed, but a project is scheduled for ʻEleʻele. West Kauaʻi waterways currently included in the 303 (d) list could benefit from a LID project in the same watershed. A partnership among the "west side" community, the Nawiliwili community, and Habitat for Humanity should be immediately formed. A successful LID project in ʻEleʻele would greatly benefit the Nawiliwili Watershed by passing on the experience and any lessons learned.

4.8. Habitat Protection and Restoration

The goal of habitat protection is to preserve the areas that are still intact in each basin. This could be accomplished by using a combination of several of the practices listed above. Habitat protection is one of the goals of the Hulēʻia National Wildlife Refuge, which includes managing native water birds. To implement habitat protection, aspects of natural hydrology will need to be restored in that area. The refuge staff will start a project to install tidal flaps and to raise the water table in order to establish wetlands. The refuge is located on the banks of Hulēʻia Stream, and it is intersected by Papakōlea Stream. Ditches, situated perpendicular to Hulēʻia Stream, run though the refuge. The tidal flaps would be placed on the ditches to hold the water in after a high tide, so that the water would not be allowed to drain back out to Hulēʻia Stream. The refuge staff has noted that after an extremely high tide, the water can stay on the refuge for weeks. The tidal flap project aims to mitigate this effect. Water from the hillside mauka of the refuge and from the estuary gets into the ditches. The project intends to hold the water on the flat areas of the refuge in order to restore the natural wetland hydrology (Mike Hawkes, personal communication, 2003). Water from Papakōlea will be used to establish wetlands in this portion of the refuge. Therefore, some of the sediment problems inherent to Papakōlea Stream may be resolved by wetland establishment. Other projects planned for the refuge include restoring native vegetation and controlling non-native species, probably with the help of KISC.

Habitat restoration activities for other areas of the watershed (Table 10) may include controlling alien and invasive species (Subsection 4.4) and restoring riparian buffer systems (Subsection 4.7.2.3). Additional habitat restoration activities would include the removal of barriers or the construction of a facilitator to bypass barriers so that fish can continue their upstream migration. Biological assessments conducted on Kauaʻi indicate that good habitat may exist upstream, but barriers prevent fish from reaching it (Kido, 1999). Physical or constructed barriers include irrigation diversions and other channel alterations such as step culverts, as well as reservoirs. Kauaʻi is still not as urbanized as Oʻahu and hence does not suffer from as many constructed channel alterations, but any future alterations should be minimized, as outlined in the Storm Water Runoff System Manual. Biological barriers, which are often overlooked, include predatory fish such as bass. The removal of this introduced species by itself would help increase native migratory fish populations. Currently, bass fishing tours are offered on Kauaʻi, and there has been some discussion about further stocking of bass in the streams and reservoirs. This practice may need further review and determination regarding potential negative environmental effects. Based on such analysis, a monitoring and control program for bass may need to be established.

4.9. Dredging of Sandbars in Hulēʻia Estuary and Moving of Boat Mooring Area

Sandbars have formed at the mouth of the Hulēʻia estuary due to many years of sediment loads reaching the area and the probable influence of the breakwall that prevents flushing of these loads to sea. These sandbars can cause safety problems by channelizing water flow and directing it at the small-boat harbor wall. DOBOR staff is concerned that during high flows, channelized water would jump the wall and force moored boats up against the back wall of the harbor (which has happened on some occasions). Also, just upstream from the sandbars is where illegally parked boats have been a persistent problem. Concerns have been raised about the illegal dumping of waste and bacterial loads from these boats. DOBOR staff has stated that it is difficult to monitor and enforce any illicit discharge of waste. A solution to both problems would be to dredge the harbor area where the sediment loads have created the sandbars to allow a more natural flow regime. Once the dredging is completed, the state moorings (that require a fee) could be moved and expanded back into the area where the illegal boats are currently located (Figure 25). This would require the illegally parked boats to either pay for mooring or move out. The funds generated could be used for boater education, pollution monitoring, and rule enforcement.

4.10. Cooperation with Total Maximum Daily Load Program

The TMDL program is an important effort toward restoring water quality in the Nawiliwili Watershed. Under the federal Clean Water Act, the state is required to either de-list impaired water bodies or establish their TMDL. One of the objectives of the TMDL program is to quantify pollutant loads for each site and then compare them to the standards. This is necessary in order to calculate load reductions required to meet the standards. In order to reduce loads, it will be necessary to determine the pollutant's source and then identify a reasonable solution.

In 2003, samples were taken from impaired and potentially impaired water bodies in the Nawiliwili Watershed for a TMDL study. These samples were taken during two storm events and under base flow conditions. According to HDOH staff, as of December 2003, the TMDL study for the Nawiliwili Watershed is nearing completion. The next few steps include releasing a draft for internal and public review, followed by a public comment period. The findings from the TMDL study should complement those of our study. Activities in the TMDL implementation plan for load reductions should merge with some of the restoration activities that have been identified in this report. A collaborative effort with respect to the TMDLs and restoration activities provided in this report should prove to have a synergistic effect and can hopefully set the bar for future collaborative efforts.

5. EXPECTED LOAD REDUCTIONS DUE TO MANAGEMENT MEASURES

This section is aimed at assessing the expected loads reductions for nutrients and sediment in the Nawiliwili Watershed, based on suggested remediation strategies or BMPs. The specific objectives of this section are:

1. To provide estimates of streamflow sediment and nutrient loads using a continuous simulation, daily time-step-based, distributed hydrological model
2. To provide estimates for reductions of annual loadings derived from the model based on suggested BMPs.

The Generalized Watershed Loading Function (GWLF) model, developed by Haith and Shoemaker (1987), is used in the calculations. The GWLF model is a simple, yet robust distributed hydrological model. The USEPA has endorsed it as a good "mid-level" model that incorporates algorithms to study the key mechanisms controlling nutrient fluxes within a watershed (USEPA, 1999). The GWLF model has been tested extensively for TMDL analysis in Pennsylvania (Chang et al., 2001; Evans et al., 2002) and also for watershed modeling studies in the United States (Lee et al., 2000; Schneiderman et al., 1998) and in foreign countries such as Bulgaria and Chile (Lazarov et al., 2000; Strobl, 2002).

Compared to other distributed hydrological models such as HSPF (Johanson et al., 1980), SWAT (Arnold et al., 1995), and AnnAGNPS (Cronshey and Theurer, 1998), the GWLF model has relatively few input data requirements. Most of this data either is readily available for the Nawiliwili Watershed or can be estimated from model calibration. The availability of data for running the GWLF model for the Nawiliwili Watershed makes the model a good candidate for preliminary distributed watershed analysis research.

5.1. Model Data Requirements

Due to insufficient data for the Nawiliwili Watershed, the GWLF model was first applied to the North Wailua River watershed, which is adjacent to the Nawiliwili Watershed. The location of the two watersheds is shown in Figure 26. At its outlet, the North Wailua River watershed has a stream gage (USGS monitoring station 16060000) that provides daily streamflow data. Monitored streamflow data on a continuous basis are not available for the Nawiliwili Watershed, thus the model results cannot be directly validated. By running the model on the North Wailua River watershed, an estimate of the model's streamflow prediction capability was assessed for a watershed similar to Nawiliwili. Also, the calibration process of the watershed model resulted in the estimation of the seepage and recession coefficients required by the GWLF model. The calibration results are presented in the next subsection.

The GWLF model requires input for transport, weather, and nutrient parameters. The first two datasets are essential for GWLF simulations, as they provide the bases for providing streamflow and sediment-yield estimates. The third dataset is required for simulation of nitrogen and phosphorus loads. The input parameters for the transport dataset are shown in Table 11.

The transport parameters are required for all the basins in the watershed. The basins are further subdivided into homogeneous areas or hydrological response units for calculating the input parameters. The various basins for the Nawiliwili Watershed are shown in Figure 27.

The weather dataset of the GWLF model includes daily total rainfall and daily mean air temperature data for the entire duration of simulation period. The sources and durations of weather input data are presented in Table 12.

The transport input parameters for curve number (CN) calculations and USLE erosion estimates were derived using GIS data layers. A USGS 10 m × 10 m resolution digital elevation model (DEM) (Figure 28) was used as the base layer for topographic computations. The base land cover map was the NOAA landsat classified image for Kaua‘i at 30 m × 30 m resolution, as shown in Figure 29. Figure 30 shows the Natural Resources Conservation Service's Soil Survey Geographic (SSURGO) soil map for the Nawiliwili Watershed.

Utilizing the base layers of DEM, land cover and various input layers are estimated using GIS software. Figure 31 shows the derived hydrological soil group (HSG) map, Figure 32 the CN map, Figure 33 the USLE *LS* factor map, and Figure 34 the derived USLE *K* factor map. (LS = slope-length factor and *K* = soil erodibility factor.)

Table 13 shows the final calculations for CN and USLE parameters derived for individual hydrological response units within the basins of the Nawiliwili Watershed.

5.2. Baseline Simulation Results

The GWLF input files for the North Wailua River watershed were derived using the identical methodology used for the Nawiliwili Watershed. Here, only the calibration results are provided to illustrate the accuracy of GWLF hydrological simulations.

Figure 35 compares the observed versus the simulated streamflows for the North Wailua River watershed. As shown in Figure 36, the R^2 between simulated and predicted streamflow is 66.9% on an almost 1:1 line ($y = 1.015x$). This result is similar to the calibrated daily streamflow values obtained in the study by Strobl (2002). The R^2 for total annual streamflow between observed and simulated runoffs (between the time period 4/1/1997 and 3/31/2000) is 91.8% (for the fitting line $y = 1.1x$).

The GWLF simulation results for streamflow and sediment yield at the outlet of each basin in the Nawiliwili Watershed are shown in Figures 37 through 52. A discussion of the results is provided in the following subsection.

5.3. Discussion of the Nawiliwili Simulation Results

Table 14 and Figures 39 and 40 show that Basin 2B (a major part of the Hulē‘ia Stream Basin) annually contributes the most sediment (7,950 tons) and streamflow (42.4 cm) at the outlet of the watershed. Although Basin 2B contains a relatively large undeveloped part of the Nawiliwili Watershed, the rainfall there is the highest among all basins (annual rainfall is 174 cm/yr). In contrast, rainfall is 140 cm/yr for Basins 1B, 3B, 4B, and 11B, and 25 cm/yr for Basins 5B, 12B, and 14B. Also, Basin 2B has HSG D soils that tend to push the CNs from forest and pasture land uses to higher values in comparison to the same land uses on HSG B or C soils. On the other hand, the relatively urbanized basins (3B, 4B, 5B, 12B, and 14B) are on HSG B soils. This causes the average CNs for Basin 2B to become comparable to those of the more urbanized basins in the Nawiliwili Watershed, as shown in Table 15.

Basin 2B provides the highest sediment yield due to its higher flow volume and its large size. However, on a per-unit-area basis, the sediment yield from Basin 2B is similar to that of Basins 1B, 4B, and 12B. Basin 11B provides the highest sediment yield of 2.69 tons/ha/yr on a per-unit-area basis. As shown in Table 15, Basin 11B has the highest slope for all basins (30.8 %) and consequently the highest average *LS* factor (6.29) of any basin. The high *LS* factor causes the mean of USLE's *KLSCP* value for Basin 11B to be the highest (0.0117) among all basins. On the other hand, the lowest slope of 2.7%, which occurs at Basin 14B, causes the per-unit-area sediment load at the outlet of that basin (0.5 tons/ha/yr) to be the least among all basins of the Nawiliwili Watershed.

5.4. Nutrient Simulation

Phosphorus and nitrogen loads were estimated for the basins of the Nawiliwili Watershed using certain assumptions. Observed nutrient data were not available for this study; therefore, some rough estimates of the default parameters for the GWLF model's input dataset were used. The input parameters are presented in Table 16. The septic and cesspool systems were modeled using the approach and simplifying assumptions described below.

First, the number of septic and cesspool systems, obtained from HDOH records, was counted for each basin using the GIS software. Then the count was multiplied by five to get a rough estimate of the population served by the systems (i.e., on average, a septic or cesspool system serves five people every day). The cesspools were treated as discharge-system-failure-type septic systems for the GWLF model input. In addition, the nutrient input from cesspools to the ground was assumed to be 1.5 times the value estimated for a watershed that has only septic systems and no cesspools. Finally, 10% of all septic systems was considered to be failing. These failures were equally divided between ponded-failure and short-circuited-system-failure types. The simulated nutrient loads for each basin are provided in Table 17.

5.5. Assessment of Land-Use Change on Runoff and Sediment Load

The GWLF can also be used to assess potential change in runoff and sediment loads based on land-use change. In this application, the model can assess either potential urbanization on watershed or potential improvements through implementation of urban BMPs. For example, for Basin 14B, if land use is changed from the current urban development to an entirely forested condition, for which the CN = 55, the GWLF simulated average annual streamflow is 23.37 cm/yr, and erosion (assuming forest *C* factors to be

0.002) reduces to 0.01 ton/yr. The reductions in streamflow volume by the GWLF simulation appear to be small. As the model does not estimate peak flow rates from the watershed, the reduction in peaks cannot be directly estimated.

Another model, the TR-55 (USDA, 1986), is more suitable for assessing a change in peak flow based on a change in land use. The following is a summary of the calculation for Basin 14B:

Area of the basin = 2.98 km^2 (1.15 mi^2)
Area weighted CN value = 67 (from Table 18)
Total flow length = 3,650 m
Sheet flow length = 50 m
Shallow concentrated flow length = 500 m
Concentrated flow length = 3,100 m
Sheet flow slope = 0.6%
Shallow concentrated flow slope = 0.6%
Concentrated flow slope = 2.74%
Time of concentration calculated using TR-55 = 0.63 hr
Design precipitation, P = 5 in. for Type I storm
Ia/P = 0.2 (calculated using Soil Conservation Service (SCS) CN equation, in which Ia is the initial abstraction)
Runoff volume for 5-inch precipitation and 67 CN = 1.8 in.

Using the above parameters, the graphs in the TR-55 manual give the unit area peak flow and the peak flow as 210 ft^3/s of discharge per square mile of watershed per inch of runoff and 433.3 ft^3/s respectively.

Now, for an undeveloped watershed condition, where CN = 55 for a good condition forest on HSG B, the following data applies:

Time of concentration = 0.97 hr (assuming that Manning's n for channel changes from 0.05 in developed condition to 0.02 in undeveloped condition)
Ia/P = 0.33
Runoff volume for the same 5-inch storm = 0.98 in.
For this case, the unit area peak flow is 110 ft^3/s of discharge per square mile of watershed per inch of runoff and peak flow is 124 ft^3/s.

As shown in the above calculations, the peak flow for the developed/urbanized condition of the watershed increases by 250% for a 5-inch design storm event. It should be kept in mind, however, that the actual increase in storm peak flow may be different from the value calculated here because of the potential routing of stormflow in storm drainpipes and culverts, a factor which is not accounted for in our calculations. An evaluation of the peak flow would require a detailed modeling of the storm system in the basin. Still, urbanization of a basin can significantly increase the peak flow rate. The increased flow would cause increased erosion in the undeveloped/agricultural areas if they exist on the downstream side of an urbanized basin.

5.6. Best Management Practices

Implementing certain urban and rural BMPs can reduce the current estimated yields of streamflow, sediment yield, and nutrients loads from different basins of the Nawiliwili Watershed. Urban BMPs include changing all cesspool systems to septic tank systems or to sewered systems being served by a wastewater treatment plant. Stormwater retention ponds can reduce the hydrograph peak flows and trap sediment by sedimentation. Rural BMPs such as riparian forest buffers or wetland vegetation can trap sediment and nutrients. Specific management practices suggested for the Nawiliwili Watershed are presented in Section 4.

5.6.1. Septic Systems

One of the highly recommended actions for this study concerns the cesspool systems. Table 19 shows the simulated nutrient loads to the basin outlets when cesspools in the respective basins are changed to normally operating septic systems or sewer systems. A comparison between load amounts in Tables 17 and 19 shows the effect of the change. The reduction in loads amounts to 25% and 16% for dissolved and total nitrogen, respectively, and 92% and 62% for dissolve and total phosphorus, respectively. We emphasize that these estimates are subject to many limitations, as explained in the following subsection.

5.6.2. Riparian Buffer Zones

An attempt was made to design a variable-width riparian buffer plan for the Nawiliwili Watershed based on Wenger (1999). Based on that study, it seems that riparian buffers are not an effective BMP for streams where the land slopes are greater than 25%. Figure 53 shows steep slopes in many parts of the watershed. Due to the high relief features in many areas, it is expected that riparian buffers may not be an ideal BMP. Moreover, accessibility to some areas may not even be possible for the implementation of these measures. Figure 54 shows areas where the system is feasible. Buffers are suggested for Basins 1 and 3 and for parts of Basins 2B and 11B. Because the parts in Basin 11B are located where agricultural land use is prevalent, the installation of buffers may prevent the sediment yield from agricultural areas from reaching the streams. Partial buffering is not effective, even if it eliminates sediment loads due to expected load generation from areas upstream of managed areas.

For each grid cell along the stream, buffer width is calculated using the following formula: width (in meters) = 15.24 m + 0.61 (slope %). To simplify the calculations, an average of all the lengths for individual streams in a basin is found. Buffer widths range from 21 to 25 m for Basin 1B, 16 to 22 m for Basin 2B, and 19 to 28 m for Basin 3B. If an area has slopes greater than 25%, then the buffers should extend beyond these high-slopes zones to an area where the slope is lower than 25% (Wenger, 1999). Such a design might not be suitable for parts of many of Hawai‘i’s watersheds, so alternative buffering measures are needed.

For buffers having a width greater than 15 m, as in this case, the removal efficiency for total suspended solids, total nitrogen, and total phosphorus can be conservatively estimated at greater than 50%. The specific load reduction can be estimated based on the baseline values described in Subsections 5.4 and 5.5. As will be explained in the following subsection, the lack of data for model validation limits us from predicting definite reduction loads. However, rough estimates suffice for use as general guidelines.

5.7. Modeling Limitations

Limitations of the modeling results can be categorized broadly into two types. The first type is due to the inherent limitations of the model itself (i.e., equations used in the model and assumptions made by the model that can limit the model's accuracy). The second type is due to the input data quality (this error needs to be controlled by the modeler). Here we take a brief look at both limitations.

The GWLF model utilizes the SCS CN technique for runoff estimation, a modified USLE along with a delivery ratio and transport capacity equations to determine sediment yield, and a very simplified lumped parameter nutrient simulation model. The model accuracy is limited by the inherent limitations of these equations. For instance, the CN technique does not take into account the rainfall intensity of individual storms. Also, the model operates on a daily time-step. Thus multiple storms occurring on a single day are lumped into one daily storm, and the storm duration within a day is not taken into account. The initial abstraction or surface retention value for each storm is calculated based on the CNs, and this can differ from the actual initial abstraction for each storm. The model estimates evapotranspiration based on general cover coefficients provided in the input data and based on the daily temperature value. The model does not take into account the soil layer's physical properties when calculating infiltration and soil moisture retention. A more physically based model that takes soil layer properties into account would provide better estimates of soil moisture accounting, but with additional input data requirements. The model's sediment yield results are dependent on the accuracy of the streamflow prediction, and the model's nutrient yield is, in turn, dependent on the sediment yield and the streamflow prediction. Thus, streamflow estimates have the highest accuracy, followed by the sediment yield estimates, and then by the nutrient yield estimates. USLE requires an average invariable input for the *C* factor, *K* factor, *P* factor, and *LS* factor. The *C* factor could vary, based on time, for the sub-basins where there is active agriculture. The variability of other factors may not be of much importance. The nutrient values are based on unit area loading and an enrichment ratio estimate. The lumped characteristics of nutrient loading are bound to incorporate errors in load estimates. In order to compare the model results or verify the simulation result's accuracy, one requires observed output for streamflow, sediment yield, and nutrient loads in the stream outlet over a sufficiently long period of time. For one Nawiliwili Watersed, such data were not found in sufficient amounts for calibration or comparison.

The modeling results are also affected by the quality of the input data provided by the modeler. The primary dataset driving the GWLF simulation is the weather dataset. Accurate precipitation input is a must for accurate simulated values for streamflow. Rainfall is highly variable throughout the watershed. It was found that for the North Wailua River watershed, rainfall ranged from 1,000 cm/yr near Mt. Waialeale to 150 cm/yr near the outlet of the watershed. The high variability in rainfall is difficult to incorporate into modeling that uses one average rainfall amount for the entire watershed. Moreover, there are limited numbers of rainfall stations (that have continuous long-term weather data) within a watershed. These weather station points may not accurately capture the variability in rainfall over the watershed on a given day (thus incorporating errors in the streamflow estimate). The weather station have missing data on some days, creating additional uncertainty and errors in the input precipitation data. A better spatially variable estimate of rainfall input (by, say, using calibrated NEXRAD data) should be used to improve model accuracy.

In this study a 10 m × 10 m horizontal resolution DEM was used. Given the generally steep terrain in Hawai‘i, this model should provide sufficient accuracy for calculating the input parameters for the GWLF model. The *LS* factors calculated by GIS, along with the watershed delineations, should be one of the more accurate input parameter estimates.

The 1:24,000 SSURGO soil map is used for this study. As the GWLF model only requires the *K* factor value and the HSG estimate, the 1:24,000-scale map should provide a sufficiently detailed estimate of the two parameters. It is expected that providing a much more detailed soil and DEM map will not drastically improve model results.

Land-use coverage used in this study is a NOAA’s 1:250,000-scale landsat classified remote sensing imagery. The data has a relatively coarse resolution of 30 m × 30 m grid cell size. The land-use data affect the estimates of CNs and *C* factors for USLE parameters. A better resolution land-use map can improve the estimates for the input parameters. If the effect of invasive tree species in the Nawiliwili Watershed needs to be studied, a detailed map of the different vegetation in the forests will be required. If a detailed map of tree covers is available, then the *C* factors can be independently calculated using the RUSLE 2.0 model and input into the GWLF model. Also, there was a lack of information about the agricultural activity within the Nawiliwili Watershed. Improving the land-use and management datasets could result in better estimates of sediment yield.

The input datasets for nutrient loads are rough estimates obtained from default values in the model’s documentation and from other GWLF studies. The dissolved loads and nutrient buildup loads in urban areas of Nawiliwili need to be estimated for the actual watershed condition in order for the results to be accurate.

6. MONITORING PLAN

Monitoring should be an integral part of the restoration and protection plan for the Nawiliwili Watershed. The objective of monitoring is to assess existing conditions and to track the progress of the various restoration and protection strategies. The current watershed condition is described in the reports for Phases 1 and 2 of this study (Furness et al., 2002; El-Kadi et al., 2003). The design of specific remediation activities might require installing new monitoring equipment and collecting data from other sources, including USGS, HDOH, NRCS, USEPA, County of Kaua‘i, and community groups. The following issues, adopted from the Draft Kailua Waterways Improvement Plan, Volume II (Tetra Tech Em Inc., 2003), should be carefully examined in order to provide a complete and effective monitoring plan.

6.1. Data Management

Data obtained so far and those to be obtained during the restoration phase (from the monitoring program and from other sources) should be compiled into a project water quality database maintained by staff of the Nawiliwili Watershed Restoration Office. Data should be systematically organized and categorized for analysis and comparison. This study has compiled many coverage layers which were plotted spatially using GIS for visual analysis; however, many of these need updating. All data should be carefully tracked and recorded to ensure that the record is as complete as possible. The resulting database can be made available on the Internet to allow participating agencies and researchers to benefit from the data and to inform the public about the implementation program and the water quality in the watershed.

6.2. Water Quality Sampling

A routine sampling program is an important component of the implementation program. The primary goal of the monitoring program is to fill in the gaps of existing knowledge and to collect a complete and regular record of surface water and groundwater quality in the watershed. Sampling of shallow groundwater (e.g., springs, seeps, and agricultural wells) should also be initiated and done on regular basis. Another important goal is to sample influent and effluent from demonstration projects and BMPs to assess their effectiveness, in order to help select applicable practices for the watershed and to advance the state of knowledge about water quality BMPs.

Monitoring results should be compared to state water quality criteria and TMDLs, where applicable, to track the progress of meeting water quality requirements and designated uses in the watershed. Subsection 1.3 summarizes data collected for Phase 2 of this study. Although the data can be useful, it is highly recommended that a new round of sampling be conducted prior to the implementation of demonstration projects or BMPs, in order to provide a baseline by which to judge future progress in meeting water quality targets. Periodic sampling—including quarterly, semiannual, and annual sampling events—would be carried out throughout the duration of the implementation program.

Monitoring should be carried out by professionals and volunteers. Using volunteers will help stretch scarce funding while giving the public a real stake in managing the program and their watershed. Another important benefit is the education of the public about watershed health and management. For this reason, it is proposed that a volunteer sampling team or teams be formed and a training program be created to fully train volunteers in proper sample collection and sample management.

6.3. Watershed Assessment

It is recommended to assess the health of the watershed by examining conditions such as the physical stability of streams and wetlands, the quality of aquatic and riparian habitats, and the presence of exotic and invasive species. The assessment should also emphasize locating pollutant source areas. Subsection 1.2 summarizes the assessment of the Nawiliwili Watershed as documented in the Phase 2 report for this study.

A watershed assessment protocol would be developed from existing bioassessment protocols for Hawaiʻi and other tropical and subtropical regions and from other stream and surface water assessment methodologies. Program staff will need training for the protocols developed. As with water quality sampling, program staff or volunteers would carry out the assessments. Assessments would be conducted at the beginning and end of the implementation program, at a minimum, and annually if resources permit. Assessment data would be entered into the data management system described previously.

6.4. Quality Assurance

All data collection and monitoring should be conducted under a rigorous quality assurance program. The purpose of the program would be to ensure that all data, whether obtained from other sources or generated through the program, are of good quality and are useable for implementing and evaluating the restoration program. Data collection, sampling, and monitoring should be conducted according to a sampling and analysis plan and quality assurance project plan (QAPP) developed specifically for the program. The QAPP would conform to state or USEPA quality assurance guidelines as appropriate, depending on the requirements of the various grant and funding sources for the implementation program. The QAPP developed during Phases 1 and 2 of this study could also be used for the restoration phase.

7. PLAN EVALUATION

7.1. Measures for Evaluating Plan Success

Major project milestones, tasks, and deliverables should be assessed regularly. Tasks include the development of public education programs and public participation activities, construction of demonstration projects, completion of monitoring activities, and establishing and implementing a monitoring program. In addition, and most important, measures of success should include the restoration program's impact on water quality. Specific objectives for measures of success include improvement of surface water quality based on analytical results; improvement of habitat quality and eradication of invasive species; physical stabilization of streams and other water bodies; and, ultimately, in cooperation with the state's TMDL program, delisting of water bodies in the watershed under Section 303(d) of the CWA. Other important measures of progress include:

- Establishment of the advisory group (see Section 2)
- Preparation of funding applications and securing funds

- Creation of the Nawiliwili Watershed Restoration Office and hiring of staff (see Section 2)
- Design and construction of demonstration projects and inplementation of BMPs
- Creation and implementation of public outreach and education programs, including a training program
- Contracting with vendors
- Adherence to program schedules and budgets
- Publication of findings and research

Table 20 includes specific measure of success for individual restoration tasks. These measures should be examined on a regular basis and updated as the projects progress.

7.2. Schedule of Plan Implementation

A proposed timeline for plan implementation is given in Table 21. However, such a plan would be subjected to extensive discussion and adjustment as community input is considered. Securing the necessary funds is the most critical and challenging part of the plan to restore the Nawiliwili Watershed. Section 10 describes sources of funds that should be pursued as soon as the plan is put into motion. Meetings of the core group, institutional partners, and volunteer groups (see Section 2) would be held to form an advisory committee to guide the process of generating proposals, with research topics that address this protection plan, for submission to various agencies. The next step would be to hire a coordinator and staff for the Nawiliwili Watershed Restoration Office, a new entity that will coordinate plan implementation. The hiring and manning of the office would take up to six months. The possibility of assigning the position to a person from a state organization, such as HDOH, should be explored to minimize the cost, especially regarding the overhead involved in setting up new office space. The chance of that happening is slim, however, considering the budgetary limitations of the state government. Tasks of the coordinator would include evaluating measures of success by reporting to the advisory committee as the projects get underway and are completed. Tasks would also include participating in project reviews and presentating project results to the community and to the project advisors.

It is possible that small projects, such as establishing buffer zones and replanting riparian vegetation, would start within six months of initial funding. Pamphlets and educational plaques could be completed within a few months; however, it may take longer to establish contacts and develop partnerships and to work on community education. Developing/producing videotapes and workshops may take up to a year. Implementing education in schools would take at least a year. To ensure continuity of current efforts, it is recommended that the watershed science curriculum developed by Pat Cockett be divided into small projects that the restoration office staff could bring into schools as seminars and projects. The ATV road stabilization project would probably take up to two years to complete, depending on the number of other projects in progress and the level of funding. Large-scale projects, such as constructed wetlands and those related to policy changes, would take about five years due to the need for multiagency cooperation. Other complicating factors include the need for extensive development plans and potential diversity of funding resources. Restoring ‘Alekoko Fishpond may extend over 10 years as a project with many phases, and eventually this project may have to spin off and become an entity in itself.

7.3. Criteria for Success of Load Reduction Strategies

As stated in Subsection 7.1, measures of success should include assessing the restoration program’s impact on water quality as manifested by load reduction of sediment and nutrients. Improvements of surface water quality should be evaluated through analytical results. Section 6 discusses the monitoring program which should be the vehicle for assessing water quality on a regular basis. As stated in that section, influent and effluent from demonstration projects and BMPs should be used to assess their efficiencies. Monitoring results should be compared to state water quality criteria and TMDLs, where applicable, to track the progress on meeting water quality requirements and designated uses in the watershed. Again, it is strongly recommended that a new round of sampling be conducted prior to implementation of any demonstration projects or BMPs, in order to provide a baseline by which to judge the progress on meeting water quality targets. Periodic sampling—including quarterly, semiannual, and annual sampling events—would be carried out throughout the duration of the implementation program.

8. REVISION OF PLAN AND PROGRAM IMPLEMENTATION

The proposed implementation program of the Nawiliwili Watershed Restoration and Protection Plan should be a living document that can be revised and refined as the program matures. Periodic updates and revisions to this program plan are anticipated in response to levels of funding, agency and public participation, future conditions and developments, and lessons learned. Additional demonstration projects may be proposed in the future as development patterns evolve and new problems or approaches become apparent. Revisions and updates are necessary if the plan is to remain relevant and effective. The measure of success discussed in the previous section should be incorporated into plan revisions to present an accurate picture of current conditions. In addition, changes in supporting conditions—such as infrastructure upgrades, development patterns and infrastructure capacity, land-use patterns, water quality regulations, and critical habitat areas—must be incorporated into the plan to support valid and effective recommendations for future work.

Review and revisions will be the responsibilities of the restoration office, with input and concurrence of the core group and partnering agencies. Revisions should take place on an as-needed basis. However, an annual review needs to be undertaken of the success of the various projects, as well as the needs of the community and watershed. Issues that require immediate changes can be addressed on an as-needed basis.

9. PRIORITIES

It was difficult to establish definitive priorities for the restoration activities due to minimal participation at community meetings. However, a few items were emphasized repeatedly. Two of these are the preparation of a water budget and the setting of instream flows. The community members who attended the meetings felt that these actions are necessary before proceeding with any of the other recommendations. These actions may create the need to re-evaluate prior studies which may have overlooked the uncertainty of instream flows and the watershed budget.

In general, the project activities can be grouped according to issues dealing with nutrient and sediment load reduction, water resource assessment, and education. The overlap of these groups is obvious. For example, preparation of a water budget, setting instream flows, and reducing sediment and nutrient loads are critical in restoring stream aquatic health. In addition, the effective design of BMPs greatly depends on accurate knowledge of the water budget of the watershed, including instream flows. Education is a cornerstone of the protection plan, which depends to great extend on community and visitors' good will and participation. During discussions at the restoration plan meetings, the following activities were given the highest priority:

- Implementation of erosion control and BMPs, including those related to nutrient load reduction
- Preparation of a water budget and setting of instream flows
- Development and implementation of a watershed curriculum
- Posting educational plaques
- Revision of NPDES files
- Collaboration of state and county agencies

Our own assessment put the activities in the order listed above. However, the overall community consensus was that all of the identified restoration activities were equally important and that the priorities would be set forth according to cost and feasibility. Action is needed by government agencies to lead the community restoration activities. The implementation of one or more of the activities recommended in this report will give the community an opportunity to finally see the results of their input.

10. ECONOMIC IMPLICATIONS OF THE WATERSHED PLAN

Economic impacts of the watershed conservation plan include potential expenditures by the agriculture, recreation and tourism, and household sectors. In addition, since all three types of users have direct and indirect connections to other sectors of the economy, these impacts will reverberate throughout the economy of Kaua'i (and for that matter, potentially throughout the entire state). Identifying these impacts and estimating their linkages will require considerably greater resources than are available to this project, but this section will outline significant elements of the overall picture.

10.1. Preliminary Considerations

Before delving into the costs of implementing the recommendations of the watershed plan, we note several considerations growing out of general economic principles. First and foremost is that "economic value" covers, in principle, any and all uses of water, including market as well as non-market uses and including costs incurred by decision-makers themselves and costs imposed on third parties. Value inheres in non-financial considerations such as aesthetic enjoyment, even though we have only imperfect means of measuring such values (and the scope of this project does not call for applying even those imperfect techniques).

Second, the recommendations of this study, if carried out, will generate both benefits and costs in pursuit of enhanced water quality. The economic value of these benefits is measured, in principle, by the total "willingness to pay" for them. Being largely non-market in character, benefits of improved water quality are very difficult to measure. This study has not attempted to do so in any way, except for a brief summary of research on the value of recreation. Nevertheless, one should keep in mind that any given level of water quality, or any program designed to achieve that level, is socially desirable only if the benefits derived from it exceed its costs. Unless the willingness of all members of society to pay for the specified level of water quality exceeds the value of resources necessary to achieve it, society would be better off applying those resources to some other goal.

Third, laws and regulations do not necessarily or precisely reflect benefits or costs, as broadly defined above. Likewise, there may be imbalances between those who fund water quality improvements (e.g., farmers or taxpayers) and those who reap the benefits (e.g., tourists and environmentalists). Imperfections in the processes of lawmaking and regulation or the inability to measure benefits and costs means that the laws and regulations may or may not reflect the values of all those who underwrite the costs or those who receive the benefits of enhanced water quality. However, laws and regulations define the requirements that sponsors of this project must implement.

Finally, any changes in regulations growing from the desire for better water quality will have economic effects beyond the direct changes themselves. For example, suppose new water quality regulations result in cattle ranchers cutting output by $100. Ranchers, in turn, will decrease purchases of all inputs, including livestock, feed, ranch labor, veterinary services, and transportation. Then feed suppliers, ranch labor, veterinarians, and others will decrease their purchases of inputs for their services. Thus the total economic impact of such a change in regulation would be magnified beyond the direct costs involved, to some multiple of $100. These effects could be studied through input–output models (Hawai‘i State, Department of Business, Economic Development and Tourism, 2002) or more sophisticated general equilibrium methods, although the requisite data are not available for present purposes.

In what follows, we first describe very generally the economic base of the area and then turn to several sources of data. None of these sources perfectly coincides with the boundaries of the watershed, and none provides a very complete description of the economic situation or how it might be affected by restoration. However, we are able to transmit some general notion of the costs of various restoration activities. Clearly, before any new regulations are devised and enforced, specific cost/benefit studies need to be undertaken.

10.2. The Economy of Kaua‘i County and the Nawiliwili Watershed

Unfortunately, for present purposes, economic data are not collected or organized to coincide with watershed boundaries. Instead, we have some data organized by census tract, some by postal zip codes, and some by the state's Tax Map Keys (TMKs). The latter is the most detailed in terms of identifying parcels, although its other data are quite limited. For purposes of characterizing the area's economy, we use census (State of Hawai‘i Data Book, online) data for tracts 404 and 405 (see Figure 55 and Table 22) even though a major portion of tract 404 lies outside the watershed.

As of 2000, about 5% of the state's population (U.S. Census Bureau, *http://quickfacts.census.gov/qfd/states/15/15007.html*) resided on Kaua‘i. The island's population density is about half the statewide average. Median household income (as of 1999) was slightly below the statewide average. Populations of census tracts 404 and 405 are heavily minority (70% to 80%) with poverty rates of 5% to 8% (Federal Financial Institutions Examination Council, 2003).

The economy of Kaua‘i County, and of these two census tracts in particular, has traditionally been grounded in agriculture, especially sugarcane growing and processing, and tourism. The gradual shutdown of sugar companies on Kaua‘i and statewide (by 2003, only the Gay & Robinson plantation remained in production on Kaua‘i) has left large tracts of land to be transformed to smaller-scale agricultural or non-agricultural uses, or to be left fallow.

In 1987, Kaua‘i County had 400 farms, averaging 560 acres. Ten years later, the number of farms rose to 468, but the average farm size declined to 421 acres. The median farm size was only 8 acres, and 62% had less than 10 acres (Census of Agriculture, 1987, 1992, 1997). Nearly 70% had farm sales valued at less than $10,000. Clearly, agriculture has shifted to smaller-scale enterprises, and many of these farms provided only a minor portion of a household's income.

Table 23 gives an impression of the types of economic activities predominant on Kaua‘i, as of 2000. Aside from the governmental sector, the lodging and the wholesale and retail trade sectors dominate, with much of the latter generated through the former. In the agriculture sector, the 1,058 jobs and about $20.6 million in income in 1993 dwindled to 971 jobs and $19.1 million in income in 2000. The closing of Līhu‘e Plantation in 2000 brought about a further major decline.

Tourism, by contrast, has grown steadily in recent years, i.e., after the devastating impact of Hurricane Iniki in 1992. Tourism and related businesses clearly form the dominant economic activity on Kaua‘i. An economic update of the island by the University of Hawai‘i Economic Research Organization (UHERO) in 2003 noted that tourism probably accounts for a larger fraction of economic activity on Kaua‘i than on any of the other islands of Hawai‘i.

Fortunately, Kaua‘i's tourism sector was well situated to avoid the worst effects of external shocks such as the 1992 hurricane, the bursting of the Japanese bubble, the high-tech bust, and the terrorist attacks of 9/11, all of which had relatively greater impacts on other Hawai‘i destinations. A heavy proportion of time-share ownership, growing cruiseship landings, and relatively light dependence on Japanese tourists all cushioned impacts that were felt more seriously on the other islands. The UHERO study also noted the growing importance of film industry activity, real estate activity, and a nascent high-tech sector. High-tech activities are thought to be helped by opportunities for telecommuting and by the Pacific Missile Range Facility, both of which tend to lessen or overcome the island's isolation.

10.3. Land Ownership, Use, and Value

As noted above, GIS data indicate that the Nawiliwili Watershed encompasses some 9,421 hectares (23,270 acres), which is about 7% of the area of Kaua‘i. Nearly one-fourth of this is conservation land. For planning purposes, one would like to know something about the ownership, use, and value of this land, as well as the distribution of each variable, to determine the effects of measures intended to improve water quality there.

The only available data on these variables are the county TMKs. This is imperfect, for present purposes, on several counts. First, many parcels lie partially within the Nawiliwili Watershed and partially in neighboring areas. Second, TMKs provide no information on current land use, only on ownership. Third, tax assessments are very imperfect measures of market valuation. Nevertheless, TMKs provide the only available data and we use them as such, deficiencies notwithstanding but duly noted.

The TMKs include 3,005 parcels of land that lie at least partly within the Nawiliwili Watershed, for a total area (as measured by GIS) of some 42,806 acres. Portions of these parcels lie outside the watershed. For example, the largest single parcel in the TMK database, belonging to Grove Farm, is 9,660 acres, of which only 309 acres are within the watershed boundaries. GIS overlays indicate an area within the watershed area totaling 23,543 acres.[5]

Most parcels are small, about the size of urban house lots. The median size is 0.232 acre; at least 1,767 parcels are less than one-quarter of an acre, and 1,164 parcels are less than one-eighth of an acre. The distribution of parcel sizes is shown in Figure 56(a), and their valuation, as indicated by tax assessments, appears in Figure 56(b).

A number of owners have multiple parcels. Consolidating these parcels gives an indication of *holdings* of a particular person or entity.[6] Where the parcels have sequential TMKs, one is tempted to conclude that the parcels are used as a consolidated whole. While this is true in many cases, some parcels or parts of parcels may be rented out or used partly for some purpose or by some person entirely different from the rest. Again, we have no

[5] As noted in the first paragraph of this subsection, the watershed encompasses some 23,270 acres in total. Estimates of the portions of tax map parcels lying within the watershed add up to 23,543 acres. The difference appears to stem from an accumulation of small errors in the GIS overlays. For the sake of consistency, discussion in the rest of this section uses the higher figure.

[6] Parcels listed under strikingly similar names (e.g., Grove Farm Co., Grove Farm Land Corp, Grove Farm Properties, Inc.) have been consolidated and treated as though owned by a single entity.

information on current uses of the parcels or holdings. The 3,005 parcels covering the watershed are owned by 2,064 persons or business entities.

Figure 57 is similar to Figure 56, but with holdings shown instead of tax parcels. These data are also restricted to that portion of each holding *within* the watershed. The apparent similarity of these two distributions is confirmed in Figure 57(b), which juxtaposes the parcels and holdings distributions in *percentage* terms. For example, 62.3% of the holdings are between one-tenth and one-fourth of an acre, while 56.6% of the parcels lie in the same size category. The difference of 5.7% is the largest of any category.

Table 24 identifies the largest landowners, i.e., those with "GIS acres in the watershed" of 10 acres or more. These 22 owners control 661 tax parcels totaling some 22,698 acres, or 96.4% of the watershed area. Holdings of between 2 and 10 acres include 129 separate tax parcels under the ownership of 59 entities, but these holdings comprise only 1.2% (273.9 acres, or 4.64 acres on average) of the watershed area. The remaining 1,983 owners have parcels totaling only 572.1 acres (2.4% of the watershed) at slightly more than a one-quarter acre each.

10.4. Recreation Benefits

Water-based recreation in the Nawiliwili Watershed and in Nawiliwili Bay clearly has considerable economic value. The first study of the economic value of beach recreation in Hawai'i was done in 1972 for O'ahu (Moncur, 1972; Moncur, 1975). The results indicate that a day at the beach for O'ahu residents is valued at $1.50 to $5.90 per person,[7] depending on the particular beach. Very little subsequent work has been done on this subject,

This report deals not with the overall value of a beach visit, but with the increase in this value due to improved water quality. No studies of this subject have been done for Hawai'i, but in other places, researchers have applied contingent valuation techniques to estimate willingness to pay (WTP) for water quality improvement at local beaches. Russell (2001) summarizes several such studies done in the Philippines, Latin America, United States, and United Kingdom. While cross-country comparisons are probably inapt, residents surveyed in Uruguay, for example, reported WTP of $14 per household per year for an "improvement" in water quality at nearby beaches. A study in Rhode Island yielded WTP estimates of $80 to $187 per household. In all these cases WTP estimates are well below 1% of annual income.

While no similar information is available for Hawai'i or, more specifically, for Kaua'i, it is apparent that in a tourist-based economy, water-based recreation can be very highly valued. Nawiliwili Bay is heavily used by beach-goers, thus the benefits of water quality improvement may well be substantial.

[7] The 1972 dollar values have been adjusted to 2003 price levels, using the consumer price index.

Another aspect of the value of water quality is the cost of health care associated with illness traceable to swimming or other water-based activities. Unfortunately, no epidemiological studies have been done for Nawiliwili on the health effects of existing contamination or the associated costs of medical care. Such studies are difficult and costly, but the lack of them could simply reflect the rarity or minor character of illnesses caused by water contamination and the lack of broad concern for such problems.

10.5. Costs of Remediation Efforts: Septic Tanks and Sewer Systems

The problem of cesspools contributing to pollution in the watershed could be alleviated by connecting residences to sewer systems or, where that alternative is prohibitively costly, by replacing cesspools with septic tanks. New technologies for septic systems should be explored. For example, EnvironEDGe Technologies, Inc.[8] (*http://www.environedge.com/*) markets septic tanks that, according to the company, are much superior to conventional tanks in terms of quality and protecting the environment. The system is watertight and lightweight, and it features a corrosion-resistant seal. It helps in reducing groundwater contamination. Again, according to the company, the system not only reduces biological oxygen demand and suspended solids by 90%, but it also reduces nitrates and fecal coliform levels by up to 95%.

Some idea of costs for these options is available from an environmental impact statement (EIS) (Hawaiʻi Pacific Engineers, Inc., 1998) of wastewater treatment facilities in the Waimānalo area on Oʻahu, as well as from vendors and installers of septic tanks.

For sewer systems, installation costs vary greatly, depending on the density of lots and location of the house vis-à-vis existing sewer lines. The EIS cited above gives costs for two areas (Table 25). One, labeled Sewer Improvement District (SID) #2, is densely developed with some 350 homes. It could connect to existing sewer lines by gravity feed. This would involve capital costs of $7,160,000 plus $110,000 for annual maintenance, or an annualized cost[9] of about $2,100 per home. In addition to the high capital cost, this alternative has technical challenges (some pipes would be below the water table) and is opposed by a majority of the homeowners.

A nearby area (SIDs #3 and #5) is somewhat smaller with only 100 homes. However, this area would require construction of an additional pumping station, with associated higher operating costs. Here, the sewer connection cost was estimated at $6,500 per household per year.

Alternatively, either area could meet wastewater objectives by installing or upgrading individual wastewater treatment systems. The Waimānalo EIS estimated capital costs for septic tanks at between $1,830 and $12,000 for the "typical" and "worst-case" scenarios, respectively. The 350 homes in SID #2 could be upgraded with individual systems at a

[8] Information is included for reference only. We do not endorse vendors or any products.
[9] Annualized cost assumes a 20 year life, 6% discount rate, and no salvage value. They are calculated using the formula $A = Pi/[1-(1+i)^{-T}]$, where $A is the annual equivalent of a principal amount $P invested for *T* years at discount rate *i*.

capital cost of $640,000. Annualizing and adding annual maintenance costs would bring the total cost estimate to $162,000, or $460 per household per year. Outfitting the other area with individual wastewater treatment systems would give a very similar estimated annual cost per household.

Another estimate of septic tank costs resulted from Internet searches and subsequent phone calls to providers of such equipment. The website *http://www.watertanks.com/category/35/* (accessed May 2004) gives prices for the tanks per se of between $500 and $1,100. Installation costs were quoted at between $2,000 and $6,000, depending on soil type, and maintenance costs at about $75 per year, based on a three-year pump-out.

The Nawiliwili Watershed, in general, is a larger area that is more rural in character and that has less densely situated homes than the Waimānalo areas studied in the EIS. Outside urban areas, sewage systems are probably prohibitively expensive. They are also less necessary, to the extent that because of the low density in rural areas, septic tanks can be operated efficiently and effectively without an accumulation of residual contamination.

Figure 21 shows TMK parcels with cesspool systems in the Nawiliwili Watershed. This information was obtained for the HDOH data and entered into our database. The total number of parcels is 470. Unfortunately, the database does not include the number or size of cesspools in each parcel. Using the price quotes listed above, the total cost of septic tanks would range from $235,000 to $517,000 for tanks, plus $940,000 to $2.82 million for installation. The average total cost would be about $2.3 million. Land owners/operators would be responsible for the annual maintenance cost. Considering Hawaiʻi's above-average living expenses, the actual cost would most likely be higher than the averages given. Yet, the numbers provided here serve as a guideline for a more accurate analysis.

10.6. Costs of Remediation Efforts: Other Proposals

This study has considered a wide range of options for controlling pollution in the Nawiliwili Watershed (Section 3). Precise and reliable data on costs for recommended measures would require extensive engineering studies, but some general notions can be obtained from extant literature. Two reports are particularly useful: the Kailua Bay Advisory Council (KBAC) watershed management plan (Tetra Tech EM Inc., 2003) and the Texas Statewide Storm Water Quality Task Force report on stormwater pollution management practices (*http://www.txnpsbook.org/About.htm*).

The KBAC report identifies several segments of the Kailua watershed needing attention and gives cost estimates for various possible pollution-control and remediation projects. The cost figures in the report can serve as a guideline for the present study.

The Texas study (also adapted for use in the KBAC report) provides information on a wider variety of remediation measures. No absolute dollar figures are provided, only a broad qualitative valuation. The valuations do not include land costs, which for both Oʻahu (as in the KBAC report) and Kauaʻi, can be expected to differ substantially from that of Texas. For example, wet ponds have relatively high space requirements, so the judgment that they are "low" in cost probably does not apply in the Kaua'i context. That said, Table 26 includes some of the KBAC conclusions.

Table 21 provides an estimate of the main items described in Section 3, which deals with proposed restoration activities. We emphasize again that all estimates are provided as guidelines and that elaborate studies should be undertaken to finalize such estimates. Uncertainties are related mostly to the absence of site-specific data regarding such factors as land price and size of installations. A good approach would be to subcontract construction activities to qualified non-profit and for-profit entities through bidding procedures. Section 2 describes a suggested structure and functions of the Nawiliwili Watershed Restoration Office, which, among other things, would be tasked with securing funds, planning and managing restoration activities, and awarding contracts to qualified vendors.

10.7. Potential Funding Sources

This section covers sources of potential funds. In addition to making public funds available, the government can institute a wide variety of regulations, subsidies, and tax schemes. For example, for the Neuse River Basin and several other watersheds, North Carolina has a system of incentive and bonus payments to landowners (Wossink and Osmond, 2002). With federal and state participation, the Conservation Reserve Enhancement Program provides payments to owners of agricultural lands for up to 15 years, as well as subsidies for BMP installation. Up to 100% of the installation costs can be covered, if the contract is a permanent one.

Among the available funding sources is HDOH's Environmental Planning Office 2001, Funding Sources for Communities – Watershed Focus. Additional information can be obtained from the Environmental Planning Office, 919 Ala Moana Blvd., Room 312, Honolulu, HI 96814, phone (808) 586-4337.

The draft Kailua Waterways Improvement Plan, Volume II (Tetra Tech Em Inc., 2003) contains a preliminary list of potential grant programs and funding sources that are available to fund the implementation program. The report lists a number of widely available programs and funding sources that may be applicable, along with a brief description of the programs. Potential funding amounts are given where available. The specific plan element(s) that may be eligible for funding under each are also noted, where applicable. As the report suggests, additional programs and funding mechanisms should be identified and leveraged for the life of the restoration program. The following sections are taken verbatim from that report.

> ***U.S. Army Corps of Engineers (USACE) Ecosystem Restoration Program:*** *Sections 206 and 1135 of the Water Resources Development Act of 1986 authorize the USACE to evaluate, plan, design, and construct projects that benefit the environment through restoration, improvement, or protection of habitat. Section 1135 projects are focused on areas affected by prior USACE projects or actions, while Section 206 projects are not. A restoration project is initiated after a detailed investigation shows it is technically feasible, environmentally acceptable, and provides cost-effective environmental benefits. The maximum federal expenditure per project is $5 million, and a local match of either 25 percent or 35 percent is*

required for Section 1135 or Section 206 projects, respectively. Land values may be credited toward the local match amount.

Watershed Initiative (Program Management, Demonstration Projects, Monitoring, Training): *Governors nominate watershed organizations from their state to receive grants to support innovative watershed-based approaches to preventing, reducing, and eliminating water pollution. The initiative will also support local communities in their efforts to expand and improve existing protection measures with tools, training, and technical assistance, and provide for ten federal liaison positions. EPA will then select 20 organizations for funding. Nominations that are likely to result in environmental improvements in a relatively short time frame and that show broad stakeholder involvement would be strong candidates. Preference will be given to watershed plans that involve multiple states and/or tribes. Funding levels from $300,000 to $1,300,000 (were) anticipated for Fiscal Year 2003.*

Clean Water Act (CWA) Section 319 Water Quality Grants (Program Management, Demonstration Projects, Monitoring, Community Education, Training): *Clean Water Act Section 319(h) funds are provided by EPA to designated state and tribal agencies to implement their approved nonpoint source management programs. State and tribal nonpoint source programs include a variety of components, including technical assistance, financial assistance, education, training, technology transfer, demonstration projects, and regulatory programs. The Hawaii Department of Health (DOH) grant requirements state that projects that prevent, control, and/or reduce nonpoint source pollution of Hawaii's water resources are eligible for funding. Projects may include, but are not limited to, one or more of the following activities:*

- *Implementation of a portion of the Hawaii Coastal Nonpoint Pollution Control Plan*
- *Implementation of BMPs*
- *Demonstration of a new or innovative BMP or institutional approaches to accelerate technology transfer and adoption*
- *Restoration of resources, enhancement of resources, information and education programs, and coordination of citizen or volunteer monitoring programs which lead to the implementation of BMPs Projects that fall within the Category 1 Watersheds as listed in Hawaii's Unified Watershed Assessment shall also be eligible. Grant requests of and up to $120,000 will be considered.*

U.S. EPA Watershed Assistance Grants (Program Management, Training): *EPA provides Watershed Assistance Grants for programs that build on cooperative agreements with one or more nonprofit organizations or other eligible entities to support watershed partnerships and long-term effectiveness. Funding supports organizational development and capacity building for watershed partnerships with a diverse membership. Small grants of $1,500 to $30,000 are available for a variety of watershed projects, and the median grant awarded in past years was $18,500.*

Wetland Program Development Grants Guidelines (Demonstrations, Monitoring): *Wetland Program Development Grants (WPDG) provide eligible applicants an opportunity to conduct projects that promote the coordination and acceleration of research, investigations, experiments, training, demonstrations, surveys, and studies relating to the causes, effects, extent, prevention, reduction, and elimination of water pollution. While WPDGs can continue to be used by recipients to build and refine any element of a comprehensive wetland program, priority is given to funding projects that address three areas identified by EPA: (1) Developing a comprehensive monitoring and assessment program; (2) improving the effectiveness of compensatory mitigation; and (3) refining the protection of vulnerable wetlands and aquatic resources. States, tribes, local governments, interstate associations, and national nonprofit, nongovernmental organizations are eligible to apply.*

Water Quality Cooperative Agreements (Demonstrations, Training, Monitoring): *Under authority of Section 104(b)(3) of the Clean Water Act, EPA makes grants to state water* *pollution control agencies, interstate agencies, and other nonprofit institutions, organizations, and individuals to promote the coordination of environmentally beneficial activities. These activities include storm-water control, sludge management, and pretreatment. Among the efforts that are eligible for funding are research, investigations, experiments, training, environmental technology demonstrations, surveys, and studies related to the causes, effects, extent, and prevention of pollution. EPA Region 9 Water Division intends to award an estimated $1.1 million in Fiscal Year 2003 to eligible applicants through assistance agreements ranging in size from $50,000 up to $150,000 for Water Quality Cooperative Agreements. EPA intends to make available at least $500,000 per year of the annual appropriation for Water Quality Cooperative Agreements, from Fiscal Year 2003 through Fiscal Year 2005, for projects that address innovative approaches to the development and implementation of total maximum daily loads (TMDL) in priority watersheds.*

Environmental Justice Grants to Small Community Groups (Education, Monitoring): *This EPA grant program provides financial assistance to eligible community groups (i.e. communitybased/ grassroots organizations, churches, or other nonprofit organizations with a focus on communitybased issues) and federally recognized tribal governments that are working on or plan to carry out projects to address environmental justice issues. Grants may be used for (1) education and awareness programs, (2) environmental justice programs (e.g., river monitoring and pollution prevention), (3) technical assistance in accessing available public information, and (4) technical assistance with gathering and interpreting existing environmental justice data. An estimated $1,500,000 will be available nationally in Fiscal Year 2003.*

Science To Achieve Results (Monitoring): *The Science To Achieve Results (STAR) program is designed to improve the quality of science used in EPA's decision-making process. STAR funds are provided for research in the areas of safe drinking water (including source water protection) and pollution prevention and new technologies, among others. The STAR program is intended to facilitate cooperation between EPA and the scientific community to help forge solutions to environmental problems. Research topic solicitations vary and are advertised in the Federal Register and through the internet, university and scientific organizations, direct mail, and other avenues.*

Bring Back the Natives Grant Program (All Aspects of the Program): *This National Fish and Wildlife Foundation (NFWF) program provides funds to restore damaged or degraded riverine habitats and their native aquatic species through watershed restoration and improved land management. The Bureau of Land Management (BLM), Bureau of Reclamation (BOR), U.S. Fish and Wildlife Service (FWS), USDA Forest Service (FS), and NFWF provide funding. Successful projects support the applied ecosystem strategy of BLM, BOR, FWS, FS, and NFWF, and address any or all of the following: (1) revised land management practices to eliminate causes of habitat degradation; (2) multiple species benefits, (3) direct benefits to native fish and aquatic community resources in watersheds with land managed by BLM, BOR, or FS; (4) multiple resource management objectives, (5) multiple project partners and innovative partnerships; (6) where appropriate, demonstration of a landscape ecosystem approach; and (7) innovative projects that develop new technology that can be shared with others.*

Native Plant Conservation Initiative (Demonstration Projects): *The NFWF's Native Plant Conservation Initiative (NPCI) supports on-the-ground conservation projects that protect, enhance, and/or restore native plant communities on public and private land. Projects typically fall into one of three categories and may contain elements of each: protection and restoration, information and education, and inventory and assessment. The BLM, FS, FWS, and National Park Service fund this program.*

The Clean Water State Revolving Fund (Demonstration Projects): *Unlike the grant programs discussed previously, the Clean Water State Revolving Fund (CWSRF) program* *provides low-interest loans for water implementation projects. Key features of the program include:*

- *Low Interest Rates, Flexible Terms: Nationally, interest rates for CWSRF loans average 2.5 percent, compared to market rates that average 5.1 percent. For a CWSRF program offering this rate, a CWSRF funded project would cost 21 percent less than projects funded at the market rate. CWSRFs can fund 100 percent of the project cost and provide flexible repayment terms up to 20 years.*
- *Significant Funding for Nonpoint Source Pollution Control and Estuary Protection: CWSRFs provide over $200 million annually to control pollution from nonpoint sources and for estuary protection, exceeding $1.6 billion to date.*
- *Assistance to a Variety of Borrowers: The CWSRF program has assisted a range of borrowers including municipalities, communities of all sizes, farmers, homeowners, small businesses, and nonprofit organizations.*
- *Partnerships with Other Funding Sources: CWSRFs partner with banks, nonprofits, local governments, and other federal and state agencies to provide the best water quality financing source for their communities.*

Storm-Water Utility (All Aspects of the Program): *The implementation program could also be funded under a storm-water utility managed by the City and County of Honolulu. There are more than 100 storm-water utilities in the United States. In general, utilities are either publicly owned and operated enterprises or privately owned enterprises whose ability to profit from providing public services is regulated by a public agency. Storm-water utility fees are imposed on property owners to pay for stormwater management, and provide a more reliable source of funds for local storm-water management than do property taxes. Methods of determining storm-water utility charges vary considerably around the country, depending on local stormwater management goals and conditions. The charge can be based on the amount of runoff generated from the property, the amount of impervious area (hard surfaces) on the property, or the assessed value of the property.*

Cost-sharing and low-interest loans are effective methods in restoration implementation. Examples include that for the Virginia agricultural incentives program (*http://vmirl.vmi.edu/ev2000/PPT/bayless.ppt*). The program covers five areas: BMP cost-share program, BMP tax credit program, conservation equipment tax credit program, BMP loan program, and small business environmental compliance assistance fund. The BMP cost-share program is administered by local Soil and Water Conservation District (SWCD) offices, which recruit participants from areas that will make the greatest impact on water quality. Eligible practices should be among the 27 BMPs that have been pre-approved, and the BMP must be part of a Natural Resource Conservation Service conservation plan. Cost-share is based on a flat per-acre rate, 75% of the eligible cost, or a combination of the flat rate and percentage of the eligible cost. There is an individual cap of $50,000, and cost-share payments are disbursed when a BMP is complete and certified.

The BMP tax credit program, also administered by local SWCD offices, is applicable to any individual or corporation engaged in agricultural production for the market. The program has 41 BMPs that are eligible for tax credit. Individuals must have a conservation plan approved by the local SWCD board, and the BMP and estimated cost must be approved for tax credit prior to installation. Tax credit, which is granted after the BMP is complete and certified, is equal to 25% of the cooperator's approved expenses but is not to exceed $17,500 in any taxable year. Finally, the tax credit must be applied in the tax year the BMP is completed, and tax credit above the individual's tax liability can be carried over for up to five years.

The equipment tax credit program provides credit for the purchase of conservation tillage equipment and advanced technology application equipment. It is applicable to any individual, partnership, or small business corporation engaged in agricultural production for the market. The individual must have a nutrient management plan approved by the local SWCD board for advanced technology application equipment. Credit can be up to 25% of the purchase cost but is not to exceed $2,500 for conservation tillage equipment or $3,750 for advanced technology application equipment. Finally, the tax credit must be applied in the tax year the equipment is purchased, and tax credit above the individual's tax liability can be carried over for up to five years.

The agricultural BMP loan program is administered by the Department of Environmental Quality (DEQ) and is applicable to any Virginia producer wishing to implement eligible BMPs in order to reduce the effect of polluted runoff entering Virginia waters. Twenty-three BMPs are eligible for the loan program. The conservation plan must be approved by the local SWCD board. Currently, the interest rate is 3%, and the minimum loan amount is $5,000. The loan repayment period is 1 to 10 years.

The small business environmental compliance assistance fund, administered cooperatively by DEQ and the Department of Business Assistance, is applicable to any small business operating in Virginia. The program covers 16 eligible BMPs, and the loan is only for the installation of structures or equipment. The interest rate is 3%, and the maximum loan amount is $50,000. The loan repayment period is to coincide with the lifespan of the BMP but is not to exceed 10 years.

11. NAWILIWILI WATERSHED RESTORATION PLAN MEETINGS

While this report was being prepared, a series of public meetings were held from October 29 to December 17, 2003, with the intent of soliciting input from the community. Table 27 lists information about meetings conducted, including the dates, topics, and names of those attending each meeting. Table 28 lists the names of meeting attendees and their respective affiliations.

The meetings were intended to allow community members to voice their opinions, offer advice, and have a hand in the planning process for the restoration of water quality. Although there was little participation, the meetings were beneficial due to the participants' great interest in the Nawiliwili Watershed and their knowledge of its problems. Our group representative (Monica Mira) also attended other gatherings, such as Mayor Bryan Baptiste's Ka Leo o Kauaʻi and the Nawiliwili Bay Watershed Council meetings, to solicit additional participation.

The Ka Leo meetings have been a successful vehicle for community members to speak to and work with county officials. Many community suggestions have come to fruition, and the community members have been able to see the results of their work. The Līhu‘e chapter of Ka Leo o Kaua‘i is looking at forming a neighborhood board in the future.

Important elements of a successful community education program are the continuous opportunity for public input and the ability make changes to plans as needed. Therefore, it is important that some mechanism for community input be in place throughout the implementation of projects described in the Nawiliwili Watershed Restoration Plan. As the restoration projects move forward, community goals may change or projects may need to be adjusted if they are not producing the desired results. Any medium for community discussion will allow the public an opportunity not only to re-evaluate its priorities with respect to the plan but also to voice its concerns in order to make the necessary adjustments.

Section 2 outlines the structure of the Nawiliwili Watershed Restoration Office, a new entity that would responsible for managing restoration activities. Various community organizations should be represented in the core group and should participate in the volunteer program organization and operation. A website should be set up to provide a schedule of restoration activities, to give information about how the public can get involved, and to host a message board for comments and concerns. It must be emphasized that the most important part of a successful watershed-based plan is the continuous public discussion on water quality issues and restoration projects.

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FIGURES

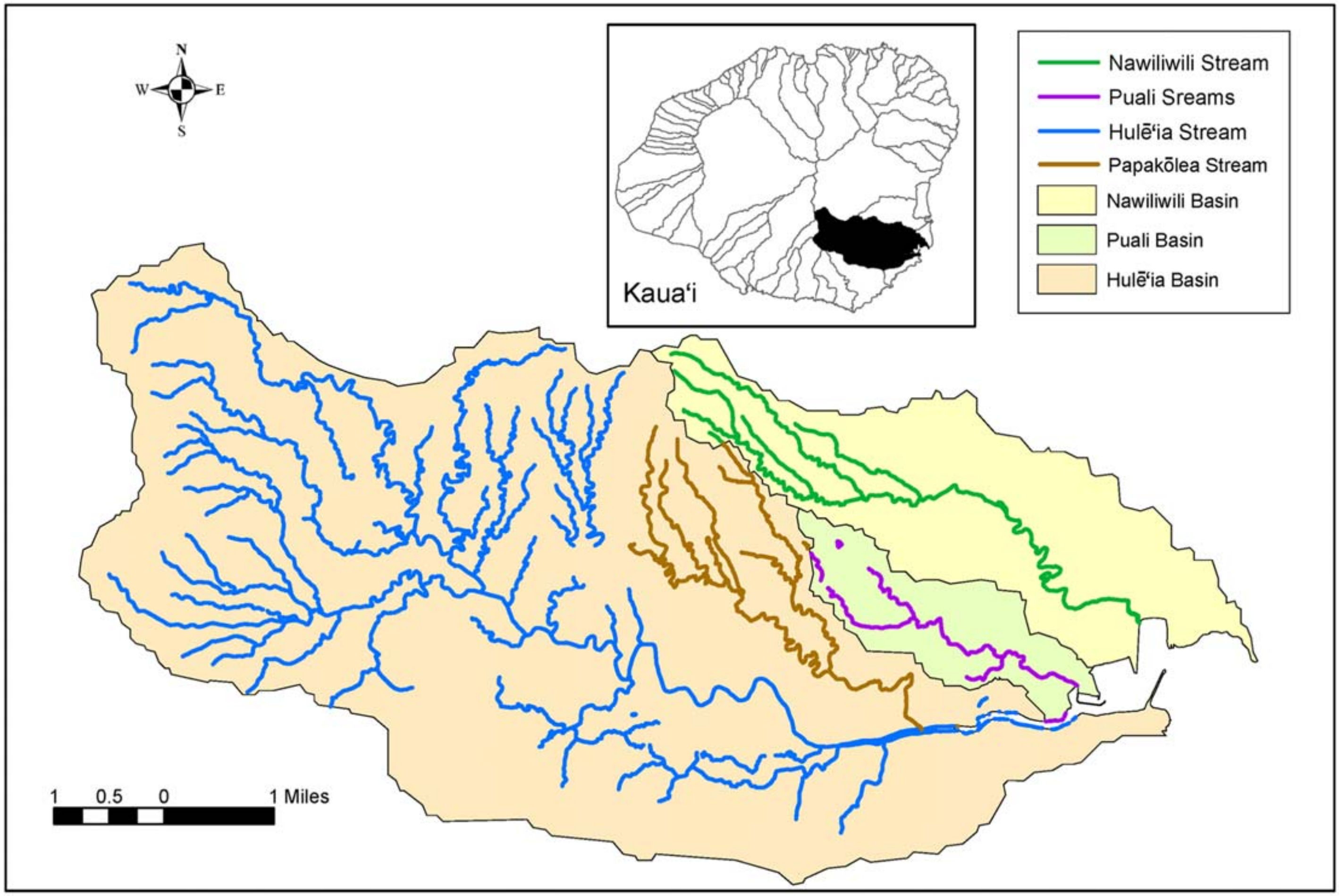

Figure 1. The Nawiliwili Watershed, Kaua'i, with its main perennial streams and their respective basins. (Source: The Internet site of the Hawaii Statewide GIS Program, *http://www.hawaii.gov/dbedt/gis/*.)

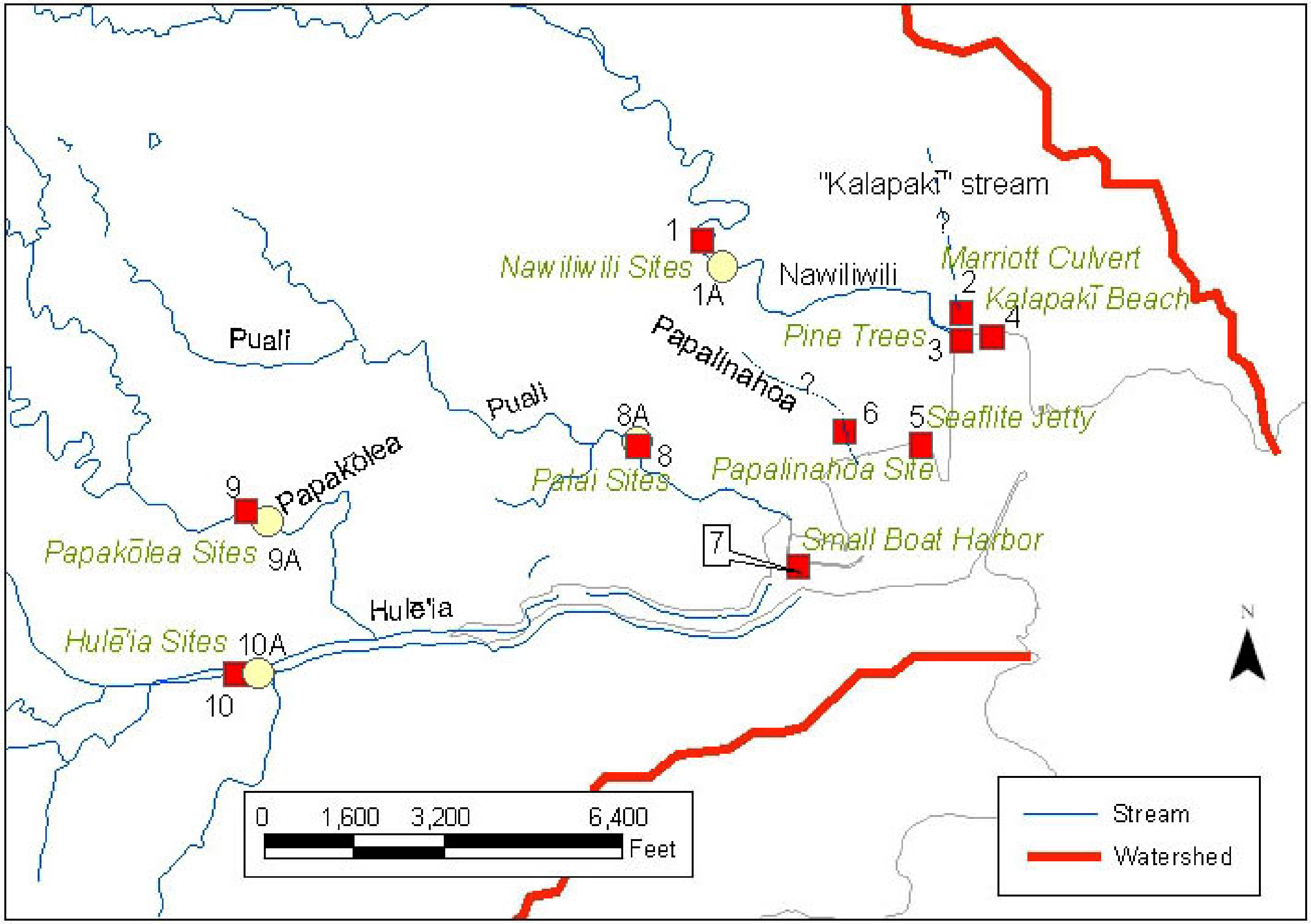

Figure 2. The Nawiliwili Watershed sampling sites. Squares represent primary sites for this study, labeled 1 through 10. Circles represent alternative sites, labeled 1A, 8A, 9A, and 10A. (See text for description of the sites.) (Source of original maps: The Internet site of the Hawaii Statewide GIS Program, *http://www.hawaii.gov/dbedt/gis/*.)

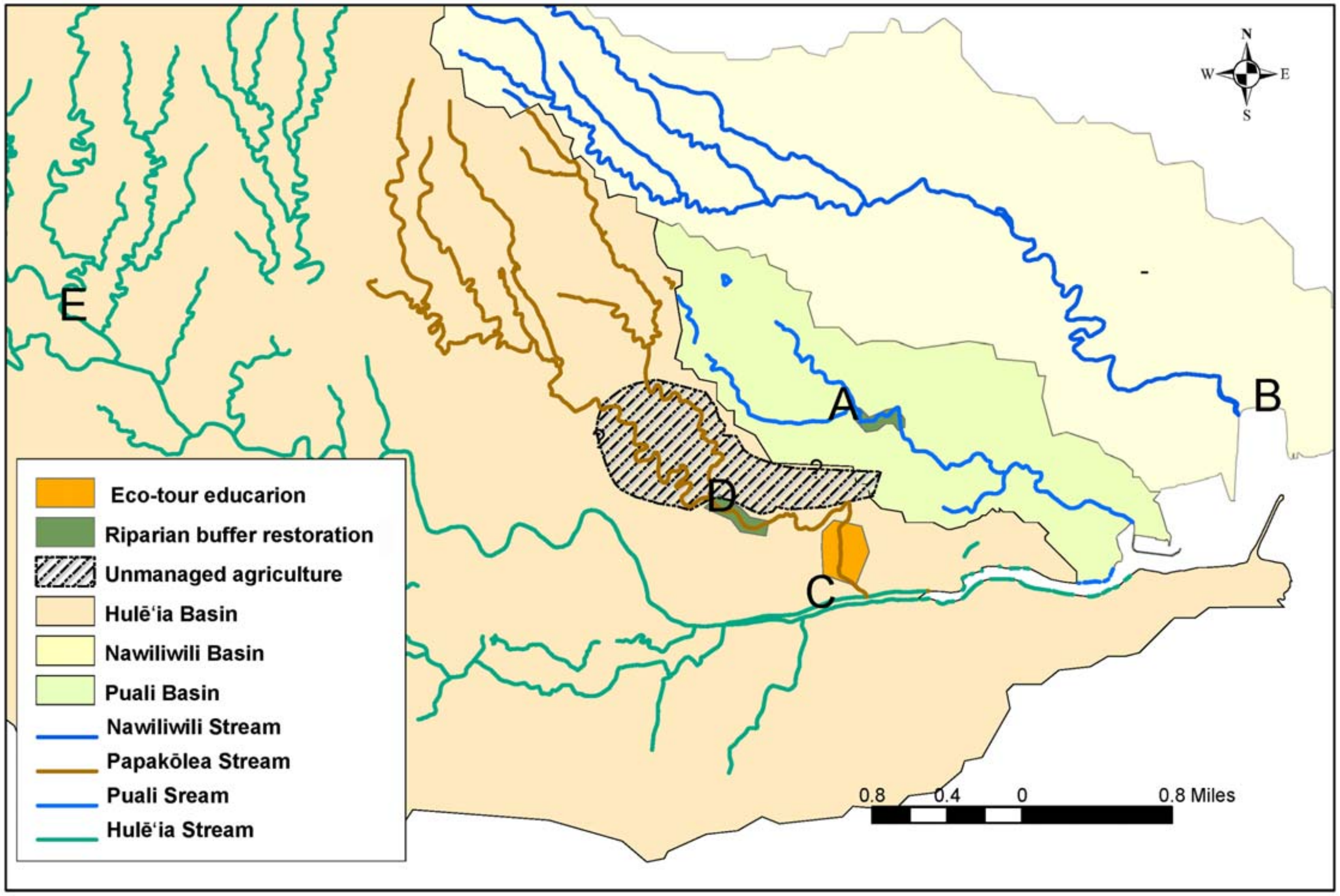

Figure 3. Areas where restoration activities are recommended. Locations A, B, C, D, and E are active or suggested restoration areas discussed in Subsection 4.7.2.3. The boundary marked by question marks are approximate. (Source of original maps: The Internet site of the Hawaii Statewide GIS Program, *http://www.hawaii.gov/dbedt/gis/*.)

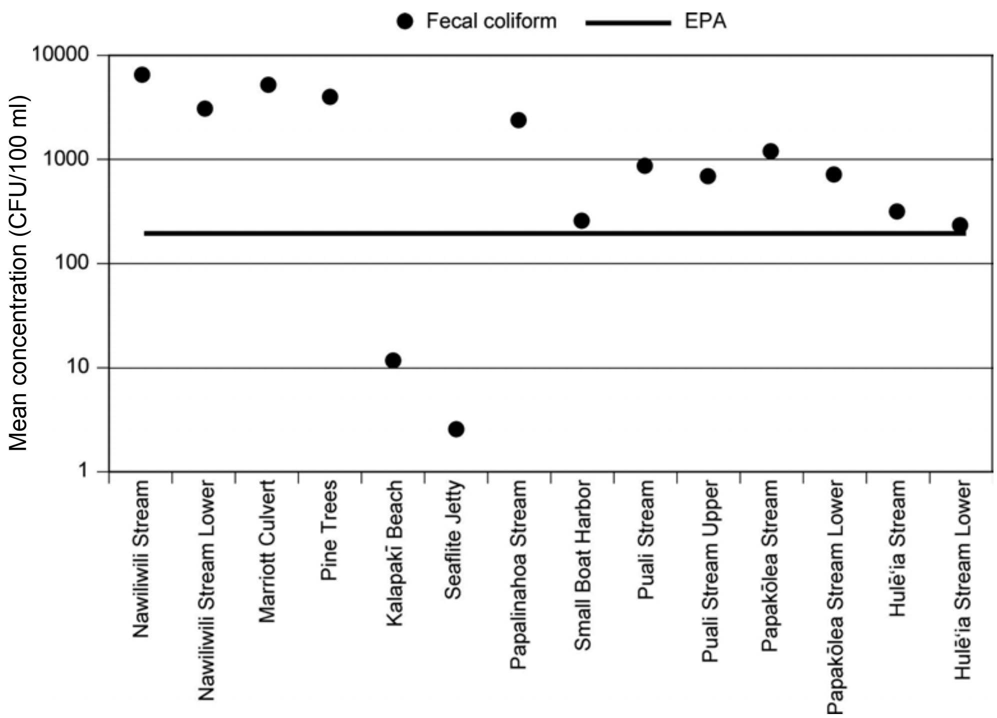

Figure 4. Fecal coliform geometric mean concentrations for various sampling sites in the Nawiliwili Watershed, Kaua'i, in relation to the U.S. Environmental Protection Agency's recreational water quality standard

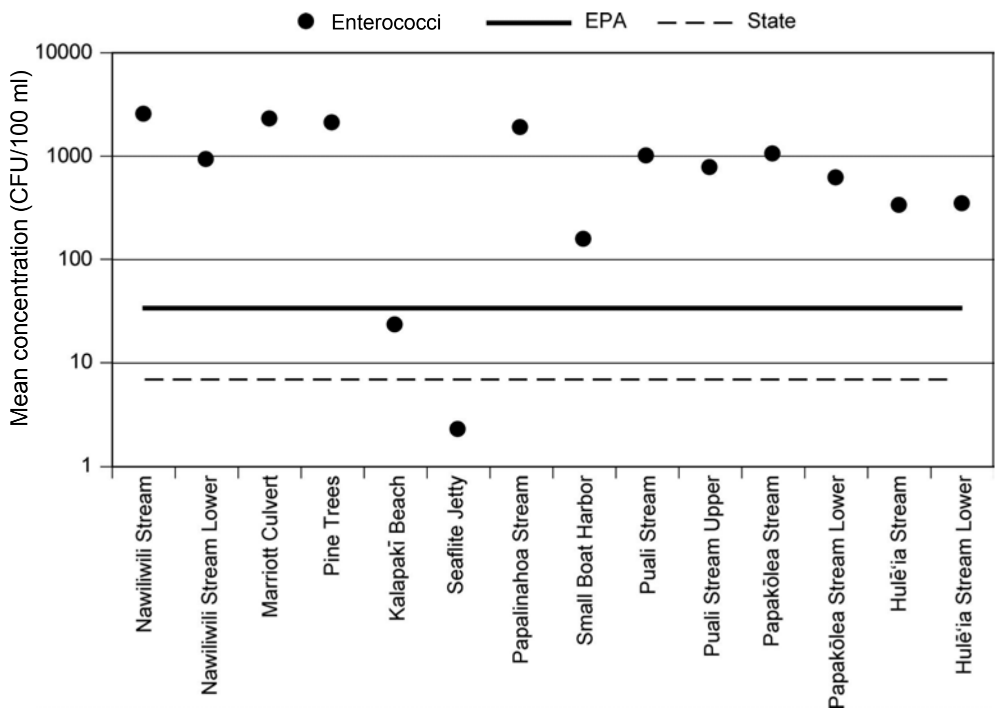

Figure 5. Enterococci geometric mean concentrations for various sampling sites in the Nawiliwili Watershed, Kaua‘i, in relation to the recreational water quality standards of the U.S. Environmental Protection Agency and the State of Hawai‘i

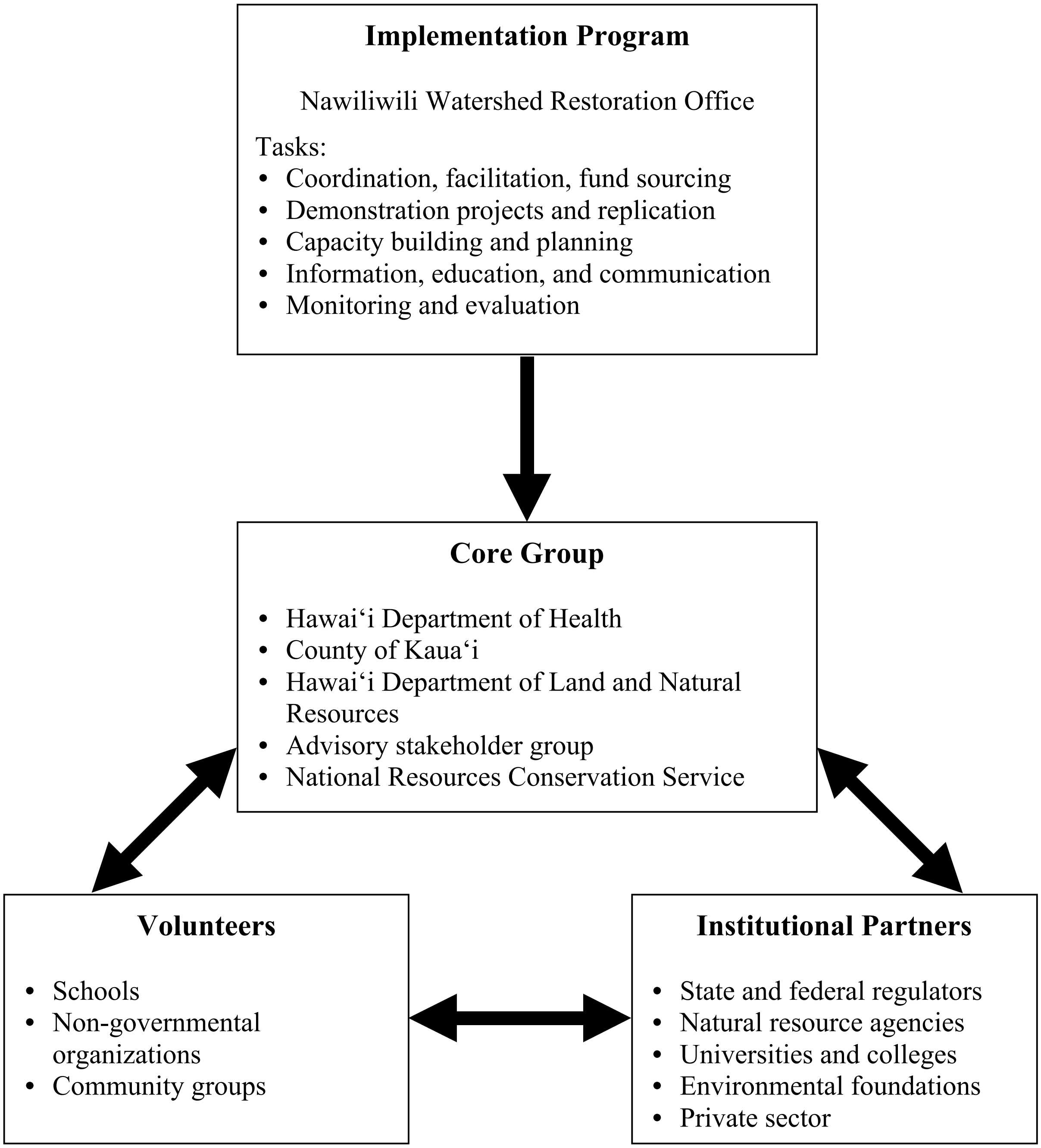

Figure 6. Structure of the proposed Nawiliwili Watershed Restoration Office

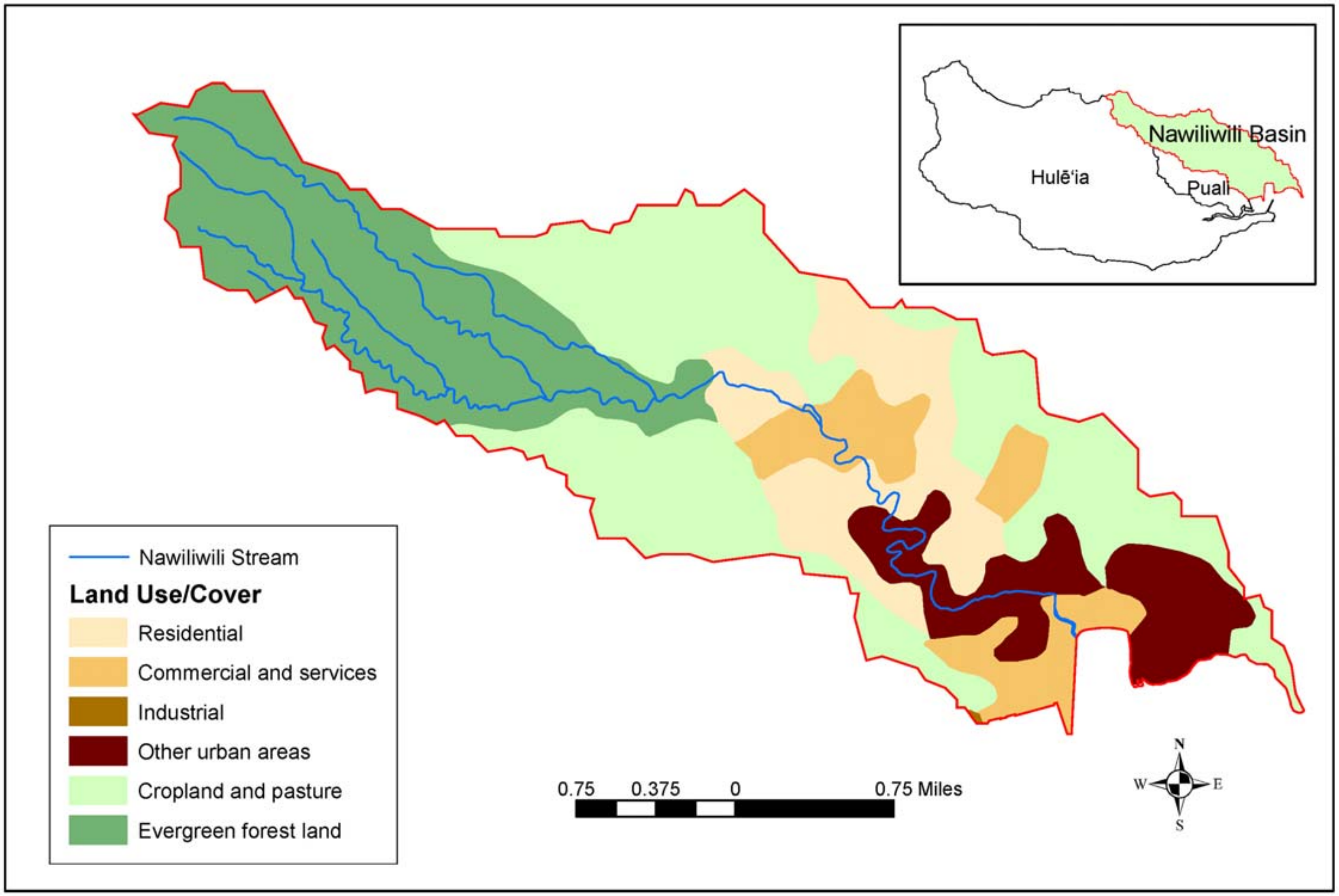

Figure 7. Land uses in the Nawiliwili Stream Basin. (Source of original maps: The Internet site of the Hawaii Statewide GIS Program, *http://www.hawaii.gov/dbedt/gis/*.)

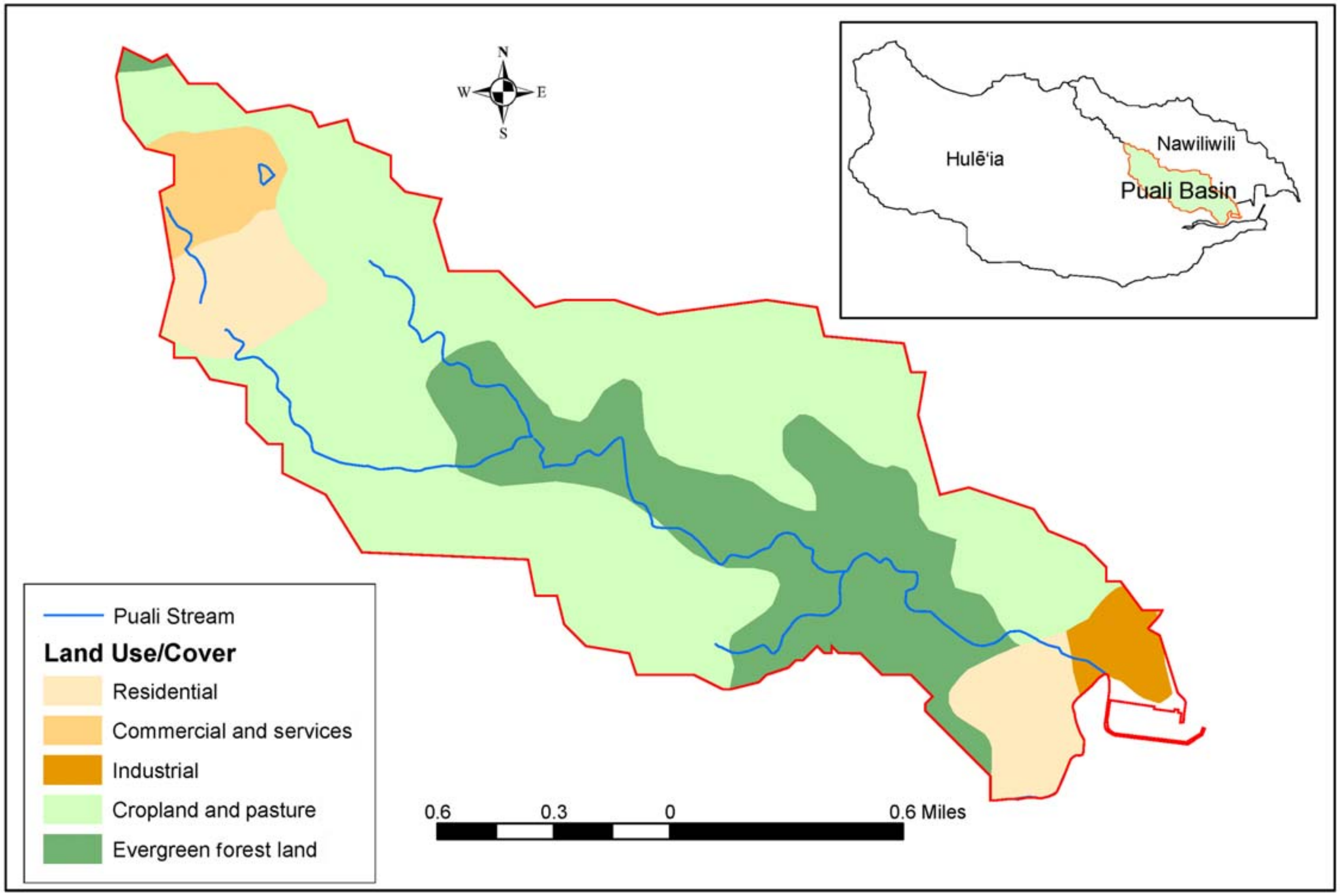

Figure 8. Land uses in the Puali Stream Basin. (Source of original maps: The Internet site of the Hawaii Statewide GIS Program, *http://www.hawaii.gov/dbedt/gis/*.)

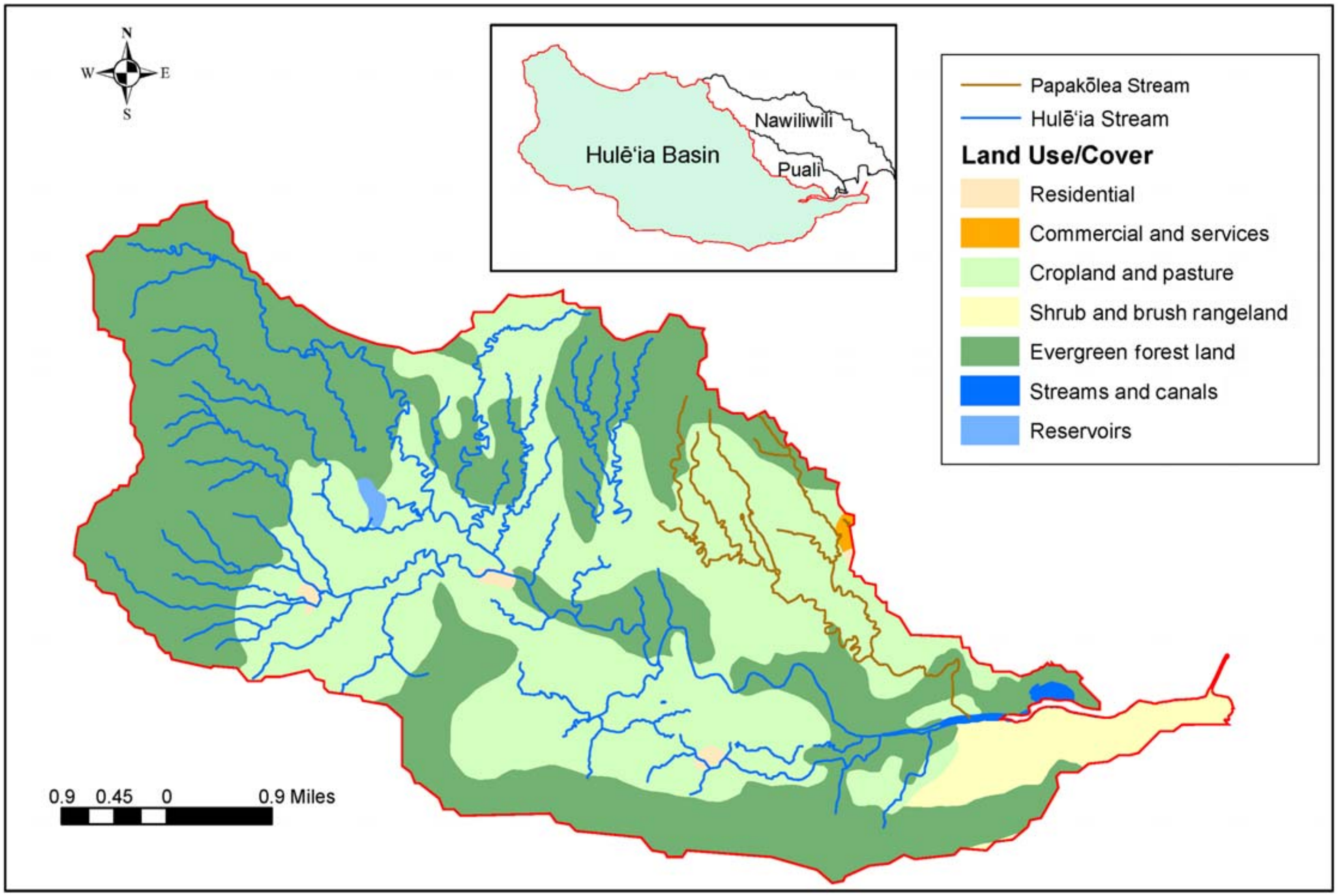

Figure 9. Land uses in the Hulēʻia Stream Basin. (Source of original maps: The Internet site of the Hawaii Statewide GIS Program, *http://www.hawaii.gov/dbedt/gis/*.)

Figure 10. Culvert discharging to Puali Stream, Kauaʻi (Photo courtesy of Mike Paul and Kristen Pavlik, Tetra Tech EM Inc., 2003)

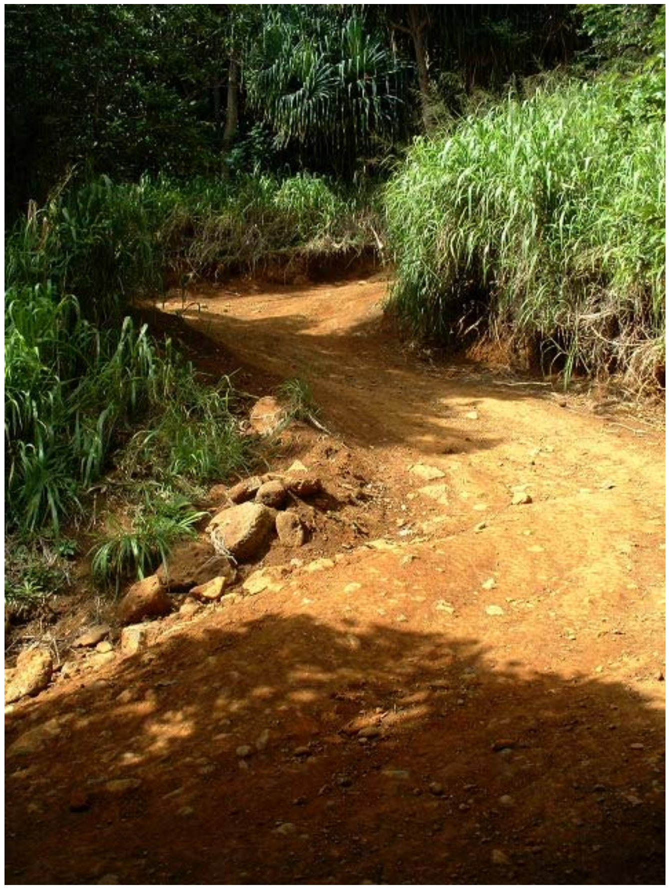

Figure 11. A steep part of a road for an ATV. Water runoff occurs in the bottom left corner of the picture. Erosion can be also seen in the same corner.

Figure 12. Paul Geisert of the the Nawiliwili Bay Watershed Council maintaining catch basin insert on Kuhio Highway

Figure 13. Possible locations for catch basin inserts near the Nawiliwili Small Boat Harbor

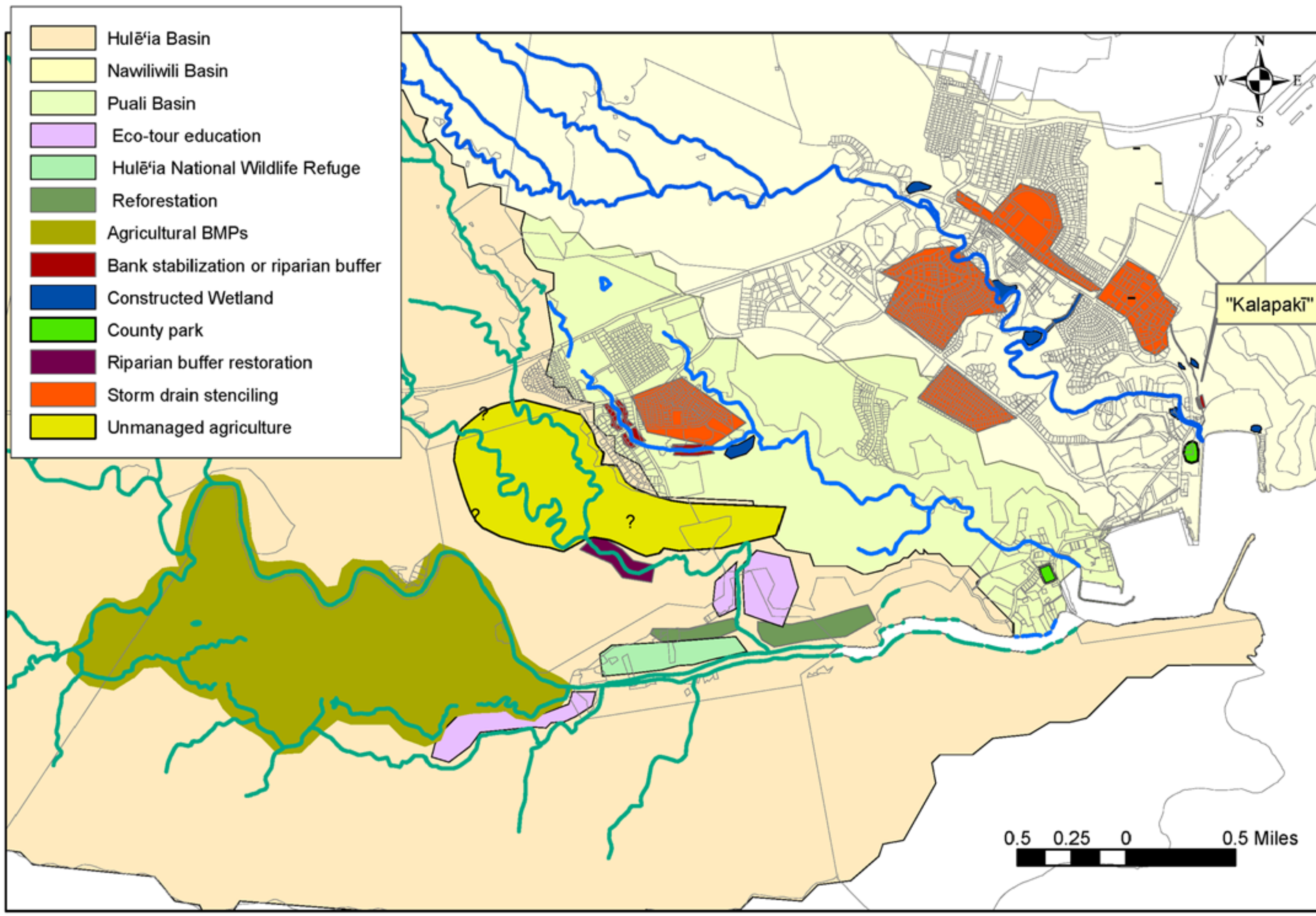

Figure 14. Approximate locations of management measures suggested for the restoration of the Nawiliwili Watershed. Question marks indicate approximate boundary. (Source of original maps: The Internet site of the Hawaii Statewide GIS Program, *http://www.hawaii.gov/dbedt/gis/*.)

Figure 15. Rice Street location for possible constructed wetland: (a) Rice Street outfall, (b) Rice Street ditch, which is probably wide enough to be modified, and (c) energy dissipater on the ditch near Nawiliwili Stream

Figure 16. Views of outfall from Rice Street at Kalena Street. The adjacent land parcel may be large enough to build a constructed wetland.

Figure 17. Views of concrete-lined channel discharging runoff into Nawiliwili Stream from Kuhio Highway. Grassy area is a possible location for a BMP.

Figure 18. Kaua'i Marriott Hotel duck pond, which is a potential location for a constructed wetland

Figure 19. Views of polluted runoff discharging from culvert into Puali Stream (Photos courtesy of Mike Paul and Kristin Pavlik, Tetra Tech EM Inc.)

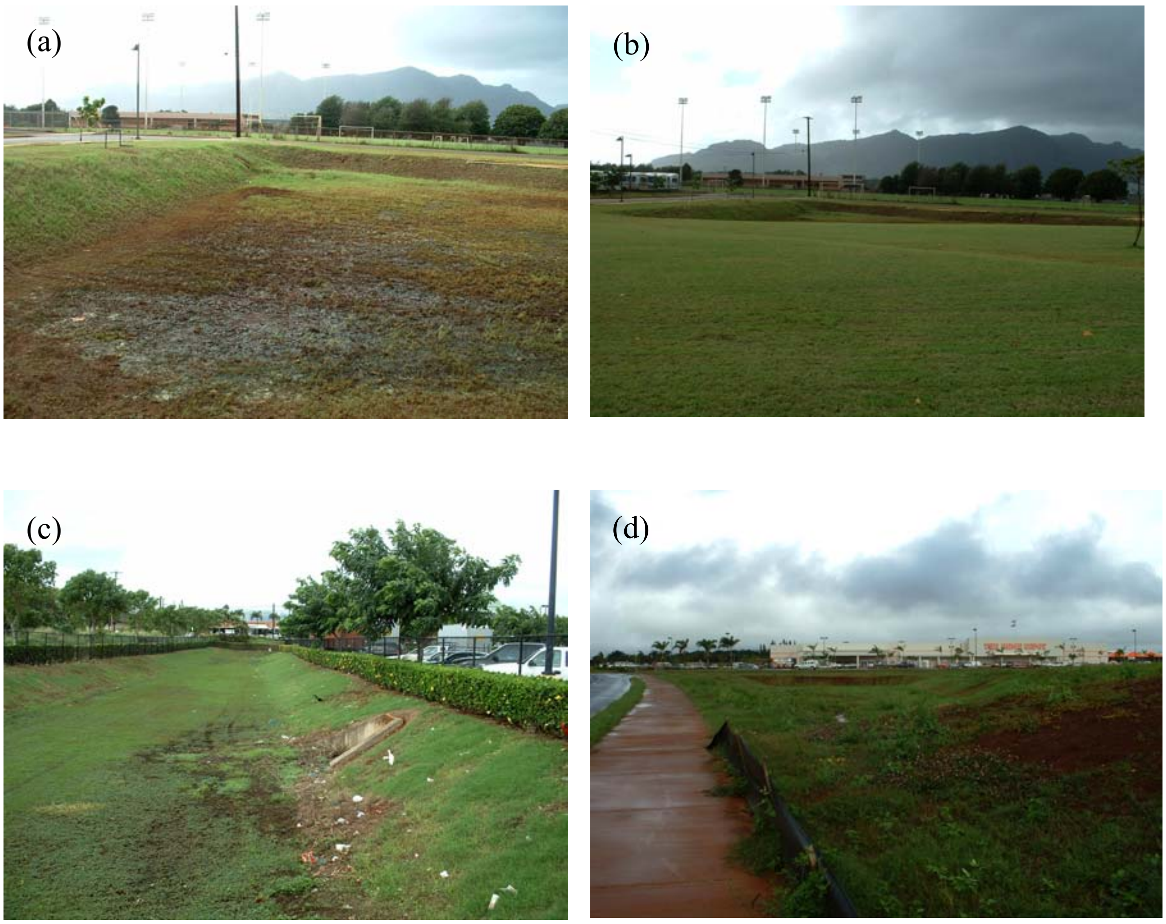

Figure 20. Existing detention basins: (a) and (b) views of detention basin at new police station in Līhuʻe, (c) BMPs at Wal-Mart, and (d) detention basin near Home Depot

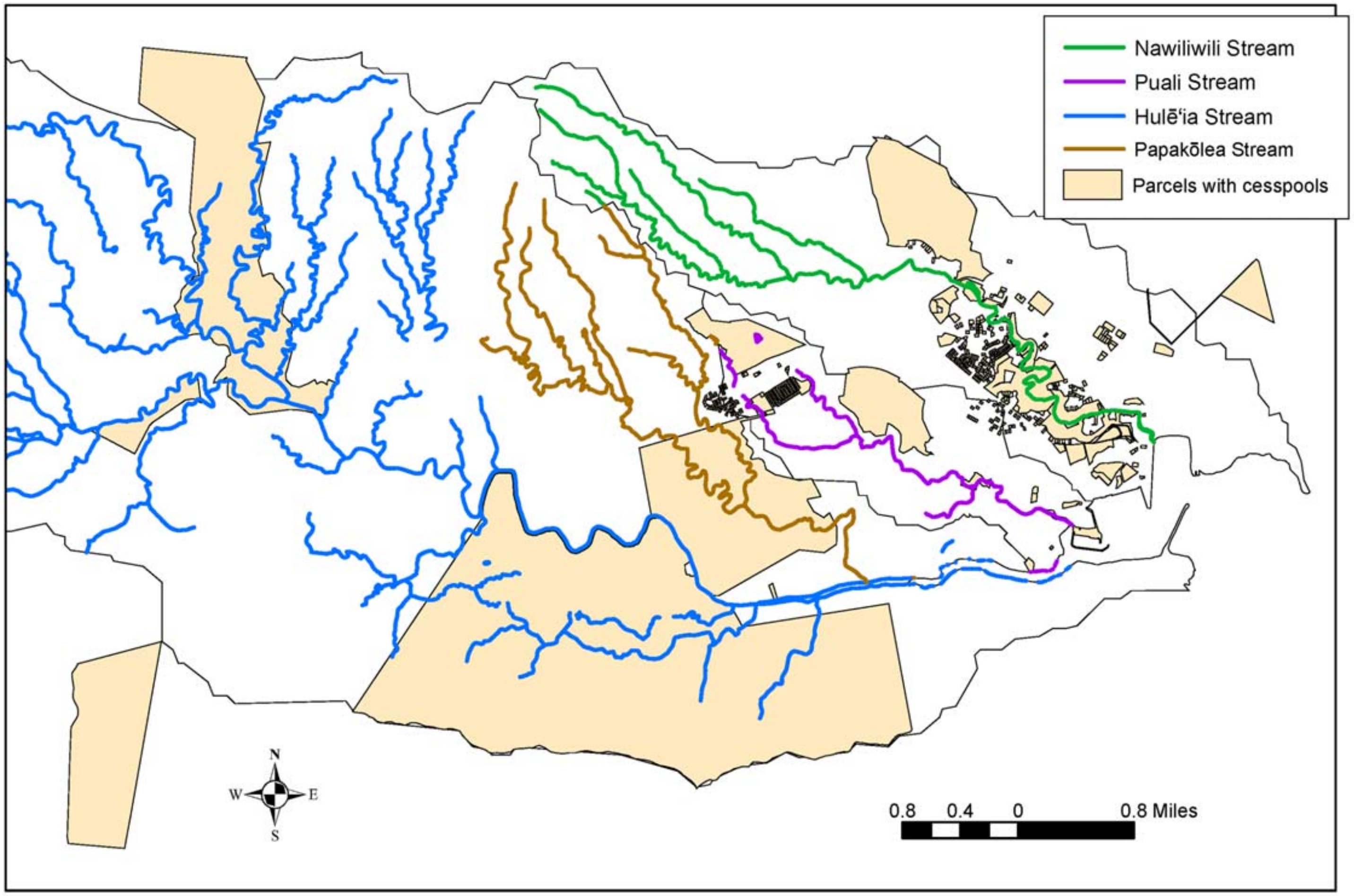

Figure 21. Parcels with cesspools in the Nawiliwili Watershed, Kaua'i. (Source of original maps: The Internet site of the Hawaii Statewide GIS Program, *http://www.hawaii.gov/dbedt/gis/*.)

Figure 22. Areas lacking riparian buffers: (a) and (b) views of fenced area near Puali Stream in Puhi, (c) gas station on banks of Puali Stream, and (d) “Kalapakī” Stream near Kaua‘i Marriott Hotel parking lot

Figure 23. Six-year-old Mahogany trees, near banks of Hulēʻia Stream

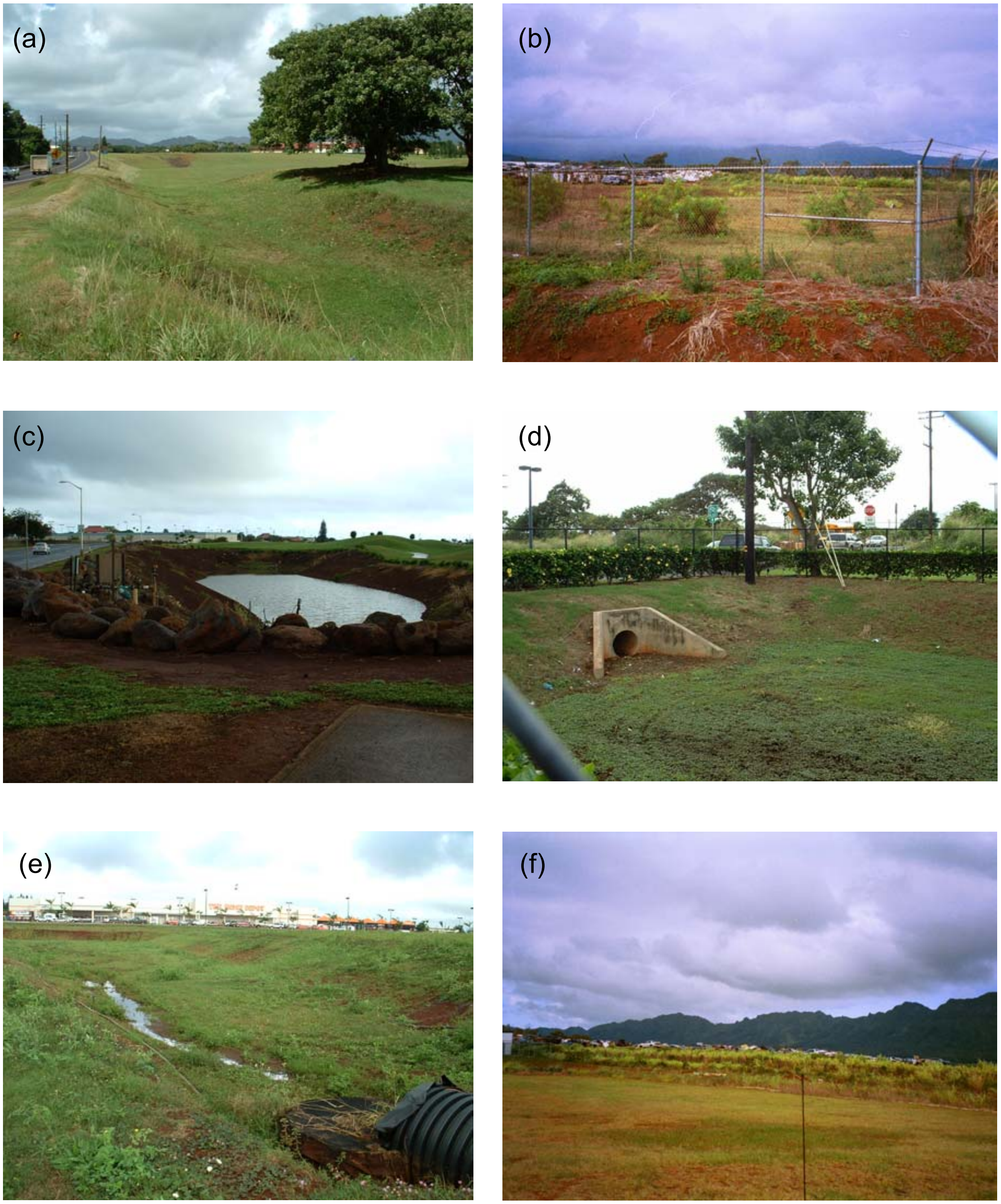

Figure 24. Existing grass channels and vegetated swales: (a) Kauaʻi Community College, (b) Puhi recycling detention basin, (c) Puakea Golf Course pond, (d) Wal-Mart, (e) detention basin near Home Depot, and (f) Kauaʻi County metals recycling detention basin

Figure 25. Illegally “parked” boats in the Hulēʻia Estuary

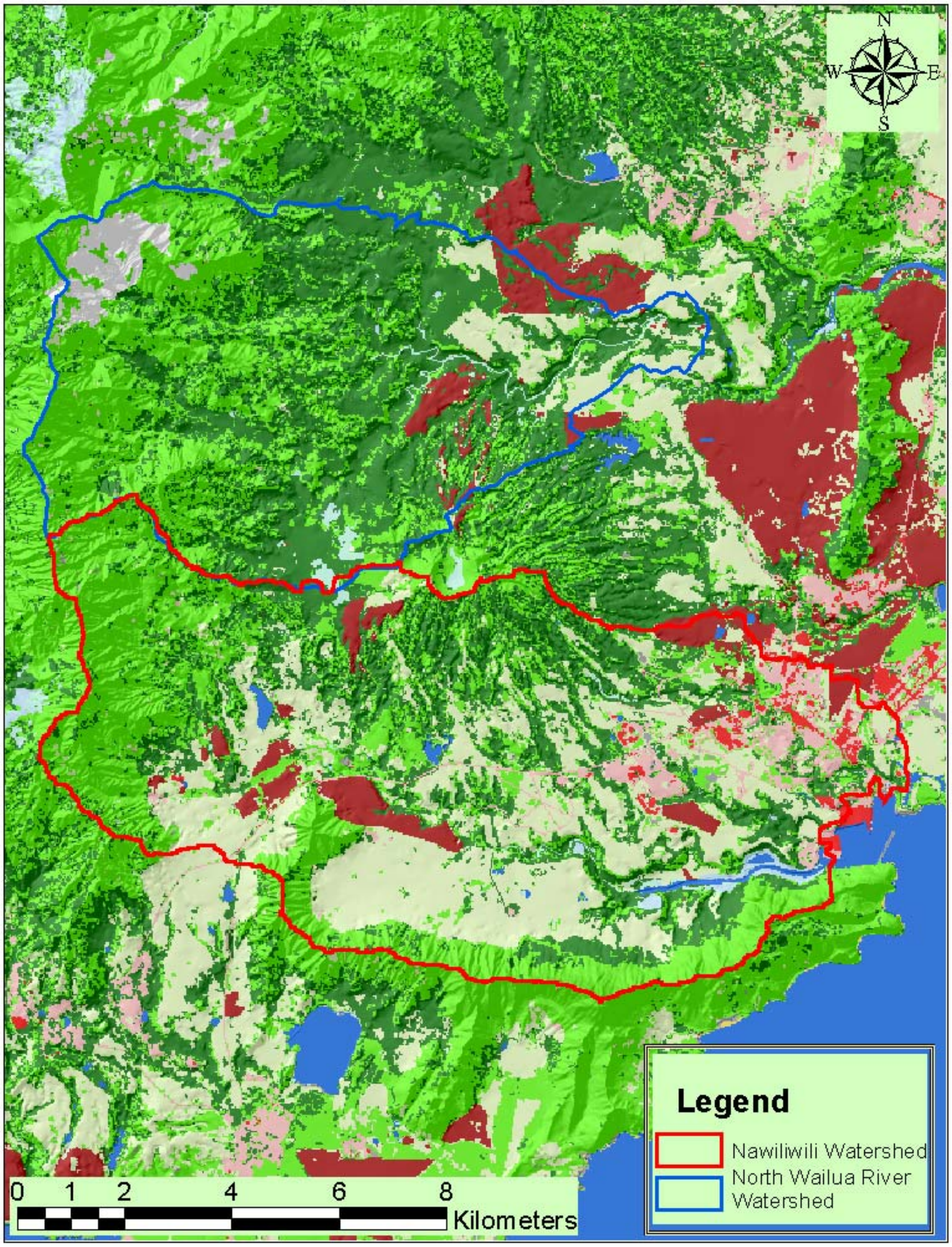

Figure 26. Location of Nawiliwili and North Wailua River watersheds, Kaua‘i

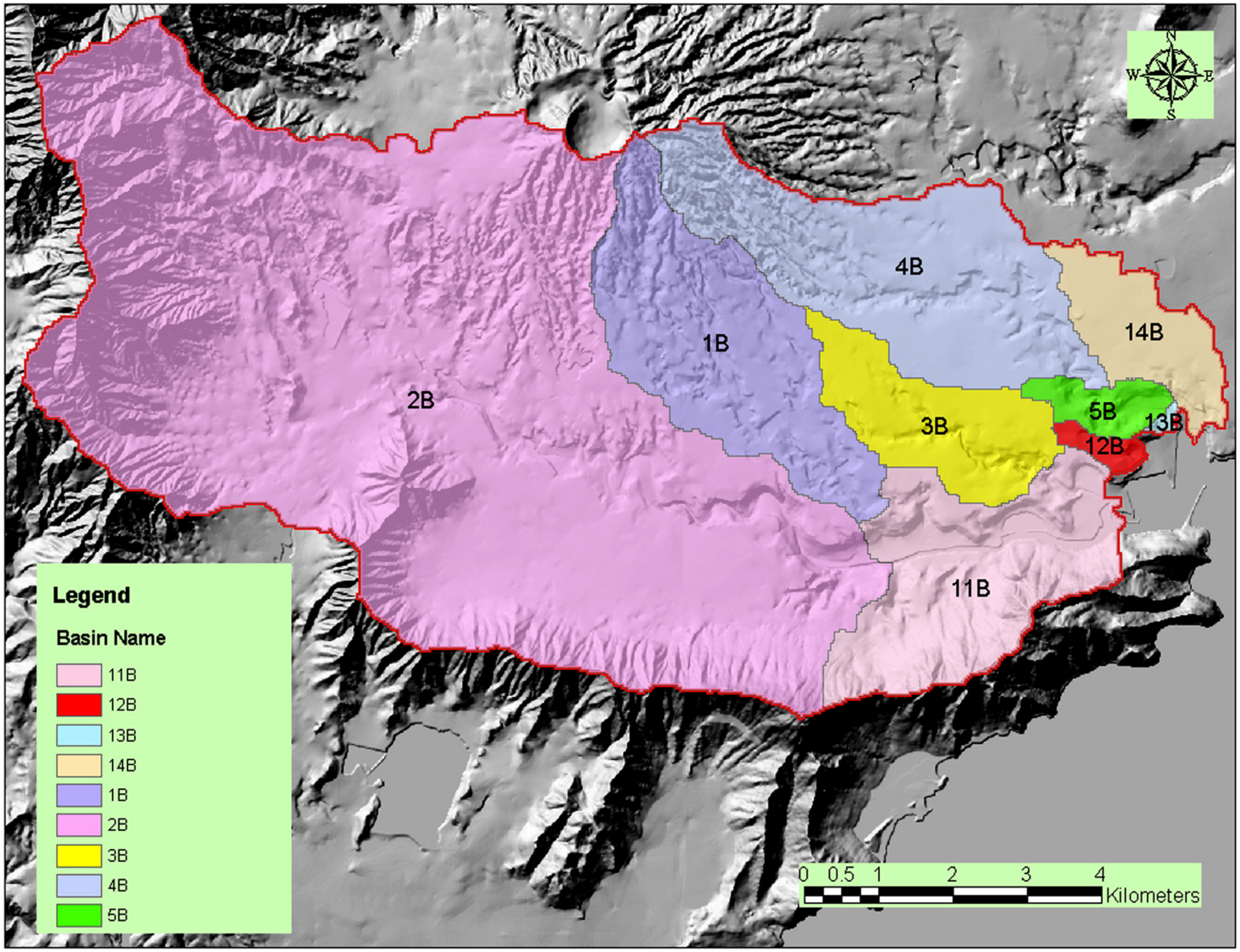

Figure 27. Basins of Nawiliwili Watershed

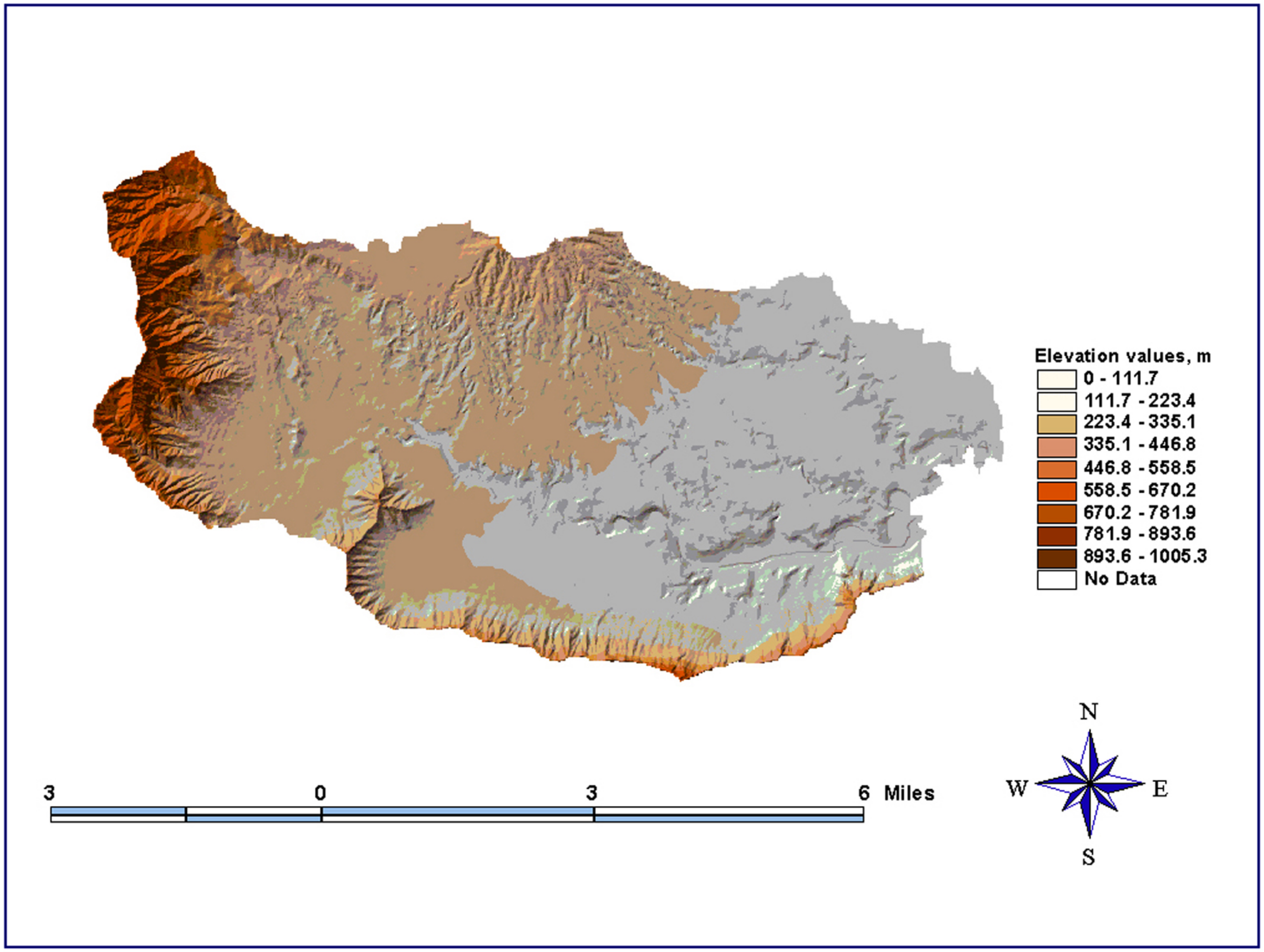

Figure 28. Digital elevation model for Nawiliwili Watershed

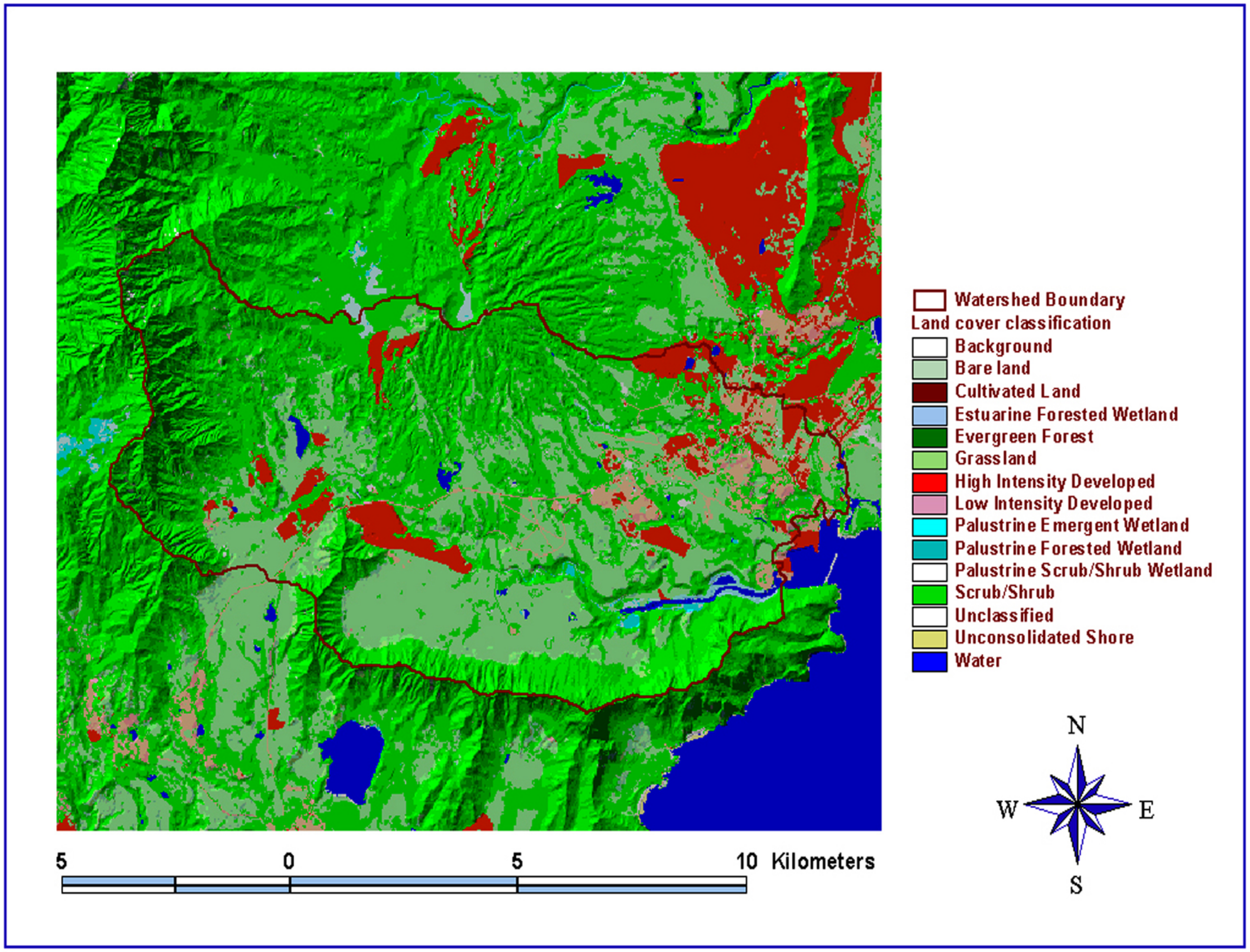

Figure 29. Land cover map for Nawiliwili Watershed

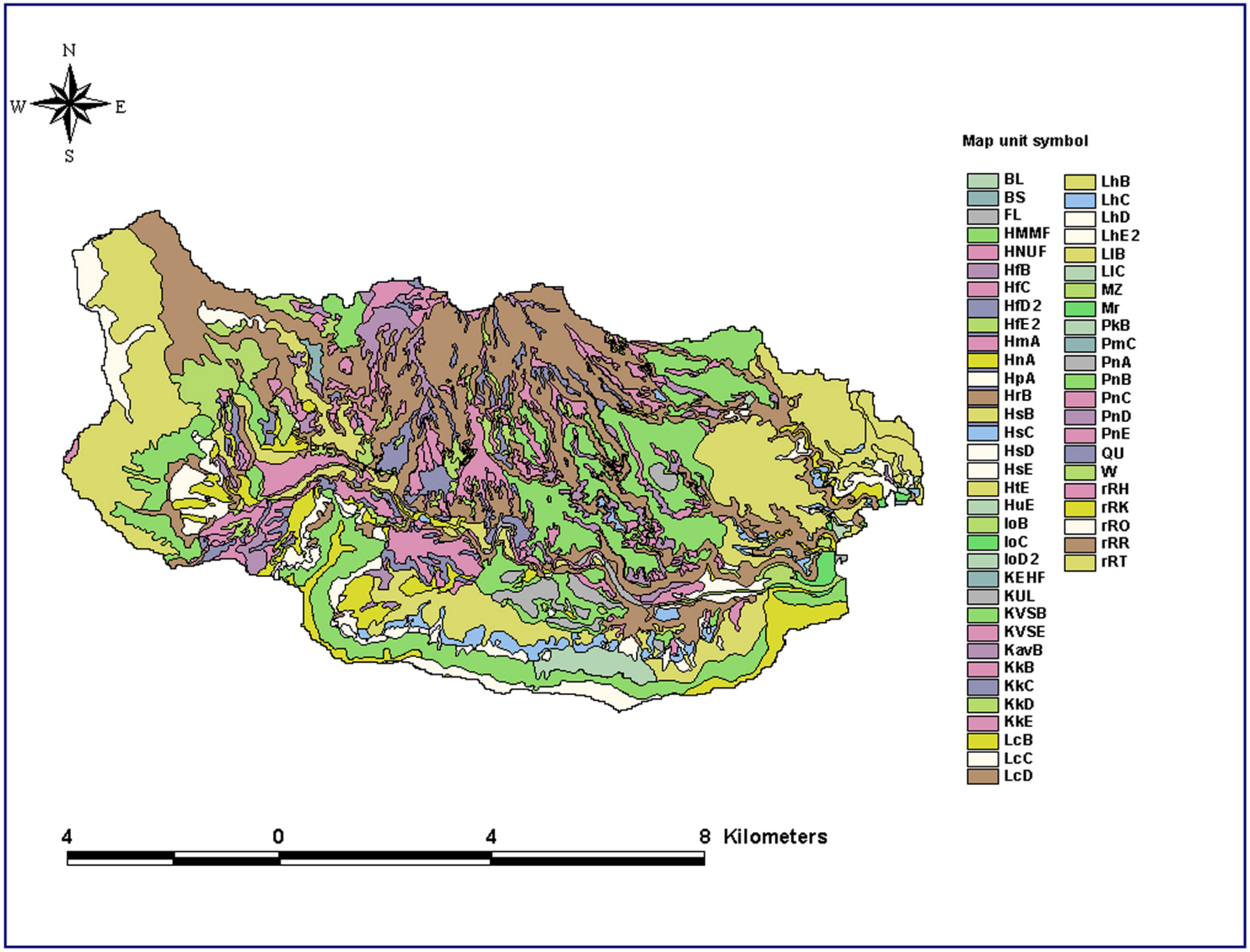

Figure 30. SSURGO soil map for Nawiliwili Watershed

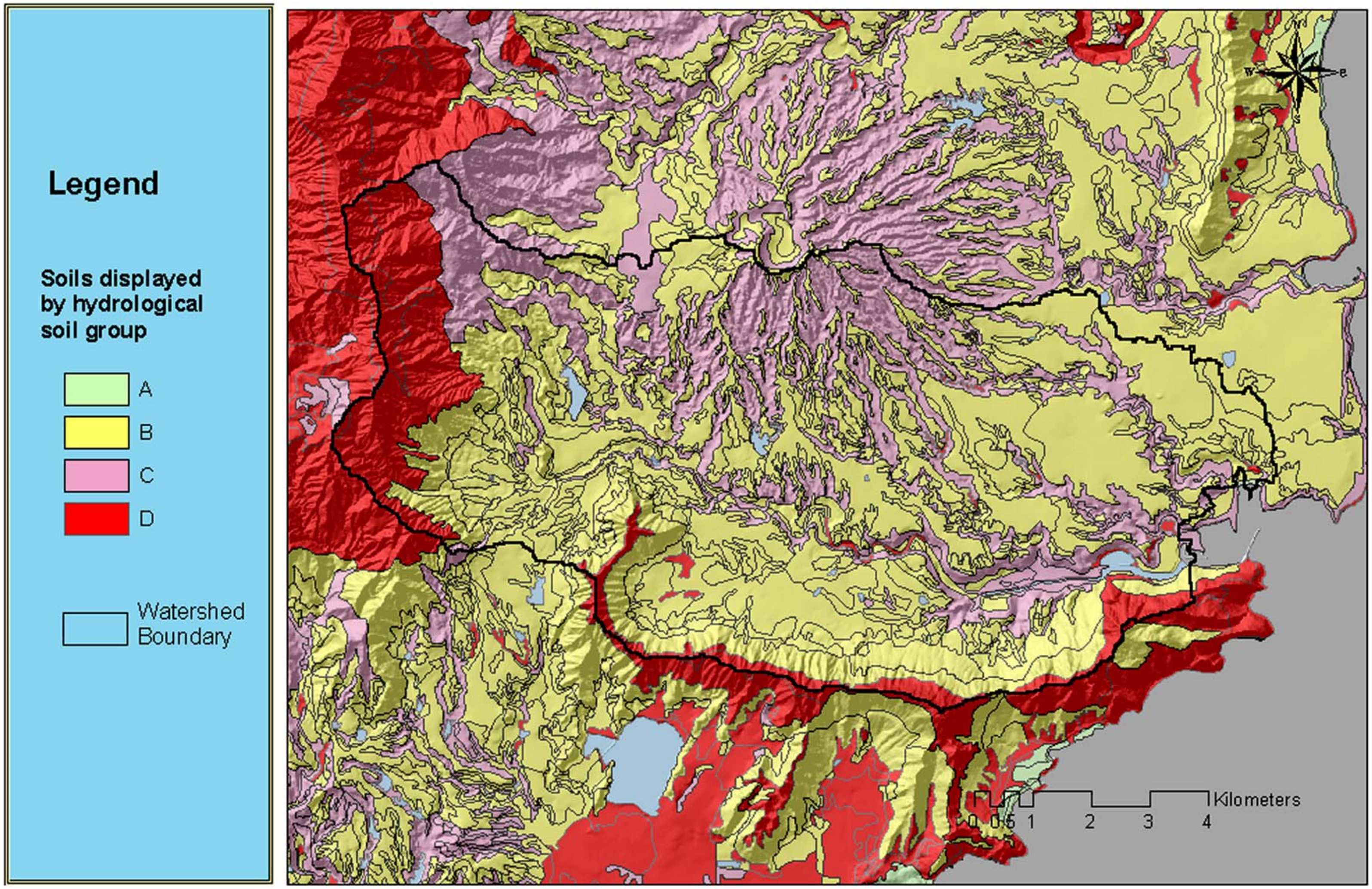

Figure 31. Hydrological soil group map for Nawiliwili Watershed

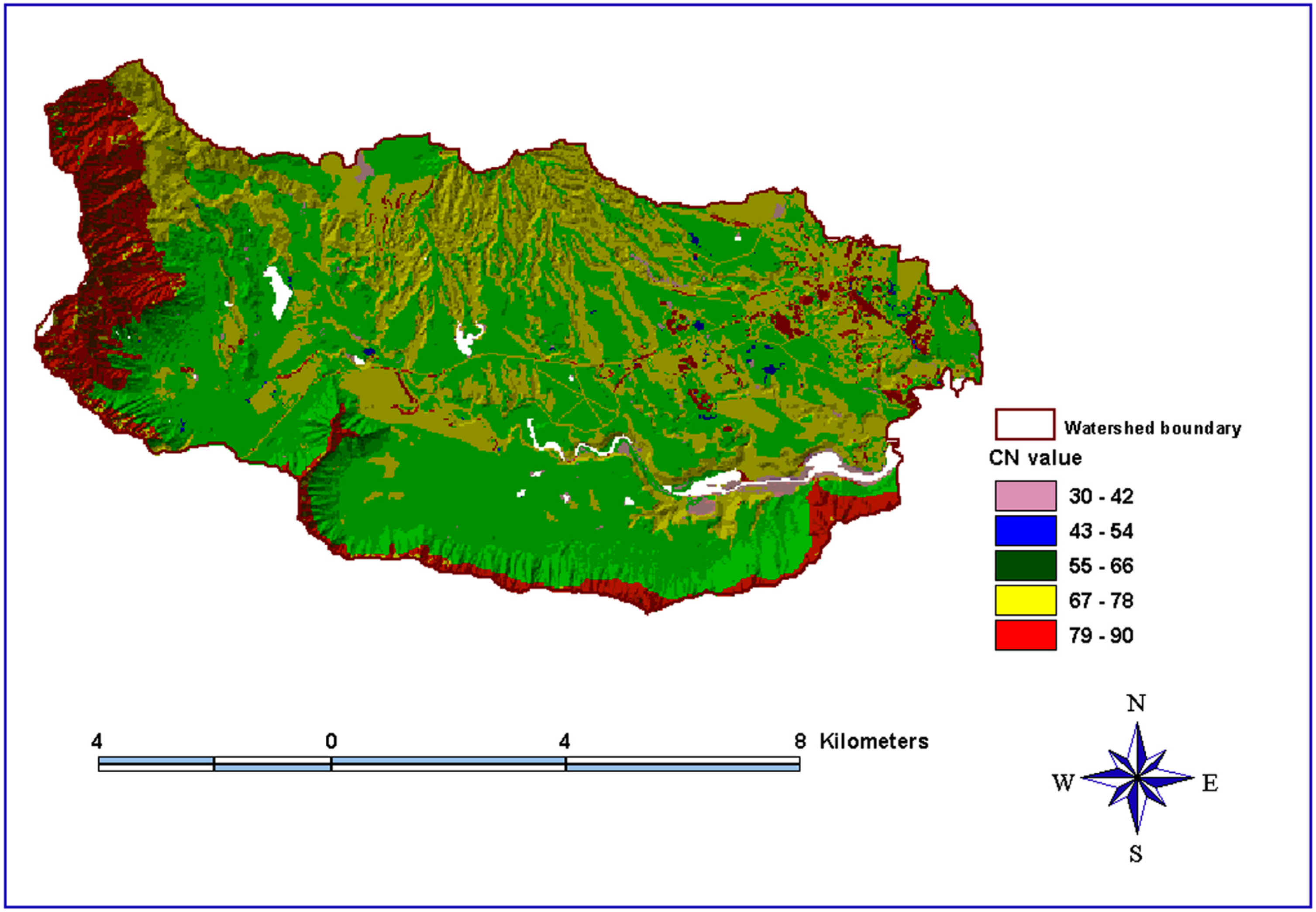

Figure 32. Curve number map for Nawiliwili Watershed

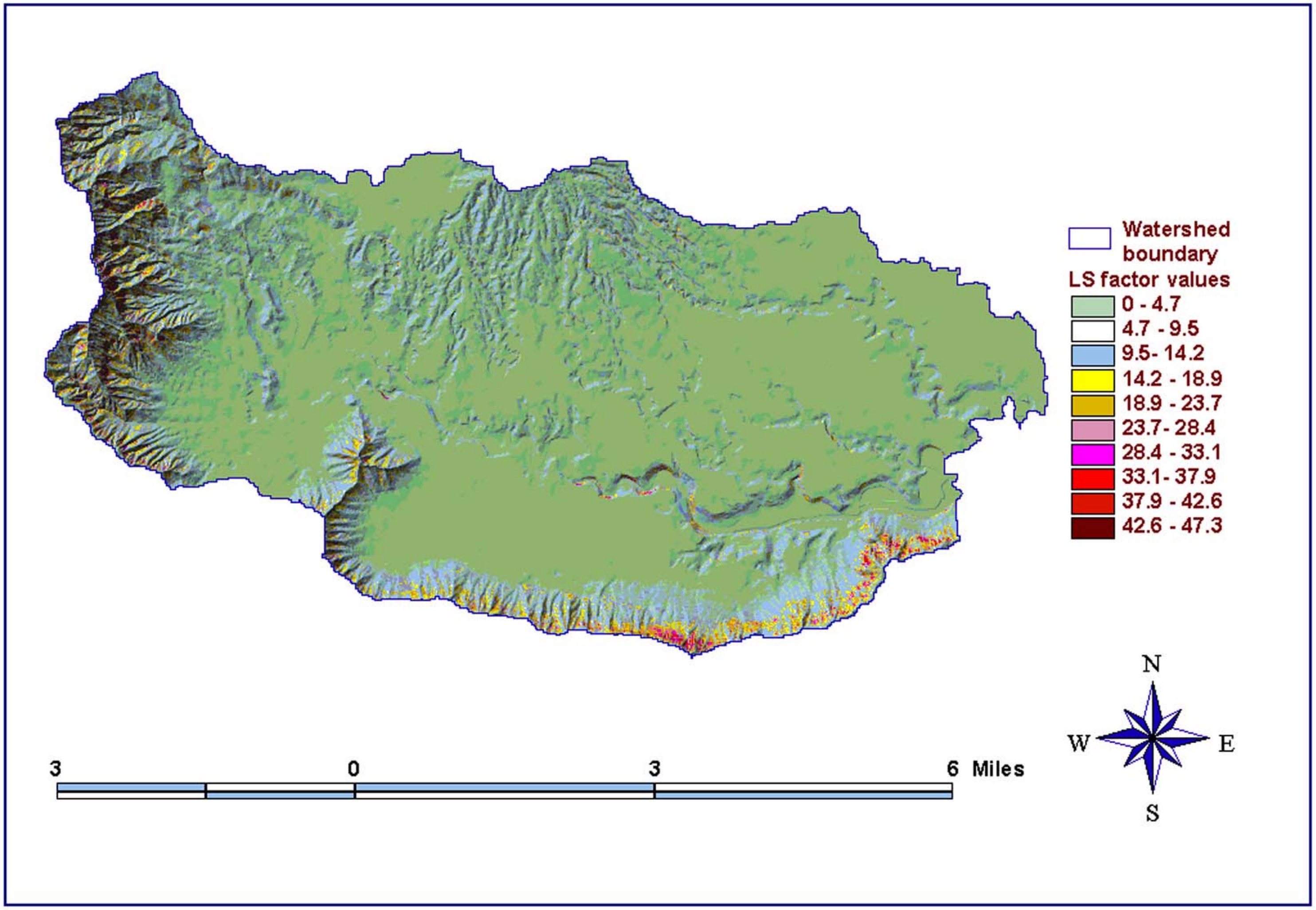

Figure 33. *LS* factor map for Nawiliwili Watershed

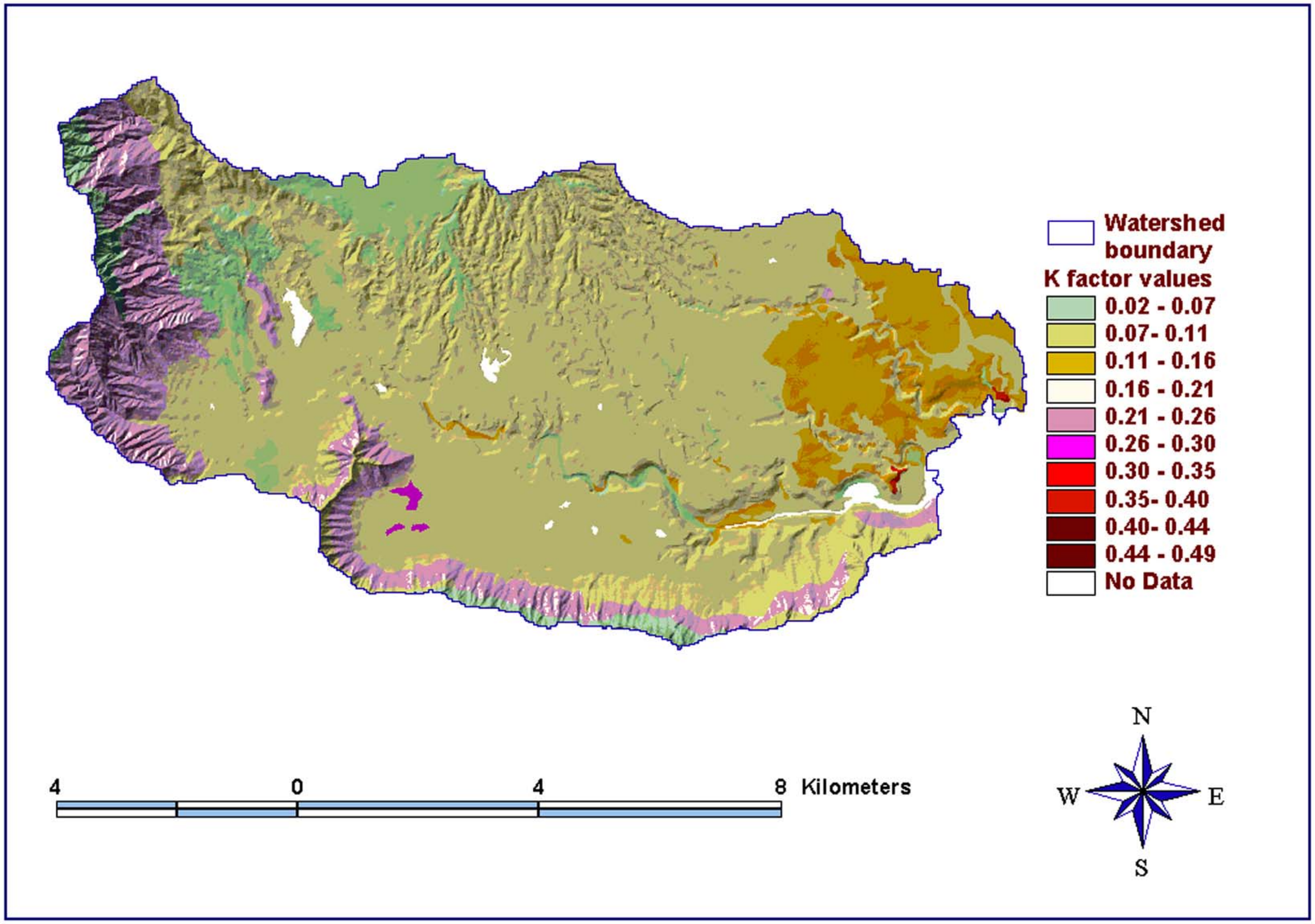

Figure 34. *K* factor map for Nawiliwili Watershed

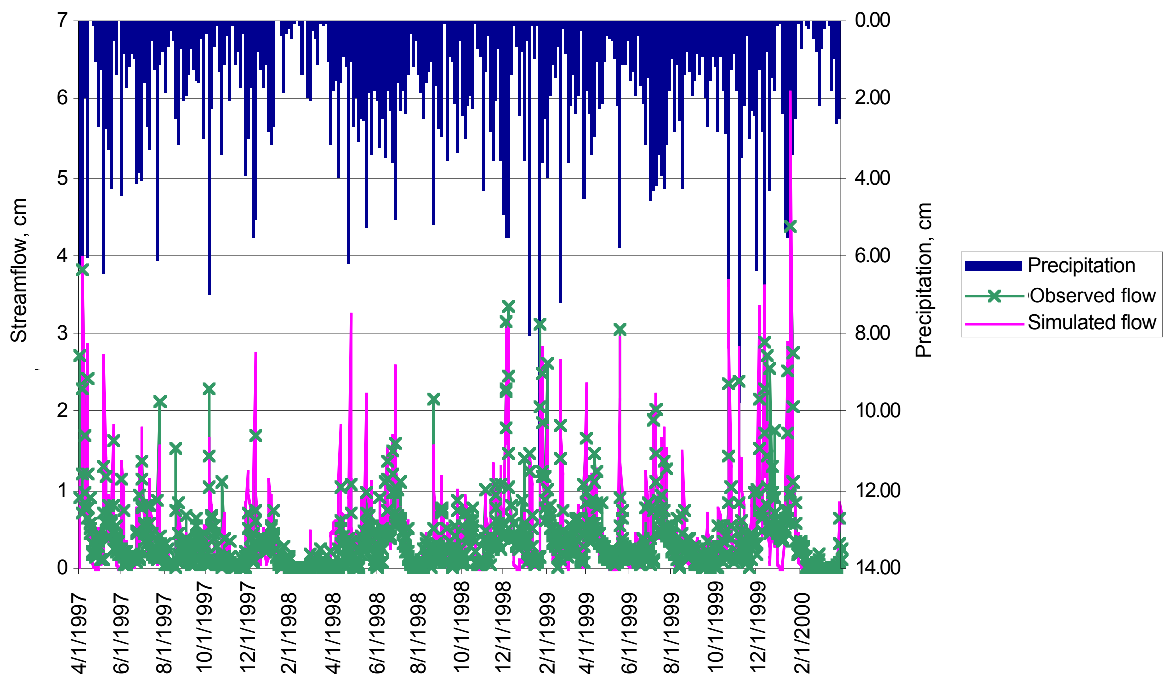

Figure 35. Observed versus simulated streamflow time plot for the North Wailua River watershed

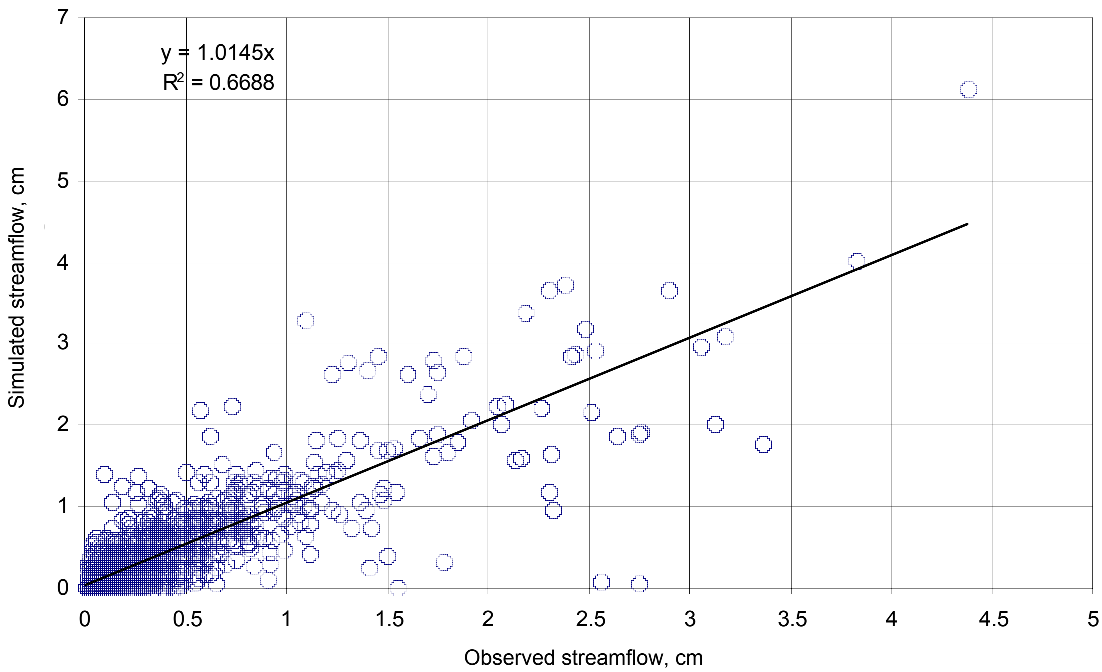

Figure 36. Scatter plot between observed streamflow and the GWLF-simulated streamflow at the outlet of North Wailua River watershed

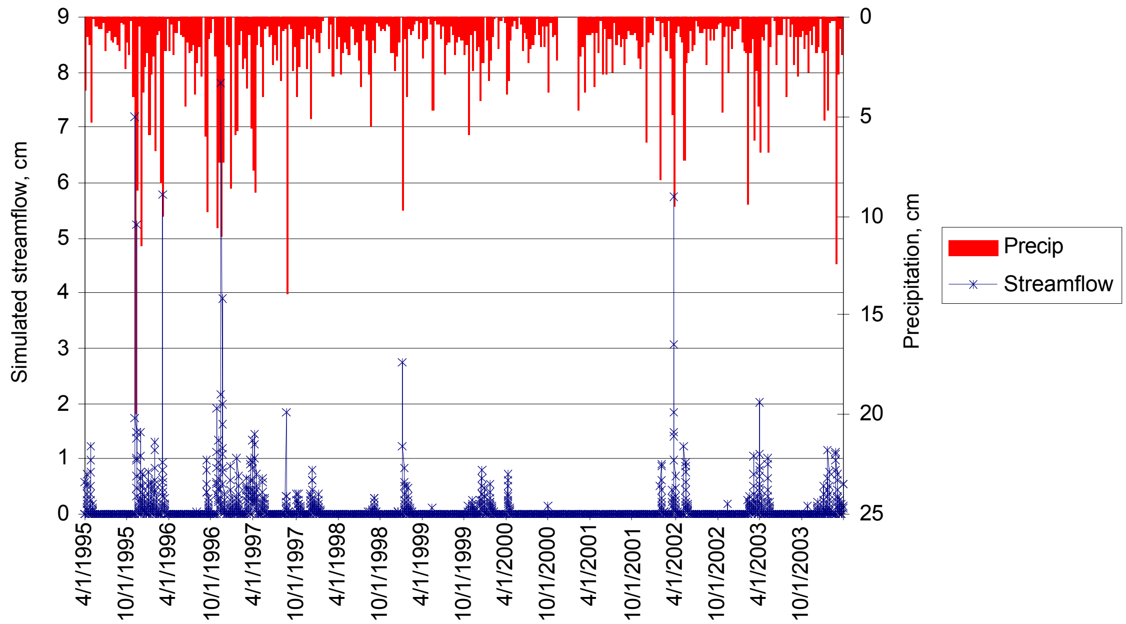

Figure 37. Daily simulated streamflow at the outlet of Basin 1B in Nawiliwili Watershed

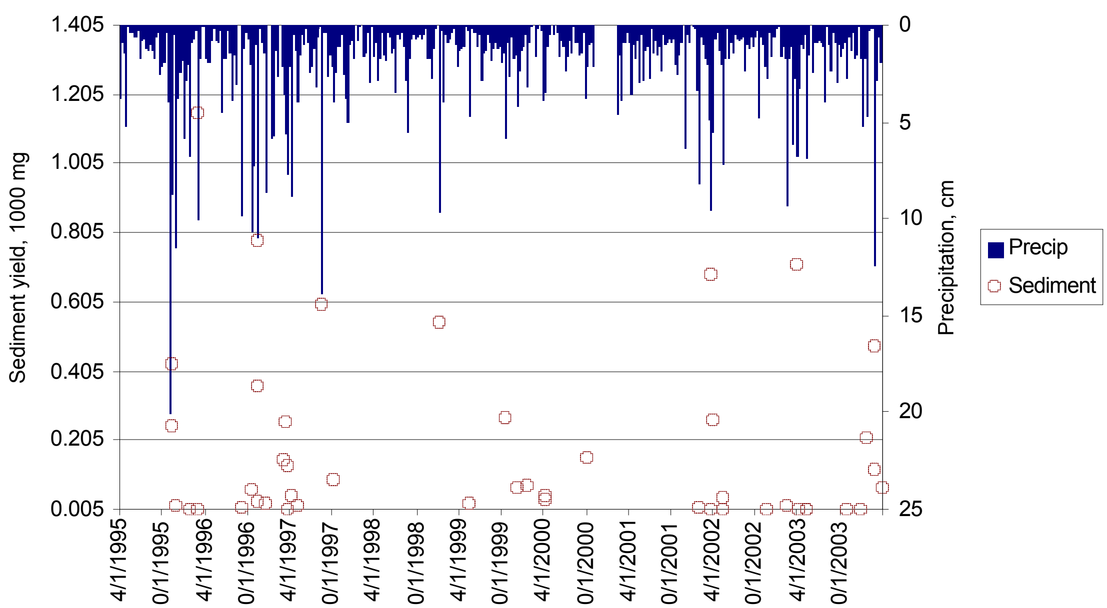

Figure 38. Daily simulated sediment yield at the outlet of Basin 1B in Nawiliwili Watershed

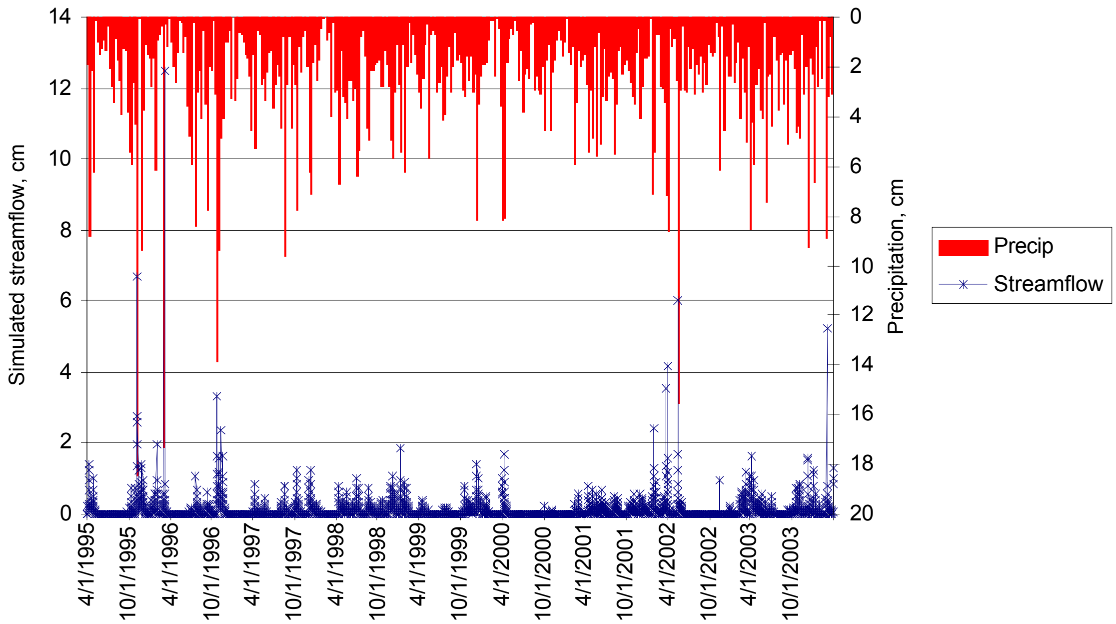

Figure 39. Daily simulated streamflow at the outlet of Basin 2B in Nawiliwili Watershed

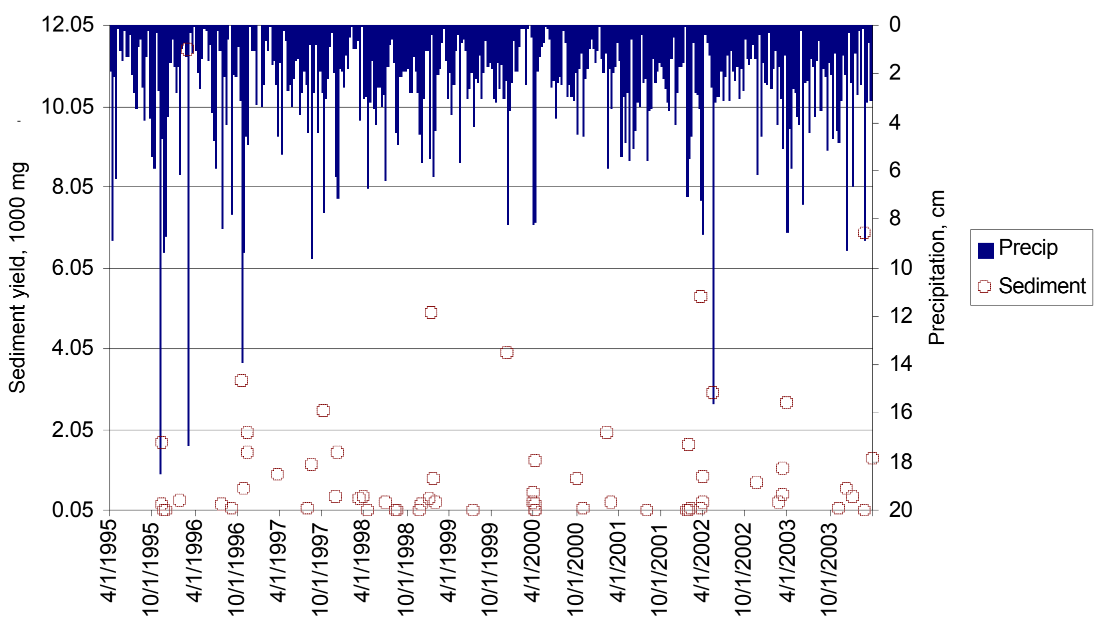

Figure 40. Daily simulated sediment yield at the outlet of Basin 2B in Nawiliwili Watershed

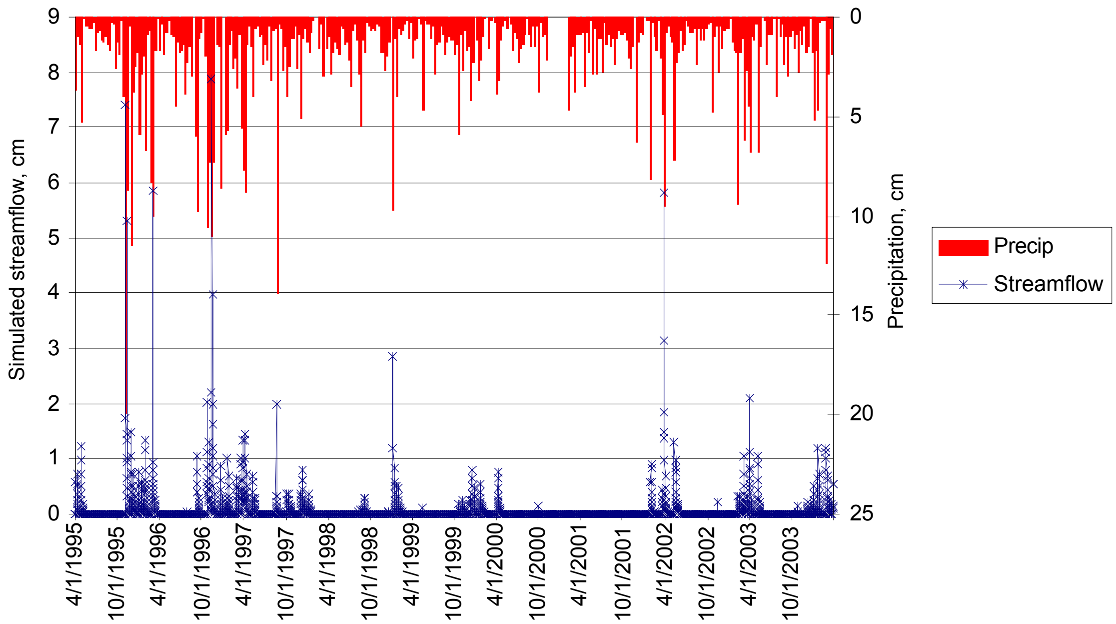

Figure 41. Daily simulated streamflow at the outlet of Basin 3B in Nawiliwili Watershed

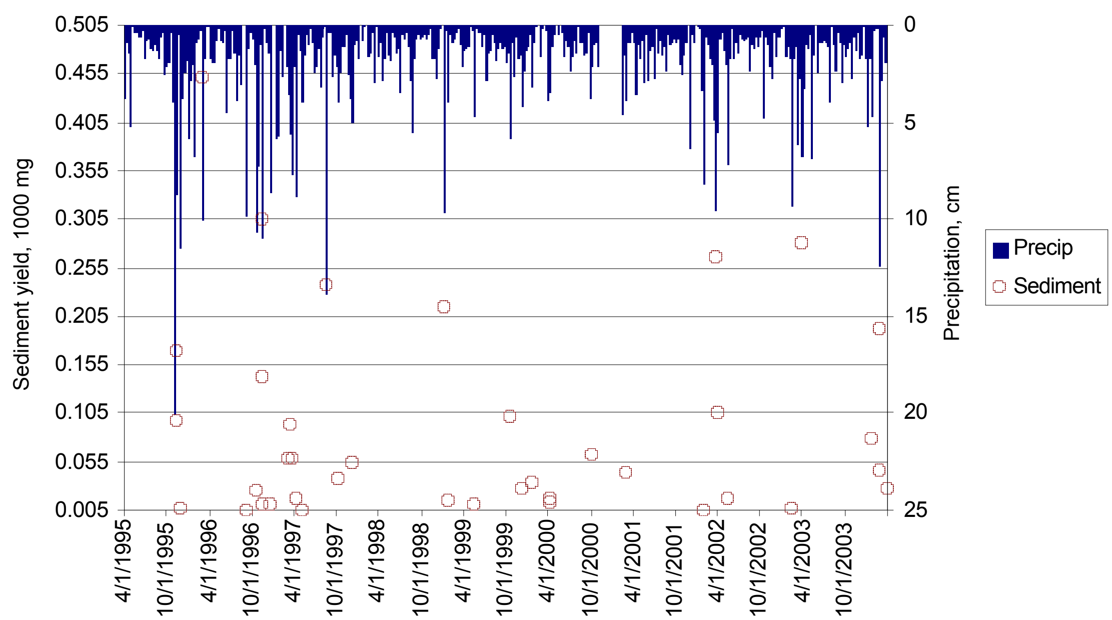

Figure 42. Daily simulated sediment yield at the outlet of Basin 3B in Nawiliwili Watershed

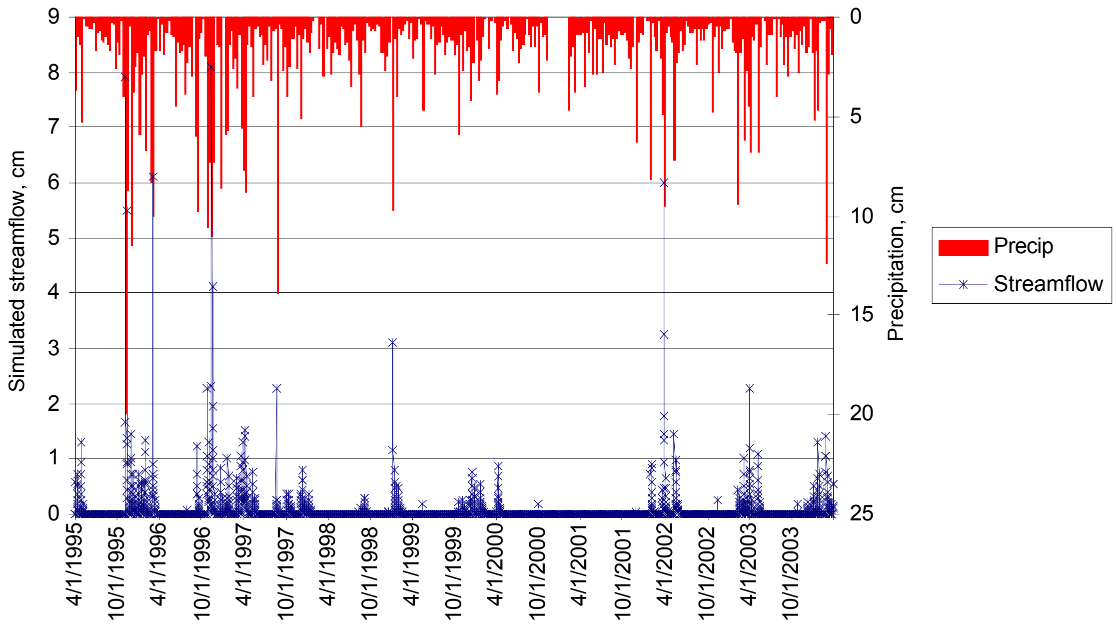

Figure 43. Daily simulated streamflow at the outlet of Basin 4B in Nawiliwili Watershed

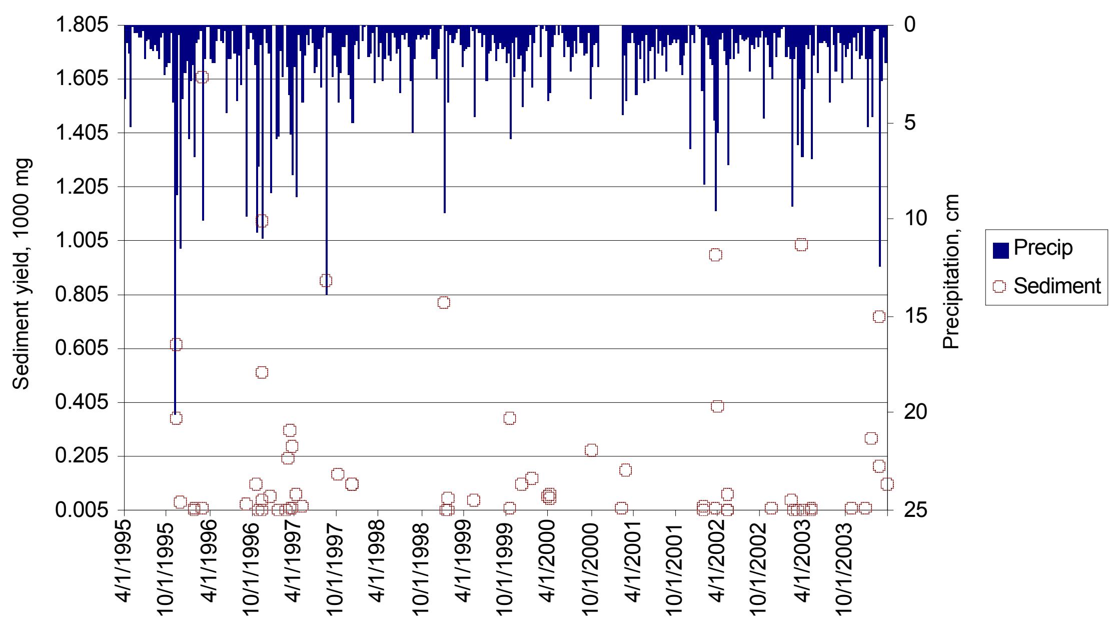

Figure 44. Daily simulated sediment yield at the outlet of Basin 4B in Nawiliwili Watershed

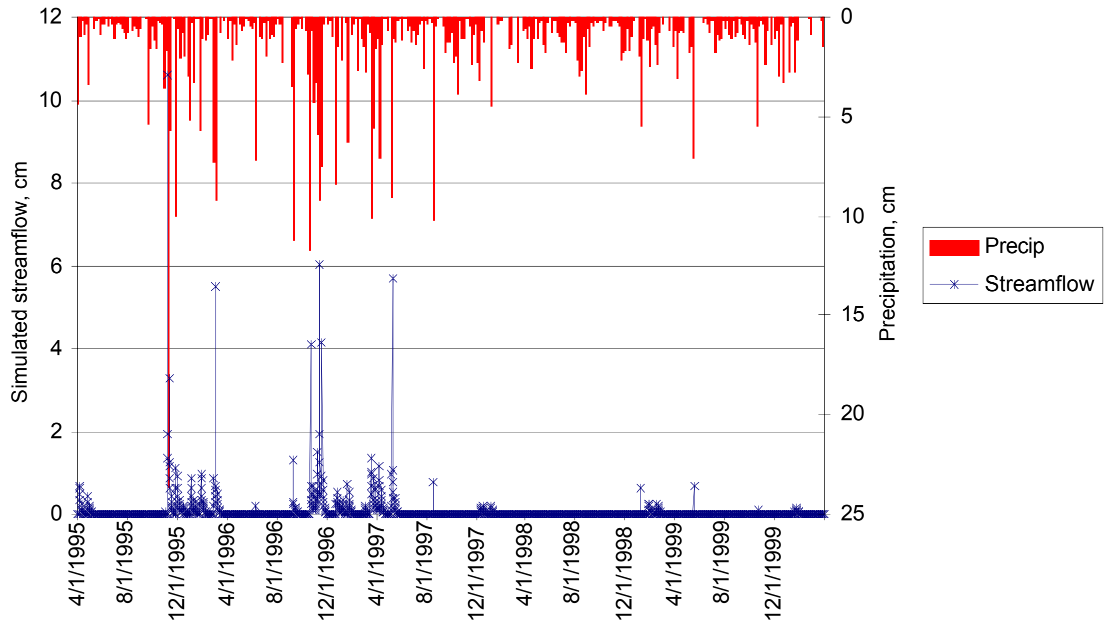

Figure 45. Daily simulated streamflow at the outlet of Basin 5B in Nawiliwili Watershed

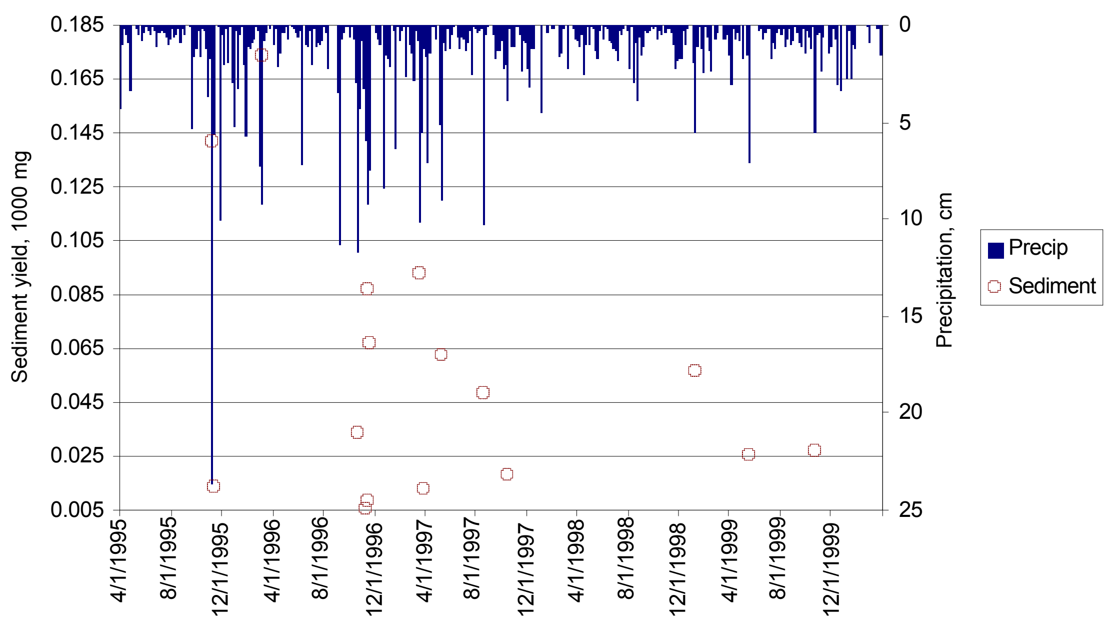

Figure 46. Daily simulated sediment yield at the outlet of Basin 5B in Nawiliwili Watershed

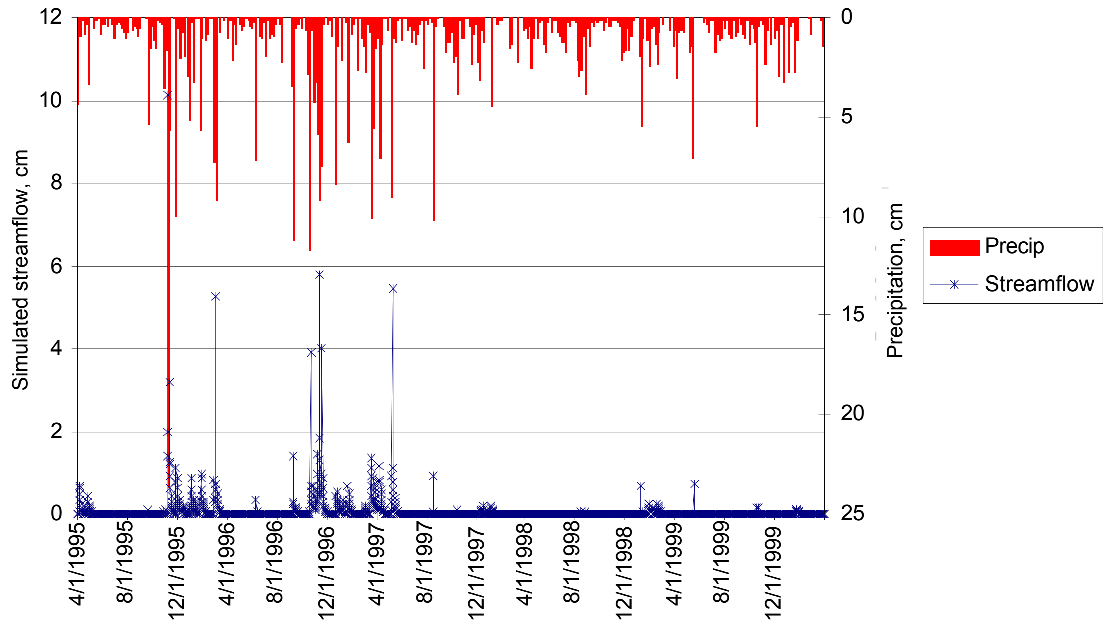

Figure 47. Daily simulated streamflow at the outlet of Basin 12B in Nawiliwili Watershed

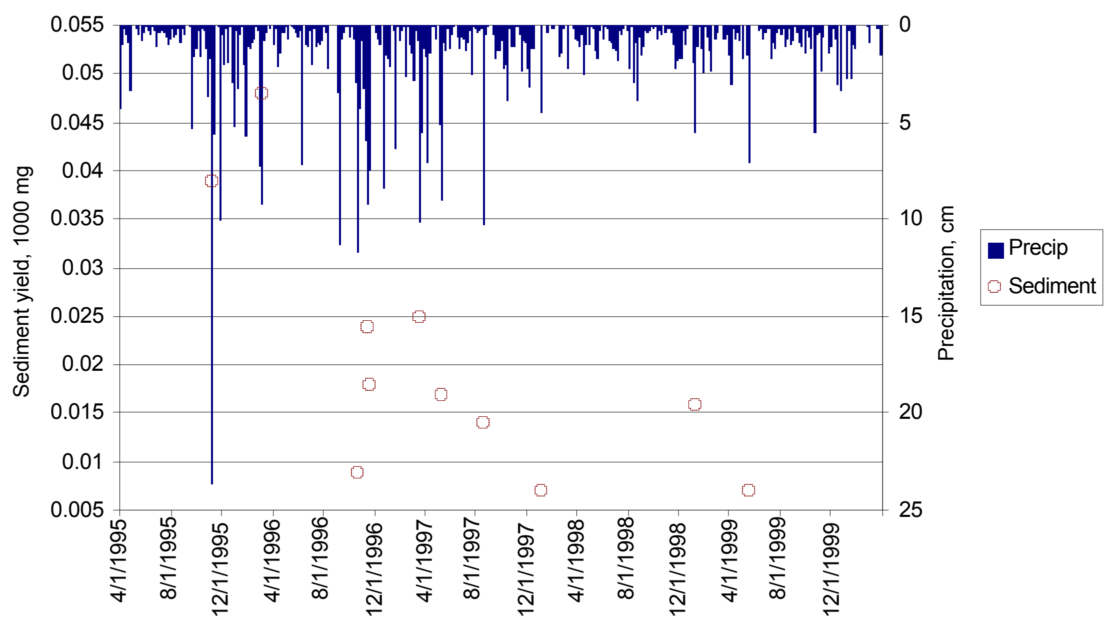

Figure 48. Daily simulated sediment yield at the outlet of Basin 12B in Nawiliwili Watershed

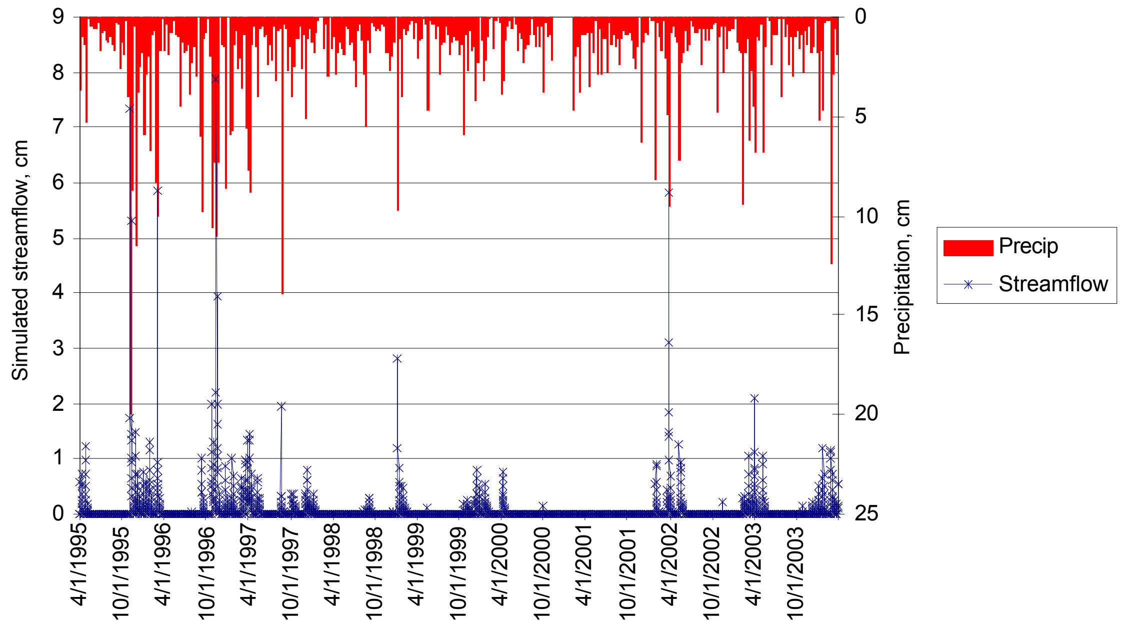

Figure 49. Daily simulated streamflow at the outlet of Basin 11B in Nawiliwili Watershed

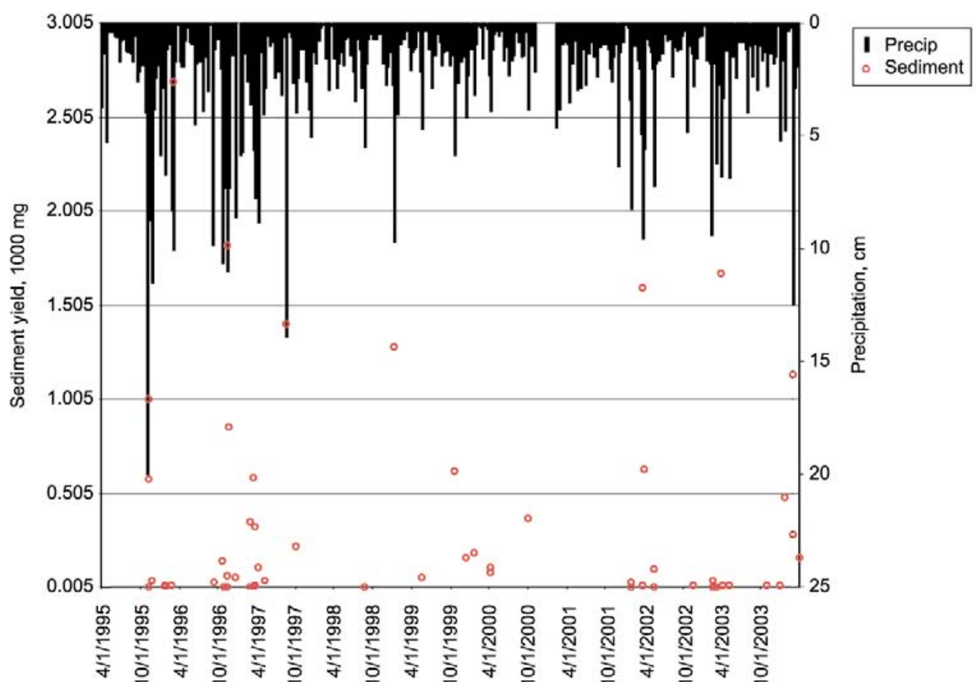

Figure 50. Daily simulated sediment yield at the outlet of Basin 11B in Nawiliwili Watershed

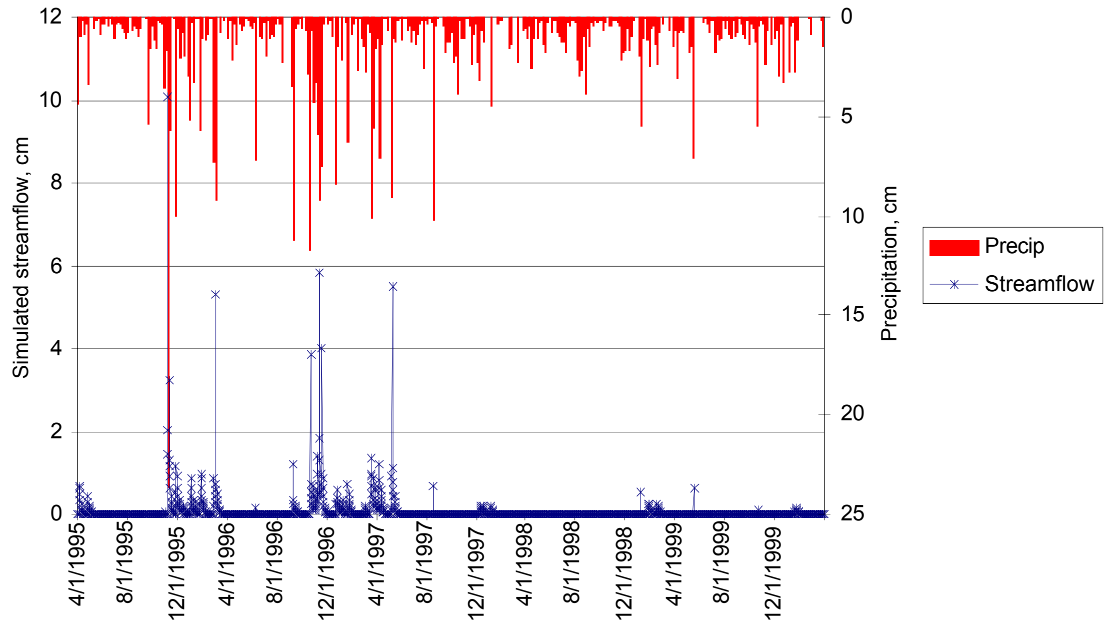

Figure 51. Daily simulated streamflow at the outlet of Basin 14B in Nawiliwili Watershed

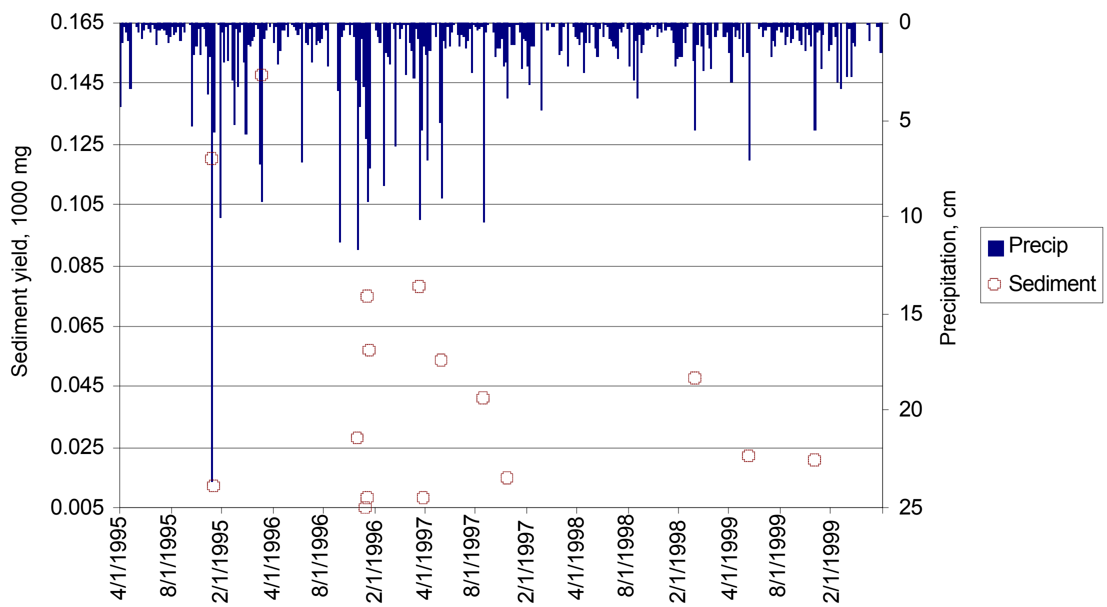

Figure 52. Daily simulated sediment yield at the outlet of Basin 14B in Nawiliwili Watershed

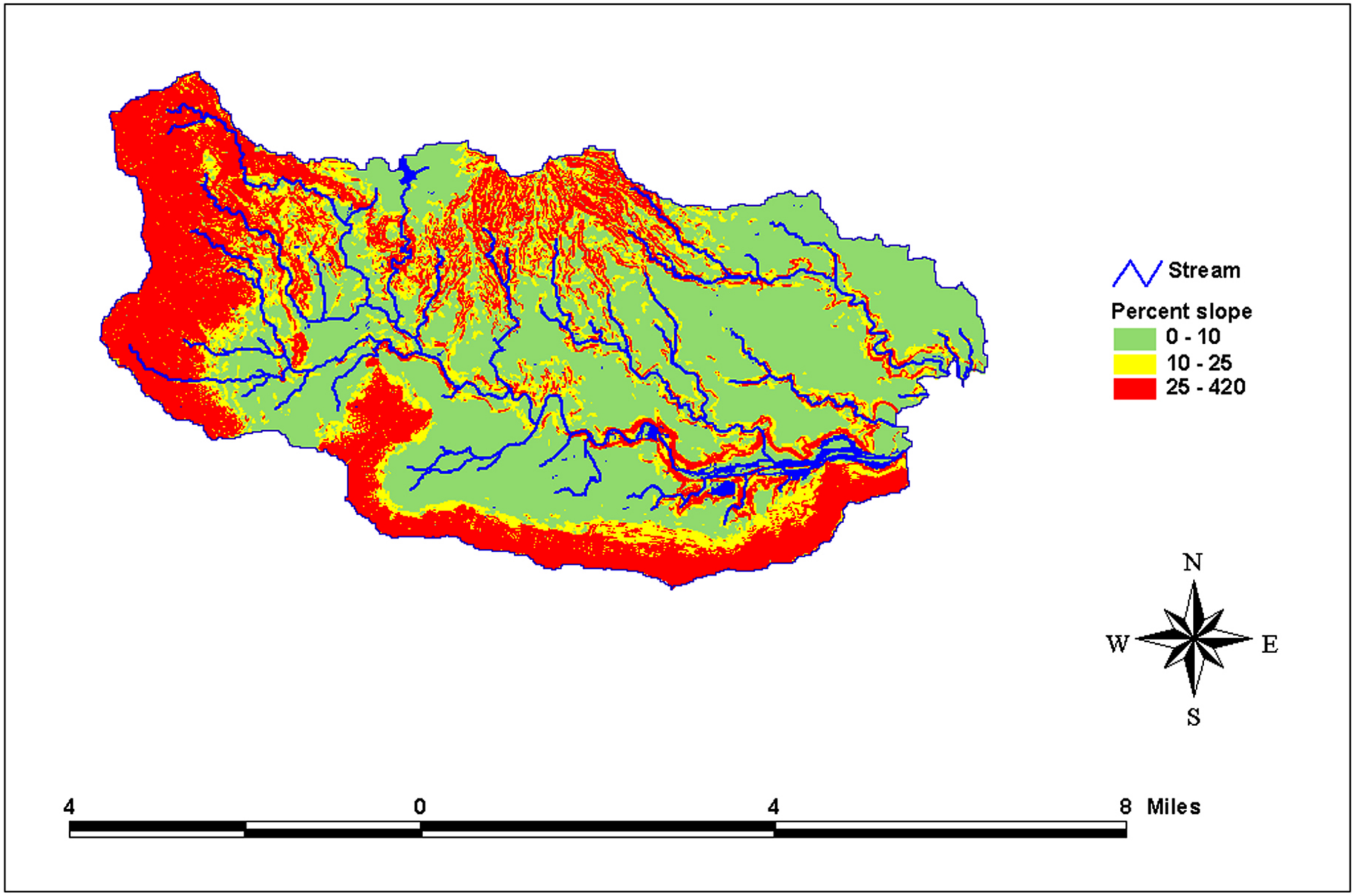

Figure 53. Nawiliwili Watershed streams overlaid on the ground surface slope map

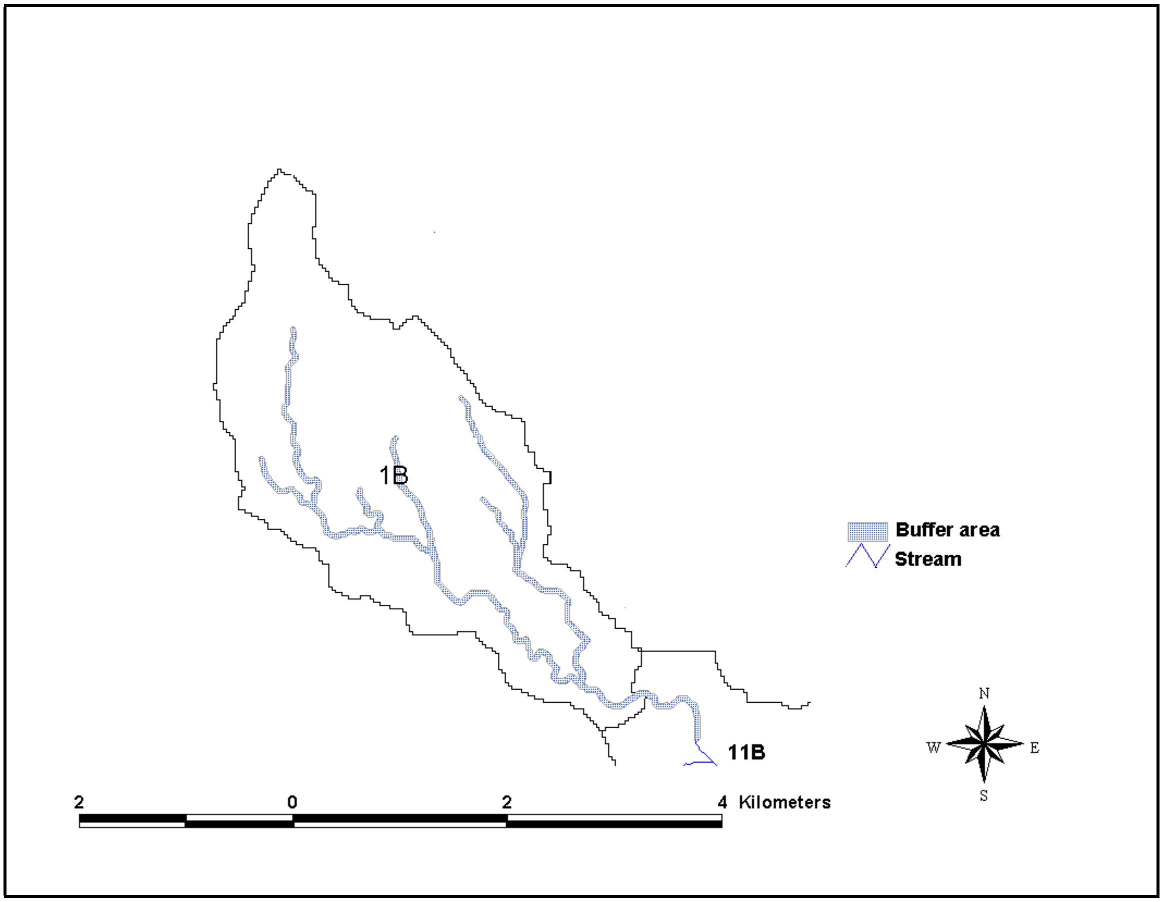

Figure 54(a). Feasible riparian buffer zones for Basin 1B in the Nawiliwili Watershed

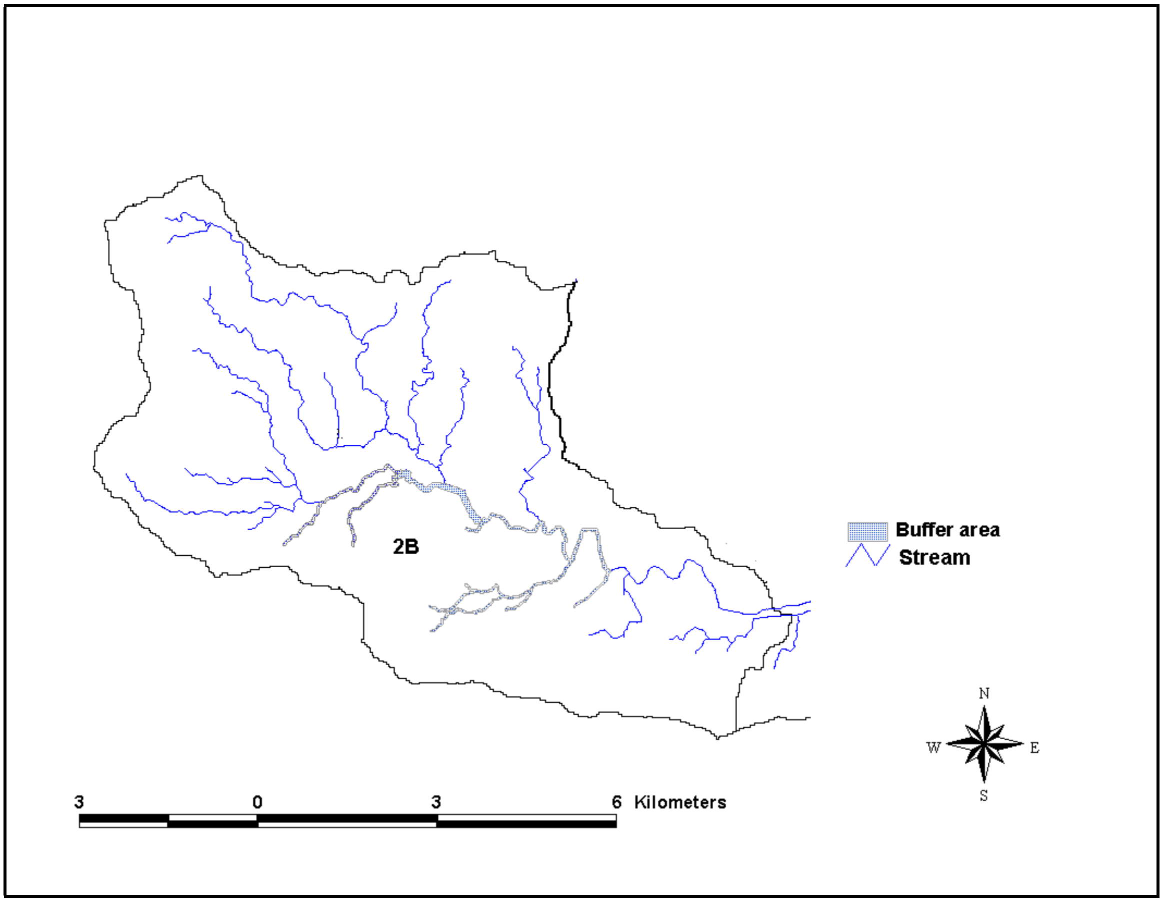

Figure 54(b). Feasible riparian buffer zones for Basin 2B in the Nawiliwili Watershed

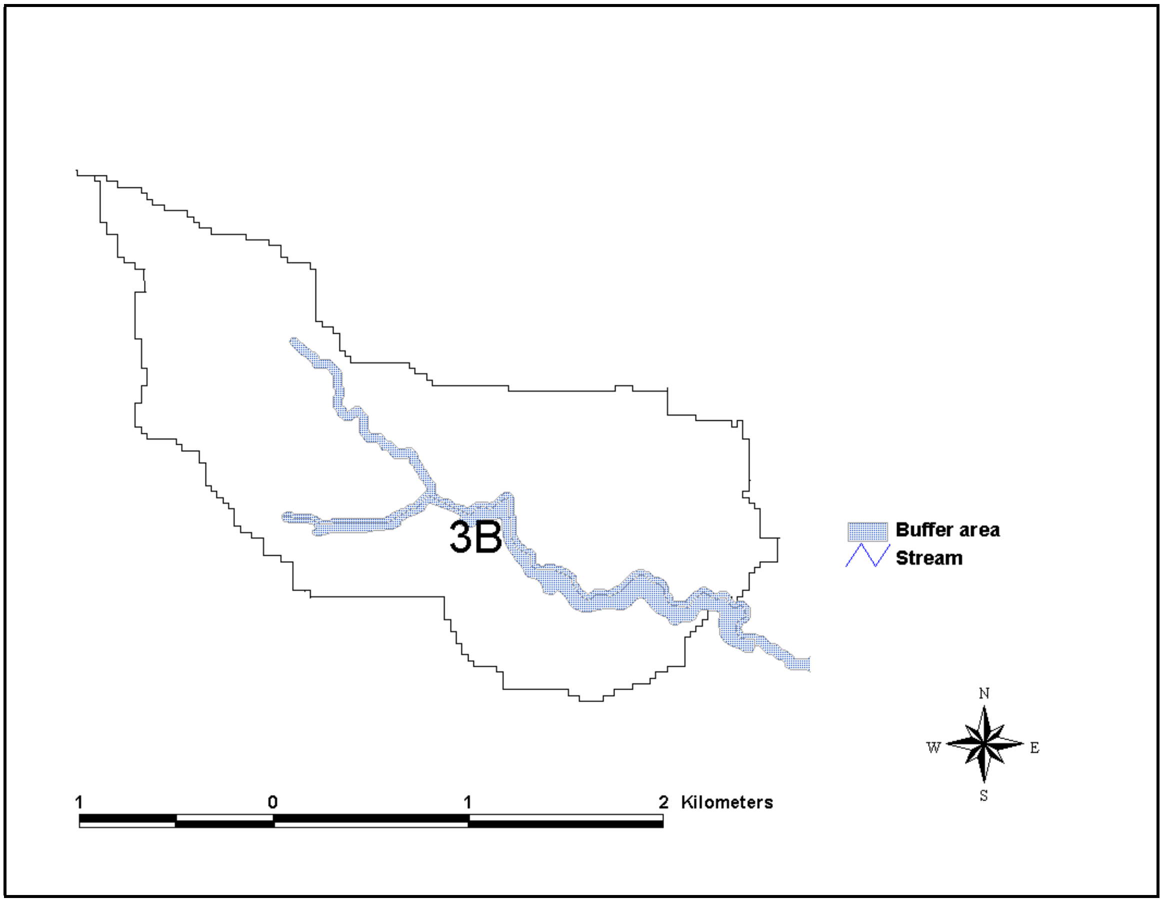

Figure 54(c). Feasible riparian buffer zones for Basin 3B in the Nawiliwili Watershed

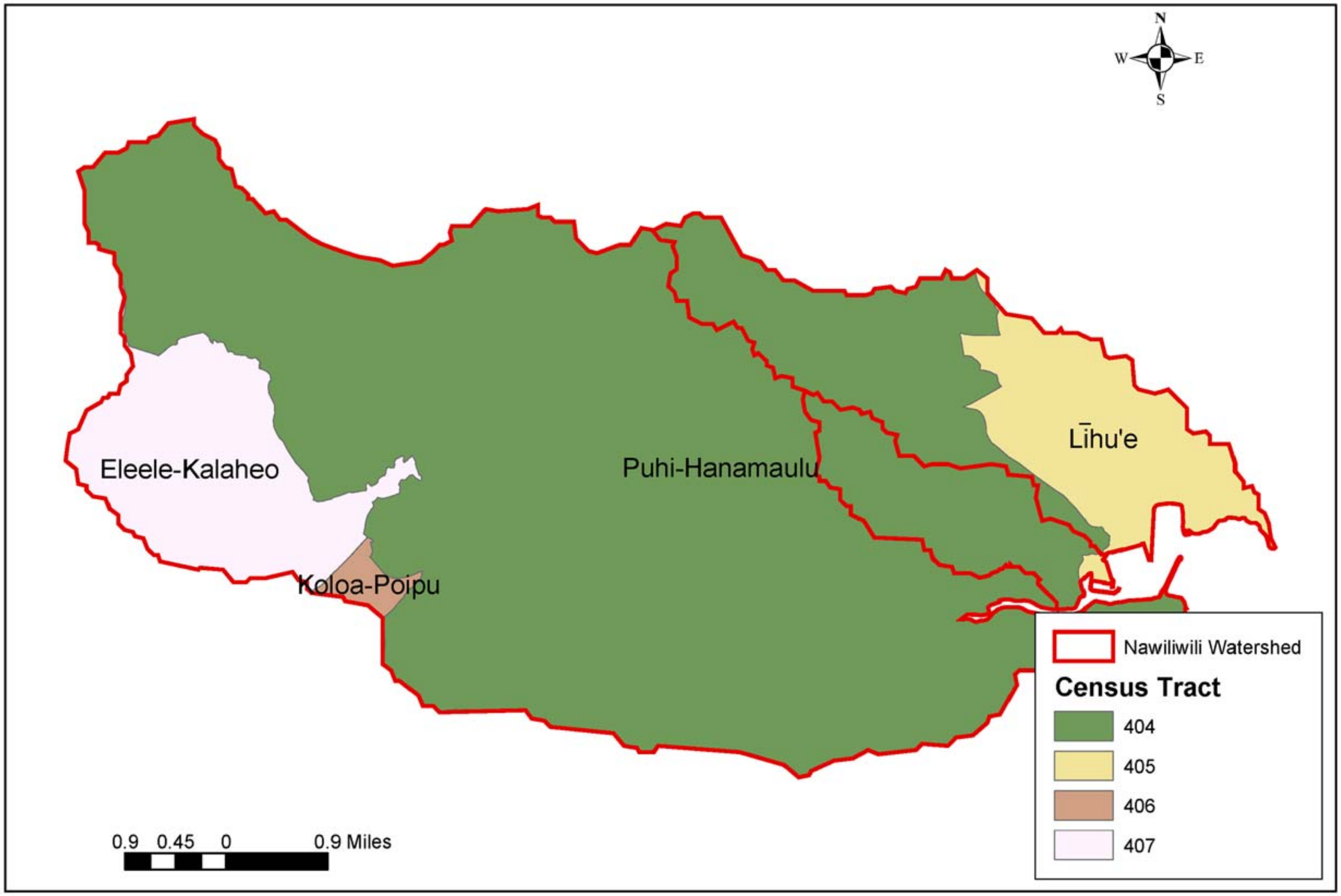

Figure 55. Census tracts in the Nawiliwili Watershed map

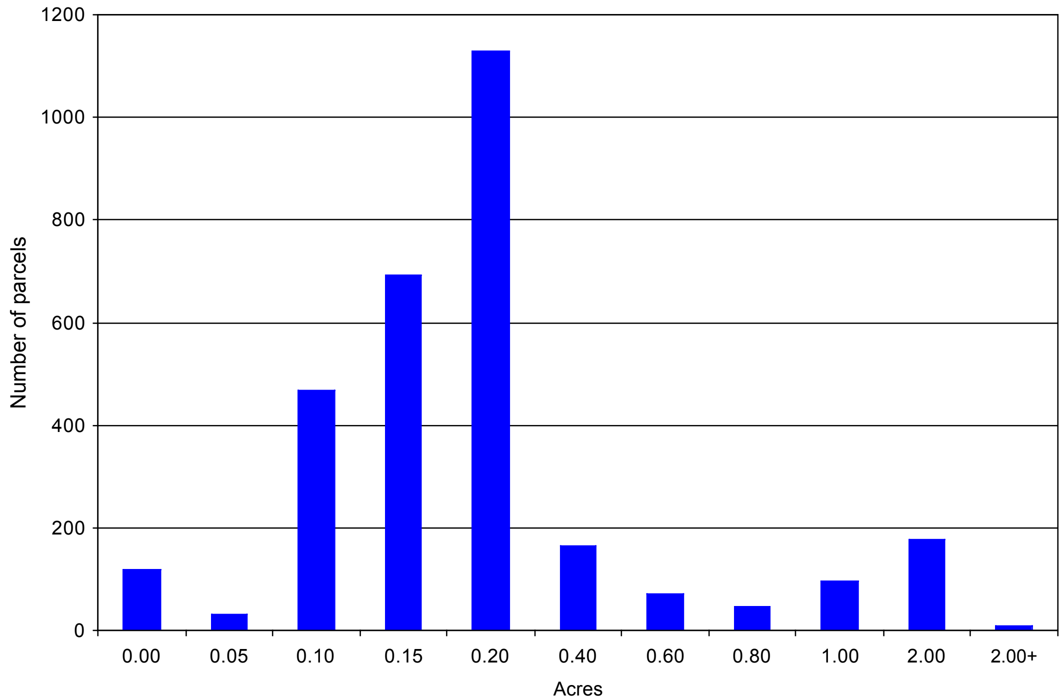

Figure 56. Distribution of parcel sizes

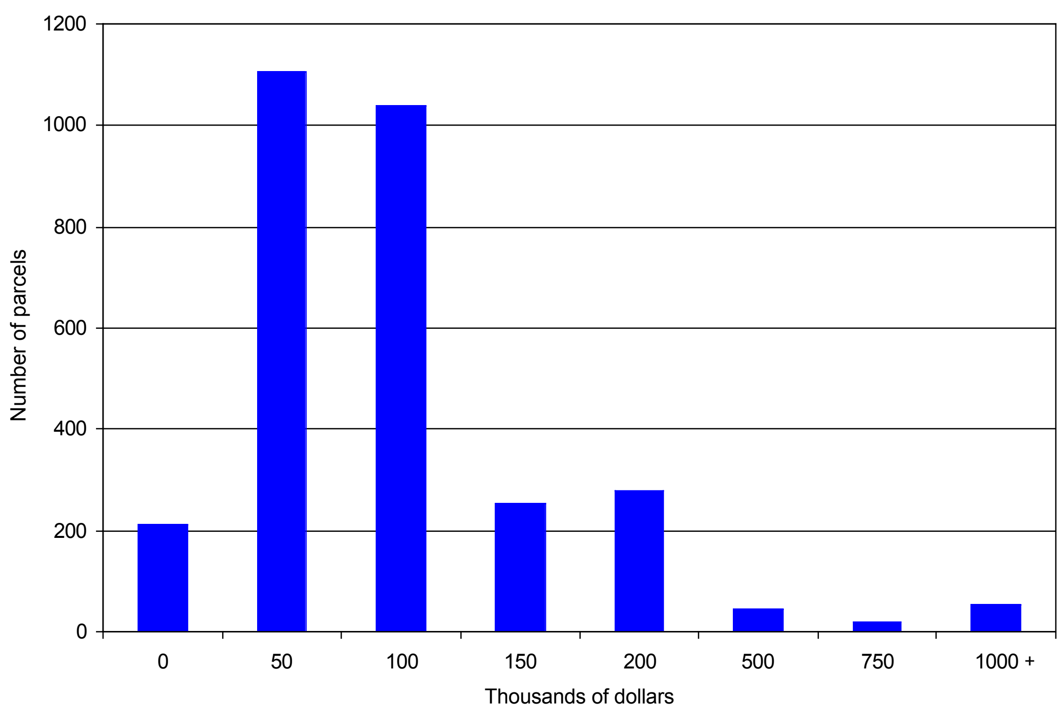

Figure 57. Distribution of land values

TABLES

Table 1. Areas of the Basins in the Nawiliwili Watershed for Various Land Uses

	Nawiliwili Stream Basin		Puali Stream Basin		Hulēʻia Stream Basin		Total Area (km^2)	% of Total Watershed Area
	Area (km^2)	% of Basin Area	Area (km^2)	% of Basin Area	Area (km^2)	% of Basin Area		
Urban								
Residential	2.17	13.36	0.53	9.96	0.38	0.53	3.08	3.29
Commercial and Services	1.63	10.02	0.21	3.85	0.10	0.14	1.93	2.06
Industrial	0.01	0.04	0.13	2.45			0.14	0.15
Other	1.78	10.93					1.78	1.89
Total Urban	5.58	34.35	0.87	16.27	0.48	0.67	6.93	7.39
Agricultural: Cropland and Pasture	6.25	38.48	3.16	59.07	31.46	43.36	40.86	43.60
Shrub and Brush Rangeland					2.93	4.03	2.93	3.12
Evergreen Forest Land	4.41	27.17	1.32	24.65	37.27	51.37	43.00	45.88
Other					0.41	0.57	0.41	0.44
Total	16.24	100	5.35	100	72.14	100	93.72	100

Note: Estimated from GIS maps of the area.

Table 2. Education and Outreach Activities

Restoration Activity	Suggested Participants
1. Create watershed curriculum for schools in the Nawiliwili Watershed (or expand and use Pat Cockett's on-line curriculum, ʻAinakumuwai). The plan also includes implementing curriculum at some level in all schools in the Nawiliwili Watershed.	Hawaiʻi Department of Education Hawaiʻi Department of Health
2. Organize Visual Assessment Protocol Workshop and video. Students will be involved in collecting long-term monitoring data and compiling the records in a database.	Hawaiʻi Department of Education and school teachers Hawaiʻi Department of Health
3. Expand native tree planting on the Hulēʻia National Wildlife Refuge.	U.S. Fish and Wildlife Service Hulēʻia National Wildlife Refuge Boy Scouts Hawaiʻi Division of Aquatic Resources
4. Design workshop or video outlining low-impact development strategies that can be implemented at the household level; optionally change policies to require viewing before permitting.	Hawaiʻi Department of Health Retail stores like Home Depot KCSA or Kauaʻi Community College County of Kauaʻi Hawaiʻi Department of Education/students
5. Organize workshop or create video to educate eco-tour guides and boat captains who operate in the Nawiliwili Watershed so that they can be responsible for some general monitoring, make responsible decisions, and educate visitors and locals alike. Issues involved include the following: a. Change policy to require that all new guides to attend workshop or view video in order to get permitted. b. Develop volunteer research tours or develop a summer class/research expedition at Kauaʻi Community College as an outlet for this training. c. Require eco-tour companies to offer educational tour at a fair price to local residents.	Hawaiʻi Department of Health Kayak and eco-tour companies Hawaiʻi Division of Boating and Ocean Recreation Kauaʻi Community College Hawaiʻi Department of Education/students

Table 2—*Continued*

Restoration Activity	Suggested Participants
6. Place educational plaques in locations frequented by tourists (e.g., near Nawiliwili Stream estuary next to the Kaua‘i Marriott Hotel).	Kaua‘i Marriott Hotel Kaua‘i County Nawiliwili Bay Watershed Council
7. Create a “working farm” for agricultural industry where BMPs can be demonstrated.	Natural Resources Conservation Service Rice Ranch Other ranchers
8. Develop community storm drain stenciling program.	Nawiliwili Bay Watershed Council Hawai‘i Department of Education Hawai‘i Department of Transportation County of Kaua‘i
9. Document BMPs in the Nawiliwili Watershed to use as a manual. Put plaques up where BMPs like sediment basins and open grass channels are located explaining to the public their purpose.	County of Kaua‘i Wal-Mart Home Depot Kaua‘i Community College
10. Restore ‘Alekoko Fishpond for use as an educational center.	Nawiliwili Bay Watershed Council Kaua‘i Community College Hawai‘i Department of Education U.S. Army Corps of Engineers U.S. Fish and Wildlife Service
11. Invite LIDs expert to speak on Kaua‘i about LIDs and produce videotape for airing on Ho‘ike.	U.S. Environmental Protection Agency Hawai‘i Division of Aquatic Resources County of Kaua‘i Ho‘ike Hawai‘i Department of Health
12. Invite panel of expert to speak about ‘ahupua‘a principles and produce a videotape for airing on Ho‘ike.	Nawiliwili Bay Watershed Council HSCR Ho‘ike
13. Integrate regular water quality monitoring with educational programs for students and community members.	Hawai‘i Department of Health Hawai‘i Department of Education Nawiliwili Bay Watershed Council
14. Provide technical education for target groups involved in construction projects (e.g., county personnel, contractors, architects, engineers, landscapers).	County of Kaua‘i Architects Engineers Hawai‘i Department of Health Landscapers

Table 3. Agricultural Restoration Activities

Restoration Activity	Suggested Participants
1. Promote Soil and Water Conservation District videos.	East and West Kaua‘i Soil and Water Conservation Districts Natural Resources Conservation Service Nawiliwili Bay Watershed Council Ho‘ike Tour companies
2. Expand the use of conveyor belt water bars near Kalepa Ridge, across from the Humane Society or south of Halfway Bridge.	Grove Farm East Kaua‘i Soil and Water Conservation District Natural Resources Conservation Service Farmers/lessees
3. Utilize water troughs located approximately 100 feet from waterways to reduce the amount of time cattle spend in/near streams.	Natural Resources Conservation Service Rice Ranch Other ranchers
4. Develop “working farm” where training workshops could be held to demonstrate working BMPs and develop partnership with farmer/rancher currently implementing BMPs.	Natural Resources Conservation Service East Kaua‘i Soil and Water Conservation District Ranchers
5. Update land-use maps.	Hawai‘i Department of Health Natural Resources Conservation Service East Kaua‘i Soil and Water Conservation District
6. Promote water recycling and conservation practices.	Soil and Water Conservation District Community members
7. Inspect roads used by tour ATV companies. Implement the following: a. Set maximum road widths. b. Educate tour companies on the effects of erosion. c. Develop self-monitoring plan. d. Stabilize steep portions. e. Promote practices in Soil and Water Conservation District videos like honeycomb matrix and geotextile mats.	Grove Farm Rice Ranch Hawai‘i Department of Health Soil and Water Conservation District Natural Resources Conservation Service Tour companies

Table 4. Summary of Suitable Uses for Recycled Water

Suitable Uses	R-1	R-2	R-3
Irrigation: (S)pray, (D)rip & Surface, S(U)bsurface, (A)LL = S D & U, Spray with (B)uffer, (N)ot allowed, /=or			
Golf course landscape	A	U/B	N
Freeway and cemetery landscapes	A	A	N
Food crops where recycled water contacts the edible portion of the crop, including all root crops	A[a]	N	N
Parks, elementary schoolyards, athletic fields, and landscapes	A	U/B	N
around some residential property			
Roadside and median landscapes	A	U/B	N
Non-edible vegetation in areas with limited public exposure	A	AB	U
Sod farms	A	AB	N
Ornamental plants for commercial use	A	AB	N
Food crops above ground and not contacted by irrigation	A	U/B	N
Pastures for milking and other animals	A	U/B	N
Fodder, fiber, and seed crops not eaten by humans	A	AB	DU
Orchards and vineyards bearing food crops	A	D/U	DU
Orchards and vineyards not bearing food crops during irrigation	A	AB	DU
Timber and trees not bearing food crops	A	AB	DU
Food crops undergoing commercial pathogen-destroying process before consumption	A	AB	DU
Supply to Impoundments: (A)llowed, (N)ot allowed			
Restricted recreational impoundments	A	N	N
Basins at fish hatcheries	A	N	N
Landscape impoundments without decorative fountain	A	A	N
Landscape impoundment with decorative fountain	A	N	N
Supply to Other Uses: (A)llowed, (N)ot allowed			
Flushing toilets and urinals	A	N	N
Structural fire fighting	A	A	N
Nonstructural fire fighting	A	A	N
Commercial and public laundries	A	N	N
Cooling saws while cutting pavement	A	N	N
Decorative fountains	A	N	N
Washing yards, lots, and sidewalks	A	N	N
Flushing sanitary sewers	A	A	N
High-pressure water blasting to clean surfaces	A	N	N
Industrial process without exposure of workers	A	A	N
Industrial process with exposure of workers	A	N	N

Table 4—*Continued*

Suitable Uses	R-1	R-2	R-3
Cooling or air conditioning system without tower, evaporative condenser, spraying, or other features that emit vapor or droplets	A	A	N
Cooling or air conditioning system with tower, evaporative condenser, spraying, or other features that emit vapor or droplets	A	A	N
Industrial boiler feed	A	A	N
Water jetting for consolidation of backfill material around potable water piping during water shortages	A	A	N
Water jetting for consolidation of backfill material around piping for recycled water, sewage, storm drainage, and gas; and electrical conduits	A	A	N
Washing aggregate and making concrete	A	A	N
Dampening roads and other surfaces for dust control	A	A	N
Dampening brushes and street surfaces in street sweeping	A	A	N

[a]Allowed under the following conditions: The turbidity of the influent to the filters is continuously measured, the influent turbidity does not exceed 5 NTU for more than 15 minutes and never exceeds 10 NTU, and there is the capacity to automatically activate chemical addition or divert the wastewater should the filter influent turbidity exceed 5 NTU for more than 15 minutes. The UV disinfection unit must conform to UV disinfection guidelines for R-1 water (appendix K in Hawai‘i State, DOH, 2002).

Table 5. Summary of Activities for Capital Improvements

Restoration Activity	Suggested Participants
1. Conduct site evaluation to determine location of storm drain outfalls, associated impervious area, and best location for BMP. Runoff volumes associated with each outfall will also need to be calculated.	Hawai‘i Department of Health County of Kaua‘i Hawai‘i Department of Transportation
2. Install catch basin inserts in target storm drains — Develop maintenance and monitoring program.	Hawai‘i Department of Health Hawai‘i Department of Transportation Nawiliwili Bay Watershed Council County of Kaua‘i
3. Install catch basin and inserts at Halfway Bridge rock quarry — Develop maintenance and monitoring program.	Halfway Bridge rock quarry Hawai‘i Department of Transportation
4. Install catch basin inserts at Nawiliwili Small Boat Harbor where boats are hauled out, washed, and refueled — Develop maintenance and monitoring program.	Hawai‘i Department of Health Hawai‘i Division of Boating and Ocean Recreation Hawai‘i Department of Land and Natural Resources
5. Build extended detention constructed wetland at Kuhio Highway storm drain outlet on Grove Farm property near Līhu‘e mill.	Hawai‘i Department of Health Hawai‘i Department of Transportation Grove Farm
6. Build constructed wetlands (pocket wetlands, utilize Storm Treat System modular wetlands, or Ocean Arks constructed wetlands at specified target storm drain outlets — Develop maintenance and monitoring program.	County of Kaua‘i Hawai‘i Department of Health Landowners Ocean Arks
7. Build constructed wetland at Kaua‘i Marriott Hotel. a. Develop maintenance and monitoring program. b. Use as community project and educational tool.	Kaua‘i Marriott Hotel Hawai‘i Department of Health Ocean Arks County of Kaua‘i A & B
8. Build detention basins (off-line) at target locations — Possible collaboration with Brownfields project.	County of Kaua‘i
9. Continue to encourage the use of drainage swales and grass channels.	County of Kaua‘i

Table 6. Summary of Activities for Control of Non-native and Invasive Species

Restoration Activity	Suggested Participants
1. Form partnership with Kauaʻi Invasive Species Committee.	Kauaʻi Invasive Species Committee
2. Develop monitoring and control program for mangrove.	Kauaʻi Invasive Species Committee U.S. Fish and Wildlife Service
a. Map existing distribution.	
b. Apply control methods.	
3. Design or implement community work days to remove monotypic forested areas and replant with more appropriate species.	Volunteers Landowners Hawaiʻi Department of Land and Natural Resources U.S. Fish and Wildlife Service Hulēʻia National Wildlife Refuge
4. Encourage pig hunting.	Hawaiʻi Division of Forestry and Wildlife Kauaʻi Invasive Species Committee

Table 7. Summary of Activities for Eliminating Cesspool Contamination

Restoration Activity	Suggested Participants
1. Eliminate the use of cesspools by connecting to existing sewer line or by substituting with septic systems.	Hawaiʻi Department of Health County of Kauaʻi, Departments of Public Works, Parks and Recreation, and Wastewater Storm Treat Systems Ocean Arks/Natural Systems Hawaiʻi
2. Perform a sanitary survey to determine, at the minimum, the number and location of cesspools still operating in Nawiliwili Watershed.	Hawaiʻi Department of Health
3. Use constructed wetlands to treat wastewater as an alternative solution to cesspools or septic systems.	Hawaiʻi Department of Health Ocean Arks and Natural Systems Hawaiʻi

Table 8. Summary of Activities for Developing a Water Budget for the Nawiliwili Watershed

Restoration Activity	Suggested Participants
1. Consult with Hawai‘i Commission on Water Resource Management to document registered diversion works and develop accurate GIS coverage.	Hawai‘i Department of Health Hawai‘i Commission on Water Resource Management
2. Consult with large landowners to determine water usage, water plans, number and location of diversion works, and frequency of diversion changes.	Hawai‘i Department of Health Nawiliwili Bay Watershed Council County of Kaua‘i Grove Farm A & B
3. Conduct a field survey to inventory all streams, diversion works, and channel alterations and verify Hawai‘i Commission on Water Resource Management documentation and record flow measurements.	Hawai‘i Department of Health County of Kaua‘i Nawiliwili Bay Watershed Council Grove Farm A & B
4. Prepare a water budget using the information gathered from the activities listed above.	Hawai‘i Department of Health Grove Farm A&B County of Kaua‘i
5. Re-evaluate monitoring studies using information obtained in the preparation of the water budget.	Hawai‘i Department of Health Nawiliwili Bay Watershed Council UH Water Resources Research Center County of Kaua‘i
6. Determine instream flows.	Hawai‘i Department of Health Nawiliwili Bay Watershed Council Hawai‘i Commission on Water Resource Management

Table 9. Summary of Activities Concerning Revision of Policies and Use of Low-Impact Development Strategies for Restoration

Restoration Activity	Suggested Participants
1. Strictly enforce current policies and regulations.	Hawai‘i Department of Health County of Kaua‘i
2. Review and revise current policies to reflect water quality goals including adopting ordinances to include low-impact development strategies to be used in all new developments. These include: a. Process runoff on-site. b. Set maximum road widths in low-traffic areas. c. Utilize natural drainage features such as grass channels and vegetated swales instead of curb and gutter. d. Protect and replant trees. e. Restrict grading. f. Minimize/reduce impervious surfaces by using smaller building footprints and pervious pavers.	Hawai‘i Department of Health County of Kaua‘i Other counties Nawiliwili Bay Watershed Council
3. Develop LIDS manual for Kaua‘i.	County of Kaua‘i
4. Review Kaua‘i County’s Storm Water Runoff System Manual to determine if revisions are necessary achieve water quality goals.	County of Kaua‘i Nawiliwili Bay Watershed Council
5. Expand native plant landscaping and xeriscaping (include plaques) at government and public facilities, and offer incentives for resorts.	Hawai‘i Department of Health Hawai‘i Department of Transportation Kaua‘i County Kaua‘i Marriott Hotel
6. Form a partnership with Habitat for Humanity to design a “sustainable” affordable residential development for Kaua‘i residents.	County of Kaua‘i Habitat for Humanity

Table 10. Summary of Activities for Habitat Protection and Restoration

Restoration Activity	Suggested Participants
1. Restore riparian buffers on stream segments where lacking or severely impaired. Locations include: a. Puali Stream in fenced area near Puhi Road. b. “Kalapaki” Stream by Kaua‘i Marriott Hotel employee parking lot.	County of Kaua‘i Grove Farm Kaua‘i Marriott Hotel Nawiliwili Bay Watershed Council Volunteers/community members
2. Remove barriers to fish migration or construct a facilitator to encourage recruitment.	Hawai‘i Department of Health Hawai‘i Department of Land and Natural Resources County of Kaua‘i Grove Farm
3. Determine need for monitoring and control program for bass and other predatory macrofauna.	Hawai‘i Department of Health Hawai‘i Department of Land and Natural Resources
4. Dredge sandbars in Hulē‘ia estuary to restore direction of flow and move illegally “parked” boats.	Hawai‘i Department of Land and Natural Resources Hawai‘i Division of Boating and Ocean Recreation
5. Protect areas with intact habitat.	Hulē‘ia National Wildlife Refuge U.S. Fish and Wildlife Service

Table 11. Input Parameters for the Transport Dataset of the GWLF Model

Data	Source
Watershed size and boundary delineation	Using 10 m × 10 m USGS DEM for Nawiliwili watershed and ArcGIS 8.3 for automatic watershed delineation
Land use/cover distribution	NOAA 30 m × 30 m landsat classified imagery and GIS
Curve numbers by source area	Curve numbers for land use using TR-55 documentation (SCS, 1986)
USLE *K* factor	From SSURGO soil data for Kauaʻi
USLE *LS* factor	Estimated using GIS from the 10 m × 10 m DEM
C factor	Based on values for cover for agricultural land use
P factor	Assumed to be 1 if no management practices such as terracing is used
Evapotranspiration cover coefficients	1 as Hawaiʻi has growing season all year round due to tropical climate
Daylight hours by month	Available using geographic coordinates of Kauaʻi
Growing season months	All months are growing season
Rainfall erosivity coefficients	Available from GWLF manual
Initial saturated storage and unsaturated storage	Assumed to be zero, not significant as it affects only the first few days of model run
Recession coefficient and seepage coefficient	From model calibration on North Wailua River watershed
Initial snow	Zero
Sediment delivery ratio	Calculated from nomograph in the model user guide based on basin area
Soil water (available water capacity)	Default 10 cm, can be estimated from SSURGO digital soil data, may have to alter based on model calibration

Table 12. Weather Data Sources

Basin ID	Temperature Data	Precipitation Data	Period of Simulation
North Wailua River watershed	Līhuʻe Airport, NOAA id 515580	Waiʻaleʻale and Opakeaa USGS stations and NOAA station 511140	1994 to 1996, 1998 to 1999, and 2000 to 2001
Basin 1B, Nawiliwili Watershed	Līhuʻe Airport, NOAA id 515582	NOAA station 518217	1995 to 2004
Basin 2B, Nawiliwili Watershed	Līhuʻe Airport, NOAA id 515581	NOAA stations 511038 and 514750	1995 to 2004
Basin 3B, Nawiliwili Watershed	Līhuʻe Airport, NOAA id 515582	NOAA station 518217	1995 to 2004
Basin 4B, Nawiliwili Watershed	Līhuʻe Airport, NOAA id 515583	NOAA station 518217	1995 to 2004
Basin 5B, Nawiliwili Watershed	Līhuʻe Airport, NOAA id 515583	NOAA station 515575	1995 to 2000
Basin 12B, Nawiliwili Watershed	Līhuʻe Airport, NOAA id 515583	NOAA station 515575	1995 to 2000
Basin 11B, Nawiliwili Watershed	Līhuʻe Airport, NOAA id 515584	NOAA station 518217	1994 to 2004
Basin 14B, Nawiliwili Watershed	Līhuʻe Airport, NOAA id 515583	NOAA station 515575	1995 to 2000

NOAA = National Oceanic and Atmospheric Administration, USGS = U.S. Geological Survey.

Table 13. Curve Number and Universal Soil Loss Equation Parameters for Individual Hydrological Response Units Within the Basins of the Nawiliwili Watershed

Basin ID	HRU ID	HRU Area (ha)	Curve Number	USLE Parameters				
				K	*LS*	*C*	*P*	*KLSCP*
11	11B	805.6	64.9	0.11	6.29	0.016	1	0.0117
13	13B	9.8	69.6	0.12	1.57	0.015	1	0.0028
2	2B1	506.1	69.5	0.13	11.11	0.010	1	0.0151
2	2B2	87.0	57.7	0.10	6.10	0.012	1	0.0072
2	2B3	133.6	69.1	0.10	1.15	0.087	1	0.0101
2	2B5	14.2	66.1	0.10	1.89	0.062	1	0.0117
2	2B6	6.8	66.7	0.10	1.00	0.066	1	0.0066
2	2B7	28.3	59.0	0.09	0.96	0.039	1	0.0033
2	2B8	22.4	67.8	0.08	1.42	0.074	1	0.0081
2	2B9	22.3	68.7	0.10	0.29	0.088	1	0.0025
2	2B10	16.3	68.2	0.10	0.62	0.088	1	0.0054
2	2B11	35.4	68.6	0.10	0.59	0.081	1	0.0048
2	2B12	822.6	58.7	0.10	0.84	0.038	1	0.0033
2	2B13	46.8	61.3	0.07	2.13	0.029	1	0.0043
2	2B14	70.4	69.0	0.07	1.40	0.073	1	0.0068
2	2B15	529.0	59.3	0.10	1.45	0.037	1	0.0051
2	2B16	19.8	55.9	0.10	0.47	0.015	1	0.0007
2	2B17	211.4	62.6	0.10	5.01	0.012	1	0.0056
2	2B18	256.7	59.9	0.10	1.00	0.036	1	0.0036
2	2B19	18.8	53.3	0.10	1.68	0.017	1	0.0028
2	2B20	1,204.7	66.2	0.09	3.16	0.013	1	0.0038
2	2B4	580.3	62.1	0.11	5.08	0.012	1	0.0071
2	2B21	1,043.5	79.2	0.15	11.21	0.011	1	0.0180
4	4B1	202.0	72.1	0.14	1.13	0.020	1	0.0031
4	4B2	841.7	65.5	0.11	2.44	0.027	1	0.0070
1	1B2	892.1	64.4	0.10	2.11	0.022	1	0.0045
3	3B1	105.7	69.3	0.10	0.61	0.030	1	0.0019
3	3B2	325.3	63.7	0.12	1.03	0.032	1	0.0041
5	5B	48.6	67.8	0.13	3.06	0.011	1	0.0045
14	14B1	145.3	70.6	0.14	0.15	0.036	1	0.0008
14	14B2	153.3	62.1	0.14	0.54	0.040	1	0.0029
5	5B1	61.5	67.8	0.14	2.12	0.021	1	0.0064
12	12B1	29.4	59.5	0.13	0.70	0.032	1	0.0030
12	12B2	13.8	79.6	0.13	1.68	0.021	1	0.0044

K = soil erodibility factor, *LS* = slope-length factor, *C* = cropping management factor, and *P* = erosion-control practice factor.

Table 14. Baseline Average Annual Streamflow and Sediment Yields Simulated by the GWLF Model for the Sub-basins of the Nawiliwili Watershed

Basin ID	Annual Streamflow (cm)	Annual Sediment Yield (tons/yr)
1B	26.10	920
2B	42.37	7,950
3B	26.21	380
4B	26.46	1,370
5B	24.97	180
11B	25.11	2,170
12B	26.16	50
14B	24.79	150

Table 15. Average Input Parameters That Affect Sediment Yield and the Output Sediment Values for the Basins in the Nawiliwili Watershed

Basin ID	Area (ha)	Mean *KLSCP* Value	Sediment (tons/yr)	Sediment (tons/ha/yr)	Slope (%)	Average Curve Number
1B	892	0.0045	920	1.03	12.8	64.4
2B	5,676	0.0081	7,950	1.40	27.7	66.2
3B	431	0.0036	380	0.88	5.7	65.1
4B	1,044	0.0063	1,370	1.31	13.0	66.8
5B	110	0.0045	180	1.64	12.9	67.8
11B	806	0.0117	2,170	2.69	30.8	64.9
12B	43	0.0035	50	1.16	6.2	69.6
14B	299	0.0019	150	0.50	2.7	66.3

K = soil erodibility factor, *LS* = slope-length factor, *C* = cropping management factor, and *P* = erosion-control practice factor.

Table 16. GWLF Model Nutrient Input Parameters for the Nawiliwili Watershed

Description	Nitrogen	Phosphorus
Nutrient concentration in soil (mg/kg)	1,000	500
Enriched undeveloped/forest/shrub nutrient concentration in runoff (mg/l)	0.5	0.03
Urban land nitrogen and phosphorus buildup per day (kg/ha-day)	0.09	0.0112
Point source/wastewater treatment plant loads (kg)	No input	No input
Dissolved nitrogen and phosphorus in groundwater (mg/l)	0.25	0.01
Septic system per capita nutrient input when there are cesspools in the watershed (g/day-person)	18	6
Septic system per capita nutrient input when there are no cesspools in the watershed (g/day-person)	12	4
Vegetative uptake of nutrients from septic systems (g/day-person)	1.6	0.4

Table 17. Annual Dissolved and Total Nutrient Loads for Basins in the Nawiliwili Watershed

Basin ID	Annual Dissolved Nitrogen Yield (tons/yr)	Total Annual Nitrogen Yield (tons/yr)	Annual Dissolved Phosphorus Yield (tons/yr)	Total Annual Phosphorus Yield (tons/yr)
1B	2.08	3.00	0.40	0.86
2B	7.60	15.55	0.36	4.34
3B	5.05	5.68	1.47	1.69
4B	8.20	10.10	2.20	2.98
5B	2.61	2.89	0.73	0.83
11B	1.88	4.05	0.03	1.12
12B	0.46	0.56	0.00	0.04
14B	0.92	1.39	0.37	0.48

Table 18. Curve Numbers for Different Land Uses in Basin 14B

Land Cover Type	Count Grid Cells	Curve Number
High-intensity developed land	437	85
Low-intensity developed land	914	70
Cultivated land	276	69
Grassland	883	58
Evergreen forest	285	55
Scrub/shrub	393	65
Scrub wetland	3	35
Emergent wetland	2	35
Unconsolidated shore	1	50
Bare sand	82	50
Water	42	98

Table 19. Nutrient Loads When All the Cesspools Are Converted to Septic Systems

Basin ID	Annual Dissolved Nitrogen Yield (tons/yr)	Total Annual Nitrogen Yield (tons/yr)	Annual Dissolved Phosphorus Yield (tons/yr)	Total Annual Phosphorus Yield (tons/yr)
1B	1.56	2.48	0.03	0.49
2B	7.59	15.54	0.35	4.33
3B	3.12	3.74	0.01	0.23
4B	5.28	7.46	0.04	0.92
5B	1.61	1.88	0.002	0.103
11B	1.36	3.52	0.03	1.11

Table 20. Cost Estimate for the Restoration Activities of the Nawiliwili Watershed and Measures of Success

Action	Year 1	Year 2	Year 3	Year 4	Year 5	Total	Notes	Measures of Success
1. WATERSHED RESTORATION CENTER								
1.1. Staff and Office Cost	$100,000	$105,000	$110,250	$115,763	$121,551	$552,563		Reports of activity as measured
1.2. Advisory Group Meetings	$10,000	$10,500	$11,025	$11,576	$12,155	$55,256		by other activities listed below
2. EDUCATION								
2.1. Education Programs in Schools	$5,000	$5,250	$5,513	$5,788	$6,078	$27,628		Number of schools involved
2.2. Native Tree Planting in Hulēʻia National Wildlife Refuge	$5,000	$5,250	$5,513	$5,788	$6,078	$27,628		Number of people involved/Number of trees planted
2.3. Educational Research Center for ʻAlekoko Fishpond	$5,000	$5,250	$5,513	$5,788	$6,078	$27,628		Number of people/Groups involved; Water quality improvement
2.4. Low Impact Development Video/Workshop	$7,000					$7,000		Number of people/groups attend training
2.5. Educational Program for Eco-Tour Operators	$1,000	$1,050	$1,103	$1,158	$1,216	$5,526		Number of people involved/Water quality improvement
2.6. Educational Plaques	$500	$525	$551	$579	$608	$2,763		Number of plaques
2.7. Storm Drain Stenciling Project	$100	$105	$110	$116	$122	$553		Number of people/Schools involved
2.8. Educational Program for Agricultural Conservation	$5,000	$5,250	$5,513	$5,788	$6,078	$27,628		Number of people involved
3. SOIL EROSION FROM AGRICULTURAL LAND								
3.1. Use of Conveyor Belt Water Bars	$1,000					$1,000		Number of belts/Water quality improvement
3.2. Relocation of Water Troughs for Cattle Away from Streams	$20,000					$20,000		Number of items relocated
3.3. Working Farm for BMP Implementation	$180,000	$20,000	$20,000	$20,000	$20,000	$260,000		Improvement of water quality
3.4. Updating Land Use Maps	$50,000					$50,000		Availability of maps

Table 20—*Continued*

Action	Year 1	Year 2	Year 3	Year 4	Year 5	Total	Notes	Measures of Success
3.5. Water Recycling and Conservation Practices	$3,000	$3,150	$3,308	$3,473	$3,647	$16,577		Volumes of water recycled
3.6. Solution for Eco-Tour and ATV Erosion Problems	$1,000	$1,050	$1,103	$1,158	$1,216	$5,526		Visual reduction of pollution
4. CAPITAL IMPROVEMENTS								
4.1. Strategy and Installation of Basins Inserts	$5,000					$5,000		Number and efficiency of insets
4.2. Construction of Storm Waters Wetlands	$2,100,000	$20,000	$21,000	$22,050	$23,153	$2,186,203	6 suggested sites	Number and area of wetlands
5. CONTROL OF NON-NATIVE/INVASIVE SPECIES								
5.1. Monitoring and Control Program for Mangrove	$10,000	$5,000	$5,250	$5,513	$5,788	$31,551		Program implemented/size of area cleared of mangrove
5.2. Community Workdays Program	$1,000	$5,000	$5,250	$5,513	$5,788	$22,551		Number of people involved
5.3. Plans to Encourage Hunting	$1,000	$1,050	$1,103	$1,158	$1,216	$5,526		Number of animal hunted
6. ELIMINATION OF CESSPOOL CONTAMINATION	$450,000	$472,500	$496,125	$520,931	$546,978	$2,486,534		Number of connections/New systems
7. DEVELOPMENT OF A WATERSHED WATER BUDGET	$10,000					$10,000		Budget completed
8. LOW IMPACT DEVELOPMENT STRATEGIES								
8.1. Basin Designation	$10,000					$10,000	Study	Study
8.2. Zoning Density	$10,000					$10,000	Study	Study
8.3. Tree, Forest, and Open Space Protection	$10,000					$10,000	Study	Study
8.4. Stormwater Management Standards	$10,000					$10,000	Study	Study
8.5. Grading Restrictions	$10,000					$10,000	Study	Study
8.6. Reducing Impervious Surface Recover	$30,000					$30,000	Study, Demonstration Project	Study; Decrease in percentage of impervious area

Table 20—*Continued*

Action	Year 1	Year 2	Year 3	Year 4	Year 5	Total	Notes	Measures of Success
8.7. Utilizing natural Features for Stormwater Management	$20,000	$5,000	$5,000	$5,000	$5,000	$40,000	Study, Demonstration Project	Study; Reduction in drainage outflow to streams
8.8. Education	$1,000					$1,000		Number of people/Agencies involved
8.9. Partnership with Agencies/Communities	$0					$0		Number of agencies/Communities involved
10. HABITAT RESTORATION AND PROTECTION	$10,000	$10,500	$11,025	$11,576	$12,155	$55,256		Restoration as measured by number and health of habitat
11. IMPROVEMENT OF HALĒ‘IA ESTUARY	$20,000	$10,000	$10,000			$40,000		Improved water quality
Total	$3,101,600	$691,430	$724,252	$748,714	$784,900	$6,050,895		

Table 21. Preliminary Timeline for the Implementation of Restoration Projects for the Nawiliwili Watershed

Project	1st 6 months	Year 1	Year 2	Year 3	Year 4	Year 5
Hiring and training of staff	Securing funding, hiring, training					
Opening Nawiliwili Watershed Restoration Office	Securing office space, organizing office structure, establishing place in community					
RESTORATION ACTIVITIES						
Education & Outreach						
4.1.1 Education Programs in Schools		Coordination and cooperation with schools and teachers, development of units	Implementation by schools and teachers			
4.1.2 Expansion of Native Tree Planting on Hulē‘ia National Wildlife Refuge	Coordination with existing agencies and partners	Ongoing implementation	Ongoing implementation	Ongoing implementation	Ongoing implementation	Ongoing implementation
4.1.3 ‘Alekoko as Educational Research Tool		Developing Plan				
4.1.4 Low Impact Development Strategies Video/Workshop		Gathering information and video production				
4.1.5 ‘Ahupua’a Video		Determine effectiveness as a college directed study project	Video production			
4.1.6 Educational Program for Eco-tour Guides		Development of Program, coordination with cooperating agencies	Implementation	Ongoing implementation	Ongoing implementation	Ongoing implementation

Table 21—*Continued*

Project	1st 6 months	Year 1	Year 2	Year 3	Year 4	Year 5
4.1.7 Educational Plaques		Determine purposes and locations. Work with schools and participating entities to manufacture the plaques. Post plaques.				
4.1.8 Storm Drain Stenciling		Advertise, designate annual community work day	Ongoing implementation	Ongoing implementation	Ongoing implementation	Ongoing implementation
4.1.9 Educational Opportunities for Reducing Water Quality Impacts from Agricultural Land		Coordination with participating agencies, development of program	Implementation			
Preventing Soil Erosion and Sedimentation from Agricultural Lands						
4.2.1 Promote Educational Videos Produced by E&KSWCD		Ongoing	Ongoing	Ongoing	Ongoing	Ongoing
4.2.2 Expand the Use of Conveyor Belt Water Bars		Determine best locations, coordinate with participating entities	Implementation			
4.2.3 Locate Water Troughs for Cattle Away From Streams		Determine best locations, coordinate with participating entities	Implementation			

Table 21—*Continued*

Project	1st 6 months	Year 1	Year 2	Year 3	Year 4	Year 5
4.2.4 Develop "Working Farm to Demonstrate BMP Implementation		Coordinate with participating entities, develop details of project	Implementation			
4.2.5 Update Land Use Maps		Update should be immediate				
4.2.6 Promote Water Recycling and Conservation Practices		Develop educational pamphlet	Distribute pamphlet			
4.2.7 Provide Solutions for ATV and Eco-Tour Erosion		Inspect Road, coordinate with landowners and tour operators, determine group to implement, determine best location and best BMP practices, begin implementation	Continue implementation and develop self monitoring plan	Self-monitoring	Self-monitoring	Self-monitoring
Capital Improvements						
4.3.1 Catch Basin Inserts		Work with State and County agencies to determine impervious area, number of storm drains and number of outlets. Determine best locations. Develop strategies for implementation.				

Table 21—*Continued*

Project	1st 6 months	Year 1	Year 2	Year 3	Year 4	Year 5
4.3.2 Constructed Wetlands		Develop project, coordinate with landowners and participants, contract vendors, prepare educational component, finalize plans for construction	Ground-breaking and completion of first wetland and development of monitoring plan, prioritize next site	Construct 2nd site wetland	Construct 1-2 wetlands per year until all sites have been completed	Construct 1-2 wetlands per year until all sites have been completed
Control of Non-native and Invasive species						
4.4.1 Form Partnership with KISC		Form partnership				
4.4.2 Develop Monitoring and Control Program for Mangrove		Work with and provide support for KISC, develop community work component	Begin control and monitoring	Ongoing control and monitoring	Ongoing control and monitoring	Ongoing control and monitoring
4.4.3 Develop Community Work Days Program		Develop a schedule of community work projects, begin implementation	Annual community workdays	Annual community workdays	Annual community workdays	Annual community workdays
4.4.4 Develop Plan to Encourage Pig Hunting		Offer support to agencies already encouraging pig hunting	Expand plan and continue support	Expand plan and continue support	Expand plan and continue support	Expand plan and continue support
4.4.5 Pig Fencing Project on HNWR		Work with Heacock and HNWR manager to obtain fencing materials. Outline a plan for a community work project to put the fencing in.				

Table 21—*Continued*

Project	1st 6 months	Year 1	Year 2	Year 3	Year 4	Year 5
Elimination of +B57 Cesspool Contamination						
4.5.1 Develop and Produce Educational Cesspool pamphlet		Produce and distribute educational pamphlet to cesspool users				
4.5.2 Work with County Agencies to Help Reduce Number of Cesspools and Plan for Future		Work with county to help ease financial burdens of cesspool conversion. Plan for future elimination of cesspools.	Plan for future elimination of cesspools. Provide support for County projects to eliminate large capacity cesspools as mandated by EPA.			
Development of Water Budget						
4.6 Develop Water Budget for Watershed		Hire contractor to carry out water budget				
Using Low-Impact Development Standards						
4.7 Use Low Impact Development Standards		Develop working relationship with county, work changing regulations and requirements for new development	Develop a LID manual	Complete production of LID manual for Kauai, promote Lid Practices to contractors, builders, architects and other entities involved w/development	Promote LID Practices to contractors, builders, architects and other entities involved w/development	Promote LID Practices to contractors, builders, architects and other entities involved w/development

Table 21—*Continued*

Project	1st 6 months	Year 1	Year 2	Year 3	Year 4	Year 5
4.7.2.6 Green Roof Demonstration Project		Identify Plants to be used in a demonstration project	Enlist community members, architects and college students to compete in a contest for the best green roof project	implement demonstration projects		
4.7.2.6 A Pervious Pavement Parking Lot Demonstration Project		Identify partner to implement pervious parking lot, based on their time-frame for construction, a more appropriate schedule can be adopted for this project				
4.7.2.7 & 4.8 Habitat Restoration/ Re-establishing Riparian Buffer Xones, Bank Stabilization		Identify appropriate Plants to be used in a demonstration project, determine best locations for re-establishing riparian buffers, plan community work days, coordinate with landowners and other participating entities	Carry out first native plant riparian restoration demonstration project	Monitor and maintain 1st restored buffer zone. Revise riparian buffer restoration project using lessons learned. Using school groups and volunteers implement project at other sites.	Implement riparian buffer restoration at other sites. Maintain and monitor other sites.	Implement riparian buffer restoration at other sites. Maintain and monitor other sites.

Table 22. Population and Household Income: Kaua‘i County and Selected Census Tracts

	Kaua‘i County	Census Tract 404	Census Tract 405
Population[a]	58,463	6,860	5,162
Median family income[b]	$51,378	$56,689	$51,450

[a]Data from Federal Financial Institutions Examination Council, http://ffiec.gov/Geocode/default.htm for 2002).
[b]Data from the U.S. Census Bureau, *http://factfinder.census.gov/* (1999).

Table 23. Employment and Income, Kaua‘i County, 2000

	No. of Jobs	Income (millions of 1982–84 dollars)
Total non-agriculture	24,492	186.491
Construction	1,075	32.595
Transportation, communication, and utilities	1,715	35.795
Wholesale and retail trades	7,279	93.560
Services	5,412	209.999
Lodging	3,725	77.088
Medical	1,875	41.822
Finance, insurance, real estate	373	33.483
Agriculture	971	19.144
Government	4,125	101.872

Source: University of Hawaii Economic Research Organization (2003), tables A2 and A3.

Table 24. Largest Kaua‘i County Landowners by Size of Holdings

	Number of Parcels	Taxable Acres	Assessed Value
Lihue Plantation (AMFAC)	13	16,706.107	$6,653,000
Grove Farm et al.	154	13,670.747	$74,304,200
William Hyde Rice, Ltd.	13	2,966.994	$2,965,300
State of Hawai‘i	126	2,713.408	$174,630,500
E.A. Knudsen Trust	7	2,523.084	$2,037,600
D.R. Campion	3	1,396.180	$958,400
Kaua‘i Lagoons	11	571.442	$43,593,400
U.S. Government	9	246.832	$2,957,200
Okada Trucking	131	140.357	$14,757,500
County of Kaua‘i	39	129.225	$10,401,800
Nuhou Corporation	8	88.852	$2,050,000
Kaua‘i Marriott Hotel	2	37.997	$21,838,400
Wilcox, Gaylord	2	34.645	$1,665,000
Weinberg Estate/Foundation	35	30.733	$11,688,500
Kamehameha Schools	33	15.478	$5,824,600
Schuler Homes, Inc.	3	12.270	$3,246,200
C. Brewer	1	8.129	$1,344,300
Puhi Enterprises Inc.	9	2.425	$798,300
Sanchez, Doreen L.	7	1.921	$548,400
Aloha Church—Assemblies et al.	1	0.000	$1,140,500
Roads	54	0.000	$0
Total	661	41,296.826	$383,403,100

Source: County of Kaua‘i tax map keys.

Table 25. Estimated Cost of Alternative Sewering

	Sewer Improvement District #2 ($/household/yr)	Sewer Improvement Districts #3 and #5 ($/household/yr)
Sewer connections	$2,100	$6,500
Septic tanks	$460	$470

Table 26. Stormwater Best Management Practices

Cover Type or BMP	Land Use			Feasibility and Benefits					Relative Cost
	Residential	Commercial	Industrial/ Hotspots	Space	Aesthetics	Habitat	Safety	Maintenance	
Native vegetation, preserved or established	Y	Y	Y	High	H	H	H	H	H
Turf grass	S	S	S	Low to High	L	L	H	H	L
Disconnect impervious areas	Y	Y	Y	Medium	M	M	H	M	M
Swales and channels	Y	Y	N	Medium	M	M	H	H	M
Bioretention/ rain gardens	Y	S	N	Medium	H	H	H	L	M
Grass filter strips	S	Y	N	Medium	M	M	H	M	M
Wet ponds	S	S	IL	High	H	H	M	L	L
Constructed wetlands/ extension detention wetlands	S	S	IL	High	H	H	M	L	L
Pervious pavement	S	Y	N	None	M	M	H	M	H
Surface sand filters	S	Y	Y	Low	M	L	H	M	L
Perimeter sand filters	S	Y	Y	Low	M	L	H	M	L
Infiltration basins	Y	Y	N	High	M	M	H	M	M
Infiltration trenches	Y	Y	N	Medium	M	L	H	M	M
Dry detention basins	S	S	N	Medium	L	L	M	L	M
Parking lot detention	N	S	N	Low	L	—	—	—	—

Source: Tetra Tech EM Inc. (2003).

Y = yes, S = sometimes, N = no, IL = use with impermeable liner; H = high, M = moderate, and L = low.

Table 27. Information About Meetings Conducted During This Study to Discuss Restoration Activities

Date	Meeting	Topic	Attendees
October 14, 2003	Na Leo o Kaua‘i, Līhu‘e	Neighborhood issues, introduce Nawiliwili restoration plan, ask for community support	
October 29, 2003	Nawiliwili Watershed Restoration Plan	Goals, objectives, strategies for improving water quality in Nawiliwili Watershed	Monika Mira Don Heacock-DAR Mike Hawkes-FWS
November 4, 2003	Na Leo o Kaua‘i, Līhu‘e	Neighborhood issues, relationship of watershed issues, building partnerships	
November 5, 2003	Nawiliwili Watershed Restoration Plan	Restoration activities (education and outreach)	Dave Martin-NBWC Steve Perry Joseph Dunsmoor Monika Mira
November 12, 2003	Nawiliwili Watershed Restoration Plan	Review of policy and regulations, LIDS	Monika Mira Jon Schlegel-NRCS
November 19, 2003	Kaua‘i Invasive Species Committee	Plans for invasive species control	
November 26, 2003	Nawiliwili Watershed Restoration Plan	Capital Improvements — catch basin inserts, constructed wetlands, sediment basins	Monika Mira Dave Martin
December 3, 2003	Nawiliwili Watershed Restoration Plan	Sediment load reduction from quarry, erosion control on agricultural roads, ATV tours	Monika Mira David Crawshaw
December 10, 2003	Nawiliwili Watershed Restoration Plan	Overview of restoration projects	Monika Mira Dennis Fujimoto Kendyce Manguchei
December 11, 2003	Nawiliwili Bay Watershed Council	Overview of restoration projects — prioritizing	Monika Mira Mahealani Silva Mrs. Trembath David Martin
December 17, 2003	Nawiliwili Watershed Restoration Plan	TMDL update	Monika Mira David Crawshaw Glenn Yamamoto Carl Arume Don Heacock Carol Larson Kendyce Manguchei

LIDS = low-impact development standards.

Table 28. Meeting Attendees and Their Affiliation

Name	Affiliation (if any)
Carl Arume	County of Kaua‘i, Department of Water
Adam Asquith	University of Hawai‘i Sea Grant College Program
Lesley Bailey	SOLIPSYS
Carl Berg	Hanalei Heritage River Program
Kyle Cockerham	Hawai‘i State, Department of Transportation — Airports
Glenn Craven	Kaua‘i Marriott Hotel
David Crawshaw	
Joseph Dunsmoor	
Jim Ehle	Habitat for Humanity
Dennis Fujimoto	*The Garden Island* newspaper
Mike Hawkes	U.S. Fish and Wildlife Service
Don Heacock	Hawai‘i State, Department of Land and Natural Resources, Division of Aquatic Resources
Carol Kimura	Chiefess Kamakahelei Middle School
Kaupena Kinimaka	Kaua‘i Marriott Hotel
Cheryl Lovell-Obatake	Nawiliwili Bay Watershed Council
Chris Machorek	Kaua‘i Marriott Hotel
David Martin	Nawiliwili Bay Watershed Council
Kendyce Menguchei	*The Garden Island* newspaper
Steve Morikawa	Hawai‘i State, Department of Transportation
Steve Perry	
Lex Riggle	U.S. Department of Agriculture, Natural Resources Conservation Service
Jon Schlegel	U.S. Department of Agriculture, Natural Resources Conservation Service
Mahealani Silva	Nawiliwili Bay Watershed Council
Amanda Skelton	East Kaua‘i Soil and Water Conservation District
David Smith	Hawai‘i State, Department of Land and Natural Resources, Division of Forestry and Wildlife
Mahealani Trembath	
Ed Tschupp	County of Kaua‘i, Department of Water
Vaughan Tyndzic	Hawai‘i State, Department of Land and Natural Resources, Division of Boating and Ocean Recreation
Gary Ueunten	Hawai‘i State, Department of Health
Glenn Yamamoto	Hawai‘i State, Department of Transportation — Highways